



IDW '19

THE 26TH INTERNATIONAL DISPLAY WORKSHOPS

Special Topics of Interest on

- AR/VR and Hyper Reality
- Automotive Displays
- Micro/Mini LEDs
- Quantum Dot Technologies

Topical Session on

- Artificial Intelligence and Smart Society(AIS)
- The 11th International Conference on 3D Systems and Applications (3DSA2019)

Workshops on

- LC Science and Technologies (LCT)
- Active Matrix Displays (AMD)
- FPD Manufacturing, Materials and Components (FMC)
- Inorganic Emissive Display and Phosphors (PH)
- OLED Displays and Related Technologies (OLED)
- 3D/Hyper-Realistic Displays and Systems (3D)
- Applied Vision and Human Factors (VHF)
- Projection and Large-Area Displays and Their Components (PRJ)
- Electronic Paper (EP)
- MEMS and Emerging Technologies for Future Displays and Devices (MEET)
- Display Electronic Systems (DES)
- Flexible Electronics (FLX)
- Touch Panels and Input Technologies (INP)

Final Program

***Sapporo Convention Center
Sapporo, Japan
November 27 – 29, 2019***

IDW '19 Online Program with “My Schedule” function

From this year, the IDW '19 Online Program is available on the Internet.

There is a very useful “My Schedule” function on the Online Program. Create a customized program based on your own interests. Log in to “My Menu”, add sessions or presentations that interest you and create your own schedule.

Access the online program here:

URL: <https://confit.atlas.jp/idw2019?lang=en>



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SPECIAL EVENT

“Sensory Illusion”

Exhibition:

Wednesday, Nov. 27 – Friday, Nov. 29, 2019
Main Hall (1F)

Special Talks:

Wednesday, Nov. 27, 2019
18:30 – 19:10
Mid-sized Hall A (1F)

PROGRAM HIGHLIGHTS

The 26th International Display Workshops will be held as IDW '19 for encouraging aggressive research and development of display technologies throughout the world and especially in the Asian region. IDW '19 focuses on the following 4 special topics and 2 topical sessions, which are extremely timely, as well as 13 active workshops.

Special Topics of Interest on

- AR/VR and Hyper Reality
- Automotive Displays
- Micro/Mini LEDs
- Quantum Dot Technologies

Topical Sessions on

- Artificial Intelligence and Smart Society
- The 11th International Conference on Three Dimensional Systems and Applications

Workshops on

- LC Science and Technologies
- Active Matrix Displays
- FPD Manufacturing, Materials and Components
- Inorganic Emissive Display and Phosphors
- OLED Displays and Related Technologies
- 3D/Hyper-Realistic Displays and Systems
- Applied Vision and Human Factors
- Projection and Large-Area Displays and Their Components
- Electronic Paper
- MEMS and Emerging Technologies for Future Displays and Devices
- Display Electronic Systems
- Flexible Electronics
- Touch Panels and Input Technologies

The three-day conference will feature 490 papers, including 4 keynote addresses, 132 invited presentations, 144 oral presentations, and 210 poster presentations. Following the plenary session of keynote addresses on Wednesday morning, presentations will begin and continue in 8 parallel oral sessions through Friday. Poster sessions, author interviews, and demonstrations will enable participants to discuss topics in detail. Exhibits by universities and display industry-related businesses will also be featured from Wednesday to Friday in parallel with workshops. IDW '19 should be of interest to not only researchers and engineers, but also managers of companies and institutions in the display community.

Special Topics of Interest on AR/VR and Hyper Reality (AR&VR)

Augmented reality (AR) and virtual reality (VR) applications employing high-performance display devices such as sensors, cameras with tracking capabilities, and computer graphics technologies have shown significant progress in the past few years.

This year, we provide several sessions on state-of-the-art optics for HMD, VR/AR display devices including Light Field Displays, the history of VR and current AR technology in industry, interaction devices/techniques using AR/VR, VR-related human perception, and medical VR systems.

Special Topics of Interest on Automotive Displays (AUTO)

AUTO, which began in 2016 as one of the Special Topics of Interests (STIs), will present wide-ranging presentations on automotive displays. This year, AUTO sessions will be held in three WSS: PRJ for projection technology, VHF for ergonomics, and INP for touch panel technology and its application. In addition, AUTO-related presentation will be made in poster exhibitions.

In the AUTO session, interesting presentations will be made, covering topics such as advanced headlamps using laser light, visibility of road signs, three-dimensional head-up displays, touch sensors, and information transmission to people outside the vehicle in addition to the display on the driver. The sessions have been arranged in a manner ideal for understanding a wide range of automotive related display technologies. AUTO will surely interest audiences such as users and designers of automobiles.

Special Topics of Interest on Micro/Mini LEDs (mLED)

At IDW '19, Micro/Mini LEDs has been established as one of the Special Topics of Interest (STI), drawing together presentations on Micro LEDs, which have garnered much interest in recent years. Micro/Mini LEDs feature the special characteristics of high luminance, low electricity consumption, wide gamuts, wide viewing angles and simple device structures. In addition to their wide ranges of applications enabling the realization of large-screen direct viewing displays to micro displays, their adoption in direct backlights is also drawing attention. Starting with an Invited Address by Professor Kei May Lau of The Hong Kong University of Science and Technology, the session will cover all the latest technologies in materials, LED atomization, mounting on substrates, and other manufacturing technologies, as well as thermal/optical design techniques, drive technologies, and applications in displays. A session is being planned in which presentations and debate will unfold regarding the latest results of the technologies that lead the micro LED field.

Special Topics of Interest on Quantum Dot Technologies (QDT)

This topic will cover all aspects of the science and technologies of Quantum Dots (QD) and Quantum Rods (QR), ranging from materials research, device structure and properties, device applications for lighting and display, manufacturing and high color gamut displays using QD. This topic will specialize in QD Technologies (QDT) in order to provide a venue for the vitalization of debates in each field.

The highlights for IDW'19 will be oral presentations and poster sessions regarding the development of recent progress in polarized QLED using Q-rods, Cd-free QD materials and devices, and QD converted micro-LED display (PH-WS), display and light source applications using high quantum-efficiency cd-free quantum-dot materials such as colloidal perovskites for full compatibility with REC 2020 (ITU-R-BT 2020) for HDR (High Dynamic Range) (MEET-WS), perovskite QDs based LEDs with high color purity emission spectra, and efficient solution-processed perovskite LED and efficient indium phosphate based QDs using sol-gel processed electron transfer layers (OLED-WS).

Topical Session on Artificial Intelligence and Smart Society (AIS)

Recently, artificial intelligence has become a common technology, and it will be a key concept of the smart societies of the future, known as "Industry 4.0" and "Society 5.0". In this scope, the relationship between information displays, artificial intelligence, and smart society will be discussed.

This year, eight invited speakers are invited, and there will be presentations that propose how to interact with information displays in a smart society where artificial intelligence is essential. Image processing with deep neural networks is already a main battlefield, and there is also a more advanced technology called GAN. In addition, joint oral sessions with INP, DES, and PRJ and joint poster sessions with DES and VHF on image processing and image quality are also planned.

Topical Session on the 11th International Conference on Three Dimensional Systems and Applications (3DSA)

3DSA is an international conference on audio-visual 3D technologies, systems, applications and other hyper-realistic systems, such as 3D

capturing and processing, 3D coding and transmission, 3D displays and systems, 3D contents and applications, computer graphics, holographic technology, human vision, augmented reality, virtual reality, immersive display systems, free viewpoint image systems, ultra-realistic audio systems, and interactive systems. It is organized by the Ultra Realistic Communication Forum (URCF) / The Virtual Reality Society of Japan (VRSJ) in Japan, 3D Interaction & Display Alliance (3DIDA) / the Industrial Technology Research Institute (ITRI) / the Society for Information Display (SID) Taipei Chapter in Taiwan, the Association of Realistic Media Industry (ARMI) / Electronics and Telecommunications Research Institute (ETRI) / and the Korean Institute of Broadcast and Media Engineers (KIBME). This year, it provides a very good opportunity to follow the recent trends in Virtual Reality presented by Professor Hirose, the president of the University of Tokyo Virtual Reality Educational Research Center.

Workshop on LC Science and Technologies (LCT)

The LC Science and Technologies (LCT) workshop showcases novel device structures, materials, and evaluation methods for advanced displays, as well as novel and emerging applications based on LCs. As excitement over the Tokyo 2020 Olympics rises, sessions are planned on the newest display technologies that maximize the viewing experience of LCDs: invited presentations are planned on ultra-high-resolution (8K), BT.2020, high dynamic range (HDR), and flexible technologies. Sessions are also planned for novel applications where LCs are used as 'smart' electrolytes or sensors, and as ultra-thin diffractive optical elements for AR/VR applications. The workshop is an excellent opportunity for participants to learn about the latest LC-based technologies and discuss future prospects.

Workshop on Active Matrix Displays (AMD)

The AMD workshop covers active matrix displays, thin film devices such as oxide TFT, Si-TFT, micro-LED, AM-OLED, sensors, and other devices. Recent paper presentations tend to focus on oxide TFT, which is highly expected to play a role in applications for higher resolution LC and OLED displays.

We highlight the oxide TFT with three dedicated sessions covering a wide area from materials, physics, devices, and processes to applications. Furthermore, we have scheduled sessions for foldable OLEDs, high resolution displays, active-matrix type micro-LEDs, emerging TFTs and advanced driving technology.

Workshop on FPD Manufacturing, Materials and Components (FMC)

The FPD Manufacturing, Materials and Components (FMC) workshop covers recent developments and achievements in the field of flat panel display technologies, including display optics, materials, components, display panel manufacturing and measurements technologies. In the FMC sessions, the papers related to Micro/Mini LEDs Displays (joint session: FMC/LCT), Advanced Material and Components (joint session: FLX/FMC), Optical Films, Quantum Dots, Metrology and Manufacturing are highlighted. Presentations on manufacturing of Micro/Mini LEDs Displays and related backlight technologies will be held in the FMC/LCT joint session. Recent trends in the fields of Projection Display will be presented at the PRJ/FMC joint session.

Workshop on Inorganic Emissive Display and Phosphors (PH)

This workshop presents the latest achievements in devices and phosphors for emissive displays, lighting, and imaging. Invited talks will present the development of novel nitride phosphors using high throughput calculation. Recent progress of QLEDs utilizing Cd-free QD and Q-Rods, flexible powder-ELD, and monolithic full-color micro-LED displays will be also presented.

Workshop on OLED Displays and Related Technologies (OLED)

The OLED workshop covers all aspects of the science and technologies of OLED, QLED and other organic devices, ranging from material science, basic device physics for OLED devices and display technologies, and other applications. The oral and poster sessions will cover OLED display and device technologies, materials and process technologies for soluble OLED and advanced technologies concerning OLED/QLED devices and materials. Recent progress such as micro-OLED displays, perovskite QD technologies, and automotive applications etc. will be reported on. We will also focus in particular on Quantum Dot Technologies (QDT) as a special topic of interest (STI).

Workshop on 3D/Hyper-Realistic Displays and Systems (3D)

The 3D/Hyper-Realistic Displays and Systems workshop will consist of many papers on 3D systems and devices for holography, autostereoscopic display, integral photography, and emerging applications for AR/VR. This year, the 3D workshop presents a lot of sessions in conjunction with the 3DSA international conference to provide a good opportunity for audiences to understand the trends in these fields. In addition, it features "illusion" and provides two oral sessions in the evening of the 27th and the morning of the 28th, and a demo exhibition over all three days.

Workshop on Applied Vision and Human Factors (VHF)

The VHF workshop covers all ergonomic factors on human interfaces, such as visual aspects, environmental related aspects, and measurements. We will hold eight oral sessions and four poster sessions, including special topic sessions on automotive applications and virtual reality, in addition to display applications, image quality and physiological factors. We will also hold a joint session on illusions. Seven invited talks will be given in the oral sessions, concerning foveated rendering HMD, dynamic signs, office applications, elevator/escalator applications, 8K microscopic surgery, motion sickness, and black MURA evaluation for automotive applications.

Workshop on Projection and Large-Area Displays and Their Components (PRJ)

The PRJ workshop covers the latest eyewear displays, automotive displays, solid-state light sources, electronic holograms, aerial displays, short throw optics, 3D-measurement optics including light detection and ranging (LiDAR), and all the projection related technologies.

This year's session will focus on AR/VR, projection mapping and lighting, Artificial Intelligence applications, automotive displays and headlamp optics, and international standardization of HMDs.

Workshop on Electronic Paper (EP)

The EP workshop focuses on emerging topics in electronic paper including novel display methods, materials, new applications, and user interface studies. Photo quality full color technology using Leuco-dyes will be discussed, in addition to Electrophoretic, Electrowetting, and Electrochromic. Driving methods for ePaper will be discussed in a joint session with DES (Display Electronic System). Aggressive challenges will be presented in the following three sessions: 1) Emerging Electronic Paper Displays, 2) Advanced Electronic Paper Displays and Systems, 3) Electrochromic Devices.

Workshop on MEMS and Emerging Technologies for Future Displays and Devices (MEET)

The MEET workshop is unique in covering all aspects of MEMS, micro-LED, Quantum Dot, nanotechnologies and emerging technologies concerning future displays, imaging devices, and emerging electron devices. The MEET workshop has established sessions on micro-LEDs and Quantum Dot/Quantum Dot light-emitting diodes for the first time in the world academic society and seeks to broaden the horizon of display and imaging technologies into cutting-edge technologies. Research

areas such as materials, basic physics, and fabrication processes are included. Among all the MEMS, Nanotechnologies and display conferences in the world, this is the only opportunity for MEMS, Nanotechnologies and cutting-edge technology researchers to gather and discuss such devices. Authorities from top research institutions around the world in this field have been invited. Invited speakers will come from CEA-LETI, Brunel University, Seoul National University, Kyung Hee University, Beijing Institute of Technology, Fuzhou University, Southern University of Science and Technology, ETH Zurich, National Chiao Tung University, BOE, PlayNitride, and Yole Développement. Together with contributed papers with high-quality content, this workshop is aimed at participants who wish to open up new fields in displays, imaging devices, and emerging devices such as carbon nanotube electron beam sources and ultraviolet light sources by using MEMS micro/nano fabrication technology, cd-free quantum-dot materials as well as highly quantum-efficient nanocrystals such as colloidal perovskites satisfying the international conditions for REC 2020 (ITU-R-BT 2020) for HDR (High Dynamic Range), high brightness and wide color-gamut micro-LEDs as next generation displays and so on.

Workshop on Display Electronic Systems (DES)

The DES workshop (Display Electronic Systems) proposes next-generation systems, advanced applications, and pursues high display performance based on advances in circuit technology and software processing technology. This year, DES-WS will organize three single and three joint oral sessions as well as five poster sessions. We will feature 8K related techniques and machine learning related image processing as at previous IDWs and state-of-the-art video coding. The 8K session covers a wide range from driving hardware to medical applications. The video coding session, which is applied to reduce video memory consumption, will focus on the latest technologies. Last but not least, our poster sessions including ones focusing on special topics of interests such as ARVR and AUTO are well worth a visit and are sure to provide enjoyable content.

Workshop on Flexible Electronics (FLX)

The FLX workshop focuses on advanced technologies for flexible electronics including foldable displays, rollable displays, wearable sensors, stretchable devices, and IoT-related devices, which are composed of a wide range of fields from material science to practical applications. The sessions cover all aspects of the most topical flexible devices and material technologies including stretchable material and device technologies, flexible displays, wearable sensors, and printed and flexible hybrid technologies.

Workshop on Touch Panels and Input Technologies (INP)

Interface technologies such as touch panels and interactive technologies which have already extended to automotive HMIs are the stars of the session. Following to the last meeting, this year, progress in in-cell force touch panels and fingerprint sensors, tactile sensors by impedance tomography, olfactory display, haptics using illusion, wearable devices for touch sensory feedback, eye contacts considering the Mona Lisa effects and so on, are topics that will be focused on. INP papers will open a new window in displays and interactive technologies, not only for devices but also for systems, making them essential viewing.

Kobayashi-Uchiike-Mikoshiba Prize

The Kobayashi-Uchiike-Mikoshiba Prize shall be conferred by the International Display Workshops General Incorporated Association Board of Directors upon a person who has both an outstanding record of accomplishments in any of the IDW fields of interest and made an outstanding contribution to the IDW. The accomplishments that are being honored shall have led to important contributions in the

advancement or application of engineering, science and technology, resulting in the realization of significant value to society.

IDW Best Paper Award and IDW Outstanding Poster Paper Award

IDW will present “IDW Best Paper Award” and “IDW Outstanding Poster Paper Award”. The award committee of IDW will select the most outstanding papers from those presented at IDW ’19. The award winners will be announced on the IDW website and given a plaque after the conference.

I-DEMO (Innovative Demonstration Session)

I-DEMO will be held on November 28 from 11:40 – 15:40 at Main Hall (1F). IDW provides the opportunity for an interdisciplinary technical demonstration/discussion in a larger space, more preparation and demonstration time than in the “Author Interviews”. Demonstration Award will be awarded to the demonstration that has the biggest impact on the audience.

SPECIAL EVENT “Sensory Illusion”

Exhibition:

Touch and somatic illusions and amazing artworks such as “Impossible Object Illusion” will be exhibited on Wednesday, November 27 – Friday, November 29, 2019 at Main Hall (1F)

Special Talks:

“A Variety of Visual Illusions”, Akiyoshi Kitaoka (Ritsumeikan Univ.)
“Latest Developments of 3D Illusion”, Kokichi Sugihara (Meiji Univ.)
Related technical sessions will be held on November 27 from 18:30 – 19:10 at Mid-sized Hall A (1F)

Exhibition

The IDW ’19 Exhibition, which will be held from November 27 through November 29, covers materials, components, manufacturing and measuring equipment, software systems and other related products for display devices. Please join in and enjoy discussions at exhibitors’ booths Main Hall (1F).

November 27 (Wed.) 12:40 – 18:00

November 28 (Thu.) 10:00 – 18:00

November 29 (Fri.) 10:00 – 14:00

Keynote Exhibition

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited at Main Hall (1F).

GENERAL INFORMATION

SPONSORSHIP

IDW '19 is sponsored by the Institute of Image Information and Television Engineers (ITE) and the Society for Information Display (SID).

CONFERENCE SITE

Sapporo Convention Center

1-1-1 Higashi-Sapporo 6-jo, Shiroishi-ku, Sapporo, 003-0006, Japan

URL: <https://www.sora-scc.jp/eng/>

ON-SITE SECRETARIAT

Telephone and fax machines for IDW '19 will be temporarily set up in the secretariat room (Room104) at Sapporo Convention Center (November 27-29).

Phone: +81-11-842-5478

RECEPTION

A buffet style reception will be held on the evening of November 27 from 19:20-21:00 at the Conference Hall (1F) in Sapporo Convention Center. As the number of tickets is limited, you are urged to make an advance reservation through the registration website.

EVENING GET-TOGETHER WITH WINE

A get-together will be held on November 26 from 18:00 to 20:00 at Restaurant 'SORA' (1F) in the conference site. Wine (sponsored by International Display Workshops General Incorporated Association) and snacks will be served to participants in a relaxed atmosphere for networking. Admission is free with your name tag.

REGISTRATION

Registration is available in advance and also on-site, however, advance registration is strongly recommended to speed up the arrival procedure at the conference site.

Registration Fees

The registration fee for IDW '19 includes admission to the conference and a USB flash drive of the proceedings.

All dates and hours indicated here are in Japan Standard Time.

	Until Oct. 25, 2019	On and After Oct. 26, 2019
Individual Member (ITE/SID/ASO*)	¥ 40,000	¥ 50,000
Non-Member**	¥ 50,000	¥ 60,000
Student***	¥ 13,000	¥ 15,000
Life Member of ITE/SID****	¥ 13,000	¥ 15,000
Reception	¥ 8,000	¥ 10,000

*ASO: Academic Supporting Organizations

(See p.17 as well as "Supporting Organizations" of workshops and topical sessions.)

**Non-Member: If you intend to join either ITE or SID, the one year membership fee will be subsidized by IDW '19 committee.

***Full-time student, photocopy of student ID is required.

****Photocopy of your membership card is required.

Please note that the payment of reduced registration fee is accepted until Oct. 25, 2019, at 23:59 (JST). The full fee will be charged for payments made on and after Oct. 26, 2019. Also note that the number of reception tickets to register on site is limited.

Additional proceedings (USB flash drive)

At the conference site	¥ 8,000
Airmail after the conference	¥12,000
Domestic mail after the conference	¥10,000

Payment

Two ways are provided for registration.

(1) e-Registration

Access the following URL.

<https://www.idw.or.jp/regist.html>

e-Registration will be accepted until November 15, 2019, at 23:59(JST).

(2) On-site Registration

Conference registration desk will open:

November 26 (Tue.) 17:00 – 20:00

November 27 (Wed.) 8:00 – 18:00

November 28 (Thu.) 8:00 – 18:00

November 29 (Fri.) 8:00 – 13:00

On-site registration fee will be payable by:

1) Cash (JAPANESE YEN only)

2) Credit Card (Visa, MasterCard, JCB, AMEX or China Union Pay)

Bank transfer, bank checks, or personal/traveler's checks are not accepted.

Cancellation Policy

Until **Oct. 25 2019, at 23:59 (JST)**, cancellation is accepted by writing to IDW '19 Secretariat to obtain refunds for registration and reception.

Please note that refunds will not be made under the following conditions:

- Cancellations received on and after Oct. 26, 2019
- No-shows
- Cancellations by presenters
- Cancellations by visa invitation letter applicants who have already received a visa invitation letter.

However, after IDW '19 closes, a USB flash drive of the proceedings will be sent to the registrants who have paid the registration fees. If it becomes difficult to hold IDW '19 due to the outbreak of infectious diseases or other unavoidable factors, we will substitute the IDW with the mail delivery of the IDW '19 proceedings at a later date to all those who have registered and completed payment.

IDW '20

The 27th International Display Workshops

Dec. 9 - 11, 2020

Fukuoka International Congress Center

Fukuoka, Japan

<https://www.idw.or.jp/>

INQUIRIES

IDW '19 Secretariat

c/o Bilingual Group Ltd.

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Academic Supporting Organizations (ASO)

- The Chemical Society of Japan
- The Electrochemical Society of Japan
- Human Interface Society
- The Illuminating Engineering Institute of Japan
- The Imaging Society of Japan
- Information Processing Society of Japan
- The Institute of Electrical Engineers of Japan
- The Institute of Electronics, Information and Communication Engineers
- The Institute of Image Electronics Engineers of Japan
- International Electrotechnical Commission
- The Japan Ergonomics Society
- The Japan Society of Applied Physics
- The Japanese Liquid Crystal Society
- The Japanese Society for Artificial Intelligence
- The Optical Society of Japan
- The Society of Automotive Engineers of Japan
- The Society of Instrument and Control Engineers
- The Society of Polymer Science, Japan
- The Virtual Reality Society of Japan
- Vision Society of Japan

Financial Supporters (as of October 1, 2019)

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**For updated information, please visit our website,
<https://www.idw.or.jp/>**

TRAVEL INFORMATION

ACCOMMODATION

JTB Hokkaido Branch will handle arrangements for your hotel reservations.

Hotel reservations can be made at the IDW official website.

<https://www.idw.or.jp/regist.html>

JTB Hokkaido Branch

Office Hours: 9:30-17:00 (Weekdays only)

Address: Urban Net Sapporo BLDG, 8th floor, North 1, West 6, Chuo-ku, Sapporo 060-0001

There will be an on-site travel information desk during the conference period to handle arrangements for transport.

VISAS

Visitors from countries/regions whose citizens must have visas should apply to the Japanese consular office or diplomatic mission in their respective countries/regions. For further details, please contact your travel agency or the local consular office in your country/region.

Attention: For some countries'/regions' citizens, official documents prepared by the secretariat will be needed. Please ask the secretariat at least two months before the conference.

RAIL PASS

Japan Railway (JR) provides the following economical passes. There are some restrictions on use, such as the lines and types of trains that can be used, and the length of validity. Please ensure you visit the following sites for more details. These passes can be purchased before your departure or after you arrive in Japan.

•Japan Rail Pass

An economical way to travel through *all parts of Japan*.

<http://www.japanrailpass.net/en/>

•Hokkaido Rail Pass

An economical pass that lets you travel *all around Hokkaido*.

<http://www2.jrhokkaido.co.jp/global/English/ticket/railpass/index.html>

•JR East-South Hokkaido Rail Pass

An economical pass that lets you travel *from around Tokyo to Sapporo*.

<http://www.jreasthokkaido.com/easthokkaido/e/>

•JR Tohoku-South Hokkaido Rail Pass

An economical pass that lets you travel *from Tohoku region to Sapporo*.

<http://www.jreasthokkaido.com/tohokuhokkaido/e/>

CLIMATE

The average temperature in Sapporo during the period is around 4°C in the daytime and -5°C at night.

Sapporo City

Sapporo City in Hokkaido is the northernmost city designated by government ordinance in Japan with a population of around 2 million. Sapporo is known for the functional rectangular grid of streets and avenues as a city modeled after Kyoto. The word "Sapporo" is originated from the Ainu (indigenous people of Japan) language and is well known as the host city for the 1972 Winter Olympics. Dishes using local Hokkaido produce and seafood rank high amongst the many charms of Sapporo, as well as being known for the annual snow festival and YOSAKOI Soran Festival.

Places of Interest

Odori Park

Odori Park divides the city center into north and south. It stretches for about 1.5 km, covering 12 blocks, and the grounds around the TV tower located there provide an oasis for people living and working in the surrounding office district.

In every corner of the park, you will find attractions, monuments, art work (including pieces by the famous Isamu Noguchi), play-areas, fountains, and of course the beauty of the seasonal flowers and trees. The park is home to 4,700 trees of 92 species such as lilacs, elms, Japanese zelkovas, azaleas and cherry trees. Many events are held here throughout the year including the world-famous Snow Festival.

Jozankei Onsen (Spa)

A 75-minute bus tour from JR Sapporo station takes you to one of the largest hot springs in Japan, Jozankei. The history of Jozankei dates back to 1866, when Miizumi Jozan, an ascetic monk, discovered the hot springs and opened a healing spa on the upper Toyohira River. The hot spring waters that bubble out of the ground at Jozankei spa resort contain sodium chloride, which is colorless, transparent, and mildly salty. These are common qualities of the water in Japanese spas.

<http://jozankei.jp/en/>

Susukino

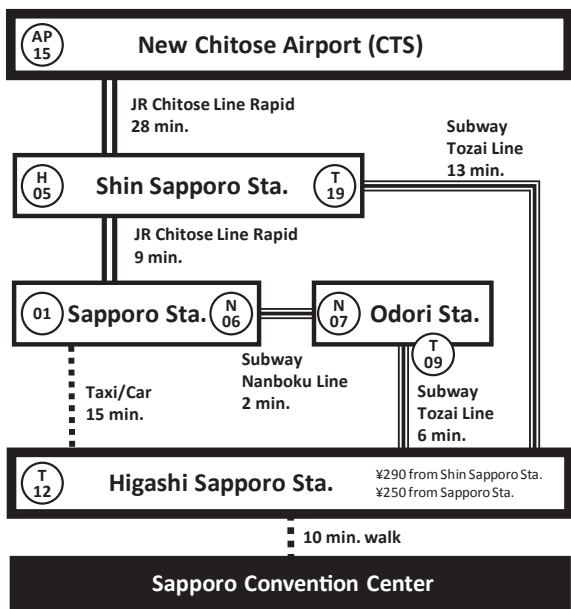
Susukino is Japan's largest entertainment district north of Tokyo, however it is not an official designation of any municipality. There are said to be approximately 4,500 bars and restaurants, including Ramen Yokocho, a narrow lane lined with shops serving Sapporo's famous ramen.

Further information

Sapporo Official Travel Guide

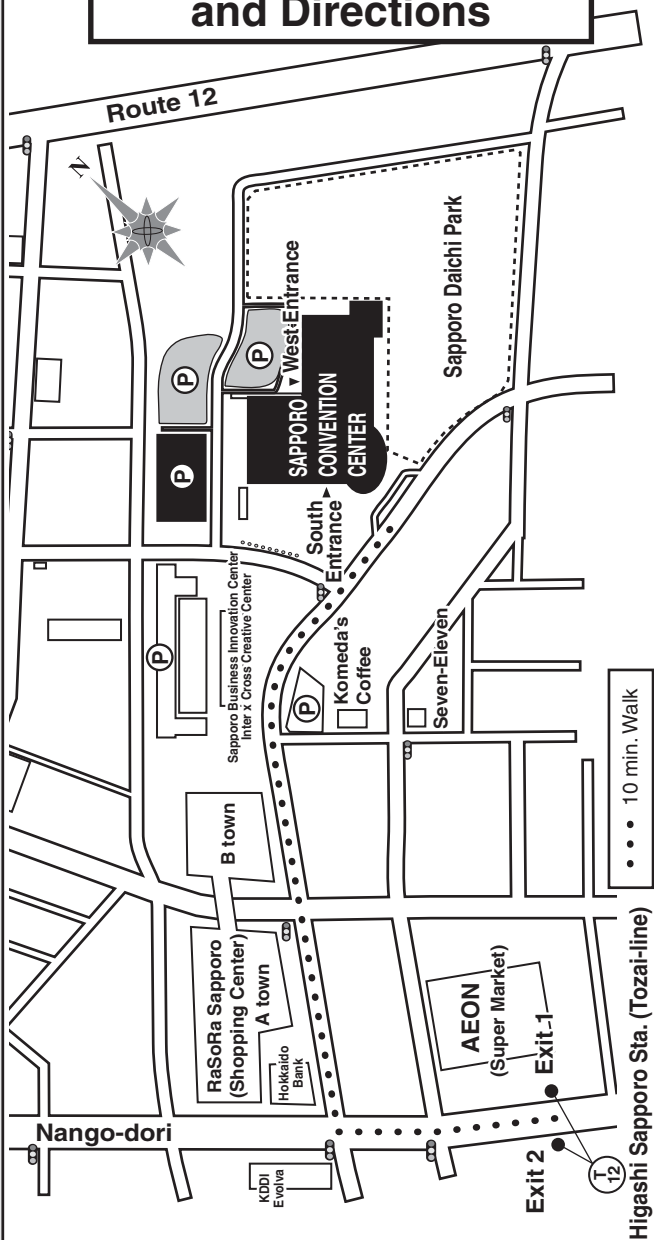
<http://www.welcome.city.sapporo.jp/english/>

Access to Conference Site

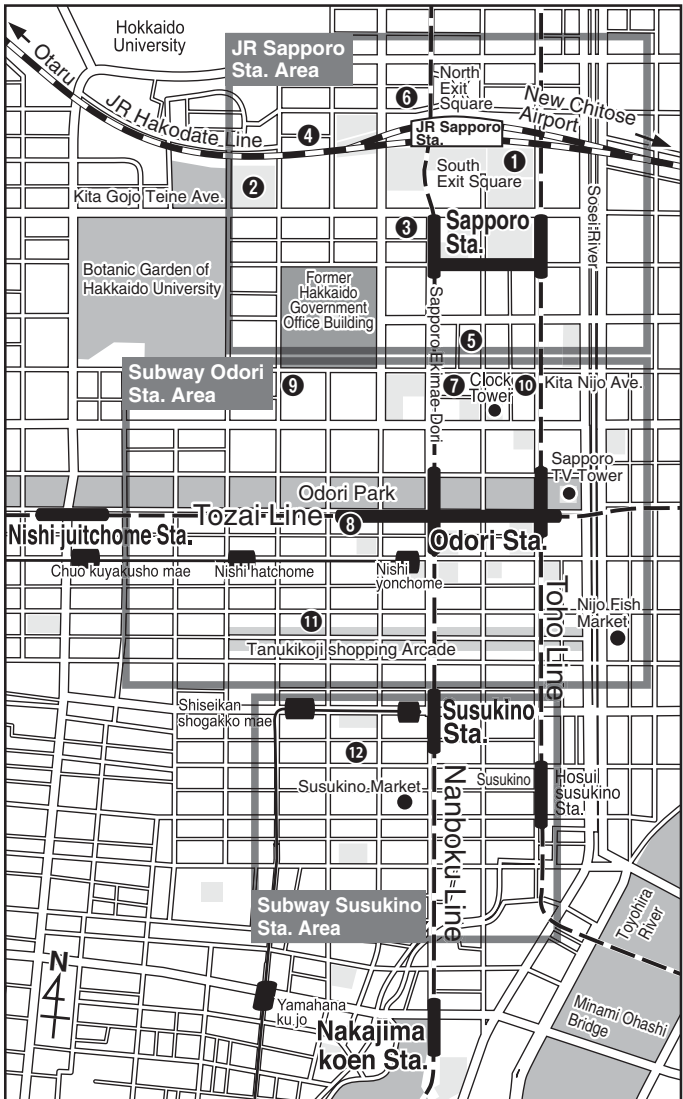


Transportation information on this program may be changed.
Please confirm the details with each airline and railway company.
(as of October 1, 2019)

Sapporo Convention Center Map and Directions



Hotel Map



JR Sapporo Sta. Area

- ① JR tower hotel nikko sapporo
- ② KEIO PLAZA HOTEL SAPPORO
- ③ HOTEL GRACERY SAPPORO
- ④ HOTEL KEIHAN SAPPORO
- ⑤ HOTEL HOKKE CLUB SAPPORO
- ⑥ HOTEL ROUTE-INN SAPPORO EKIMAE KITAGUCHI

Subway Odori Sta. Area

- ⑦ UNIZO INN SAPPORO
- ⑧ HOTEL RESOL TRINITY SAPPORO
- ⑨ SAPPORO GARDEN PALACE
- ⑩ SAPPORO SUMIRE HOTEL
- ⑪ HOTEL SUNROUTE NEW SAPPORO

Subway Susukino Sta. Area

- ⑫ HOTEL ROUTE-INN SAPPORO CHUO

Plenary Sessions

Wednesday, November 27

Plenary

9:20-9:40

Conference Hall

Opening

Master of Ceremony: Hiromi Katoh, Executive Chair, IDW '19

Opening Remarks

9:20

Shinichi Komura (General Chair, IDW '19)

Helge Seetzen (President, SID)

Itsuo Kumazawa (Vice President, ITE)

Munehiro Kimura (Program Chair, IDW '19)

9:40-11:00

Conference Hall

Keynote Addresses

Chair: Munehiro Kimura (Program Chair, IDW '19)

Co-Chair: Shinichi Komura (General Chair, IDW '19)

Keynote Address - 1 Bringing the New Age Display with Social Innovation

9:40

**Yasuhisa Itoh¹*

1. Sharp Corporation (Japan)

Based on the social infrastructure upgrade, the creation of new applications as well as diversification demands for display technology, it is possible for the display market to grow sustainably in the future. I will talk about next generation display technology aiming at such social innovation.

Keynote Address - 2 Human Centered Automotive Cockpit HMI

10:20

**Taro Oike¹*

1. Mazda Motor (Japan)

An automotive display in the cockpit is an HMI device. It projects useful information for the driver, but it can also cause driver distractions. Driving safety is the most important factor in automobiles, and HMI device design requirements must be met for that purpose. Since automotive displays emit and reflect light, light control technology is important for automotive displays.

11:10-12:30

Conference Hall

Invited Addresses

Chair: Munehiro Kimura (Program Chair, IDW '19)

Co-Chair: Shinichi Komura (General Chair, IDW '19)

Invited Address - 1 Monolithic Micro-LED Full-Color Micro-Displays

11:10

**Kei May Lau¹*

1. The Hong Kong Univ. of S&T (Hong Kong)

Monolithic LED arrays with color conversion schemes for full-color displays will be reported. Two micro-LED arrays fabricated using blue and dual wavelength LED epilayers are extended to full-color by quantum-dot down conversion technology. Both approaches exhibit feasible manufacturability and decent visual quality, showing promise toward volume production of full-color micro-displays.

Invited Address - 2 Artificial Intelligence: from Pixels and Phonemes to Semantic Understanding and Interactions

11:50

**Achin Bhowmik¹*

1. Starkey Hearing Techs. (United States of America)

In the recent years, unprecedented advances in artificial intelligence (AI) technologies and applications are being enabled by rapid developments in machine learning, big data, and specialized computing architectures. We will review how devices are increasingly being endowed with technologies to sense and understand the world, often surpassing human-level performances, and ushering in a new wave of intelligent applications.

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)
Sapporo Convention Center

Special Topics of Interest on AR/VR and Hyper Reality

Wednesday, November 27

13:45-15:05

Room 108

PRJ1/FMC1: AR/VR

Chair: Satoshi Ouchi (Hitachi)
Co-Chair: Hirotsugu Yamamoto (Utsunomiya Univ.)

PRJ1/ FMC1 - 1 **Invited Modeling, Algorithm, and Implementation of Resolution-Tripled Near-Eye Light Field Displays**
13:45 *Zong Qin¹, Jui-Yi Wu¹, Ping-Yen Chou¹,
Cheng-Ting Huang¹, Yu-Ting Chen¹, Yi-Pai Huang¹
1. National Chiao Tung University (Taiwan)

A physical model incorporating all factors affecting the retinal image formation in a near-eye light field display is proposed, based on which, an algorithm recombining subpixels across elemental images to nearly triple the resolution is developed. Finally, an e-shifting method is suggested to further enhance the resolution to 30 pixels-per-degree.

PRJ1/ FMC1 - 2 **Possibility of Deblurring Aerial Image Based on Deconvolution Processing**
14:05 *Hayato Kikuta^{1,2}, Hirotsugu Yamamoto^{2,3}
1. Mitsubishi Electric Corp. (Japan), 2. Utsunomiya University (Japan), 3. ACCEL (Japan)

This paper proposes a deblurring an aerial image formed with aerial imaging by retro-reflection. We have measured the point spread function (PSF) according to the incident angle to the retro-reflector. Simulated results show possibility of deblurring the aerial image by applying the deconvolution processing based on the obtained PSF.

PRJ1/ FMC1 - 3 **Volume-Holographic Multiplexed-Mirror Waveguide for Head-Mounted Display**
14:25 *Takeru Utsugi¹, Mayumi Sasaki², Kazuhiko Ono², Yukinobu Tada²
1. Hitachi, Ltd. (Japan), 2. Hitachi-LG Data Storage, Inc. (Japan)

As a waveguide for a head mounted display, we propose a volume-holographic multiplexed-mirror waveguide, which could achieve high luminance efficiency, wide field of view and excellent transparency. We clearly demonstrate that high performance waveguide is achieved by the combination of multiplex-recorded hologram and broad wavelength light sources.

AR/VR

**PRJ1/
FMC1 - 4
14:45** **High See-Through and High Efficiency Waveguide
for Head Mounted Displays and Waveguide
Evaluations**

**Ryuji Ukai¹, Takuma Kuno¹, Toshiteru Nakamura¹,
Masahito Uchiyama¹, Satoshi Ouchi¹*

1. Hitachi, Ltd. (Japan)

We have developed head mounted displays with high see-through property and high luminance which could be utilized outside safely without dimming glasses. We specified required performance threshold and developed beam-splitter-array waveguide to achieve the requirements. We also established versatile waveguide measurement method applicable to different-type waveguides.

15:20-16:50

Room 107

LCT2: LC Flat Diffractive Optics

Chair: Toshiaki Nose (Akita Prefecture University)
Co-Chair: Hiroyuki Yoshida (Osaka University)

**LCT2 - 1 *Invited* Fundamentals and Applications of Liquid
15:20 Crystal-Based, Polarization-Dependent Diffractive
Optics Fundamentals and Applications of Liquid
Crystal-Based, Polarization-Dependent Diffractive
Optics**

**Hiroyuki Yoshida¹, SeongYong Cho¹, Yuto Tsuboi¹,
Yuji Tsukamoto¹, Masanori Ozaki¹*

1. Osaka University (Japan)

There is recently interest in LC-based diffractive optical elements (DOEs) that enable modulation of the light phasefront through the spatial distribution of its optic axis. The operating principles of both transmissive and reflective devices are reviewed and their applications are discussed.

**LCT2 - 2 *Invited* Ultimate Planar Optics for AR/VR and Next
15:40 Generation Displays**

**Nelson Tabirian¹, David Roberts¹, Anna Tabirian¹,
Brian R Kimball², Timothy J Bunning³*

*1. BEAM Engineering for Advanced Measurements
Co. (United States of America), 2. U.S. Army Natick
Soldier Systems Center, Natick, Massachusetts
(United States of America), 3. Air Force Research
Laboratories, Wright-Patterson Air Force Base, Ohio
(United States of America)*

Only one planar optics technology – diffractive waveplates – has shown capability to match large sizes and low-cost of Fresnel optics and the bandwidth of refractive optics. Electrically switchable and tunable with low-power controls, the thinnest lenses, prisms, and holograms make diffractive waveplate optics best suitable for AR/VR applications.

**LCT2 - 3 *Invited* Emerging Near-eye Displays with
16:05 Pancharatnam-Berry Optical Elements**

**TAO ZHAN¹, JIANGHAO XIONG¹, JUNYU ZOU¹,
GUANJUN TAN¹, SHIN-TSON WU¹*

*1. University of Central Florida (United States of
America)*

Near-eye displays with enhanced images quality are developed with planar optics employing Pancharatnam-Berry (PB) phase. Advanced broadband PB deflectors and lenses are fabricated to enhance the apparent pixel density and reduce the chromatic aberrations in immersive near-eye displays. Both simulation and experimental results are presented.

**LCT2 - 4 *Fast-response Pancharatnam-Berry Lens for Head-
16:30 up Displays***

*Xiuying Ren¹, *Sida Li¹, Yueda Liu¹, Yan Li¹, Yikai Su¹*

1. Shanghai Jiao tong University (China)

In this paper we demonstrate fast-response Pancharatnam-Berry lenses (PBLs) based on polymer-stabilized liquid crystal. After photo-alignment technique and UV curing, the PBLs show submillisecond response time. Based on two identical PBLs, a head-up display system that can generate four different diopters is demonstrated.

AR/VR

17:00-18:30

Mid-sized Hall A

VHF3/DES3: Virtual Reality

Chair: Takashi Shibata (Tokyo Univ. of Social Welfare)

Co-Chair: Johan Bergquist (Consultant)

**VHF3/ *Invited* VR Headset with Human-Eye Resolution
DES3 - 1**

17:00 *Osku Sahlsten¹

1. Varjo Technologies Oy (Finland)

With current display manufacturing methods, it would be very hard to produce a single near eye display that offers 60 pixels / degree resolution over the whole field of view and is small enough to fit into the headset. In case of greater than 90-degree field of view, basically 6k x 6k panel would be required. With the high refresh rates of virtual reality applications, this would mean also very large data transfer rates and high rendering load on GPU's. Varjo overcome these challenges by composing the single eye image from two different display sources, while minimizing the effect on total rendering load. High angular resolution is used on the area where it is mostly needed. Precise analysis of displays with geometrical- and optical adjustments is needed to blend the 2 separate images to a one uniform scene.

Also presented in Innovative Demonstration Session (see p. 280)

**VHF3/
DES3 - 2
17:25** ***Invited Metrology challenges in Near to Eye Display
Characterization for Human Factors Correlation***
**Richard Lee Austin¹, Bruce Denning¹, John Penczek²*
*1. Gamma Scientific (United States of America), 2.
University of Colorado, Boulder (United States of
America)*

We present metrology challenges and solutions to measure Near Eye Displays performance parameters that can produce visual discomfort and headaches. Accurate measurement data correlates to what the eye perceives when the entrance pupil of the Light Measurement Device (LMD) matches the location and pointing direction of the display user's eye.

**VHF3/
DES3 - 3
17:50** ***Optic Flow, but Not Retinal Flow, Is Essential to
Induce VR Sickness***
**Hiroyasu Ujike¹, Kei Hyodo¹, Mitsunori Tada¹,
Koudai Ito¹*
*1. National Institute of Advanced Industrial Science
and Technology (Japan)*

We conducted an experiment measuring VR sickness using HMD, manipulating optic flow and retinal flow in three conditions. The results showed that sickness scores increased according to the amount of optic flow, but not of retinal flow, indicating that optic flow, not retinal flow, is essential to induced VR sickness.

**VHF3/
DES3 - 4
18:10** ***Color Perception Comparison of Scene Images
between Head-Mounted Display and Desktop
Display***
**Tomonori Nishimura¹, Keita Hirai¹, Takahiko Horiuchi¹*
1. Chiba University (Japan)

In this paper, subjective evaluation experiments using scene images were conducted to investigate the difference of luminance and chroma perception between an HMD and a desktop display. The results showed that the perception of luminance and chroma of the HMD were higher compared with those of the desktop display.

Author Interviews
18:30 - 19:00

Thursday, November 28

14:30-17:00

Main Hall

Poster DESp3: Medical VR**DESp3 - 1L Towards Next Generation Neurosurgical Microscope: A VR Assisted Prototype System**

*Yuji Oyamada¹, Sadao Nakajima¹, Kazutake Uehara²,
Hiroki Yoshioka³, Masamichi Kurosaki¹

1. Tottori University (Japan), 2. Tottori University
Hospital (Japan), 3. Tottori Prefectural Central Hospital
(Japan)

We aim to develop a Virtual Reality assisted neurosurgical microscope system that displays medical information from multiple resources even with a single display. For this ultimate purpose, we developed a prototype system. We conducted a small user study to discuss both hardware and software issues to be improved.

Also presented in Innovative Demonstration Session (see p. 280)

AR/VR

Main Hall

Poster DESp4: Driving Technique for VR**DESp4 - 1L Reduced Resolution Driving Scheme for High-Resolution Immersive Displays**

*Seungjun Park¹, Young-In Kim¹, Ki-Hyuk Seul¹,
Seok-Jeong Song¹, Jina Bae¹, Hyoungsik Nam¹

1. Kyung Hee University (Korea)

To extend line times for high-resolution and wide viewing angle displays in virtual reality applications, we present a novel foveation-based reduced resolution driving scheme. For 4,800x4,800 and 9,600x9,600 resolutions, effective vertical resolutions are reduced to 30.3% and 21.0%. Thus, line times can be extended to 330.0% and 476.2%.

EXHIBITION

12:40 – 18:00 Wednesday, Nov. 27

10:00 – 18:00 Thursday, Nov. 28

10:00 – 14:00 Friday, Nov. 29

Main Hall (1F)

Sapporo Convention Center

Free admission with your registration name tag

17:20-18:40

Room 108

PRJ3: Image Quality and Display Devices

Chair: Andrés Vásquez Quintero (University of Ghent)
Co-Chair: Tetsuji Suzuki (JVC KENWOOD)

PRJ3 - 1 Invited Fast Switching, High Accuracy LCoS for 3D Holographic Applications

17:20

**Huang-Ming Philip Chen¹, Jhou-Pu Yang¹, Yao-Chung Chang¹*

1. National Chiao Tung University (Taiwan)

A 0.7-inch, 4K2K LCoS-SLM with full 2π radians phase modulation to cover depth-focus image was developed. The full phase modulation was found 0.9 and 1.5 ms under the digital driving scheme with DV = 1.75 V at T=45 °C. A 200 mm depth of 3D reconstruction holographic image was demonstrated.

PRJ3 - 2 Invited High Resolution Phase-only 4K2K LCoS Spatial Light Modulator for Holographic Display Technology

17:40

**Chun-Wei Tsai¹, Tse Li¹, Chen Wang¹*

1. Jasper Display Corp. (JDC) (Taiwan)

High resolution, full phase modulation, small pixel pitch, high aperture ratio, and fast response time are the requirements to enhance the quality of holographic display by using the LCoS-SLM. In this paper, we develop a 3D floating holographic display and to increase the angle of view as 36.67 degree with high resolution phase-only 4K2K LCoS-SLM.

PRJ3 - 3 Temperature Dependence Measurement of Color Speckle for Projected Fiber-out White Laser Beam from RGB Laser Module

18:00

**Junichi Kinoshita¹, Keizo Ochi¹, Akira Takamori¹, Kazuhisa Yamamoto¹, Kazuo Kuroda², Koji Suzuki³, Keisuke Hieda⁴*

1. Osaka University (Japan), 2. Utsunomiya University (Japan), 3. Oxide Corporation (Japan), 4. HIOKI. E.E.CORPORATION (Japan)

Temperature dependence of color speckle of the projected image of a fiber-out white laser beam from a laser module with red, green, blue laser diodes was measured. Larger temperature dependence of the red laser diode was found to greatly affect the performance of the white beam and color-speckle.

PRJ3 - 4 Standardization Activities for Head-Mounted Displays from Ergonomics Aspects

18:20

**Kei Hyodo¹, Hiroyasu Ujike², Mitsunori Tada²*

1. Yuasa System Co. Ltd. (Japan), 2. AIST (Japan)

As novel display devices, head-mounted displays (HMD) are getting popular. These devices have unique characteristics. Because of those, there are immediate requirements of having standards to evaluate those HMDs to avoid unwanted impacts to viewers. In order to answer those, ISO TC 159/SC4/WG2 and WG12 started developing standards for HMDs.

Author Interviews

18:50 - 19:20

AR/VR

Friday, November 29

9:00-10:35	Room 206
INP5: AR/VR Interactive Technologies	

Chair: Takamichi Nakamoto (Tokyo Institute of Technology)
Co-Chair: Shunsuke Yoshimoto (University of Tokyo)

INP5 - 1 *Invited* Utilization or Elimination of Mona Lisa Effect for Eye Contact with Characters

9:00

**Hironori Mitake¹, Hsueh Han Wu¹, Taro Ichii¹,
Kazuya Tateishi¹, Shoichi Hasegawa¹*

1. Tokyo Institute of Technology (Japan)

Interactive characters as digital signage are becoming popular. Eye contact from the character in appropriate situation may cause sense of awareness from the character, and attract people attention. Also, widely used planar display cause Mona Lisa effect. We focused on positive and negative aspect of the effect, and created novel way to enable eye contact from characters to viewers, which is utilizing or eliminating the Mona Lisa effect.

Also presented in Innovative Demonstration Session (see p. 281)

INP5 - 2 *Invited* Olfactory Display and its Application

9:25

**Takamichi Nakamoto¹*

1. Tokyo Institute of Technology (Japan)

An olfactory display is a device to present smells. We have studied multi-component olfactory display to generate a variety of smells. Our recent model consists of multiple micro dispensers and a surface acoustic wave atomizer. Both desktop-type and wearable type olfactory displays together with their contents were developed.

**INP5 - 3 *Invited* Electromechanical Impedance Tomography
9:50 for Soft Tactile Sensor**

**Shunsuke Yoshimoto¹*

1. The University of Tokyo (Japan)

This study introduces a tactile sensing technology based on a tomographic approach with conductors for imaging of pressure distribution. The proposed technology enabled designing the soft tactile sensor, characterized by high positional accuracy, adjustable sensitivity and range, and a relatively simple fabrication process.

**INP5 - 4 *An Interactive Holographic Light-Field Display*
10:15 *Color-Aided 3D-touch User Interface***

**Ivan Alexis Sanchez Salazar Chavarria¹,
Tomoya Nakamura¹, Masahiro Yamaguchi¹*

1. Tokyo Institute of Technology (Japan)

The author's group previously demonstrated a holographic light-field display with a 3D touch interface, based on the detection of scattered light by the user. That interface is now improved by realizing real-time interactivity and the implementation of 3D motion detection using the color information captured by an RGB sensor.

Author Interviews

12:10 - 12:40

10:40-12:00	Small Hall
3DSA7/3D7: Virtual Reality 1	

Chair: Tomohiro Tanikawa (The Univ. of Tokyo)

Co-Chair: Kenji Yamamoto (NICT)

**3DSA7/
3D7 - 1 *Invited* Research and Development of Second
10:40 *Generation Virtual Reality***

**Michitaka Hirose¹*

1. The University of Tokyo (Japan)

Novel VR technology (second generation VR) is introduced. After short review of technological advances to date, the author discusses benefits of VR in the areas of education and training that are expected as major application of VR technology.

**3DSA7/
3D7 - 2
11:00** ***Invited Computer Vision, AI, AR Technology in Various Industries***
**You-Kwang Wang^{1,2}, Hung-Ya Tsa², Chih-Hao Chuang³, Chien-Yu Chen¹*
1. National Taiwan University of Science and Technology (Taiwan), 2. OSENSE Technology Co. (Taiwan), 3. National Taiwan University (Taiwan)

AR technology is currently the most popular human-computer interaction interface. We get a spatial point cloud through computer vision and AI technology. And completed several projects according to different scene requirements.

**3DSA7/
3D7 - 3
11:20** ***Invited Impressive 3D CG Technologies for Automotive HUDs with Wide FOV***
**Haruhiko Okumura¹, Takashi Sasaki¹, Aira Hotta¹, Masahiro Sekine¹*
1. Toshiba Corp. (Japan)

We have applied various kinds of 3D CG technologies to increase the Field Of View (FOV) and visibility of displayed images for the monocular HUD. As a results, we successfully developed impressive 3D CG technologies for HUDs with wide FOV and high visibility.

**3DSA7/
3D7 - 4
11:40** ***Invited Air Floating Image Based on a Dihedral Corner Reflector Array***
**YUKI MAEDA¹*
1. Parity Innovations Co. Ltd. (Japan)

An air floating image and its applications based on a dihedral corner reflector array are introduced in this paper. An observer can see the air floating image by the naked eye and manipulate it by touching the air floating image using finger sensor system.

Also presented in Innovative Demonstration Session (see p. 278)

Author Interviews
 12:10 - 12:40

13:20-14:40	Small Hall
3D8/3DSA8: Virtual Reality 2	

Chair: You Kwang Wang (Osense Technology)
 Co-Chair: Haruki Mizushima (Tokushima University)

3D8/3DSA8 - 1 13:20 ***Invited* Service VR Training System: VR Simulator of Man-to-Man Service with Mental/Emotional Sensing and Intervention**

**TOMOHIRO TANIKAWA¹, Yuki Ban¹, Kazuma Aoyama¹, Eiji Shinbori², Shigeru Komatsubara², Michitaka Hirose¹*
1. The University of Tokyo (Japan), 2. Dai Nippon Printing Co., Ltd. (Japan)

In this paper, we introduce our concept and preliminary implementation of service VR training system. For training services, emotional skills are very important. Thus, our service VR simulator consist of mental/emotional sensing devices, estimating algorithm and intervention approaches.

3D8/3DSA8 - 2 13:40 **A HMD for Users with Any Interocular Distance**

**Jung-Young Son¹, Hyoung Lee¹, Jung Kim¹, Beom-Ryeol Lee², Wook-Ho Son², Tetiana Venkel³*
1. Konyang University (Korea), 2. Electronics and Telecommunication Research Institute (Korea), 3. Chernivtsi University (Ukraine)

A prototype HMD which can automatically adjust interocular distance in the range of 55 mm to 75 mm in accordance with those of users. The main component of the HMD is a linear motor which shifts the modularized left and right eye's projection and camera optics in accordance with the measured interocular distance of a user. The total adjusting time of the distance is less than 10 seconds. The weight of the HMD is slightly less than 500 g and it is worn by a head belt. The HMD is somewhat heavy and unbalanced due to the distribution of the weight along the nose side but the head belt holds tightly the HMD on its place and it works well.

3D8/3DSA8 - 3 **Withdrawn**

3D8/3DSA8 - 5L 14:00 **Proposal for Light Field Mirage**

**Yoshiharu Momonoi^{1,2}, Koya Yamamoto², Yasuhiro Takaki²*
1. Samsung R&D Institute Japan (Japan), 2. Tokyo University of Agriculture and Technology (Japan)

Mirage, which consists of a pair of parabolic mirrors, is a well-known 360-degree display system. This study explored replacing the parabolic mirrors in Mirage with multiple flat-panel light field displays to realize Light Field Mirage. Rays emitted from 3D objects are reconstructed for 360-degree viewing. Preliminary experiments were conducted.

**3D8/
3DSA8 - 4
14:20** **Accuracy Verification of Visual Appearance
Acquisition Device of Non-Metallic Material Based
on Sparse SVBRDF**

**Tsung-Lin Lu¹, Yu-Lun Liu¹, Yu-Cheng Hsieh¹, Tzung-Han Lin¹*

*1. National Taiwan University of Science and
Technology (Taiwan)*

In this paper, we proposed a visual appearance acquisition device comparing with commercial product. Our device is capable of restoring the visual appearance for non-metallic materials based on spatially varying bidirectional reflectance distribution function (SVBRDF). A benchmark comparing to commercial product Radiant Vision is carried out to verify the reliability of the proposed device.

AR/VR

15:00-16:20	Room 108
PRJ7/LCT8: Eyewear	

Chair: Dieter Cuypers (CMST)
Co-Chair: Subaru Kawasaki (JNC Korea)

**PRJ7/
LCT8 - 1
15:00** **LC Lens Fabricated by Photoalignment for AR/VR
Systems**

**Wei-Wei Chen¹, Jui-Wen Pan¹, Shie-Chang Jeng¹*

1. National Chiao Tung University (Taiwan)

A concept for an electrically tunable liquid crystal (LC) lens using a hole-patterned electrode and the vertical alignment liquid crystal cell by circular photoalignment is demonstrated. The proposed LC lens is a polarizer-free negative lens(0D~-0.93D) by changing the driving voltage. The proposed LC lens can be applied for AR/VR applications.

**PRJ7/
LCT8 - 2
15:20** **Effect of Processing Parameters on Visual Quality
for Liquid Crystal Displays Compatible with Contact
Lenses**

**Andres Vasquez Quintero¹, Pablo Perez-Merino²,
Sudha Sudha¹, Lucas Oorlynck¹, Herbert De Smet¹*

*1. Ghent University / imec, Centre for Microsystems
Technology CMST (Belgium), 2. Instituto de
Investigacion Sanitaria Fundacion Jimenez Diaz
(Spain)*

This paper presents the effect of processing parameters on the contrast and optical quality of guest-host liquid crystal cells intended for smart contact lens applications. The effects were measured by means of cavity interferometry and model fitting. Optical quality was qualitatively assessed by means of target images.

**PRJ7/
LCT8 - 3
15:40** **Miniature Liquid Crystal Lens Optimizations**

**Dieter Cuypers¹, Rik Verplancke¹, Herbert De Smet¹*

1. imec and Ghent University (Belgium)

Small, switchable liquid crystal based polymer Fresnel lenses are discussed, considering design optimizations for performance.

**PRJ7/
LCT8 - 4
16:00**

**Ferroelectric Liquid Crystal Dammann Grating: for
LiDAR Applications**

**Zhengnan Yuan¹, Zhibo Sun¹, Abhishek K Srivastava¹*

*1. The Hong Kong University of Science and
Technology (Hong Kong)*

We propose a ferroelectric liquid crystal Dammann grating (FLCDG) based polarization modulated depth-mapping system. Innovatively, FLCDG is used as high-speed shutter in this system. The application of FLCDG enables LiDAR as one-shot capturing system instead of iterative scanning. Moreover, the proposed device shows a fast data-collection time period (50 μ s) for per 49 points that can be further increased depending on the damman grating, and provide low cost solution to the problem.

Author Interviews

16:30 - 17:00

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)
Sapporo Convention Center

I-DEMO (Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters

Thursday, Nov. 28, 2019

11:40 – 15:40

Main Hall (1F)
Sapporo Convention Center

Special Topics of Interest on Automotive Displays

Wednesday, November 27

13:41-14:56

Room 206

INP1: In-Cell Touch Panels and Fingerprint Sensors

Chair: Noemie Ballot (ISORG)
Co-Chair: Yuji Suzuki (Japan Display Inc.)

INP1 - 1 *Invited* Evaluation of the Integrated In-cell 13:41 Electromagnetic Resonance Sensor and Capacitive Touch Sensor

**Yuji Suzuki¹, Satoshi Uchino¹, Kohei Azumi¹,
Tadayoshi Katsuta¹, Daichi Suzuki¹, Hiroyuki Wakana¹,
Kaoru Ito¹*

1. Japan Display Inc. (Japan)

We developed in-cell EMR reflective LCD panel, which shares the sensor pattern with capacitive touch sensor, without additional sensor layer. This technology contributes many benefits for thin design and less weight of the panel compared with conventional EMR products. This paper shows our in-cell EMR and capacitive touch sensing performance.

Also presented in Innovative Demonstration Session (see p. 281)

INP1 - 2 Withdrawn

INP1 - 5L Reduction of Moving Optical Illusion Through 14:06 Synchronization with Eye Movement

**Yuki Kubota¹, Tomohiko Hayakawa¹,
Masatoshi Ishikawa¹*

1. The University of Tokyo (Japan)

Optical illusions distort our visual information. We propose a system that enables control of imagery rotation synchronously with eye movement. Our subject experiment using Rotating Snakes Illusion suggests that the appropriate performances of compensation can reduce the intensity of the illusion even without eye fixation.

INP1 - 3 *Invited* Large-Area Optical Fingerprint Sensors for 14:31 Next Generation Smartphones

**Noemie Ballot¹*

1. ISORG (France)

Printing-based organic photodiodes have demonstrated cost effective process and compatibility with Flat Panel industry equipment making large area optical fingerprint sensors viable for volume production. Large area thin film-based optical collimator enables simple behind display integration. Advantages of this technology are high security level for fingerprint, enhanced ease of use and slim module.

15:20-16:45

Mid-sized Hall A

VHF2: Ergonomics for Automotive Applications

Chair: Yoshie Imai (Mitsubishi Elec.)

Co-Chair: Yukio Endo (AGC)

VHF2 - 1 *Invited* Application of Visibility Index Function for Driving

15:20

**Katsunori Okajima¹*

1. Yokohama National University (Japan)

We demonstrate VIF (Visibility Index Function) can be applied for precisely simulating and improving the visibility of driving environments as well as human-interface devices in driving. The VIF is convenient to design information display and traffic signs with considering visibility while driving.

VHF2 - 2 Effect of External Human Machine Interface (eHMI) of Automated Vehicle on Pedestrian's Recognition

15:45

**Naoto Matsunaga¹, Tatsuru Daimon¹, Naoki Yokota¹, Satoshi Kitazaki²*

1. Keio University (Japan), 2. National Institute of Advanced Industrial Science and Technology (Japan)

The interaction between a pedestrian and an automated vehicle equipped with an external human machine interface at an unsignalized crosswalk is discussed. The external human machine interface has the potential to provide an effective communication cue from which the pedestrian can judge whether the automated vehicle is yielding to them.

VHF2 - 3 Influence of Cabin Vibration on Driver's Depth Perception and Subjective Conviction When Using Automotive 3D Head-Up Display -Basic Study on the Relationship between Degree of Correction and Driver's Recognition-

16:05

**Kazuki Matsunashi¹, Tatsuru Daimon², Ryo Noguchi¹, Ken'ichi Kasazumi³, Toshiya Mori³*

1. Graduate School of Keio (Japan), 2. University of Keio (Japan), 3. Panasonic Corporation (Japan)

This study discusses the driver's depth perception and subjective conviction to be corrected for in the display contents of an automotive three-dimensional head-up display, such as navigation arrows, based on the levels of the basic correction method used to reduce the effect of car vibration due to various road surfaces.

**VHF2 - 4 The Evaluation for Visibility of a Back Image on a
16:25 Transparent Display**

**Naruki Yamada¹, Yoshinori Iguchi¹, Yukihiro Tao¹
1. AGC Inc. (Japan)*

Transparent display is useful device for some applications but has a privacy issue that a back image appears on the opposite side to the display image. We investigated the condition human cannot see a back image.

Thursday, November 28

9:00-10:15	Room 206
INP3: Haptic Technologies (1)	

Chair: Makoto Sato (Tokyo Institute of Technology)
Co-Chair: Nobuyuki Hashimoto (Citizen)

**INP3 - 1 *Invited* Widespread Hapbeat: Tension Based
9:00 Necklace Type Haptic Display**

**Yusuke Yamazaki¹, Hironori Mitake¹, Akihiko Shirai²,
Shoichi Hasegawa¹
1. Tokyo Institute of Technology (Japan), 2. GREE, Inc. (Japan)*

Hapbeat is a wearable haptic device which can easily enhance the immersion of digital contents such as VR, gaming, music, movie, etc. In this paper, I explain a basic mechanism of Hapbeat and a series of challenges to widespread it into the public.

Also presented in Innovative Demonstration Session (see p. 281)

**INP3 - 2 *Invited* Comptics: A System for Making and Sharing
9:25 Haptic Experience**

**Toshiki Wada¹, Hiroyoshi Togo¹
1. NTT (Japan)*

We have developed a haptic system, Comptics, that enables easy and rapid making, playing, and sharing of haptic experience. Comptics is composed of a haptic stimulation device, wearable user interface, and design and communication protocols (DCP) on a computer that uses unhearable signals.

**INP3 - 3 *Invited* Buttock Skin Stretch Devices for Enhancing
9:50 Driving Experience**

**Masashi Konyo¹
1. Tohoku University (Japan)*

A new concept of buttock skin stretch to induce the perception of shear forces while sitting is reported. The buttock skin stretch is suitable for a driving simulator to enhance the whole-body experiences such as the centrifugal force of the car and the inclination of the car body in driving.

Also presented in Innovative Demonstration Session (see p. 281)

AUTO

Author Interviews

10:40 - 11:10

14:30-17:00

Main Hall

Poster DESp5: Display Electronics for Automotive

DESp5 - 1L Optimizing LSF Shape for Robust and Uniform Backlighting of Automotive Displays with Direct-Lit Local-Dimming

**Maxim Schmidt¹, Julian Ritter¹, Chihao Xu¹*

1. Saarland University (Germany)

In this paper, radial LSFs for direct-lit BLUs are modelled with three parameters and can render different shapes for a same influence. Diverse LSF shapes are analyzed in terms of robustness in production as well as power saving capabilities regarding local-dimming. Characteristic measures for an optimum shape are proposed.

17:20-18:50

Room 206

INP4: Haptic Technologies (2)

Chair: Masashi Konyo (Tohoku University)

Co-Chair: Vibol Yem (Tokyo Metropolitan University)

INP4 - 1 *Invited* Sensory Illusion Beyond Real Haptics

17:20

**Norio Nakamura^{1,2}*

1. AIST (Japan), 2. Miraisens, Inc. (Japan)

'DigitalHaptics™' is the world first invention of illusionary haptics technology, developed originally by AIST based on Neuro Science. It realized many miracle haptics such as Pushing, Pulling, Texture, and Softness in the Air, and theoretically enables the almost all kinds of haptic feeling, as same as visual composition of RGB.

INP4 - 2 *Invited* Wearable Tactile Device for Fingertip Interaction with Virtual World

17:45

**Vibol Yem¹*

1. Tokyo Metropolitan University (Japan)

Author developed a wearable tactile device mounted to the fingertips for interaction with objects in the virtual environment. The device can provide sensations of pressure, low-frequency vibration and forward-flexion illusionary force in thumb, index and middle fingers by electrical stimulation; and high-frequency vibration and skin deformation by mechanical stimulation.

Also presented in Innovative Demonstration Session (see p. 281)

INP4 - 3 ***Invited* Input and Output Interaction Technologies**
18:10 **for Flexible Touch Panels**
**Ki-Uk Kyung¹*
1. KAIST (Korea)

This talk will introduce recent technologies for polymer based sensors and actuators. Polymer based tactile sensors support functions of detecting multiple contact forces as well as touch positions. Flexible actuators may provide haptic cues to users.

INP4 - 4L **8.4 Tactile Touch Display Using Segmented-**
18:35 **Electrode Array as Both Tactile Pixels and Touch**
 Sensors
**Takuya Asai¹, Hiroshi Haga¹, Shin Takeuchi¹,*
Harue Sasaki¹, Koji Shigemura¹
1. Tianma Japan (Japan)

We developed an electrostatic-tactile touch display using a segmented-electrode array as both tactile pixels and touch sensors. This structure allows presenting real localized tactile textures in any shape. A driving scheme in which the tactile strength is independent of the grounding state of the human body was also demonstrated.

Also presented in Innovative Demonstration Session (see p. 281)

Author Interviews
18:50 - 19:20



Friday, November 29

10:40-12:20	Room 108
PRJ5: Automotive Display	

Chair: Kazuhiro Ohara (Marubun)
Co-Chair: Masayuki Takayama (Honda)

PRJ5 - 1 ***Invited* Advanced Automotive Interior Lighting and**
10:40 **Exterior Displays**
**Karlheinz Blankenbach¹, Robert Isele²,*
Mathias Roennfeldt³, Uli Hiller⁴
1. Pforzheim University (Germany), 2. BMW
(Germany), 3. Lightworks (Germany), 4. Osram Opto
Semiconductors (Germany)

Autonomous driving has a huge impact on cars. We present advanced solutions for interior pixelated lighting and exterior displays. Examples are visualization of driving mode by the steering wheel and information for other road users. Calibrated RGB LED systems provide the best solution in terms of optical quality and safety.

**PRJ5 - 2 *Invited* Laser Crystal Phosphor Automobile
11:00 Headlight Integrated with Beam Control and LiDAR**
**Y. P. Chang^{1,2}, Alan Wang¹, Wood-Hi Cheng²,
Kenneth Li³*
*1. Taiwan Color Optics, Inc. (Taiwan), 2. National Chun
Hsing University (Taiwan), 3. Optonomous
Technologies Inc. (United States of America)*

This paper describes the development of high performance crystal phosphor with applications to automobile headlights, smart headlights, and LiDAR such that many limitations are eliminated and through integration, which could lower the cost of the system. A patent pending design of a smart headlight integrated with a LiDAR sensor using a single DMD will be described.

**PRJ5 - 3 *Invited* Laser Light Sources for Next Generation
11:20 Automotive Lighting Applications**
**Meng Han¹, Julian Carey¹, Paul Rudy¹*
1. SLD Laser (United States of America)

Progress in development of blue laser diodes and their integration with phosphors enabled a new category of solid state light sources for automotive lighting. In this paper, a dynamic laser light module consisting of blue laser diode, a MEMS scanner and remote phosphor for adaptive driving beam and future intelligent lighting will be introduced.

**PRJ5 - 4 *Invited* Augmenting Reality In Automobiles
11:40 **Jamieson Jamieson Christmas¹***
1. Envisics Ltd (UK)

AR-HUD offering a compelling safety case for the automotive market. Thus far HUD adoption has been impaired by the physical volume of the optical system required to create a wide field of view. Envisics have developed revolutionary holographic technology that addresses these challenges while delivering class leading image metrics.

**PRJ5 - 5 Development of Image Quality Simulation for Laser
12:00 Scanning Projector Using Microlens Screen**
**Hiroyuki Tanabe¹*
1. Ricoh Industrial Solutions Inc (Japan)

Speckle can be reduced by using a scanning projector with microlens screen. However, the diffraction noises and the scanning-line-moire generated and degrades the image quality. To calculate these noises, the simulation was developed by integrating geometric and wave optics model. The simulation was validated by comparing with experimental result.

Author Interviews
12:10 - 12:40

Special Topics of Interest on Micro/Mini LEDs

Wednesday, November 27

17:00-18:35

Mid-sized Hall B

AMD3: Driving Technology of Micro/Mini LED Displays

Chair: Kazumasa Nomoto (Sony)

Co-Chair: Keisuke Omoto (Apple)

AMD3 - 1 *Invited* Crystal LED Display System for Immersive 17:00 Viewing Experience

**Katsuhiro Tomoda¹, Norifumi Kikuchi¹, Goshi Biwa^{2,1},
Hisashi Kadota^{1,2}*

*1. Sony Semiconductor Solutions Corporation
(Japan), 2. Sony Corporation (Japan)*

We developed a novel active matrix driving technology that integrates RGB micro LEDs and a micro IC in each pixel for our Crystal LED display system. With precise tiling technology, a large-scale image with immersive viewing experience can be delivered.

AMD3 - 2 *Invited* Active Matrix Driving Mini-LED Device 17:25

**Chin-Lung Ting¹, Chung-Kuang Wei¹, Li-Wei Mau¹,
Ker-Yih Kao¹, Ho-Tien Chen¹, Minoru Shibazaki²*

*1. Innolux Corporation (Taiwan), 2. Innolux Japan
(Japan)*

We have developed a glass- or flexible substrate-based AM driving mini-LED device. The AM driving mini-LED device controls each mini-LED element precisely with TFT, and can be applied to PID and BL of LCD, improving the optical performance of dynamic range, CR, color purity and viewing angle performance of the display.

AMD3 - 3 *Invited* A 200-ppi Full Color Active Matrix Micro-LED 17:50 Display with Low-Temperature-Poly-Silicon TFT Backplane

**Masaya Tamaki¹, Sho Nakamitsu¹, Hiroaki Ito¹,
Takanobu Suzuki¹, Masahiko Nishide¹, Kunio Imaizumi¹,
Katsumi Yamanoguchi¹, Fanny Rahadian¹,
Katsumi Aoki¹, Seiji Matsuda¹, Ryoichi Yokoyama¹*

1. Kyocera Corporation (Japan)

A 1.8-inch 200-ppi full color active matrix micro light emitting diode (LED) display prototype has been developed with a low-temperature-poly-silicon (LTPS) TFT backplane. The frame rate of 240Hz and the luminance of 2000nits, both of which are promising attributes for high motion image quality and high dynamic range (HDR) applications, being superior to existing display technologies, were achieved by our LTPS TFT technology.

AMD3 - 4 Active Matrix Monolithic Full-Color LED Micro Display
18:15

**Longheng Qi¹, Xu Zhang¹, Wing Cheung Chong¹,
Peian Li¹, Chak Wah Tang¹, Kei May Lau¹*

*1. The Hong Kong University of Science and
Technology (Hong Kong)*

An active matrix monolithic full-color LED micro-display is demonstrated, combining monolithic blue GaN-on-Si LED array and quantum dots down conversion technology. This full-color scheme shows feasible manufacturability and visual quality, paving a new pathway toward volume production of full-color LED micro-display in the near future.

Author Interviews

18:30 - 19:00

Thursday, November 28

9:00-10:20	Mid-sized Hall A
FMC4/LCT4: Micro LED Display	

Chair: K Kälantär (Global Optical Solutions)
Co-Chair: Seiji Shibahara (Sony Home Entertainment & Sound Products Inc.)

**FMC4/ *Invited* High-Resolution (1,000 to over 3,000 ppi)
LCT4 - 1 Full-Color Silicon Display for Augmented and Mixed
9:00 Reality**

**Hidenori Kawanishi¹, Hiroaki Onuma¹,
Masumi Maegawa¹, Takashi Kurisu², Takashi Ono²,
Shigeyuki Akase¹, Shinji Yamaguchi¹, Naoto Momotani²,
Yusuke Fujita¹, Yuhei Kondo², Kentaro Kubota²,
Toshimi Yoshida¹, Yuta Ikawa¹, Tsuyoshi Ono²,
Hiroyoshi Higashisaka², Yasuaki Hirano²,
Shinsuke Anzai¹*

*1. Sharp Fukuyama Semiconductor Co., Ltd. (Japan),
2. Sharp Fukuyama Laser Co., Ltd (Japan)*

We present the status of III-nitride micro-LED display bonded onto silicon backplane. 0.38-inch full-colour display with a resolution of 1,053 ppi has been successfully demonstrated. Progress toward higher resolution is also described. We believe our Silicon Display is ideally suited for near-to-eye displays for augmented and mixed reality.

Also presented in Innovative Demonstration Session (see p. 279)

FMC4/ LCT4 - 2 **Invited A New Generation of HDR Display with Super Multi-Zones Mini LED**
9:20 *Jianping Zheng¹, Zhuo Deng¹, Ling Wu¹, Poping Shen¹, Junyi Li¹, Jianmou Huang¹
 1. XiaMen Tianma Microelectronics Company, Ltd. (China)

We propose a new generation of HDR display with active matrix mini-LED backlight for LCD. The display enables super multi-zones display by using new type of backlight drive, which achieved better contrast and less halo defect. Through both instrument test and perception experiments, we evaluated the performance of HDR LCD.

FMC4/ LCT4 - 3 **Invited Monolithic Integration of GaN-Micro-LED and Si-MOSFET for Bio-application**
9:40 *Hiroto Sekiguchi^{1,2}, Hiroki Yasunaga¹, Kazuaki Tsuchiyama¹, Keisuke Yamane¹, Hiroshi Okada¹, Akihiro Wakahara¹
 1. Toyohashi University of Technology (Japan), 2. PRESTO, JST (Japan)

A micro light-emitting diodes (LED) has been attention as an optical stimulation tool for optogenetics. In this study, a needle-type microLED probe was fabricated for neuroscience. In addition, the monolithic integration of microLED and Si-MOSFET using wafer bonding technique was challenged toward the realization of multifunctional devices.

FMC4/ LCT4 - 4 **An Active Matrix Mini-LEDs Backlight Based on a-Si**
10:00 *Bin Liu^{1,2}, quansheng liu², jia li², yongyuan qiu², junling liu², yong yang², hongyuan xu², Juncheng Xiao², feng zhu², hang zhou¹, Xin Zhang²
 1. Peking University Shenzhen Graduate School (China), 2. China Star Optoelectronics Technology (China)

In this work, we fabricate an active matrix mini-LEDs backlight based on a-Si. The driving mechanism with 2T1C and process flow are discussed in detail. IR-drop is analyzed and improved. The gray scale is controlled by PWM method with the number of 64 (6 bit), and the maximum brightness is up to 20,000nits.

Author Interviews
 10:40 - 11:10

10:40-13:10

Main Hall

Poster FMCp1: Micro/Mini LEDs

FMCp1 - 1 Monolithic Light-Guide Plate with Prism Structure for 1.5D 32 Dimming Zones and Narrow Border LCD

**Chao-Min Yang¹, ChihChun Chang¹, Yatan HSiao¹, Wenlin Cheng¹*

1. AU Optronics Corporation (Taiwan)

We have succeeded in build-in prism structure on 15.6 PMMA- LGP and there are two kind of collimating LGP. Both are defined by the dimming factor m and η to describe it. The 15.6 sample property include 1.5D segment dimming with 32 zones, the VESA STANDAREDER HDR600.

FMCp1 - 2 High Performance GaN-based Micro-LEDs with Improved Ambient Contrast Ratio

**Ke Zhang^{1,2}, Tingting Han³, Hoi-sing Kwok^{1,2}, Zhaojun Liu^{1,2}*

1. Hong Kong University of Science and Technology (Hong Kong), 2. Southern University of Science and Technology (China), 3. Shenzhen Refond Optoelectronics CO., LTD (China)

GaN-based Micro-LEDs have shown great potential in various filed, such as solid-state lighting, display, sensor, visible light communication and multifunctional devices. The performance of Micro-LEDs in various operating environment drew enormous attention recently. We report high performance Micro-LEDs on sapphire substrate with device size scaling to 30 μ m and ultra-high current density of 100A/cm² under applied bias of 4V. The Micro-LED devices can keep comparable performance after extreme environment test with an emission wavelength of 460nm. We also proposed three method to improve ambient contrast ratio including optical method, anti-reflection film and optimized device structure.

FMCp1 - 3L Design of Mini-LED Backlight Using Reflective Mirror Dots with High Luminance Uniformity for Mobile LCDs

**Sho Kikuchi¹, Senshi Nasu¹, Takahiro Ishinabe², Hideo Fujikake²*

1. National Institute of Technology, Sendai College (Japan), 2. Tohoku University (Japan)

A new mini-LED local dimming backlight with reflective dots is proposed for high uniformity, high contrast, and low power consumption in small LCDs. The proposed backlight, comprising a small number of mini-LEDs, was verified as having high luminance uniformity due to the optimized backlight thickness and light distribution of mini-LEDs.

Friday, November 29

13:20-14:40	Conference Hall
MEET5: Micro/NanoDisplays and Nanotechnology Application (1)	

Chair: Poopathy Kathirgamanathan (Brunel University London)
 Co-Chair: Kyu Chang Park (KyungHee University)

MEET5 - 1 Invited Design Considerations for Holographic Retinal Projection Display
 13:20

**Christophe Martinez¹, Fabian Rainouard¹,
 Basile Meynard¹
 1. CEA Leti (France)*

We present design considerations for the development of a retinal projection display based on the association of a photonic integrated circuit and a pixelated hologram. Unexpected behavior concerning the randomness distribution of the emitting elements in our display is highlighted.

MEET5 - 2 Withdrawn

MEET5 - 5L Invited Comparison of LTPS, Oxide and LTPO TFTs for Micro-LED Displays
 13:40

**Jin Jang¹, Suihui Lee¹, Hyo-min Kim¹, Yuanfeng Chen¹
 1. Advanced Display Research Center, Kyung Hee University*

We review here the LTPS and oxide TFT technologies for micro-LED displays. We have developed BLA of a-Si for LTPS TFTs, exhibiting a high field-effect mobility over 150cm²/Vs for p-channel device. On the other hand, oxide TFTs using bulk-accumulation (BA) mode exhibits an effective field effect mobility over 50 cm²/Vs. The BLA TFT backplane was applied to drive a micro-LED displays using digital driving. Oxide TFT backplane was used for micro-LED with high contrast ratio. The LTPO technology and QD color conversion technology will be explained for micro-LED displays.

mLEDs

SID Display Week 2020

June 7 - 12, 2020

San Francisco Moscone Convention Center
 San Francisco, California, USA
<http://www.displayweek.org/>

MEET5 - 3 *Invited* Investigation of Temperature-Dependent Behaviors of Micro-LED Displays

14:00

**Zhaojun Liu¹, Bo Lu¹, Minggang Liu², Yong Fan², Jiayu Lee², Yan Wang¹, Hao-Chung Kuo³, Xiaowei Sun¹*

1. Southern University of Science and Technology (China), 2. Shenzhen China Star Optoelectronics Technology Co., Ltd (China), 3. National Chiao Tung University (Taiwan)

Micro-LED display consist of arrays of Micro-LEDs and driving back-plane with bonding technologies. As the size of LED get smaller, the amount of LED chips becomes a huge number. The thermal issue of Mini/Micro-LEDs needs to be considered. We report a 32×32 flexible Mini-LEDs array with driving current of 10mA under applied bias of 2.6V. The result of testing temperature distribution in different brightness shows that the Mini-LED array satisfy the requirement of thermal stability.

MEET5 - 4 *Invited* Towards High Resolution Active-Matrix GaN μ -LED Based Micro Displays

14:20

*Junyang Nie^{2,1}, Zhijie Ke³, Yongai Zhang¹, Xiongtu Zhou¹, Tailiang Guo¹, Congyan Lu⁵, Yiren Chen⁵, Zhangxu Pan⁶, Ling Li⁴, Di Geng⁴, Hang Song⁵, Zheng Gong⁶, *Jie Sun¹, Qun Yan^{1,2}*

1. Fuzhou University (China), 2. Xi'an Jiaotong University (China), 3. Xiamen Changelight Co. Ltd. (China), 4. Institute of Microelectronics, Chinese Academy of Sciences (China), 5. Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Science, China (China), 6. Guangdong Institute of Semiconductor Industry Technology, Guangdong Academy of Sciences (China)

We focus on the design/fabrication of active matrix 0.55 inch 1323 ppi micro displays based on GaN μ -LED arrays with Si CMOS driver prepared by flip-chip bonding. The process is optimized for manufacturing. A pioneer work of integrating 2D material transistors with GaN μ -LEDs is also discussed.

IDW '20

The 27th International Display Workshops

Dec. 9 - 11, 2020

Fukuoka International Congress Center

Fukuoka, Japan

<https://www.idw.or.jp/>

15:00-16:20	Conference Hall
MEET6: Micro/NanoDisplays and Nanotechnology Application (2)	

Chair: Chih-Jen Shih (ETH Zurich, Switzerland)
 Co-Chair: Kyu Chang Park (KyungHee University)

MEET6 - 1 Invited Toward for Ultimate Displays with MicroLED by PixeLED Display Technology

15:00
**Ying-Tsang (Falcon) Liu¹, Kuan-Yung Liao¹, Yun-Li Li¹*
1. PlayNitride Inc. (Taiwan)

MicroLED display is an emerging technology with high brightness, wide color gamut, and high aperture ratio. Based on our PixeLED[®] display technology to build MicroLED display, and SMAR·Tech[™] to build defect free panel, we are heading to mass production for MicroLED display.

MEET6 - 2 Invited Impressive Technologies for MicroLED Displays

15:20
**Zine Bouhamri¹, Eric Virey¹*
1. Yole Developpement (France)

MicroLED is a promising display technology. There are however still many technical challenges that need to be tackled before it is ready for consumer products. Mass transfer of the microLED chips is the elephant in the room, but many others could prove as challenging and possibly derail the microLED roadmap.

MEET6 - 3 17.3-in Mini-LEDs Halo Effect and Human Factor Study for High-End Notebook Application

15:40
**Hao-Hao Wu¹, Jenn-Jia Su¹, Chun-Sheng Li¹, Han-Ping Kuo¹, Yu-Hsiu Chang¹, Chia-En Fuh¹, Bo-Yuan Su¹*
1. AU Optronics Corporation (Taiwan)

Local dimming technology could increase contrast. Most of halo effect study is based on face-view. This paper would indicate performance and halo effect at different viewing angle. Finally, we proposed a 17.3-inch Mini-LEDs notebook module that can reach HDR1000 specification and less suffer from low contrast at different viewing angle.

IMID 2020

Aug. 25 – 28, 2020

COEX

Seoul, Korea

<http://www.imid.or.kr/>

MEET6 - 4L In-situ EUV Irradiation for Etching Residual Removal of AM Mini-LED

YONG DENG¹, JUNLING LIU¹, *MINLI TAN¹,
MIN XIONG¹, LIANGYI CAI¹, WENBO LIU¹,
QUANSHENG LIU¹, YIFENG YANG¹, RUI ZHAO¹,
WEIMIN ZHANG¹

*1. Shenzhen China Star Optoelectronic Technology
Company, Ltd. (China)*

Given the demand of high current drive, AM Mini-LED backplane usually uses dense plum-blossom-type design to optimize hole lapping. However, this porous design leads to a serious M2 etching residual issue. By using in-situ EUV irradiation, the infiltration of etchant to porous structure can be increased and the etching residual can be removed without affecting electrical characteristics of the device.

Author Interviews

16:30 - 17:00

SPECIAL EVENT

“Sensory Illusion”

Exhibition:

Wednesday, Nov. 27 – Friday, Nov. 29, 2019
Main Hall (1F)

Special Talks:

Wednesday, Nov. 27, 2019
18:30 – 19:10
Mid-sized Hall A (1F)

Special Topics of Interest on Quantum Dot Technologies

Thursday, November 28

9:00-10:35

Room 204

OLED4: QD Material & Devices

Chair: Takeo Wakimoto (Merck Performance Materials)
Co-Chair: Toshiaki Ikuta (JNC Corp.)

OLED4 - 1 *Invited* Anion Exchange Perovskite Quantum-Dots 9:00 for Highly Efficient Light Emitting Devices

**Takayuki Chiba¹, Junji Kido¹*

1. Yamagata University (Japan)

Perovskites quantum dots have attracted much attention for used in display and lighting applications, owing to their narrow band emission with high photoluminescence quantum yields, color tunability, and solution processability. Here, we demonstrate ligand-exchange and anion-exchange perovskite quantum dots using ammonium salts for use in highly efficient light-emitting devices.

OLED4 - 2 *Invited* Efficient Perovskite Light-Emitting Diodes 9:20 Enabled by Synergetic Device Architecture

*Yanqing Li¹, Yang Shen¹, *Jianxin Tang¹*

1. Soochow University (China)

In this work, we demonstrated a facile route was realized by combining bioinspired moth-eye nanostructures and half-ball lens to enhance light outcoupling. As a result, the maximum external quantum efficiency of green perovskite light-emitting diodes was improved to 28.2%, which represented a substantial step toward achieving practical applications of PeLEDs.

OLED4 - 3 Efficient Indium Phosphate Based Quantum Dot 9:40 Light Emitting Diode Using Sol-Gel Processed Electron Transfer Layer

**Ji Eun Yeom¹, Dong Hyun Shin¹, Mude Nagarjuna Naik¹,
Raju Lampande¹, Jang Hyuk Kwon¹*

1. Kyung Hee University (Korea)

Here, we report an efficient indium phosphate (InP) based inverted red Quantum Dot-Light Emitting Diodes (QLEDs) by incorporating a sol-gel processed Mg-doped ZnO layer. The red InP-QLED with our sol-gel processed Mg:ZnO layer reveals a maximum EQE of 7.7% , which is significantly higher than the ZnO and Mg:ZnO nanoparticles layers. These results suggest that the sol-gel processed Mg-doped ZnO layer is relatively efficient in terms of performances.

OLED4 - 4 Ambient Contrast Ratio Study of QD-OLED Devices
10:00

**SU PAN¹*

1. Shenzhen China Star Optoelectronics Display Technology Co.,Ltd (China)

Quantum dots are promising color conversion materials to achieve high resolution full color display with wide color gamut and low cost. In this work, we studied the ambient contrast ratio of QD-OLED devices and demonstrated an optimal structure to realize high contrast displays

OLED4 - 5L Solution-Processed Indium-Gallium-Nitride (InGaN) Blue Light-Emitting Diodes (LEDs)
10:20

**TADAHIKO HIRAI¹, TETSUO TSUCHIYA²*

1. CSIRO (Australia), 2. AIST (Japan)

A soluble form of InGaN was synthesized, producing a solution that exhibited blue photo-luminescence (PL) upon UV light exposure. This solution was used in the fabrication of a blue light-emitting diode (LED) that was produced using solution processable methods, a world first for an InGaN-base LED. The PL properties of the solution and the electro-luminescence (EL) and device characteristics of the LED are presented.

Author Interviews

10:40 - 11:10

10:40-13:10

Main Hall

Poster FMCp2: Quantum Dot Technologies

FMCp2 - 1 Wide Color Gamut White Light-Emitting Diode Using Quantum Dot/Siloxane Hybrid Encapsulation Material with Excellent Environmental Stability

**Junho Jang¹, Da-Eun Yoon¹, Seung-Mo Kang¹,
 Ilson Lee¹, Doh C. Lee¹, Byeong-Soo Bae¹*

1. Korea Advanced Institute of Science and Technology (Korea)

We report a luminescent light-emitting diode (LED) encapsulation material using quantum dot (QD)/siloxane hybrid (TSE-QD). The TSE-QD shows exceptional stability under high temperature (120°C in ambient) and various chemicals. TSE-QD based white LED also exhibits superior reliability under high temperature/high humidity and wide color gamut (116 % of NTSC).

10:40-13:10

Main Hall

PHp2: QD Phosphors**PHp2 - 1** Withdrawn**PHp2 - 2** Withdrawn**PHp2 - 3L** **Ligand Exchange of Core/Shell CuInS₂/ZnS Quantum Dots for Preparation of Their Homogeneous Ink**

**Momo Shiraishi¹, Yoshiki Iso¹, Tetsuhiko Isobe¹,
Takehiro Seshimo², Yueh-Chun Liao², Kunihiro Noda²,
Dai Shiota²*

*1. Keio University (Japan), 2. Tokyo Ohka Kogyo
Company, Ltd. (Japan)*

1-Dodecanethiol on CuInS₂/ZnS quantum dots (QDs) was exchanged with cyclohexanethiol. The obtained QDs were transparently dispersed in alicyclic diepoxy compound to yield the QD ink for ink-jet printing. This homogeneous dispersion is attributed to similarity in molecular structure between the ligand and the ink component.

10:40-13:10

Main Hall

OLEDp2: OLED/QDT poster**OLEDp2 - 1** Withdrawn**OLEDp2 - 2** **The Effect of Particle Size on the Optical and Electrical Characteristics of Quantum Dot Light-Emitting Diode using Zinc Oxide Nanoparticles**

**Da-Young Park¹, Dae-gye Moon¹*

1. Soonchunhyang University (Korea)

The electrical and optical characteristics of QLEDs with 3 and 8 nm ZnO nanoparticles (NPs) were investigated. The QLED with 8 nm ZnO NPs exhibited maximum luminance of 64,360 cd/m² and 4.5 times higher current efficiency compared to the 3 nm ZnO device.

OLEDp2 - 3 Withdrawn**OLEDp2 - 4** **High Efficiency Green Quantum Dot Light-Emitting Diodes with Surface-treated Indium Phosphide**

**Wei Jiang¹, Hee Yeop Chae¹*

1. SungKyunkwan University (Korea)

The multi-shelled green InP QDs were synthesized by using the phosphorus source of (DMA)₃P and the narrow FWHM of 46nm was obtained. The PLQY of 64% was achieved after the surface treatment and the maximum quantum efficiency of 2.68% and the current efficiency of 7.7cd/A were achieved for quantum dot light emitting diodes.

OLEDp2 - 5 Withdrawn**OLEDp2 - 6L The Influence of Bottom Layer on the Performance of Perovskite LEDs**

**Jungwon Kim¹, Min Chul Suh¹*

1. Kyung Hee University (Korea)

We found the interface mixing could be occurred when a hydrophilic interlayer is utilized. To solve this problem we tried to change the perovskite precursor materials to exclude interlayer. As a result, we found that we could skip the interlayer by changing a composition of perovskite.

OLEDp2 - 7L Mechanisms of Operation in Quantum-Dot Light-Emitting Diodes

**Shoichi sano¹, Takashi Nagase^{1,2}, Takashi Kobayashi^{1,2}, Hiroyoshi Naito^{1,2}*

1. Osaka prefecture university (Japan), 2. The Research Institute for Molecular Electronic Devices (RIMED), Osaka Prefecture University (Japan)

Mechanisms of operation in quantum-dot light-emitting diodes (QLEDs) have been investigated theoretically and experimentally. Important factors governing the current efficiency of QLED were examined using a machine learning approach. High hole injection barrier to QD is the dominant efficiency limiting factor, and the machine learning result was confirmed experimentally. A mechanism of high current efficiency even in the presence of high hole injection was discussed in terms of device simulation.

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW '19.

IDW'19 Award winners will be announced on the IDW website: <https://www.idw.or.jp/award.html>

17:20-18:40

Conference Hall

MEET2: EL Quantum Dots Technologies

Chair: Frank Yan (Fuzhou University)

Co-Chair: Jang Hyuk Kwon (Kyung Hee University)

MEET2 - 1 Invited Quantum Dot Electroluminescence to Achieve Saturated Colours for REC2020 Compatibility

17:20

**Poopathy Kathirgamanathan¹,
Muttulingam Kumaravel¹**1. Brunel University London (UK)*

Using solvent based surface engineering of sol-gel derived ZnO electron injector, red QLEDs with a current efficiency of 32.6 cdA^{-1} and a power efficiency of 18.6 lmW^{-1} at 1000 cdm^{-2} for Cd based QDs. We also report dark red electroluminescent InP/ZnS QDs ($x,y = 0.672, 0.325$) with a maximum current and power efficiency of 3.6 cdA^{-1} and 4.7 lmW^{-1} respectively.

MEET2 - 2 Withdrawn**MEET2 - 3 Invited Ultra-Bright Quantum-Dot Light-Emitting Diodes**

18:00

Shuming Chen¹1. Southern University of Science and Technology (China)*

Thermal stability of quantum dots (QDs) and thermal management of QD light-emitting diodes (QLEDs) could significantly affect the performance, especially the efficiency roll-off behaviors of QLEDs. With effective thermal management, the efficiency roll-off is significantly suppressed and consequently our developed green QLEDs exhibit an unprecedented high brightness of over 10^6 cd/m^2 at a current density of $J=3500 \text{ mA/cm}^2$ and a external quantum efficiency of $\sim 10\%$, which is an order of magnitude higher than that of all reported QLEDs.

QDT

MEET2 - 4 Invited Efficient and Stable Light Emitting Diodes Based on Luminescent Nanocrystals

18:20

Kai Wang¹, Xiangtian Xiao^{1,2}, Zhaojin Wang¹, Taikang Ye¹1. Southern University of Science and Technology (China), 2. The University of Hong Kong (Hong Kong)*

Efficiencies of electroluminescence perovskite LEDs were enhanced significantly by lowering surface defects and balancing charge injection. Moreover, optical and thermal stabilities of photoluminescence quantum dot LEDs and perovskite LEDs were also improved greatly by introducing the Quantum Dot Luminescent Micro-Sphere (QLuMiS) technology.

Author Interviews

18:50 - 19:20

Friday, November 29

9:00-10:20	Conference Hall
MEET3: Emerging Quantum Dots and Nanotechnologies (1)	

Chair: Christophe Martinez (CEA LETI)
 Co-Chair: Haizheng Zhong (Beijing Institute of Technology)

MEET3 - 1 *Invited* Developing Cd-free QLEDs for Display Applications

9:00

**Zhuo Chen¹, Dong Li¹, Boris Kristal¹, Jingwen Feng¹, Zhigao Lu¹, Gang Yu¹, Yanzhao Li¹, Xinguo Li¹, Xiaoguang Xu¹*

1. BOE Technology Group Co., Ltd. (China)

In this study, we investigated the effect of magnesium (Mg) doping in ZnO nanoparticles, in balancing the charge transfer in InP-based QLED devices. Through optimizing QD structures and devices, red InP QLEDs with the current efficiencies as high as 11.6 cd/A were fabricated.

MEET3 - 2 *Invited* Horizontally Oriented Exciton Dipoles in Solution-Processed Quantum Dot Solids

9:20

**Chih-Jen Shih¹, Jakub Jagielski¹, Simon Solari¹, Sudhir Kumar¹*

1. ETH Zurich, Switzerland (Switzerland)

It is well-known that the horizontally oriented exciton transition dipole moments in thin films of quantum emitters can direct radiation perpendicular to the substrate, maximizing the light outcoupling efficiency. Exciton orientation control has been reported in many thermally evaporated organic molecular thin films but has not yet been realized in solution-processed quantum dots films. Here, we demonstrate that excitons in solution-processed thin films comprised of colloidal quantum wells (CQWs) of lead trihalide perovskites are horizontally oriented, with thin-film photoluminescent quantum yields of up to 90%.

MEET3 - 3 *Invited* Controlling Charge Injection Properties of Quantum Dot Light-Emitting Diodes

9:40

**Jeonghun Kwak¹, Seunghyun Rhee¹, Taesoo Lee¹, Guen-Woo Baek¹, Kyunghwan Kim¹, Yeseul Park¹*

1. Seoul National University (Korea)

Efficient charge carrier injection is one of the most important factors to achieve high performance quantum dot (QD) light-emitting diodes (QLEDs). Here, we investigated the effects of charge carrier injection properties on the QLED performance by modifying the surface ligands of QDs and by adopting an interlayer between the QD layer and the charge transport layer.

MEET3 - 4 *Invited* High Efficiency Cadmium-free Red Quantum Dot-Light Emitting Diodes

10:00

**Jang Hyuk Kwon¹*

1. Kyung Hee University (Korea)

We report a high efficiency inverted red indium phosphide (InP) based quantum dot-light emitting diode (QD-LED) by optimizing InP-QD properties as well as interfacial contact between electron transport layer and emissive QDs, and applying self-aging approach. Our QD-LED exhibits substantial improvement in the external quantum efficiency from 4.42 to 10.2% after several days of self-aging.

10:40-11:40	Conference Hall
MEET4: Emerging Quantum Dots and Nanotechnologies (2)	

Chair: Shuming Chen (Southern University of Science and Technology)

Co-Chair: Jang Hyuk Kwon (KyungHee University)

MEET4 - 1 *Invited* In-situ Fabricated Perovskite Quantum Dots for Display Applications

10:40

**Haizheng Zhong¹*

1. Beijing Institute of Technology (China)

Halide perovskite quantum dots exhibit desired photoluminescence properties with high quantum yields, wide wavelength tunability, and ultra-narrow emissions, which are suitable for display technology. Here we describe the in-situ fabrication of perovskite quantum dots and their use in prototype devices and display system.

MEET4 - 2 Withdrawn

MEET4 - 3 *Invited* Hybrid Colloidal Quantum Dot Photonic Devices

11:20

**Chien-chung Lin^{1,2}*

1. National Chiao Tung University (Taiwan), 2. Industrial Technology Research Institute (Taiwan)

In recent years, colloidal quantum dots (CQDs) have been the focus of attention due to their highly efficient illumination, narrow linewidth emission, and widely tunable emission wavelength. Various types of devices have been implemented for the photonic devices to incorporate these novel materials. Both photon generation and absorption can be accomplished by CQDs and the corresponding light emitting diodes and solar cells can be designed to utilize their special characteristics. In this talk, we will provide our latest progress on such devices and the past experience we had in our lab. The highly reliable CQD package will play a crucial rule for the next generation photonic devices.

Author Interviews

12:10 - 12:40

13:20-14:20

Room 206

FMC7: Quantum Dot

Chair: Takao Tomono (Toppan Printing)
Co-Chair: Yukito Saitoh (FUJIFILM Corporation)

**FMC7 - 1 *Invited* Quantum Rod Enhancement Films for
13:20 Modern LCDs**

*Swadesh Kumar Gupta¹, Maksym F Prodanov¹,
Chengbin Kang¹, Cheng Chun Hin¹,
Valerii V Vashchenko¹, *Abhishek Kumar Srivastava¹
1. hong kong university of science and technology
(Hong Kong)*

Quantum rod films, comprising the aligned quantum rods, emits polarized light that could potentially improve the efficiency of the LCD. In this talk, we will discuss about the High-quality alignment of the QRs showing a high polarization ratio for the PL. We developed these QREF containing red and green QRs, in the same films, for their application in LCD backlights. These films offer wider color gamut and almost two times higher optical efficiency (i.e. ~7.8%) for the conventional LCDs.

**FMC7 - 2 Wide Color Gamut Display Solution Using Hybrid-
13:40 typed Perovskite Quantum Dots White LEDs**

*Chieh-Yu Kang¹, Chih-Hao Lin¹, *Chun-Lin Tsai¹, Chin-Wei Sher¹, Ting-zhu Wu², Po-Tsung Lee¹, Hao-Chung Kuo¹
1. National Chiao Tung University (Taiwan), 2. Xiamen University (China)*

This study presents that hybrid-typed Perovskite WLED has higher luminous efficiency (85 lm/W) compared to solid-typed and good wide color gamut performance (123 % of NTSC and 92 % of Rec. 2020). Lower operation temperature and better reliability (over 500 hours) result have also been demonstrated under this design.

**FMC7 - 3 A Novel Display Technology — Perovskite Quantum
14:00 Dot Display with Blue OLEDs**

**Miao Duan¹, Dongze Li¹, Zhiping Hu¹, Wenxiang Peng¹, Yongwei Wu¹, Yongming Yin¹, Bo He¹, Pei Jiang¹, Feng Jiang², Lifu Shi², Haizheng Zhong², Shu-jih Chen¹, Chia-Yu Lee¹, Xin Zhang¹
1. Shenzhen China Star Optoelectronics Semiconductor Display Technology Co., Ltd. (China),
2. Beijing Institute of Technology (China)*

We fabricated 6.6-inch perovskite quantum dot displaypanel by inkjet printing technology, being cooperated withactive matrix organic light emitting diodes. Here, 3-stackblue OLEDs with top-emission structure acted as backlightand green perovskite layer acted as color downconverter,which exhibited excellent performances such as high colorpurity.

Topical Session on Information Display, Artificial Intelligence, and Smart Society

Wednesday, November 27

15:20-16:35

Room 206

AIS1/INP2: Smart Society and Information Display

Chair: Katashi Nagao (Nagoya University)

Co-Chair: Toshiaki Fujii (Nagoya University)

AIS1/ INP2 - 1 *Invited* Adaptive Spatial User Interfaces That Activate Us

15:20 *Kazuyuki Fujita¹

1. Tohoku University (Japan)

His talk covers adaptive spatial user interfaces to make the users more active and productive. He introduces several projects including Ambient Suite that enhances communication among multiple participants and AI-Supported Meeting Space in which the space itself behaves as another participant to make the meeting more productive.

AIS1/ INP2 - 2 *Invited* Automated Vibrotactile Generation Based on Texture Images or Material Attributes Using GAN

15:45 *Yuki Ban¹, Yusuke Ujitoko^{2,3}

1. The University of Tokyo (Japan), 2. Hitachi, Ltd. (Japan), 3. The University of Electro-Communication (Japan)

We propose the vibrotactile feedback designing system using GAN-based vibrotactile signal generator. Our system generate signals presenting specific tactile impression based on user-defined parameters or images. User studies showed that it was not possible to distinguish between vibrations generated using this model and vibrations recorded from the actual material surface.

AIS1/ INP2 - 3 *Invited* Vibrotactile Signal Generation with GAN

16:10 *Shotaro Agatsuma¹, Shin Takahashi¹, Satoshi Saga²

1. University of Tsukuba (Japan), 2. Kumamoto University (Japan)

To create valuable content for haptic display, we propose a method of generating alternative data from acquired one instead of collecting a great number of data from real textures. We made a data generation model based on Generative Adversarial Network and held experiments to evaluate the performance of the model.

17:00-18:25

Room 206

AIS2: AI and Information Display

Chair: Yuki Ban (The University of Tokyo)
Co-Chair: Kazuyuki Fujita (Tohoku University)

**AIS2 - 1 *Invited* AI-Powered Education: Smart Learning
17:00 Environment with Large Interactive Displays**

**Katashi Nagao¹*

1. Nagoya University (Japan)

Our university is currently developing a smart learning environment that can train students to enhance their presentation and discussion skills. It includes an automatic evaluation system that efficiently records, analyses, and evaluates the presenter's presentation and discussion skills. We call such education promoted by the AI technologies AI-Powered Education.

**AIS2 - 2 *Invited* Light-field image processing Using deep
17:25 neural network**

**Toshiaki Fujii¹*

1. Nagoya University (Japan)

In this paper, we report results of our experiments where deep neural networks (DNNs) are adopted to perform the light-field image processing. Experimental results show that we can successfully reduce the computation cost by using DNN with almost the same performance of conventional methods.

**AIS2 - 3 Deep Convolution Neural Networks for Painting-like
17:50 3D Rendering**

**Zhi Yang¹, Pei-Li Sun¹, Tzung-Han Lin¹*

*1. National Taiwan University of Science and
Technology (Taiwan)*

A 3D rendering model which uses deep convolutional neural networks to imitate 2D painting style is proposed. User can feed the networks with simple paintings of specific objects to render images of 3D objects with any orientations in accordance with the painting style.

**AIS2 - 4L Outdoor Wild Bird Detection Based on YOLO
18:10 Algorithm**

**Bo-Cheng Zhu¹, Tzung-Han Lin¹, Yao-Chuan Tsa²,
Kuang-Wen Hsieh², Fuh-Min Fan², Perng-Kwei Lei²*

*1. National Taiwan University of Science and
Technology (Taiwan), 2. National Chung-Hsing
University (Taiwan)*

This study focuses on outdoor bird detection in video surveillance to reduce the risk of avian influenza (AI) in poultry farms. Once a bird is detected, our system will trigger another action to drive away the bird. We utilized YOLO algorithm for object detection, and add diversity samples to the dataset to train the model, then recognition accuracy is improved.

Author Interviews

18:30 - 19:00

Thursday, November 28

14:30-17:00

Main Hall

Poster AISp1/DESp2: Image Processing

AISp1/
DESp2 - 1

Hardware Acceleration for Multi-Scale Object Detection Based on Dense Pyramid Feature

**Congrui Wu¹, Tianmin Rao¹, Ran Duan¹, Xiao Zhang¹*

1. BOE Technology Group Co., Ltd (China)

ACF is a method for object detection which approximately constructing a dense feature pyramid used for Adaboost classifier. Our work focuses on this method and implement the whole detection process on heterogeneous hardware platform. This design achieves a detection performance of 134 fps consuming less hardware resources.

AISp1/
DESp2 - 2L

Saliency Map Prediction Using a Method of Object Detection

**Tsuyoshi Kushima¹, Masaki Hisano¹*

1. The University of Electro-Communications (Japan)

Although there are many models which mimic human visual information search, their performance couldn't match that of human beings. We propose a new model which reflects receiving characteristics of the human visual system because these characteristics are not considered enough in the previous models.

14:30-17:00

Main Hall

Poster AISp2/VHFp6: Deep Learning for Image Quality

AISp2/
VHFp6 - 1

Automatic Selection of Preferable Tone-Mapping Method Based on Deep Learning

**Hirofumi Sasaki¹, Keita Hirai¹, Takahiko Horiuchi¹*

1. Chiba University (Japan)

The preference of a tone-mapped HDR image appearance depends on an applied Tone-Mapping method and an input scene content. In this paper, based on a deep learning technique, we propose a system to automatically select a Tone-Mapping method that provides a preferable appearance of an input HDR image.

Also presented in Innovative Demonstration Session (see p. 278)



Friday, November 29

13:20-14:35	Room 108
PRJ6/AIS3: AI	

Chair: Makio Kurashige (DNP)
 Co-Chair: Satoshi Ouchi (Hitachi)

PRJ6/ AIS3 - 1 ***Invited* Visual Illusions Expressed by Deep Neural Networks**
13:20 **Taisuke Kobayashi¹, Eiji Watanabe^{1,2}*

1. Japan/Aichi/National Institute for Basic Biology (Japan), 2. Japan/Aichi/The Graduate University for Advanced Studies (SOKENDAI) (Japan)

The predictive coding theory, which is one of mathematical models of the visual information processing of the brain, were incorporated to deep neural networks. We found that the deep neural networks represented the motion for illusion images that were not moving physically, much like human visual perception.

PRJ6/ AIS3 - 2 **Vertical View Human Action Recognition from Range Images**
13:40 **Akinobu Watanabe¹, Keiichi Mitani¹*

1. Hitachi, Ltd. (Japan)

We developed the human joints' position estimation technique and the person tracking technique from upward view range image of TOF sensor, and confirmed the correct prediction ratio of hands' position is 97%, and confirmed the person tracking error is reduced to 1/7.

Also presented in Innovative Demonstration Session (see p. 280)

PRJ6/ AIS3 - 3 **High Efficiency Information Presentation Method for Head Mounted Display on Work Support**
14:00 **Takuya Nakamichi¹, Chiyo Ohno¹, Shoji Yamamoto¹, Koji Yamasaki¹*

1. Hitachi, Ltd. (Japan)

We developed an information presentation method for head mounted displays that does not interfere with the field worker. This method achieves low power consumption by a processing method that does not require a graphic processing unit and a camera for space recognition.

**PRJ6/
AIS3 - 4L
14:20** **High-Speed and High-Brightness Color Single-Chip
DLP Projector Using High-Power LED-Based Light
Sources**

**Yoshihiro Watanabe^{1,2}, Masatoshi Ishikawa²*

*1. Tokyo Institute of Technology (Japan), 2. University
of Tokyo (Japan)*

This paper proposes a high-speed and high-brightness color projector with a single-chip-DLP configuration that meets the demands for compactness and speed by introducing light sources based on luminescent concentration from LEDs and an optimized optical system. Furthermore, with the unique control circuit of the projector, it actualizes various projection functions.

15:00-16:10	Room 107
DES6/AIS4: Image Processing	

Chair: Yuji Oyamada (Tottori University)
Co-Chair: Mutsumi Kimura (Ryukoku univ.)

**DES6/
AIS4 - 1
15:00** ***Invited* Deep Learning-Based Image Processing
Algorithms in 8K Era**

**SukJu Kang¹*

1. Sogang University (Korea)

This paper presents the deep learning-based inverse tone mapping algorithms for high dynamic range imaging. Specifically, the technical contents of various deep learning-based inverse tone mapping techniques, which are currently being studied, are explained, and the performance of representative methods are compared.

**DES6/
AIS4 - 2
15:25** ***Invited* Omnidirectional/360-degree Image and Video
Standardizations Status**

**Junichi Hara¹*

1. RICOH Company, LTD. (Japan)

This presentation reports technical aspects of the omnidirectional/360-degree image and video standardizations; ISO/IEC 19566-6 JPEG 360 and ISO/IEC 23090-2 Omnidirectional Media Format (OMAF) international standards. And this also introduces functions of these next version omnidirectional picture standards that now are discussed in standardization meetings, and discusses its applications.



**DES6/
AIS4 - 3
15:50**

**An Advanced TV Program Logo Processing
Algorithm for Preventing OLED TV Image Sticking**

**Lin Cheng¹, Yang Rao¹, Yufeng Jin¹, Yin-Hung Chen¹,
Ming-Jong Jou¹, Bin Zhao¹, Xin Zhang¹*

*1. Shenzhen China Star Optoelectronics Technology
Company (China)*

In this paper, a TV logo post-processing system is proposed to relieve the burn-in phenomenon on OLED TV. It contains generic logo detection algorithm and identification mechanism to adapt to video real-time processing and temporary channel change events. With the logo restrain function, OLED TV image-sticking phenomenon would be alleviated.

Author Interviews
16:30 - 17:00

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)
Sapporo Convention Center

SPECIAL EVENT

“Sensory Illusion”

Exhibition:

Wednesday, Nov. 27 – Friday, Nov. 29, 2019
Main Hall (1F)

Special Talks:

Wednesday, Nov. 27, 2019
18:30 – 19:10
Mid-sized Hall A (1F)

Topical Session on The 11th International Conference on 3D Systems and Applications

Wednesday, November 27

13:40-13:45	Opening	Small Hall
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3DSA

Opening Remarks

13:40

Shiro Suyama¹, 1. Tokushima Univ. (Japan)

13:45-15:05	3DSA1/3D1: Holography 1	Small Hall
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Chair: Hoang Yan Lin (Nat. Taiwan Univ.)
Co-Chair: Takashi Kakue (Chiba Univ.)

3DSA1/ 3D1 - 1 *Invited* Complex Spatial Light Modulation for Holographic Displays

13:45

**Hwi Kim¹*

1. Korea University (Korea)

Complex light modulation is a fundamental and crucial issue for holographic displays. We propose three-phase amplitude structure that has three fixed phase and controllable amplitudes to implement a single complex value. In this study, it is also expected to implement an ultra-low noise holographic display with active complex modulation.

3DSA1/ 3D1 - 2 **Withdrawn**

3DSA1/ 3D1 - 5L **A Fast Hologram Calculation Method Based on the Light Field Rendering**

14:05

**Tiantian Zhang¹, Li Liu¹, Jun Xia¹*

1. Southeast University (China)

We propose a new method based on ray-sampling (RS) algorithm to reconstruct the holographic light field. Different from the previous method, we accumulate elemental images in the space domain without any Fourier transform. The results demonstrate that the proposed method successfully reconstructs the 3D scene with accurate depth cues.

**3DSA1/
3D1 - 3
14:25** **Performance Improvement for Computer-Generated Holographic Stereogram Based on Integral Imaging**
**Zi Wang¹, Guoqiang Lv¹, Qibin Feng¹*
1. Hefei University of Technology (China)

We want to introduce several recent works for improving the performance of integral imaging (II) based holographic stereogram (HS). First, we have proposed a resolution-enhanced II-based HS using the moving array lenslet technique (MALT). [1] Second, we have proposed the concept of resolution priority HS (RPHS) for the first time, which is based on the principle of resolution priority II, by adding a quadratic phase term on the conventional Fourier transform. [2] Finally, a simple and fast algorithm for computer-generated hologram (CGH) based on pinhole-type II using a look-up table was proposed. [3]

**3DSA1/
3D1 - 4
14:45** **Analysis About System Parameters of Self-interference Incoherent Digital Holographic Recording System Utilizing Geometric Phase Lens**
**KiHong Choi¹, Jongmin Kim¹, Keehoon Hong², Joongki Park², Sung-Wook Min¹*
1. Kyung Hee University (Korea), 2. Electronics and Telecommunications Research Institute (Korea)

Self-interference incoherent digital holography utilizing the geometric phase lens has recently been developed with a super-simple design and the compactness of system structure. In this study, some of the acquisition performance related to the system parameters are analyzed to enhance the hologram acquisition quality.

15:20-16:40	Small Hall
3D2/3DSA2: Holography 2	

Chair: Hwi Kim (Korea Univ.)
 Co-Chair: Yuji Sakamoto (Hokkaido Univ.)

**3D2/
3DSA2 - 1
15:20** **Invited Evaluation of Hologram Quality Based on Digital and Analog Types of Spatial Light Modulators**
*Chih-Hao Chuang¹, Siao-Ting Li², Chien-Yu Chen², *Hoang-Yan Lin¹, Kuan-Hsu Fan-Chiang³, Hsien-Chang Tsai³*
1. National Taiwan University (Taiwan), 2. National Taiwan University of Science and Technology (Taiwan), 3. Himax Display Inc. (Taiwan)

A prototype system of head-mounted holographic display with multi-depth is presented. The system adopts the modified Gerchberg-Saxton algorithm to produce the phase-only functions on digital and analog types of spatial light modulators. Furthermore, the proposed system could achieve multi-depth by using human-eye focusing and zooming mechanism. Finally, the quality of images is also analyzed and evaluated.

**3D2/
3DSA2 - 2
15:40** **Invited Development of 72K Ultra-High-Resolution
SLMoG System For High-Capacity Digital
Holography Image**

**Jae-Eun Pi¹, Ji-Hun Choi¹, Jong-Heon Yang¹, Chi-Young Hwang¹, Gi Heon Kim¹, Hee-Ok Kim¹, Young-gi Kim², Myung Yu Kim², Ha Kyun Lee³, Chi-Sun Hwang¹, Jinwoong Kim¹*

1. ETRI (Korea), 2. Silicon Works (Korea), 3. MVTech (Korea)

We present ultra-high-resolution digital holography operation system supporting 72K x 3.2K spatial-light-modulator on glass (SLMoG) panel which is composed of the state-of-the-art 1 μ m-pitch pixel. To control the high-capacity digital holography image, we have developed 40 Gbps optical transmit (Tx) / receive (Rx) and high-speed data handling system. Furthermore, we designed 6K channel of source driver IC with 1:2 demultiplexer (DeMux) control signal to operate 72K column line by using multi-MIPI interface.

**3D2/
3DSA2 - 3
16:00** **Reducing the Effect of Crosstalk Noise from
Defocused Multi-Depth Holographic Image with a
Rasterize Encoding Method**

**Siao-Ting Li¹, Chih-Hao Chuang², Chung Feng Kuo¹, Hoang-Yan Lin², Chin-I Huang³, Chien-Yu Chen¹*

1. National Taiwan University of Science and Technology (Taiwan), 2. National Taiwan University (Taiwan), 3. National Kaohsiung First University of Science and Technology (Taiwan)

Crosstalk noise from defocused light affects the image quality of target image in multi-depth holographic display system. In this study, we propose a defocused light noise reduction with the rasterize encoding method. With the objective image quality analysis, it proves that the proposed method could improve the image quality.

**3D2/
3DSA2 - 4
16:20** **The Holographic Information Projection System
Based on Holographic Optical Element**

**Wen-Kai Lin^{1,2}, Hung-Pin Chen², Bor-Shyh Lin¹, Wei-Chia Su²*

1. National Chiao Tung University (Taiwan), 2. National Changhua University of Education (Taiwan)

In this paper, a projection type holographic display based on HOE was proposed. The viewing angle of the holographic image is larger than the maximum diffraction angle of the SLM which was employed to display CGH. The theory and aberration were analyzed via the ray tracing technique.

17:00-18:20

Small Hall

3DSA3/3D3: Light Field 1

Chair: Yasuhiro Takaki (Tokyo Univ. of A&T)
Co-Chair: Hirotsugu Yamamoto (Utsunomiya Univ.)

**3DSA3/
3D3 - 1** **Depth Range Control in Visually Equivalent Light
Field 3D (VELF3D) Display**

17:00 *Munekazu Date¹, Shinya Shimizu¹, Hideaki Kimata¹
1. Nippon Telegraph and Telephone Corporation
(Japan)

Light field displays have limited display depth range, which is a serious issue in supporting live action content. Though generating depth maps and re-rendering is a solution, it incurs huge computational cost. In this paper, we achieve depth range compression simply by calculating the weighted average of multi-camera images.

Also presented in Innovative Demonstration Session (see p. 278)

**3DSA3/
3D3 - 2** **Withdrawn**

**3DSA3/
3D3 - 5L** **An Adaptive Time-Division Multiplexing Parallax
Barrier Allowing Multiple Observers**

17:20 *Bin Yang¹, Hideki Kakeya¹
1. University of Tsukuba (Japan)

We propose an autostereoscopic display allowing multiple observers with adaptive time-division multiplexing parallax barrier. To make sure that every observer is in the proper viewing zone to enable stereoscopy, the number of time-division multiplexing is switched in accordance with the distance between the observers.

**3DSA3/
3D3 - 3** **High Field-of-View Near-Eye Display Using Total
Internal Reflection Prism and Holographic Printing
Technique**

*Jinsoo Jeong¹, Juhyun Lee¹, Byoung-ho Lee¹
1. Seoul National University (Korea)

By using holographic printing, high field-of-view (FOV) holographic eye-piece for near-eye display can be implemented. However, due to the high FOV, it is hard to separate the reference and signal beam. We used total internal reflection prism to solve the problem and an augmented reality holographic near-eye display is implemented.

**3DSA3/
3D3 - 4** **Withdrawn**

**3DSA3/
3D3 - 6L
18:00**

**Slim Holographic Retina Display Based on
Holographic Waveguide**

**Li Liu¹, Tiantian Zhang¹, Jun Xia¹*

1. Southeast University (China)

In this paper, we propose a slim system for holographic retina display on the basis of holographic waveguide and holographic optical elements (HOEs), promising in augmented reality (AR) system. By attaching the spatial light modulator (SLM) to the waveguide directly, we decrease the form factor of the AR system greatly.

Author Interviews

18:30 - 19:00

Thursday, November 28

9:00-10:20	Small Hall
3D4/VHF4/3DSA4: Illusion	

Chair: Sumio Yano (Shimane University)

Co-Chair: Yuzo Hisatake (Shizuoka Univ.)

3D4/VHF4/ Invited Innovative Mobile Force Display: Buru-Navi

3DSA4 - 1

**Hiroaki Gomi¹, Sho Ito¹, Ryoma Tanase¹*

9:00

1. NTT Communication Science Labs. (Japan)

Humans capture the environmental world not only by vision but also by somatosensory information. Here we introduce several types of mobile force-display gadgets 'Buru-Navi' recently developed, and showcase some application trials for pedestrian navigation and for enhancing immersive sensation along a video scene.

3D4/VHF4/ Invited Displaying Deformation of Virtual Objects

3DSA4 - 2

Using Visuo-Haptic Interaction

9:20

**Yuki Ban¹*

1. The University of Tokyo (Japan)

We developed the visuo-haptic shape display system with which users can deform virtual objects dynamically. Our system senses how the force is applied to the grasping object, and deforms the virtual grasping object and the virtual hands according to the direction and size of the force.

3D4/VHF4/ Invited Real-World Implementations of Visual

3DSA4 - 3

Illusions by Using Augmented Reality Techniques

9:40

**Takahiro Kawabe¹*

1. NTT Communication Science Laboratories (Japan)

Visual illusions refer to perceptual experiences wherein the appearance of objects and scenes is distorted. By taking advantage of the illusion which is often interpreted as undesired elements in perception, our technique can offer visual experiences which are not produced on the basis of the previous techniques.

3D4/VHF4/ 3DSA4 - 4 Gloss Enhancement Beyond Projector Performance Using the Glare Illusion

10:00 *Shinji Nagata¹, Toshiyuki Amano¹

1. Wakayama University (Japan)

The glare illusion is a well-known illusory perception in which a region appears brighter than its actual luminance when surrounded by a gradation of luminance. We propose a method of enhancing gloss beyond projector performance using this glare illusion. The effectiveness of the proposed method is confirmed by comparing it with the proposed and conventional method.

Author Interviews

10:40 - 11:10

10:40-13:10

Main Hall

Poster 3Dp1/3DSA1: 3D and Hyper-realistic Displays and Applications 1

3Dp1/ 3DSA1 - 1 Compact Binocular Holographic Head-Mounted Display Using Viewing Zone Expansion Method with Multiple Light Sources

*Kazuya Furuta¹, Yuji Sakamoto¹

1. Hokkaido University (Japan)

Holographic head mounted displays (HMDs) for augmented reality (AR) are being researched for use as work support because they can display images at a free depth. It is necessary to miniaturize the size of such devices for practical use. This paper proposes a compact binocular HMD for AR.

Also presented in Innovative Demonstration Session (see p. 279)

3Dp1/ 3DSA1 - 2 Quality Analysis of Light-Waves Considering Transmission Errors of Various Images for Wireless Transmission System of CGHs

*Kazuhiro Yamaguchi¹, Yuji Sakamoto²

1. Suwa University of Science (Japan), 2. Hokkaido University (Japan)

In this paper, a wireless transmission system model for computer-generated holograms is constructed, and quality of light-waves considering transmission errors of CGH are analyzed by using computer simulations. SNRs (Signal to noise ratio) of light-waves reconstructed from transmitted CGHs having some transmission errors were measured and evaluated.

**3Dp1/
3DSAp1 - 3 Optimization Technique for Phase-Only Computer-Generated Holograms Based on Gradient Descent Method**

**Shujian Liu¹, Yuki Nagahama¹, Yasuhiro Takaki¹*

1. Tokyo University of Agriculture and Technology (Japan)

A new phase optimization technique for computer-generated holograms is proposed, which iteratively updates the phase distribution directly from the root mean square error of the reconstructed image using the chain rule. The number of iterations required for the proposed technique is much less than that required for the Gerchberg-Saxton algorithm.

**3Dp1/
3DSAp1 - 4 Electronic Holographic Display Using MEMS-SLM with 40 Degree Viewing Zone**

**Yoshitaka Takekawa¹, Yuki Nagahama¹, Yuzuru Takashima², Yasuhiro Takaki¹*

1. Tokyo University of Agriculture and Technology (Japan), 2. University of Arizona (United States of America)

The illumination of the MEMS-SLM by short laser pulses can dramatically increase the viewing zone of holographic images without reducing the pixel pitch. We demonstrate the generation of 3D images with a viewing zone angle of 40 degrees using the DMD with a pixel pitch of 13.68 micrometers.

**3Dp1/
3DSAp1 - 5 Digital Holographic Observation of a Wavefront Generated by a Digitally Designed Holographic Optical Element (DDHOE)**

**Tatsuki Tahara^{1,2}, Koki Wakunami¹, Boaz Jessie Jackin¹, Yasuyuki Ichihashi¹, Ryutaro Oi¹*

1. National Institute of Information and Communications Technology (Japan), 2. Japan Science and Technology Agency (Japan)

Using digital holography, we observe a wavefront generated by a digitally designed holographic optical element (DDHOE). Experimental results show the performance of digital holographic observation as an evaluation tool for DDHOEs. Quantitative wavefront sensing has the potential to evaluate a DDHOE fabricated by a wavefront printer in detail.

**3Dp1/
3DSAp1 - 6 The Design of Head-up Display Based on Holographic Optical Element**

**Guan-Li Chen¹, Wen-Kai Lin^{1,2}, Shao-Kui Zhou^{1,2}, Wei-Chia Su¹*

1. National Changhua University of Education (Taiwan), 2. National Chiao Tung University (Taiwan)

This study designed a HUD based on HOE and a projection system. In this system, the exit pupil is placed on the eyes of the observer and provides an image. The system has a larger FOV due to the placement of the exit pupil on the eyes of the observer.

3Dp1/ 3DSAp1 - 7 The Full Color Maxwellian-view Display Based on Holographic Optical Element

**Shao-Kui Zhou^{1,2}, Wen-Kai Lin^{1,2}, Bor-Shyh Lin¹, Wei-Chia Su²*

1. National Chiao Tung University (Taiwan), 2. National Changhua University of Education (Taiwan)

A full color Maxwellian-view display based on HOE is proposed. The device can offer observers the information from the mask. The image quality won't be affected when focus on different distance. The HOE with the wavelength multiplexing can reconstruct the full color backlight to get full color image.

3Dp1/ 3DSAp1 - 8 High-resolution Mesh-based Computer-generated Hologram Synthesis Using Fast Fourier Transform with Graphics Processing Unit

**Han-Ju Yeom¹, Sanghoon Cheon¹, Keehoon Hong¹, Seoungbae Cho¹, Seungtaik Oh², Joongki Park¹*

1. Electronics and Telecommunications Research Institute (Korea), 2. Studio Macrograph (Korea)

To reduce the calculation time of synthesizing mesh-based computer-generated hologram (CGH), we define valid frequency domain in off-axis condition which makes different path of DC and three-dimensional (3D) object. Also, we propose a graphics processing unit (GPU) based fast Fourier transform (FFT) method for calculating angular spectrum of mesh-based CGH.

3Dp1/ 3DSAp1 - 9 Effective Encoding of Binary Phase Hologram Using Error Diffusion

**Minsik Park¹, Jeho Nam¹, Seunghyup Shin¹, Jinwoong Kim¹*

1. Electronics and Telecommunications Research Institute (Korea)

The paper proposed the algorithm to improve the performance of the conventional BERD in transforming the complex hologram into binary phase hologram to be applied into binary phase-only SLM. We can get the image quality more than PSNR 16dB in the numerical reconstruction of the binary phase hologram.

3Dp1/ 3DSAp1 - 10 Interactive Operation of Projection-type Holographic Display Based on HOE Screen when Using Ray-sampling Plane

**Rintaro Miura^{1,2}, Yasuyuki Ichihashi², Takashi Kakue¹, Hiroshi Amano^{1,2}, Hiroshi Hashimoto^{1,2}, Koki Wakunami², Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹*

1. Chiba University (Japan), 2. NICT (Japan)

To realize interactive operation of 3D image projected on HOE screen, we calculated and displayed the holograms from the data of light-ray information which was loaded depending on the position of the finger detected by the motion sensor.

3Dp1/ 3DSAp1 - 11 Direct Light Removal and Image Quality Evaluation of Large Screen Holographic Projection

**Shoki Kikukawa¹, Tomoyoshi Shimobaba¹, Takashi Kakue¹, Tomoyoshi Ito¹*

1. Chiba University (Japan)

In this paper, we constructed a time-division reproduction system of holographic projection using a DMD (Digital Mirror Device). We succeeded in removing the direct light in projected images and enlarging the projected images by changing a sampling pitch of the original image.

3Dp1/ 3DSAp1 - 12 Distortion Correction and Optical Reconstruction of Point-cloud Object for the Projection-type Color Holographic Display Based on HOE Screen

**Hiroshi Amano^{1,2}, Yasuyuki Ichihashi², Takashi Kakue¹, Koki Wakunami², Hiroshi Hashimoto^{1,2}, Rintaro Miura^{1,2}, Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹*

1. Chiba University (Japan), 2. National Institute of Information and Communications Technology (Japan)

By using the holographic optical element screen, an aerial-projection display of three-dimensional images can be realized up close which the scale is free. However, the projected image is distorted when an object is placed far from the hologram plane. In this study, we corrected the distortion by shift point cloud.

3Dp1/ 3DSAp1 - 13 Hologram Calculation of Light-in-flight Recording by Holography based on Numerical Simulation Model with FDTD Method

**Takashi Kakue¹, Naoki Takada², Keita Tojo¹, Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹*

1. Chiba University (Japan), 2. Kochi University (Japan)

We propose a numerical simulation model to calculate a hologram of light-in-flight recording by holography. The proposed model is based on not only ray tracing but also finite-difference time-domain method. We succeeded in numerically reconstructing light pulse propagation with total reflection from the hologram calculated by the proposed model.

3Dp1/ 3DSAp1 - 14 Calculation Reduction Method for Computer-Generated Hologram Using Angular Redundancy and Color Space Conversion

**Ryota Furukawa¹, Tomoyoshi Shimobaba¹, Takashi Kakue¹, Tomoyoshi Ito¹*

1. Chiba University (Japan)

We propose a calculation reduction method for computational holograms using angular redundancy of light field by color space conversion. The angular redundancy could be enhanced by the properties of color space. We confirmed that the computational complexity can be reduced by about 20%.

3Dp1/ 3DSAp1 - 15 Highly Parallel Special-Purpose Computer for Electroholography on System on a Chip

**Yota Yamamoto¹, Nobuyuki Masuda²,
Hirotaka Nakayama³, Tomoyoshi Shimobaba¹,
Takashi Kakue¹, Tomoyoshi Ito¹*

*1. Chiba University (Japan), 2. Tokyo University of
Science (Japan), 3. National Astronomical
Observatory of Japan (Japan)*

For realizing electroholography, a compact and high-performance computer is required. In this study, we implemented highly parallel special-purpose computer for electroholography on system on a chip. As a result, we succeeded in speeding up calculation 200 times faster than a CPU and a GPU.

3Dp1/ 3DSAp1 - 16 Multiview Image Correction for Visually Equivalent Light Field 3D Display

**Takasuke Nagai¹, Munekazu Date¹, Shinya Shimizu¹,
Hideaki Kimata¹*

*1. Nippon Telegraph and Telephone Corporation
(Japan)*

The multiview-based light field displays assume that viewpoints of source images are strictly parallel and equally spaced. It is however difficult to arrange multiple cameras by actually satisfying such assumptions. In this paper, we propose a method to virtually parallelize multiple cameras and synthesize regularized light fields.

Also presented in Innovative Demonstration Session (see p. 280)

3Dp1/ 3DSAp1 - 17 Development of Switchable LF Camera for Capturing 2D/3D Movie

**Tae-Hyun Lee¹, Jae-Won Lee¹, Kyung-Il Joo¹, Min-
Kyu Park¹, Heewon Park¹, Ki-Chul Kwon², Munkh-
Uchral Erdenibat², Young-Tae Lim², Nam Kim², Hak-
Rin Kim¹*

*1. Kyungpook National University (Korea), 2.
Chungbuk National University (Korea)*

We developed a fast switchable light field (LF) camera which can simultaneously capture the 2D and 3D videos based on implemented switchable polarization-dependent micro-lens array (MLA). The proposed LF camera system was demonstrated that can simultaneously capture the 2D and 3D video even in high speed driving over 1000 fps.

3Dp1/ 3DSAp1 - 18 An Active Barrier Autostereoscopic Display with Less Crosstalk

**Ayuki Hayashishita¹, Takuya Matsumoto²,
Kaoru Kusafuka², Hideki Kakeya¹*

1. The University of Tsukuba (Japan), 2. KYOCERA Corporation (Japan)

We propose an autostereoscopic display system using a monochrome panel as an active parallax barrier. We confirm that placing a monochrome panel for barrier in front of the color imaging panel generates less crosstalk than placing it behind.

3Dp1/ 3DSAp1 - 19 Resolution Evaluation of a Simplified Super Multi-View Head-Mounted Display

**Takaaki Ueno¹, Yuki Nagahama¹, Yasuhiro Takaki¹*

1. Tokyo University of Agriculture and Technology (Japan)

We have proposed the simplification technique of the super multi-view head-mounted display to reduce the system and computation costs. This study provided a resolution evaluation of the prototype system. The resolution was higher than 14.3 pixels/degree when the eyes' focus was at 380-530 mm and 700-1,200 mm.

3Dp1/ 3DSAp1 - 20 Comparative Study on Layered Light-Field Displays and Optimization Methods

**Keita Maruyama¹, Keita Takahashi¹, Toshiaki Fujii¹,
Munekazu Date², Hideaki Kimata²*

1. Department of Information and Communication Engineering Graduate School of Engineering, Nagoya University (Japan), 2. NTT Media Intelligence Laboratories, Nippon Telegraph and Telephone Corporation (Japan)

We focus on two factors that affect the performance of layered light-field displays: the layer device and optimization method. We quantitatively compared the performances of different architecture of layered light-field displays (LCD, HOE, and S-IPS LCD) and their optimization methods (analytical method and CNN-based method).

3Dp1/ 3DSAp1 - 21 Light Field Acquisition from Focal Stack via a Deep CNN

**Yasutaka Inagaki¹, Keita Takahashi¹, Toshiaki Fujii¹*

1. Nagoya University (Japan)

We succeeded in acquiring a dense light field from a focal stack, i.e., only a few images with different focused depth, by using a deep convolutional neural network (CNN) trained for this purpose. We validated our method through both simulative and real-camera experiments.

**3Dp1/
3DSAp1 - 22 Displaying Live 3-D Video from a Multi-View Camera
on a Layered Display**

**Yusuke Ota¹, Keita Maruyama¹, Ryutaroh Matsumoto¹,
Keita Takahashi¹, Toshiaki Fujii¹*

1. Nagoya University (Japan)

We present a pipeline that displays 3D videos captured by a multi-view camera (ProFUSION25) on a layered display in real time. The layered display is a kind of light field displays. To develop this pipeline, we used a CNN that calculates a layer pattern to reduce processing time.

Also presented in Innovative Demonstration Session (see p. 280)

**3Dp1/
3DSAp1
- 23L Implemented of Images and Sounds Person
Tracking System Using Directional Volumetric
Display**

**Mitsuru Baba¹, Ryuji Hirayama^{2,3}, Naoto Hoshikawa⁴,
Hirotaaka Nakayama⁵, Tomoyoshi Shimobaba¹,
Tomoyoshi Ito¹, Atsushi Shiraki¹*

*1. Chiba University (Japan), 2. Research Fellow of the
Japan Society for the Promotion of Science (Japan),
3. Tokyo University of Science (Japan), 4. National
Institute of Technology, Oyama College (Japan), 5.
National Astronomical Observatory of Japan (Japan)*

In previous study, we developed the directional volumetric display which can display multiple images in different directions. In this study, we implemented a method of person tracking for the directional volumetric display to enable transmitting images and sounds following person using motion capture.

**3Dp1/
3DSAp1
- 24L Development of Volumetric Display Capable of
Transmitting Information in Different Languages
Using Language Identification**

**Taishin Murase¹, Ryuji Hirayama^{2,3}, Naoto Hoshikawa⁴,
Hitoraka Nakayama⁵, Tomoyoshi Shimobaba¹,
Tomoyoshi Ito¹, Atsushi Shiraki¹*

*1. Chiba University (Japan), 2. Research Fellow of the
Japan Society for the Promotion of Science (Japan),
3. Tokyo University of Science (Japan), 4. National
Institute of Technology, Oyama College (Japan), 5.
National Astronomical Observatory of Japan (Japan)*

We developed a directional volumetric display that exhibits different images depending on the viewing direction. The display can be expected to be applied to multilingual signage that transmits information in different languages. In this study, we develop a display that exhibits images according to the language used by the observer.

**3Dp1/
3DSAp1
- 25L**

**Simulation of Target Observation Area Formed by
HOE Screen with Function of Concave Mirror**

**Hiroshi Hashimoto^{1,2}, Yasuyuki Ichihashi²,
Takashi Kakue¹, Koki Wakunami², Hiroshi Amano^{1,2},
Rintaro Miura^{1,2}, Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹*

*1. Chiba University (Japan), 2. National Institute of
Information and Communications Technology (Japan)*

When three-dimensional images is reconstructed in projection-type holographic display based on a holographic optical element screen, the observation area is limited to narrow range. In this study, we simulated and evaluated the observation area in order to expand the observation area quantitatively.

**3Dp1/
3DSAp1
- 26L**

**Development of Three-Dimensional Aerial Image
Display System by Integral Photography**

**Yuya Sota¹, Sumio Yano¹*

1. Shimane University (Japan)

Using integral photography, the three-dimensional aerial image display equipment was developed experimentally using the double reflection micro mirror array. The range of viewing area and depth reproduction of the prototype device were examined by subjective evaluation experiments.

**3Dp1/
3DSAp1
- 27L**

**Volumetric 3D System Using Rotating -Confirmation
of Image Distortion and its Compensation-**

**Ken Muto¹*

*1. Japan / Tokai / Electrical and Electronic Engineering
(Japan)*

We have suggested a novel method of volumetric 3D display, in which multi layer of screen images are projected on a rotating spiral screen. In this study, we focused on possible distortion of 3D image in our volumetric 3D display system and its compensation.

**3Dp1/
3DSAp1
- 28L**

**Improved Fabrication Process of Holographic
Waveguide Combiner in a Head Mounted Display
System**

**Hung-Pin Chen¹, Wen-Kai Lin², Shao-Kui Zhou², Wei-
Chia Su¹*

*1. National Changhua University of Education
(Taiwan), 2. National Chiao Tung University (Taiwan)*

In this research, we propose a simplified way to expand the exit pupil of a holographic Head Mounted Display (HMD). The divergent spherical wave is transmitted in the waveguide, and a large diffraction area is formed to make an output Holographic Optical Element (HOE).

**3Dp1/
3DSAp1
- 29L**

Light Field Camera with Pan-tilt Function

**Yuta Yamaguchi^{1,2}, Yasuhiro Takaki¹*

1. Tokyo University of Agriculture and Technology (Japan), 2. Research Fellow of Japan Society for the Promotion of Science (Japan)

A light field camera with a high-speed pan-tilt function is proposed. The system consisted of two lens arrays, a two-dimensional actuator, and an image sensor. The experimental system was constructed using 103.5- μm pitch lens arrays and a 4K image sensor and the pan-tilt and refocus functions were verified.

**3Dp1/
3DSAp1
- 30L**

The Application of a New Type of Depth Camera to Teach Gymnastics

**Tsanming Ou¹, Tomoki Miyamoto¹, Yuki Kurosawa¹, Takahide Otomo¹, Yuko Hoshino¹, Mitsuho Yamada¹*

1. Tokai University (Japan)

As Japanese society increasingly ages, there are more and more people who do sports to improve their quality of life, and there have been a number of studies on the use of humanoid robots to teach gymnastics. We attempted to use a new type of sensor in this kind of system and tested its performance.

14:30-17:00

Main Hall

Poster 3DSAp2/3Dp2: 3D and Hyper-realistic Displays and Applications 2

**3DSAp2/
3Dp2 - 1**

The Full Color See-through Head Mounted Display Based on Transmission-type Holographic Optical Elements and Parallel Plane Mirrors

**Zih-Yuan Wong¹, Wen-Kai Lin^{1,2}, Shao-Kui Zhou^{1,2}, Wei-Chia Su¹*

1. National Changhua University of Education (Taiwan), 2. National Chiao Tung University (Taiwan)

The full color see-through head mounted display (HMD) which consists of two transmission-type HOEs, two parallel plane mirrors and a single image source is proposed. The red, green and blue incident light will overlap at the output HOE. Then the dispersion of transmission hologram will be compensated.

**3DSAp2/
3Dp2 - 2**

Unsupervised Monocular Depth Estimation for Autonomous Driving

*Chih-Shuan Huang¹, *Wan-Nung Tsung¹, Wei-Jong Yang¹, Chin-Hsing Chen¹*

1. National Cheng Kung University (Taiwan)

3D technology with range information has become a staple requirement in computer vision. For this reason, we believe that the depth information can effectively improve the vision capabilities for many applications. In this paper, we proposed an unsupervised monocular depth estimation network to extract the depth map of street views.

**3DSAp2/
3Dp2 - 3** **VR Viewing Test of 3D Reconstructed Content
Generated by Markerless Motion Capture in Wide
Area**

**Masaaki Matsumura¹, Kazuki Okami¹, Hajime Noto¹,
Hideaki Kimata¹*

*1. NTT Media Intelligence Laboratories, Nippon
Telegraph and Telephone Corporation (Japan)*

Recent years, the visualization techniques for wide area with AR and VR have been attracting attention. We propose the method to create a real-scaled VR viewing experience using images of actual handball game. And then, we test the experience can be entertained without feeling of discomfort using user questionnaires.

**3DSAp2/
3Dp2 - 4** **Withdrawn**

**3DSAp2/
3Dp2 - 5** **Enhancing Visual Quality of Multi-view 360 Video
Compression Pipeline**

**Junyoung Yun¹, Hong-Chang Shin², Gwangsoon Lee²,
Jong-Il Park¹*

*1. Hanyang University (Korea), 2. Electronics and
Telecommunications Research Institute (Korea)*

A three degrees of freedom plus(3DoFP) video formatting pipeline was presented at MPEG-I Visual. A 3DoFP video gives motion parallax for users' slight translational movement as well as rotation. The given 3DoFP pipeline is based on virtual view synthesis using multiple view color and depth images on which visual redundancies among the given view images are removed. Extracted necessary image areas from redundancy removal process are packed, transmitted and reconstructed to show contents to end users. However, the early researches on view synthesis uses all redundant information, the impact of removed redundant area is not explored much. In this work, we present a method for enhancing final synthesized image quality of the given pipeline dealing with redundancy removal.

**3DSAp2/
3Dp2 - 6** **Eye-Matching Video Calling System by Use of Aerial
Screen with AIRR**

**Kengo Fujii¹, Ryota Kakinuma¹, Masaki Yasugi^{1,2},
Hirotugu Yamamoto^{1,2}*

1. Utsunomiya Univ. (Japan), 2. JST ACCEL (Japan)

Aerial screen formed with AIRR has been utilized for a video calling system that features viewpoint matching. We can virtually place a camera at an arbitrary position on the aerial screen because the screen is aerial and AIRR employs a beam splitter. Polarization filtering is used to take clear pictures.

3DSAp2/ 3Dp2 - 7 Immersive Reaction of Medaka to Omnidirectional Aerial Display

**Erina Abe¹, Hirotsugu Yamamoto¹*

1. Utsunomiya University (Japan)

This paper reports the responses of medaka that is surrounded by rotating stripes shown on an omnidirectional aerial display. We measure the time of reaction in three conditions and compare the difference between one and several medaka. The results suggests omnidirectional aerial display evokes immersive sensation on medaka.

3DSAp2/ 3Dp2 - 8 Tabletop Aerial DFD Display with AIRR

**Yoshiki Terashima¹, Kengo Fujii¹, Shiro Suyama², Hirotsugu Yamamoto^{1,3}*

1. University of Utsunomiya (Japan), 2. University of Tokushima (Japan), 3. JST ACCEL (Japan)

This paper proposes a tabletop two-layered aerial display system with aerial imaging by retro-reflection (AIRR). Then, we have realized an aerial depth-fused 3D (DFD) display. We investigate the relationships between the two-layered-images distance and the observation distance. The result shows that the two-layered-images distance increases with the observation distance.

3DSAp2/ 3Dp2 - 9 See-Through Aerial Concave Display by Use of Fresnel Lens and AIRR with Polarization Modulation

**Shuto Hatsumi¹, Kazuki Shimose¹, Masaki Yasugi^{1,2}, Hirotsugu Yamamoto^{1,2}*

1. Utsunomiya university (Japan), 2. JST,ACCEL (Japan)

This paper proposes an optical system for see-through aerial concave display. Due to aberration of Fresnel lens, a 2D image on a flat-panel display is converted to a convex image. Then, the convex image is converted to an aerial concave image with AIRR (Aerial Imaging by Retro-Reflection) in see-through structure.

3DSAp2/ 3Dp2 - 10 Object-centered View Synthesis Using Learning-based Image Inpainting

**HONG-CHANG SHIN¹, Gwangsoon Lee¹, Ho min Eum¹, Jeong-Il Seo¹*

1. ETRI (Korea)

This paper presents object-centered view synthesis technique using multilayer concept. we divide the image into multiple layers based on depth information and then provide different motion parallaxes for each layer depending on the depth. When the disocclusion region appears due to motion parallax, the uncovered region is filled by using learning-based image inpainting.

**3DSAp2/
3Dp2 - 11 Texture-based Depth Frame Interpolation for Precise
2D to 3D Conversion**

**Kuan-Ting Lee¹, En-Shi Shih¹, Jar-Ferr Yang¹*

1. National Cheng Kung University (Taiwan)

A texture-based depth interpolation system was proposed. It can interpolate two depth keyframes, by combining depth estimation, error compensation, noise elimination, and forward/backward depth merging. Results confirmed that errors in the estimated depth are few. The bi-directional propagation can overcome the occlusion of objects and handle the zoom in/out circumstance.

**3DSAp2/
3Dp2 - 12 Volumetric Graphics Using Laser-Induced
Microbubbles in Glycerin Containing Gold Nanorods**

**Taisei Chiba¹, Kota Kumagai, Yoshio Hayasaki¹*

1. Utsunomiya University (Japan)

A laser-induced bubble display with glycerin containing gold nanorods as a screen material was developed. The gold nanorods is used to reduce the required energy of laser pulses for the bubble formation toward a large volumetric bubble graphics.

**3DSAp2/
3Dp2 - 13 Investigation of Single-Pixel Imaging Using
Recurrent Neural Network**

**Ikuo Hoshi¹, Tomoyoshi Shimobaba¹, Takashi Kakue¹,
Tomoyoshi Ito¹*

1. Chiba University (Japan)

We propose a reconstruction method for single-pixel imaging. Recently, reconstruction methods using deep neural networks have been studied. However, these methods need much calculation. In this paper, we investigated to reconstruct images from a single-pixel device using a recurrent neural network and decrease the calculation amount.

**3DSAp2/
3Dp2 - 14 Perceived Depth in Arc 3D Display Can Penetrate
into Behind Real Object by Moving Arc 3D Images in
Contrast to Unpenetrated Perceived Depth in
Stereoscopic Display**

**Kisa Nakano¹, Takahiko Yoshida¹, Haruki Mizushima¹,
Shiro Suyama¹*

1. Tokushima University (Japan)

Arc 3D display can solve serious difficulty in perceived depth penetration into or behind the real object in stereoscopic image only by moving head or 3D image position. Arc 3D image can be successfully perceived around desired position even in or behind the real object.

**3DSAp2/
3Dp2 - 15 Real-Object DFD Method Can Change Perceived
Depths of Dark Real Object and Occluded Rear Real
Object to in Front and Behind**

**Oku Iwamoto¹, Haruki Mizushina¹, Shiro Suyama¹*

1. Tokushima University (Japan)

Depth-fused 3D display can successfully change perceived depth of occluded rear real object from behind rear object to in front of front object by adding rear object image behind and in front of rear object. Moreover, perceived depth of dark real object can be changed by changing added front-display transmittance.

**3DSAp2/
3Dp2 - 16 A New 3D Display Utilizing Occlusion Effect by
Frames, Gap and Bend of Side-by-Side 2D Displays
Over Moving Stimuli**

**Rune Oyama¹, Shiou Suyama¹, Haruki Mizushina¹*

1. Tokushima University (Japan)

Separating two side-by-side displays with frames and gap can improve virtual perceived depth of moving stimuli behind frames and/or gap by occlusion effect, rather than displays fastening together without them. Horizontal bend and/or vertical inclination in two 2D displays and curved moving stimuli can significantly enlarge virtual perceived depth.

**3DSAp2/
3Dp2 - 17 Perceived Depth Instability Difference of Aerial
Image in CMA (Crossed Mirror Array) by Changing
Fixation Point of Eyes**

**Kohei Yamamoto¹, Shiro Suyama¹, Haruki Mizushina¹*

1. Tokushima Univ. (Japan)

Perceived depths of aerial image in crossed mirror array have large instability towards fixation point of eyes, even when aerial image is geometrical optical real image. When fixation points are changed apart from aerial image, perceived depth deviations are increased toward fixation point in front of or behind aerial image.

**3DSAp2/
3Dp2 - 18 3D Image Depth Enlargement in Large Edge-Based
DFD Display with Long Viewing Distance by Blurring
Edge Images**

**Hideto Matsubara¹, Haruki Mizushina¹, Shiro Suyama¹*

1. Tokushima University (Japan)

We can successfully extend depth-fusion limit of front-rear gap from two image depths to one perceived depth by blurring edge image in large Edge-based DFD display with long-viewing distance. As viewing distance is increased, blurring width for depth-fusion can be effectively reduced.

**3DSAp2/
3Dp2 - 19**

Monocular Perceived Depth Improvement Using Motion Parallax in Arc 3D Display and Dependence on Motion Cycle Time

**Kazuya Tango¹, Shiro Suyama¹, Haruki Mizushima¹*

1. Tokushima Univ (Japan)

Saturation degradation of perceived depth of 50 mm by monocular motion parallax in head-tracking system can be successfully improved to large perceived depth of 180 cm by using Arc 3D display without delay time. Head motion cycle affects perceived depth and cycle time of 2 sec is the most stable.

3DSA

**3DSAp2/
3Dp2 - 20L**

Comparison of Hologram Calculation Implementations for Wavefront Recording Plane Method Using Look-up Table Method and Direct Calculation Method

**Hidenari Yanagihara¹, Tomoyoshi Shimobaba¹, Takashi Kakue¹, Tomoyoshi Ito¹*

1. Chiba University (Japan)

We evaluated calculation times of computer-generated holograms based on wavefront recording plane method using several implementations in the combination of look-up table method and direct calculation method in order to realize real-time electro-holography system. We confirmed that there are different characteristics between CPU and GPU implementations.

**3DSAp2/
3Dp2 - 21L**

Efficient Computation of Binary-Weighted Computer-Generated Hologram for Gradation Representable Electroholography

**Ren Noguchi¹, Tomoya Sakaguchi¹, Hiromi Sannomiya¹, Kohei Suzuki¹, Minoru Oikawa¹, Yuichiro Mori¹, Takashi Kakue², Tomoyoshi Shimobaba², Tomoyoshi Ito², Naoki Takada¹*

1. Kochi University (Japan), 2. Chiba University (Japan)

We proposed fast computation for the gradation representable electro-holography using the bit planes comprising binary-weighted computer-generated hologram (CGH). We succeeded in reducing the duplicate CGH calculation of same object points. Consequently, the proposed method is 2.7 times faster than the previous method.

SID Display Week 2020

June 7 - 12, 2020

San Francisco Moscone Convention Center

San Francisco, California, USA

<http://www.displayweek.org/>

3DSAp2/ 3Dp2 - 22L Cost-effective Portable Holographic Projector Using a Single Board Computer

**Yoshiki Moriguchi¹, Hiromi Sannomiya¹, Tomoya Sakaguchi¹, Kohei Suzuki¹, Yuuki Tanaka¹, Hirotaka Nakayama², Minoru Oikawa¹, Yuichiro Mori¹, Takashi Kakue³, Tomoyoshi Shimobaba³, Tomoyoshi Ito³, Naoki Takada¹*

1. Kochi University (Japan), 2. National Astronomical Observatory of Japan (Japan), 3. Chiba University (Japan)

We proposed cost-effective portable holographic projector composed of a portable digital micromirror device board and a single board computer. Consequently, the proposed projector succeeded to project the reconstructed video at 60 fps.

3DSAp2/ 3Dp2 - 23L Real-Time Spatiotemporal Division Multiplexing Electroholography of Point-cloud 3D Model Comprising 920,000 Points Using Multiple GPU Cluster System

**Hiromi Sannomiya¹, Hirotaka Nakayama², Minoru Oikawa¹, Yuichiro Mori¹, Takashi Kakue³, Tomoyoshi Shimobaba³, Tomoyoshi Ito³, Naoki Takada¹*

1. Kochi University (Japan), 2. National Astronomical Observatory of Japan (Japan), 3. Chiba University (Japan)

We demonstrated real-time electroholographic 3-D movie reconstruction using spatiotemporal division multiplexing technique on a multiple GPU cluster system including 13 GPUs connected through gigabit ethernet network. We succeeded to display reconstructed 3-D movie consisting of 912,462 object points.

3DSAp2/ 3Dp2 - 24L Holographic Projection System for Drawing Fingertip Trajectory Obtained from Depth Camera

**Kohei Suzuki¹, Minoru Oikawa¹, Yuichiro Mori¹, Takashi Kakue², Tomoyoshi Shimobaba², Tomoyoshi Ito², Naoki Takada¹*

1. Kochi University (Japan), 2. Chiba University (Japan)

We proposed to the interactive holographic projection system for drawing the trajectory of fingertip on 3D object. The proposed system can project the trajectory of fingertip obtained using the depth camera at 90 fps.

3DSAp2/ 3Dp2 - 25L Magnetic Hologram Reconstruction Using Magneto-Optical Light Modulator Array Based on Domain Wall Motion

**Ryo Higashida¹, Nobuhiko Funabashi¹, Ken-ichi Aoshima¹, Kenji Machida¹*

1. NHK (Japan)

A magneto-optical light modulator array capable of displaying a magnetic interference pattern by the application of an external magnetic field was fabricated. This array showed that magneto-optical spatial light modulator based on current-induced domain wall motion has sufficient light-modulation characteristics for reconstructing holographic images.

3DSAp2/ 3Dp2 - 26L Interactive Holographic 3D Display System

**Min Sung Yoon¹, Soo-Myung Park¹*

1. Electronics and Telecommunications Research Institute, (Korea)

In this paper, we demonstrate that holographic 3D content of 1,024 views related with all directions of 360 degrees is calculated by FFT-based CGH algorithm and is encoded by the Burkhardt encoding. We represents it onto the interactive holographic display system, which can support wide-viewing range of 60 degrees and directly interact between the user and holographic 3D scenes.

3DSAp2/ 3Dp2 - 27L Contact Lens Display Based on Holography

**Junpei Sano¹, Shujian Liu¹, Yuki Nagahama¹, Yasuhiro Takaki¹*

1. Tokyo University of Agriculture and Technology (Japan)

Holographic display technique is used to generate images far from the display device embedded in a contact lens to enable an eye focus on the images. The see-through function is also provided using the phase-only SLM and the laser backlight. The proposed image formation and see-through functions were experimentally verified.

3DSAp2/ 3Dp2 - 28L Effect of Non-uniformity of Optical Phase Modulation in Liquid Crystal Devices on Holographic Image Quality

**Kazuma Chida¹, Yoshitomo Isomae^{1,2}, Takahiro Ishinabe¹, Yosei Shibata¹, Hideo Fujikake¹*

1. Tohoku University (Japan), 2. Research Fellow of Japan Society for the Promotion of Science (Japan)

We investigated the effect of non-uniformity of phase distribution in liquid crystal phase modulator on holographic image quality by using simulation. As a result, non-uniform phase distribution in a pixel degrades diffraction efficiency, and non-uniform phase distribution on the entire liquid crystal on silicon panel decreases resolution of holographic images.

14:30-17:00

Main Hall

Poster VHFp5/3DSAp3: Human Factors

VHFp5/ 3DSAp3 - 1 Fundamental Head Movement and Gaze Analysis on the Influence of Surround Sound on People

**Yasuyoshi Kobayashi¹, Shinya Mochiduki¹,
Mitsuho Yamada¹
1. Tokai University (Japan)*

Recent advances in sound technology have been remarkable in conjunction with high definition images. The possibility of an objective evaluation of synergistic effect of image and two kinds of sound was examined based on head and eye movement.

VHFp5/ 3DSAp3 - 2 Simple Stereoscopic Image System Based on Fresnel Plate

*Chung-Jen Ou², *Shang-Ru Yang¹, Wei-Chia Su¹
1. National Changhua University of Education
(Taiwan), 2. Hsiuping University of Science and
Technology (Taiwan)*

A simple configuration for reflective floating images by using the Fresnel plate is demonstrated. The virtual images can be generated by active and passive strategies. Results show that the method can generate a scenario for small meeting discussion. Mathematical formulation to eliminate distortion is addressed.

VHFp5/ 3DSAp3 - 3L Development of One-Dimensional Integral Photography

**Akira Hasegawa¹, Sumio Yano¹
1. Shimane University (Japan)*

A one - dimensional integral photograph showing only horizontal parallax was developed. And, it was possible not only to display the object arranged in the computer by one-dimensional integral photography, but also to capture and display the real object. In addition, evaluation of depth perception and measurement of accommodation response were performed using a prototype one-dimensional integral photograph.

IMID 2020

Aug. 25 – 28, 2020

COEX

Seoul, Korea

<http://www.imid.or.kr/>

17:20-18:40

Small Hall

3DSA5/3D5: Light Field 2

Chair: Jung-Young Son (Konyang Univ.)
Co-Chair: Munekazu Date (NTT)

**3DSA5/
3D5 - 1
17:20** **An Improved View Synthesis of Light Field Images
for Supporting 6 Degrees-of-Freedom**

**Sangwoon Kwak¹, Joungil Yun¹, Won-Sik Cheong¹,
Jeongil Seo¹
1. ETRI (Korea)*

In this paper, virtual view synthesis of sparse light field images is considered. We analyze the patch-wise 3D warping and blending methods of the conventional view synthesis, and propose an improved algorithm for supporting 6DoF. We suggest an enhancement for the super-pixel and additional blending weights, and present experimental results using multi-view contents of MPEG.

**3DSA5/
3D5 - 2
17:40** **GPU-Accelerated Interactive Virtual View Synthesis
from Light Field Images**

**Hyeonjin Jung¹, Joungil Yun², Won-Sik Cheong²,
Youngmin Yi¹
1. University of Seoul (Korea), 2. Electronics and
Telecommunications Research Institute (Korea)*

We present a GPU based acceleration of a virtual view synthesis from multiple Light Field images. For the synthesis of a 2K virtual view from 24 images of the same resolution, we achieved 21.31 FPS using four Titan V GPUs with algorithmic optimizations, which corresponds 923 times of speedup.

**3DSA5/
3D5 - 3
18:00** **Accommodation Response to a Super-Multiview
Display Based on Time-Division Multiplexing
Parallax Barrier**

**Yuta Watanabe¹, Hideki Kakeya¹
1. University of Tsukuba (Japan)*

We have measured the focal accommodation response of viewers to a dense light field generated by time-division sextuplexing parallax barriers. We have confirmed that focal accommodation in front of or behind the display screen is induced as expected.

**3DSA5/
3D5 - 4
18:20** **An Autostereoscopic Display with Time-Multiplexed
Directional Backlight Using a Curved Lens Array**

**Garimagai Borjigin¹, Hideki Kakeya¹
1. University of Tsukuba (Japan)*

We propose an autostereoscopic display with a curved directional backlight unit. The proposed backlight unit composed of a curved lens array and dot-matrix light sources suppresses the influence of filed curvature. Thus the crosstalk level is reduced without adding an additional layer of lens.

Author Interviews

18:50 - 19:20

Friday, November 29

9:00-10:20	Small Hall
3D6/3DSA6: Distinguished Display	

Chair: Hideki Kakeya (Univ. of Tsukuba)

Co-Chair: Yuki Maeda (Parity Innovations)

3D6/ 3DSA6 - 1 Invited Importance of Continuous Motion Parallax in Monocular and Binocular 3D Perception

9:00 *Haruki Mizushima¹, Shiro Suyama¹

1. Tokushima University (Japan)

Motion parallax is one of the cues of human depth perception. It provides sufficient depth information even in monocular viewing, and improves degradation of stereoscopic depth by visual acuity difference of both eyes. In this paper we demonstrate importance of continuous motion parallax in monocular and binocular depth perception.

3D6/ 3DSA6 - 2 Further Crosstalk Reduction Method with Eye-Tracking for Glasses-Free Stereoscopic Display in Both Portrait and Landscape Modes

9:20 *Yukiya Yamaguchi¹, Hiroyuki Nakamura¹, Goro Hamagishi¹, Kayo Yoshimoto¹, Takuya Matsumoto², Kaoru Kusafuka², Hideya Takahashi¹

1. Osaka City University (Japan), 2. Kyocera Corporation (Japan)

We propose a crosstalk reduction method with an eye-tracking system for glass-free stereoscopic displays in both portrait and landscape modes. We can reduce crosstalk by dividing a screen into multiple areas and displaying black images on the subpixels observed simultaneously with both eyes in each divided area.

3D6/ 3DSA6 - 3 Measurement of Moiré Patterns in 3D Display

9:40 *Hea In Jeong¹, Seo Young Choi², Young Ju Jeong¹

1. Sookmyung Women's University (Korea), 2. Korea Institute of Lighting & ICT (Korea)

The moiré pattern can be produced when developing 3D displays which can lead to a 3D quality degradation. A measurement algorithm is required to estimate how much moiré pattern has occurred. In this paper, we propose a measurement algorithm that can calculate the moiré artifact generated in displays.

**3D6/
3DSA6 - 4
10:00**

GPU Acceleration of Algorithm to Design Directional Volumetric Display for Real-time Processing

**Daiki Matsumoto¹, Ryuji Hirayama^{2,3}, Naoto Hoshikawa⁴, Hirotaka Nakayama⁵, Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹, Atsushi Shiraki¹*

1. Chiba University (Japan), 2. Research Fellow of the Japan Society for the Promotion of Science (Japan), 3. Tokyo University of Science (Japan), 4. National Institute of Technology, Oyama College (Japan), 5. National Astronomical Observatory of Japan (Japan)

In this study, we attempted GPU acceleration of an algorithm to design a directional volumetric display. As a result, the GPU implementation was up to 45 times faster than the CPU implementation. We also confirmed that the GPU implementation could cooperate with a person tracking system in real-time.

3DSA

10:40-12:00

Small Hall

3DSA7/3D7: Virtual Reality 1

Chair: Tomohiro Tanikawa (The Univ. of Tokyo)
Co-Chair: Kenji Yamamoto (NICT)

**3DSA7/
3D7 - 1
10:40**

***Invited* Research and Development of Second Generation Virtual Reality**

**Michitaka Hirose¹*

1. The University of Tokyo (Japan)

Novel VR technology (second generation VR) is introduced. After short review of technological advances to date, the author discusses benefits of VR in the areas of education and training that are expected as major application of VR technology.

**3DSA7/
3D7 - 2
11:00**

***Invited* Computer Vision, AI, AR Technology in Various Industries**

**You-Kwang Wang^{1,2}, Hung-Ya Tsa², Chih-Hao Chuang³, Chien-Yu Chen¹*

1. National Taiwan University of Science and Technology (Taiwan), 2. OSENSE Technology Co. (Taiwan), 3. National Taiwan University (Taiwan)

AR technology is currently the most popular human-computer interaction interface. We get a spatial point cloud through computer vision and AI technology. And completed several projects according to different scene requirements.

**3DSA7/
3D7 - 3
11:20** ***Invited* Impressive 3D CG Technologies for
Automotive HUDs with Wide FOV**
**Haruhiko Okumura¹, Takashi Sasaki¹, Aira Hotta¹,
Masahiro Sekine¹*
1. Toshiba Corp. (Japan)

We have applied various kinds of 3D CG technologies to increase the Field Of View (FOV) and visibility of displayed images for the monocular HUD. As a results, we successfully developed impressive 3D CG technologies for HUDs with wide FOV and high visibility.

**3DSA7/
3D7 - 4
11:40** ***Invited* Air Floating Image Based on a Dihedral
Corner Reflector Array**
**YUKI MAEDA¹*
1. Parity Innovations Co. Ltd. (Japan)

An air floating image and its applications based on a dihedral corner reflector array are introduced in this paper. An observer can see the air floating image by the naked eye and manipulate it by touching the air floating image using finger sensor system.

Also presented in Innovative Demonstration Session (see p. 278)

Author Interviews
 12:10 - 12:40

I-DEMO **(Innovative Demonstration Session)**

Live demonstrations
 of emerging information display technologies
 by oral and poster presenters
 Thursday, Nov. 28, 2019
 11:40 – 15:40
 Main Hall (1F)
 Sapporo Convention Center

13:20-14:40

Small Hall

3D8/3DSA8: Virtual Reality 2

Chair: You Kwang Wang (Osense Technology)
Co-Chair: Haruki Mizushima (Tokushima University)

3D8/3DSA8 - 1 13:20 ***Invited* Service VR Training System: VR Simulator of Man-to-Man Service with Mental/Emotional Sensing and Intervention**

**TOMOHIRO TANIKAWA¹, Yuki Ban¹, Kazuma Aoyama¹, Eiji Shinbori², Shigeru Komatsubara², Michitaka Hirose¹*
1. The University of Tokyo (Japan), 2. Dai Nippon Printing Co., Ltd. (Japan)

In this paper, we introduce our concept and preliminary implementation of service VR training system. For training services, emotional skills are very important. Thus, our service VR simulator consist of mental/emotional sensing devices, estimating algorithm and intervention approaches.

3D8/3DSA8 - 2 13:40 **A HMD for Users with Any Interocular Distance**

**Jung-Young Son¹, Hyoung Lee¹, Jung Kim¹, Beom-Ryeol Lee², Wook-Ho Son², Tetiana Venkel³*
1. Konyang University (Korea), 2. Electronics and Telecommunication Research Institute (Korea), 3. Chernivtsi University (Ukraine)

A prototype HMD which can automatically adjust interocular distance in the range of 55 mm to 75 mm in accordance with those of users. The main component of the HMD is a linear motor which shifts the modularized left and right eye's projection and camera optics in accordance with the measured interocular distance of a user. The total adjusting time of the distance is less than 10 seconds. The weight of the HMD is slightly less than 500 g and it is worn by a head belt. The HMD is somewhat heavy and unbalanced due to the distribution of the weight along the nose side but the head belt holds tightly the HMD on its place and it works well.

3D8/3DSA8 - 3 **Withdrawn**

3D8/3DSA8 - 5L 14:00 **Proposal for Light Field Mirage**

**Yoshiharu Momonoi^{1,2}, Koya Yamamoto², Yasuhiro Takaki²*

1. Samsung R&D Institute Japan (Japan), 2. Tokyo University of Agriculture and Technology (Japan)

Mirage, which consists of a pair of parabolic mirrors, is a well-known 360-degree display system. This study explored replacing the parabolic mirrors in Mirage with multiple flat-panel light field displays to realize Light Field Mirage. Rays emitted from 3D objects are reconstructed for 360-degree viewing. Preliminary experiments were conducted.

**3D8/
3DSA8 - 4
14:20** **Accuracy Verification of Visual Appearance
Acquisition Device of Non-Metallic Material Based
on Sparse SVBRDF**

**Tsung-Lin Lu¹, Yu-Lun Liu¹, Yu-Cheng Hsieh¹, Tzung-Han Lin¹*

*1. National Taiwan University of Science and
Technology (Taiwan)*

In this paper, we proposed a visual appearance acquisition device comparing with commercial product. Our device is capable of restoring the visual appearance for non-metallic materials based on spatially varying bidirectional reflectance distribution function (SVBRDF). A benchmark comparing to commercial product Radiant Vision is carried out to verify the reliability of the proposed device.

15:00-16:20	Small Hall
3DSA9/3D9: Data Compression	

Chair: Hideaki Kimata (NTT)
Co-Chair: Miwa Katayama (NHK)

**3DSA9/
3D9 - 1
15:00** **Verification of Compression Architecture for 3DoF+
Immersive Video Delivery**

**Gwangsoon Lee¹, Hong-Chang Hong¹, Homin Eum¹,
Jeongil Seo¹*

1. ETRI (Korea)

This paper introduces a compression architecture for delivering 3DoF+ immersive video, which can be applied to existing video encoder. Specifically, this paper includes a pruning algorithm that can reduce the redundancy among multiple views while maintaining the higher image quality of rendered view.

**3DSA9/
3D9 - 2
15:20** **FDM-based Global Motion Estimation for Dynamic
3D Point Cloud Compression**

**SO MYUNG LEE¹, Li Cui¹, Tianyu Dong¹, Eun-Yong Chang², Jihun Cha², Euee S. JANG¹*

*1. Hanyang University (Korea), 2. Electronics and
Telecommunications Research Institute (Korea)*

In this paper, we propose a fast global motion estimation (GME) for dynamic 3D point cloud compression (PCC). We applied fast distortion measurement method(FDM) to replace and reduce the computational complexity of GME. The experimental results show that the proposed method is two times faster than MPEG V-PCC.

**3DSA9/
3D9 - 3
15:40**

MPEG Video-based Point Cloud Coding Based on JPEG

**Tianyu Dong¹, So Myung Lee¹, Euee S. Jang¹
1. Hanyang University (Korea)*

In this paper, we proposed a method to design MPEG Video-based point cloud compression (V-PCC) based on JPEG. We chose JPEG for its simplicity, low computational complexity, and ubiquitous support of encoder and decoder. For performance evaluation, we compared the proposed method with the HEVC-based V-PCC reference software.

**3DSA9/
3D9 - 4
16:00**

Fast Calculation Method for Computer-Generated Holograms Using Saccade Suppression by Lowering the Resolution Based on Fresnel Zone Plate Reduction

**WEI LINGJIE¹, Fumio Okuyama², Yuji Sakamoto¹
1. Hokkaido University (Japan), 2. New Generation Medical Center (Japan)*

Saccade is a very rapid movement of our both eyes that transfer between two or more gazing center, with almost no sensitivity of visual information from the eyes to the brain. In this study, it is possible to reduce the computational complexity of CGH by lowering the resolution of the CGH when the saccade occurred.

Author Interviews

16:30 - 17:00

SPECIAL EVENT

“Sensory Illusion”

Exhibition:

Wednesday, Nov. 27 – Friday, Nov. 29, 2019
Main Hall (1F)

Special Talks:

Wednesday, Nov. 27, 2019
18:30 – 19:10
Mid-sized Hall A (1F)

Workshop on LC Science and Technologies

Wednesday, November 27

13:40-15:00

Room 107

LCT1: Evaluation Techniques

Chair: Masaru Inoue (Toyo Tech. LLC)

Co-Chair: Yoshinori Iwashita (DIC)

LCT1 - 1 DC Image Sticking in Liquid Crystal Displays Caused by Polyimide Anion Radicals

13:40

**Yasutomo Nagano¹, Takanori Mori¹*

1. JNC Petrochemical Corporation (Japan)

We investigated the anion radical effect from aromatic imide groups in polyimide alignment layers of liquid crystal cells by means of electron spin resonance and absorption measurements. We found anion radicals generated by ultra-violet or blue light irradiation shows a clear correlation to DC image sticking.

LCT1 - 2 The Systematically Investigation on the Influence Factor on Vertical Alignment State of Polyimide-free Liquid Crystal Displays

14:00

**Yu Zhang^{1,2}, Song Lan², Qian Li², Xingwu Chen²,
Te-Jen Tseng², Chung-Ching Hsieh²*

1. Peking University Shenzhen Graduate School (China), 2. Shenzhen China Star Optoelectronics Technology Co., Ltd (China)

In this report, we systematically investigated the influence of types of substrate, different treatment method, the concentration of additive, the routes and temperature of process on the polyimide-free liquid crystal display. We presume two key factors, one is self-assembly capability, the other is hydrogen bond force.

LCT1 - 3 Second-Harmonic Imaging of Flexoelectric Polarization in Various Liquid Crystal Cells

14:20

**Koichiro Shirota¹, Fumito Araoka¹, Yutaka Yamagata¹*

1. RIKEN (Japan)

Since the flexoelectric polarization of LCs attracts much attention in the LCD industry, we visualize the flexoelectric polarization in nematic LCs with SHG microscopy. The observed flexoelectric polarization is induced by applying an electric field to various nematic LCs with positive or negative dielectric anisotropy in several types of cells.

LCT1 - 4 Withdrawn

LCT1 - 5L 14:40 A Novel Orientation Method for Nematic LCs by Using Magnetic Field Lines with Permanent Magnets and Electric Field for Assisting the Reorientation

*Yoshihiro Aoyagi¹, Yuichi Saito¹, *Yukihiro Kudoh¹, Taiju Takahashi¹*

1. Kogakuin University (Japan)

We proposed an LC orientation treatment method that was used by the magnetic field lines and the electric field for assisting the director reorientation. It was shown that a radial orientation could be obtained by performing this process with the vertical alignment cell in the initial state.

15:20-16:50

Room 107

LCT2: LC Flat Diffractive Optics
Special Topics of Interest on AR/VR and Hyper Reality

Chair: Toshiaki Nose (Akita Prefecture University)
Co-Chair: Hiroyuki Yoshida (Osaka University)

LCT2 - 1 15:20 Invited Fundamentals and Applications of Liquid Crystal-Based, Polarization-Dependent Diffractive Optics

**Hiroyuki Yoshida¹, SeongYong Cho¹, Yuto Tsuboi¹, Yuji Tsukamoto¹, Masanori Ozaki¹*

1. Osaka University (Japan)

There is recently interest in LC-based diffractive optical elements (DOEs) that enable modulation of the light phasefront through the spatial distribution of its optic axis. The operating principles of both transmissive and reflective devices are reviewed and their applications are discussed.

LCT2 - 2 15:40 Invited Ultimate Planar Optics for AR/VR and Next Generation Displays

**Nelson Tabirian¹, David Roberts¹, Anna Tabirian¹, Brian R Kimball², Timothy J Bunning³*

1. BEAM Engineering for Advanced Measurements Co. (United States of America), 2. U.S. Army Natick Soldier Systems Center, Natick, Massachusetts (United States of America), 3. Air Force Research Laboratories, Wright-Patterson Air Force Base, Ohio (United States of America)

Only one planar optics technology – diffractive waveplates – has shown capability to match large sizes and low-cost of Fresnel optics and the bandwidth of refractive optics. Electrically switchable and tunable with low-power controls, the thinnest lenses, prisms, and holograms make diffractive waveplate optics best suitable for AR/VR applications.

**LCT2 - 3 *Invited* Emerging Near-eye Displays with
16:05 Pancharatnam-Berry Optical Elements**

**TAO ZHAN¹, JIANGHAO XIONG¹, JUNYU ZOU¹,
GUANJUN TAN¹, SHIN-TSON WU¹*

*1. University of Central Florida (United States of
America)*

Near-eye displays with enhanced images quality are developed with planar optics employing Pancharatnam-Berry (PB) phase. Advanced broadband PB deflectors and lenses are fabricated to enhance the apparent pixel density and reduce the chromatic aberrations in immersive near-eye displays. Both simulation and experimental results are presented.

**LCT2 - 4 Fast-response Pancharatnam-Berry Lens for Head-
16:30 up Displays**

*Xiuying Ren¹, *Sida Li¹, Yueda Liu¹, Yan Li¹, Yikai Su¹*

1. Shanghai Jiao tong University (China)

In this paper we demonstrate fast-response Pancharatnam-Berry lenses (PBLs) based on polymer-stabilized liquid crystal. After photo-alignment technique and UV curing, the PBLs show submillisecond response time. Based on two identical PBLs, a head-up display system that can generate four different diopters is demonstrated.

17:00-18:00

Room 107

LCT3: Advanced LCD Technologies

Chair: Hiroyuki Okada (University of Toyama)

Co-Chair: Koichi Miyachi (JSR)

**LCT3 - 1 A Four-Ways Viewing Angle Controllable Display
17:00 using Specify Pixel Structure and Separated
Rubbing Method**

**Limei Jiang¹, Huilong Zheng¹, ChiaMin Yu¹,
Smart Chung¹*

*1. InfoVision Optoelectronics (Kunshan) Co., Ltd.
(China)*

We present a viewing angle controllable display capable of displaying in two viewing modes, i.e. wide view mode and four-ways privacy mode. Pixel is divided into two domains of perpendicular LC orientation direction with separated rubbing method. By controlling the LC phase retardation at off-axis, viewing angle switching realized.

LCT3 - 2 Optimization of Color and Transmittance in a Dye-Doped Chiral-Nematic Liquid Crystal Cell

17:20

**Seung-Min Nam¹, Seung-Won Oh¹, Jae-Won Huh¹,
Seong-Min Ji¹, Eunjung Lim², Jinhong Kim²,
Tae-Hoon Yoon¹*

*1. Pusan National University (Korea), 2. LG Chem.
(Korea)*

Among various dye-doped liquid crystal (LC) devices, a chiral-nematic LC cell provides the highest transmittance difference between its transparent and opaque states. We propose a systematic approach to find the optimal dye mixing for black color in the opaque state and optimization method in the parameter space for the maximum transmittance difference.

LCT3 - 3 An In-Screen Optical Fingerprint Recognition Structure for Full-Screen LCD

17:40

**HaiLiang Wang¹, Yan Lin¹, Ling Wu¹, Poping Shen¹,
JunYi Li¹, JianMou Huang¹, Yan Yang¹, Ting Zhou¹*

1. Xiamen Tianma Microelectronics Co., Ltd. (China)

We report a new type of LCD screen with an in-screen optical fingerprint recognition structure. This in-screen fingerprint recognition structure uses layers on the TFT&CF glass to make a collimating structure for accurate recognition. It can achieve fingerprint recognition at any position on the screen. It has a better user experience than traditional fixed location recognition.

LCT3 - 4L Withdrawn

Author Interviews

18:30 - 19:00

Thursday, November 28

9:00-10:20	Mid-sized Hall A
FMC4/LCT4: Micro LED Display <i>Special Topics of Interest on Micro/Mini LEDs</i>	

Chair: K Kälantär (Global Optical Solutions)
 Co-Chair: Seiji Shibahara (Sony Home Entertainment & Sound Products Inc.)

FMC4/ LCT4 - 1 ***Invited High-Resolution (1,000 to over 3,000 ppi) Full-Color Silicon Display for Augmented and Mixed Reality***
9:00

**Hidenori Kawanishi¹, Hiroaki Onuma¹, Masumi Maegawa¹, Takashi Kurisu², Takashi Ono², Shigeyuki Akase¹, Shinji Yamaguchi¹, Naoto Momotani², Yusuke Fujita¹, Yuhei Kondo², Kentaro Kubota², Toshimi Yoshida¹, Yuta Ikawa¹, Tsuyoshi Ono², Hiroyoshi Higashisaka², Yasuaki Hirano², Shinsuke Anzai¹*

1. Sharp Fukuyama Semiconductor Co., Ltd. (Japan),
2. Sharp Fukuyama Laser Co., Ltd (Japan)

We present the status of III-nitride micro-LED display bonded onto silicon backplane. 0.38-inch full-colour display with a resolution of 1,053 ppi has been successfully demonstrated. Progress toward higher resolution is also described. We believe our Silicon Display is ideally suited for near-to-eye displays for augmented and mixed reality.

Also presented in Innovative Demonstration Session (see p. 279)

FMC4/ LCT4 - 2 ***Invited A New Generation of HDR Display with Super Multi-Zones Mini LED***
9:20

**Jianping Zheng¹, Zhuo Deng¹, Ling Wu¹, Poping Shen¹, Junyi Li¹, Jianmou Huang¹*

1. Xiamen Tianma Microelectronics Company, Ltd. (China)

We propose a new generation of HDR display with active matrix mini-LED backlight for LCD. The display enables super multi-zones display by using new type of backlight drive, which achieved better contrast and less halo defect. Through both instrument test and perception experiments, we evaluated the performance of HDR LCD.

FMC4/ LCT4 - 3 **Invited Monolithic Integration of GaN-Micro-LED and Si-MOSFET for Bio-Application**
9:40 *Hiroto Sekiguchi^{1,2}, Hiroki Yasunaga¹, Kazuaki Tsuchiyama¹, Keisuke Yamane¹, Hiroshi Okada¹, Akihiro Wakahara¹
 1. Toyohashi University of Technology (Japan), 2. PRESTO, JST (Japan)

A micro light-emitting diodes (LED) has been attention as an optical stimulation tool for optogenetics. In this study, a needle-type microLED probe was fabricated for neuroscience. In addition, the monolithic integration of microLED and Si-MOSFET using wafer bonding technique was challenged toward the realization of multifunctional devices.

FMC4/ LCT4 - 4 **An Active Matrix Mini-LEDs Backlight Based on a-Si**
10:00 *Bin Liu^{1,2}, quansheng liu², jia li², yongyuan qiu², junling liu², yong yang², hongyuan xu², Juncheng Xiao², feng zhu², hang zhou¹, Xin Zhang²
 1. Peking University Shenzhen Graduate School (China), 2. China Star Optoelectronics Technology (China)

In this work, we fabricate an active matrix mini-LEDs backlight based on a-Si. The driving mechanism with 2T1C and process flow are discussed in detail. IR-drop is analyzed and improved. The gray scale is controlled by PWM method with the number of 64 (6 bit), and the maximum brightness is up to 20,000nits.

Author Interviews
 10:40 - 11:10

10:40-13:10

Main Hall

Poster LCTp1: Evaluation Technologies

LCTp1 - 1 **Enhanced Flexoelastic Ratio of Mesogenic Dopant-Doped Nematic Liquid Crystals**
 *Jongyoon Kim¹, Ji-Hoon Lee¹
 1. Chonbuk National University (Korea)

The enhanced flexoelastic ratio of mesogenic dopants (MDs)-doped nematic liquid crystals (NLCs) is studied. The flexoelastic ratio increased up to 139 % than pure nematic liquid crystals (NLCs) after doping MD. The mechanism of the enhanced flexoelastic ratio is presumably related to the large dipole moment of MDs.

LCT

LCTp1 - 2 Study on Local Area Transient Response Cause by Flexoelectric Effect of FFS Mode LCD

**Kun Tsai Huang¹, Yu Wen Hung¹, Ri-Xen Fang¹,
Conrad Lee¹, Sung-Chin Lin¹, Chia-Hua Yu¹*

1. HannStar Display (Taiwan)

Flicker is a serious problem in FFS mode LCD, flexoelectric effect is a main reason to affect the flicker phenomenon in FFS LCD panel. In this paper, we analysis the mechanism of Flicker phenomenon in local area. Different driving frequency of FFS LCD panel was discussed.

LCTp1 - 3 Withdrawn

LCTp1 - 4 Novel Measurement Method for Difference of Flexo-coefficients (e_{11} - e_{33}) by Using Disclination Lines in HAN Cells with Concentric Rubbing Treatment

**Taiju Takahashi¹, Noriki Shirai¹, Yukihiro Kudoh¹*

1. Kogakuin University (Japan)

We propose a novel evaluation method for the difference of flexo-coefficients ' e_{11} - e_{33} '. A HAN cell with in-plane electrodes treated concentric rubbing is used. Positions of disclination lines which occur due to the flexo-polarization under applying the dc electric field are used for evaluating e_{11} - e_{33} with fitting of numerical calculated results.

LCTp1 - 5L A Study on Gray Level Dependence of Influence Due to Flexoelectric Effect in FFS LCDs

**Daisuke Inoue¹, Tomomi Miyake¹, Mitsuhiro Sugimoto¹*

1. Tianma Japan, Ltd. (Japan)

Though transmittance dependency of DC offset voltage that relate to image sticking made a quadratic function, its bottom position and flicker minimum DC offset voltage depend on gray level due to flexoelectric effect. We demonstrated influence of flexoelectric effect changes depending on slit electrode width and black matrix width.

10:40-13:10

Main Hall

Poster LCTp2: Alignment Technologies

LCTp2 - 1 Vertical Alignment Surface Aligned by LED Light for High Yield Liquid Crystal Display Production

**Man Chun Tseng¹, Chen Xiang Zhao¹, Hon Wah Chiu¹,
Shu Tuen Tang¹, Fion Sze-Yan Yeung¹, Hoi Sing Kwok¹*

*1. The Hong Kong University Of Science and
Technology (Hong Kong)*

Most of the available photoalignment materials require polarized deep UV irradiation with a finite dosage. With the consideration of the current limitation with such a small working window, a vertical photoalignment surface by non-polarized blue LED light irradiation is proposed and demonstrated. It has good stability and performance.

LCTp2 - 2 Broadband In-Cell Quarter Wave Plate Using a Combination of Solution-processed Self-aligning Liquid Crystal Polymer by Coating Technique and Photoalignment

**Zhibo SUN^{1,2}, Zhengnan YUAN^{1,2},
Abhishek Kumar Srivastava^{1,2}, Hoi-Sing KWOK^{1,2,3}*

1. Department of Electronic and Computer Engineering, Hong Kong University of Science and Technology (Hong Kong), 2. State Key Laboratory on Advanced Displays and Optoelectronics and Technologies, the Hong Kong University of Science and Technology, Hong Kong (Hong Kong), 3. Jockey Club Institute for Advanced Study, Hong Kong University of Science and Technology (Hong Kong)

A new kind of in-cell solution-processed broadband quarter wave plate for the circular polarizer made of liquid crystal polymer using coating technique has been proposed and manufactured in this work. The transmittance and reflectance spectrum can show high ambient contrast ratio (ACR) improvement for the light emitting display system.

LCTp2 - 3 The Influence of PI and Reactive Mesogens to the Formation and Stability of Pretilt Angle

**Wei Cui¹, Hongquan Wei², Te-Jen Tseng²,
Chung-Ching Hsieh²*

1. Peking University Shenzhen Graduate School/ Shenzhen China Star Optoelectronics Technology Co., Ltd (China), 2. Shenzhen China Star Optoelectronics Technology Co., Ltd (China)

In the large-area fabrication of real panel, black circle and banding mura arised. This phenomenon was improved by adjusting the structure of PI and RM : PI with rigid side chain and RM with soft sturcture could make smaller pretilt angle and better pretilt stability.

LCTp2 - 4 The Investigation of Alignment Film Effect on High Resolution(8K) Liquid Crystal Display Transmittance

**Yu Zhang¹, Yan-Jun Song², Yong-Chao Zhao², Chung-Ching Hsieh²*

1. Peking University Shenzhen Graduate School, Shenzhen , China (China), 2. Shenzhen China Star Optoelectronics Technology Co. Ltd., Shenzhen, China (China)

The relationship between the alignment film and the transmittance of the liquid crystal display was investigated. By analysis of liquid crystal efficiency,the effect of the alignment film on the transmittance is mainly derived from two aspects: the optical properties of the PI film and the effective Δn .

LCTp2 - 5 Polar Anchoring Properties of Photoalignment Polyimide Films

**Wei-Wei Chen¹, Jui-Wen Pan¹, Shie-Chang Jeng¹*

1. National Chiao Tung University (Taiwan)

The polar anchoring properties, such as pretilt angle and anchoring energy, of commercial photoalignment polyimide films were studied in the vertical alignment nematic liquid crystal cells. The influences of the irradiation energy of linear polarized UV light on anchoring properties were investigated. The polar anchoring energy is $\sim 5 \times 10^{-5}$ J/m².

10:40-13:10

Main Hall

Poster LCTp3: Viewing Angle Control

LCTp3 - 1 Viewing Angle Controllable LCDs with RGBW CF

*Mengqing Zhu¹, Shaonan Zhang¹, Jun Jiang¹,
Smart Chung¹, Wei Quan¹, *Jiajun Shen¹*

*1. InfoVision Optoelectronics (Kunshan) Co., Ltd.
(China)*

This paper researched a viewing angle controllable FFS-LCD with RGBW CF, the measurement results show good anti-peep effect and low contrast ratio. Compared with conventional device and by analyzed the root causes of light leakage, we propose some methods to improve contrast ratio.

LCTp3 - 2 Withdrawn

LCTp3 - 3 Gray Level Inversion Improvement for Viewing Angle Controllable LCD

**Jiajun Shen¹, Limei Jiang¹, Zhongfei Zou¹,
Huiling Zheng¹, Smart Chung¹*

*1. InfoVision Optoelectronics (Kunshan) Co., Ltd
(China)*

We proposed a novel method to solve gray level inversion of viewing angle controllable LCDs. By narrowing the overlap area between pixel and bias electrode, brightness at white state increases obviously at large view in privacy mode. Experiment proved that gray level inversion in privacy mode can be effectively improved.

LCTp3 - 4 Effect of Concentration of the Guest Dichroic Dye in Guest-Host Liquid Crystal Panel for Viewing Angle Controller of Display

**Ho-Jin Choi¹, Hyunseung Lee¹, Seunghee Lim¹,
Sooyoung Park¹, Seungkil Baek¹, Ji-Hoon Lee¹*

1. Chonbuk National University (Korea)

In this paper, we experimentally demonstrated the viewing angle control using the guest-host (GH) liquid crystal (LC) panel and measured its viewing angle property, extinction coefficients corresponding to concentration of the guest dichroic dye in GH LC panel.

LCTp3 - 5L Microscopic Polymer Structure Formation of PDLCs by Patterned UV Irradiation for Viewing Angle Controllable LCDs

**Sou Matsuoka¹, Takahiro Ishinabe¹, Yosei Shibata¹, Hideo Fujikake¹*

1. Tohoku University (Japan)

We established a control technique of the polymer aggregation structure in PDLCs by the pattern UV exposure using a photomask to control the diffused light distribution of PDLCs. As a result, we clarified that successfully achieved a precise control of the fine polymer aggregation structure by used the polymerization inhibitor.

14:30-17:00

Main Hall

Poster LCTp4: High Image Quality

LCT

LCTp4 - 1 Research on Liquid Crystal Efficiency and Viewing Angle Performance of Pixel Boundary in LCD Display

**Wu Cao¹, Qi Zhang¹, Yinfeng Zhang¹, Yihe Zhang¹, Yunlun Lin¹, Juncheng Xiao¹*

1. Shenzhen China Star Optoelectronics Semiconductor Display Technology Co., LTD (China)

Impacts of pixel size on liquid crystal efficiency and voltage-transmittance curve at pixel boundary area are fully investigated by 3D simulation and observation. It is found that smaller pixel or domain size will suffer from efficiency or Tr% loss slightly (e.g. about 7% from 75UD to 55UD).

LCTp4 - 2 An MVA-LCD with Low Color Washout by New Pixel Design

**Qi Zhang¹*

1. Shenzhen China Star Optoelectronics Technology Co., Ltd. (China)

In order to improve the color washout of multi-domain vertical alignment (MVA) LCD in low gray scale, a new pixel design with reduced color washout and high transmittance is proposed. In the new pixel design, the ITO slit angles of the R/G/B sub-pixels are changed to varying degrees, and the central V-Trunk is blocked by metal. As a result, the color washout is greatly improved (about 40%) without loss of transmittance.

LCTp4 - 3 Quantitative Research of Light Scattering Intensity from Liquid Crystal on Luminance in the Black State of ADS LCDs

**Xueqiang Qian¹, Dongchuan Chen¹, Bingyang Liu¹, Kaixuan Wang¹, Hongming Zhan¹, Xi Chen¹*

1. BOE Display Technology Co., Ltd. (China)

We quantitatively investigated the relation between the luminance in the black state and scattering index of liquid crystal, in order to choose optimized liquid crystal to improve the contrast ratio. It was found that scattering index decreased from $0.345 \times 10^5 \text{m/N}$ to $0.137 \times 10^5 \text{m/N}$, the contrast ratio would improve from 1000:1 to 1800:1.

LCTp4 - 4 Withdrawn

14:30-17:00

Main Hall

Poster LCTp5: New LC Technologies

LCTp5 - 1 Analysis of Optical Performance Degradation in an Ion-Doped Liquid Crystal Cell

**Jeong-Ho Seo¹, Jae-Won Huh¹, Seung-Won Oh¹, Seung-Min Nam¹, Eunjung Lim², Jinhong Kim², Tae-Hoon Yoon¹*

1. Pusan National University (Korea), 2. LG Chem. (Korea)

We report an analysis of the optical performance degradation in an ion-doped liquid crystal cell. When an electric field is applied to the cell for a long time, the optical performance becomes non-uniform, and the haze value in the opaque state decreased. Based on the measurement of the optical and physical characteristics, we estimated that the degradation is caused by ionic materials.

LCTp5 - 2 Ion-Doped Liquid Crystal Light Shutter Switchable Among Transparent, Haze-Free Opaque, and High-Haze Opaque States

**Ho-jin Sohn¹, Jae-Won Huh¹, Jeong-Ho Seo¹, Seung-Won Oh¹, Sang-Hyeok Kim¹, Tae-Hoon Yoon¹*

1. Pusan National University (Korea)

Tristate switching of a liquid-crystal (LC) cell among the transparent, haze-free opaque, and high-haze opaque states is proposed. Owing to its simple switching process, the proposed LC cell is promising for the development of a multipurpose switchable window.

LCTp5 - 3 UV-Curable Silica NPs as a Reinforcing Component in Reverse Mode Polymer-Network LC Light-Scattering Device Fabricated Under Different Curing Conditions

**Eriko Fukuda¹, Mitsuhiro Akimoto¹, Masahiro Miyazaki¹, Shunsuke Kobayashi¹*

1. Sanyo-Onoda City University (Japan)

We examine how curing condition affects the alternation of electro-optical properties of reverse-mode polymer network liquid crystal with UV-curable silica nanoparticles (UVC-NPs). It is found that incorporation of UVC-NPs has almost the same effect as increasing the curing temperature by around +10°C.

LCTp5 - 4 Surfactants Synergistically Contributes to Reduction of Driving Voltage of Reverse-Mode Polymer Network Liquid Crystals with UV-Curable Nanoparticles

**Masahiro Miyazaki¹, Mitsuhiro Akimoto¹, Eriko Fukuda¹, Hiroya Nishikawa², Shunsuke Kobayashi¹*

1. Sanyo-Onoda City University (Japan), 2. RIKEN (CEMS) (Japan)

We demonstrate that combination of UV-curable silica nanoparticles (UVC-NPs) with polymerizable surfactants greatly reduce the threshold and saturation voltages of a reverse-mode polymer network liquid crystal device. Morphological observation reveals the role played by added surfactants.

LCTp5 - 5L Flexible Vertically Aligned Polymer Network Liquid Crystal Using Transferred Spacers Bonded by Photoreactive Mesogens for Smart Window Films

**Hayato Isa¹, Takahiro Ishinabe¹, Yosei Shibata¹, Hideo Fujikake¹*

1. Tohoku University (Japan)

We have developed flexible vertical alignment polymer network liquid crystal using transferred spacers for smart window applications. We clarified that application of photoreactive mesogens to the substrates enabled bonding two substrates and control of the liquid crystal alignment and we achieved a small radius of curvature.

LCTp5 - 6L Light Scattering of Ordinary Ray in Reverse Mode LC Cell Assisted by Micro Lens Effect

**Kosuke Sagawa¹, Rumiko Yamaguchi¹, Satoshi Yanase²*

1. Akita University (Japan), 2. Akita Industrial Technology Center (Japan)

We have propose a reverse mode LC cell prepared using a hole-patterned electrode substrate. Light scattering properties are obtained through the micro-lens effect with a short focal length and index mismatching between LC and polymer. Ordinary incident light can also be scattered by non-uniform electric field.

LCTp5 - 7L Tunable Narrow-bandpass Filter Using Blue Phase Liquid Crystal Etalon for Real-time Multi-spectral Imaging Systems

**Kosuke Shinatake¹, Takahiro Ishinabe¹, Yosei Shibata¹, Hideo Fujikake¹*

1. Tohoku University (Japan)

We proposed a tunable narrow-bandpass filter using a blue phase liquid crystal etalon filter and a multi-bandpass interference filter for real-time multi-spectral imaging systems. We theoretically clarified this filter has high transmittance > 80% and confirmed a control of transmission wavelengths can be achieved by this filter.

LCTp5 - 8L Electro-Optical Properties and Stabilities of Polymer Network Liquid Crystal Films with Polymer Wall Structure

**SeYong Eom¹, Da-Som Yoon², Tae-Hoon Kwon¹, Soon-Bum Kwon^{1,2}*

1. Hoseo University (Korea), 2. NDIS Corporation (Korea)

In order to secure the mechanical stability of polymer network liquid crystal films based on plastic substrate, polymer wall structures were introduced into LC layers. Excellent electro-optical properties, mechanical and thermal stabilities were achieved by optimizing the material and process parameters of them. The details of the study are presented.

Also presented in Innovative Demonstration Session (see p. 278)

LCTp5 - 9L Relationship between Liquid Crystal Molecular Behaviors and Dielectric Loss for Microwave Frequency Phase Shifters

**Yoichi Murakami¹, Yosei Shibata¹, Hiroyasu Sato¹, Takahiro Ishinabe¹, Qiang Chen¹, Hideo Fujikake¹*

1. Tohoku University (Japan)

For realization of phase shifter using liquid crystal (LC), we evaluated the relation between molecular structure of LC and dielectric loss in microwave frequency. We considered that dielectric loss can be reduced by thermal vibration suppression of LC molecules.

14:30-17:00

Main Hall

Poster LCTp6: Hybridized Material Technologies

LCTp6 - 1 Polymer Dispersed-Liquid Crystal Displays with Low Driving Voltage

**Gi Heon Kim¹, Won-Jae Lee¹, Chi-Sun Hwang¹*

1. ETRI (Korea)

A nematic LC and thermal-curable mixtures were cured by thermal polymerization. We investigated their effects on the electro-optical performance and the morphology. The thermally induced polymer dispersed-liquid crystal displays showed strong scattering behavior despite low cell gap and low driving voltage (< 20V).

LCTp6 - 2 Photo-patterned Cholesteric Liquid Crystals for Transparent Computer-generated Waveguide Holography with Visible Playback Capability

**SeongYong Cho¹, Hiroyuki Yoshida¹, Masanori Ozaki¹*

1. Osaka university (Japan)

A completely transparent waveguide holography in the visible light region is demonstrated based on a photo-patterned cholesteric liquid crystal, which reflects only infrared light. The transparent device also demonstrates that the encoded optical phase information can be coupled out of waveguide mode through visible wave-guided light and observed in free-space.

LCTp6 - 3 A Novel Transparent Screen Based on Polymer Network Liquid Crystal

**Zhiqing Shi¹, Zhengyu Feng¹, Surgaltu Borjigin¹, Limei Zeng¹, Pojen Chiang¹, Shujih Chen¹, Chiayu Lee¹, Xin Zhang¹*

1. Shenzhen China Star Optoelectronics Semiconductor Display Technology Co.,Ltd. (China)

In this work, a novel 28 inch transparent screen based on polymer network liquid crystal (PNLC) was developed successfully and presented to satisfy customer's desire requirement. The color display system combining a transparent screen and a projector has properties of high transmittance and information showing ability.

LCT

I-DEMO (Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters

Thursday, Nov. 28, 2019

11:40 – 15:40

Main Hall (1F)

Sapporo Convention Center

Friday, November 29

9:00-10:35	Mid-sized Hall A
LCT5/FMC5: High Performance 8K LCDs	

Chair: Koichi Miyachi (JSR)
Co-Chair: Toshimitsu Tsuzuki (NHK)

**LCT5/
FMC5 - 1
9:00** ***Invited* Novel Liquid Crystal Display mode UV²All
with Photo Alignment Technology for a Large-
Screen 8K Display**

**Shinichi Terashita¹, Kouichi Watanabe¹,
Fumikazu Shimoshikiryoh¹
1. Sharp Corporation (Japan)*

We have developed a new liquid crystal display mode UV²All which is suitable for a large screen 8K display and commercialized as the 80 8K TV. UV²All has brought large superiority that are 1.3 times higher transmittance, 35% faster response, and wider viewing angle property to compare with UV²A.

**LCT5/
FMC5 - 2
9:25** ***Invited* Novel Pixel Structure for the Improving
Optical Performances of 8K LCD Panel**

**Kwangsoo Bae¹, Minjoeng Oh¹, Beomsoo Park¹,
Young Je Cho¹, Sang Hwan Cho¹, Dong Hwan Kim¹
1. Samsung Display (Korea)*

We report on novel pixel architecture for improving the transmittance and reducing the gamma distortion to minimize the color shift in a 8K QUHD LCD panel with the hG-2D technology. This technology has the excellent transmittance by matching the LC distortions on the vertical electrode and two data lines which is asymmetrically positioned. Besides, by shielding the LC distortion line at the oblique viewing angle, the gamma distortion can be effectively suppressed. Through the QUHD panel with our structure, superior performances to normal LCD could be clearly demonstrated.

**LCT5/
FMC5 - 3
9:50** ***Invited* 17-inch Laser Backlight LCD with 8K, 120-Hz
Driving and BT.2020 Color Gamut**

*Yoichi Asakawa¹, Ken Onoda¹, Hiroaki Kijima¹,
*Shinichi Komura¹
1. Japan Display Inc. (Japan)*

We succeeded in prototyping a 17-inch 8K liquid crystal display satisfying the BT.2020 specification. The pixel density of the display is 510 ppi, while its color gamut covers 98% of that of BT.2020. The liquid crystal response time is 5 ms, which is sufficient for 120-Hz driving.
Also presented in Innovative Demonstration Session (see p. 278)

**LCT5/
FMC5 - 4L
10:15**

**55 High Contrast Ratio Panel Produced by Pixel
Level Local Dimming Technology**

**Chun-chi Chen¹, Yan-Xue Wang¹, Young-Yuan Qiu¹,
Gang Yu¹, Chung-Yi Chiu¹, Bin Zhao¹, Xin Zhang¹*

*1. China Star Optoelectronics Technology Company,
Ltd. (China)*

The contrast ratio is a important index for the LCD optics. The higher contrast ratio, the picture quality reconstructed by LCD is better. LCD module is constructed by back light and optical switch. And the LC is not an ideal optical switch, so the contrast ratio of LCD is lower than OLED. We use dual cell which can use pixel level local dimming to improve the contrast ratio, and it can make the contrast ratio from 5000:1 to 200000:1.

10:40-12:10

Mid-sized Hall A

LCT6: New LC Applications

Chair: Hideo Ichinose (Merck Performance Materials Ltd.)
Co-Chair: Fumito Araoka (RIKEN)

**LCT6 - 1 *Invited* Transport of Ions, Electrons and Molecules
10:40 in Nanostructured Liquid Crystals for Their New
Applications**

**Takashi Kato¹*

1. The University of Tokyo (Japan)

Here we present our recent approaches to use a variety of nanostructured liquid crystal materials forming smectic, columnar, and bicontinuous cubic structures for transport of ion, electron, and water molecules. They are applied to thin-film materials for electrolytes of lithium ion batteries and solar cells, and water treatment membranes.

**LCT6 - 2 *Invited* Cellulose Derivatives for Color Imaging
11:05 Applications**

**Seiichi Furumi¹*

1. Tokyo University of Science (Japan)

Cellulose is the most abundant organic compound on the earth, and has attracted considerable interest as one of sustainable materials. Cellulose derivatives are well-known to exhibit cholesteric liquid crystal (CLC) with visible reflection. This presentation reports on our research accomplishments of cellulose CLCs for full-color imaging and mechanical stress sensing.

LCT6 - 3 Withdrawn

LCT

LCT6 - 4L 11:30 Dye-Doped Liquid Crystal Light Shutter Fabricated by Thermally-Induced Phase Separation

**Yeongyu Choi¹, Seung-Won Oh¹, Tae-Hoon Yoon¹
1. Pusan National University (Korea)*

A dye-doped LC/polymer light shutter fabricated with the thermally-induced phase separation (TIPS) method is demonstrated. The TIPS method does not degrade the dye during the fabrication process. The fabricated LC cell exhibits excellent optical performance, which is suitable for a light shutter with superior black color. This fabrication method can be applied for the high visibility of see-through displays.

LCT6 - 5L 11:50 High Performance Liquid Crystal on Silicon Spatial Light Modulator (LCOS-SLM) and Flicker Noise Reduction of Multiple Spots

**Hiroshi Tanaka¹, Hiroto Sakai¹, Munenori Takumi¹, Haruyoshi Toyoda¹
1. Hamamatsu photonics K.K. (Japan)*

We developed LCOS-SLM as a spatial light modulator for precise pure phase control. Generation of stable multiple spot patterns (MSPs) is important in laser processing, microscopy. We proposed flicker noise reduction method of the MSPs which generated by the LCOS-SLM and confirmed reduction of noise from 2% to 0.5%.

Author Interviews

12:10 - 12:40

13:20-14:30

Room 204

LCT7/FLX5: Flexible LCDs

Chair: Shinichiro Oka (Japan Display Inc.)
Co-Chair: Toshimasa Eguchi (Sumitomo Bakelite Co., Ltd.)

LCT7/ FLX5 - 1 13:20 Invited Flexible LCD with Colorless Polyimide

**Kaijun Wang¹, Chungue Yuan¹, Zhuhui Li¹, Li Zhang¹, Qiao Huang¹, Linshuang Li¹, Shujih Chen¹, Chia-Yu Lee¹, Xin Zhang²*

*1. Shenzhen China Star Optoelectronics Semiconductor Display Technology Co.Ltd. (China),
2. Shenzhen China Star Optoelectronics Technology Co., Ltd. (China)*

We successfully realized 14-inch flexible LCD using colorless polyimide(cPI) as substrate. The LCD panel has the thickness less than 0.3 mm, which is IPS mode with some special materials and designs for avoiding predictable risks and solving issues during process.

**LCT7/
FLX5 - 2
13:45** **Invited Ultra-High Contrast OLCD: Thin and Light
Dual Cell LCDs on Plastic**
**Paul A Cain¹, James Harding¹, William Reeves¹,
May Wheeler¹*
1. FlexEnable Ltd (UK)

We report on a breakthrough approach for creating dual cell LCDs on ultra-thin plastic films that can significantly reduce inter-cell separation, resulting in a simpler construction that avoids the need for compensation films and other trade-offs. The resulting structure is particularly suited to TVs, monitors and automotive displays.

**LCT7/
FLX5 - 3
14:10** **Formation of Polymer Walls with a High Aspect
Ratio on a Plastic Substrate**
**Su Min Do¹, Tae Hoon Choi¹, Jae Won Huh¹,
Yeongyu Choi¹, Tae Hoon Yoon¹*
1. Pusan National University (Korea)

We formed polymer walls with a high aspect ratio on a plastic substrate. Polymer walls are formed without a photomask through the phase separation of liquid crystal/reactive mesogen mixture induced by a spatial difference of elastic energy and electric field intensity.

**LCT7/
FLX5 - 4L
14:30** **New Approach to Process Simplification for Flexible
TFT-LCD**
**Cheng-He Ruan¹, Chih-Yuan Hou¹, Chia-Jen Li¹,
Shih-Min Chen¹, Min-Zi Hong¹*
1. AU Optronics Corporation (Taiwan)

A new approach is proposed to fabricate flexible TFT-LCD with minimal process steps. Single substrate and without conventional cell process is obtained by introducing AOC and developed PDLC coating on the top of array without PI alignment process. The 4.99 294ppi AOC prototype LCD on a single substrate was fabricated.

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)
Sapporo Convention Center

LCT

15:00-16:20	Room 108
PRJ7/LCT8: Eyewear	
<i>Special Topics of Interest on AR/VR and Hyper Reality</i>	

Chair: Dieter Cuypers (CMST)
Co-Chair: Subaru Kawasaki (JNC Korea)

**PRJ7/
LCT8 - 1
15:00** **LC Lens Fabricated by Photoalignment for AR/VR Systems**
**Wei-Wei Chen¹, Jui-Wen Pan¹, Shie-Chang Jeng¹*
1. National Chiao Tung University (Taiwan)

A concept for an electrically tunable liquid crystal (LC) lens using a hole-patterned electrode and the vertical alignment liquid crystal cell by circular photoalignment is demonstrated. The proposed LC lens is a polarizer-free negative lens (0D~-0.93D) by changing the driving voltage. The proposed LC lens can be applied for AR/VR applications.

**PRJ7/
LCT8 - 2
15:20** **Effect of Processing Parameters on Visual Quality for Liquid Crystal Displays Compatible with Contact Lenses**
**Andres Vasquez Quintero¹, Pablo Perez-Merino², Sudha Sudha¹, Lucas Oorlynck¹, Herbert De Smet¹*
1. Ghent University / imec, Centre for Microsystems Technology CMST (Belgium), 2. Instituto de Investigacion Sanitaria Fundacion Jimenez Diaz (Spain)

This paper presents the effect of processing parameters on the contrast and optical quality of guest-host liquid crystal cells intended for smart contact lens applications. The effects were measured by means of cavity interferometry and model fitting. Optical quality was qualitatively assessed by means of target images.

**PRJ7/
LCT8 - 3
15:40** **Miniature Liquid Crystal Lens Optimizations**
**Dieter Cuypers¹, Rik Verplancke¹, Herbert De Smet¹*
1. imec and Ghent University (Belgium)

Small, switchable liquid crystal based polymer Fresnel lenses are discussed, considering design optimizations for performance.

PRJ7/
LCT8 - 4
16:00

**Ferroelectric Liquid Crystal Dammann Grating: for
LiDAR Applications**

**Zhengnan YUAN¹, Zhibo SUN¹,
Abhishek K SRIVASTAVA¹*

*1. The Hong Kong University of Science and
Technology (Hong Kong)*

We propose a ferroelectric liquid crystal Dammann grating (FLCDG) based polarization modulated depth-mapping system. Innovatively, FLCDG is used as high-speed shutter in this system. The application of FLCDG enables LiDAR as one-shot capturing system instead of iterative scanning. Moreover, the proposed device shows a fast data-collection time period ($50\mu\text{s}$) for per 49 points that can be further increased depending on the damman grating, and provide low cost solution to the problem.

Author Interviews
16:30 - 17:00



Workshop on Active Matrix Displays

Wednesday, November 27

13:40-15:15

Mid-sized Hall B

AMD1: Foldable Technology of OLED Displays

Chair: Koichi Miwa (LG Display Co.,Ltd)
Co-Chair: Keisuke Omoto (Apple)

AMD1 - 1 *Invited* Development of Foldable AMOLED Displays Based on Neutral-Plane Splitting Concept

13:40

**Masumi Nishimura¹, Kisako Takebayashi¹,
Masatomo Hishinuma¹, Hajime Yamaguchi¹,
Akio Murayama¹*

1. Japan Display Inc. (Japan)

Splitting of the mechanical neutral plane is a promising concept for foldable displays because it reduces the folding stress and stiffness of the display. We verified the concept experimentally and developed 5.5-inch full high-definition foldable AMOLED displays, which endured 150 k inward folding cycles with folding radius of 3 mm.

AMD1 - 2 *Invited* Ubiquitous Display, The Golden Age of OLED 14:05

**Chenggong Wang¹, Zhibo Yao¹, Yifan Liu¹, Xianrui Qian¹,
Jiye Xia¹*

1. Visionox Technology Inc (China)

The AMOLED display technology became more and more popular in the display field. However, there are still many challenges for this technology. We spend a lot of time working on it to make progress of the mass production of AMOLED, especially for the flexible AMOLED.

AMD1 - 3 **Withdrawn**

AMD1 - 5L **Stretchable Oxide TFTs on PI/SEBS Substrate**

14:30

**Chanju Park¹, Suhui Lee¹, Jin Jang¹*

1. Kyung Hee University (Korea)

We present stretchable amorphous indium-gallium-zinc-oxide (a-IGZO) thin-film transistors (TFTs) transferred onto styrene ethylene/butylene styrene (SEBS) thermoplastic elastomer. The fabricated stretchable oxide TFT showed electrical properties even after 40% strain without mechanical and electrical degradations. This stiff island on the stretchable substrate was demonstrated to enable for stretchable electronics.

AMD1 - 4 Positive Bias-Stress Stability of Flexible Amorphous InGaZnO Thin Film Transistors with Double-Stacked Gate Insulators

14:55

**Chengyuan Dong¹, Guochao Liu¹, Ying Zhang¹,
Guofeng Feng¹, Wen Zhang¹*

1. Shanghai Jiao Tong University (China)

Double-stacked gate insulators (SiO_x/TaO_x) made flexible amorphous InGaZnO thin film transistors more stable under both mechanical bending and positive bias-stress, which was assumed to result from their better neutral plane position and front-channel interface states. A simple model was built to explain this improvement effect.

15:20-16:45

Mid-sized Hall B

AMD2: High Resolution Display

Chair: Junichi Takeya (University of Tokyo)
Co-Chair: Hiroki Hamada (Kindai Univ.)

AMD2 - 1 Invited Development of 88-inch 120Hz 8K OLED TV for Mass Production

15:20

**Koichi Miwa¹, Hyun-Haeng Lee¹, Seong-Eok Han¹,
Yong-Joon Heo¹, Du-Hwan Oh¹, Shin-Kyun Park¹*

1. LG Display Co., Ltd. (Korea)

88-inch 8K OLED TV has been launched to the market. The display features 7680 x 4320 pixel resolution and 120Hz refresh rate. White OLED on Oxide TFT backplane architecture is applied as were in our 4K/2K OLED TV products. Design and driving features will be presented in this paper.

AMD2 - 2 Invited 5291 ppi OLED Display with C-Axis Aligned Crystalline Oxide Semiconductor

15:45

**Shuichi Katsui¹, Hidetomo Kobayashi¹,
Takashi Nakagawa¹, Yuki Tamatsukuri¹,
Hideaki Shishido¹, Shogo Uesaka¹, Ryohei Yamaoka¹,
Takaaki Nagata¹, Tomoya Aoyama¹, Yutaka Okazaki¹,
Takayuki Ikeda¹, Shunpei Yamazaki¹*

1. Semiconductor Energy Laboratory Co., Ltd. (Japan)

C-axis aligned crystalline oxide semiconductor field-effect transistor (CAAC-OS FET) can be scaled down to a width and length of 60 nm. We have fabricated an organic light-emitting diode (OLED) display with more than 5000 ppi required in virtual reality (VR) displays by using CAAC-OS FETs as the backplane.

AMD2 - 3 **Novel Compensation Pixel Circuit with Simultaneous Emission Driving Scheme for High-Resolution AMOLED Displays**
16:10

**Jui-Hung Chang¹, Chin-Hsien Tseng¹, Sung-Chun Chen¹, Chih-Lung Lin¹*

1. National Cheng Kung University (Taiwan)

This proposed work using simultaneous emission (SE) driving scheme to compensate for the V_{TH} variations of LTPS TFTs for high-resolution AMOLED displays. Simulated results demonstrate that the relative current error rates are all below 3.5% when V_{TH} of driving TFT varies by ± 0.5 V.

AMD2 - 4L **75-inch LCD Displays with AM MiniLED Local Dimming Backlight Units on Glass**
16:30

*Juncheng Xiao¹, *Jiayang Fei¹, Hongyuan Xu¹, Yongyuan Qiu¹, Quansheng Liu¹, Yong Yang¹, Junling Liu¹, Jiaqing Zhuang¹, Chunming Liu¹, Daobing Hu¹, Xin Zhang¹*

1. Shenzhen China Star Optoelectronics Technology Co., Ltd (China)

We developed AM miniLED local dimming backlight systems on glass for 75-inch LCD displays, with each consisting of 5184 zones. The display achieves HDR, which is comparable to those of Dual-cells and OLEDs. In addition, the system exhibit advantages such as low fabrication cost, long life time and more energy-efficient.

17:00-18:35

Mid-sized Hall B

AMD3: Driving Technology of Micro/Mini LED Displays
Special Topics of Interest on Micro/Mini LEDs

Chair: Kazumasa Nomoto (Sony)

Co-Chair: Keisuke Omoto (Apple)

AMD3 - 1 ***Invited* Crystal LED Display System for Immersive Viewing Experience**
17:00

**Katsuhiro Tomoda¹, Norifumi Kikuchi¹, Goshi Biwa^{2,1}, Hisashi Kadota^{1,2}*

1. Sony Semiconductor Solutions Corporation (Japan), 2. Sony Corporation (Japan)

We developed a novel active matrix driving technology that integrates RGB micro LEDs and a micro IC in each pixel for our Crystal LED display system. With precise tiling technology, a large-scale image with immersive viewing experience can be delivered.

AMD3 - 2 *Invited* Active Matrix Driving mini-LED Device

17:25

**Chin-Lung Ting¹, Chung-Kuang Wei¹, Li-Wei Mau¹,
Ker-Yih Kao¹, Ho-Tien Chen¹, Minoru Shibazaki²*

*1. Innolux Corporation (Taiwan), 2. Innolux Japan
(Japan)*

We have developed a glass- or flexible substrate-based AM driving mini-LED device. The AM driving mini-LED device controls each mini-LED element precisely with TFT, and can be applied to PID and BL of LCD, improving the optical performance of dynamic range, CR, color purity and viewing angle performance of the display.

AMD3 - 3 *Invited* A 200-ppi Full Color Active Matrix Micro-LED Display with Low-Temperature-Poly-Silicon TFT Backplane

17:50

**Masaya Tamaki¹, Sho Nakamitsu¹, Hiroaki Ito¹,
Takanobu Suzuki¹, Masahiko Nishide¹, Kunio Imaizumi¹,
Katsumi Yamanoguchi¹, Fanny Rahadian¹,
Katsumi Aoki¹, Seiji Matsuda¹, Ryoichi Yokoyama¹*

1. Kyocera Corporation (Japan)

A 1.8-inch 200-ppi full color active matrix micro light emitting diode (LED) display prototype has been developed with a low-temperature-poly-silicon (LTPS) TFT backplane. The frame rate of 240Hz and the luminance of 2000nits, both of which are promising attributes for high motion image quality and high dynamic range (HDR) applications, being superior to existing display technologies, were achieved by our LTPS TFT technology.

AMD3 - 4 *Active Matrix Monolithic Full-Color LED Micro Display*

18:15

**Longheng Qi¹, Xu Zhang¹, Wing Cheung Chong¹,
Peian Li¹, Chak Wah Tang¹, Kei May Lau¹*

*1. The Hong Kong University of Science and
Technology (Hong Kong)*

An active matrix monolithic full-color LED micro-display is demonstrated, combining monolithic blue GaN-on-Si LED array and quantum dots down conversion technology. This full-color scheme shows feasible manufacturability and visual quality, paving a new pathway toward volume production of full-color LED micro-display in the near future.

Author Interviews

18:30 - 19:00

Thursday, November 28

9:00-10:20

Mid-sized Hall B

AMD4: Emerging TFTs

Chair: Hyun Jae Kim (Yonsei Univ.)

Co-Chair: Yosei Shibata (Tohoku Univ.)

AMD4 - 1 Invited Active-Matrix Driven Flexible mini-LED Displays Based on High-Performance Organic Single-Crystal TFTs

9:00

Jun Takeya^{1,2}1. The University of Tokyo (Japan), 2. Organo-Circuit Inc. (Japan)*

A newly developed technologies of flexible active-matrix mini-LED displays are presented. The backplane is based on high-performance organic single-crystal TFTs laminated on screen-printed large-area plastic substrates. The devices are suited to the application for large-area signages.

Also presented in Innovative Demonstration Session (see p. 278)

AMD4 - 2 Invited Printing of 3D Electronic Circuits and Organic Thin-Film Transistors

9:25

Takeo Minari¹, Qingqing Sun¹, Wanli Li¹, Xuying Liu², Masayuki Kanehara³1. National Institute for Materials Science (NIMS) (Japan), 2. Zhengzhou University (China), 3. C-INK Co., Ltd. (Japan)*

We propose a large-scale fabrication method of electronic devices based on solution-processed coating and printing. This method relies on bottom-up printing processes using soluble metal nanoparticles and organic semiconductors, resulting in thin-film electronic devices to be printed at room temperature without application of heat. We successfully fabricated high-performance organic thin-film transistors on plastic and paper substrates. In addition, the printing technique with 1-micron line width and space was also achieved. Our fabrication method is very promising for low-cost fabrication of high-resolution flexible electronics.

AMD4 - 3 Withdrawn**SID Display Week 2020**

June 7 - 12, 2020

San Francisco Moscone Convention Center

San Francisco, California, USA

<http://www.displayweek.org/>

AMD4 - 4L 9:50 Integrated Polycrystalline Silicon Photomask Technology for Low-Temperature Polycrystalline Silicon (LTPS) TFTs

**Jia-Hong Ye¹, Ching-Liang Huang¹, Kuo-Yu Huang¹, Maw-Song Chen¹, Wen-Ching Tsai¹, Wei-Ming Huang¹, Yang-An Wu¹*

1. AUO (Taiwan)

A novel Four-Photomask complementary metal oxide semiconductor (CMOS) technology for low temperature polycrystalline silicon (poly-Si) thin film transistors (LTPS TFTs) was proposed in the first time. The combination of poly-Si layer and P plus (P+) region definitions within one lithography process was realized by a half-tone photomask. In this paper, the characteristics of TFTs within a half-tone Poly-Si Photomask of lithography processes were reported and compared with electrical characteristics of typical Six-Photomask lithography processes. The Integrated Poly-Si Photomask Technology can be applied to reduce the numbers of photomask of making an IGZO and LTPS Hybrid TFTs Array.

AMD4 - 5L 10:05 Improving Performances of Oxide Phototransistors Using a Mechano-Chemically Treated Porous Structure as The Visible Light Absorption Layer

**I Sak Lee¹, Bennet Nii Akwei Brown², Dongwoo Kim¹, Sujin Jung¹, Byung Ha Kang¹, Hyun Jae Kim¹*

1. Yonsei University (Korea), 2. Columbia University (United States of America)

In this research, we suggest indium gallium zinc oxide (IGZO) thin film transistors (TFTs) for detection of visible light using a porous oxide layer (POL) resulting from mechano-chemical treatment. When compared with conventional IGZO TFT, the IGZO TFT with the POL exhibits photoresponsivity of 341.32 A/W, photosensitivity of 1.10×10^6 , and detectivity of 4.54×10^{10} Jones under 532 nm light illumination.

Author Interviews

10:40 - 11:10

AMD

IDW '20

The 27th International Display Workshops

Dec. 9 - 11, 2020

Fukuoka International Congress Center

Fukuoka, Japan

<https://www.idw.or.jp/>

10:40-13:10

Main Hall

Poster AMDp1: Oxide TFTs**AMDp1 - 1 Improvement in Carrier Mobility of ZnON Transistor by Tantalum Encapsulation****Minjae Kim¹, Jae Kyeong Jeong¹**1. Hanyang Univ. (Korea)*

The TaOx/ZnON thin-film stack showed a more uniform distribution of nanocrystalline ZnON with an increased stoichiometric anion lattice compared to control ZnON thin-films. Significantly, improved mobility of 89.4 cm²/Vs were achieved for TaOx/ZnON TFTs. This improvement can be explained by the removal and passivation effect of TaOx film on ZnON.

AMDp1 - 2 Withdrawn**AMDp1 - 3 Withdrawn****AMDp1 - 4 Stable and High-Mobility Oxide TFTs Using Low-Temperature Processed ZTO/IZO Stacked Channels****Tsubasa Moritsuka¹, Hiroyuki Uchiyama¹**1. Hitachi, Ltd. (Japan)*

We fabricated Zn-Sn-O (ZTO)-based oxide and In-Zn-O (IZO) stacked channel thin-film transistors (TFTs) by experimentally using ultraviolet (UV) annealing for activation. The field-effect mobility was about 30 cm²/Vs, and the threshold voltage (V_{th}) was -3.5 V at the UV annealing temperature of 200°C. These TFTs improved the reliability of the negative gate bias illumination stress (NBIS) test more than the In-Ga-Zn-O (IGZO) TFTs did. The ZTO/IZO stacked channel TFTs are promising candidates for next-generation flexible devices.

AMDp1 - 5 Transfer Characteristics of H₂O₂-Doped ZrInZnO Thin Film Transistors**Sangmin Lee¹, Bohyeon Jeon¹, Byoungdeog Choi¹**1. Sungkyunkwan University (Korea)*

Solution-processed zirconium-indium-zinc-oxide thin-film transistors (ZIZO TFTs) were fabricated with and without hydrogen peroxide (H₂O₂). With an incorporation of H₂O₂ into the channel layer, threshold voltage shift under positive bias stress were improved. We realized the reduced trap density of ZIZO TFTs with 2 M H₂O₂ incorporation.

AMDp1 - 6 Study on the Influence Factors of ESD Defect for a-IGZO TFT

**Ding Yuan Li¹, Ru Wang Guo¹, Tian Zhen Liu¹,
Xian Xue Duan¹, Sang Jin Kim¹, Sang Soo Park¹,
Ming Ming Chu¹, Xin Hong Chen¹, Li Li Wei¹,
Hai Feng Chen¹, Wei Fang¹*

1. BOE HF (China)

In this work, the influence factor for Electrostatic Dis-charge [ESD] on amorphous Indium Gallium Zinc Oxide Thin Film Transistors [a-IGZO TFTs] was studied using glass substrate with different properties. We identified glass back side roughness and sag have connection with ESD defect rate, the result showed higher glass substrate sag and lower back side roughness with higher ESD defect rate after process.

AMDp1 - 7 Study on Promoting Transmittance on Dielectric Multi-layers for IGZO LCD Displays

**Ningbo Yi^{1,2}, Lixia Li², Sibang Long², Sen Yan²,
Feng Zhao²*

*1. Peking University Shenzhen Graduate School
(China), 2. Shenzhen China Star Optoelectronics
Technology Co., LTD (China)*

It was demonstrated that the layered structure of SiO_x and SiN_x is a good candidate to be gate insulator and passivation layers in IGZO TFT. However, this multi-layered structure could introduce issues of transmittance at aperture area in single glass of TFT side based optics physics. It is a good solution to improve the transmittance via optimizing structures of GI and PV layers, which could be adopted in IGZO-TFT LCD displays.

**AMDp1 - 8 Characteristics of Top-gate Self-aligned Oxide A-IGZO TFT With Copper Light Shield Layer
Characteristics of Top-Gate Self-Aligned Oxide A-IGZO TFT With Copper Light Shield Layer**

**Qian Ma^{1,2}, Xingyu Zhou², YuanJun Hsu², Yuanchun Wu²*

*1. Peking University Shenzhen Graduate School
(China), 2. Shenzhen China Star Optoelectronics
Technology Co., LTD (China)*

A top-gate self-aligned oxide amorphous indium-gallium-zinc-oxide (a-IGZO) thin-film transistor (TFT) was examined for active matrix organic light-emitting diode (AMOLED) display. The device exhibited robust device performance, such as excellent threshold voltage uniformity, high mobility, and good gate bias stress stabilities. Furthermore, remarkable short channel characteristics were achieved.

AMDp1 - 9 Fluorine-doped Indium Gallium Zinc Oxide Thin-Film Transistors Fabricated via Solution Process

**Donghee Choi¹, Byoungdeog Choi¹*

1. University of Sungkyunkwan (Korea)

Fluorine-doped indium-gallium-zinc-oxide thin-film transistors were fabricated using a sol-gel process. The devices showed the enhanced electrical properties of V_{th} , saturation mobility, subthreshold swing and positive bias stress stability with an incorporation of the fluorine into the IGZO channel layer. This may be attributed the effect of fluorine doping. It generates the free electron by replacing the oxygen atoms and decreases the total trap states by occupying the oxygen vacancies.

AMDp1 - 10 Analysis and Solution of 4/5/6 levels related issues in a-IGZO TFT Gate Driving Circuits for 32-in FHD TFT-LCD

**suping xi¹, tianhong Wang¹, longqiang Shi¹, yifang chou¹, shiming Ge¹, chuhong Dai¹, jiajia Yu¹, Liang Hu¹, Jiang Zhu¹, wei Shao¹*

1. China Star Optoelectronics Technology (China)

In this paper, 4/5/6 levels related issues in two different a-IGZO TFT gate driving circuits for 32-in FHD TFT-LCD have been analytical and settled. The two different circuits are called GOA_A (STT structure) and GOA_B (big channel length structure), respectively. Both GOA_A and GOA_B circuits have the phase problem at 4/5/6 levels in TD1, and these phase problems have been settled in TD 2 by regulating the HVA signal voltage. The horizontal line at 4/5/6 levels can only be found in GOA_B of TD1 and these horizontal line at 4/5/6 levels have also been solved in TD 2, while GOA_A have no such problems in TD1 and TD2. The details can be presented in this paper.

AMDp1 - 11 Investigation of Hump Phenomenon in a-IGZO Thin-Film Transistors under Positive Bias Stress

**Xinlv Duan¹*

1. Institute of Microelectronics of the Chinses Academy of Sciences (China)

The hump phenomenon in InGaZnO thin-film transistors (IGZO TFTs) under positive bias stress (PBS) has been investigated by varying channel width and extended length. The results show that the parasitic channel is located at the edge area of the active region along the spreading current direction.

AMDp1 - 12 Withdrawn

AMDp1 - 13 High-Mobility and High-Reliability Top-Gate Self-Aligned IGZO TFTs with Incorporate High Density Passivation Layer (HDP) after PV Deposition

*Peng Zhang^{1,2}, Guo Zhen Lin^{1,2}, Ning Shu Zhao^{1,2},
Tao Le Zhang^{1,2,3}, Jun Yuan Hsu^{1,2}, Bo Jiang Yao^{2,1}

1. Shenzhen China Star Optoelectronics Technology Co., Ltd. (China), 2. National Engineering Laboratory for AMOLED Process Technology (China), 3. School of Electronic and Computer Engineering, Shenzhen Graduate School, Peking University (China)

A top-gate self-aligned IGZO TFT with HDP incorporation after PV deposition was developed. The addition of HDP can effectively hamper the invasion of the outside water and gas, reduce the defects of the IGZO interface and subgap. Finally, high-mobility and high-reliability self-aligned IGZO TFT with PBTS 1.57V and NBTIS 1.03V was obtained.

AMDp1 - 14 Effect of Mo and MoTi Serving as a Barrier Layer for Cu Source/Drain Electrodes on Performances of Amorphous Silicon and IGZO TFTs

*Chuanbao Luo¹, Qianyi Zhang¹, Ziran Li¹,
Xuechao Ren¹, Xiaolong Meng¹, Dai Tian¹, Bisheng Mo¹,
Xiaohu Wei¹, Xialiang Yuan¹, Shijian Qin¹

1. Shenzhen China Star Optoelectronics Technology Co., Ltd (China)

The research reveals the effect of Mo and MoTi film on the suppression of Cu diffusion for BCE structure of a-Si and a-IGZO devices during severe thermal process. Electrical characters depict that a-IGZO film is superior to a-Si for suppressing Cu diffusion, resulting from untraceable Cu signal in ToF-SIMS.

AMDp1 - 15 Effect of Fluorine Doping on Illumination Stability of Solution-Processed IGZO TFTs

*Kyung-Mo Jung¹, Jongsu Oh¹, Kyoung-Rae kim¹,
Eun Kyo Jung¹, Jungwoo Lee¹, Yong-Sang Kim¹

1. Sungkyunkwan University (Korea)

This study investigated the effect of F doping though NBIS comparison between F-doped and conventional IGZO TFTs. The oxygen vacancies in the IGZO layer were reduced and the bandgap of the IGZO was widened by F doping. As a result of this, the illumination stability of F doped-TFTs was improved.

AMDp1 - 16 a-IGZO TFT Gate Integrated Driver Circuit with AC-Dirven Pull-Down TFTs for High stability

**Eun kyo Jung¹, Jongsu Oh¹, Jungwoo Lee¹,
KeeChan Park², Jae-Hong Jeon³, Yong-Sang Kim¹*

1. Sungkyunkwan University (Korea), 2. Konkuk University (Korea), 3. Korea Aerospace University (Korea)

In the proposed gate driver circuit, pull-down TFTs are AC-driven with a duty ratio of 33.3% through CLK pulse instead of DC-driven through VDD power line. The simulation result exhibits output pulse of 1069th stage, 1071st stage, and 1073rd stage output pulse based on FHD, frame frequency of 120 Hz.

AMDp1 - 17 Effect of Ambient Atmosphere on Abnormal Degradation Behavior in Metal-Oxide Thin-Film Transistor under Positive Gate-Bias and Temperature Stress

**JIAPENG LI¹, Lei Lu², Zhihe Xia¹, Sisi Wang¹,
Zhichao Zhou¹, Runxiao Shi¹, Hoi-Sing Kwok^{3,1},
Man Wong¹*

1. The Hong Kong University of Science and Technology (Hong Kong), 2. Peking Univeristy (China), 3. Jockey Club Institute for Advanced Study (Hong Kong)

Positive gate-bias and temperature stress were performed on the respective metal-oxide thin-film transistors as fabricated and stored in air ambience for three months. An abnormal negative shift of the transfer characteristics was observed, and a channel width-dependence of device degradation occurred after long-term storing.

AMDp1 - 18L Microwave Assisted Amorphous Oxide Thin-Film Transistors with Polymer Gate Dielectrics

**SeongCheol Jang¹, Kihyeon Bae¹, Kyung Jin Lee¹,
Hyun-Suk Kim¹*

1. Chungnam National University (Korea)

In this work, a-IGZO TFTs were fabricated at room temperature by the synergistic combination of microwave annealing and polymer gate dielectrics. a-IGZO TFTs were successfully fabricated at room temperature and show good electrical properties and stability.

AMDp1 - 19L Transparent AMOLED Display Derived by Metal Oxide Thin Film Transistor with Praseodymium Doping

**HUA XU¹, Miao XU², Min Li¹, Lei Wang², Junbiao Peng²*

1. Guangzhou New Vision Opto-electronic Technology Co.,Ltd. (China), 2. South China University of Technology (China)

Praseodymium-doped indium zinc oxide (Pr:IZO) have been employed as the channel layer of thin film transistors (TFTs). The TFTs with Pr doping exhibited a remarkable suppression of the light induced instability. A negligible photo-response and remarkable enhancement in negative gate bias stress under illumination (NIBS) were achieved in the Pr:IZO TFTs. Meanwhile, the Pr:IZO TFTs showed reasonable characteristics with a high field effect mobility of 18.4 cm²/Vs, SS value of 0.15 V/decade, and I_{on}/I_{off} ratio of 10⁹. A prototype of fully transparent AMOLED display was successfully fabricated to demonstrate the potential of Pr-doping TFTs applied in transparent devices.

AMDp1 - 20L Withdrawn

AMDp1 - 21L Improved Mobility and Stability of Indium-free Oxide Thin Film Transistor by Metal Capping Layer

**Ji-Min Park¹, Ho-Hyun Nahm², Hyun-Suk Kim¹*

1. Chungnam National University (Korea), 2. Korea Advanced Institute of Science and Technology (Korea)

In this work, to get better electrical properties, metal capping layer and lift-off lithography process of a new type of Indium-free amorphous thin films and associated thin-film transistors (TFTs) were investigated. As a result, optimized TFTs showed high mobility (< 30cm²/Vs) and excellent stability than conventional InZnO TFTs.

AMDp1 - 22L Improved pH Reliability of Solution-Processed In₂O₃ Field-Effect Transistors via Ga Doping and Different Annealing Temperatures

JoonHui Park¹, Jeongsoo Hong², Kyung Hwan Kim²,
*YOU SEUNG RIM¹

1. Sejong University (Korea), 2. Gachon University (Korea)

Studies of metal oxide semiconductors-based biosensors have focused on detection properties done typically by specific target receptor attachment. However, the exploration of metal oxide semiconductors with different physical and chemical properties has still not been considered widely through an understanding of the liquid-solid interface. In this study, we examined the effect of different Ga content on solution-processed indium oxide films and their transistors. As a result, we confirmed that surface defects could be suppressed by the addition of Ga, which affected the pH reliability of devices under different pH environments.

AMDp1 - 23L Contact Properties between Low-Resistive Al-Based Source/Drain and InO_x in Top-Gate Bottom-Contact Oxide Thin-Film Transistor for Application to the Vertical-TFT

*Sori Jeon¹, Kwang-Heum Lee¹, Seung-Hee Lee¹,
Chi-Sun Hwang², Sang-Hee Ko Park¹

1. Korea Advanced Institute of Science and Technology (KAIST) (Korea), 2. Electronics and Telecommunications Research Institute (ETRI) (Korea)

Vertical-TFT is a promising structure to realize ultra-high resolution displays. Especially, low-resistive Al-based source/drain is necessary to reduce RC delay. Since vertical-TFT is bottom-contact structure, source/drain is oxidized during InO_x semiconductor deposition. Here, we present the quantitative analysis result of metal/active contact properties in top-gate bottom-contact structured TFT, mimicking vertical-TFT.

AMDp1 - 24L High Mobility p-type Tin Oxide Thin-Film by Adopting Passivation Layer

*Song-Yi Ahn¹, Hyun-Suk Kim¹

1. Chungnam National University (Korea)

The effects of SiO₂ passivation on tin monoxide (SnO) semiconductor was investigated. In X-ray photoelectron spectroscopy studies revealed that the tail-state above valence band maximum was clearly detected in SiO₂-capped SnO film which may improve the p-type conductivity. As a result, the resulting SnO thin-film transistors show enhanced electrical properties.

AMDp1 - 25L Photo-Induced Instability Behaviors of IGZO TFTs Caused by the Reversible Charge Trapping

**ChangBum Park¹, Ji Xiang Gong¹, Martin S¹*

1. China Star Optoelectronics Semiconductor Display Technology (China)

Photo-induced instability phenomena were investigated in IGZO TFT. The photo-responsivity behaviors attributed to the induced gate bias reveal that, resulting from their substantial trapping feature, photo-carriers (electrons and holes) activated in IGZO solid contribute differently to the negative shift V_{th} of the device. The bidirectional switching behavior under photo-irradiation also clearly indicates that the hysteresis enhancement predominantly comes from the long-lived reversible charge effect (holes) in n-type devices.

14:30-17:00

Main Hall

Poster AMDp2: Active-Matrix Devices

AMDp2 - 1 Self-Heating Effect of Low-Temperature Polycrystalline Silicon Thin Film Transistor Considering Grain Boundary Protrusion

**Abu Bakar Siddik¹, Md Hasnat Rabbi¹, Sangyeon Bae¹, Mohammad Masum Billah¹, Jin Jang¹*

1. Kyung Hee University (Korea)

A proper estimation of the self-heating effect is crucial to ensure the reliable performance of high mobility transistors. We perform Silvaco TCAD based thermal distribution modeling in grain, grain boundary (GB) and protrusion of excimer laser annealed (ELA) low-temperature polycrystalline (LTPS) silicon thin-film transistors (TFTs).

AMDp2 - 2 14-in. 3k2k LTPS-LCD with 120Hz Driving for Notebook

**Ting Wang¹, Hongbo Zhou¹, Hao Wu¹, Junyi Li¹, Xiufeng Zhou¹*

1. Xiamen Tianma Microelectronics Co., Ltd. (China)

In recent years, with the rise of the e-sports industry, the proportion of game laptop with high frequency screen is increasing. Therefore high frequency plus high resolution is the inevitable trend. The high frequency and high resolution result in a reduction in charging time and a increment in loading. In this paper, a latest 14-in. 3k2k LCD with 120Hz driving for notebook with larger charging ability and lower loading was developed by Tianma Microelectronics Co.Ltd.

AMDp2 - 3 Comparing Single Gate TFT to Dual Gate TFT for OLED Compensation Circuit

*Kook Chul Moon^{1,2}, *Won-Kyu Lee³, Ji Xu¹,
Insun Hwang¹, Junfeng Li¹*

1. Visionox Technology Inc. (China), 2. Gachon University (Korea), 3. Kunshan Govisionox Optoelectronics (GVO) Co. Ltd. (China)

Dual gate TFT has been widely used for AMOLED pixel compensation circuit to reduce leakage current and to have good reliability. The study shows that single gate TFT has better off-state performance than dual gate TFT. Therefore, new pixel compensation circuit designed with only single gate TFTs is suggested.

AMDp2 - 4 3 μm a-Si TFT Technology for High-Performance and Cost-Effective Liquid Crystal Displays

**Yani Chen^{1,2}, Jiaqing Zhuang², Hongyuan Xu²,
Zhixiong Jiang², Tian Ou², Daobin Hu², Jinjie Wang²,
Shengdong Zhang¹*

1. Peking University Shenzhen Graduate School (China), 2. Shenzhen China Star Optoelectronics Technology Co., Ltd (China)

Herein, we successfully demonstrate the implement of 3 mm channel length of a-Si TFT process on 55 LCD panels, which facilitates to remarkably reduce the thickness of gate insulator and metal and the manufacture time without sacrificing the display quality, leading to the well balance between low-cost and high image quality.

AMDp2 - 5 Factor Analysis and Evaluation Method for Power Degradation of LTPS LCD

**guochang lai¹, huangyao wu¹, liangjie li¹, xiufeng zhou¹,
junyi li¹*

1. XiaMen Tianma Microelectronics Company (China)

Based on the current development and application of high frequency 90Hz and 120Hz game phones, all of which severely test designers' thinking about the power consumption of integrated circuits, it can be seen that both consumers and designers have launched a new wave of challenges to the battery life of integrated circuits.

AMDp2 - 6 P-type LTPS Gate Driver to Generate Simultaneous and Overlapping Progressive Outputs for High-Resolution AMOLED Displays

**Fu-Hsing Chen¹, Chin-Hsien Tseng¹, Wei-Sheng Liao¹,
Chih-Lung Lin¹*

1. National Cheng Kung University (Taiwan)

A new low-temperature polycrystalline silicon (LTPS) gate driver is developed for active-matrix organic light-emitting diode (AMOLED) pixel circuits using simultaneous-emission (SE) driving scheme. Simulated results indicate that the proposed circuit successfully generates waveforms within the rising time of 0.6 μs under the RC loadings of 9.96 k Ω and 21.2 pF.

AMDp2 - 7 A Novel Pull-down Holding Circuit of a-si Gate Driver on Array

**Tian hong WANG¹*

*1. Shenzhen China Star Optoelectronics
Semiconductor Display Technology Co.,Ltd (China)*

This paper proposes a novel pull-down holding circuit which can improve the pull-down holding ability under a-si process. Through adding only one thin film transistor(TFT) that we can achieve this purpose. What's more, this novel circuit can discharge the Pn node in the pull-down holding block.

AMDp2 - 8 Withdrawn

AMDp2 - 9 A Research on Pixel Design of TDDI Infinity Display

**Zhjie Wang¹, Xiufeng Zhou¹, Guochang Lai¹,
Jiaqi Kang¹, Wenfu Qiu¹, Huangyao Wu¹, Hongbo Zhou¹,
Junyi Li¹*

*1. Research and Development Division, XiaMen
Tianma Microelectronics Co. (China)*

Based on the LTPS process, we can ensure that the display crosstalk problem of the TDDI infinity display and the flickering of the grayscale image are solved without affecting the touch function through optimization of the pixel design.

AMDp2 - 10 An Analysis of Horizontal-Crosstalk in Colum Inversion Type 8Domain Large Size and Ultra High Resolution TFT-LCDs

**Xiaowen LV¹, Haiyan Quan¹, Wenfang Li¹,
Yanxue Wang¹, Longqiang Shi¹, Xiaobin Hu¹, Jing Zhu¹,
Tianhong Wang¹, Yifang Zhou¹, Chung-Yi Chiu¹*

*1. Shenzhen China Star Optoelectronics Technology
Co., Ltd (China)*

Horizontal-crosstalk in colum inversion type 8Domain 75in 8K TFT-LCDs is theoretically studied, the mechanism for crosstalk is confirmed through experiment. The result show that the data coupling and share TFT discharge to common electrode cause line and block crosstalk respectively. The suggestions for reduce horizontal crosstalk are proposed.

IMID 2020

Aug. 25 – 28, 2020

COEX

Seoul, Korea

<http://www.imid.or.kr/>

AMDp2 - 11 Analysis of Horizontal-Mura Caused by Reset's Abnormal Delay of GOA Output

**Xinmao Qiu¹, Yao Liu¹, Hongjiang Wu¹, Hongtao Lin¹,
Baoqiang Wang¹, Wenchao Wang¹, Yaochao Lv¹,
Guichun Hong¹, Min Zhou¹, Zuwen Liu¹*

*1. Fuzhou BOE Optoelectronics Technology Co., Ltd
(China)*

A rare failure named Horizontal-Mura Caused by Reset's abnormal Delay of GOA Output is studied systemically. By increasing frame frequency, changing TFT size ratio and increasing channel Length, the leakage current of voltage Gout's Gate (PU) can be reduced, and Mura phenomenon can be significantly alleviated.

AMDp2 - 12 Advanced TFT Modeling Techniques for GOA Driver Circuit Design Optimization

**An-thung Cho¹, James Hsu¹, Wade Chen¹, York Lu¹,
Yu-ming Xia¹, Chao Wei¹, Jie Ding¹, Yong Zhang¹, Li-
feng Wu²*

*1. Chuzhou HKC Optoelectronics Technology Co. Ltd
(China), 2. Huada Emphyrean Software Co., Ltd. China
(China)*

The design methodology for gate driving circuit (GOA) is critical to reduce the production cost and power consumption for TFT-LCD. The process fluctuation in the manufacturing of TFT can cause the malfunction of GOA. TFT compact model is the key to take process fluctuation into consideration during design stage.

AMDp2 - 13 A Narrow Border Design and Low Power Consumption of a-Si:H TFT Gate Driver Circuit

*Jhongciao Ke^{1,2}, Tehen Chung², Chiate Liao²,
Chiamin Yu², Yanbing Qiao², Zhongfei Zou²,
Limei Jiang², Xiaojun Guo¹

*1. Shanghai Jiao Tong University (China), 2. InfoVision
Optoelectronics (Kunshan) Co., Ltd. (China)*

In this paper, an integrated hydrogenated amorphous silicon (a-Si:H) thin-film transistor (TFT) gate driver circuit design for narrow border and low power consumption in the small-size panel is proposed. The border can be decreased from 1 mm to 0.8 mm, which can be further improved to 0.65 mm. In addition, the power consumption of circuit can be reduced by using the 25% duty ratio 8 clock signals with high reliability.

AMDp2 - 14L E/E Inverter Using Four-Terminal Poly-Ge_xSn_{1-x} TFTs on Glass

**Ryo Miyazaki¹, Akito Hara¹*

1. Tohoku Gakuin University (Japan)

We demonstrated an E/E inverter using polycrystalline germanium-tin (poly-Ge_xSn_{1-x}) thin-film transistors (TFTs) fabricated via metal-induced crystallization (MIC) using Cu. The TFTs in the E/E inverter comprises a planar four-terminal (4T) structure, in which the TFTs were enabled to be normally-off by the control gate voltage (V_{CG}). The inverter performance was varied by changing V_{CG} .

Friday, November 29

9:00-10:30	Mid-sized Hall B
AMD5: Oxide TFT: Device Fundamentals	

Chair: Kazumasa Nomoto (Sony)
Co-Chair: Hideya Kumomi (Tokyo Tech)

AMD5 - 1 *Invited* Switching Characteristic Enhancement of P-type Cu₂O TFTs

9:00

*Dongwoo Kim¹, I Sak Lee¹, Sujin Jung¹, Sung Min Rho¹,
Hyun Jae Kim¹

1. Yonsei University (Korea)

We propose three methods to enhance switching characteristics of p-type Cu₂O thin film transistors (TFTs) by passivating the copper oxide TFTs with silicon dioxide (SiO₂) using sputtering, oxidizing the back channel of copper oxide with hypochlorous acid (HClO), and doping gallium into the Cu₂O film.

AMD5 - 2 *Invited* High Mobility Metal-Oxide Devices for Display SoP and 3D Brain-Mimicking IC

9:25

**Albert Chin¹, Te Jui Yen¹, Cheng Wei Shih¹, You-Da Chen¹*

1. National Chiao Tung University (Taiwan)

Owing to fast technology evolution, the n-type SnO₂ thin-film transistor (TFT) can reach high mobility of 238 cm²/Vs and p-type SnO TFT has high hole mobility of 7.6 cm²/Vs. These high mobility complementary TFTs is the enabling technology for display system-on-panel and the ultra-fast three-dimensional brain-mimicking IC.



AMD5 - 3 **High Mobility Oxide TFT Based on In-rich In-Ga-Sn-O Semiconductors with Nanocrystalline Structures**

9:50

**XUERU MEI², HUAFEI XIE¹, NIAN LIU², MACAI LU², Lei Wen², Shujih Chen², Shengdong Zhang², Chiayu Lee², Xin Zhang²*

1. Peking University (China), 2. Shenzhen China Star Optoelectronics Semiconductor Display Technology Co., Ltd (China)

In-rich In-Ga-Sn-O film with nanocrystalline structure was prepared as the active layer for high mobility TFT. The prepared top-gate self-aligned TFTs using the IGTO film deposited at low O₂ gas ratio and low power exhibited excellent transfer characteristics with high mobility of 25.33cm²/Vs, ss of 0.33V/decade, threshold voltage of 0.98V.

AMD5 - 4 **Simulation Study of Self-Heating and Edge Effects on Oxide-Semiconductor TFTs: Channel-Width Dependence**

10:10

**Katsumi Abe¹, Kazuki Ota¹, Takeshi Kuwagaki¹*

1. Silvaco Japan Co., Ltd. (Japan)

We studied the channel-width dependence of oxide-semiconductor TFTs via a device simulator. The results show that the ON-current is affected by two factors: self-heating and edge effects. The former increases the current with a rise in temperature, while the latter produces the high edge current-density caused by its strong electric-field.

10:40-12:15

Mid-sized Hall B

AMD6: Oxide TFT: Device Application

Chair: Chuan Liu (Sun Yat-sen University)

Co-Chair: Susumu Horita (JAIST)

AMD6 - 1 **Invited High Performance Short Channel Oxide TFTs for Transparent Top Emission OLED TVs**

10:40

**Chanki Ha¹, Eunah Heo¹, Wonbeom Yoo¹, Heungjo Lee¹, Keun-Yong Ban¹, Jonguk Bae¹, Jongwoo Kim¹*

1. LG Display (Korea)

High performance TFTs with a short channel and good uniformity are required to mass-produce transparent top emission OLED TV. The uniformity of V_{th} and I_{on} are improved by controlling effective channel length. Negative V_{th} shift under NBTiS conditions is improved by optimizing light shield and buffer layers.

AMD6 - 2 *Invited* Development of High Mobility Top Gate IGZO-TFT for Automotive OLED Display
11:05

**Yujiro Takeda¹, Aman Mehadi¹, Shogo Murashige¹,
Kazuatsu Ito¹, Izumi Ishida¹, Shinji Nakajima¹,
Hiroshi Matsukizono¹, Naoki Makita¹*

1. SHARP Corporation (Japan)

High performance IGZO-TFT with top gate structure was developed for automotive OLED display backplane. By optimizing the process conditions, we achieved the mobility of 32 cm²/Vs with enhanced threshold voltage. The PBT/NBT/NBIT reliability are good enough to use in OLED application. The prototype 12.3 flexible automotive OLED display was successfully demonstrated.

Also presented in Innovative Demonstration Session (see p. 279)

AMD6 - 3 *Invited* Top-Gate Oxide TFTs with Ion-Implanted Source/Drain Regions in Advanced LTPS Technology
11:30

**Isao Suzumura¹, Toshihide Jinnai¹, Hajime Watakabe¹,
Akihiro Hanada¹, Ryo Onodera¹, Tomoyuki Ito¹*

1. Japan Display Inc. (Japan)

This study develops advanced LTPS TFT technology with top-gate self-aligned oxide TFTs using Generation 6 mother glass. Source and drain regions of the oxide TFTs are formed by ion implantation through a gate insulator with a gate metal mask. The optimized oxide TFTs demonstrates good short-channel performance.

AMD6 - 4 *Fabrication of Top-Gate Self-Aligned Amorphous InGaSnO TFTs with High Mobility*
11:55

**Nian Liu¹, Huafei Xie², Xueru Mei¹, Macai Lu¹, Lei Wen¹,
Shujiah Chen¹, Shengdong Zhang², Chiayu Lee¹,
Xin Zhang¹*

*1. Shenzhen China Star Optoelectronics
Semiconductor Display Technology Co.Ltd.,
China (China), 2. School of Electronic and Computer
Engineering, Peking University, Shenzhen, China
(China)*

The effect of deposition condition of dielectric layer on top-gate self-aligned amorphous InGaSnO TFT have been discussed, higher N₂O/SiH₄ gas ratio and medium power are better. The resulting a-IGTO TFT at Gen.4.5 glass exhibited good uniformity and high mobility of 28.57cm²/Vs, sweep swing of 0.27 V/decade, threshold voltage of 0.53V.

Author Interviews

12:10 - 12:40



13:20-14:40

Mid-sized Hall B

AMD7: Oxide TFT: Fabrication Process

Chair: Toshiaki Arai (JOLED Inc.)
Co-Chair: Yujiro Takeda (Sharp)

**AMD7 - 1 *Invited* Nanostructured IGZO Thin-Film Transistors
13:20 with Remarkably Enhanced Current Density and
 On-Off Ratio**

*Kairong Huang¹, *Chuan Liu¹*

1. Sun Yat-sen University (China)

We develop oxide TFTs with nanoscale and periodic degenerately doped heterostructures by using a strategy based on near-field nanolithography. These nanostructured TFTs remarkably enhanced in current density, compared with homogeneous IGZO TFTs. The on-off ratio was higher than 10^9 , with notably scaling effect with channel length.

**AMD7 - 2 Effect of Lanthanum Doping on the Electrical
13:45 Performance of Spray Coated ZnO Thin Film
 Transistor**

**RAVINDRA NAIK BUKKE¹, NARENDRA NAIK MUDE,
JEWEL KUMER SAHA, YOUNGOO KIM, JIN JANG*

1. KYUNG HEE UNIVERSITY (Korea)

We studied the effect of lanthanum incorporation on the electrical properties of ZnO TFT fabricated by spray pyrolysis. The turn-on voltage (V_{ON}) shifts towards 0 V by La doping. Also, Subthreshold swing (SS) decreases significantly from 387 to 251 mV/dec, by incorporation of lanthanum in ZnO.

**AMD7 - 3 Highly Stable High Mobility Top-gate Structured
14:05 Oxide TFT by Supplying Optimized Oxygen and
 Hydrogen to Semiconductors**

**Jong Beom Ko¹, Seung-Hee Lee¹, Sang-Hee Ko Park¹*

*1. Korea Advanced Institute of Science and
Technology (Korea)*

Top-gate self-aligned structured TFT is appropriate for the high-end display. However, it is hard to realize highly stable high mobility characteristics, because GI deposition affects active surface in top-gate structure. Here we realize highly stable high mobility oxide TFTs by using thermal-ALD and oxygen sourcing plasma treatment for GI process.

AMD7 - 4L 14:25 Low-Temperature IGZO Technology on Transparent Plastic Foil by Atmospheric Spatial Atomic Layer Deposition

*Corné Frijters^{1,2}, Roy Verbeek¹, Gerard de Haas¹, Tung Huei Ke³, Erwin Vandenplas³, Marc Ameys³, Jan-Laurens van der Steen¹, Gerwin Gelinck^{1,4}, Eric Meulenkamp¹, Paul Poodt^{1,2}, Auke Kronemeijer¹, *Ilias Katsouras¹*

1. TNO/Centre (Netherlands), 2. SALDtech B.V. (Netherlands), 3. imec (Belgium), 4. Eindhoven University of Technology (Netherlands)

We use sALD to deposit IGZO and Al₂O₃ layers in top-gated self-aligned TFTs, achieving a low-temperature process flow ($\leq 200^{\circ}\text{C}$). We attain mobility of 8 cm²/Vs and switch-on voltage of -0.1 V for transistors with channel lengths down to 1 μm , enabling a 200 ppi QVGA display on transparent PEN foil.

Also presented in Innovative Demonstration Session (see p. 279)

15:00-16:25

Mid-sized Hall B

AMD8: Advanced Driving Technology for High-quality Display

AMD

Chair: Masahide Inoue (Huawei Techs. Japan)
Co-Chair: Isao Suzumura (Japan Display Inc.)

AMD8 - 1 15:00 Invited High Performance Oxide TFT Technology for Med.-Large Size OLED Displays

**Toshiaki Arai¹*

1. JOLED Inc. (Japan)

We have developed highly reliable oxide TFT technology for the OLED displays. Even for the flexible displays or the gate driver integrated high resolution (~350 ppi) OLED displays, 10-years-lifetime is achieved. By combining OLED printing technology, we realize high productivity in middle-large size OLED display manufacturing.

AMD8 - 2 15:25 A 6T1C Dynamic Threshold Voltage Compensation IGZO-GOA Circuit for 31-inch AMOLED Display with Slim Border

**Yan Xue^{1,2}, Baixiang Han¹, Xian Wang¹, Shuai Zhou¹, Gary Chaw¹, Chun-Hsiung Fang¹, Yuan-Chun Wu¹*

1. CSOT (China), 2. Peiking university (China)

A simple 6T1C gate driver on array (GOA) circuit has been proposed to reduce border with in displays. In this circuit, the lifetime of GOA can be improved by introducing a dynamic V_{th} compensation system. Finally, the GOA circuit was placed in a 31-inch AMOLED display to testify the function.

**AMD8 - 3 New 3.5T2C Pixel Circuit with Symmetrical Structure
15:45 for 3D AMOLED Displays**

**Chieh-An Lin¹, Li-Jung Chen¹, Chia-Ling Tsai¹, Chih-Lung Lin¹*

1. National Cheng Kung University (Taiwan)

This paper proposes the 3.5T2C pixel circuit compensating for threshold voltage (V_{TH}) variation of LTPS-TFTs and preventing image flicker. Simulation results show that the relative current error rates under V_{TH} variations are all below 4.37 %. Furthermore, OLEDs are turned off during the programming period, thereby achieving flicker-free images.

**AMD8 - 4 A Novel OLED Pixel Circuit with Controllable
16:05 Threshold Voltage Compensation Time**

**Jung Chul Kim¹, Seonghwan Hong¹, Sujin Jung¹,
Mihee Sin², Jun Suk Yoo², Han Wook Hwang²,
Yong Min Ha², Hyun Jae Kim¹*

1. Yonsei University (Korea), 2. LG Display, Ltd. (Korea)

This paper proposes a novel pixel circuit that adopts low temperature polycrystalline silicon thin-film transistors (LTPS TFTs) to compensate deviation of threshold voltage (V_{TH}) of the driving TFTs (D-TFTs) and uses overlapping compensation times (T_{COM}) to extend the period of precise sensing V_{TH} variation of the D-TFTs in each pixel. Simulation and experimental results demonstrate the proposed pixel circuit under 120 Hz Ultra High Definition (UHD) driving condition has the same compensation performance as the 60 Hz Full HD (FHD) driving condition. Therefore, the proposed pixel circuit is suitable to be used in AMOLED display with high resolution and high-frame rate and can realize uniform OLED current (I_{OLED}) with high immunity to V_{TH} variation of the D-TFTs.

Author Interviews

16:30 - 17:00

Supporting Organizations:

International Workshop on Active-Matrix Flatpanel Displays and
Devices
Technical Committee on Electronic Information Displays (EID),
Electronics Society, IEICE
Thin Film Materials & Devices Meeting

Workshop on FPD Manufacturing, Materials and Components

Wednesday, November 27

13:45-15:05

Room 108

PRJ1/FMC1: AR/VR

Special Topics of Interest on AR/VR and Hyper Reality

Chair: Satoshi Ouchi (Hitachi)
Co-Chair: Hirotsugu Yamamoto (Utsunomiya Univ.)

PRJ1/ FMC1 - 1 **Invited Modeling, Algorithm, and Implementation of Resolution-Tripled Near-Eye Light Field Displays**

13:45

*Zong Qin¹, Jui-Yi Wu¹, Ping-Yen Chou¹, Cheng-Ting Huang¹, Yu-Ting Chen¹, Yi-Pai Huang¹

1. National Chiao Tung University (Taiwan)

A physical model incorporating all factors affecting the retinal image formation in a near-eye light field display is proposed, based on which, an algorithm recombining subpixels across elemental images to nearly triple the resolution is developed. Finally, an e-shifting method is suggested to further enhance the resolution to 30 pixels-per-degree.

PRJ1/ FMC1 - 2 **Possibility of Deblurring Aerial Image Based on Deconvolution Processing**

14:05

*Hayato Kikuta^{1,2}, Hirotsugu Yamamoto^{2,3}

1. Mitsubishi Electric Corp. (Japan), 2. Utsunomiya University (Japan), 3. ACCEL (Japan)

This paper proposes a deblurring an aerial image formed with aerial imaging by retro-reflection. We have measured the point spread function (PSF) according to the incident angle to the retro-reflector. Simulated results show possibility of deblurring the aerial image by applying the deconvolution processing based on the obtained PSF.

PRJ1/ FMC1 - 3 **Volume-Holographic Multiplexed-Mirror Waveguide for Head-Mounted Display**

14:25

*Takeru Utsugi¹, Mayumi Sasaki², Kazuhiko Ono², Yukinobu Tada²

1. Hitachi, Ltd. (Japan), 2. Hitachi-LG Data Storage, Inc. (Japan)

As a waveguide for a head mounted display, we propose a volume-holographic multiplexed-mirror waveguide, which could achieve high luminance efficiency, wide field of view and excellent transparency. We clearly demonstrate that high performance waveguide is achieved by the combination of multiplex-recorded hologram and broad wavelength light sources.

FMC

**PRJ1/
FMC1 - 4
14:45** **High See-Through and High Efficiency Waveguide
for Head Mounted Displays and Waveguide
Evaluations**

**Ryuji Ukai¹, Takuma Kuno¹, Toshiteru Nakamura¹,
Masahito Uchiyama¹, Satoshi Ouchi¹*

1. Hitachi, Ltd. (Japan)

We have developed head mounted displays with high see-through property and high luminance which could be utilized outside safely without dimming glasses. We specified required performance threshold and developed beam-splitter-array waveguide to achieve the requirements. We also established versatile waveguide measurement method applicable to different-type waveguides.

15:20-16:40

Room 108

FMC2: Metrology and Manufacturing

Chair: K Kälantär (Global Optical Solutions)
Co-Chair: Toshiaki Nonaka (Merck Performance Materials)

**FMC2 - 1 *Invited* Surface Strain Analysis of Bending
15:20 Substrates for Design of Flexible Devices**

**Atsushi Shishido¹*

1. Tokyo Institute of Technology (Japan)

Fracture and fatigue of bending flexible materials and devices prevent their commercialization. The problem is that quantitative understanding has not been explored on bending behavior. Here we report quantitative analysis of surface strain of bending substrates by a surface labeled grating method.

**FMC2 - 2 Metrology Issues of a Non-Planar Light Source with
15:40 Radius Comparable to that of Measurement Field**

**K Kälantär¹, Tomonori Tashiro¹, Yasuki Yamauchi¹*

1. Yamagata University (Japan)

The effect of small curvature radius on characteristics of non-planar light sources (NPLS) has been studied using flexible OLEDs. The bending effect on light emission through the substrate was simulated and the issues extracted. The metrologies of NPLSs were studied by simulating the MF's area on different NPLSs.

**FMC2 - 3 Researches of Process Reduction for Viewing Angle
16:00 Controllable LCD**

**Shih-Bin Liu¹, Lujie Wang¹, Jun Jiang¹, Yanbing Qiao¹,
Chia-Te Liao¹, Te-Chen Chung¹*

*1. InfoVision Optoelectronics (Kunshan) Co., Ltd.
(China)*

In this paper, a better condition is found to maintain the thickness of PR for half-tone technology, and some issues of process reduction in B-ITO and M3 layers are solved. These issues of topology for M3 after ashing and last wet etching are still being studied.

FMC2 - 4 **Research on Failure Factors of Salt Spray Test and the Solutions for COG 2.4mm-down-border LTPS LCM**

16:20

**zuoyin li¹, xianfeng lin¹, zhenqing xie¹, chunrong lin¹, lihua zheng¹, fushan dai¹, dandan yan¹, xiaoyu wang¹, changjuan zhang¹, qingwen hu¹, xuexin lan¹, guozhao chen¹, junyi li¹, lei wang¹*

1. Xiamen Tianma Microelectronics Co., Ltd., Xiamen, China (China)

The salt spray test is failed more and more frequently for full-screen display. Experiments were done to research the possible factors. It revealed that the combination of PI (polyimide), silver conductive glue and the dispensed location resulted in the failure. Based on the analysis, the improvement solutions were proposed.

17:00-18:30

Room 108

FLX1/FMC3: Advanced Materials and Components for Flexible Electronics

Chair: Toshihide Kamata (National Institute of Advanced Industrial Science and Technology)

Co-Chair: Makoto Arai (ULVAC Inc.)

FLX1/ FMC3 - 1 **Invited Printed Invisible Silver-Grid Transparent Electrode on Flexible Epoxy Film and Application to Powder Electroluminescent Device**

17:05

**Masato Ohsawa¹, Natsuki Hashimoto¹, Naoki Takeda², Shota Tsuneyasu², Toshifumi Satoh²*

1. ULVAC, Inc. (Japan), 2. Tokyo Polytechnic University (Japan)

Invisible Ag-grid transparent electrodes have been printed on a flexible epoxy film. The Ag-grid electrode were laminated with a poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) layer. The electrode shows no noticeable resistance change throughout the bending cycles at a bending radius of 1.0 mm. The transparent electrode-based powder electroluminescent device develops excellent flexibility.

FLX1/ FMC3 - 2 **Al Alloying Effect in Functionalization of Mechanical Resistance to Foldable Display Interconnections**

17:30

**Chiharu Kura¹, Mototaka Ochi¹, Hiroyuki Okuno², Hiroshi Goto²*

1. Kobe Steel, LTD. (Japan), 2. Kobelco Research Institute, Inc. (Japan)

For the metal interconnection in foldable displays, bending resistance is essential in addition to heat resistance and low electrical resistivity. The bending resistance of Al-Nd alloy interconnections can be controlled by precipitation of intermetallic compounds. Then, the Al alloy interconnections capable of dry-etching patterning have also been developed.

FLX1/ FMC3 - 3 **Withdrawn**

**FLX1/
FMC3 - 5L
17:50**

**Roll-to-roll Processing of Transparent and Robust
Permeation Barrier Films for Flexible Electronics**

**John Fahlteich¹, Michiel Top¹, Stefan Hinze¹,
Uwe Meyer¹, Tobias Vogt¹, Valentijn von Morgen²,
Matthias Fahland¹*

*1. Fraunhofer Institute for Organic Electronics,
Electron Beam and Plasma Technology FEP
(Germany), 2. DuPont Teijin Films Ltd. (UK)*

Water vapor permeability of permeation barrier films and thin film encapsulation coatings is determined both by intrinsic factors: material and technology selection and extrinsic factors: e.g. particle contamination or process defects. This paper discusses optimization strategies to achieve low permeability gas barrier films that are robust in roll-to-roll processing and integration to devices. Water vapor transmission rates of $< 5 \cdot 10^{-4}$ g/(m²d) at 38°C / 90 % r.h. are demonstrated reproducibly in a full roll-to-roll process chain using a sputtered barrier layer and a protective top-coat.

**FLX1/
FMC3 - 4
18:10**

**Improvement of the Corrosion Resistance of TCO/
Ag/TCO Structure for Transparent Conductive Layer**

**Yuto Toshimori¹, Sohei Nonaka¹*

1. Mitsubishi Materials Corporation (Japan)

The corrosion resistance of TCO/Ag/TCO structure was improved by using new Ag alloy and TCO. These can inhibit corrosion defect which was one of the biggest challenges for practical use. It can be applied to various devices, such as display electrodes, touch sensor and IR cut film.

Author Interviews

18:30 - 19:00

SPECIAL EVENT

“Sensory Illusion”

Exhibition:

Wednesday, Nov. 27 – Friday, Nov. 29, 2019
Main Hall (1F)

Special Talks:

Wednesday, Nov. 27, 2019
18:30 – 19:10
Mid-sized Hall A (1F)

Thursday, November 28

9:00-10:20

Mid-sized Hall A

FMC4/LCT4: Micro LED Display

Special Topics of Interest on Micro/Mini LEDs

Chair: K Kälantär (Global Optical Solutions)
Co-Chair: Seiji Shibahara (Sony Home Entertainment & Sound Products Inc.)

FMC4/ LCT4 - 1 9:00 ***Invited High-Resolution (1,000 to over 3,000 ppi) Full-Color Silicon Display for Augmented and Mixed Reality***

**Hidenori Kawanishi¹, Hiroaki Onuma¹, Masumi Maegawa¹, Takashi Kurisu², Takashi Ono², Shigeyuki Akase¹, Shinji Yamaguchi¹, Naoto Momotani², Yusuke Fujita¹, Yuhei Kondo², Kentaro Kubota², Toshimi Yoshida¹, Yuta Ikawa¹, Tsuyoshi Ono², Hiroyoshi Higashisaka², Yasuaki Hirano², Shinsuke Anzai¹*

1. Sharp Fukuyama Semiconductor Co., Ltd. (Japan),
2. Sharp Fukuyama Laser Co., Ltd (Japan)

We present the status of III-nitride micro-LED display bonded onto silicon backplane. 0.38-inch full-colour display with a resolution of 1,053 ppi has been successfully demonstrated. Progress toward higher resolution is also described. We believe our Silicon Display is ideally suited for near-to-eye displays for augmented and mixed reality.

Also presented in Innovative Demonstration Session (see p. 279)

FMC4/ LCT4 - 2 9:20 ***Invited A new Generation of HDR Display with Super Multi-Zones Mini LED***

**Jianping Zheng¹, Zhuo Deng¹, Ling Wu¹, Poping Shen¹, Junyi Li¹, Jianmou Huang¹*

1. XiaMen Tianma Microelectronics Company, Ltd. (China)

We propose a new generation of HDR display with active matrix mini-LED backlight for LCD. The display enables super multi-zones display by using new type of backlight drive, which achieved better contrast and less halo defect. Through both instrument test and perception experiments, we evaluated the performance of HDR LCD.

FMC4/ LCT4 - 3 9:40 ***Invited Monolithic Integration of GaN-micro-LED and Si-MOSFET for Bio-application***

**Hiroto Sekiguchi^{1,2}, Hiroki Yasunaga¹, Kazuaki Tsuchiyama¹, Keisuke Yamane¹, Hiroshi Okada¹, Akihiro Wakahara¹*

1. Toyohashi University of Technology (Japan), 2. PRESTO, JST (Japan)

A micro light-emitting diodes (LED) has been attention as an optical stimulation tool for optogenetics. In this study, a needle-type microLED probe was fabricated for neuroscience. In addition, the monolithic integration of microLED and Si-MOSFET using wafer bonding technique was challenged toward the realization of multifunctional devices.

**FMC4/
LCT4 - 4
10:00**

An Active Matrix Mini-LEDs Backlight Based on a-Si

**Bin Liu^{1,2}, quansheng liu², jia li², yongyuan qiu²,
junling liu², yong yang², hongyuan xu², Juncheng Xiao²,
feng zhu², hang zhou¹, Xin Zhang²*

*1. Peking University Shenzhen Graduate School
(China), 2. China Star Optoelectronics Technology
(China)*

In this work, we fabricate an active matrix mini-LEDs backlight based on a-Si. The driving mechanism with 2T1C and process flow are discussed in detail. IR-drop is analyzed and improved. The gray scale is controlled by PWM method with the number of 64 (6 bit), and the maximum brightness is up to 20,000nits.

Author Interviews

10:40 - 11:10

10:40-13:10

Main Hall

**Poster FMCp1: Micro/Mini LEDs
Special Topics of Interest on Micro/Mini LEDs**

**FMCp1 - 1 Monolithic Light-Guide Plate with Prism Structure
for 1.5D 32 Dimming Zones and Narrow Border LCD**

**Chao-Min Yang¹, ChihChun Chang¹, Yatan HSiao¹,
Wenlin Chemg¹*

1. AU Optronics Corporation (Taiwan)

We have succeeded in build-in prism structure on 15.6 PMMA- LGP and there are two kind of collimating LGP. Both are defined by the dimming factor m and η to describe it. The 15.6 sample property include 1.5D segment dimming with 32 zones, the VESA STANDAREDER HDR600.

**I-DEMO
(Innovative Demonstration Session)**

Live demonstrations
of emerging information display technologies
by oral and poster presenters

Thursday, Nov. 28, 2019

11:40 – 15:40

Main Hall (1F)

Sapporo Convention Center

FMCP1 - 2 High Performance GaN-based Micro-LEDs with Improved Ambient Contrast Ratio

**Ke Zhang^{1,2}, Tingting Han³, Hoi-sing Kwok^{1,2}, Zhaojun Liu^{1,2}*

1. Hong Kong University of Science and Technology (Hong Kong), 2. Southern University of Science and Technology (China), 3. Shenzhen Refond Optoelectronics CO., LTD (China)

GaN-based Micro-LEDs have shown great potential in various filed, such as solid-state lighting, display, sensor, visible light communication and multifunctional devices. The performance of Micro-LEDs in various operating environment drew enormous attention recently. We report high performance Micro-LEDs on sapphire substrate with device size scaling to 30μm and ultra-high current density of 100A/cm2 under applied bias of 4V. The Micro-LED devices can keep comparable performance after extreme environment test with an emission wavelength of 460nm. We also proposed three method to improve ambient contrast ratio including optical method, anti-reflection film and optimized device structure.

FMCP1 - 3L Design of Mini-LED Backlight Using Reflective Mirror Dots with High Luminance Uniformity for Mobile LCDs

**Sho Kikuchi¹, Senshi Nasu¹, Takahiro Ishinabe², Hideo Fujikake²*

1. National Institute of Technology, Sendai College (Japan), 2. Tohoku University (Japan)

A new mini-LED local dimming backlight with reflective dots is proposed for high uniformity, high contrast, and low power consumption in small LCDs. The proposed backlight, comprising a small number of mini-LEDs, was verified as having high luminance uniformity due to the optimized backlight thickness and light distribution of mini-LEDs.

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)
Sapporo Convention Center

10:40-13:10

Main Hall

Poster FMCp2: Quantum Dot Technologies**Special Topics of Interest on Quantum Dot Technologies****FMCp2 - 1 Wide Color Gamut White Light-Emitting Diode Using Quantum Dot/Siloxane Hybrid Encapsulation Material with Excellent Environmental Stability**

**Junho Jang¹, Da-Eun Yoon¹, Seung-Mo Kang¹,
Ilson Lee¹, Doh C. Lee¹, Byeong-Soo Bae¹*

*1. Korea Advanced Institute of Science and
Technology (Korea)*

We report a luminescent light-emitting diode (LED) encapsulation material using quantum dot (QD)/siloxane hybrid (TSE-QD). The TSE-QD shows exceptional stability under high temperature (120°C in ambient) and various chemicals. TSE-QD based white LED also exhibits superior reliability under high temperature/high humidity and wide color gamut (116 % of NTSC).

10:40-13:10

Main Hall

Poster FMCp3: Metrology & Manufacturing**FMCp3 - 1 Investigation on the Effects of 365nm UV Light Irradiation on the Polyimide Alignment Film**

**Mudan Chen¹, Li Yang¹, Chiamin Yu¹, Peter Liao¹*

*1. InfoVision Optoelectronics (Kunshan) Co., Ltd
(China)*

We have investigated the effects of ultraviolet light with wavelength of 365nm irradiation on polyimide alignment film. We compared image quality and image sticking of a IPS-LCD before and after irradiation, the experiment showed mura appeared and image sticking became bad through irradiating a certain amount of exposure energy.

FMCp3 - 2 Reliability Improvement of Narrow Down-border TED Product Based on LTPS-TFT LCD Technology

**Binbin Chen¹, Zuoyin Li¹, Haitao Duan¹,
Guozhao Chen¹, Junyi Li¹, Lei Wang¹*

1. Xiamen Tianma Microelectronics Co., Ltd. (China)

We analyzed the failure route of metal corrosion and solved this issue by improving the coverage effect of passivation film on metal line. Otherwise, electrochemical corrosion mechanism was carried out to explain the failure mechanism and low potential difference metal was proposed to decrease the defective rate to 0.

FMCp3 - 3 Withdrawn

FMCP3 - 4 Fabrication and Characteristics of Heat-Dissipation Sheet Patterned with Graphene and Polymer Adhesive

**Jong-Keun Choi¹, Byung-Min Park¹, Kwan-Young Han¹*

1. University of Dankook (Korea)

In this study, we developed graphene sheet with excellent thermal conductivity and adhesion. In order to improve the thermal conductivity and adhesion, a heat-dissipation sheet was fabricated by designing graphene and polymer adhesive pattern, and the characteristics were evaluated.

FMCP3 - 5 Post-oven Induced Surface Hydrophobicity Degradation of CF₄ Plasma Treated Polyimide Photo Resistance

**Letao Zhang^{1,2}, Xiaoliang Zhou², Peng Zhang¹, Yingchun Fan¹, Qiankun Xu¹, Liangfen Zhang¹, Xiaoxing Zhang¹, Yuan Jun Hsu¹, Shengdong Zhang²*

*1. Shenzhen China Star Optoelectronics Semiconductor Display Technology Co., Ltd. (China),
2. Peking University (China)*

Polyimide films were treated by CF₄ plasma to serve as bank material for inkjet printing OLED. Excellent hydrophobicity was thus obtained due to the F implantation. However, degradation of hydrophobicity was observed by post-oven, an inevitable process for inkjet printing. This degradation is probably caused by the H₂O/O₂ chemical adsorption.

FMCP3 - 6 High Resolution Technologies of 1.0 μm L/S Using PSM Specialized in DUV Broadband Illumination

**Kanji Suzuki¹, Manabu Hakko¹, Miwako Ando¹, Koichi Takasaki¹, Nobuhiko Yabu¹, Kouhei Nagano¹, Nozomu Izumi¹*

1. Canon Inc. (Japan)

To meet the demands for high resolution, we designed a PSM specialized in DUV broadband illumination and evaluated resolution performance with the PSM. In this paper, we present the ability of 1.0 μm L/S pattern resolution with our PSM based on simulation results and exposure test results.

FMCP3 - 7 Mechanical Exfoliated Large Scale CVD-Graphene Using Water-Soluble WO₃ Supporting Layer

**Seung-Il Kim¹, Seok Ki Hyeong¹, Ji Yun Moon¹, Jae-Hyun Lee¹*

1. Ajou University (Korea)

We will introduce a large area clean graphene transfer method that solves the problems encountered during the transfer process of CVD graphene. WO₃ can transfer high-quality graphene synthesized on a Ge substrate without a defect, and there is no chemical etching process due to its water-soluble nature.

FMCP3 - 8 Effects of Annealing Gas on Electrical Properties of La_2O_3 Gate Dielectrics

**Minjun Song¹, Byoungdeog Choi¹*

1. University of Sungkyunkwan (Korea)

Solution-processed lanthanum oxide (La_2O_3) films were formed on the Si substrates under N_2 and O_2 ambience annealing conditions. Compared to N_2 conditions, flat-band voltage shifted to positive gate bias direction and leakage current was less for O_2 annealed devices resulted from the reduction of the oxygen-related trap sites in the film.

FMCP3 - 9 Reduction of Oxide Defects in $\text{ZrO}_2/\text{Al}_2\text{O}_3/\text{ZrO}_2$ Dielectrics by Incorporating Hydrogen Peroxide

**Gaeun Lee¹, Byoungdeog Choi¹*

1. Sungkyunkwan University (Korea)

Capacitance- and current-voltage characteristics of $\text{ZrO}_2/\text{Al}_2\text{O}_3/\text{ZrO}_2$ (ZAZ) capacitors with an addition of hydrogen peroxide (H_2O_2) were identified. From the results, leakage current and interface trap density of the H_2O_2 -doped devices decreased due to reduction of oxygen vacancies in ZAZ layers. H_2O_2 effect on the electrical behaviors was qualitatively analyzed.

FMCP3 - 10 Electro-Optical Performance of OLED with MEH-PPV Fabricated by Solution Process

**Seok Je Lee^{1,2}, Fangnan Yao², Seung Il Lee¹, Cao Jin², Woo Young Kim¹, Chang Bum Moon¹, Chul Gyu Jhun^{1,2}*

1. Hoseo University (Korea), 2. Shanghai University (China)

We investigated the effects of solvents and concentration on the electro-optical performance of the organic light emitting diode (OLED) fabricated by the solution process. From the experimental results, we optimized the fabrication method of it and we figure out the underlying mechanism of carrier flow by the trap state.

14:30-17:00

Main Hall

Poster FMCP4: Light Shaping Optics

FMCP4 - 1 A New 3D Image Switching Method in Arc 3D Display by Selecting Desired Arcs in Arc Array by Projectors with Different Illumination Angles for Changing Depths

**Kazuki Seko¹, Haruki Mizushima¹, Shiro Suyama¹*

1. Tokushima University (Japan)

We can successfully achieve rewriting or switching 3D images in Arc 3D display by separately illuminating desired arc-shaped scratches in 3×3 scratch array when array pitch is 29 mm according to projector resolution of 1 mm. Perceived depth can be changed by illumination angle change.

FMCP4 - 2 Withdrawn

FMCP4 - 3 Withdrawn

FMCP4 - 4L Forming Multiple Aerial 3D Images by Use of Infinity Mirror, AIRR, and DS3D Display

**Kazunari Chiba¹, Daiki Nishimura¹,
Masayuki Shinohara³, Hirotsugu Yamamoto^{1,2}*

1. Utsunomiya Univ. (Japan), 2. JST ACCEL (Japan), 3. OMRON Corp. (Japan)

This paper proposes a new way of aerial display application based on infinity mirror, AIRR (Aerial Imaging by Retro-Reflection) and DS3D (Directional Scattering 3D) display. Our proposed method can form multiple aerial 3D images in a compact display setups.

FMCP4 - 5L Reduction of Blur of Aerial Image Formed with AIRR by Use of Paired Masked Retro-reflectors

**Ryota Kakinuma¹, Norikazu Kawagishi^{1,2},
Hirotsugu Yamamoto^{1,3}*

1. Utsunomiya University (Japan), 2. Yazaki Corporation (Japan), 3. JST, ACCEL (Japan)

We propose a new optical system to form an aerial image by use of a pair of masked retro-reflectors. The masked edge increases sharpness of the aerial image. Because the retro-reflectors are masked complementarily so as to have a negative-positive relationship, there is no missing part of the aerial image.

FMCP4 - 6L Measurement of Crosstalk in an Energy-Harvesting Projector Utilizing a Uniform Luminescent Layer

**Ryo Matsumura¹, Yasuhiro Tsutsumi¹, Ichiro Fujieda¹*

1. Ritsumeikan University (Japan)

When a uniform luminescent layer is incorporated in the screen for an energy-harvesting projector, the crosstalk inside the screen limits its contrast ratio to 1×10^5 . It would not degrade its spatial resolution if the pixel size were set adequately larger than the thickness of the luminescent layer.

FMCP4 - 7L Evaluation of Image Resolution of Aerial Image Based on Slanted Knife Edge Method

**Norikazu Kawagishi^{1,2}, Ryota Kakinuma¹,
Hirotsugu Yamamoto^{1,3}*

1. Utsunomiya University (Japan), 2. Yazaki Corporation (Japan), 3. JST ACCEL (Japan)

We report image resolution measurement of an aerial image based on the slanted edge method. From the slanted edge image, edge spread function (ESF) is calculated by projecting the profile with some methods. We have compared three projecting method to obtain ESF. Furthermore, the proposed method is utilized for AIRR.

14:30-17:00

Main Hall

Poster FMCp5: Materials & Components

FMCp5 - 1 Photonic Crystal Multilayers Make 100% BT. 2020 Possible

**Bingyang Liu¹, Dongchuan Chen¹, Xiawei Yun¹,
Xueqiang Qian¹, Kaixuan Wang¹, Hongming Zhan¹,
Xi Chen¹*

1. BOE Technology Group Co., Ltd. (China)

Photonic crystal multilayers are well-designed, which can form two strong reflection peaks and minimize cyan and yellow light penetrating panels. As a result, the color gamut of LCDs with those photonic crystal multilayers in cell can reach 100% BT.2020, much better than the presentation of QD-LCDs.

FMCp5 - 2 Research on the Reliability of Sealant Materials for Narrow Border Products

**Maoqiang Chi¹, Bai Bai¹, Xuan Du¹, Yanjun Song¹,
Chung-Ching Hsieh¹*

1. Shenzhen China Star Optoelectronics Technology Co. Ltd., Shenzhen, China (China)

With the development of technology, narrow border products have become one of the research hotspots in the field of LCD. These products put forward higher requirement for sealant materials, especially the material reliability. Sealant pollution is the focus of the reliability assessment. In this paper, a new test method was used to study the pollution of seal materials in the design of simulated narrow border products, also the mechanism of sealant pollution was explored, we hope that our research could provide direction for the development and revision of sealant materials for narrow border products.

FMCp5 - 3 Withdrawn

FMCp5 - 4 Withdrawn

FMCp5 - 5 Proposal of Novel Temperature-Independent Zero-Zero-Birefringence Polymer for Real-Color Display

*Yuma Kobayashi¹, *Kohei Watanabe¹, Yasuhiro Koike^{1,2}*

1. Keio University (Japan), 2. Keio Photonics Research Institute (Japan)

In a simple binary copolymerization process, we synthesized temperature-independent zero-zero-birefringence polymer (TIZZBP) films with high heat resistance, sufficient mechanical strength and high transparency. The novel TIZZBP film will be widely used to achieve real-color images not only for vehicle-mounted displays but also flexible displays.

FMCP5 - 6L Transparent Conductive Ga-Al-ZnO Film Fabricated by Facing Targets Sputtering System

*Kyung Hwan Kim¹, Yu Jin Kim¹, You Seung Rim², Jeongsoo Hong¹

1. Gachon University (Korea), 2. Sejong University (Korea)

Ga and Al doped ZnO thin films were fabricated by facing targets sputtering system with various deposition conditions including input current, oxygen atmosphere and thermal treatment temperature. In this study, we investigated the change of electrical, optical and structural properties by fabrication conditions.

FMCP5 - 7L Investigation of Solution-Processed α -Fe₂O₃ / ZnO Multilayer for Photoelectrode

*Jeongsoo Hong¹, Kyung Hwan Kim¹, You Seung Rim², Nobuhiro Matsushita³

1. Gachon university (Korea), 2. Sejong University (Korea), 3. Tokyo Institute of Technology (Japan)

α -Fe₂O₃ / ZnO multilayer films fabricated by using spin-spray method and properties of each layer and α -Fe₂O₃ / ZnO film were investigated. First, as-deposited ZnO layer on glass substrate exhibited high transmittance of above 80 % in visible range and a low resistivity. The formation of α -Fe₂O₃ layer on glass substrate was confirmed by XRD. This α -Fe₂O₃ layer was successively deposited on ZnO layer and it was confirmed that α -Fe₂O₃ / ZnO double layered films could be fabricated by aqueous solution process.

FMCP5 - 8L Capacitance-Voltage Characteristics of Solution-Based HfZr-Silicate Gate Dielectrics

*Nara Lee¹, Pyungho Choi¹, Byoungdeog Choi¹

1. Sungkunkwan University(Korea)

In this study, Al/(HfZrO₄)_{1-x}(SiO₂)_x/p-Si capacitors were fabricated and evaluated as a function of SiO₂ content in the films. From the result, electrical properties enhanced such as oxide charge and breakdown voltage as the SiO₂ concentration x increased and reliability improved as well.

IMID 2020

Aug. 25 – 28, 2020

COEX

Seoul, Korea

<http://www.imid.or.kr/>

Friday, November 29

9:00-10:35	Mid-sized Hall A
LCT5/FMC5: High Performance 8K LCDs	

Chair: Koichi Miyachi (JSR)
Co-Chair: Toshimitsu Tsuzuki (NHK)

**LCT5/
FMC5 - 1
9:00** ***Invited* Novel Liquid Crystal Display mode UV²All
with Photo Alignment Technology for a Large-
Screen 8K Display**

**Shinichi Terashita¹, Kouichi Watanabe¹,
Fumikazu Shimoshikiryoh¹
1. Sharp Corporation (Japan)*

We have developed a new liquid crystal display mode UV²All which is suitable for a large screen 8K display and commercialized as the 80 8K TV. UV²All has brought large superiority that are 1.3 times higher transmittance, 35% faster response, and wider viewing angle property to compare with UV²A.

**LCT5/
FMC5 - 2
9:25** ***Invited* Novel Pixel Structure for the Improving
Optical Performances of 8K LCD Panel**

**Kwangsoo Bae¹, Minjoeng Oh¹, Beomsoo Park¹,
Young Je Cho¹, Sang Hwan Cho¹, Dong Hwan Kim¹
1. Samsung Display (Korea)*

We report on novel pixel architecture for improving the transmittance and reducing the gamma distortion to minimize the color shift in a 8K QUHD LCD panel with the hG-2D technology. This technology has the excellent transmittance by matching the LC distortions on the vertical electrode and two data lines which is asymmetrically positioned. Besides, by shielding the LC distortion line at the oblique viewing angle, the gamma distortion can be effectively suppressed. Through the QUHD panel with our structure, superior performances to normal LCD could be clearly demonstrated.

**LCT5/
FMC5 - 3
9:50** ***Invited* 17-inch Laser Backlight LCD with 8K, 120-Hz
Driving and BT.2020 Color Gamut**

*Yoichi Asakawa¹, Ken Onoda¹, Hiroaki Kijima¹,
*Shinichi Komura¹
1. Japan Display Inc. (Japan)*

We succeeded in prototyping a 17-inch 8K liquid crystal display satisfying the BT.2020 specification. The pixel density of the display is 510 ppi, while its color gamut covers 98% of that of BT.2020. The liquid crystal response time is 5 ms, which is sufficient for 120-Hz driving.
Also presented in Innovative Demonstration Session (see p. 278)

**LCT5/
FMC5 - 4L
10:15**

55 High Contrast Ratio Panel Produced by Pixel Level Local Dimming Technology

**Chun-chi Chen¹, Yan-Xue Wang¹, Young-Yuan Qiu¹, Gang Yu¹, Chung-Yi Chiu¹, Bin Zhao¹, Xin Zhang¹*

1. China Star Optoelectronics Technology Company, Ltd. (China)

The contrast ratio is a important index for the LCD optics. The higher contrast ratio, the picture quality reconstructed by LCD is better. LCD module is constructed by back light and optical switch. And the LC is not an ideal optical switch, so the contrast ratio of LCD is lower than OLED. We use dual cell which can use pixel level local dimming to improve the contrast ratio, and it can make the contrast ratio from 5000:1 to 200000:1.

11:00-11:40

Room 206

FMC6: Retardation Management

Chair: Takashi Sato (ZEON)
Co-Chair: Daisuke Ogomi (Nitto Denko Corporation)

FMC6 - 1 Withdrawn

**FMC6 - 2
11:00**

New type 1/4-Wave Plate Film for OLED Panels

**Jiro Ishihara¹, Kenji Yoda¹, Shunsuke Takagi¹, Kazuhiro Osato¹, Yuji Shibata¹, Taku Hatano¹*

1. ZEON CORPORATION (Japan)

We will introduce a new type 1/4-wave plate film (QWP) for OLED displays. The QWP film consists of two layers with positive and negative intrinsic properties, which results in smaller reflectance and color shift than other type of conventional QWP on OLED. We have achieved mass-production by new production process.

**FMC6 - 3
11:20**

Novel Chromakey Technology with Polarizer and Retardation Film

**Yoshiaki Asanoi¹, Muneo Kaneko², Kazuya Yoshimura¹, Katsunori Takada¹, Akinori Izaki¹*

1. Nitto Denko Corporation (Japan), 2. Kansai Televisiaon Co.Ltd. (Japan)

We have developed a novel chromakey technology with polarizer and retardation film. A fine greenish color which is required for image composing of chromakey can be produced by optimizing the retardation. It is superior with conventional method at various points.

Also presented in Innovative Demonstration Session (see p. 279)

Author Interviews

12:10 - 12:40

13:20-14:20

Room 206

FMC7: Quantum Dot

Special Topics of Interest on Quantum Dot Technologies

Chair: Takao Tomono (Toppan Printing)
Co-Chair: Yukito Saitoh (FUJIFILM Corporation)

**FMC7 - 1 *Invited* Quantum Rod Enhancement Films for
13:20 Modern LCDs**

*Swadesh Kumar Gupta¹, Maksym F Prodanov¹,
Chengbin Kang¹, Cheng Chun Hin¹,
Valerii V Vashchenko¹, *Abhishek Kumar Srivastava¹
1. hong kong university of science and technology
(Hong Kong)*

Quantum rod films, comprising the aligned quantum rods, emits polarized light that could potentially improve the efficiency of the LCD. In this talk, we will discuss about the High-quality alignment of the QRs showing a high polarization ratio for the PL. We developed these QREF containing red and green QRs, in the same films, for their application in LCD backlights. These films offer wider color gamut and almost two times higher optical efficiency (i.e. ~7.8%) for the conventional LCDs.

**FMC7 - 2 Wide Color Gamut Display Solution Using Hybrid-
13:40 typed Perovskite Quantum Dots White LEDs**

*Chieh-Yu Kang¹, Chih-Hao Lin¹, *Chun-Lin Tsai¹,
Chin-Wei Sher¹, Ting-zhu Wu², Po-Tsung Lee¹,
Hao-Chung Kuo¹
1. National Chiao Tung University (Taiwan), 2. Xiamen
University (China)*

This study presents that hybrid-typed Perovskite WLED has higher luminous efficiency (85 lm/W) compared to solid-typed and good wide color gamut performance (123 % of NTSC and 92 % of Rec. 2020). Lower operation temperature and better reliability (over 500 hours) result have also been demonstrated under this design.

**FMC7 - 3 A Novel Display Technology—Perovskite Quantum
14:00 Dot Display with Blue OLEDs**

**Miao Duan¹, Dongze Li¹, Zhiping Hu¹, Wenxiang Peng¹,
Yongwei Wu¹, Yongming Yin¹, Bo He¹, Pei Jiang¹,
Feng Jiang², Lifu Shi², Haizheng Zhong²,
Shu-jih Chen¹, Chia-Yu Lee¹, Xin Zhang¹
1. Shenzhen China Star Optoelectronics
Semiconductor Display Technology Co., Ltd. (China),
2. Beijing Institute of Technology (China)*

We fabricated 6.6-inch perovskite quantum dot displaypanel by inkjet printing technology, being cooperated withactive matrix organic light emitting diodes. Here, 3-stackblue OLEDs with top-emission structure acted as backlightand green perovskite layer acted as color downconverter,which exhibited excellent performances such as high colorpurity.

15:00-16:20	Room 206
FMC8: Advanced Material	

Chair: Atsuko Fujita (JNC Corporation)
 Co-Chair: Seiki Ohara (AGC)

FMC8 - 1 *Invited* Carrier Glass Substrates for Electronic Display Fabrication
 15:00

**Kazutaka Hayashi¹*
 1. AGC Inc. (Japan)

Non-alkali glass substrates are used as carrier substrates in various electronic device fabrication. In this paper, overview of the requirements for the carrier substrates are described. Thermal shrinkage, stiffness, optical transmittance and residual stress of the glass substrate are important to fabricate display devices, such as flexible OLED display.

FMC8 - 2 Blackening of TFT Wiring by Depositing High Durability Film
 15:20

**Keita Umemoto¹, Shin Okano, Yukiya Sugiuchi, Takeshi Ohtomo, Ichiro Shiono*
 1. Mitsubishi Materials Corporation (Japan)

Blackening of TFT wiring enables higher resolution and improved design of various kinds of displays. In this paper, we will introduce the material design concept and properties of high durability thin film for blackening of TFT wiring.

FMC8 - 5L Transparent Flexible Electrode with Conductive Coating Induced by Proton Implantation of Emeraldine Polyaniline Covalently Functionalized on Polydimethylsiloxane
 15:40

**Pen-Cheng Wang¹, Tsan-Feng Lu¹, Tzu-Hsiang Lin¹, Ching-Jung Lo², Ping-Ching Pai², Chen-Kan Tseng², Hui-Yu Tsai¹, Ming-Wei Lin¹, Tsung-Min Hung²*
 1. National Tsing Hua University (Taiwan), 2. Chang Gung Memorial Hospital (Taiwan)

Transparent thin films of polyaniline covalently fabricated on flexible polydimethylsiloxane substrates by surface modification with N-(3-trimethoxysilylpropyl)aniline for robust aniline polymerization could alternatively be redoped by proton implantation without incorporating an undesired labile/hygroscopic dopant acid that tends to compromise operation of encapsulated modules or MEMS components developed for flexible display applications.

FMC8 - 3 Withdrawn



FMC8 - 4
16:00

**Photosensitive Materials with Zirconia
Nanotechnology**

**Hiroki Chisaka¹, Kouichi Misumi¹, Dai Shiota¹,
Katsumi Ohmori¹, Lei Zheng², Robert J. Wiacek², Z.
Serpil Gonen Williams²*

*1. Tokyo Ohka Kogyo Co., Ltd. (Japan), 2. Pixelligent
Technologies LLC (United States of America)*

The combination of ZrO₂ nanocrystals and photosensitive technologies led to new photosensitive materials and inks with high refractive index and inkjet properties superior to conventional materials. Moreover, high resolution and high transparency was achieved even with thick films. This material is useful for next generation applications such as flexible displays.

Author Interviews

16:30 - 17:00

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW '19.

IDW'19 Award winners will be announced on the IDW website: <https://www.idw.or.jp/award.html>

EXHIBITION

12:40 – 18:00 Wednesday, Nov. 27

10:00 – 18:00 Thursday, Nov. 28

10:00 – 14:00 Friday, Nov. 29

Main Hall (1F)

Sapporo Convention Center

Free admission with your registration name tag

Workshop on Inorganic Emissive Display and Phosphors

Thursday, November 28

10:40-13:10

Main Hall

Poster PHp1: Phosphors and Devices

PHp1 - 1 Powder Electroluminescent Device with Flexible Invisible Silver-Grid Transparent Electrode

**Naoki Takeda¹, Kazuki Yanagawa¹, Natsuki Hashimoto², Masato Ohsawa², Shota Tsuneyasu¹, Toshifumi Satoh¹*

1. Tokyo Polytechnic University (Japan), 2. ULVAC, Inc. (Japan)

Powder electroluminescent devices (PELDs) have high potential of commercial applications because of their flat light emission and printing processes. In this study, we develop PELDs on gravure offset printed invisible Ag-grid laminated with PEDOT:PSS transparent electrodes. The PELDs with the invisible Ag-grid transparent electrodes showed excellent electroluminescent properties.

PHp1 - 2 Polarized Light from In-Plane Aligned $\text{Y}_2\text{WO}_6\text{:Gd}$ Nanorod Films Prepared by Dip Coating Method

*Kenta Igarashi¹, Ryota Kanai¹, *Ariyuki Kato¹*

1. Nagaoka University of Technology (Japan)

In-plane aligned $\text{Y}_2\text{WO}_6\text{:Gd}$ nanorod films were prepared by dip coating method. Weakly polarized emission band around 460 nm was observed from the films. The observed polarization was found to be explained by the theory of emission affected by the light confinement effect in nanorods.

PH

PHp1 - 3 Photonic Crystal Embed Light Guiding Structure for LED

**Kuo-Jung Huang¹, Wen-Kai Lin^{1,2}, Chien-Chang Chiu¹, Wei-Chia Su¹, Fu-Li Hsiao¹*

1. National Changhua University of Education (Taiwan), 2. National Chiao Tung University (Taiwan)

We designed a device that is use the a Fabry-Pérot structure combining the photonic crystal that we call Photonic Crystal Embed Light Guiding. This devices was employed to lead light-emitting diode(LED) has efficacious directivity.

PHp1 - 4 Electrospinning of Flexible Conjugated Polymer Nanofibers with Efficient Luminescence and Electrical Conductivity

**Yani Chen¹, Jinjie Wang², Shengdong Zhang¹*

1. Peking University Shenzhen Graduate School (China), 2. Shenzhen China Star Optoelectronics Technology Co., Ltd. (China)

Herein, we have successfully applied direct electrospinning method to rigid copolymer F8T2. The electrospun F8T2 nanofibers exhibit high anisotropy, strong photosensitivity and remarkably improved luminescence and electrical conductivity compared to spin-coating analogue. Our work provides a promising avenue for flexible and high quality display applications. Herein, we have successfully applied direct electrospinning method to rigid copolymer F8T2. The electrospun F8T2 nanofibers exhibit high anisotropy, strong photosensitivity and remarkably improved luminescence and electrical conductivity compared to spin-coating analogue. Our work provides a promising avenue for flexible and high quality display applications.

PHp1 - 5L Formation of ZnAl₂O₄ Thin Film for Deep Ultraviolet Emitting Phosphor and Evaluation of Luminescence Properties

**Kaito Imagawa¹, Hiroko Kominami¹, Yoichiro Nakanishi¹, Kazuhiko Hara¹*

1. Shizuoka University (Japan)

ZnAl₂O₄ thin films for deep UV emitting phosphor were prepared by thermal diffusion of ZnO and α-sapphire substrate at 1000 °C. From analysis of UV emission intensity by cathodoluminescence and penetration depth, it is considered that emitting layer of 650 nm was formed.

PHp1 - 6L Preparation of Mn Doped Mg₂TiO₄ Deep Red Emitting Phosphor by Liquid Phase Synthesis

**Keisuke Warita¹, Hiroko Kominami¹, Yoichiro Nakanishi¹, Kazuhiko Hara¹*

1. Shizuoka University (Japan)

Mg₂TiO₄:Mn deep red emitting phosphor was synthesized by a liquid phase synthesis using urea and PEG. The inhomogeneous and agglomeration of the particle decreased, and fine particle phosphor was obtained. Mg₂TiO₄ phase was preferentially formed and observed at 658 nm and 670 nm under 450 nm excitation.

10:40-13:10

Main Hall

Poster PHp2: QD Phosphors***Special Topics of Interest on Quantum Dot Technologies*****PHp2 - 1** **Withdrawn****PHp2 - 2** **Withdrawn****PHp2 - 3L** **Ligand Exchange of Core/Shell CuInS₂/ZnS Quantum Dots for Preparation of Their Homogeneous Ink**

**Momo Shiraishi¹, Yoshiki Iso¹, Tetsuhiko Isobe¹,
Takehiro Seshimo², Yueh-Chun Liao², Kunihiro Noda²,
Dai Shiota²*

*1. Keio University (Japan), 2. Tokyo Ohka Kogyo
Company, Ltd. (Japan)*

1-Dodecanethiol on CuInS₂/ZnS quantum dots (QDs) was exchanged with cyclohexanethiol. The obtained QDs were transparently dispersed in alicyclic diepoxy compound to yield the QD ink for ink-jet printing. This homogeneous dispersion is attributed to similarity in molecular structure between the ligand and the ink component.

Friday, November 29

10:40-11:55

Room 204

PH1: Phosphors and Devices

Chair: Rong-Jun Xie (Xiamen University)

Co-Chair: Koutoku Ohmi (Tottori University)

PH1 - 1 ***Invited* Discovery of Novel Nitride Phosphors by High Throughput Calculation****10:40**

**Rong-Jun Xie¹, Shuxing Li¹, Zhenbin Wang²,
Shyue Ping Ong²*

*1. Xiamen University (China), 2. University of
California, San Diego (United States of America)*

Discovery of new phosphors with interesting properties is driven by rapid advances in lighting and displays. In this paper, we screened and searched for a super-broadband phosphor Sr₂AlSi₂NO₆:Eu²⁺ by using high throughput calculations. The emission of the phosphor covered the whole range of the visible light, enabling to create super-high color rendition white light when pumped by a UV-LED chip.

PH

PH1 - 2 Monolithic Full-color LED Micro-display Using Dual Wavelength LED Epilayers

11:00

**Peian Li¹, Xu Zhang¹, Yangfeng Li¹, Longheng Qi¹,
Chak Wah Tang¹, Kei May Lau¹*

*1. The Hong Kong University of Science and
Technology (Hong Kong)*

A passive-matrix InGaN LED full-color micro-display with 40×40 pixels (120×40 RGB subpixels) and subpixel pitch of $40 \mu\text{m} \times 120 \mu\text{m}$ was demonstrated. Full-color emission was realized by applying patterned red quantum dot color conversion layer onto a monolithic blue/green dual wavelength LED array.

PH1 - 3 Polarized Emitting qLEDs Based on Aligned Quantum Rods as Active Material

11:20

*Hendrik Schlicke¹, Christoph Schloen¹, Tobias Jochum¹,
Sören Becker¹, Horst Weller^{1,2}, *Jan S Niehaus¹*

*1. Fraunhofer CAN (Germany), 2. University of
Hamburg (Germany)*

In this contribution we present polarized emitting qLEDs based on aligned quantum rods as active materials, which are a promising candidate for future display generations requiring linearly polarized light. The achieved DOP values exceed the values of currently published devices.

PH1 - 4L Development of $(\text{La}, \text{Y})_3\text{Si}_6\text{N}_{11}:\text{Ce}^{3+}$ Nitride Yellow Phosphors for High-Power Excitation

11:40

**Yuhei Inata¹, Shiho Takashina¹*

1. Mitsubishi Chemical Corp. (Japan)

$(\text{La}, \text{Y})_3\text{Si}_6\text{N}_{11}:\text{Ce}^{3+}$ (LSN) phosphor has been used for white LEDs in back light units (BLUs). We have succeeded in developing LSN phosphors with wide color variations and excellent luminescence properties. We expect that LSN phosphors will be used not only in BLUs but also in other lighting and laser devices.

Author Interviews

12:10 - 12:40

Supporting Organizations:

Phosphor Research Society, The Electrochemical Society of Japan
The 125th Research Committee on Mutual Conversion between
Light and Electricity, Japan Society for Promotion of Science

Workshop on OLED Displays and Related Technologies

Wednesday, November 27

13:40-15:00

Room 204

OLED1: OLED Devices

Chair: Takahisa Shimizu (NHK)

Co-Chair: Ken-ichi Nakayama (Osaka University)

OLED1 - 1 *Invited* Investigation of Carrier Recombination and Device Stability in Phosphorescent and TADF OLEDs

13:40

**Sebastian Reineke¹, Paul-Anton Will¹, Jinhan Wu¹, Axel Fischer¹, Simone Lenk¹*

1. Technische Universität Dresden (Germany)

This presentation will discuss both a detailed investigation of the charge carrier recombination in state-of-the-art OLEDs and an engineering route to increase device lifetime and efficiency by forming so-called ultrastable glass layers. For the latter, both phosphorescent and TADF OLEDs are presented.

OLED1 - 2 Analysis Method for Dynamics of Exciton in Organic Light-Emitting Diodes Based on Thermally Activated Delayed Fluorescence Emitters: Magnetic Field Effect as Footprint of Exciton

14:00

**Masaki Tanaka¹, Ryo Nagata¹, Hajime Nakanotani¹, Chihaya Adachi¹*

1. Kyushu University (Japan)

We investigated magnetic field effects (MFEs) of thermally activated delayed fluorescence based organic light-emitting diodes (TADF-OLEDs) to understand exciton dynamics under device operation. Our analysis showed a clear evidence of triplet annihilation such as triplet exciton-polaron interaction.

OLED1 - 3 Enhanced Color Purity of Alternating Current-Driven Micro-Cavity Organic Light Emitting Diode

14:20

**Duck-Kyu Lim¹, Byeonggon Kim¹, Hak-Rin Kim¹*

1. Kyungpook National University (Korea)

We introduced the micro-cavity effect on Alternating Current-Driven Polymer Light Emitting Diodes and investigated the color purity enhancement effect depending on the organic layer thickness condition. We have analyzed the electric field inside the device by the finite-difference time-domain method and fabricated the designed optimal devices.

OLED1 - 4 An Aging Current Model for OLED Degradation**14:40****Qian CHEN¹**1. The Institute of Microelectronics of the Chinese Academy of Sciences (China)*

This work presents a new aging current model of organic light-emitting diode (OLED). It can predict the OLED current with different stress time under some aging conditions, which can be used in related simulation software to describe the degradation of OLED.

15:20-16:40**Room 204****OLED2: OLED Material**

Chair: Takahiro Komatsu (JOLED)

Co-Chair: Hitoshi Kuma (Idemitsu Kosan)

OLED2 - 1 *Invited* Long-Persistent Luminescence from Organic Molecules**15:20****Ryota Kabe^{1,2,3}**1. Okinawa Institute of Science and Technology Graduate University (Japan), 2. Kyushu University (Japan), 3. JST ERATO Adachi Molecular Exciton Engineering Project (Japan)*

We demonstrate long persistent luminescence from simple mixtures of two appropriate organic materials. Moreover, emission color of organic LPL can be tuned by the extra emitter dopants. We also demonstrated a polymer-based organic LPL system that is flexible, transparent, and solution-processable.

OLED2 - 2 Highly Efficient Deep Blue Fluorescence Emitter Based on Highly Conjugated Boron Structure**15:40****Hanjong Yoo¹, Daehyun Ahn¹, Hyuna Lee¹, Juyoung Lee¹, Janghyuk Kwon¹**1. Kyung Hee University (Korea)*

We synthesized and evaluated new deep blue fluorescence emitter, KH-FBD1. This emitter exhibits pure deep blue PL spectrum peak at 452 nm with 20 nm full width half maximum. Fabricated device shows high efficiency of 7.4% with deep blue color coordinate of (0.14, 0.07). In addition, this device indicates long operational lifetime (LT₉₅) of 100 hours at initial luminance 1,000 cd/m². It also shows high efficiency of 12.7% in high T₁ device with maintaining the deep blue color characteristic.

OLED2 - 3 Key Technologies in Soluble OLED Materials**16:00**

**Koichiro Iida¹, Koichi Ishibashi¹, Yoshiko Shoji¹,
Kazuhiro Nagayama¹, Yuki Oshima¹, Hideki Gorohmaru¹*

1. Mitsubishi Chemical Corporation (Japan)

High-performance soluble OLED materials have been developed. Our wide library of platform was effective for improving device performance. For wide color gamut, new emitters with deep in color and narrow full-width at half maximum were developed. Further, solvent systems having physical properties suitable for improving film uniformity were found.

OLED2 - 4 Ellipsometry, XRR, and GCIB-TOF-SIMS Analysis of Small Molecule Layers in Solution Process and Vacuum Deposition Process**16:20**

**Takahiro Shibamori¹, Sachiko Kojima¹, Aki Suzuki¹,
Yusaku Tanahashi¹, Takashi Miyamoto¹*

1. Toray Research Center, Inc. (Japan)

Ellipsometry, XRR, and GCIB-TOF-SIMS are applied to investigation of the spin-coating process as comparison of spin-coated samples and vacuum evaporated samples. The residual solvent of spin-coating process was observed in spin-coated samples by GCIB-TOF-SIMS. The result suggested that it can cause the decrease of refractive index observed in ellipsometry.

17:00-18:25**Room 204****OLED3: OLED Display**

Chair: Taishi Tsuji (NIPPON STEEL Chemical & Material)

Co-Chair: Masaya Adachi (Japan Display Inc)

OLED3 - 1 Invited Development of Long Lifetime and High Performance OLED Display with Wide Temperature Range**17:00**

**Masanobu Mizusaki¹, Masakazu Shibasaki¹,
Yuto Tsukamoto¹, Tokiyoshi Umeda¹, Hiroshi Tsuchiya¹,
Shinji Shimada¹*

1. Sharp Corporation (Japan)

We developed the long lifetime OLED display by optimizing each organic layer materials. In particular, the optimization of a hole-transport layer material improved the lifetime of the blue-OLED significantly at high temperature such as 85 °C. The developed OLED display would be useful for automotive application.

Also presented in Innovative Demonstration Session (see p. 279)

**OLED3 - 2 An Investigation on the Effect of Bending on the
17:20 Circular Polarizer of an Organic Light Emitting
Diode Display**

**Phuc Toan Dang¹, Jimin Park¹, Ji-Hoon Lee¹*

1. Chonbuk National University (Korea)

This work reports the experimental research results of the retardation change of a reactive mesogen type quarter-wave plate (QWP) by bending when the slow axis the QWP is oriented with the bending axis according to perpendicular or parallel directions. Moreover, the effect of the retardation changes on the antireflective properties of a quasi-circular polarizer taken accounts for an organic light-emitting diode in the simulation. Based on the obtained results, we assign that the light leakage reduced gradually with bending effect in the vertical viewing orientation, while it was increased in the horizontal viewing direction regardless of the orientation of the slow axis.

OLED3 - 3 Withdrawn

**OLED3 - 4L Efficient Electron Injection into Organic
17:40 Semiconductors Induced by Hydrogen Bonds**

**Hirohiko Fukagawa¹, Munehiro Hasegawa²,
Katsuyuki Morii^{2,3}, Kazuma Suzuki⁴, Tsubasa Sasaki¹,
Takahisa Shimizu¹*

*1. NHK (Japan), 2. Nippon Shokubai Co., Ltd. (Japan),
3. Osaka University, Nippon Shokubai Research
Alliance Laboratories (Japan), 4. Tokyo University of
Science (Japan)*

It was found that stable bases widely used in organic syntheses as catalysts can lower the electron injection barrier in organic light-emitting diodes. In contrast to conventional n-doping, the reduction of the injection barrier caused by adding bases is induced by the formation of hydrogen bonds between hosts and bases.

**OLED3 - 5L Spectral Narrowing and Efficiency Enhancing in
17:55 Deep-Red Organic Light Emitting Diode**

**Yuichiro Kawamura¹, Takushi Shiomi¹, Kei-
ichi Yasukawa¹, Shota Sawano¹, Hiromi Nakano¹,
Hisato Matsumoto¹, Toshinari Ogiwara¹, Keiji Okinaka¹,
Kazumasa Nagao², Kazunari Kawamoto²*

*1. Idemitsu Kosan Co., Ltd. (Japan), 2. Toray Industries,
Inc. (Japan)*

We developed both thermally activated delayed fluorescence materials with high performances and spectral-narrow fluorescent dopants for deep-red organic light-emitting diodes. We achieved the efficiency of 46 cd/A at 10 mA/cm² and the LT95 of around 90 hours at 50 mA/cm² in the top emission device at CIE_x = 0.679.

OLED3 - 6L Significance of Energy-Level Alignment in 3D Perovskite ELs
18:10 Significance of Energy-Level Alignment in 3D Perovskite ELs

**KIHYUNG SIM¹, HAYATO KAMIOKA²,
JUNGHWAN KIM¹, HIDEO HOSONO¹*

*1. Materials Research Center for Element Strategy,
Tokyo Institute of Technology, (Japan), 2. Department
of Physics, College of Humanities and Sciences,
Nihon University (Japan)*

In this study, we report a significant phenomenon that EL performances for 3D materials, such as CsPbX₃, are governed by adjacent charge transport layers, which is possibly due to nonradiative recombination resulting from the small exciton binding energy. To overcome this issue, we developed a new electron transport layer (ETL) that enhances exciton confinement effect in 3D CsPbX₃. Consequently, we achieved ultra-high brightness of 500,000 cd/m² at a very small operating voltage of 5V.

Author Interviews
18:30 - 19:00

Thursday, November 28

9:00-10:35	Room 204
OLED4: QD Material & Devices	
<i>Special Topics of Interest on Quantum Dot Technologies</i>	

Chair: Takeo Wakimoto (Merck Performance Materials)
Co-Chair: Toshiaki Ikuta (JNC Corp.)

OLED4 - 1 Invited Anion Exchange Perovskite Quantum-Dots
9:00 for Highly Efficient Light Emitting Devices

**Takayuki Chiba¹, Junji Kido¹
1. Yamagata University (Japan)*

Perovskites quantum dots have attracted much attention for used in display and lighting applications, owing to their narrow band emission with high photoluminescence quantum yields, color tunability, and solution processability. Here, we demonstrate ligand-exchange and anion-exchange perovskite quantum dots using ammonium salts for use in highly efficient light-emitting devices.



**OLED4 - 2 *Invited* Efficient Perovskite Light-Emitting Diodes
9:20 Enabled by Synergetic Device Architecture**

*Yanqing Li¹, Yang Shen¹, *Jianxin Tang¹
1. Soochow University (China)*

In this work, we demonstrated a facile route was realized by combining bioinspired moth-eye nanostructures and half-ball lens to enhance light outcoupling. As a result, the maximum external quantum efficiency of green perovskite light-emitting diodes was improved to 28.2%, which represented a substantial step toward achieving practical applications of PeLEDs.

**OLED4 - 3 Efficient Indium Phosphate Based Quantum Dot
9:40 Light Emitting Diode Using Sol-gel processed
Electron Transfer Layer**

**Ji Eun Yeom¹, Dong Hyun Shin¹, Mude Nagarjuna Naik¹,
Raju Lampande¹, Jang Hyuk Kwon¹
1. Kyung Hee University (Korea)*

Here, we report an efficient indium phosphate (InP) based inverted red Quantum Dot-Light Emitting Diodes (QLEDs) by incorporating a sol-gel processed Mg-doped ZnO layer. The red InP-QLED with our sol-gel processed Mg:ZnO layer reveals a maximum EQE of 7.7% , which is significantly higher than the ZnO and Mg:ZnO nanoparticles layers. These results suggest that the sol-gel processed Mg-doped ZnO layer is relatively efficient in terms of performances.

**OLED4 - 4 Ambient Contrast Ratio Study of QD-OLED Devices
10:00**

**SU PAN¹
1. Shenzhen China Star Optoelectronics Display
Technology Co.,Ltd (China)*

Quantum dots are promising color conversion materials to achieve high resolution full color display with wide color gamut and low cost. In this work, we studied the ambient contrast ratio of QD-OLED devices and demonstrated an optimal structure to realize high contrast displays.

**OLED4 - 5L Solution-Processed Indium-Gallium-Nitride (InGaN)
10:20 Blue Light-Emitting Diodes (LEDs)**

**TADAHIKO HIRAI¹, TETSUO TSUCHIYA²
1. CSIRO (Australia), 2. AIST (Japan)*

A soluble form of InGaN was synthesized, producing a solution that exhibited blue photo-luminescence (PL) upon UV light exposure. This solution was used in the fabrication of a blue light-emitting diode (LED) that was produced using solution processable methods, a world first for an InGaN-base LED. The PL properties of the solution and the electro-luminescence (EL) and device characteristics of the LED are presented.

**Author Interviews
10:40 - 11:10**

10:40-13:10

Main Hall

Poster OLEDp1: OLED poster

OLEDp1 - 1 Low Reflection Automotive Display for Driving Safety

**Qian Li¹, Bing Zhang¹, Puyu Qi¹, Cuicui Liang¹,
Zhiqiang Wang¹, Youxiong Feng¹*

1. BOE Technology Group Co., Ltd (China)

Driving Safety requires high performance display possessing a good readability under high brightness ambient light. In order to improve the visional effect, a specially designed module structure was applied to OLED display so the reflectivity can be reduced to an excellent value of 0.918%.

OLEDp1 - 2 A 14-inch Foldable OLED Display with Excellent Optical and Mechanical Performances

*Bing Zhang¹, *Puyu Qi¹, Zhiqiang Wang¹, Yanping Ren¹,
Zhengde Lai¹, Zhongjie Wang¹, Suncun Li¹,
Zhongliu Yang¹, Xuan Luo¹, Ping Luo¹, Shanghong Li¹,
Yudan Shui¹, Mengyue Fan¹, Yue Tian¹, Youxiong Feng¹*

1. BOE Technology Group Co., Ltd. (China)

A 14-inch WQHD foldable AMOLED display was developed with superior optical and mechanical performances. High Adobe and DCI-P3 color space coverage indicates its excellent color expression capacity. No obvious optical and structural degradation could be detected after 240h static and 100,000 times dynamic bending tests.

OLEDp1 - 3 Withdrawn

OLEDp1 - 4 OLED Display Device Fabricated by Inkjet Printing Process

**Ye Yun¹, Liu Xin¹, Tang Qian¹, Guo Tai Liang¹,
Cao Xiang Hong¹, Yu Yong Shen¹*

1. Fuzhou University (China)

In this work, a multilayer OLED device is fabricated by inkjet printing process. Optimized bank structure is used to improve the sub-pixel uniformity. By adjusting the process parameters such as plasma processing time and vacuum dry speed, the quality of the film fabricated by inkjet printing is improved.

OLEDp1 - 5 Wide-Bandgap Bipolar Material with High Thermal Stability

*Sheng-Chieh Lin¹, Yu-Chieh Cheng¹, Man-Kit Leung¹,
Jiun-Haw Lee¹, *Tien-Lung Chiu²*

1. National Taiwan University (Taiwan), 2. Yuan Ze University (Taiwan)

A new organic compound was synthesized with bipolar carrier mobility, high singlet/triplet energies, and high thermal stability (193 °C) with suitable molecular design. As the host of blue phosphorescent OLED, it shows maximum current efficiency, power efficiency, and external quantum efficiency of 58.7 cd/A, 59.3 lm/W, and 28.6%, respectively.

OLEDp1 - 6 Analysis of Semi-Transparent Cathode Performance Based on Fabrication Methods

**Haewon Kim¹, Hai Xu¹, Xiaoning Liu¹, Wenbin Jia¹,
Yuan Can¹, Huaiting Shih¹*

1. Hefei BOE Joint, BOE Technology Group Co., LTD (China)

By studying the transmittance rates and transmittance non-uniformity characteristics of various types of semi-transparent metal cathode within the visible light range and found that each performance varied according to the composition ratio, deposition rate and surface condition of alloy. These results suggest that the manufacturing method of semi-transparent metal cathode affects the performance and luminance imbalance of top emissive OLED TVs, and so on.

OLEDp1 - 7 A Study of Encapsulation Structure for TFT Reliability in Top Emission OLED Display

**Jae Young Oh¹, Seung Hee Nam¹, Kwon-Shik Park¹,
SooYoung Yoon¹, InByeong Kang¹, Jae Kyeong Jeong²*

1. LG Display (Korea), 2. Hanyang University (Korea)

Preventing hydrogen and water vapor from permeating through encapsulation layer plays an important role in TFT Reliability. To improve a blocking characteristic, encapsulation inorganic layers were studied. A SiN_x and SiO₂ multilayered inorganic deposition method for OLED has been developed to obtain a reliable performance.

OLEDp1 - 8 The Challenge of OLED Display Quality in Low Gray Scale

**kan cruise zhang¹, peng le dang¹, yi zheng¹,
george peng¹*

1. visionox technology incorporated company from Langfang in China (China)

In this paper, two kinds of display defects under low gray scale are analyzed and we find the mechanism of the defect from the driving principle and TFT characteristics. 1. Vertical mura 2. Color deviation Finally, we summarize the control standards for TFT characteristics in order to meet the display quality of AMOLED at low gray scale, and introduces the temporary measures for improving the problems mentioned using display system

OLEDp1 - 9 Withdrawn

OLEDp1 - 10 Withdrawn

OLEDp1 - 11 Soluble Host Materials with Ortho-Phenylene Group for Blue Phosphorescent Devices

Hui Jae Choi¹, Ohyoung Kim¹, Chil Won Lee¹,
*Byung Doo Chin¹

1. Dankook University (Korea)

Blue phosphorescent organic light-emitting diodes (OLED) were prepared with the host materials designed for solution process. 1,3-bis(carbazole-9-yl)benzene as the core structure with various ortho-phenyl groups between the carbazole moieties were prepared for the purpose of reducing symmetry and planarity of the molecules, hereby improving the solubility and device efficiency.

OLEDp1 - 12L Efficient Blue Phosphorescent Organic Light-Emitting Diode with Long Triplet Lifetime TADF Host

Tien-Lung Chiu¹, Tse-Ying Chen², Yi-May Huang³,
Man-Kit Leung³, Jiun-Haw Lee³, *YU-CHENG CHIU²

1. Yuan Ze University (Taiwan), 2. National Taiwan University of Science and Technology (Taiwan), 3. National Taiwan University (Taiwan)

A new wide bandgap material, CbzBzCN, was successfully synthesized to be the host of an efficient blue phosphorescent light emitting diode (OLED), which also particularly performs a very long lifetime of triplet excitons reach approximate 2 msec. The OLED showed the maximum current efficiency and external quantum efficiency of 46.3 cd/A and 18.7%, respectively.

OLEDp1 - 13L Photo-Crosslinkable Hole Transport Material for Efficient Solution Processed Light Emitting Diode

*Hyein Ha¹, Min Chul Suh¹

1. Kyung Hee University (Korea)

We investigated new crosslinkable hole transport materials (HTMs) for efficient solution-processed OLEDs. Especially, we developed the intrinsically photo-crosslinkable HTMs by adding nitrene type photo-crosslinking agent. Finally, we compared the device performances of those prepared with HTMs having semi-IPN composition as we reported before.

OLEDp1 - 14L Influence of Exciton-Polaron Quenching Occurring at the Interface Mixing Zone on the Operational Lifetime of Solution-Processed OLED

**NA THI LE¹, Ja Yeon Lee¹, Min Chul Suh¹*

1. Department of Information Display, Kyunghee University (Korea)

The serious driving voltage rise in HOD could be evidence of EPQ causing device degradation. Strong deterioration was observed when the recombination-zone coincides with the interface-mixing zone, where a higher degree of EPQ occurs. Device lifetime was improved by 8 times as the recombination was confined away from interface mixing zone of solution-processed device.

OLEDp1 - 15L OLED Micropatterning by Plasma Etch

**JAEWAN CHO¹*

1. SKKU (Korea)

The micropatterning of OLED by plasma etch was investigated. The luminescence of patterned OLED micropixels was evaluated when the pixels were fabricated by photolithography and plasma etch.

OLEDp1 - 16L Lifetime Improvement of Organic Light-Emitting Diodes Using Cyclo-Olefin Polymer Film as Passivation for Flexible Display

**Ki-Su Kim¹, Byung-Min Park¹, Kwan-Young Han¹*

1. Dankook University (Korea)

In this study, we have optimized the passivation method of COP film to improve the lifetime and reliability of OLED devices. COP film is suitable as a passivation for flexible displays because of its excellent optical properties, flexibility and gas barrier property. These advantages can the replace conventional passivation methods.

10:40-13:10

Main Hall

Poster OLEDp2: OLED/QDT poster

Special Topics of Interest on Quantum Dot Technologies

OLEDp2 - 1 Withdrawn

OLEDp2 - 2 The Effect of Particle Size on the Optical and Electrical Characteristics of Quantum Dot Light-Emitting Diode Using Zinc Oxide Nanoparticles

**Da-Young Park¹, Dae-gye Moon¹*

1. Soonchunhyang University (Korea)

The electrical and optical characteristics of QLEDs with 3 and 8 nm ZnO nanoparticles (NPs) were investigated. The QLED with 8 nm ZnO NPs exhibited maximum luminance of 64,360 cd/m² and 4.5 times higher current efficiency compared to the 3 nm ZnO device.

OLEDp2 - 3 Withdrawn

OLEDp2 - 4 High Efficiency Green Quantum Dot Light-Emitting Diodes with Surface-treated Indium Phosphide

**Wei Jiang¹, Hee Yeop Chae¹*

1. SungKyunKwan University (Korea)

The multi-shelled green InP QDs were synthesized by using the phosphorus source of (DMA)₃P and the narrow FWHM of 46nm was obtained. The PLQY of 64% was achieved after the surface treatment and the maximum quantum efficiency of 2.68% and the current efficiency of 7.7cd/A were achieved for quantum dot light emitting diodes.

OLEDp2 - 5 Withdrawn

OLEDp2 - 6L The Influence of Bottom Layer on the Performance of Perovskite LEDs

**Jungwon Kim¹, Min Chul Suh¹*

1. Kyung Hee University (Korea)

We found the interface mixing could be occurred when a hydrophilic interlayer is utilized. To solve this problem we tried to change the perovskite precursor materials to exclude interlayer. As a result, we found that we could skip the interlayer by changing a composition of perovskite.

OLEDp2 - 7L Mechanisms of Operation in Quantum-Dot Light-Emitting Diodes

**Shoichi sano¹, Takashi Nagase^{1,2}, Takashi Kobayashi^{1,2}, Hiroyoshi Naito^{1,2}*

1. Osaka prefecture university (Japan), 2. The Research Institute for Molecular Electronic Devices (RIMED), Osaka Prefecture University (Japan)

Mechanisms of operation in quantum-dot light-emitting diodes (QLEDs) have been investigated theoretically and experimentally. Important factors governing the current efficiency of QLED were examined using a machine learning approach. High hole injection barrier to QD is the dominant efficiency limiting factor, and the machine learning result was confirmed experimentally. A mechanism of high current efficiency even in the presence of high hole injection was discussed in terms of device simulation.

IDW '20

The 27th International Display Workshops

Dec. 9 - 11, 2020

Fukuoka International Congress Center

Fukuoka, Japan

<https://www.idw.or.jp/>

17:20-18:40

Room 204

OLED5: OLED Optical Design

Chair: Yasunori Kijima (Huawei Technologies Japan K. K.)
 Co-Chair: kengo Kishino (idemitsu Kosan Co, Ltd.)

OLED5 - 1 *Invited* Self Assembled Cathode Patterning for AMOLED
17:20

**Michael G. Helander¹, Zhibin Wang¹, Jacky Qiu¹,
 Yilu Chang¹, Qi Wang¹, Yingjie Zhang¹
 1. OTI Lumionics Inc. (Canada)*

Patterning of the cathode layer in top-emission AMOLED displays has been a technological barrier to realize both large area top emission AMOLED displays, and high transparency AMOLED displays. Using ConducTorr(TM) Electrode materials we demonstrate the first mass production ready cathode patterning process in a high-resolution OLED using self-assembly.

OLED5 - 2 Thermal Evaporation Process Based organic/Ag/organic Transparent Conducting Electrode for Flexible Optoelectronic Applications
17:40

**Subin Lee¹, Hyeong Woo Bae¹, Jang Hyuk Kwon¹,
 Jun Sik Oh¹
 1. Kyung Hee University (Korea)*

Herein, we report a new organic/Ag/organic (OAO) multilayer flexible transparent electrode fabricated a thermal evaporation process. This OAO electrode showed superior optical and electrical characteristics of which transmittance of 81.34% at 550 nm wavelength and low sheet resistance of 9.51 Ω /sq. Its flexible reliability is also very excellent as sheet resistance variation at the radius of curvature of 5 mm with bending cycles of 2,000 is negligible. Fabricated green phosphorescent organic light emitting diodes with this OAO electrode showed high current efficiency of 75.1 cd/A.

OLED5 - 3 Design of Color Filter Based on Metallic Nanostructure and Color Conversion Material for White OLED Display
18:00

**Hye-Bin Yang¹, Wonrea Kim², Younghoon Kim²,
 Musun Kwak², Young-Joo Kim¹
 1. Yonsei University (Korea), 2. LG Display (Korea)*

We have designed and optimized the geometric parameters of metallic nanostructure with color conversion material as a color filter for white-OLED display to enhance the optical efficiency. Optical intensity of red and green light in white OLED was increased by 73.0% and 29.1%, respectively after applying metallic nanostructure with quantum-dot materials.

- OLED5 - 4** **Light Extraction and Viewing Angle Characteristics of Nano-Structure Embedded Top-Emitting OLEDs Fabricated by Vacuum Deposition Processes**
18:20 **Doo-Hee Cho¹, Young-Sam Park¹, Hyunsu Cho¹, Kang Me Lee¹, Hye Jin Yun¹, Seung-Youl Kang¹, Seong-Deok Ahn¹, Hyunkoo Lee¹*
1. ETRI (Korea)

We fabricated the nano-structure applicable for a highly efficient and color stable TEOLED by using thermal evaporation and organic vapor phase deposition, respectively. The nano-structure integrated TEOLEDs showed efficiency increase by 12% (thermal evaporation) and 32% (OVPD), respectively. The $\Delta(u'v')$ from normal direction to 30° were 0.06 and 0.03, respectively.

Author Interviews

18:50 - 19:20

Friday, November 29

9:00-10:15

Room 204

OLED6: OLED Advanced Technologies

Chair: Yoshimasa Sakai (MITSUBISHI CHEMICAL)
 Co-Chair: Sukekazu Aratani (Samsung Electronics)

OLED6 - 1 *Invited* OLED/OPD-on-Silicon for Near-to-Eye Microdisplays and Sensing Applications

9:00

**Karsten Fehse¹, Dirk Schlebusch¹, Philipp Wartenberg¹, Steffen Ulbricht¹, Gerd Bunk¹, Stephan Brenner¹, Matthias Schober¹, Christian Schmidt¹, Bernd Richter¹, Uwe Vogel¹*

1. Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP (Germany)

We present microdisplays designed for high resolution on the one as well as for low power usage scenarios on the other side. Further information on application of organic semiconductor and CMOS technology in sensor devices for fingerprint scanner, organic photodiodes for near infrared sensing and fluorescence sensors will be presented.

OLED

OLED6 - 2 **Ultra High Resolution Imaging Light Measurement Device for Subpixel Metrology of μ -LEDs and OLED-Displays**

9:20

**Tobias Steinell¹, Thilo Gemeinhardt¹, Martin Wolf¹*

1. Instrument Systems GmbH (Germany)

We present ultra-high resolution measurements of (Micro-) OLED displays for subpixel metrology in display production and laboratories. A 150 megapixel camera merged with a high-end spectroradiometer allows for one-shot subpixel analysis of complete displays with spectroradiometric accuracy. An integrated pixel-shifter increases resolution to effectively 600 megapixels.

OLED6 - 3 **Enhanced Operational Stability of Quantum Dot based Light-Emitting Diodes by Improving Charge Injection Balance**
9:40

**Seunghyun Rhee¹, Jun Hyuk Chang¹, Donghyo Hahm¹, Kyunghwan Kim¹, Hak June Lee¹, Kookheon Char¹, Changhee Lee¹, Wan Ki Bae², Jeonghun Kwak¹*

1. Seoul National University (Korea), 2. Sungkyunkwan University (Korea)

Charge injection balance is the key factor for high efficiency and lifetime of quantum dot light-emitting diodes (QLEDs). However, it is unidentified how the operational conditions affect lifetime of QLEDs. Herein, grounded on the quantitative assessment, the impact of electrical parameters to QLEDs performance and operational stability is identified.

OLED6 - 4L **Formation Mechanism of Spontaneous Orientation Polarization in Evaporated Films of Organic Light-Emitting Diode Materials**
10:00

**Yutaka Noguchi¹, Kohei Osada¹, Hisao Ishii²*

1. Meiji University (Japan), 2. Chiba University (Japan)

Spontaneous orientation polarization (SOP) affects the device performance of OLEDs. To understand and control SOP, we have studied the formation mechanism. The SOP formation likely results from a balance between an electrostatic interaction of permanent dipole moment and van der Waals interaction on the film surface during deposition.

Author Interviews

12:10 - 12:40

Supporting Organizations:

The Japanese Society of Printing Science and Technology
The Society of Photography and Imaging of Japan

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW '19.

IDW'19 Award winners will be announced on the IDW website: <https://www.idw.or.jp/award.html>

Workshop on 3D/Hyper-Realistic Displays and Systems

Wednesday, November 27

3D

13:40-13:45

Small Hall

Opening

Opening Remarks

13:40

Shiro Suyama¹, 1. Tokushima Univ. (Japan)

13:45-15:05

Small Hall

3DSA1/3D1: Holography 1

Chair: Hoang Yan Lin (Nat. Taiwan Univ.)

Co-Chair: Takashi Kakue (Chiba Univ.)

3DSA1/ 3D1 - 1 *Invited* **Complex Spatial Light Modulation for Holographic Displays**

13:45

**Hwi Kim¹*

1. Korea University (Korea)

Complex light modulation is a fundamental and crucial issue for holographic displays. We propose three-phase amplitude structure that has three fixed phase and controllable amplitudes to implement a single complex value. In this study, it is also expected to implement an ultra-low noise holographic display with active complex modulation.

3DSA1/ 3D1 - 2 **Withdrawn**

3DSA1/ 3D1 - 5L **A Fast Hologram Calculation Method Based on the Light Field Rendering**

14:05

**Tiantian Zhang¹, Li Liu¹, Jun Xia¹*

1. Southeast University (China)

We propose a new method based on ray-sampling (RS) algorithm to reconstruct the holographic light field. Different from the previous method, we accumulate elemental images in the space domain without any Fourier transform. The results demonstrate that the proposed method successfully reconstructs the 3D scene with accurate depth cues.

**3DSA1/
3D1 - 3
14:25**

Performance Improvement for Computer-Generated Holographic Stereogram Based on Integral Imaging
*Zi Wang¹, Guoqiang Lv¹, Qibin Feng¹
1. Hefei University of Technology (China)

We want to introduce several recent works for improving the performance of integral imaging (II) based holographic stereogram (HS). First, we have proposed a resolution-enhanced II-based HS using the moving array lenslet technique (MALT). [1] Second, we have proposed the concept of resolution priority HS (RPHS) for the first time, which is based on the principle of resolution priority II, by adding a quadratic phase term on the conventional Fourier transform. [2] Finally, a simple and fast algorithm for computer-generated hologram (CGH) based on pinhole-type II using a look-up table was proposed. [3]

**3DSA1/
3D1 - 4
14:45**

Analysis about System Parameters of Self-Interference Incoherent Digital Holographic Recording System Utilizing Geometric Phase Lens
*KiHong Choi¹, Jongmin Kim¹, Keehoon Hong², Joongki Park², Sung-Wook Min¹
1. Kyung Hee University (Korea), 2. Electronics and Telecommunications Research Institute (Korea)

Self-interference incoherent digital holography utilizing the geometric phase lens has recently been developed with a super-simple design and the compactness of system structure. In this study, some of the acquisition performance related to the system parameters are analyzed to enhance the hologram acquisition quality.

15:20-16:40

Small Hall

3D2/3DSA2: Holography 2

Chair: Hwi Kim (Korea Univ.)
Co-Chair: Yuji Sakamoto (Hokkaido Univ.)

**3D2/
3DSA2 - 1
15:20**

Invited Evaluation of Hologram Quality Based on Digital and Analog Types of Spatial Light Modulators
Chih-Hao Chuang¹, Siao-Ting Li², Chien-Yu Chen²,
*Hoang-Yan Lin¹, Kuan-Hsu Fan-Chiang³, Hsien-Chang Tsai³
1. National Taiwan University (Taiwan), 2. National Taiwan University of Science and Technology (Taiwan), 3. Himax Display Inc. (Taiwan)

A prototype system of head-mounted holographic display with multi-depth is presented. The system adopts the modified Gerchberg-Saxton algorithm to produce the phase-only functions on digital and analog types of spatial light modulators. Furthermore, the proposed system could achieve multi-depth by using human-eye focusing and zooming mechanism. Finally, the quality of images is also analyzed and evaluated.

**3D2/
3DSA2 - 2
15:40** **Invited Development of 72K Ultra-High-Resolution
SLMoG System for High-Capacity Digital
Holography Image**

**Jae-Eun Pi¹, Ji-Hun Choi¹, Jong-Heon Yang¹, Chi-Young Hwang¹, Gi Heon Kim¹, Hee-Ok Kim¹, Young-gi Kim², Myung Yu Kim², Ha Kyun Lee³, Chi-Sun Hwang¹, Jinwoong Kim¹*

1. ETRI (Korea), 2. Silicon Works (Korea), 3. MVTech (Korea)

We present ultra-high-resolution digital holography operation system supporting 72K x 3.2K spatial-light-modulator on glass (SLMoG) panel which is composed of the state-of-the-art 1 μ m-pitch pixel. To control the high-capacity digital holography image, we have developed 40 Gbps optical transmit (Tx) / receive (Rx) and high-speed data handling system. Furthermore, we designed 6K channel of source driver IC with 1:2 demultiplexer (DeMux) control signal to operate 72K column line by using multi-MIPI interface.

**3D2/
3DSA2 - 3
16:00** **Reducing the Effect of Crosstalk Noise From
Defocused Multi-Depth Holographic Image with a
Rasterize Encoding Method**

**Siao-Ting Li¹, Chih-Hao Chuang², Chung Feng Kuo¹, Hoang-Yan Lin², Chin-I Huang³, Chien-Yu Chen¹*

1. National Taiwan University of Science and Technology (Taiwan), 2. National Taiwan University (Taiwan), 3. National Kaohsiung First University of Science and Technology (Taiwan)

Crosstalk noise from defocused light affects the image quality of target image in multi-depth holographic display system. In this study, we propose a defocused light noise reduction with the rasterize encoding method. With the objective image quality analysis, it proves that the proposed method could improve the image quality.

**3D2/
3DSA2 - 4
16:20** **The Holographic Information Projection System
Based on Holographic Optical Element**

**Wen-Kai Lin^{1,2}, Hung-Pin Chen², Bor-Shyh Lin¹, Wei-Chia Su²*

1. National Chiao Tung University (Taiwan), 2. National Changhua University of Education (Taiwan)

In this paper, a projection type holographic display based on HOE was proposed. The viewing angle of the holographic image is larger than the maximum diffraction angle of the SLM which was employed to display CGH. The theory and aberration were analyzed via the ray tracing technique.

17:00-18:20

Small Hall

3DSA3/3D3: Light Field 1

Chair: Yasuhiro Takaki (Tokyo Univ. of A&T)
Co-Chair: Hirotsugu Yamamoto (Utsunomiya Univ.)

**3DSA3/
3D3 - 1** **Depth Range Control in Visually Equivalent Light
Field 3D (VELF3D) Display**

17:00 *Munekazu Date¹, Shinya Shimizu¹, Hideaki Kimata¹
1. Nippon Telegraph and Telephone Corporation
(Japan)

Light field displays have limited display depth range, which is a serious issue in supporting live action content. Though generating depth maps and re-rendering is a solution, it incurs huge computational cost. In this paper, we achieve depth range compression simply by calculating the weighted average of multi-camera images.

Also presented in Innovative Demonstration Session (see p. 278)

**3DSA3/
3D3 - 2** **Withdrawn**

**3DSA3/
3D3 - 5L** **An Adaptive Time-Division Multiplexing Parallax
Barrier Allowing Multiple Observers**

17:20 *Bin Yang¹, Hideki Kakeya¹
1. University of Tsukuba (Japan)

We propose an autostereoscopic display allowing multiple observers with adaptive time-division multiplexing parallax barrier. To make sure that every observer is in the proper viewing zone to enable stereoscopy, the number of time-division multiplexing is switched in accordance with the distance between the observers.

**3DSA3/
3D3 - 3** **High Field-of-View Near-Eye Display Using Total
Internal Reflection Prism and Holographic Printing
Technique**

*Jinsoo Jeong¹, Juhyun Lee¹, Byoung-ho Lee¹
1. Seoul National University (Korea)

By using holographic printing, high field-of-view (FOV) holographic eye-piece for near-eye display can be implemented. However, due to the high FOV, it is hard to separate the reference and signal beam. We used total internal reflection prism to solve the problem and an augmented reality holographic near-eye display is implemented.

**3DSA3/
3D3 - 4** **Withdrawn**

**3DSA3/
3D3 - 6L
18:00**

**Slim Holographic Retina Display Based on
Holographic Waveguide**

**Li Liu¹, Tiantian Zhang¹, Jun Xia¹*

1. Southeast University (China)

In this paper, we propose a slim system for holographic retina display on the basis of holographic waveguide and holographic optical elements (HOEs), promising in augmented reality (AR) system. By attaching the spatial light modulator (SLM) to the waveguide directly, we decrease the form factor of the AR system greatly.

Author Interviews

18:30 - 19:00

3D

Thursday, November 28

9:00-10:20	Small Hall
3D4/VHF4/3DSA4: Illusion	

Chair: Sumio Yano (Shimane University)

Co-Chair: Yuzo Hisatake (Shizuoka Univ.)

3D4/VHF4/ Invited Innovative Mobile Force Display: Buru-Navi

3DSA4 - 1

**Hiroaki Gomi¹, Sho Ito¹, Ryoma Tanase¹*

9:00

1. NTT Communication Science Labs. (Japan)

Humans capture the environmental world not only by vision but also by somatosensory information. Here we introduce several types of mobile force-display gadgets 'Buru-Navi' recently developed, and showcase some application trials for pedestrian navigation and for enhancing immersive sensation along a video scene.

**3D4/VHF4/ Invited Displaying Deformation of Virtual Objects
3DSA4 - 2 Using Visuo-Haptic Interaction**

9:20

**Yuki Ban¹*

1. The University of Tokyo (Japan)

We developed the visuo-haptic shape display system with which users can deform virtual objects dynamically. Our system senses how the force is applied to the grasping object, and deforms the virtual grasping object and the virtual hands according to the direction and size of the force.

3D4/VHF4/ 3DSA4 - 3 9:40 *Invited* **Real-World Implementations of Visual Illusions by Using Augmented Reality Techniques**
**Takahiro Kawabe¹*

1. NTT Communication Science Laboratories (Japan)

Visual illusions refer to perceptual experiences wherein the appearance of objects and scenes is distorted. By taking advantage of the illusion which is often interpreted as undesired elements in perception, our technique can offer visual experiences which are not produced on the basis of the previous techniques.

3D4/VHF4/ 3DSA4 - 4 10:00 **Gloss Enhancement beyond Projector Performance Using the Glare Illusion**
**Shinji Nagata¹, Toshiyuki Amano¹*

1. Wakayama University (Japan)

The glare illusion is a well-known illusory perception in which a region appears brighter than its actual luminance when surrounded by a gradation of luminance. We propose a method of enhancing gloss beyond projector performance using this glare illusion. The effectiveness of the proposed method is confirmed by comparing it with the proposed and conventional method.

Author Interviews

10:40 - 11:10

10:40-13:10	Main Hall
Poster 3Dp1/3DSAp1: 3D and Hyper-realistic Displays and Applications 1	

3Dp1/ 3DSAp1 - 1 **Compact Binocular Holographic Head-Mounted Display Using Viewing Zone Expansion Method with Multiple Light Sources**

**Kazuya Furuta¹, Yuji Sakamoto¹*

1. Hokkaido University (Japan)

Holographic head mounted displays (HMDs) for augmented reality (AR) are being researched for use as work support because they can display images at a free depth. It is necessary to miniaturize the size of such devices for practical use. This paper proposes a compact binocular HMD for AR.

Also presented in Innovative Demonstration Session (see p. 279)

**3Dp1/
3DSAp1 - 2 Quality Analysis of Light-Waves considering
Transmission Errors of Various Images for Wireless
Transmission System of CGHs**

**Kazuhiro Yamaguchi¹, Yuji Sakamoto²*

*1. Suwa University of Science (Japan), 2. Hokkaido
University (Japan)*

In this paper, a wireless transmission system model for computer-generated holograms is constructed, and quality of light-waves considering transmission errors of CGH are analyzed by using computer simulations. SNRs (Signal to noise ratio) of light-waves reconstructed from transmitted CGHs having some transmission errors were measured and evaluated.

**3Dp1/
3DSAp1 - 3 Optimization Technique for Phase-Only Computer-
Generated Holograms Based on Gradient Descent
Method**

**Shujian Liu¹, Yuki Nagahama¹, Yasuhiro Takaki¹*

*1. Tokyo University of Agriculture and Technology
(Japan)*

A new phase optimization technique for computer-generated holograms is proposed, which iteratively updates the phase distribution directly from the root mean square error of the reconstructed image using the chain rule. The number of iterations required for the proposed technique is much less than that required for the Gerchberg-Saxton algorithm.

**3Dp1/
3DSAp1 - 4 Electronic Holographic Display Using MEMS-SLM
with 40 Degree Viewing Zone**

**Yoshitaka Takekawa¹, Yuki Nagahama¹,
Yuzuru Takashima², Yasuhiro Takaki¹*

*1. Tokyo University of Agriculture and Technology
(Japan), 2. University of Arizona (United States of
America)*

The illumination of the MEMS-SLM by short laser pulses can dramatically increase the viewing zone of holographic images without reducing the pixel pitch. We demonstrate the generation of 3D images with a viewing zone angle of 40 degrees using the DMD with a pixel pitch of 13.68 micrometers.

3D

**3Dp1/
3DSAp1 - 5 Digital Holographic Observation of a Wavefront
Generated by a Digitally Designed Holographic
Optical Element (DDHOE)**

**Tatsuki Tahara^{1,2}, Koki Wakunami¹, Boaz Jessie Jackin¹,
Yasuyuki Ichihashi¹, Ryutaro Oi¹*

*1. National Institute of Information and
Communications Technology (Japan), 2. Japan
Science and Technology Agency (Japan)*

Using digital holography, we observe a wavefront generated by a digitally designed holographic optical element (DDHOE). Experimental results show the performance of digital holographic observation as an evaluation tool for DDHOEs. Quantitative wavefront sensing has the potential to evaluate a DDHOE fabricated by a wavefront printer in detail.

**3Dp1/
3DSAp1 - 6 The Design of Head-up Display Based on
Holographic Optical Element**

**Guan-Li Chen¹, Wen-Kai Lin^{1,2}, Shao-Kui Zhou^{1,2},
Wei-Chia Su¹*

*1. National Changhua University of Education
(Taiwan), 2. National Chiao Tung University (Taiwan)*

This study designed a HUD based on HOE and a projection system. In this system, the exit pupil is placed on the eyes of the observer and provides an image. The system has a larger FOV due to the placement of the exit pupil on the eyes of the observer.

**3Dp1/
3DSAp1 - 7 The Full Color Maxwellian-view Display Based on
Holographic Optical Element**

**Shao-Kui Zhou^{1,2}, Wen-Kai Lin^{1,2}, Bor-Shyh Lin¹, Wei-
Chia Su²*

*1. National Chiao Tung University (Taiwan), 2. National
Changhua University of Education (Taiwan)*

A full color Maxwellian-view display based on HOE is proposed. The device can offer observers the information from the mask. The image quality won't be affected when focus on different distance. The HOE with the wavelength multiplexing can reconstruct the full color backlight to get full color image.

**3Dp1/
3DSAp1 - 8 High-resolution Mesh-Based Computer-Generated
Hologram Synthesis Using Fast Fourier Transform
with Graphics Processing Unit**

**Han-Ju Yeom¹, Sanghoon Cheon¹, Keehoon Hong¹,
Seoungbae Cho¹, Seungtaik Oh², Joongki Park¹*

*1. Electronics and Telecommunications Research
Institute (Korea), 2. Studio Macrograph (Korea)*

To reduce the calculation time of synthesizing mesh-based computer-generated hologram (CGH), we define valid frequency domain in off-axis condition which makes different path of DC and three-dimensional (3D) object. Also, we propose a graphics processing unit (GPU) based fast Fourier transform (FFT) method for calculating angular spectrum of mesh-based CGH.

**3Dp1/
3DSAp1 - 9 Effective Encoding of Binary Phase Hologram Using Error Diffusion**

**Minsik Park¹, Jeho Nam¹, Seunghyup Shin¹,
Jinwoong Kim¹*

*1. Electronics and Telecommunications Research
Institute (Korea)*

The paper proposed the algorithm to improve the performance of the conventional BERD in transforming the complex hologram into binary phase hologram to be applied into binary phase-only SLM. We can get the image quality more than PSNR 16dB in the numerical reconstruction of the binary phase hologram.

**3Dp1/
3DSAp1 - 10 Interactive Operation of Projection-type Holographic Display Based on HOE Screen when Using Ray-sampling Plane**

**Rintaro Miura^{1,2}, Yasuyuki Ichihashi², Takashi Kakue¹,
Hiroshi Amano^{1,2}, Hiroshi Hashimoto^{1,2}, Koki Wakunami²,
Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹*

1. Chiba University (Japan), 2. NICT (Japan)

To realize interactive operation of 3D image projected on HOE screen, we calculated and displayed the holograms from the data of light-ray information which was loaded depending on the position of the finger detected by the motion sensor.

**3Dp1/
3DSAp1 - 11 Direct Light Removal and Image Quality Evaluation of Large Screen Holographic Projection**

**Shoki Kikukawa¹, Tomoyoshi Shimobaba¹,
Takashi Kakue¹, Tomoyoshi Ito¹*

1. Chiba University (Japan)

In this paper, we constructed a time-division reproduction system of holographic projection using a DMD (Digital Mirror Device). We succeeded in removing the direct light in projected images and enlarging the projected images by changing a sampling pitch of the original image.

**3Dp1/
3DSAp1 - 12 Distortion Correction and Optical Reconstruction of Point-cloud Object for the Projection-type Color Holographic Display Based on HOE Screen**

**Hiroshi Amano^{1,2}, Yasuyuki Ichihashi², Takashi Kakue¹,
Koki Wakunami², Hiroshi Hashimoto^{1,2}, Rintaro Miura^{1,2},
Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹*

*1. Chiba University (Japan), 2. National Institute of
Information and Communications Technology (Japan)*

By using the holographic optical element screen, an aerial-projection display of three-dimensional images can be realized up close which the scale is free. However, the projected image is distorted when an object is placed far from the hologram plane. In this study, we corrected the distortion by shift point cloud.

3Dp1/ 3DSAp1 - 13 Hologram Calculation of Light-in-flight Recording by Holography based on Numerical Simulation Model with FDTD Method

**Takashi Kakue¹, Naoki Takada², Keita Tojo¹,
Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹*

1. Chiba University (Japan), 2. Kochi University (Japan)

We propose a numerical simulation model to calculate a hologram of light-in-flight recording by holography. The proposed model is based on not only ray tracing but also finite-difference time-domain method. We succeeded in numerically reconstructing light pulse propagation with total reflection from the hologram calculated by the proposed model.

3Dp1/ 3DSAp1 - 14 Calculation Reduction Method for Computer-Generated Hologram Using Angular Redundancy and Color Space Conversion

**Ryota Furukawa¹, Tomoyoshi Shimobaba¹,
Takashi Kakue¹, Tomoyoshi Ito¹*

1. Chiba University (Japan)

We propose a calculation reduction method for computational holograms using angular redundancy of light field by color space conversion. The angular redundancy could be enhanced by the properties of color space. We confirmed that the computational complexity can be reduced by about 20%.

3Dp1/ 3DSAp1 - 15 Highly Parallel Special-Purpose Computer for Electroholography on System on a Chip

**Yota Yamamoto¹, Nobuyuki Masuda²,
Hirotaka Nakayama³, Tomoyoshi Shimobaba¹,
Takashi Kakue¹, Tomoyoshi Ito¹*

1. Chiba University (Japan), 2. Tokyo University of Science (Japan), 3. National Astronomical Observatory of Japan (Japan)

For realizing electroholography, a compact and high-performance computer is required. In this study, we implemented highly parallel special-purpose computer for electroholography on system on a chip. As a result, we succeeded in speeding up calculation 200 times faster than a CPU and a GPU.

3Dp1/ 3DSAp1 - 16 Multiview Image Correction for Visually Equivalent Light Field 3D Display

**Takasuke Nagai¹, Munekazu Date¹, Shinya Shimizu¹, Hideaki Kimata¹*

1. Nippon Telegraph and Telephone Corporation (Japan)

The multiview-based light field displays assume that viewpoints of source images are strictly parallel and equally spaced. It is however difficult to arrange multiple cameras by actually satisfying such assumptions. In this paper, we propose a method to virtually parallelize multiple cameras and synthesize regularized light fields.

Also presented in Innovative Demonstration Session (see p. 280)

3Dp1/ 3DSAp1 - 17 Development of Switchable LF Camera for Capturing 2D/3D Movie

**Tae-Hyun Lee¹, Jae-Won Lee¹, Kyung-Il Joo¹, Min-Kyu Park¹, Heewon Park¹, Ki-Chul Kwon², Munkh-Uchral Erdenibat², Young-Tae Lim², Nam Kim², Hak-Rin Kim¹*

1. Kyungpook National University (Korea), 2. Chungbuk National University (Korea)

We developed a fast switchable light field (LF) camera which can simultaneously capture the 2D and 3D videos based on implemented switchable polarization-dependent micro-lens array (MLA). The proposed LF camera system was demonstrated that can simultaneously capture the 2D and 3D video even in high speed driving over 1000 fps.

3Dp1/ 3DSAp1 - 18 An Active Barrier Autostereoscopic Display with Less Crosstalk

**Ayuki Hayashishita¹, Takuya Matsumoto², Kaoru Kusafuka², Hideki Kakeya¹*

1. The University of Tsukuba (Japan), 2. KYOCERA Corporation (Japan)

We propose an autostereoscopic display system using a monochrome panel as an active parallax barrier. We confirm that placing a monochrome panel for barrier in front of the color imaging panel generates less crosstalk than placing it behind.

3Dp1/ 3DSAp1 - 19 Resolution Evaluation of a Simplified Super Multi-View Head-Mounted Display

**Takaaki Ueno¹, Yuki Nagahama¹, Yasuhiro Takaki¹*

1. Tokyo University of Agriculture and Technology (Japan)

We have proposed the simplification technique of the super multi-view head-mounted display to reduce the system and computation costs. This study provided a resolution evaluation of the prototype system. The resolution was higher than 14.3 pixels/degree when the eyes' focus was at 380–530 mm and 700–1,200 mm.

3Dp1/ 3DSAp1 - 20 Comparative Study on Layered Light-Field Displays and Optimization Methods

**Keita Maruyama¹, Keita Takahashi¹, Toshiaki Fujii¹, Munekazu Date², Hideaki Kimata²*

1. Department of Information and Communication Engineering Graduate School of Engineering, Nagoya University (Japan), 2. NTT Media Intelligence Laboratories, Nippon Telegraph and Telephone Corporation (Japan)

We focus on two factors that affect the performance of layered light-field displays: the layer device and optimization method. We quantitatively compared the performances of different architecture of layered light-field displays (LCD, HOE, and S-IPS LCD) and their optimization methods (analytical method and CNN-based method).

3Dp1/ 3DSAp1 - 21 Light Field Acquisition from Focal Stack via a Deep CNN

**Yasutaka Inagaki¹, Keita Takahashi¹, Toshiaki Fujii¹*

1. Nagoya University (Japan)

We succeeded in acquiring a dense light field from a focal stack, i.e., only a few images with different focused depth, by using a deep convolutional neural network (CNN) trained for this purpose. We validated our method through both simulative and real-camera experiments.

3Dp1/ 3DSAp1 - 22 Displaying Live 3-D Video from a Multi-View Camera on a Layered Display

**Yusuke Ota¹, Keita Maruyama¹, Ryutaroh Matsumoto¹, Keita Takahashi¹, Toshiaki Fujii¹*

1. Nagoya University (Japan)

We present a pipeline that displays 3D videos captured by a multi-view camera (ProFUSION25) on a layered display in real time. The layered display is a kind of light field displays. To develop this pipeline, we used a CNN that calculates a layer pattern to reduce processing time.

Also presented in Innovative Demonstration Session (see p. 280)

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW '19.

IDW'19 Award winners will be announced on the IDW website: <https://www.idw.or.jp/award.html>

3Dp1/
3DSAp1
- 23L

Implemented of Images and Sounds Person Tracking System Using Directional Volumetric Display

**Mitsuru Baba¹, Ryuji Hirayama^{2,3}, Naoto Hoshikawa⁴, Hirotaka Nakayama⁵, Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹, Atsushi Shiraki¹*

1. Chiba University (Japan), 2. Research Fellow of the Japan Society for the Promotion of Science (Japan), 3. Tokyo University of Science (Japan), 4. National Institute of Technology, Oyama College (Japan), 5. National Astronomical Observatory of Japan (Japan)

In previous study, we developed the directional volumetric display which can display multiple images in different directions. In this study, we implemented a method of person tracking for the directional volumetric display to enable transmitting images and sounds following person using motion capture.

3Dp1/
3DSAp1
- 24L

Development of Volumetric Display Capable of Transmitting Information in Different Languages Using Language Identification

**Taishin Murase¹, Ryuji Hirayama^{2,3}, Naoto Hoshikawa⁴, Hirotaka Nakayama⁵, Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹, Atsushi Shiraki¹*

1. Chiba University (Japan), 2. Research Fellow of the Japan Society for the Promotion of Science (Japan), 3. Tokyo University of Science (Japan), 4. National Institute of Technology, Oyama College (Japan), 5. National Astronomical Observatory of Japan (Japan)

We developed a directional volumetric display that exhibits different images depending on the viewing direction. The display can be expected to be applied to multilingual signage that transmits information in different languages. In this study, we develop a display that exhibits images according to the language used by the observer.

3Dp1/
3DSAp1
- 25L

Simulation of Target Observation Area Formed by HOE Screen with Function of Concave Mirror

**Hiroshi Hashimoto^{1,2}, Yasuyuki Ichihashi², Takashi Kakue¹, Koki Wakunami², Hiroshi Amano^{1,2}, Rintaro Miura^{1,2}, Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹*

1. Chiba University (Japan), 2. National Institute of Information and Communications Technology (Japan)

When three-dimensional images is reconstructed in projection-type holographic display based on a holographic optical element screen, the observation area is limited to narrow range. In this study, we simulated and evaluated the observation area in order to expand the observation area quantitatively.

3D

- 3Dp1/
3DSAp1
- 26L** **Development of Three-Dimensional Aerial Image Display System by Integral Photography**
**Yuya Sota¹, Sumio Yano¹*
1. Shimane University (Japan)

Using integral photography, the three-dimensional aerial image display equipment was developed experimentally using the double reflection micro mirror array. The range of viewing area and depth reproduction of the prototype device were examined by subjective evaluation experiments.

- 3Dp1/
3DSAp1
- 27L** **Volumetric 3D System Using Rotating -Confirmation of Image Distortion and its Compensation-**
**Ken Muto¹*
1. Japan / Tokai / Electrical and Electronic Engineering (Japan)

We have suggested a novel method of volumetric 3D display, in which multi layer of screen images are projected on a rotating spiral screen. In this study, we focused on possible distortion of 3D image in our volumetric 3D display system and its compensation.

- 3Dp1/
3DSAp1
- 28L** **Improved Fabrication Process of Holographic Waveguide Combiner in a Head Mounted Display System**
**Hung-Pin Chen¹, Wen-Kai Lin², Shao-Kui Zhou², Wei-Chia Su¹*
1. National Changhua University of Education (Taiwan), 2. National Chiao Tung University (Taiwan)

In this research, we propose a simplified way to expand the exit pupil of a holographic Head Mounted Display (HMD). The divergent spherical wave is transmitted in the waveguide, and a large diffraction area is formed to make an output Holographic Optical Element (HOE).

- 3Dp1/
3DSAp1
- 29L** **Light Field Camera with Pan-tilt Function**
**Yuta Yamaguchi^{1,2}, Yasuhiro Takaki¹*
1. Tokyo University of Agriculture and Technology (Japan), 2. Research Fellow of Japan Society for the Promotion of Science (Japan)

A light field camera with a high-speed pan-tilt function is proposed. The system consisted of two lens arrays, a two-dimensional actuator, and an image sensor. The experimental system was constructed using 103.5- μm pitch lens arrays and a 4K image sensor and the pan-tilt and refocus functions were verified.

3Dp1/
3DSAp1
- 30L

The Application of a New Type of Depth Camera to Teach Gymnastics

**Tsanming Ou¹, Tomoki Miyamoto¹, Yuki Kurosawa¹,
Takahide Otomo¹, Yuko Hoshino¹, Mitsuho Yamada¹*

1. Tokai University (Japan)

As Japanese society increasingly ages, there are more and more people who do sports to improve their quality of life, and there have been a number of studies on the use of humanoid robots to teach gymnastics. We attempted to use a new type of sensor in this kind of system and tested its performance.

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)
Sapporo Convention Center

EXHIBITION

12:40 – 18:00 Wednesday, Nov. 27

10:00 – 18:00 Thursday, Nov. 28

10:00 – 14:00 Friday, Nov. 29

Main Hall (1F)

Sapporo Convention Center

Free admission with your registration name tag

14:30-17:00

Main Hall

Poster 3DSAp2/3Dp2: 3D and Hyper-realistic Displays and Applications 2

3DSAp2/3Dp2 - 1 The Full Color See-through Head Mounted Display Based on Transmission-type Holographic Optical Elements and Parallel Plane Mirrors

**Zih-Yuan Wong¹, Wen-Kai Lin^{1,2}, Shao-Kui Zhou^{1,2}, Wei-Chia Su¹*

1. National Changhua University of Education (Taiwan), 2. National Chiao Tung University (Taiwan)

The full color see-through head mounted display (HMD) which consists of two transmission-type HOEs, two parallel plane mirrors and a single image source is proposed. The red, green and blue incident light will overlap at the output HOE. Then the dispersion of transmission hologram will be compensated.

3DSAp2/3Dp2 - 2 Unsupervised Monocular Depth Estimation for Autonomous Driving

*Chih-Shuan Huang¹, *Wan-Nung Tsung¹, Wei-Jong Yang¹, Chin-Hsing Chen¹*

1. National Cheng Kung University (Taiwan)

3D technology with range information has become a staple requirement in computer vision. For this reason, we believe that the depth information can effectively improve the vision capabilities for many applications. In this paper, we proposed an unsupervised monocular depth estimation network to extract the depth map of street views.

3DSAp2/3Dp2 - 3 VR Viewing Test of 3D Reconstructed Content Generated by Markerless Motion Capture in Wide Area

**Masaaki Matsumura¹, Kazuki Okami¹, Hajime Noto¹, Hideaki Kimata¹*

1. NTT Media Intelligence Laboratories, Nippon Telegraph and Telephone Corporation (Japan)

Recent years, the visualization techniques for wide area with AR and VR have been attracting attention. We propose the method to create a real-scaled VR viewing experience using images of actual handball game. And then, we test the experience can be entertained without feeling of discomfort using user questionnaires.

3DSAp2/3Dp2 - 4 Withdrawn

**3DSAp2/
3Dp2 - 5 Enhancing Visual Quality of Multi-view 360 Video
Compression Pipeline**

**Junyoung Yun¹, Hong-Chang Shin², Gwangsoon Lee²,
Jong-Il Park¹*

*1. Hanyang University (Korea), 2. Electronics and
Telecommunications Research Institute (Korea)*

A three degrees of freedom plus(3DoFP) video formatting pipeline was presented at MPEG-I Visual. A 3DoFP video gives motion parallax for users' slight translational movement as well as rotation. The given 3DoFP pipeline is based on virtual view synthesis using multiple view color and depth images on which visual redundancies among the given view images are removed. Extracted necessary image areas from redundancy removal process are packed, transmitted and reconstructed to show contents to end users. However, the early researches on view synthesis uses all redundant information, the impact of removed redundant area is not explored much. In this work, we present a method for enhancing final synthesized image quality of the given pipeline dealing with redundancy removal.

**3DSAp2/
3Dp2 - 6 Eye-Matching Video Calling System by Use of Aerial
Screen with AIRR**

**Kengo Fujii¹, Ryota Kakinuma¹, Masaki Yasugi^{1,2},
Hirotsugu Yamamoto^{1,2}*

1. Utsunomiya Univ. (Japan), 2. JST ACCEL (Japan)

Aerial screen formed with AIRR has been utilized for a video calling system that features viewpoint matching. We can virtually place a camera at an arbitrary position on the aerial screen because the screen is aerial and AIRR employs a beam splitter. Polarization filtering is used to take clear pictures.

**3DSAp2/
3Dp2 - 7 Immersive Reaction of Medaka to Omnidirectional
Aerial Display**

**Erina Abe¹, Hirotsugu Yamamoto¹*

1. Utsunomiya University (Japan)

This paper reports the responses of medaka that is surrounded by rotating stripes shown on an omnidirectional aerial display. We measure the time of reaction in three conditions and compare the difference between one and several medaka. The results suggests omnidirectional aerial display evokes immersive sensation on medaka.



**3DSAp2/
3Dp2 - 8**

Tabletop Aerial DFD Display with AIRR

**Yoshiki Terashima¹, Kengo Fujii¹, Shiro Suyama²,
Hirotsugu Yamamoto^{1,3}*

*1. University of Utsunomiya (Japan), 2. University of
Tokushima (Japan), 3. JST ACCEL (Japan)*

This paper proposes a tabletop two-layered aerial display system with aerial imaging by retro-reflection (AIRR). Then, we have realized an aerial depth-fused 3D (DFD) display. We investigate the relationships between the two-layered-images distance and the observation distance. The result shows that the two-layered-images distance increases with the observation distance.

**3DSAp2/
3Dp2 - 9**

See-Through Aerial Concave Display by Use of Fresnel Lens and AIRR with Polarization Modulation

**Shuto Hatsumi¹, Kazuki Shimose¹, Masaki Yasugi^{1,2},
Hirotsugu Yamamoto^{1,2}*

*1. Utsunomiya university (Japan), 2. JST,ACCEL
(Japan)*

This paper proposes an optical system for see-through aerial concave display. Due to aberration of Fresnel lens, a 2D image on a flat-panel display is converted to a convex image. Then, the convex image is converted to an aerial concave image with AIRR (Aerial Imaging by Retro-Reflection) in see-through structure.

**3DSAp2/
3Dp2 - 10**

Object-centered View Synthesis Using Learning-based Image Inpainting

**HONG-CHANG SHIN¹, Gwangsoon Lee¹, Ho min Eum¹,
Jeong-Il Seo¹*

1. ETRI (Korea)

This paper presents object-centered view synthesis technique using multilayer concept. we divide the image into multiple layers based on depth information and then provide different motion parallaxes for each layer depending on the depth. When the disocclusion region appears due to motion parallax, the uncovered region is filled by using learning-based image inpainting.

**3DSAp2/
3Dp2 - 11**

Texture-based Depth Frame Interpolation for Precise 2D to 3D Conversion

**Kuan-Ting Lee¹, En-Shi Shih¹, Jar-Ferr Yang¹*

1. National Cheng Kung University (Taiwan)

A texture-based depth interpolation system was proposed. It can interpolate two depth keyframes, by combining depth estimation, error compensation, noise elimination, and forward/backward depth merging. Results confirmed that errors in the estimated depth are few. The bi-directional propagation can overcome the occlusion of objects and handle the zoom in/out circumstance.

- 3DSAp2/
3Dp2 - 12** **Volumetric Graphics Using Laser-Induced Microbubbles in Glycerin Containing Gold Nanorods**
**Taisei Chiba¹, Kota Kumagai, Yoshio Hayasaki¹*
1. Utsunomiya University (Japan)

A laser-induced bubble display with glycerin containing gold nanorods as a screen material was developed. The gold nanorods are used to reduce the required energy of laser pulses for the bubble formation toward a large volumetric bubble graphics.

- 3DSAp2/
3Dp2 - 13** **Investigation of Single-Pixel Imaging Using Recurrent Neural Network**
**Ikuo Hoshi¹, Tomoyoshi Shimobaba¹, Takashi Kakue¹, Tomoyoshi Ito¹*
1. Chiba University (Japan)

We propose a reconstruction method for single-pixel imaging. Recently, reconstruction methods using deep neural networks have been studied. However, these methods need much calculation. In this paper, we investigated to reconstruct images from a single-pixel device using a recurrent neural network and decrease the calculation amount.

- 3DSAp2/
3Dp2 - 14** **Perceived Depth in Arc 3D Display Can Penetrate into Behind Real Object by Moving Arc 3D Images in Contrast to Unpenetrated Perceived Depth in Stereoscopic Display**
**Kisa Nakano¹, Takahiko Yoshida¹, Haruki Mizushima¹, Shiro Suyama¹*
1. Tokushima University (Japan)

Arc 3D display can solve serious difficulty in perceived depth penetration into or behind the real object in stereoscopic image only by moving head or 3D image position. Arc 3D image can be successfully perceived around desired position even in or behind the real object.

- 3DSAp2/
3Dp2 - 15** **Real-Object DFD Method Can Change Perceived Depths of Dark Real Object and Occluded Rear Real Object to in Front and Behind**
**Oku Iwamoto¹, Haruki Mizushima¹, Shiro Suyama¹*
1. Tokushima University (Japan)

Depth-fused 3D display can successfully change perceived depth of occluded rear real object from behind rear object to in front of front object by adding rear object image behind and in front of rear object. Moreover, perceived depth of dark real object can be changed by changing added front-display transmittance.

**3DSAp2/
3Dp2 - 16 A New 3D Display Utilizing Occlusion Effect by
Frames, Gap and Bend of Side-by-Side 2D Displays
Over Moving Stimuli**

**Rune Oyama¹, Shiro Suyama¹, Haruki Mizushima¹*

1. Tokushima University (Japan)

Separating two side-by-side displays with frames and gap can improve virtual perceived depth of moving stimuli behind frames and/or gap by occlusion effect, rather than displays fastening together without them. Horizontal bend and/or vertical inclination in two 2D displays and curved moving stimuli can significantly enlarge virtual perceived depth.

**3DSAp2/
3Dp2 - 17 Perceived Depth Instability Difference of Aerial
Image in CMA (Crossed Mirror Array) by Changing
Fixation Point of Eyes**

**Kohei Yamamoto¹, Shiro Suyama¹, Haruki Mizushima¹*

1. Tokushima Univ. (Japan)

Perceived depths of aerial image in crossed mirror array have large instability towards fixation point of eyes, even when aerial image is geometrical optical real image. When fixation points are changed apart from aerial image, perceived depth deviations are increased toward fixation point in front of or behind aerial image.

**3DSAp2/
3Dp2 - 18 3D Image Depth Enlargement in Large Edge-Based
DFD Display with Long Viewing Distance by Blurring
Edge Images**

**Hideto Matsubara¹, Haruki Mizushima¹, Shiro Suyama¹*

1. Tokushima University (Japan)

We can successfully extend depth-fusion limit of front-rear gap from two image depths to one perceived depth by blurring edge image in large Edge-based DFD display with long-viewing distance. As viewing distance is increased, blurring width for depth-fusion can be effectively reduced.

**3DSAp2/
3Dp2 - 19 Monocular Perceived Depth Improvement Using
Motion Parallax in Arc 3D Display and Dependence
on Motion Cycle Time**

**Kazuya Tango¹, Shiro Suyama¹, Haruki Mizushima¹*

1. Tokushima Univ (Japan)

Saturation degradation of perceived depth of 50 mm by monocular motion parallax in head-tracking system can be successfully improved to large perceived depth of 180 cm by using Arc 3D display without delay time. Head motion cycle affects perceived depth and cycle time of 2 sec is the most stable.

**3DSAp2/
3Dp2 - 20L** **Comparison of Hologram Calculation
Implementations for Wavefront Recording Plane
Method Using Look-up Table Method and Direct
Calculation Method**

**Hidenari Yanagihara¹, Tomoyoshi Shimobaba¹,
Takashi Kakue¹, Tomoyoshi Ito¹*

1. Chiba University (Japan)

We evaluated calculation times of computer-generated holograms based on wavefront recording plane method using several implementations in the combination of look-up table method and direct calculation method in order to realize real-time electro-holography system. We confirmed that there are different characteristics between CPU and GPU implementations.

**3DSAp2/
3Dp2 - 21L** **Efficient Computation of Binary-Weighted
Computer-Generated Hologram for Gradation
Representable Electroholography**

**Ren Noguchi¹, Tomoya Sakaguchi¹, Hiromi Sannomiya¹,
Kohei Suzuki¹, Minoru Oikawa¹, Yuichiro Mori¹,
Takashi Kakue², Tomoyoshi Shimobaba², Tomoyoshi Ito²,
Naoki Takada¹*

*1. Kochi University (Japan), 2. Chiba University
(Japan)*

We proposed fast computation for the gradation representable electro-holography using the bit planes comprising binary-weighted computer-generated hologram (CGH). We succeeded in reducing the duplicate CGH calculation of same object points. Consequently, the proposed method is 2.7 times faster than the previous method.

**3DSAp2/
3Dp2 - 22L** **Cost-effective Portable Holographic Projector Using
a Single Board Computer**

**Yoshiki Moriguchi¹, Hiromi Sannomiya¹,
Tomoya Sakaguchi¹, Kohei Suzuki¹, Yuuki Tanaka¹,
Hirotaka Nakayama², Minoru Oikawa¹, Yuichiro Mori¹,
Takashi Kakue³, Tomoyoshi Shimobaba³, Tomoyoshi Ito³,
Naoki Takada¹*

*1. Kochi University (Japan), 2. National Astronomical
Observatory of Japan (Japan), 3. Chiba University
(Japan)*

We proposed cost-effective portable holographic projector composed of a portable digital micromirror device board and a single board computer. Consequently, the proposed projector succeeded to project the re-constructed video at 60 fps.

**3DSAp2/
3Dp2 - 23L Real-Time Spatiotemporal Division Multiplexing
Electroholography of Point-cloud 3D Model
Comprising 920,000 Points Using Multiple GPU
Cluster System**

**Hiromi Sannomiya¹, Hirotaka Nakayama²,
Minoru Oikawa¹, Yuichiro Mori¹, Takashi Kakue³,
Tomoyoshi Shimobaba³, Tomoyoshi Ito³, Naoki Takada¹*

*1. Kochi University (Japan), 2. National Astronomical
Observatory of Japan (Japan), 3. Chiba University
(Japan)*

We demonstrated real-time electroholographic 3-D movie reconstruction using spatiotemporal division multiplexing technique on a multiple GPU cluster system including 13 GPUs connected through gigabit ethernet network. We succeeded to display reconstructed 3-D movie consisting of 912,462 object points.

**3DSAp2/
3Dp2 - 24L Holographic Projection System for Drawing
Fingertip Trajectory Obtained from Depth Camera**

**Kohei Suzuki¹, Minoru Oikawa¹, Yuichiro Mori¹,
Takashi Kakue², Tomoyoshi Shimobaba², Tomoyoshi Ito²,
Naoki Takada¹*

*1. Kochi University (Japan), 2. Chiba University
(Japan)*

We proposed to the interactive holographic projection system for drawing the trajectory of fingertip on 3D object. The proposed system can project the trajectory of fingertip obtained using the depth camera at 90 fps.

**3DSAp2/
3Dp2 - 25L Magnetic Hologram Reconstruction Using Magneto-
Optical Light Modulator Array Based on Domain
Wall Motion**

**Ryo Higashida¹, Nobuhiko Funabashi¹, Ken-
ichi Aoshima¹, Kenji Machida¹*

1. NHK (Japan)

A magneto-optical light modulator array capable of displaying a magnetic interference pattern by the application of an external magnetic field was fabricated. This array showed that magneto-optical spatial light modulator based on current-induced domain wall motion has sufficient light-modulation characteristics for reconstructing holographic images.

3DSAp2/ Interactive Holographic 3D Display System

3Dp2 - 26L

**Min Sung Yoon¹, Soo-Myung Park¹*

1. Electronics and Telecommunications Research Institute, (Korea)

In this paper, we demonstrate that holographic 3D content of 1,024 views related with all directions of 360 degrees is calculated by FFT-based CGH algorithm and is encoded by the Burkhardt encoding. We represents it onto the interactive holographic display system, which can support wide-viewing range of 60 degrees and directly interact between the user and holographic 3D scenes.

3DSAp2/ Contact Lens Display Based on Holography

3Dp2 - 27L

**Junpei Sano¹, Shujian Liu¹, Yuki Nagahama¹, Yasuhiro Takaki¹*

1. Tokyo University of Agriculture and Technology (Japan)

Holographic display technique is used to generate images far from the display device embedded in a contact lens to enable an eye focus on the images. The see-through function is also provided using the phase-only SLM and the laser backlight. The proposed image formation and see-through functions were experimentally verified.

3DSAp2/ Effect of Non-uniformity of Optical Phase Modulation in Liquid Crystal Devices on Holographic Image Quality

3Dp2 - 28L

**Kazuma Chida¹, Yoshitomo Isomae^{1,2}, Takahiro Ishinabe¹, Yosei Shibata¹, Hideo Fujikake¹*

1. Tohoku University (Japan), 2. Research Fellow of Japan Society for the Promotion of Science (Japan)

We investigated the effect of non-uniformity of phase distribution in liquid crystal phase modulator on holographic image quality by using simulation. As a result, non-uniform phase distribution in a pixel degrades diffraction efficiency, and non-uniform phase distribution on the entire liquid crystal on silicon panel decreases resolution of holographic images.

IDW '20

The 27th International Display Workshops

Dec. 9 - 11, 2020

Fukuoka International Congress Center

Fukuoka, Japan

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17:20-18:40

Small Hall

3DSA5/3D5: Light Field 2

Chair: Jung-Young Son (Konyang Univ.)
Co-Chair: Munekazu Date (NTT)

**3DSA5/
3D5 - 1
17:20** **An Improved View Synthesis of Light Field Images
for Supporting 6 Degrees-of-Freedom**

**Sangwoon Kwak¹, Joungil Yun¹, Won-Sik Cheong¹,
Jeongil Seo¹
1. ETRI (Korea)*

In this paper, virtual view synthesis of sparse light field images is considered. We analyze the patch-wise 3D warping and blending methods of the conventional view synthesis, and propose an improved algorithm for supporting 6DoF. We suggest an enhancement for the super-pixel and additional blending weights, and present experimental results using multi-view contents of MPEG.

**3DSA5/
3D5 - 2
17:40** **GPU-Accelerated Interactive Virtual View Synthesis
from Light Field Images**

**Hyeonjin Jung¹, Joungil Yun², Won-Sik Cheong²,
Youngmin Yi¹
1. University of Seoul (Korea), 2. Electronics and
Telecommunications Research Institute (Korea)*

We present a GPU based acceleration of a virtual view synthesis from multiple Light Field images. For the synthesis of a 2K virtual view from 24 images of the same resolution, we achieved 21.31 FPS using four Titan V GPUs with algorithmic optimizations, which corresponds 923 times of speedup.

**3DSA5/
3D5 - 3
18:00** **Accommodation Response to a Super-Multiview
Display Based on Time-Division Multiplexing
Parallax Barrier**

**Yuta Watanabe¹, Hideki Kakeya¹
1. University of Tsukuba (Japan)*

We have measured the focal accommodation response of viewers to a dense light field generated by time-division sextuplexing parallax barriers. We have confirmed that focal accommodation in front of or behind the display screen is induced as expected.

**3DSA5/
3D5 - 4
18:20** **An Autostereoscopic Display with Time-Multiplexed
Directional Backlight Using a Curved Lens Array**

**Garimagai Borjigin¹, Hideki Kakeya¹
1. University of Tsukuba (Japan)*

We propose an autostereoscopic display with a curved directional backlight unit. The proposed backlight unit composed of a curved lens array and dot-matrix light sources suppresses the influence of filed curvature. Thus the crosstalk level is reduced without adding an additional layer of lens.

Author Interviews

18:50 - 19:20

Friday, November 29

9:00-10:20	Small Hall
3D6/3DSA6: Distinguished Display	

Chair: Hideki Kakeya (Univ. of Tsukuba)
Co-Chair: Yuki Maeda (Parity Innovations)

3D6/3DSA6 - 1 **Invited Importance of Continuous Motion Parallax in Monocular and Binocular 3D Perception**
9:00 **Haruki Mizushima¹, Shiro Suyama¹*
 1. Tokushima University (Japan)

Motion parallax is one of the cues of human depth perception. It provides sufficient depth information even in monocular viewing, and improves degradation of stereoscopic depth by visual acuity difference of both eyes. In this paper we demonstrate importance of continuous motion parallax in monocular and binocular depth perception.

3D6/3DSA6 - 2 **Further Crosstalk Reduction Method with Eye-Tracking for Glasses-Free Stereoscopic Display in Both Portrait and Landscape Modes**
9:20 **Yukiya Yamaguchi¹, Hiroyuki Nakamura¹, Goro Hamagishi¹, Kayo Yoshimoto¹, Takuya Matsumoto², Kaoru Kusafuka², Hideya Takahashi¹*
 1. Osaka City University (Japan), 2. Kyocera Corporation (Japan)

We propose a crosstalk reduction method with an eye-tracking system for glass-free stereoscopic displays in both portrait and landscape modes. We can reduce crosstalk by dividing a screen into multiple areas and displaying black images on the subpixels observed simultaneously with both eyes in each divided area.

3D6/3DSA6 - 3 **Measurement of Moiré Patterns in 3D Display**
9:40 **Hea In Jeong¹, Seo Young Choi², Young Ju Jeong¹*
 1. Sookmyung Women's University (Korea), 2. Korea Institute of Lighting & ICT (Korea)

The moiré pattern can be produced when developing 3D displays which can lead to a 3D quality degradation. A measurement algorithm is required to estimate how much moiré pattern has occurred. In this paper, we propose a measurement algorithm that can calculate the moiré artifact generated in displays.



**3D6/
3DSA6 - 4
10:00**

GPU Acceleration of Algorithm to Design Directional Volumetric Display for Real-time Processing

**Daiki Matsumoto¹, Ryuji Hirayama^{2,3}, Naoto Hoshikawa⁴, Hirotaka Nakayama⁵, Tomoyoshi Shimobaba¹, Tomoyoshi Ito¹, Atsushi Shiraki¹*

1. Chiba University (Japan), 2. Research Fellow of the Japan Society for the Promotion of Science (Japan), 3. Tokyo University of Science (Japan), 4. National Institute of Technology, Oyama College (Japan), 5. National Astronomical Observatory of Japan (Japan)

In this study, we attempted GPU acceleration of an algorithm to design a directional volumetric display. As a result, the GPU implementation was up to 45 times faster than the CPU implementation. We also confirmed that the GPU implementation could cooperate with a person tracking system in real-time.

10:40-12:00

Small Hall

3DSA7/3D7: Virtual Reality 1

Special Topics of Interest on AR/VR and Hyper Reality

Chair: Tomohiro Tanikawa (The Univ. of Tokyo)
Co-Chair: Kenji Yamamoto (NICT)

**3DSA7/
3D7 - 1
10:40**

Invited Research and Development of Second Generation Virtual Reality

**Michitaka Hirose¹*

1. The University of Tokyo (Japan)

Novel VR technology (second generation VR) is introduced. After short review of technological advances to date, the author discusses benefits of VR in the areas of education and training that are expected as major application of VR technology.

**3DSA7/
3D7 - 2
11:00**

Invited Computer Vision, AI, AR Technology in Various Industries

**You-Kwang Wang^{1,2}, Hung-Ya Tsa², Chih-Hao Chuang³, Chien-Yu Chen¹*

1. National Taiwan University of Science and Technology (Taiwan), 2. OSENSE Technology Co. (Taiwan), 3. National Taiwan University (Taiwan)

AR technology is currently the most popular human-computer interaction interface. We get a spatial point cloud through computer vision and AI technology. And completed several projects according to different scene requirements.

**3DSA7/
3D7 - 3
11:20** ***Invited* Impressive 3D CG technologies for
Automotive HUDs with Wide FOV**
**Haruhiko Okumura¹, Takashi Sasaki¹, Aira Hotta¹,
Masahiro Sekine¹*
1. Toshiba Corp. (Japan)

We have applied various kinds of 3D CG technologies to increase the Field Of View (FOV) and visibility of displayed images for the monocular HUD. As a results, we successfully developed impressive 3D CG technologies for HUDs with wide FOV and high visibility.

**3DSA7/
3D7 - 4
11:40** ***Invited* Air Floating Image Based on a Dihedral
Corner Reflector Array**
**YUKI MAEDA¹*
1. Parity Innovations Co. Ltd. (Japan)

An air floating image and its applications based on a dihedral corner reflector array are introduced in this paper. An observer can see the air floating image by the naked eye and manipulate it by touching the air floating image using finger sensor system.

Also presented in Innovative Demonstration Session (see p. 278)

Author Interviews
 12:10 - 12:40



13:20-14:40	Small Hall
3D8/3DSA8: Virtual Reality 2	
<i>Special Topics of Interest on AR/VR and Hyper Reality</i>	

Chair: You Kwang Wang (Osense Technology)
 Co-Chair: Haruki Mizushima (Tokushima University)

3D8/3DSA8 - 1 13:20 ***Invited Service VR Training System: VR Simulator of Man-to-Man Service with Mental/Emotional Sensing and Intervention***

**TOMOHIRO TANIKAWA¹, Yuki Ban¹, Kazuma Aoyama¹, Eiji Shinbori², Shigeru Komatsubara², Michitaka Hirose¹*

1. The University of Tokyo (Japan), 2. Dai Nippon Printing Co., Ltd. (Japan)

In this paper, we introduce our concept and preliminary implementation of service VR training system. For training services, emotional skills are very important. Thus, our service VR simulator consist of mental/emotional sensing devices, estimating algorithm and intervention approaches.

3D8/3DSA8 - 2 13:40 ***A HMD for Users with Any Interocular Distance***

**Jung-Young Son¹, Hyoung Lee¹, Jung Kim¹, Beom-Ryeol Lee², Wook-Ho Son², Tetiana Venkel³*

1. Konyang University (Korea), 2. Electronics and Telecommunication Research Institute (Korea), 3. Chernivtsi University (Ukraine)

A prototype HMD which can automatically adjust interocular distance in the range of 55 mm to 75 mm in accordance with those of users. The main component of the HMD is a linear motor which shifts the modularized left and right eye's projection and camera optics in accordance with the measured interocular distance of a user. The total adjusting time of the distance is less than 10 seconds. The weight of the HMD is slightly less than 500 g and it is worn by a head belt. The HMD is somewhat heavy and unbalanced due to the distribution of the weight along the nose side but the head belt holds tightly the HMD on its place and it works well.

3D8/3DSA8 - 3 ***Withdrawn***

3D8/3DSA8 - 5L 14:00 ***Proposal for Light Field Mirage***

**Yoshiharu Momonoi^{1,2}, Koya Yamamoto², Yasuhiro Takaki²*

1. Samsung R&D Institute Japan (Japan), 2. Tokyo University of Agriculture and Technology (Japan)

Mirage, which consists of a pair of parabolic mirrors, is a well-known 360-degree display system. This study explored replacing the parabolic mirrors in Mirage with multiple flat-panel light field displays to realize Light Field Mirage. Rays emitted from 3D objects are reconstructed for 360-degree viewing. Preliminary experiments were conducted.

**3D8/
3DSA8 - 4
14:20** **Accuracy Verification of Visual Appearance
Acquisition Device of Non-Metallic Material Based
on Sparse SVBRDF**

**Tsung-Lin Lu¹, Yu-Lun Liu¹, Yu-Cheng Hsieh¹, Tzung-Han Lin¹*

*1. National Taiwan University of Science and
Technology (Taiwan)*

In this paper, we proposed a visual appearance acquisition device comparing with commercial product. Our device is capable of restoring the visual appearance for non-metallic materials based on spatially varying bidirectional reflectance distribution function (SVBRDF). A benchmark comparing to commercial product Radiant Vision is carried out to verify the reliability of the proposed device.

3D

15:00-16:20	Small Hall
3DSA9/3D9: Data Compression	

Chair: Hideaki Kimata (NTT)
Co-Chair: Miwa Katayama (NHK)

**3DSA9/
3D9 - 1
15:00** **Verification of Compression Architecture for 3DoF+
Immersive Video Delivery**

**Gwangsoon Lee¹, Hong-Chang Hong¹, Homin Eum¹,
Jeongil Seo¹*

1. ETRI (Korea)

This paper introduces a compression architecture for delivering 3DoF+ immersive video, which can be applied to existing video encoder. Specifically, this paper includes a pruning algorithm that can reduce the redundancy among multiple views while maintaining the higher image quality of rendered view.

**3DSA9/
3D9 - 2
15:20** **FDM-based Global Motion Estimation for Dynamic
3D Point Cloud Compression**

**SO MYUNG LEE¹, Li Cui¹, Tianyu Dong¹, Eun-Yong Chang², Jihun Cha², Euee S. JANG¹*

*1. Hanyang University (Korea), 2. Electronics and
Telecommunications Research Institute (Korea)*

In this paper, we propose a fast global motion estimation (GME) for dynamic 3D point cloud compression (PCC). We applied fast distortion measurement method(FDM) to replace and reduce the computational complexity of GME. The experimental results show that the proposed method is two times faster than MPEG V-PCC.

**3DSA9/
3D9 - 3
15:40**

MPEG Video-based Point Cloud Coding Based on JPEG

**Tianyu Dong¹, So Myung Lee¹, Euee S. Jang¹
1. Hanyang University (Korea)*

In this paper, we proposed a method to design MPEG Video-based point cloud compression (V-PCC) based on JPEG. We chose JPEG for its simplicity, low computational complexity, and ubiquitous support of encoder and decoder. For performance evaluation, we compared the proposed method with the HEVC-based V-PCC reference software.

**3DSA9/
3D9 - 4
16:00**

Fast Calculation Method for Computer-Generated Holograms Using Saccade Suppression by Lowering the Resolution Based on Fresnel Zone Plate Reduction

**WEI LINGJIE¹, Fumio Okuyama², Yuji Sakamoto¹
1. Hokkaido University (Japan), 2. New Generation Medical Center (Japan)*

Saccade is a very rapid movement of our both eyes that transfer between two or more gazing center, with almost no sensitivity of visual information from the eyes to the brain. In this study, it is possible to reduce the computational complexity of CGH by lowering the resolution of the CGH when the saccade occurred.

Author Interviews
16:30 - 17:00

Workshop on Applied Vision and Human Factors

Wednesday, November 27

13:40-13:45	Mid-sized Hall A
Opening	

Opening Remarks

13:40

Shin-ichi Uehara¹, 1. AGC (Japan)

Wednesday, November 27

13:45-15:10	Mid-sized Hall A
VHF1: Image Quality and Measurements	

Chair: Kenichiro Masaoka (NHK)

Co-Chair: Keita Hirai (Chiba Univ.)

VHF1 - 1 A Fundamental Evaluation of Visual Resolution of Displays Considering Different Sub-Pixel Structures

13:45

**Daisuke Nakayama¹, Midori Tanaka¹, Takahiko Horiuchi¹*

1. Chiba University (Japan)

We conducted a psychometric evaluation of different display sub-pixel structures. Our assessments of the RGB sub-pixel structure showed that the vertical visual resolution was higher than the horizontal visual resolution. In addition, the visual resolution itself differed according to the sub-pixel structures.

VHF1 - 2 Perceptually Optimized Image Enhancement for OLED Displays in Power-constrained Conditions

14:05

**Hsuan-Chi Huang¹, Pei-Li Sun¹*

1. National Taiwan University of Science and Technology (Taiwan)

A psycho-visual experiment was conducted to optimize the parameters of an image enhancement model for OLED displays to maintain image quality in power-constrained conditions.

**VHF1 - 3 Estimation of Equivalent Conditions for Display
14:25 Sparkle Measurement**

**Makio Kurashige¹, Gen Furui¹, Kazutoshi Ishida¹,
Shumpei Nishio¹, Toshiyuki Nakai¹, Hiroko Suzuki¹,
Masayuki Tsunekawa¹, Yukimitsu Iwata¹,
Norinaga Nakamura¹*

1. Dai Nippon Printing Co., Ltd. (Japan)

Various measurement conditions of sparkle contrast were analysed in terms of the equivalent area of the resolution spot of the imaging system on the display. The results show the possibility to achieve the equivalent measurement conditions among different measurement distance, F-number and focal length of imaging lens.

**VHF1 - 4L Repeatability and Reproducibility Considerations
14:45 for BlackMURA Measurements**

**Ingo Rotscholl¹, Tobias Porsch¹, Udo Krüger¹*

1. TechnoTeam Bildverarbeitung GmbH (Germany)

The Uniformity measurement standard for Displays, which is used for automotive applications, describes precise setup and alignment procedures to ensure reproducible measurement results. However, the influences of the tested device and the ILMD are not considered in detail. This contribution shows experiments and simulations to estimate these influences as well.

15:20-16:45

Mid-sized Hall A

**VHF2: Ergonomics for Automotive Applications
*Special Topics of Interest on Automotive Displays***

Chair: Yoshie Imai (Mitsubishi Elec.)
Co-Chair: Yukio Endo (AGC)

**VHF2 - 1 *Invited* Application of Visibility Index Function for
15:20 Driving**

**Katsunori Okajima¹*

1. Yokohama National University (Japan)

We demonstrate VIF (Visibility Index Function) can be applied for precisely simulating and improving the visibility of driving environments as well as human-interface devices in driving. The VIF is convenient to design information display and traffic signs with considering visibility while driving.

**VHF2 - 2 Effect of External Human Machine Interface (eHMI)
15:45 of Automated Vehicle on Pedestrian's Recognition**

**Naoto Matsunaga¹, Tatsuru Daimon¹, Naoki Yokota¹,
Satoshi Kitazaki²*

*1. Keio University (Japan), 2. National Institute of
Advanced Industrial Science and Technology (Japan)*

The interaction between a pedestrian and an automated vehicle equipped with an external human machine interface at an unsignalized crosswalk is discussed. The external human machine interface has the potential to provide an effective communication cue from which the pedestrian can judge whether the automated vehicle is yielding to them.

**VHF2 - 3 Influence of Cabin Vibration on Driver's Depth
16:05 Perception and Subjective Conviction When Using
Automotive 3D Head-Up Display -Basic Study on the
Relationship between Degree of Correction and
Driver's Recognition-**

**Kazuki Matsunaga¹, Tatsuru Daimon², Ryo Noguchi¹,
Ken'ichi Kasazumi³, Toshiya Mori³*

*1. Graduate School of Keio (Japan), 2. University of
Keio (Japan), 3. Panasonic Corporation (Japan)*

This study discusses the driver's depth perception and subjective conviction to be corrected for in the display contents of an automotive three-dimensional head-up display, such as navigation arrows, based on the levels of the basic correction method used to reduce the effect of car vibration due to various road surfaces.

**VHF2 - 4 The Evaluation for Visibility of a Back Image on a
16:25 Transparent Display**

**Naruki Yamada¹, Yoshinori Iguchi¹, Yukihiro Tao¹*

1. AGC Inc. (Japan)

Transparent display is useful device for some applications but has a privacy issue that a back image appears on the opposite side to the display image. We investigated the condition human cannot see a back image.

17:00-18:30

Mid-sized Hall A

VHF3/DES3: Virtual Reality

Special Topics of Interest on AR/VR and Hyper Reality

Chair: Takashi Shibata (Tokyo Univ. of Social Welfare)
Co-Chair: Johan Bergquist (Consultant)

VHF3/ DES3 - 1 ***Invited VR Headset with Human-Eye Resolution***
17:00 *Osku Sahlsten¹
1. Varjo Technologies Oy (Finland)

With current display manufacturing methods, it would be very hard to produce a single near eye display that offers 60 pixels / degree resolution over the whole field of view and is small enough to fit into the headset. In case of greater than 90-degree field of view, basically 6k x 6k panel would be required. With the high refresh rates of virtual reality applications, this would mean also very large data transfer rates and high rendering load on GPU's. Varjo overcome these challenges by composing the single eye image from two different display sources, while minimizing the effect on total rendering load. High angular resolution is used on the area where it is mostly needed. Precise analysis of displays with geometrical- and optical adjustments is needed to blend the 2 separate images to a one uniform scene.

Also presented in Innovative Demonstration Session (see p. 280)

VHF3/ DES3 - 2 ***Invited Metrology Challenges in Near to Eye Display Characterization for Human Factors Correlation***
17:25 *Richard Lee Austin¹, Bruce Denning¹, John Penczek²
1. Gamma Scientific (United States of America), 2. University of Colorado, Boulder (United States of America)

We present metrology challenges and solutions to measure Near Eye Displays performance parameters that can produce visual discomfort and headaches. Accurate measurement data correlates to what the eye perceives when the entrance pupil of the Light Measurement Device (LMD) matches the location and pointing direction of the display user's eye.

VHF3/ DES3 - 3 ***Optic Flow, but Not Retinal Flow, Is Essential to Induce VR Sickness***
17:50 *Hiroyasu Ujike¹, Kei Hyodo¹, Mitsunori Tada¹, Koudai Ito¹
1. National Institute of Advanced Industrial Science and Technology (Japan)

We conducted an experiment measuring VR sickness using HMD, manipulating optic flow and retinal flow in three conditions. The results showed that sickness scores increased according to the amount of optic flow, but not of retinal flow, indicating that optic flow, not retinal flow, is essential to induced VR sickness.

**VHF3/
DES3 - 4
18:10** **Color Perception Comparison of Scene Images
between Head-Mounted Display and Desktop
Display**

**Tomonori Nishimura¹, Keita Hirai¹, Takahiko Horiuchi¹
1. Chiba University (Japan)*

In this paper, subjective evaluation experiments using scene images were conducted to investigate the difference of luminance and chroma perception between an HMD and a desktop display. The results showed that the perception of luminance and chroma of the HMD were higher compared with those of the desktop display.

Author Interviews
18:30 - 19:00



Thursday, November 28

9:00-10:20	Small Hall
3D4/VHF4/3DSA4: Illusion	

Chair: Sumio Yano (Shimane University)
Co-Chair: Yuzo Hisatake (Shizuoka Univ.)

3D4/VHF4/ 3DSA4 - 1 **Invited Innovative Mobile Force Display: Buru-Navi**
9:00 **Hiroaki Gomi¹, Sho Ito¹, Ryoma Tanase¹
1. NTT Communication Science Labs. (Japan)*

Humans capture the environmental world not only by vision but also by somatosensory information. Here we introduce several types of mobile force-display gadgets 'Buru-Navi' recently developed, and showcase some application trials for pedestrian navigation and for enhancing immersive sensation along a video scene.

3D4/VHF4/ 3DSA4 - 2 **Invited Displaying Deformation of Virtual Objects
Using Visuo-Haptic Interaction**
9:20 **Yuki Ban¹
1. The University of Tokyo (Japan)*

We developed the visuo-haptic shape display system with which users can deform virtual objects dynamically. Our system senses how the force is applied to the grasping object, and deforms the virtual grasping object and the virtual hands according to the direction and size of the force.

3D4/VHF4/ 3DSA4 - 3 Invited Real-World Implementations of Visual Illusions by Using Augmented Reality Techniques
9:40

**Takahiro Kawabe¹*

1. NTT Communication Science Laboratories (Japan)

Visual illusions refer to perceptual experiences wherein the appearance of objects and scenes is distorted. By taking advantage of the illusion which is often interpreted as undesired elements in perception, our technique can offer visual experiences which are not produced on the basis of the previous techniques.

3D4/VHF4/ 3DSA4 - 4 Gloss Enhancement beyond Projector Performance Using the Glare Illusion
10:00

**Shinji Nagata¹, Toshiyuki Amano¹*

1. Wakayama University (Japan)

The glare illusion is a well-known illusory perception in which a region appears brighter than its actual luminance when surrounded by a gradation of luminance. We propose a method of enhancing gloss beyond projector performance using this glare illusion. The effectiveness of the proposed method is confirmed by comparing it with the proposed and conventional method.

Author Interviews

10:40 - 11:10

14:30-17:00

Main Hall

Poster VHFp1: Image Quality

VHFp1 - 1 The Study on New Evaluation Index of Color MPRT (Motion Picture Response Time) Considering Human Sensitivity Characteristic

**JINYONG KIM¹, Seungwon Jung¹*

1. LG Display (Korea)

In this study, we introduce a new evaluation index for color motion blur characteristic using Color MPRT (Motion Picture Response Time). We have already introduced the Color MPRT in SID 2019, and this study proposes a new evaluation index for C-MPRT based on the C-MPRT evaluation method. When humans see the display, Motion blur is a very important factor about image quality. In the past, we were considered only the luminance component when considering the motion blur characteristics of the display. However, when evaluating the performance of the display, the motion blur characteristic of the color is also an important factor.

VHFp1 - 2 Perceptual Artifacts on the Liquid Crystal Displays with a Mini-LED Backlight

**Zhenping Xia¹, Fuyuan Hu¹, Cheng Cheng¹*

1. Suzhou University of Science and Technology (China)

The halo artifacts on the liquid crystal displays with a mini-LED backlight needs to be reduced to an invisible level to achieve a better high dynamic range display system. The evaluation model and visibility threshold of the artifacts are established and investigated respectively through systematic perception experiments.

VHFp1 - 3L The Color Difference Modification between Direct View and Side View after Color Adaptation on LCD

**Qi-Lun Wu¹, Chien-Wen Chen¹*

1. AU Optronics Corporation (Taiwan)

In this study, the color adaptation phenomenon was considered to adjust the CIE dE₀₀ formula, and a direct and side view color difference formula on liquid crystal display (LCD) was established. From the results of psychophysical experiments, the formula for considering color adaptation has a high correlation ($R^2 = 0.86$).

VHF

14:30-17:00

Main Hall

Poster VHFp2: Physiological and Psychophysical Factors

VHFp2 - 1 The Subjective Evaluation Experiment for the Estimation of Helmholtz-Kohlrausch Effect under the Ambient Lighting Conditions

**Kota Nakagawa¹, Hisakazu Aoyanagi², Hiroaki Takamatsu², Yoshifumi Shimodaira¹, Gosuke Ohashi¹*

1. University of Shizuoka (Japan), 2. NEC Display Solutions, Ltd (Japan)

The purpose of this study is to carry out the subjective evaluation experiment for natural images to measure the magnitude of Helmholtz-Kohlrausch effect under ambient lighting conditions. We found that the magnitude of the H-K effect and the saturation tends to decrease as the brightness of the environment increases.

VHFp2 - 2 Examination of Memory Retention Evaluation System Easy to Use for Elderly Using Touch Panel People

**Takatsugu Sugano¹, Muneo Yamada¹, Tomoaki Nakano¹*

1. Meijo University (Japan)

It is very important to evaluate the memory retention of elderly people in daily life. OSPAN is effective as method for early detection of deterioration in memory ability, but has problems in usability. In this research, we improve the usability of OSPAN and propose new evaluation system for elderly people.

VHFp2 - 3 Visual Discomfort of Transparent LCDs for Mixed Reality Applications

*Yen-Min Chen¹, *Pei-Li Sun¹*

1. National Taiwan University of Science and Technology (Taiwan)

In mixed reality applications of flat panel transparent displays, binocular rivalry is the main reason causing visual discomfort. A series of psycho-visual experiments were conducted to scale the visual discomfort of a transparent LCD in different viewing conditions and a masking method is introduced to reduce the unpleasant ghosting effect.

VHFp2 - 4 A Mental Fatigue Measurement System Based on Face Images

**Yuki Kurosawa¹, Miho Shinohara¹, Shinya Mochiduki¹, Yuko Hoshino¹, Mitsuho Yamada¹*

1. Tokai University (Japan)

In this study, we focused on eye movements during gaze and lip movements during speech, and examined a measurement method of mental fatigue. Face images can be taken easily with a camera, and eye and lip movements are used as an indicator of objective emotions and physical condition.

VHFp2 - 5 CdS Photo-Sensor Simulate the Signal Transmission for Display Evaluation

*Chung-Jen Ou², *Fan-Ru Lin¹, Wei-Chia Su¹*

1. National Changhua University of Education (Taiwan), 2. Hsiuping University of Science and Technology (Taiwan)

Retina model is being constructed by the microchips with the CdS sensor for the pixel signal. Configuration can be applied to the interactive display environment between the surrounding lightings and the contrast of the display. Information on the response time and the criterions to maintain the image qualities can be model.

VHFp2 - 6L Proposal for a Database of Gaze Points When Looking at Paintings

**Yusuke Nosaka¹, Takuya Sarugaku¹, Shinya Mochizuki¹, Mitsuho Yamada¹*

1. Tokai University (Japan)

By constructing a database of eye movements and gaze point distribution when looking at paintings, it is possible to clarify the relationship between the artist's intention and the viewer's eye movement. Here, we introduce our experimental method and initial experimental results.

VHFp2 - 7L Study on Incongruence of Binocular Images for Blue Based on Occlusion Avoidance Behavior When Gazing at the Rim of a Column

**Shinya Mochiduki¹, Yukina Tamura¹, Miho Shinohara¹, Hiroaki Kudo², Mitsuho Yamada¹*

1. Tokai University (Japan), 2. Nagoya University (Japan)

Our experimental method that can examine only whether blue is involved in the detection of incongruence of binocular retinal images during occlusion perception, and describe the experiment. Result, no convergence eye movement occurred during occlusion perception, suggesting that blue processed by the koniocellular couldn't detect incongruence of binocular retinal images.

14:30-17:00

Main Hall

Poster VHFp3/INPp2: Ergonomics of Interaction Technologies

VHFp3/INPp2 - 1 Wearable Stick-Slip Display on Fingertip to Reproduce Rubbing Sensation

**Honoka Haramo¹, Vibol Yem¹, Yasushi Ikei¹, Makoto Sato¹*

1. Tokyo Metropolitan University (Japan)

We developed a wearable stick-slip display using a rotating cylindrical contactor to reproduce friction sensation during rubbing a material. This paper introduces the mechanism of our device and a method to reproduce sensation of rubbing a silicon rubber or a wood based on the data measured by a force sensor.

Also presented in Innovative Demonstration Session (see p. 280)

VHFp3/INPp2 - 2 The Research of Touch Performance for Huge Displays

**Kyungmok Mo¹, Sinhu Choi¹, Seungwon Jung¹*

1. LG DISPLAY (Korea)

In this study, we research the major touch performance evaluation methods for touch-applied products on large displays and examine the studies that reflect cognitive evaluation and visual characteristics. Based on this, I would like to suggest an appropriate quantitative indicator of touch performance by investigating the environment where large touch products are utilized.

VHFp3/
INPp2 - 3

**A New Athlete Performance Analysis Method Using
4K Video and Wireless Eye Movement Measurement
Device**

**Takuya Sarugaku¹, Yasuyoshi Kobayashi¹,
Reiko Koyama¹, Shinya Mochiduki¹, Mitsuho Yamada¹*

1. Tokai University (Japan)

It is thought that analyzing line-of-sight movement during sports may provide insight into exceptional athletic skill. In this study, we propose a method to analyze the athlete's performance using the athlete's line of sight measured by a wireless eye movement measurement device, and his/her movement taken by 4K images.

14:30-17:00

Main Hall

**Poster VHFp4/DESp1: Ergonomics and Display
Electronics**

VHFp4/
DESp1 - 1

**Spatio-Temporal LED Driving for Subjective Super-
Resolution of Grayscale Images**

**Kojiro Matsushita¹, Toyotaro Tokimoto², Kengo Fujii¹,
Hirotugu Yamamoto^{1,3}*

*1. Utsunomiya University (Japan), 2. DaoApp
Technology Co, Ltd. (Taiwan), 3. JST, ACCEL (Japan)*

We have implemented a novel LED driving circuit to evoke subjective super-resolution effect on grayscale images by use of FPGA. An 8-bit grayscale image is oversampled and coded into multiple subframes, which are shown on an LED panel at a high frame rate. We have confirmed subjective super-resolution.

I-DEMO

(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters

Thursday, Nov. 28, 2019

11:40 – 15:40

Main Hall (1F)

Sapporo Convention Center

14:30-17:00

Main Hall

Poster VHFp5/3DSAp3: Human Factors

VHFp5/ 3DSAp3 - 1 Fundamental Head Movement and Gaze Analysis on the Influence of Surround Sound on People

**Yasuyoshi Kobayashi¹, Shinya Mochiduki¹, Mitsuho Yamada¹*

1. Tokai University (Japan)

Recent advances in sound technology have been remarkable in conjunction with high definition images. The possibility of an objective evaluation of synergistic effect of image and two kinds of sound was examined based on head and eye movement.

VHFp5/ 3DSAp3 - 2 Simple Stereoscopic Image System Based on Fresnel Plate

*Chung-Jen Ou², *Shang-Ru Yang¹, Wei-Chia Su¹*

1. National Changhua University of Education (Taiwan), 2. Hsiuping University of Science and Technology (Taiwan)

A simple configuration for reflective floating images by using the Fresnel plate is demonstrated. The virtual images can be generated by active and passive strategies. Results show that the method can generate a scenario for small meeting discussion. Mathematical formulation to eliminate distortion is addressed.

VHFp5/ 3DSAp3 - 3L Development of One-Dimensional Integral Photography

**Akira Hasegawa¹, Sumio Yano¹*

1. Shimane University (Japan)

A one - dimensional integral photograph showing only horizontal parallax was developed. And, it was possible not only to display the object arranged in the computer by one-dimensional integral photography, but also to capture and display the real object. In addition, evaluation of depth perception and measurement of accommodation response were performed using a prototype one-dimensional integral photograph.

14:30-17:00

Main Hall

Poster AISp2/VHFp6: Deep Learning for Image Quality

**AISp2/
VHFp6 - 1 Automatic Selection of Preferable Tone-Mapping
Method Based on Deep Learning**

**Hirofumi Sasaki¹, Keita Hirai¹, Takahiko Horiuchi¹*

1. Chiba University (Japan)

The preference of a tone-mapped HDR image appearance depends on an applied Tone-Mapping method and an input scene content. In this paper, based on a deep learning technique, we propose a system to automatically select a Tone-Mapping method that provides a preferable appearance of an input HDR image.

Also presented in Innovative Demonstration Session (see p. 278)

17:20-18:40

Mid-sized Hall A

VHF5: Physiological and Psychophysical Factors

Chair: Hiroyasu Ujike (AIST)

Co-Chair: Masamitsu Harasawa (NHK)

**VHF5 - 1 17:20 Invited A Modeling Approach to Investigate the
Relationship Between Motion Sickness Severity and
Visual Motion**

**Akira Tanaka¹, Norihiro Sugita², Makoto Yoshizawa²,
Tomoyuki Yambe²*

*1. Fukushima University (Japan), 2. Tohoku University
(Japan)*

In this study, dynamic characteristics between image motion and severity of visually induced motion sickness (VIMS) was modeled as a Hammerstein model, which consists of a static nonlinear function followed by a linear system. The results indicate the change in subjective VIMS score may be estimated from image motions.

VHF5 - 2 Withdrawn

VHF5 - 4L
17:45

Blue Light Promotes Heart Rate Recovery After Exercise

**Emi Yuda¹, Yutaka Yoshida², Kento Yamamoto³, Junichiro Hayano⁴*

1. Tohoku University Graduate School of Engineering (Japan), 2. Nagoya City University Graduate School of Art and Engineering (Japan), 3. University of Tsukuba Graduate School of Sports Medicine (Japan), 4. Nagoya City University Graduate School of Medical Sciences (Japan)

Today, various sports and competitions are performed under artificial lighting, whether indoors or outdoors. We studied if the color of the lighting affects athletic ability. Comparing orange light that did not contain melanopsin stimulating component, blue light rich in melanopsin stimulating components prompted heart rate (HR) recovery after submaximal exercise.

VHF

VHF5 - 3
18:05

Immanent Dichromatic in Trichromatic Observer: Based on MDS Analyses of R-G Neutral- and Y-B Only Changed- Stimuli Observation Results

**Shoko Hira¹, Asuka Sako¹, Ryusuke Uto¹, Kota Kanari², Minoru Ohkoba², Tomoharu Ishikawa², Miyoshi Ayama², Sakuichi Ohtsuka¹*

1. Kagoshima University (Japan), 2. Utsunomiya University (Japan)

Immanent dichromatic in color normal observers is investigated by MDS (Multidimensional-Scaling). The results show that (1) color-constellations yielded when observing R-G neutral- and Y-B only changed-stimuli strongly evidence concave-shaped like dichromatic, whereas (2) those gained when observing Y-B neutral- and R-G only changed-stimuli evidence oval-shape of saturation-brightness.

VHF5 - 5L
18:25

Effects of Motion Sickness on Driving Tasks

**Daisuke Sugiyama¹, Shigehito Tanahashi¹*

1. Niigata University (Japan)

We investigated how the effect of motion sickness on the succession of the driving tasks of the car by conducting two experiments. The results of experiment 1 suggested that the seriousness of motion sickness in no driving tasks condition was higher than that in driving tasks condition.

Author Interviews

18:50 - 19:20

Friday, November 29

13:20-14:45	Mid-sized Hall A
VHF6: Ergonomics for Display Applications I	

Chair: Nobuyuki Hiruma (NHK-ES)
 Co-Chair: Gosuke Ohashi (Shizuoka University)

VHF6 - 1 *Invited* Trends in Human-Centric Office Design
13:20

**Michihiko Okamoto¹, Takao Kiyoshige¹, Toru Ohkawa¹,
 Taishirou Iwasaki¹, Yousuke Shimoda¹
 1. Takenaka Corporation (Japan)*

Recently, many companies have dramatically changed workstyle and workplace of their office workers. Specially for achieving high productivity, providing high value, and employing talented people. Hot keywords are Human-Centric, ABW (Activity Based Working), wellness of employees and biophilia. Takenaka Corporation introduce the latest office trends.

VHF6 - 2 *Invited* Development and IEC Standardization of
13:45 Electronic Display for Elevator and Escalator

**Junkai Li¹, Huixun Li², Weixiang Xue³
 1. Zhejiang Usenc Technology Co.,Ltd (China), 2.
 CANNY ELEVATOR CO.,LTD (China), 3. Otis Electric
 Elevator Co., Ltd (China)*

This paper introduces the industry application status of electronic display for elevator and escalator. The issues of current technology and developing trend are discussed. The latest standardization status in ISO, CEN, CEA and IEC TC110 will also be introduced.

VHF6 - 3 Educational Effectiveness and Learner Behavior
14:10 When Using Desktop-Style VR System

**Takashi Shibata¹, Erika Drago², Takayuki Araki³,
 Tatsuya Horita⁴
 1. Tokyo University of Social Welfare (Japan), 2.
 Musashino University Chiyoda High School (Japan),
 3. Musashino University (Japan), 4. Tohoku University
 (Japan)*

An experimental class using a desktop-style virtual reality system was conducted in a school to examine the educational effectiveness and learner's behavior. The results show that sharing educational materials in 3D promotes discussion in group work.

VHF6 - 4L
14:30

Cylindrical Transparent Display with Hologram Screen

**Tomoharu Nakamura¹, Akira Tanaka¹, Tsuyoshi Kaneko¹, Masanori Iwasaki¹, Takayuki Kurihara¹, Noriyuki Kato¹, Koji Kuramoto¹, Hidehiko Takanashi¹, Yuji Nakahata¹*

1. Sony Corporation (Japan)

We have developed a hologram screen with higher transparency and higher diffraction efficiency compared to conventional transparent screens. We have applied this screen to a cylindrical transparent display, and propose a display system creating a feeling of actually there reality to 2D images with the combination of sensing technology using multiple high-speed cameras.

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)
Sapporo Convention Center

SPECIAL EVENT

“Sensory Illusion”

Exhibition:

Wednesday, Nov. 27 – Friday, Nov. 29, 2019
Main Hall (1F)

Special Talks:

Wednesday, Nov. 27, 2019
18:30 – 19:10
Mid-sized Hall A (1F)

15:00-16:25

Mid-sized Hall A

VHF7: Ergonomics for Display Applications II

Chair: Nobuyuki Hiruma (NHK-ES)
Co-Chair: Shin-ichi Uehara (AGC)

**VHF7 - 1 *Invited* Standardization of Ergonomics
15:00 Requirements for 'Dynamics Sign' in ISO**

**Hiroshi Watanabe¹, Hiroyasu Ujike¹, Nana Itoh¹,
Ken Sagawa¹, Reiko Sakata², Akiko Imahashi²,
Naoki Furuhashi², Masami Aikawa²
1. AIST (Japan), 2. Mitsubishi Elec. (Japan)*

Dynamic signs are a developing technology that provide warning and guidance information using images that change spatially and temporally depending on the situation. We introduce our ISO-related efforts toward standardization of dynamic signs from the viewpoint of visibility based on the results of ergonomics studies.

VHF7 - 2 Withdrawn

**VHF7 - 4L Development of an 8K-class 3D Shooting System for
15:25 Microscopic Surgery and the World's First Shooting**

**Taiichiro Kurita¹
1. NHK Technologies, Inc. (Japan)*

An 8K-class 3D shooting system for microscopic surgery is developed. The system equips two small UHD cameras with 5120 (H) x 4320 (V) pixels and 59.94 Hz frame rate. The world's first shooting using the system was conducted and fine 8K3D video of the surgery is successfully displayed after editing.

**VHF7 - 3 Computational Classification of Texture Contents in
15:50 the Shitsukan Research Database**

**Norifumi Kawabata¹
1. Tokyo University of Science (Japan)*

In this paper, we used the Shitsukan Research Database from Web for free of charge. First, we generated texture evaluation images by H.265/HEVC. We assessed the generated images by texture analysis, and discussed results. Next, based on experimental results, we considered for classification method of texture types by SVM.

**VHF7 - 5L Advanced Reflectionless Technology for Reflected
16:10 Glare Reduction**

**Yu Hung Chen¹, Kai Chieh Chang¹
1. AU Optronics Corporation (Taiwan)*

In this paper, we propose the new surface treatment technology (A.R.T.) that can increase ACR and GKR significantly under complex illumination. A subjective experiment of visual performance is executed that the difference of subjective rating results of new and commonly surface treatments of legibility and comfort are significant under specular illumination.

Author Interviews

16:30 - 17:00

Supporting Organizations:

Technical Committee on Electronic Information Displays (EID),
Electronics Society, IEICE
Technical Group on Information Display, ITE



Workshop on Projection and Large-Area Displays and Their Components

Wednesday, November 27

13:40-13:45

Room 108

Opening

Opening Remarks

13:40

*Satochi Ouchi¹, Hirotsugu Yamamoto², 1. Hitachi (Japan),
2. Utsunomiya Univ. (Japan)*

13:45-15:05

Room 108

PRJ1/FMC1: AR/VR

Special Topics of Interest on AR/VR and Hyper Reality

Chair: Satoshi Ouchi (Hitachi)

Co-Chair: Hirotsugu Yamamoto (Utsunomiya Univ.)

PRJ1/

FMC1 - 1

13:45

Invited Modeling, Algorithm, and Implementation of Resolution-Tripled Near-Eye Light Field Displays

**Zong Qin¹, Jui-Yi Wu¹, Ping-Yen Chou¹, Cheng-Ting Huang¹, Yu-Ting Chen¹, Yi-Pai Huang¹*

1. National Chiao Tung University (Taiwan)

A physical model incorporating all factors affecting the retinal image formation in a near-eye light field display is proposed, based on which, an algorithm recombining subpixels across elemental images to nearly triple the resolution is developed. Finally, an e-shifting method is suggested to further enhance the resolution to 30 pixels-per-degree.

PRJ1/

FMC1 - 2

14:05

Possibility of Deblurring Aerial Image Based on Deconvolution Processing

**Hayato Kikuta^{1,2}, Hirotsugu Yamamoto^{2,3}*

1. Mitsubishi Electric Corp. (Japan), 2. Utsunomiya University (Japan), 3. ACCEL (Japan)

This paper proposes a deblurring an aerial image formed with aerial imaging by retro-reflection. We have measured the point spread function (PSF) according to the incident angle to the retro-reflector. Simulated results show possibility of deblurring the aerial image by applying the deconvolution processing based on the obtained PSF.

**PRJ1/
FMC1 - 3
14:25** **Volume-Holographic Multiplexed-Mirror Waveguide
for Head-Mounted Display**
**Takeru Utsugi¹, Mayumi Sasaki², Kazuhiko Ono²,
Yukinobu Tada²*
*1. Hitachi, Ltd. (Japan), 2. Hitachi-LG Data Storage,
Inc. (Japan)*

As a waveguide for a head mounted display, we propose a volume-holographic multiplexed-mirror waveguide, which could achieve high luminance efficiency, wide field of view and excellent transparency. We clearly demonstrate that high performance waveguide is achieved by the combination of multiplex-recorded hologram and broad wavelength light sources.

**PRJ1/
FMC1 - 4
14:45** **High See-Through and High Efficiency Waveguide
for Head Mounted Displays and Waveguide
Evaluations**
**Ryuji Ukai¹, Takuma Kuno¹, Toshiteru Nakamura¹,
Masahito Uchiyama¹, Satoshi Ouchi¹*
1. Hitachi, Ltd. (Japan)

We have developed head mounted displays with high see-through property and high luminance which could be utilized outside safely without dimming glasses. We specified required performance threshold and developed beam-splitter-array waveguide to achieve the requirements. We also established versatile waveguide measurement method applicable to different-type waveguides.

Author Interviews
18:30 - 19:00

I-DEMO (Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters
Thursday, Nov. 28, 2019
11:40 – 15:40
Main Hall (1F)
Sapporo Convention Center

Thursday, November 28

9:00-10:20	Room 108
PRJ2: Optical Components	

Chair: Hidekazu Hatanaka (USHIO)

Co-Chair: Juiwei Pan (Chiao Tung Univ.)

PRJ2 - 1 *Invited* Watt-class Operation of GaN-based Blue and Green Laser Diodes

9:00

**Hideki Watanabe¹, Yusuke Nakayama¹, Yukio Hoshina¹, Masahiro Murayama¹, Yuichiro Kikuchi², Yukihisa Kogure², Yasuhiro Kadowaki², Koichi Mizutani³, Takahiro Koyama¹, Noriyuki Fuutagawa¹, Hidekazu Kawanishi¹, Toshiya Uemura³, Katsunori Yanashima¹*

1. Sony Corporation (Japan), 2. Sony Semiconductor Manufacturing Corporation (Japan), 3. Toyoda Gosei Co., Ltd. (Japan)

Visible laser diodes have recently attracted a great deal of attention as light sources for various display and lighting applications. In this paper, recent progress in green and blue lasers developed at Sony, which realize watt-class output power, are reported.

PRJ2 - 2 Laser Beam Modulation with a Fast Focus Tunable Lens for Speckle Reduction in Laser Projection Displays

9:20

*Zequan Jian¹, *Zhaomin Tong¹, Yifei Ma¹, Mei Wang¹, Suotang Jia¹, Xuyuan Chen^{1,2}*

1. Shanxi University (China), 2. University of Southeast Norway (Norway)

We propose a laser speckle reduction method using a fast focus tunable lens (FTL). Different laser beams are generated after modulating the FTL. Thus, when the laser beams are used to illuminate a diffuser, various speckle images are obtained, and the summed speckle images yield a speckle image with reduced speckle contrast ratio.

PRJ2 - 3 Achromatic Total Internal Reflection Prism in DLP Projection System

9:40

**Ya-Chi Lu¹, Jhong-Syuan Li¹, Kao-Der Chang², Shie-Chang Jeng¹, Jui-Wen Pan¹*

1. National Chiao Tung University (Taiwan), 2. Industrial Technology Research Institute (Taiwan)

Two different types of the achromatic TIR prism set are designed to mini projector. Type1 prism set is the first prism with a small Abbe number material stacked with the second prism with a large Abbe number material. Type2 prism set is an opposite design to Type1 prism set.

PRJ2 - 4 High Power Red Laser Diode for Projector Light Source

10:00

**Masato Hagimoto¹, Shintaro Miyamoto¹, Yuki Kimura¹, Haruki Fukai¹, Manabu Hashizume¹, Satoshi Kawanaka¹*

1. USHIO OPTO SEMICONDUCTORS, INC. (Japan)

We developed 638nm and 642nm red laser diodes with 3.5W pulse / 2.4W CW operation. The 3.5W pulsed operation and wall plug efficiency of 43% are the world's highest in 638nm to the best of our knowledge. The lineups of multiple wavelengths are ideal as red light sources for projector.

10:20-10:38

Room 108

Short Presentation PRJp1: Projection Technologies

All authors of poster papers for the PRJp1 session will give 3-minute oral presentations with no discussion time.

Author Interviews

10:40 - 11:10

PRJ

14:30-17:00

Main Hall

Poster PRJp1: Projection Technologies

PRJp1 - 1 Developing an Augmented Reality System of Nail Make-up

**Yen-Ju Chou¹, Tzung-Han Lin¹*

1. National Taiwan University of Science and Technology (Taiwan)

We developed system for AR application. In practice, we utilized color to extract nail area. Additional color projector, which is well calibrated, will cast desired patterns on nails. As a result, augmented and vivid patterns on nail are carried out by our formulated algorithm. It's useful for customers and nail-salon.

PRJp1 - 2 Forming Two-View Aerial Signage Over an LED panel by Use of a Retro-Reflective Slit-Array

**Daiki Nishimura¹, Hirotsugu Yamamoto^{1,2}*

1. Utsunomiya university (Japan), 2. JST, ACCEL (Japan)

We propose an optical system for two-view aerial signage over an LED panel. A retro-reflective slit array and a beam splitter are placed in front of the LED panel and form the aerial image over the LED panel. The aerial signage shows different apparent images depending on the viewing directions.

PRJp1 - 3 Image Analysis by Drone System for Environmental Inspection

*Chung-Jen Ou², *Ming-Jun Liu¹, Der-Chin Chen¹*

1. Feng-Chia University (Taiwan), 2. Hsiuping University of Science and Technology (Taiwan)

This report explores the application of the aerial image system that integrated with the micro-recorder or micro-projector for environmental inspection. Corresponding display technology, combined with drones and artificial intelligence judgment criteria, can improve the application and complete the contribution of image display technology for cross-discipline application.

PRJp1 - 4 Color-Changeable and Touchable Volumetric Display by Projection of Aerial Plasma Emission

**Shun Miura¹, Kota Kumagai¹, Yoshio Hayasaki¹*

1. Utsunomiya University (Japan)

Projection of volumetric images with aerial plasma voxels formed by femtosecond laser pulses was performed with two parabolic mirrors with a variable color filter. The projection enables us to change the color of voxels and touch the voxels safely.

PRJp1 - 5L Exploring the Combination of Optical Components Suitable for the Large Device to Form Aerial Image by AIRR

**Masaki Yasugi^{1,2}, Hirotsugu Yamamoto^{1,2}*

1. Utsunomiya University (Japan), 2. JST, ACCEL (Japan)

This paper reports comparative study of optical components to form life-scale aerial image formed with AIRR (aerial imaging by retro-reflection). We assembled four life-size aerial devices that surrounds a user. We found that locating prism-type retro-reflector above the light source and the beam splitter gives brightness and high contrast.

PRJp1 - 6L Laser Converter Lighting System Using Compound Recycling Reflectors

**Kenneth Li¹*

1. Optonomous Technologies Inc. (United States of America)

Compact laser converter lighting system using diffuser and phosphor plates have been designed and being developed. With the addition of light recycling using a compound parabolic reflector, the brightness will be increased with a small output angle for ease in coupling.

17:20-18:40

Room 108

PRJ3: Image Quality and Display Devices

Special Topics of Interest on AR/VR and Hyper Reality

Chair: Andrés Vásquez Quintero (University of Ghent)
Co-Chair: Tetsuji Suzuki (JVC KENWOOD)

PRJ3 - 1 *Invited* Fast Switching, High Accuracy LCoS for 3D Holographic Applications

17:20

**Huang-Ming Philip Chen¹, Jhou-Pu Yang¹, Yao-Chung Chang¹*

1. National Chiao Tung University (Taiwan)

A 0.7-inch, 4K2K LCoS-SLM with full 2π radians phase modulation to cover depth-focus image was developed. The full phase modulation was found 0.9 and 1.5 ms under the digital driving scheme with DV = 1.75 V at T=45 °C. A 200 mm depth of 3D reconstruction holographic image was demonstrated.

PRJ3 - 2 *Invited* High Resolution Phase-only 4K2K LCoS Spatial Light Modulator for Holographic Display Technology

17:40

**Chun-Wei Tsai¹, Tse Li¹, Chen Wang¹*

1. Jasper Display Corp. (JDC) (Taiwan)

High resolution, full phase modulation, small pixel pitch, high aperture ratio, and fast response time are the requirements to enhance the quality of holographic display by using the LCoS-SLM. In this paper, we develop a 3D floating holographic display and to increase the angle of view as 36.67 degree with high resolution phase-only 4K2K LCoS-SLM.

PRJ3 - 3 Temperature Dependence Measurement of Color Speckle for Projected Fiber-out White Laser Beam from RGB Laser Module

18:00

**Junichi Kinoshita¹, Keizo Ochi¹, Akira Takamori¹, Kazuhisa Yamamoto¹, Kazuo Kuroda², Koji Suzuki³, Keisuke Hieda⁴*

1. Osaka University (Japan), 2. Utsunomiya University (Japan), 3. Oxide Corporation (Japan), 4. HIOKI E.E.CORPORATION (Japan)

Temperature dependence of color speckle of the projected image of a fiber-out white laser beam from a laser module with red, green, blue laser diodes was measured. Larger temperature dependence of the red laser diode was found to greatly affect the performance of the white beam and color-speckle.

**PRJ3 - 4 Standardization Activities for Head-Mounted
18:20 Displays from Ergonomics Aspects**

**Kei Hyodo¹, Hiroyasu Ujike², Mitsunori Tada²*

1. Yuasa System Co. Ltd. (Japan), 2. AIST (Japan)

As novel display devices, head-mounted displays (HMD) are getting popular. These devices have unique characteristics. Because of those, there are immediate requirements of having standards to evaluate those HMDs to avoid unwanted impacts to viewers. In order to answer those, ISO TC 159/SC4/WG2 and WG12 started developing standards for HMDs.

Author Interviews

18:50 - 19:20

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

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Special Talks:

Wednesday, Nov. 27, 2019
18:30 – 19:10
Mid-sized Hall A (1F)

Friday, November 29

9:00-10:35	Room 108
PRJ4: Projection Mapping and Lighting	

Chair: Shinsuke Shikama (Setsunan Univ.)
 Co-Chair: Petra Aswendt (ViALUX GmbH)

**PRJ4 - 1 *Invited* Projection and Large Area Displays of
 9:00 Artworks for Public Exhibits**

**Naoko Tosa¹, Yang Qin¹, Ryohei Nakatsu¹
 1. Kyoto University (Japan)*

Owing to the advance of projection and large area displays, art exhibition at public area became possible. We have various experiences of exhibiting our artworks in two ways; exhibition using projection mapping and one using large LED screens. Based on such experiences we discuss relevant ways of public art exhibition.

**PRJ4 - 2 *Invited* Perceptual Appearance Control by
 9:20 Projection-Induced Illusion**

**Ryo Akiyama¹, Goshiro Yamamoto², Toshiyuki Amano³,
 Takafumi Taketomi¹, Alexander Plopski¹,
 Yuichiro Fujimoto¹, Masayuki Kanbara¹,
 Christian Sandor⁴, Hirokazu Kato¹
 1. Nara Institute of Science and Technology (Japan),
 2. Kyoto University (Japan), 3. Wakayama University
 (Japan), 4. City University of Hong Kong (Hong Kong)*

When a projector displays images on real-world objects, result colors are affected by surface color and environmental light. Limited colors can be presented through projection because of these factors. We overcome this limitation by controlling projection color based on human perceived color.

**PRJ4 - 3 *Invited* New Concept Ultra Short Throw Projector for
 9:40 Consumer**

**Ryutaro Otake¹, Misa Sakurai, Masakatsu Ito,
 Hiroshi Nakade, Yuuji Taniue, Masaru Matsumori
 1. Panasonic Corporation (Japan)*

Flat panel TV gradually shifts to large screen size like 65 because the price of large screen TV goes down. However our living space doesn't enlarge. So flat TV influences on interior design much more. To solve such kind of problems we suggested a new concept projector for consumer.

Also presented in Innovative Demonstration Session (see p. 280)

PRJ

PRJ4 - 4 *Invited* Industrial DLP Projection Technology

10:00 **Petra Aswendt¹, Roland Hoefling¹*
 1. ViALUX GmbH (Germany)

This paper provides a view on DLP micro-mirror technology outside of digital cinema and data projectors. It shows that these MEMS offer significant potential when driven by the high-performance industrial control chipset. The principle of operation and the architecture of a hardware/software co-design for an industrial programming environment are described. Selected use cases are highlighted.

PRJ4 - 5L *Laser Phosphor Light Source with Hot Spot for Intelligent Headlight using DMD for Ultra-High Beam Applications*

**Kenneth Li¹, Y.P. Chang²*
 1. Optonomus Technologies Inc. (United States of America), 2. Taiwan Color Optics, Inc. (Taiwan)

An intelligent headlight using a single DMD and a laser pumped crystal phosphor plate producing a hot spot for extreme high beam has been designed and develop. Initial experiment results using a DMD projection engine will be presented.

10:40-12:20	Room 108
PRJ5: Automotive Display	
<i>Special Topics of Interest on Automotive Displays</i>	

Chair: Kazuhiro Ohara (Marubun)
 Co-Chair: Masayuki Takayama (Honda)

PRJ5 - 1 *Invited* Advanced Automotive Interior Lighting and Exterior Displays

**Karlheinz Blankenbach¹, Robert Isele²,
 Mathias Roennfeldt³, Uli Hiller⁴*
 1. Pforzheim University (Germany), 2. BMW (Germany), 3. Lightworks (Germany), 4. Osram Opto Semiconductors (Germany)

Autonomous driving has a huge impact on cars. We present advanced solutions for interior pixelated lighting and exterior displays. Examples are visualization of driving mode by the steering wheel and information for other road users. Calibrated RGB LED systems provide the best solution in terms of optical quality and safety.

**PRJ5 - 2 *Invited* Laser Crystal Phosphor Automobile
11:00 Headlight Integrated with Beam Control and LiDAR**
**Y. P. Chang^{1,2}, Alan Wang¹, Wood-Hi Cheng², Kenneth Li³*
1. Taiwan Color Optics, Inc. (Taiwan), 2. National Chun Hsing University (Taiwan), 3. Optonamous Technologies Inc. (United States of America)

This paper describes the development of high performance crystal phosphor with applications to automobile headlights, smart headlights, and LiDAR such that many limitations are eliminated and through integration, which could lower the cost of the system. A patent pending design of a smart headlight integrated with a LiDAR sensor using a single DMD will be described.

**PRJ5 - 3 *Invited* Laser Light Sources for Next Generation
11:20 Automotive Lighting Applications**
**MENG HAN¹, Julian Carey¹, Paul Rudy¹*
1. SLD Laser (United States of America)

Progress in development of blue laser diodes and their integration with phosphors enabled a new category of solid state light sources for automotive lighting. In this paper, a dynamic laser light module consisting of blue laser diode, a MEMS scanner and remote phosphor for adaptive driving beam and future intelligent lighting will be introduced.

**PRJ5 - 4 *Invited* Augmenting Reality In Automobiles
11:40**
**Jamieson Jamieson Christmas¹*
1. Envisics ltd (UK)

AR-HUD offering a compelling safety case for the automotive market. Thus far HUD adoption has been impaired by the physical volume of the optical system required to create a wide field of view. Envisics have developed revolutionary holographic technology that addresses these challenges while delivering class leading image metrics.

**PRJ5 - 5 Development of Image Quality Simulation for Laser
12:00 Scanning Projector Using Microlens Screen**
**Hiroyuki Tanabe¹*
1. Ricoh Industrial Solutions Inc (Japan)

Speckle can be reduced by using a scanning projector with microlens screen. However, the diffraction noises and the scanning-line-moire generated and degrades the image quality. To calculate these noises, the simulation was developed by integrating geometric and wave optics model. The simulation was validated by comparing with experimental result.

Author Interviews
 12:10 - 12:40



13:20-14:35	Room 108
PRJ6/AIS3: AI	

Chair: Makio Kurashige (DNP)
 Co-Chair: Satoshi Ouchi (Hitachi)

PRJ6/ AIS3 - 1 13:20 *Invited* **Visual Illusions Expressed by Deep Neural Networks**

**Taisuke Kobayashi¹, Eiji Watanabe^{1,2}*
1. Japan/Aichi/National Institute for Basic Biology (Japan), 2. Japan/Aichi/The Graduate University for Advanced Studies (SOKENDAI) (Japan)

The predictive coding theory, which is one of mathematical models of the visual information processing of the brain, were incorporated to deep neural networks. We found that the deep neural networks represented the motion for illusion images that were not moving physically, much like human visual perception.

PRJ6/ AIS3 - 2 13:40 **Vertical View Human Action Recognition from Range Images**

**Akinobu Watanabe¹, Keiichi Mitani¹*
1. Hitachi, Ltd. (Japan)

We developed the human joints' position estimation technique and the person tracking technique from upward view range image of TOF sensor, and confirmed the correct prediction ratio of hands' position is 97%, and confirmed the person tracking error is reduced to 1/7.

Also presented in Innovative Demonstration Session (see p. 280)

PRJ6/ AIS3 - 3 14:00 **High Efficiency Information Presentation Method for Head Mounted Display on Work Support**

**Takuya Nakamichi¹, Chiyo Ohno¹, Shoji Yamamoto¹, Koji Yamasaki¹*
1. Hitachi, Ltd. (Japan)

We developed an information presentation method for head mounted displays that does not interfere with the field worker. This method achieves low power consumption by a processing method that does not require a graphic processing unit and a camera for space recognition.

PRJ6/ AIS3 - 4L 14:20 **High-Speed and High-Brightness Color Single-Chip DLP Projector Using High-Power LED-Based Light Sources**

**Yoshihiro Watanabe^{1,2}, Masatoshi Ishikawa²*
1. Tokyo Institute of Technology (Japan), 2. University of Tokyo (Japan)

This paper proposes a high-speed and high-brightness color projector with a single-chip-DLP configuration that meets the demands for compactness and speed by introducing light sources based on luminescent concentration from LEDs and an optimized optical system. Furthermore, with the unique control circuit of the projector, it actualizes various projection functions.

15:00-16:20

Room 108

PRJ7/LCT8: Eyewear

Special Topics of Interest on AR/VR and Hyper Reality

Chair: Dieter Cuypers (CMST)
Co-Chair: Subaru Kawasaki (JNC Korea)

**PRJ7/
LCT8 - 1 LC Lens Fabricated by Photoalignment for AR/VR Systems**

15:00 *Wei-Wei Chen¹, Jui-Wen Pan¹, Shie-Chang Jeng¹
1. National Chiao Tung University (Taiwan)

A concept for an electrically tunable liquid crystal (LC) lens using a hole-patterned electrode and the vertical alignment liquid crystal cell by circular photoalignment is demonstrated. The proposed LC lens is a polarizer-free negative lens(0D~-0.93D) by changing the driving voltage. The proposed LC lens can be applied for AR/VR applications.

**PRJ7/
LCT8 - 2 Effect of Processing Parameters on Visual Quality for Liquid Crystal Displays Compatible with Contact Lenses**

15:20 *Andres Vasquez Quintero¹, Pablo Perez-Merino²,
Sudha Sudha¹, Lucas Oorlynck¹, Herbert De Smet¹
1. Ghent University / imec, Centre for Microsystems
Technology CMST (Belgium), 2. Instituto de
Investigacion Sanitaria Fundacion Jimenez Diaz
(Spain)

This paper presents the effect of processing parameters on the contrast and optical quality of guest-host liquid crystal cells intended for smart contact lens applications. The effects were measured by means of cavity interferometry and model fitting. Optical quality was qualitatively assessed by means of target images.

**PRJ7/
LCT8 - 3 Miniature Liquid Crystal Lens Optimizations**

15:40 *Dieter Cuypers¹, Rik Verplancke¹, Herbert De Smet¹
1. imec and Ghent University (Belgium)

Small, switchable liquid crystal based polymer Fresnel lenses are discussed, considering design optimizations for performance.

EXHIBITION

12:40 – 18:00 Wednesday, Nov. 27

10:00 – 18:00 Thursday, Nov. 28

10:00 – 14:00 Friday, Nov. 29

Main Hall (1F)

Sapporo Convention Center

Free admission with your registration name tag

**PRJ7/
LCT8 - 4
16:00**

**Ferroelectric Liquid Crystal Dammann Grating: for
LiDAR Applications**

**Zhengnan YUAN¹, Zhibo SUN¹,
Abhishek K SRIVASTAVA¹*

*1. The Hong Kong University of Science and
Technology (Hong Kong)*

We propose a ferroelectric liquid crystal Dammann grating (FLCDG) based polarization modulated depth-mapping system. Innovatively, FLCDG is used as high-speed shutter in this system. The application of FLCDG enables LiDAR as one-shot capturing system instead of iterative scanning. Moreover, the proposed device shows a fast data-collection time period (50 μ s) for per 49 points that can be further increased depending on the damman grating, and provide low cost solution to the problem.

**Author Interviews
16:30 - 17:00**

Supporting Organizations:

Consortium of Visible Laser Diode Applications
Laser Display and lighting conference
Laser Display Technology Research Group, Optical Society of Japan
Technical Group on Information Display, ITE
The Laser Society of Japan

SID Display Week 2020

June 7 - 12, 2020

San Francisco Moscone Convention Center
San Francisco, California, USA

<http://www.displayweek.org/>

IMID 2020

Aug. 25 – 28, 2020

COEX

Seoul, Korea

<http://www.imid.or.kr/>

Workshop on Electronic Paper

Wednesday, November 27

17:00-17:05

Room 207

Opening

Opening Remarks

17:00

Keisuke hashimoto¹, 1. E Ink Japan (Japan)

17:05-18:35

Room 207

EP1: Emerging Electronic Paper Displays

Chair: Makoto Omodani (Tokai University)

Co-Chair: Masayoshi Higuchi (NIMS)

EP1 - 1 *Invited* Photo-Quality Single Pixel Full-Color Rewritable Sheets with Leuco Dyes

17:05

**Kenichi Kurihara¹, Yuriko Kaino¹, Aya Shuto¹, Hiroshi Mizuno¹, Satoko Asaoka¹, Takehisa Ishida¹, Kenji Takagi¹, Isao Takahashi¹, Hirohisa Amago², Taichi Takeuchi², Asuka Tejima², Maho Watanabe², Yuki Oishi¹, Takahiro Kamei¹, Kazumasa Nomoto¹*

1. Sony Corporation (Japan), 2. Sony Global Manufacturing & Operations Corporation (Japan)

We have developed a laser-addressed photographic-quality rewritable sheet by using a 426-ppi single pixel full-color structure of a thin stacked C/M/Y thermochromic leuco-dye system with an unrecognized parallax. This development will facilitate new applications of on-demand rewritable image design on various surfaces.

EP1 - 2 *Invited* Magnetically Written Electrophoretic Display

17:30

**CC Tsai¹*

1. E Ink Holdings Ink. (Taiwan)

A new magnetically written electrophoretic display technology (MEPD) has been demonstrated that requires no TFT backplane to image. MEPD maintains the essential paper-like characteristics of ePaper. It has the reflective paperlike look, and is readable in direct sunlight. Moreover no power is required for static image. It has the flexibility suitable for bendable, rollable, or foldable applications. MEPD has been coated in a roll-to-roll production line, and is especially applicable for no-lag stylus input and/or large format applications.

EP1 - 3 *Invited* Understanding the Mechanisms of E-ink Operation
17:55

**Bo-Ru Yang¹*

1. Sun Yat-Sen University (China)

Owing to the unique features of electrophoretic E-ink displays, including the bistability, paper-like appearance, and sunlight visibility, E-ink has been applied in many IoT environments. We will summarize the mechanisms frequently used while designing the E-ink displays, which may facilitate the new beginners to start their research in E-ink fields.

EP1 - 4L Comparison of Handwriting Performance of Paper / Tablet / e-paper in Various Conditions Including Standing Position
18:20

**Kanao Fujisaki¹*

1. Tokai University (Japan)

Evaluations were performed in writing speed and subjective impression of handwriting task on paper, tablet, e-paper. The tasks were performed at the three conditions: (1)writing on a desk, (2)writing without desk, (3) writing in a standing position. Our results indicated advantages of e-paper especially in the standing position.

Author Interviews

18:30 - 19:00

Thursday, November 28

9:00-10:35	Room 107
EP2/DES4: Advanced Electronic Paper Displays and Systems	

Chair: Norihisa Kobayashi (Chiba Univ.)

Co-Chair: Haruhiko Okumura (Toshiba)

EP2/ Withdrawn
DES4 - 1

EP2/ *Invited* High-Performance and Low-Power Full Color Reflective LCD for New Applications
DES4 - 5L 9:00

**Hiroyuki Hako¹, Ming Ni¹, Junichi Hashimoto¹, Takashi Sato¹, Shinji Shimada¹, Kiyoshi Minoura¹, Akiko Itoh¹, Kohei Tanaka¹, Hiroshi Matsukizono¹, Masashi Otsubo¹*

1. SHARP Corporation (Japan)

We have developed a reflective LCD with full color video image and low power consumption. 22-inch and 11-inch prototype have achieved excellent optical properties and flicker-less 1Hz driving by a new twisted VA-LC mode, reliable materials, an optimal electrode design with micro reflective structure (MRS), and IGZO-TFT technology.

Also presented in Innovative Demonstration Session (see p. 280)

EP2/ DES4 - 2 **Invited Reflective Electro-Wetting Displays for Out Of Home Display Applications**
9:25 *Doeke J Oostra¹
 1. Etulipa (Netherlands)

Etulipa develops reflective digital displays for out of home advertisement using electro-wetting display technology. The black and white character application for electronic changeable copy boards is tested in the field. A matrix panel has been developed for full color displays. The panel has been designed for a seamless experience.

EP2/ DES4 - 3 **Invited Specification for Color E-paper**
9:50 *Alex Henzen^{1,2}, Guofu Zhou^{1,2,3}
 1. South China Normal University (China), 2. Liquid Light Ltd. (China), 3. Shenzhen Guohua Optoelectronics (China)

E-paper has been approached as a normal display, and measurements are based on measurements as used for emissive displays, or at the very best reflective monochrome LCD. This may be adequate for gray-scale e-paper displays, but as soon as color is added, these metrics are no longer suitable. This paper introduces a better way to evaluate color e-paper displays.

EP2/ DES4 - 4 **The Driving System of Electrowetting Display Based on Multi-Gray Dynamic Symmetry Driving Waveform**
10:15 *shanling Lin¹, Mingyong Qian¹, Zhixian Lin¹,
 Tailiang Guo¹
 1. Fuzhou University (China)

In order to play video in real time of electrowetting display, a display driving system which included a DVI video codec system and FPGA timing control system was designed. The paper also proposed an improved multi-gray scales dynamic symmetrical driving waveform, which improved the oil-splitting phenomenon and suppressed the charge-trapping phenomenon while increasing the gray level.

10:35-10:38

Room 107

EPp1: Short Presentation: Electronic Paper

All authors of poster papers for the EPp1 session will give 3-minute oral presentations with no discussion time.

Author Interviews
 10:40 - 11:10

14:30-17:00

Main Hall

Poster EPp1: Electronic Paper**EPp1 - 1L Conducting Polypyrrole-Silica Nanocomposite Particles for Electrophoretic Display****Naohiro Takahashi¹, Shuichi Maeda¹**1. Tokai University (Japan)*

We have prepared organic conducting nanocomposite particles that utilize polypyrrole as conducting parts and small silica particles as dispersants. We found that the polypyrrole-silica nanocomposite particles can be utilized as display elements for electrophoretic display and black inks for printed electronics due to their high colloid stability.

17:20-18:20

Room 107

EP3: Electrochromic Devices

Chair: Shuichi Maeda (Tokai University)

Co-Chair: Yoshihiko Hotta (Ricoh)

EP3 - 1L Nature-Inspired Flexible Electrochromic Devices**17:20****Masayoshi Higuchi¹, Yukio Fijii¹, Shigeki Kuroiwa², Keishi Ohashi², Yoshiharu Hamada³, Akihiko Kubota³**1. National Institute for Materials Science (Japan), 2. Waseda University (Japan), 3. Tama Art University (Japan)*

Nature-inspired flexible electrochromic devices have been fabricated using electrochromic metallo-supramolecular polymer for the first time in the world. The use of Ru(II)-based polymer, which changes the color between red and green, and the multi-layer coating method have enabled to reproduce the nature of a real fallen leaf by the devices.

EP3 - 2L Optimization of Prussian Blue Modified Counter Electrode in Ag Deposition-based Electrochromic Device**17:35****Shunsuke Kimura¹, Kazuki Nakamura¹, Norihisa Kobayashi¹**1. Chiba University (Japan)*

Prussian blue modified electrode was introduced into Ag deposition-based electrochromic (EC) device as the counter-reaction material for charge compensation of Ag redox. We discuss the bi-stability of the optical states and desirable features of Prussian blue film for metal deposition based EC device.

EP3 - 3L
17:50

Relationship of Thickness of ITO Particle-modified Counter Electrode into Electrochromic Properties of 10-methylphenothiazine

**Zhuang Liang¹, Kazuki Nakamura¹, Norihisa Kobayashi¹
1. Chiba University (Japan)*

We have already reported a novel multicolor electrochromism in a single device by introducing a porous counter electrode having high capacitance. In this paper, we investigated the effect of capacitance properties of the counter electrode into coloration properties of 10-methylphenothiazine molecule.

EP3 - 4L
18:05

Ultrahigh Cycle Stability in an Electrochromic Device with Fe(II)-Based Metallo-Supramolecular Polymer

**SANJOY MONDAL¹, MASAYOSHI HIGUCHI¹
1. Electronic Functional Macromolecules Group,
National Institute for Materials Science (NIMS),
(Japan)*

Ultrahigh cycle stability more than 100,000 cycles has been achieved in an electrochromic device with an Fe(II)-based metallo-supramolecular polymer layer and a modified counter electrode layer. The reversible color change between bluish-violet and colorless occurred at low applied voltages and the transmittance change reached > 60%.

Author Interviews
18:50 - 19:20

EP

I-DEMO **(Innovative Demonstration Session)**

Live demonstrations
of emerging information display technologies
by oral and poster presenters

Thursday, Nov. 28, 2019

11:40 – 15:40

Main Hall (1F)

Sapporo Convention Center

Workshop on MEMS and Emerging Technologies for Future Displays and Devices

Thursday, November 28

9:00-9:10	Conference Hall
Opening	

Opening Remarks

9:00

Masayuki Nakamoto¹, 1. Shizuoka University (Japan)

9:10-10:30	Conference Hall
MEET1: Novel Materials, Fundamental Components and Process Technologies	

Chair: Jin Jang (KyungHee University)

Co-Chair: Chien-chung Lin (National Chiao Tung University)

MEET1 - 1 *Invited* High Brightness Electron Beam with Carbon Nanotube (CNT) Cold Cathode

9:10

**Kyu Chang Park¹, Ha Rim Lee¹, Boklae Cho²*

1. KyungHee University (Korea), 2. Korea Research Institute for Science and Standard (Korea)

We fabricated high brightness electron beam with carbon nanotube (CNT) cold cathode. The beam brightness strongly depends on the virtual source size of CNT cold cathode. Based on the beam brightness simulation and measurement, we could obtain micro-focused electron beam with higher electron emission current for large area, high resolution imaging.

MEET1 - 2 Electron Beam Lithography of PMMA Film Using Direct Growth CNT Cold Cathode Emitter

9:30

**Ok Jung Hwang¹, Ha Rim Lee¹, Kyu Chang Park¹*

1. University of Kyunghee (Korea)

We have developed on electron beam (e-beam) lithography system with novel electron source using vertically aligned carbon nanotubes (VACNTs). After the beam was exposed, the PMMA film on ITO glass was developed in MIBK: IPA developer (MIBK: IPA=1:3). As a result, we observed lithography pattern less than 100 um without electric and magnetic lens. This cold cathode emitter is differentiated from the previous electron source for e-beam lithography.

MEET1 - 3 9:50 SOURCE 2D Simulation for High Resolution Carbon Nanotube Cold Cathode Fabrication

**Da Woon Kim¹, Ha Rim Lee¹, Boklae Cho²,
Kyu Chang Park¹*

*1. University of Kyung Hee (Korea), 2. Korea Research
Institute for Science and Standard (Korea)*

High-resolution electron microscopy requires an electron source with high brightness and resolution. We simulated and fabricated the carbon nanotube (CNT) cold cathode with high resolution. For the simulation, we used SOURCE 2D simulator and fabricated self-focused CNT based electron beam. The beam shows micron scale resolution with optimized self-focused CNT beam design. The beam spot size depends on the various parameters, such as depth, width and driving conditions.

MEET1 - 4 10:10 Effects on X-ray Imaging Quality by Manipulation of Cold Cathode Emitter Density

**Jisoo Oh¹, Yi Yin Yu¹, Kyu Chang Park¹*

1. Kyung Hee University (Korea)

The relationship between the density of electron emitters and x-ray image quality has been investigated. Under diode mode, x-ray images have been successfully acquired even under 30kV of bias. The electron emitters were selectively patterned VACNTs. With respect to the inter-emitter pitch, even at the same electrical energy, different patterns showed different image qualities. By optimizing the CNT pattern, we expect that we can develop a high-resolution x-ray source without using additional focusing components.

Author Interviews

10:40 - 11:10

MEET

10:40-13:10

Main Hall

Poster MEETp1: Novel Components and Process Technologies

MEETp1 - 1 Morphological Properties of Nickel-Cobalt Double Hydroxides Prepared by Facile Wet-Chemical Method

**Kyung Ho Kim¹, Sena Motoyama, Maho Suzuki,
Yoshio Abe, Midori Kawamura, Takayuki Kiba*

1. Kitami Institute of Technology (Japan)

We synthesized nickel-cobalt double hydroxides (Ni-Co DHs) via a facile wet-chemical method at a relatively low reaction temperature and investigated their morphological properties with different Co precursors. With cobalt nitrate hexahydrate, the nanosheets were interconnected each other, while, the nanolayered structure was observed with cobalt acetate tetrahydrate.

MEETp1 - 2 Briggs -- Rauscher Oscillating Reaction for Color Display

*Chung-Jen Ou², Wei-Ren Lin², Zhao-Wei Cheng²,
Yan-Hua Chiu², Chiao-Jou Chiu², *Chin-Hua Ou¹*

*1. Feng-Chia University (Taiwan), 2. Hsiuping
University of Science and Technology (Taiwan)*

Briggs–Rauscher reaction exhibit three optical states: yellow, blue and the transparency, which are happen to be the color mixing for white balance. This report considers the color mixing evaluation procedures for the possible application of this reaction for the display application.

17:20-18:40

Conference Hall

MEET2: EL Quantum Dots Technologies***Special Topics of Interest on Quantum Dot Technologies***

Chair: Frank Yan (Fuzhou University)

Co-Chair: Jang Hyuk Kwon (Kyung Hee University)

MEET2 - 1 *Invited* Quantum Dot Electroluminescence to Achieve Saturated Colours for REC2020 Compatibility

17:20

**Poopathy Kathirgamanathan¹,
Muttulingam Kumaravel¹*

1. Brunel University London (UK)

Using solvent based surface engineering of sol-gel derived ZnO electron injector, red QLEDs with a current efficiency of 32.6 cdA⁻¹ and a power efficiency of 18.6 lmW⁻¹ at 1000 cdm⁻² for Cd based QDs. We also report dark red electroluminescent InP/ZnS QDs (x,y = 0.672, 0.325)) with a maximum current and power efficiency of 3.6 cdA⁻¹ and 4.7 lmW⁻¹ respectively.

MEET2 - 2 Withdrawn**MEET2 - 3 *Invited* Ultra-Bright Quantum-Dot Light-Emitting Diodes**

18:00

**Shuming Chen¹*

*1. Southern University of Science and Technology
(China)*

Thermal stability of quantum dots (QDs) and thermal management of QD light-emitting diodes (QLEDs) could significantly affect the performance, especially the efficiency roll-off behaviors of QLEDs. With effective thermal management, the efficiency roll-off is significantly suppressed and consequently our developed green QLEDs exhibit an unprecedented high brightness of over 10⁶ cd/m² at a current density of J=3500 mA/cm² and a external quantum efficiency of ~10%, which is an order of magnitude higher than that of all reported QLEDs.

**MEET2 - 4 *Invited* Efficient and Stable Light Emitting Diodes
Based on Luminescent Nanocrystals**

18:20

**Kai Wang¹, Xiangtian Xiao^{1,2}, Zhaojin Wang¹, Taikang Ye¹*

1. Southern University of Science and Technology (China), 2. The University of Hong Kong (Hong Kong)

Efficiencies of electroluminescence perovskite LEDs were enhanced significantly by lowering surface defects and balancing charge injection. Moreover, optical and thermal stabilities of photoluminescence quantum dot LEDs and perovskite LEDs were also improved greatly by introducing the Quantum Dot Luminescent Micro-Sphere (QLuMiS) technology.

Author Interviews

18:50 - 19:20

Friday, November 29

9:00-10:20

Conference Hall

**MEET3: Emerging Quantum Dots
and Nanotechnologies (1)**

Special Topics of Interest on Quantum Dot Technologies

Chair: Christophe Martinez (CEA LETI)

Co-Chair: Haizheng Zhong (Beijing Institute of Technology)

**MEET3 - 1 *Invited* Developing Cd-free QLEDs for Display
Applications**

9:00

**Zhuo Chen¹, Dong Li¹, Boris Kristal¹, Jingwen Feng¹,
Zhigao Lu¹, Gang Yu¹, Yanzhao Li¹, Xinguo Li¹,
Xiaoguang Xu¹*

1. BOE Technology Group Co., Ltd. (China)

In this study, we investigated the effect of magnesium (Mg) doping in ZnO nanoparticles, in balancing the charge transfer in InP-based QLED devices. Through optimizing QD structures and devices, red InP QLEDs with the current efficiencies as high as 11.6 cd/A were fabricated.

**MEET3 - 2 *Invited* Horizontally Oriented Exciton Dipoles in
Solution-Processed Quantum Dot Solids**

9:20

**Chih-Jen Shih¹, Jakub Jagielski¹, Simon Solari¹,
Sudhir Kumar¹*

1. ETH Zurich, Switzerland (Switzerland)

It is well-known that the horizontally oriented exciton transition dipole moments in thin films of quantum emitters can direct radiation perpendicular to the substrate, maximizing the light outcoupling efficiency. Exciton orientation control has been reported in many thermally evaporated organic molecular thin films but has not yet been realized in solution-processed quantum dots films. Here, we demonstrate that excitons in solution-processed thin films comprised of colloidal quantum wells (CQWs) of lead trihalide perovskites are horizontally oriented, with thin-film photoluminescent quantum yields of up to 90%.

MEET3 - 3 *Invited* Controlling Charge Injection Properties of Quantum Dot Light-Emitting Diodes

9:40

**Jeonghun Kwak¹, Seunghyun Rhee¹, Taesoo Lee¹,
Guen-Woo Baek¹, Kyunghwan Kim¹, Yeseul Park¹*

1. Seoul National University (Korea)

Efficient charge carrier injection is one of the most important factors to achieve high performance quantum dot (QD) light-emitting diodes (QLEDs). Here, we investigated the effects of charge carrier injection properties on the QLED performance by modifying the surface ligands of QDs and by adopting an interlayer between the QD layer and the charge transport layer.

MEET3 - 4 *Invited* High Efficiency Cadmium-free Red Quantum Dot-Light Emitting Diodes

10:00

**Jang Hyuk Kwon¹*

1. Kyung Hee University (Korea)

We report a high efficiency inverted red indium phosphide (InP) based quantum dot-light emitting diode (QD-LED) by optimizing InP-QD properties as well as interfacial contact between electron transport layer and emissive QDs, and applying self-aging approach. Our QD-LED exhibits substantial improvement in the external quantum efficiency from 4.42 to 10.2% after several days of self-aging.

10:40-11:40	Conference Hall
MEET4: Emerging Quantum Dots and Nanotechnologies (2)	
<i>Special Topics of Interest on Quantum Dot Technologies</i>	

Chair: Shuming Chen (Southern University of Science and Technology)

Co-Chair: Jang Hyuk Kwon (KyungHee University)

MEET4 - 1 *Invited* In-situ Fabricated Perovskite Quantum Dots for Display Applications

10:40

**Haizheng Zhong¹*

1. Beijing Institute of Technology (China)

Halide perovskite quantum dots exhibit desired photoluminescence properties with high quantum yields, wide wavelength tunability, and ultra-narrow emissions, which are suitable for display technology. Here we describe the in-situ fabrication of perovskite quantum dots and their use in prototype devices and display system.

MEET4 - 2 *Withdrawn*

MEET4 - 3 *Invited* Hybrid Colloidal Quantum Dot Photonic Devices

11:20

**Chien-chung Lin^{1,2}*

1. National Chiao Tung University (Taiwan), 2. Industrial Technology Research Institute (Taiwan)

In recent years, colloidal quantum dots (CQDs) have been the focus of attention due to their highly efficient illumination, narrow linewidth emission, and widely tunable emission wavelength. Various types of devices have been implemented for the photonic devices to incorporate these novel materials. Both photon generation and absorption can be accomplished by CQDs and the corresponding light emitting diodes and solar cells can be designed to utilize their special characteristics. In this talk, we will provide our latest progress on such devices and the past experience we had in our lab. The highly reliable CQD package will play a crucial rule for the next generation photonic devices.

Author Interviews

12:10 - 12:40

13:20-14:40	Conference Hall
<p align="center">MEET5: Micro/NanoDisplays and Nanotechnology Application (1) <i>Special Topics of Interest on Micro/Mini LEDs</i></p>	

Chair: Poopathy Kathirgamanathan (Brunel University London)
Co-Chair: Kyu Chang Park (KyungHee University)

MEET5 - 1 *Invited* Design Considerations for Holographic Retinal Projection Display

13:20

**Christophe Martinez¹, Fabian Rainouard¹, Basile Meynard¹*

1. CEA Leti (France)

We present design considerations for the development of a retinal projection display based on the association of a photonic integrated circuit and a pixelated hologram. Unexpected behavior concerning the randomness distribution of the emitting elements in our display is highlighted.

MEET5 - 2 Withdrawn

MEET

**MEET5
- 5L
13:40**

***Invited* Comparison of LTPS, Oxide and LTPO TFTs
for Micro-LED Displays**

**Jin Jang¹, Suihui Lee¹, Hyo-min Kim¹, Yuanfeng
Chen¹*

*1. Advanced Display Research Center, Kyung Hee
University*

We review here the LTPS and oxide TFT technologies for micro-LED displays. We have developed BLA of a-Si for LTPS TFTs, exhibiting a high field-effect mobility over $150\text{cm}^2/\text{Vs}$ for p-channel device. On the other hand, oxide TFTs using bulk-accumulation (BA) mode exhibits an effective field effect mobility over $50\text{ cm}^2/\text{Vs}$. The BLA TFT backplane was applied to drive a micro-LED displays using digital driving. Oxide TFT backplane was used for micro-LED with high contrast ratio. The LTPO technology and QD color conversion technology will be explained for micro-LED displays.

**MEET5 - 3 *Invited* Investigation of Temperature-dependent
Behaviors of Micro-LED Displays**

14:00

**Zhaojun Liu¹, Bo Lu¹, Minggang Liu², Yong Fan²,
Jiayu Lee², Yan Wang¹, Hao-Chung Kuo³, Xiaowei Sun¹*

*1. Southern University of Science and Technology
(China), 2. Shenzhen China Star Optoelectronics
Technology Co., Ltd (China), 3. National Chiao Tung
University (Taiwan)*

Micro-LED display consist of arrays of Micro-LEDs and driving backplane with bonding technologies. As the size of LED get smaller, the amount of LED chips becomes a huge number. The thermal issue of Mini/Micro-LEDs needs to be considered. We report a 32×32 flexible Mini-LEDs array with driving current of 10mA under applied bias of 2.6V. The result of testing temperature distribution in different brightness shows that the Mini-LED array satisfy the requirement of thermal stability.

IDW '20

The 27th International Display Workshops

Dec. 9 - 11, 2020

Fukuoka International Congress Center

Fukuoka, Japan

<https://www.idw.or.jp/>

MEET5 - 4 Invited Towards High Resolution Active-Matrix GaN μ -LED Based Micro Displays

*Junyang Nie^{2,1}, Zhijie Ke³, Yongai Zhang¹, Xiongtu Zhou¹, Tailing Guo¹, Congyan Lu⁵, Yiren Chen⁵, Zhangxu Pan⁶, Ling Li⁴, Di Geng⁴, Hang Song⁵, Zheng Gong⁶, *Jie Sun¹, Qun Yan^{1,2}*

1. Fuzhou University (China), 2. Xi'an Jiaotong University (China), 3. Xiamen Changelight Co. Ltd. (China), 4. Institute of Microelectronics, Chinese Academy of Sciences (China), 5. Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Science, China (China), 6. Guangdong Institute of Semiconductor Industry Technology, Guangdong Academy of Sciences (China)

We focus on the design/fabrication of active matrix 0.55 inch 1323 ppi micro displays based on GaN μ -LED arrays with Si CMOS driver prepared by flip-chip bonding. The process is optimized for manufacturing. A pioneer work of integrating 2D material transistors with GaN μ -LEDs is also discussed.

15:00-16:20	Conference Hall
<p align="center">MEET6: Micro/NanoDisplays and Nanotechnology Application (2)</p> <p align="center"><i>Special Topics of Interest on Micro/Mini LEDs</i></p>	

Chair: Chih-Jen Shih (ETH Zurich, Switzerland)
Co-Chair: Kyu Chang Park (KyungHee University)

MEET6 - 1 Invited Toward for Ultimate Displays with MicroLED by PixeLED Display Technology

**Ying-Tsang (Falcon) Liu¹, Kuan-Yung Liao¹, Yun-Li Li¹*
1. PlayNitride Inc. (Taiwan)

MicroLED display is an emerging technology with high brightness, wide color gamut, and high aperture ratio. Based on our PixeLED[®] display technology to build MicroLED display, and SMAR·Tech[™] to build defect free panel, we are heading to mass production for MicroLED display.

MEET6 - 2 Invited Impressive Technologies for MicroLED Displays

**Zine Bouhamri¹, Eric Virey¹*
1. Yole Developpement (France)

MicroLED is a promising display technology. There are however still many technical challenges that need to be tackled before it is ready for consumer products. Mass transfer of the microLED chips is the elephant in the room, but many others could prove as challenging and possibly derail the microLED roadmap.

MEET

**MEET6 - 3 17.3-in Mini-LEDs Halo Effect and Human Factor
15:40 Study for High-End Notebook Application**

**Hao-Hao Wu¹, Jenn-Jia Su¹, Chun-Sheng Li¹, Han-Ping Kuo¹, Yu-Hsiu Chang¹, Chia-En Fuh¹, Bo-Yuan Su¹*

1. AU Optronics Corporation (Taiwan)

Local dimming technology could increase contrast. Most of halo effect study is based on face-view. This paper would indicate performance and halo effect at different viewing angle. Finally, we proposed a 17.3-inch Mini-LEDs notebook module that can reach HDR1000 specification and less suffer from low contrast at different viewing angle.

**MEET6 - 4L In-situ EUV Irradiation for Etching Residual Removal
16:00 of AM Mini-LED**

*Yong Deng¹, Junling Liu¹, *Minli Tan¹, Min Xiong¹, Liangyi Cai¹, Wenbo Liu¹, Quansheng Liu¹, Yifeng Yang¹, Rui Zhao¹, Weimin Zhang¹*

1. Shenzhen China Star Optoelectronic Technology Company, Ltd. (China)

Given the demand of high current drive, AM Mini-LED backplane usually uses dense plum-blossom-type design to optimize hole lapping. However, this porous design leads to a serious M2 etching residual issue. By using in-situ EUV irradiation, the infiltration of etchant to porous structure can be increased and the etching residual can be removed without affecting electrical characteristics of the device.

Author Interviews

16:30 - 17:00

SPECIAL EVENT

“Sensory Illusion”

Exhibition:

Wednesday, Nov. 27 – Friday, Nov. 29, 2019
Main Hall (1F)

Special Talks:

Wednesday, Nov. 27, 2019
18:30 – 19:10
Mid-sized Hall A (1F)

Workshop on Display Electronic Systems

Wednesday, November 27

13:40-13:45

Room 207

Opening

Opening Remarks

13:40

**Haruhiko Okumura¹, 1. Toshiba (Japan)*

13:45-15:00

Room 207

DES1: 8K Systems

Chair: Ryutaro Oke (Panasonic Liquid Crystal Display)

Co-Chair: Hyun-Wook Lim (SAMSUNG ELECTRONICS)

DES1 - 1 *Invited* Development of 8K-UHD 3D Display for Advanced Digital Surgical Imaging

13:45

**Hiromasa Yamashita¹, Junichi Maruyama¹, Ryutaro Oke², Kenkichi Tanioka¹, Toshio Chiba¹*

1. Kairos Co., Ltd. (Japan), 2. Panasonic Liquid Crystal Display Co., Ltd. (Japan)

We have developed a prototype of 55-inch 8K ultra-high definition (UHD) three-dimensional (3D) display using a polarization filter for advanced digital surgical imaging with the new camera system with 8K-UHD resolution (7680 x 4320 pixels), which is 16 times as much as that of high-definition (HD; 1920 x 1080 pixels).

DES1 - 2 *Invited* Driver Technology for 8K Ultra High Definition TV

14:10

**Hyun-Wook Lim¹, Yong-Hoon Yu¹, Jinho Kim¹, Byoung-Yoon Jang¹, Jung-Pil Lim¹, Kyoung-Ho Ryu¹, Kil-Hoon Lee¹, Kyoung-Ho Kim¹, Young-Min Choi¹, Jae-Youl Lee¹*

1. Samsung Electronics (Korea)

Driver technology for large 8K UHD 120Hz 10bit color display is presented in 0.13- μ m high-voltage CMOS process for column driver IC, and 14nm CMOS process for TCON. The proposed auto-optimized equalizer could compensate -21.4dB channel loss for 4Gbps receiver per lane for 82-inches 8K UHD panel. The proposed line-overdrive technique could compensate insufficient charging time for each line using variable LUT.

**DES1 - 3 *Invited* Adaptive Functions in Timing Controller for
14:35 8K4K High Resolution and Large Size Panel
Application**

**Pu Jen Cheng¹, Tung Ying Wu¹, Cheng Che Tsai¹*

1. Himax Technology (Taiwan)

Many panel makers keep committed to manufacture 8K4K LCD panel in recent years. There are some panel issues accompanying by higher resolution and larger panel size, like source driver ability and side viewing color shift (especially in the VA type panel). We propose the adaptive functions to improve the image quality for high resolution and large size panel in Timing Controller (T-CON).

15:20-16:40

Room 207

DES2: Driving Technology

Chair: Chih-Wen Lu (Nat. Tsing Hua Univ.)

Co-Chair: Keiichi Nakajima (Tianma Japan)

**DES2 - 1 Relationship Between Charging Rate and Color
15:20 Gamma Cross-talk for TFT-LCD with Flip Pixel
Driven Architecture**

**Jing LIU¹, Sikun Hao¹, Wei li¹*

*1. Shenzhen China Star Optoelectronics Technology
Co., Ltd (CSOT) (China)*

Color gamma crosstalk (CCT) formula, which compares the luminance of three primary-color images with the luminance of gray-level image, is a way of measuring color expression. In this paper, the negative correlation between charging rate and CCT in the thin film transistor liquid crystal display (TFT-LCD) with flip pixel driven architecture is studied. Based on the analysis and understanding, line overdrive (OD) technology is applied to reduce the value of CCT to the standard range.

**DES2 - 2 New External Compensated Circuit with Buffer IC
15:40 for High-Resolution AMOLED Displays**

**Feng-Ching Cheng¹, Po-Syun Chen¹, Chia-Lun Lee¹,
Chih-Lung Lin¹*

1. National Cheng Kung University (Taiwan)

This work presents a new pixel circuit based on LTPS TFTs compensating for TFT V_{TH} variations and V_{DD} I-R drops for AMOLED displays. The simulated results show that the relative current error rates are less than 4.87% with TFT V_{TH} of ± 0.5 V and -0.5 V V_{DD} I-R drops.

DES2 - 3 Highly Reliable a-IGZO TFT Gate Driver Circuit to Suppress Threshold Voltage Shift of Pull-down TFT

16:00

**Jungwoo Lee¹, Jongsu Oh¹, Eun Kyo Jung¹, KeeChan Park², Jae-Hong Jeon³, Yong-Sang Kim¹*

1. Sungkyunkwan University (Korea), 2. Konkuk University (Korea), 3. Korea Aerospace University (Korea)

We present the highly reliable gate driver circuit using AC-driven method of a pull-down TFTs. Two pull-down TFTs are driven with duty ratio of 33.3% and 66.7%, respectively, VOUT discharge completely. The proposed circuit can minimize coupling noise by discharging the Q and VOUT node constantly except for output period.

DES2 - 4 Novel Driving Methods of Gate Driver Circuit for Depletion Mode Oxide TFTs

16:20

**Jongsu Oh¹, Kyung-Mo Jung¹, Soo-Yeon Lee², KeeChan Park³, Jae-Hong Jeon⁴, Yong-Sang Kim¹*

1. Sungkyunkwan University (Korea), 2. Seoul National University (Korea), 3. Konkuk University (Korea), 4. Korea Aerospace University (Korea)

We introduce novel driving methods of pull-down unit in a gate driver circuit for enhancement and depletion mode a-IGZO thin-film transistors (TFTs). Using 3T1C diode connection structure, our circuit can compensate for V_{TH} of pull-down unit in the enhancement mode and can be normally operated in the depletion mode.

17:00-18:30

Mid-sized Hall A

VHF3/DES3: Virtual Reality

Special Topics of Interest on AR/VR and Hyper Reality

Chair: Takashi Shibata (Tokyo Univ. of Social Welfare)

Co-Chair: Johan Bergquist (Consultant)

VHF3/ *Invited* VR Headset with Human-Eye Resolution

DES3 - 1

17:00

**Osku Sahlsten¹*

1. Varjo Technologies Oy (Finland)

With current display manufacturing methods, it would be very hard to produce a single near eye display that offers 60 pixels / degree resolution over the whole field of view and is small enough to fit into the headset. In case of greater than 90-degree field of view, basically 6k x 6k panel would be required. With the high refresh rates of virtual reality applications, this would mean also very large data transfer rates and high rendering load on GPU's. Varjo overcome these challenges by composing the single eye image from two different display sources, while minimizing the effect on total rendering load. High angular resolution is used on the area where it is mostly needed. Precise analysis of displays with geometrical- and optical adjustments is needed to blend the 2 separate images to a one uniform scene.

Also presented in Innovative Demonstration Session (see p. 280)

**VHF3/
DES3 - 2
17:25** **Invited Metrology Challenges in Near to Eye Display
Characterization for Human Factors Correlation**
**Richard Lee Austin¹, Bruce Denning¹, John Penczek²*
*1. Gamma Scientific (United States of America), 2.
University of Colorado, Boulder (United States of
America)*

We present metrology challenges and solutions to measure Near Eye Displays performance parameters that can produce visual discomfort and headaches. Accurate measurement data correlates to what the eye perceives when the entrance pupil of the Light Measurement Device (LMD) matches the location and pointing direction of the display user's eye.

**VHF3/
DES3 - 3
17:50** **Optic Flow, but Not Retinal Flow, Is Essential to
Induce VR Sickness**
**Hiroyasu Ujike¹, Kei Hyodo¹, Mitsunori Tada¹,
Koudai Ito¹*
*1. National Institute of Advanced Industrial Science
and Technology (Japan)*

We conducted an experiment measuring VR sickness using HMD, manipulating optic flow and retinal flow in three conditions. The results showed that sickness scores increased according to the amount of optic flow, but not of retinal flow, indicating that optic flow, not retinal flow, is essential to induced VR sickness.

**VHF3/
DES3 - 4
18:10** **Color Perception Comparison of Scene Images
between Head-Mounted Display and Desktop
Display**
**Tomonori Nishimura¹, Keita Hirai¹, Takahiko Horiuchi¹*
1. Chiba University (Japan)

In this paper, subjective evaluation experiments using scene images were conducted to investigate the difference of luminance and chroma perception between an HMD and a desktop display. The results showed that the perception of luminance and chroma of the HMD were higher compared with those of the desktop display.

Author Interviews
18:30 - 19:00

SID Display Week 2020

June 7 - 12, 2020

San Francisco Moscone Convention Center

San Francisco, California, USA

<http://www.displayweek.org/>

Thursday, November 28

9:00-10:35

Room 107

**EP2/DES4: Advanced Electronic Paper
Displays and Systems**

Chair: Norihisa Kobayashi (Chiba Univ.)

Co-Chair: Haruhiko Okumura (Toshiba)

**EP2/
DES4 - 1** **Withdrawn**

**EP2/
DES4 - 5L** **High-Performance and Low-Power Full Color
Reflective LCD for New Applications**

9:00

**Hiroyuki Hakoi¹, Ming Ni¹, Junichi Hashimoto¹,
Takashi Sato¹, Shinji Shimada¹, Kiyoshi Minoura¹,
Akiko Itoh¹, Kohei Tanaka¹, Hiroshi Matsukizono¹,
Masashi Otsubo¹*

1. SHARP Corporation (Japan)

We have developed a reflective LCD with full color video image and low power consumption. 22-inch and 11-inch prototype have achieved excellent optical properties and flicker-less 1Hz driving by a new twisted VA-LC mode, reliable materials, an optimal electrode design with micro reflective structure (MRS), and IGZO-TFT technology.

Also presented in Innovative Demonstration Session (see p. 280)

**EP2/
DES4 - 2** ***Invited* Reflective Electro-Wetting Displays for Out
Of Home Display Applications**

9:25

**Doeke J Oostra¹*

1. Etulipa (Netherlands)

Etulipa develops reflective digital displays for out of home advertisement using electro-wetting display technology. The black and white character application for electronic changeable copy boards is tested in the field. A matrix panel has been developed for full color displays. The panel has been designed for a seamless experience.

**EP2/
DES4 - 3** ***Invited* Specification for Color E-paper**

9:50

**Alex Henzen^{1,2}, Guofu Zhou^{1,2,3}*

*1. South China Normal University (China), 2. Liquid
Light Ltd. (China), 3. Shenzhen Guohua
Optoelectronics (China)*

E-paper has been approached as a normal display, and measurements are based on measurements as used for emissive displays, or at the very best reflective monochrome LCD. This may be adequate for gray-scale e-paper displays, but as soon as color is added, these metrics are no longer suitable. This paper introduces a better way to evaluate color e-paper displays.

**EP2/
DES4 - 4
10:15** **The Driving System of Electrowetting Display Based on Multi-Gray Dynamic Symmetry Driving Waveform**
**shanling Lin¹, Mingyong Qian¹, Zhixian Lin¹,
Tailiang Guo¹*
1. Fuzhou University (China)

In order to play video in real time of electrowetting display, a display driving system which included a DVI video codec system and FPGA timing control system was designed. The paper also proposed an improved multi-gray scales dynamic symmetrical driving waveform, which improved the oil-splitting phenomenon and suppressed the charge-trapping phenomenon while increasing the gray level.

Author Interviews

10:40 - 11:10

14:30-17:00	Main Hall
Poster VHFp4/DESp1: Ergonomics and Display Electronics	

**VHFp4/
DESp1 - 1** **Spatio-Temporal LED Driving for Subjective Super-Resolution of Grayscale Images**
**Kojiro Matsushita¹, Toyotaro Tokimoto², Kengo Fujii¹,
Hirotsugu Yamamoto^{1,3}*
*1. Utsunomiya University (Japan), 2. DaoApp
Technology Co, Ltd. (Taiwan), 3. JST, ACCEL (Japan)*

We have implemented a novel LED driving circuit to evoke subjective super-resolution effect on grayscale images by use of FPGA. An 8-bit grayscale image is oversampled and coded into multiple subframes, which are shown on an LED panel at a high frame rate. We have confirmed subjective super-resolution.

	Main Hall
Poster AISp1/DESp2: Image Processing	

**AISp1/
DESp2 - 1** **Hardware Acceleration for Multi-Scale Object Detection Based on Dense Pyramid Feature**
**Congrui Wu¹, Tianmin Rao¹, Ran Duan¹, Xiao Zhang¹*
1. BOE Technology Group Co., Ltd (China)

ACF is a method for object detection which approximately constructing a dense feature pyramid used for Adaboost classifier. Our work focuses on this method and implement the whole detection process on heterogeneous hardware platform. This design achieves a detection performance of 134 fps consuming less hardware resources.

AIsp1/ DESp2 - 2L Saliency Map Prediction Using a Method of Object Detection

**Tsuyoshi Kushima¹, Masaki Hisano¹*

1. The University of Electro-Communications (Japan)

Although there are many models which mimic human visual information search, their performance couldn't match that of human beings. We propose a new model which reflects receiving characteristics of the human visual system because these characteristics are not considered enough in the previous models.

Main Hall

Poster DESp3: Medical VR
Special Topics of Interest on AR/VR and Hyper Reality

DESp3 - 1L Towards Next Generation Neurosurgical Microscope: A VR Assisted Prototype System

**Yuji Oyamada¹, Sadao Nakajima¹, Kazutake Uehara², Hiroki Yoshioka³, Masamichi Kurosaki¹*

1. Tottori University (Japan), 2. Tottori University Hospital (Japan), 3. Tottori Prefectural Central Hospital (Japan)

We aim to develop a Virtual Reality assisted neurosurgical microscope system that displays medical information from multiple resources even with a single display. For this ultimate purpose, we developed a prototype system. We conducted a small user study to discuss both hardware and software issues to be improved.

Also presented in Innovative Demonstration Session (see p. 280)

Main Hall

Poster DESp4: Driving Technique for VR
Special Topics of Interest on AR/VR and Hyper Reality

DESp4 - 1L Reduced Resolution Driving Scheme for High-Resolution Immersive Displays

**Seungjun Park¹, Young-In Kim¹, Ki-Hyuk Seul¹, Seok-Jeong Song¹, Jina Bae¹, Hyoungsik Nam¹*

1. Kyung Hee University (Korea)

To extend line times for high-resolution and wide viewing angle displays in virtual reality applications, we present a novel foveation-based reduced resolution driving scheme. For 4,800x4,800 and 9,600x9,600 resolutions, effective vertical resolutions are reduced to 30.3% and 21.0%. Thus, line times can be extended to 330.0% and 476.2%.

**Poster DESp5: Display Electronics for Automotive
Special Topics of Interest on Automotive Displays**

DESp5 - 1L Optimizing LSF Shape for Robust and Uniform Backlighting of Automotive Displays with Direct-Lit Local-Dimming

**Maxim Schmidt¹, Julian Ritter¹, Chihao Xu¹*

1. Saarland University (Germany)

In this paper, radial LSFs for direct-lit BLUs are modelled with three parameters and can render different shapes for a same influence. Diverse LSF shapes are analyzed in terms of robustness in production as well as power saving capabilities regarding local-dimming. Characteristic measures for an optimum shape are proposed.

Friday, November 29

13:20-14:35

Room 107

DES5: Video Coding

Chair: Seishi Takamura (NTT)
Co-Chair: Haruhiko Okumura (Toshiba)

DES5 - 1 Invited Emerging Technologies toward Future Video Coding

13:20

**Seishi Takamura¹*

1. NTT Corporation (Japan)

In this paper, we first overview the ever-advancing history of video coding technology and standardization activities as well as evolution of video communication traffic. Then we review latest standardization activity on video coding, and introduce two examples of our new approach, real-entity-oriented coding in particular, to further enhance visual quality and compression performance.

DES5 - 2 Invited Next Generation Video Coding in 8K era - Versatile Video Coding and AI

13:45

**Tomohiro Ikai¹, Eiichi Sasaki¹, Yukinobu Yasugi¹,
Tomonori Hashimoto¹, Tianyang Zhou¹, Takeshi Chujoh¹,
Tomoko Aono¹, Norio Itoh¹*

1. Sharp Corporation (Japan)

Displays and video compression are key drivers in emerging 4K/8K and VR/AR video market. Versatile Video Coding (VVC), under development as the next generation video coding, inevitably changes our society in the 2020s. This paper shows VVC key components including simplification and improvement aspects and shows neural network's difficulty and significance in compressed video.

Also presented in Innovative Demonstration Session (see p. 281)

**DES5 - 3 *Invited* MPEG Point Cloud Compression; First
14:10 Standard for Immersive Media**

**Ohji Nakagami¹*

1. Sony Corporation (Japan)

This paper introduces recent MPEG activity on Point Cloud Compression (PCC) standard planned to be released in 2020 as a part of ISO/IEC 23090 series. The paper explains two complementary technologies, Video-based PCC and Geometry-based PCC. The coding algorithm, the compression performance, and the use-cases are discussed.

15:00-16:10

Room 107

DES6/AIS4: Image Processing

Chair: Yuji Oyamada (Tottori University)

Co-Chair: Mutsumi Kimura (Ryukoku univ.)

**DES6/
AIS4 - 1 *Invited* Deep Learning-based Image Processing
15:00 Algorithms in 8K Era**

**SukJu Kang¹*

1. Sogang University (Korea)

This paper presents the deep learning-based inverse tone mapping algorithms for high dynamic range imaging. Specifically, the technical contents of various deep learning-based inverse tone mapping techniques, which are currently being studied, are explained, and the performance of representative methods are compared.

**DES6/
AIS4 - 2 *Invited* Omnidirectional/360-degree Image and Video
15:25 Standardizations Status**

**Junichi Hara¹*

1. RICOH Company, LTD. (Japan)

This presentation reports technical aspects of the omnidirectional/360-degree image and video standardizations; ISO/IEC 19566-6 JPEG 360 and ISO/IEC 23090-2 Omnidirectional Media Format (OMAF) international standards. And this also introduces functions of these next version omnidirectional picture standards that now are discussed in standardization meetings, and discusses its applications.

**DES6/
AIS4 - 3 An Advanced TV Program Logo Processing
15:50 Algorithm for Preventing OLED TV Image Sticking**

**Lin Cheng¹, Yang Rao¹, Yufeng Jin¹, Yin-Hung Chen¹,
Ming-Jong Jou¹, Bin Zhao¹, Xin Zhang¹*

1. Shenzhen China Star Optoelectronics Technology Company (China)

In this paper, a TV logo post-processing system is proposed to relieve the burn-in phenomenon on OLED TV. It contains generic logo detection algorithm and identification mechanism to adapt to video real-time processing and temporary channel change events. With the logo restrain function, OLED TV image-sticking phenomenon would be alleviated.

Author Interviews

16:30 - 17:00

Supporting Organizations:

IEEE Sapporo Section

Special Interest Group on Mixed Reality (SIG-MR), The Virtual Reality Society of Japan

Technical Committee on Electronic Information Displays (EID), Electronics Society, IEICE

Technical Committee on Image Engineering (IE), Information and Systems Society, IEICE

Technical Group on Information Display, ITE

Technical Group on Information Sensing Technologies (IST), The Institute of Image Information and Television Engineers, ITE

The Society of Automotive Engineers of Japan

Workshop on Flexible Electronics

Wednesday, November 27

FLX

17:00-17:05

Room 108

Opening

Opening Remarks

17:00

Toshihide Kamata¹, 1. AIST (Japan)

17:05-18:30

Room 108

FLX1/FMC3: Advanced Materials and Components for Flexible Electronics

Chair: Toshihide Kamata (National Institute of Advanced Industrial Science and Technology)

Co-Chair: Makoto Arai (ULVAC Inc.)

**FLX1/
FMC3 - 1
17:05**

Invited Printed Invisible Silver-Grid Transparent Electrode on Flexible Epoxy Film and Application to Powder Electroluminescent Device

**Masato Ohsawa¹, Natsuki Hashimoto¹, Naoki Takeda², Shota Tsuneyasu², Toshifumi Satoh²*

1. ULVAC, Inc. (Japan), 2. Tokyo Polytechnic University (Japan)

Invisible Ag-grid transparent electrodes have been printed on a flexible epoxy film. The Ag-grid electrode were laminated with a poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) layer. The electrode shows no noticeable resistance change throughout the bending cycles at a bending radius of 1.0 mm. The transparent electrode-based powder electroluminescent device develops excellent flexibility.

**FLX1/
FMC3 - 2
17:30**

Al Alloying Effect in Functionalization of Mechanical Resistance to Foldable Display Interconnections

**Chiharu Kura¹, Mototaka Ochi¹, Hiroyuki Okuno², Hiroshi Goto²*

1. Kobe Steel, LTD. (Japan), 2. Kobelco Research Institute, Inc. (Japan)

For the metal interconnection in foldable displays, bending resistance is essential in addition to heat resistance and low electrical resistivity. The bending resistance of Al-Nd alloy interconnections can be controlled by precipitation of intermetallic compounds. Then, the Al alloy interconnections capable of dry-etching patterning have also been developed.

**FLX1/
FMC3 - 3**

Withdrawn

**FLX1/
FMC3 - 5L
17:50**

**Roll-to-roll Processing of Transparent and Robust
Permeation Barrier Films for Flexible Electronics**

**John Fahlteich¹, Michiel Top¹, Stefan Hinze¹,
Uwe Meyer¹, Tobias Vogt¹, Valentijn von Morgen²,
Matthias Fahland¹*

*1. Fraunhofer Institute for Organic Electronics,
Electron Beam and Plasma Technology FEP
(Germany), 2. DuPont Teijin Films Ltd. (UK)*

Water vapor permeability of permeation barrier films and thin film encapsulation coatings is determined both by intrinsic factors: material and technology selection and extrinsic factors: e.g. particle contamination or process defects. This paper discusses optimization strategies to achieve low permeability gas barrier films that are robust in roll-to-roll processing and integration to devices. Water vapor transmission rates of $<5 \cdot 10^{-4}$ g/(m²d) at 38°C / 90 % r.h. are demonstrated reproducibly in a full roll-to-roll process chain using a sputtered barrier layer and a protective top-coat.

**FLX1/
FMC3 - 4
18:10**

**Improvement of the Corrosion Resistance of TCO/
Ag/TCO Structure for Transparent Conductive Layer**

**Yuto Toshimori¹, Sohei Nonaka¹*

1. Mitsubishi Materials Corporation (Japan)

The corrosion resistance of TCO/Ag/TCO structure was improved by using new Ag alloy and TCO. These can inhibit corrosion defect which was one of the biggest challenges for practical use. It can be applied to various devices, such as display electrodes, touch sensor and IR cut film.

Author Interviews

18:30 - 19:00

SPECIAL EVENT

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Thursday, November 28

14:30-17:00

Main Hall

Poster FLXp1: Flexible Electronics Technologies

FLXp1 - 1 Electromagnetic Interference Shielding Using ITO Nano-branch and Metal Nano-Particle Decoration

**Youngho Kim¹, Hak Ki Yu¹*

1. Ajou University (Korea)

The ITO branches were used for transparent and flexible electromagnetic interference shielding devices. Nano branch structure is expected to increase EMI shielding efficiency through inter-reflection with each branch. In order to increase the electromagnetic absorption rate of the ITO branch, novel metal nanodot is decorated. The application method to the transparent substrate is transfer using NaCl as sacrificial layer.

FLXp1 - 2 Withdrawn

FLXp1 - 3 Withdrawn

FLXp1 - 4 Effect of Contaminant Particles on Folding of Encapsulating Organic-Inorganic Multilayer for Foldable OLEDs

**Yun taek Park¹, Sang woo Kim¹, Gui young Han¹,
Sung min Cho¹*

1. University of Sungkyunkwan (Korea)

The stability of the organic-inorganic multilayer thin films was evaluated when they were folded inward or outward in 1 mm radius according to the size of the contaminant particles and the thickness of the multilayer thin films.

FLXp1 - 5 Withdrawn

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)
Sapporo Convention Center

FLX

FLXp1 - 6 Effect of OCA Properties on Foldable AMOLED Panel with a Module Structure

**Yali Liu¹, Yongzhen Jia², Zhengzhou Liu³, Di Wu³, Haoqun Li¹, Zhuo Zhang¹*

1. WuHAN CHINA STAR OPTOELECTRONICS SEMICONDUCTOR DISPLAY TECHNOLOGY CO.,LTD (China), 2. Shenzhen China Star Optoelectronics Technology Co., Ltd, Shenzhen, 518132, China (China), 3. State Key Laboratory of Materials Processing and Die & Mould Technology, Huazhong University of Science and Technology, Wuhan, 430074, China (China)

The main design goal of the foldable OLED display is to avoid the film stack failure caused by bending stress during repeated folding and unfolding. This paper models and simulates the structure of the foldable OLED screen module, and explores the visco-hyperelastic mechanical characteristics for optical clear adhesive, such as the factors of influence of hyperelastic modulus, viscoelastic parameters and Poisson's ratio.

FLXp1 - 7 Room-Temperature Solution-Synthesized p-type Copper(I) Iodide Semiconductors for Transparent Thin Film Transistors and Complementary Electronics

**Ao Liu¹, Huihui Zhu¹, Yong-Young Noh¹*

1. Pohang University of Science and Technology (POSTECH) (Korea)

Developing p-type transparent semiconductors has attracted great interest over the past decades to realize complementary p-n junction devices and circuits by cost-effective graphic art processes. Here we report two kinds of transparent p-type Cu-based transistors (CuI and Cu_xO), which can be synthesized using solution process at plastic-compatible temperatures.

I-DEMO

(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters
Thursday, Nov. 28, 2019
11:40 – 15:40
Main Hall (1F)
Sapporo Convention Center

FLXp1 - 8 A High Performance 3-bit Ripple Counter Circuit Based on Organic TFTs for Flexible Read Out Integrated Circuit

**Hansai Ji¹, Di Geng¹, Yuxin Gong¹, Qian Chen¹, Xinyin Duan¹, Yue Su¹, Xuwen Shi¹, Linrun Feng², Zhe Liu², Minghua Tang³, Simon Ogier⁴, Ling Li¹, Ming Liu¹*

1. Institute of microelectronics of the academy of science (China), 2. Wuhan LinkZill Technology Co., Ltd. (China), 3. Xiangtan University (China), 4. NeuDrive Limited (China)

We propose a high performance 3-bit negative edge-triggered ripple counter based on Organic Thin Film Transistors (OTFTs). All the logic gate circuits used in this work are inverters and NAND circuits based on OTFTs with large zero-VGS load. A voltage range of 0 to 30V and a frequency of 12.5KHz clock signal is used for the ripple counter as input clock input. A high output level of ~27.4V and a low output level of ~4 or 5V are measured at the 2nd and 3rd stages' output node of the ripple counter. Their frequencies are one quarter and one eighth of the input signal's frequency. The output signal of the proposed ripple counter changes when its input signal falls to low level from high.

FLXp1 - 9L Scribing Tool and Cutting Method for Ultra-thin Glass

**Tomoki Nakagaki¹, Takashi Kawabata¹, Hiroshi Takimoto², Tadahiro Furukawa³*

1. Mitsuboshi Diamond Industrial Co., Ltd. (Japan), 2. Nippon Electric Glass Co., Ltd. (Japan), 3. Yamagata University (Japan)

We developed a new scribing tool for ultra-thin glass, since ultra-thin glass cannot be cut well by general cutting methods. Using this tool, we examined not only the cutting of ultra-thin glass but also the cutting of ultra-thin glass during fabrication process for OLED lighting device.

FLXp1 - 10L Semiconducting Carbon Nanotube-Based Stretchable Transistors

**Dongseob Ji¹, Jimin Kwon¹, Haksoon Jung¹, Yong-Young Noh¹*

1. Pohang University of Science and Technology (Korea)

Realizing stretchable electronics requires special materials with intrinsically elastic or durable properties. One of candidates is the semiconducting carbon nanotube due to its excellent mechanical property and ultra-high charge transport mobility. In this work, the stretchable transistor is composed of sorted single-walled carbon nanotube (SWNT) semiconductors and insulating elastomer.

17:20-18:30

Mid-sized Hall B

FLX2: Stretchable and Flexible Devices

Chair: Manabu Ito (Toppan Printing Co.)
Co-Chair: Mitsuru Nakata (NHK)

FLX2 - 1 17:20 *Invited* Development of Flexible / Stretchable Epoxy Film with High Thermal Stability, Especially Suitable for Versatile Printed Electronics Applications

**Noriyasu Yamane¹, Kenta Yamamoto¹, Kotaro Nozawa¹, Takashi Komori¹, Tomohide Murase¹, Takayoshi Hirai¹*

1. Mitsubishi Chemical Corporation (Japan)

Authors developed two types of novel epoxy films with excellent printability for conductive or dielectric inks without surface treatments. High flexible type shows high durability against repeated folding. Stretchable type shows high elongation and recovery. These are recommendable for substrates of FHE, foldable displays or lighting devices, stretchable/wearable sensors, etc.

FLX2 - 2 17:45 *Invited* High Performance IGTO Transistors with Stretchable Gate Dielectric Layer

**Jae Kyeong Jeong¹, Jae Seok Hur¹, Jeong Oh Kim¹*

1. Hanyang University (Korea)

Flexible/stretchable active-matrix electronics strongly demand the design of new concept material, which should have the good electrical properties and mechanical durability. In this paper, we will address the design of hybrid dielectric film, which consists of the polymer-based backbone and high permittivity additive. By virtue of smart cross linker selection, we are able to achieve the high performance oxide transistor with the hybrid polymer gate dielectric film. The fabricated transistors can withstand the 100 times mechanical bending stress under an extremely small curvature radius of 1mm. Simultaneously, they exhibit the high mobility of $> 20 \text{ cm}^2/\text{Vs}$ and $I_{\text{ON/OFF}}$ ratio of $> 10^7$, indicating that this approach can be one of the ways for the highly mechanically stable electronics.

FLX2 - 3 18:10 *Study on Top-Gate Self-Aligned InGaZnO TFTs on PI Substrate*

**Nian Liu¹, Huafei Xie², Macai Lu¹, Xueru Mei¹, Lei Wen¹, Shujiah Chen¹, Shengdong Zhang², Chiayu Lee¹, Xin Zhang¹*

1. Shenzhen China Star Optoelectronics Semiconductor Display Technology Co.Ltd., China (China), 2. School of Electronic and Computer Engineering, Peking University, Shenzhen, China (China)

We discussed the effect of polyimide substrate on TFTs, the water from polyimide diffused into IGZO which deteriorated device characteristic. By reducing hydrogen content in GI we optimized device characteristic, and GI 1step deposition is more stable. Finally, we did the static bending and dynamic test, TFTs keep good stability.

Author Interviews

18:50 - 19:20

Friday, November 29

9:00-10:15

Room 107

FLX3: Printed TFT Technologies

FLX

Chair: Hiroki Meada (Dai Nippon Printing Co., Ltd.)
 Co-Chair: Takashi Nagase (Osaka Prefecture University)

FLX3 - 1 9:00 *Invited* **Printed Thin Film Transistors Using Semi-Conductive Single Wall Carbon Nanotube-Polymer Complexes**

**Seiichiro Murase¹, Kazuki Isogai¹, Takayoshi Hirai¹,
 Yasuhiro Kobayashi¹, Kenta Noguchi¹, Hiroji Shimizu¹
 1. Toray Industries, Inc. (Japan)*

We have achieved high performance on printed TFTs with a mobility up to 155 cm²/Vs, which is world leading level performance as a printed TFT, using highly enriched semi-conductive single wall carbon nanotube (SWCNT) and semi-conductive polymer complexes. This technology can be applied to various IoT devices.

FLX3 - 2 9:25 *Invited* **Towards Ideal Printed Organic Transistors**

*Fuhua Dai¹, *Chuan Liu¹
 1. Sun Yat-sen University (China)*

Many organic thin-film transistors (OTFTs) exhibit non-ideal current-voltage characteristics that deviate from the ideal field-effect transistor or TFTs. The physical origins include the Schottky contact injection, strong localization of carriers, interfacial dipolar disorders, and etc. To this end, we have developed theoretical understandings and various optimization method to overcome the above problems. The resulting transistors exhibit almost ideal current-voltage behaviors, featuring the high mobility values reaching 10 cm²/Vs.

SID Display Week 2020

June 7 - 12, 2020

San Francisco Moscone Convention Center

San Francisco, California, USA

<http://www.displayweek.org/>

**FLX3 - 3 *Invited* Development of High Performance
9:50 Semiconductor Inks for Printed Field-Effect
 Transistors For Flexible Display**

*Huihui Zhu¹, Ao Liu¹, Dongseob Ji¹, *YONG-
YOUNG NOH¹*

*1. Pohang University of Science and Technology
(POSTECH) (Korea)*

Although organic-inorganic halide perovskites continue to generate considerable interest with the high potential to be widely applied in a variety of optoelectronic devices, there are some critical obstacles to practical applications such as the toxicity of lead, the relatively low field effect mobility and the strong hysteresis during operation. Here we develop a universal approach to significantly improve mobility and operational stability, and reduce the hysteresis of perovskite-based transistors simultaneously through coupling low-dimensional lead-free perovskite material $(\text{C}_6\text{H}_5\text{C}_2\text{H}_4\text{NH}_3)_2\text{SnI}_4$ (hereafter abbreviated as $(\text{PEA})_2\text{SnI}_4$) with embedded conjugated polymers wrapped semiconducting carbon nanotubes (semi-CNTs). In the $(\text{PEA})_2\text{SnI}_4$ /semi-CNTs hybrid systems, semi-CNTs can contribute as smooth tracks for carriers to transport with less scattering and trapping of perovskite grain boundaries. We also demonstrate the extraordinary performance of $(\text{PEA})_2\text{SnI}_4$ /semi-CNTs hybrid phototransistors with ultrahigh photoresponsivity and photosensitivity, which is found to be on a par with the best devices available to date.

10:40-12:15

Room 107

FLX4: Wearable Sensors and Devices

Chair: Yasuyoshi Mishima (National Institute of Advanced
 Industrial Science and Technology)

Co-Chair: Hiroyuki Endoh (NEC Corp.)

**FLX4 - 1 *Invited* Ultra-Flexible Organic Imager and Sensors
10:40 *Tomyouki Yokota¹, Takao Someya¹**

1. The University of Tokyo (Japan)

We have developed ultra-flexible and lightweight organic electronics and photonics devices with few micron substrates. Our organic imager has pixel pitches as small as 50 μm , with resolutions of up to 262 ppi. Using our ultra-flexible organic imager, we succeed to measure the spatial photoplethysmography (PPG) mapping.

IMID 2020

Aug. 25 – 28, 2020

COEX

Seoul, Korea

<http://www.imid.or.kr/>

**FLX4 - 2 *Invited* Organic TFT-based Biosensors
11:05 Functionalized with Artificial Receptors**

**Tsuyoshi Minami¹*

*1. Institute of Industrial Science, The University of
Tokyo (Japan)*

We have studied organic thin-film transistors (OTFTs) functionalized with artificial receptors as a new sensing platform for a variety of targets such as small ions and molecules, and biomacromolecules. Herein, the detection of biogenic amines by OTFT and real-time monitoring of glucose by OTFT integrated microfluidic system are demonstrated.

FLX

**FLX4 - 3 *Invited* Ultra-Conformable Biodevice for Advanced
11:30 Medicine and Healthcare**

**Toshinori Fujie¹*

1. Tokyo Institute of Technology (Japan)

Ultra-conformable biodevices (namely printed nanofilms) are developed by combining polymeric nanosheets and printing technologies with variety of unique inks. The printed nanofilms allowed for continuous monitoring of biosignals or directing biofunctions, represented by the measurement of surface electromyogram, analysis of neural activity, and wireless delivery of a light into tumors to perform phototherapy.

**FLX4 - 4 Polysilicon CMOS TFTs on Ultrathin and Flexible
11:55 Stainless Steel Substrates**

**Miki Trifunovic¹, Aditi Chandra¹, Mao Ito¹, Sarah Khoo¹,
Arvind Kamath¹*

1. Thin Film Electronics Inc. (United States of America)

CMOS polysilicon TFTs fabricated on flexible stainless steel substrates are thinned down to 5 μm thickness. Bending tests show minimal change in TFT performance at 2.5 mm bending radius after 10,000 tensile bend cycles.

Author Interviews

12:10 - 12:40

IDW '20

The 27th International Display Workshops

Dec. 9 - 11, 2020

Fukuoka International Congress Center

Fukuoka, Japan

<https://www.idw.or.jp/>

13:20-14:50

Room 204

LCT7/FLX5: Flexible LCDs

Chair: Shinichiro Oka (Japan Display Inc.)
Co-Chair: Toshimasa Eguchi (Sumitomo Bakelite Co., Ltd.)

LCT7/ Invited Flexible LCD with Colorless Polyimide

**FLX5 - 1
13:20**

**Kaijun Wang¹, Chungue Yuan¹, Zhuhui Li¹, Li Zhang¹,
Qiao Huang¹, Linshuang Li¹, Shujih Chen¹, Chia-
Yu Lee¹, Xin Zhang²*

- 1. Shenzhen China Star Optoelectronics
Semiconductor Display Technology Co.Ltd. (China),*
- 2. Shenzhen China Star Optoelectronics Technology
Co., Ltd. (China)*

We successfully realized 14-inch flexible LCD using colorless polyimide(cPI) as substrate. The LCD panel has the thickness less than 0.3 mm, which is IPS mode with some special materials and designs for avoiding predictable risks and solving issues during process.

**LCT7/ Invited Ultra-High Contrast OLCD: Thin and Light
FLX5 - 2 Dual Cell LCDs on Plastic**

13:45

**Paul A Cain¹, James Harding¹, William Reeves¹,
May Wheeler¹*

- 1. FlexEnable Ltd (UK)*

We report on a breakthrough approach for creating dual cell LCDs on ultra-thin plastic films that can significantly reduce inter-cell separation, resulting in a simpler construction that avoids the need for compensation films and other trade-offs. The resulting structure is particularly suited to TVs, monitors and automotive displays.

**LCT7/ Formation of Polymer Walls with a High Aspect
FLX5 - 3 Ratio on a Plastic Substrate**

14:10

**Su Min Do¹, Tae Hoon Choi¹, Jae Won Huh¹,
Yeongyu Choi¹, Tae Hoon Yoon¹*

- 1. Pusan National University (Korea)*

We formed polymer walls with a high aspect ratio on a plastic substrate. Polymer walls are formed without a photomask through the phase separation of liquid crystal/reactive mesogen mixture induced by a spatial difference of elastic energy and electric field intensity.

**LCT7/ New Approach to Process Simplification for Flexible
FLX5 - 4L TFT-LCD**

14:30

**Cheng-He Ruan¹, Chih-Yuan Hou¹, Chia-Jen Li¹,
Shih-Min Chen¹, Min-Zi Hong¹*

- 1. AU Optronics Corporation (Taiwan)*

A new approach is proposed to fabricate flexible TFT-LCD with minimal process steps. Single substrate and without conventional cell process is obtained by introducing AOC and developed PDLC coating on the top of array without PI alignment process. The 4.99 294ppi AOC prototype LCD on a single substrate was fabricated.

15:00-16:00

Room 204

FLX6: Advanced Process and Evaluation for Flexible Electronics

Chair: Tadahiro Furukawa (Yamagata University)

Co-Chair: Akira Nakazawa (AGC Inc.)

FLX6 - 1 *Invited* Solution-Processing of Inorganic and Hybrid Materials for High Performance Flexible Electronics

15:00

Myung-Gil Kim¹1. Sungkyunkwan University (Korea)*

To improve the electrical properties in solution-processed high-performance, large-area flexible electronics, we employed hybrid structures of a multifunctional organic-semiconductor/amorphous oxide semiconductor, nanomaterials/amorphous oxide semiconductors, and chalcogenide-gel. With the novel hybrid structures and new processing strategy, we could demonstrate enhancement of mobility, electrical stability, and exceptional mechanical stability.

FLX6 - 2 Analysis and Design of Mechanical Stresses on Foldable Devices

15:25

**Nao Ando¹, Kei Hyodo¹, Hisao Sasaki¹, Yoshihito Ota¹, Tomoki Sasayama², Yoshihiko Iwao², Tomoya Tsuda², Nao Terasaki³*

1. YUASA SYSTEM (Japan), 2. Shimadzu Co. (Japan), 3. AIST (Japan)

Knowledge of mechanical stresses on foldable devices is important to develop them. When you study stresses, you should control motion profile then study dynamic strain energy. In our study, we slightly adjusted each testing conditions to figure out effect from these difference and sensitivity of the analyzing method.

Also presented in Innovative Demonstration Session (see p. 281)

FLX6 - 3 Withdrawn

EXHIBITION

12:40 – 18:00 Wednesday, Nov. 27

10:00 – 18:00 Thursday, Nov. 28

10:00 – 14:00 Friday, Nov. 29

Main Hall (1F)

Sapporo Convention Center

Free admission with your registration name tag

**FLX6 - 4L To Make a Flexible Patch Type Photoelectric Pulse
15:45 Wave Sensor Highly Sensitivity**

**Mana Hashimoto¹, Kazuki Ihara¹, Hiroshi Kajitani¹,
Hiroyuki Endo¹*

1. NEC Corporation. (Japan)

Recently, research about emotion estimation by using vital data was developed actively. In current type sensor, emotion estimation could carried out slightly in motion-condition due to a gap between the skin and the device. A flexible patch type sensor could be acquired large amount of data even motion-condition.

Author Interviews

16:30 - 17:00

Workshop on Touch Panels and Input Technologies

Wednesday, November 27

13:40-13:41	Room 206
Opening	

Opening Remarks

13:40

Nobuyuki Hashimoto¹, 1. Citizen Watch (Japan)

13:41-14:56	Room 206
INP1: In-Cell Touch Panels and Fingerprint Sensors <i>Special Topics of Interest on Automotive Displays</i>	

Chair: Noemie Ballot (ISORG)
 Co-Chair: Yuji Suzuki (Japan Display Inc.)

INP1 - 1 *Invited* Evaluation of the Integrated In-cell Electromagnetic Resonance Sensor and Capacitive Touch Sensor

13:41

**Yuji Suzuki¹, Satoshi Uchino¹, Kohei Azumi¹,
 Tadayoshi Katsuta¹, Daichi Suzuki¹, Hiroyuki Wakana¹,
 Kaoru Ito¹*

1. Japan Display Inc. (Japan)

We developed in-cell EMR reflective LCD panel, which shares the sensor pattern with capacitive touch sensor, without additional sensor layer. This technology contributes many benefits for thin design and less weight of the panel compared with conventional EMR products. This paper shows our in-cell EMR and capacitive touch sensing performance.

Also presented in Innovative Demonstration Session (see p. 281)

INP1 - 2 **Withdrawn**

INP1 - 5L **Reduction of Moving Optical Illusion through Synchronization with Eye Movement**

14:06

**Yuki Kubota¹, Tomohiko Hayakawa¹,
 Masatoshi Ishikawa¹*

1. The University of Tokyo (Japan)

Optical illusions distort our visual information. We propose a system that enables control of imagery rotation synchronously with eye movement. Our subject experiment using Rotating Snakes Illusion suggests that the appropriate performances of compensation can reduce the intensity of the illusion even without eye fixation.

**INP1 - 3 *Invited* Large-Area Optical Fingerprint Sensors for
14:31 Next Generation Smartphones**

**Noemie Ballot¹*

1. ISORG (France)

Printing-based organic photodiodes have demonstrated cost effective process and compatibility with Flat Panel industry equipment making large area optical fingerprint sensors viable for volume production. Large area thin film-based optical collimator enables simple behind display integration. Advantages of this technology are high security level for fingerprint, enhanced ease of use and slim module.

INP1 - 4 Withdrawn

15:20-16:35

Room 206

AIS1/INP2: Smart Society and Information Display

Chair: Katashi Nagao (Nagoya University)

Co-Chair: Toshiaki Fujii (Nagoya University)

**AIS1/ *Invited* Adaptive Spatial User Interfaces That
INP2 - 1 Activate Us**

15:20

**Kazuyuki Fujita¹*

1. Tohoku University (Japan)

His talk covers adaptive spatial user interfaces to make the users more active and productive. He introduces several projects including Ambient Suite that enhances communication among multiple participants and AI-Supported Meeting Space in which the space itself behaves as another participant to make the meeting more productive.

**AIS1/ *Invited* Automated Vibrotactile Generation based on
INP2 - 2 Texture Images or Material Attributes Using GAN**

15:45

**Yuki Ban¹, Yusuke Ujitoko^{2,3}*

1. The University of Tokyo (Japan), 2. Hitachi, Ltd.

*(Japan), 3. The University of Electro-Communication
(Japan)*

We propose the vibrotactile feedback designing system using GAN-based vibrotactile signal generator. Our system generate signals presenting specific tactile impression based on user-defined parameters or images. User studies showed that it was not possible to distinguish between vibrations generated using this model and vibrations recorded from the actual material surface.

AIS1/
INP2 - 3
16:10
Invited Vibrotactile Signal Generation with GAN
**Shotaro Agatsuma¹, Shin Takahashi¹, Satoshi Saga²*
1. University of Tsukuba (Japan), 2. Kumamoto University (Japan)

To create valuable content for haptic display, we propose a method of generating alternative data from acquired one instead of collecting a great number of data from real textures. We made a data generation model based on Generative Adversarial Network and held experiments to evaluate the performance of the model.

Author Interviews
18:30 - 19:00

Thursday, November 28

9:00-10:15	Room 206
INP3: Haptic Technologies (1)	
<i>Special Topics of Interest on Automotive Displays</i>	

Chair: Makoto Sato (Tokyo Institute of Technology)
Co-Chair: Nobuyuki Hashimoto (Citizen)

INP3 - 1
9:00
Invited Widespread Hapbeat: Tension Based Necklace Type Haptic Display
**Yusuke Yamazaki¹, Hironori Mitake¹, Akihiko Shirai², Shoichi Hasegawa¹*
1. Tokyo Institute of Technology (Japan), 2. GREE, Inc. (Japan)

Hapbeat is a wearable haptic device which can easily enhance the immersion of digital contents such as VR, gaming, music, movie, etc. In this paper, I explain a basic mechanism of Hapbeat and a series of challenges to widespread it into the public.

Also presented in Innovative Demonstration Session (see p. 281)

INP3 - 2
9:25
Invited Comptics: A System for Making and Sharing Haptic Experience
**Toshiki Wada¹, Hiroyoshi Togo¹*
1. NTT (Japan)

We have developed a haptic system, Comptics, that enables easy and rapid making, playing, and sharing of haptic experience. Comptics is composed of a haptic stimulation device, wearable user interface, and design and communication protocols (DCP) on a computer that uses unhearable signals.

INP3 - 3 *Invited* Buttock Skin Stretch Devices for Enhancing Driving Experience

9:50

**Masashi Konyo¹*

1. Tohoku University (Japan)

A new concept of buttock skin stretch to induce the perception of shear forces while sitting is reported. The buttock skin stretch is suitable for a driving simulator to enhance the whole-body experiences such as the centrifugal force of the car and the inclination of the car body in driving.
Also presented in Innovative Demonstration Session (see p. 281)

Author Interviews

10:40 - 11:10

14:30-17:00

Main Hall

Poster INPp1: Interactive Technologies

INPp1 - 1 Non-contact Hand Vein Imaging by Use of Aerial Guiding Illumination with AIRR

**Ikuya Saji¹, Kazuki Kawai², Ryosuke Kujime³,
hirotsugu Yamamoto^{1,4}*

1. Utsunomiya University (Japan), 2. Kowa Optical Products, Co., Ltd. (Japan), 3. Pi PHOTONICS, Inc. (Japan), 4. JST,ACCEL (Japan)

We propose a optical system aimed for non- contact hand-vein input. A floating aerial image is formed to guide a user's hand to the focused position and to illuminate the hand for vein imaging. We can install a camera in the illumination optics because of the high NA of AIRR.

INPp1 - 2 Withdrawn

INPp1 - 3 Withdrawn

INPp1 - 4L AroundSense: An Input Method for Gestures around a Smartphone

**Kaho Kato¹, Kohei Matsumura², Yuta Sugiura¹*

1. Keio University (Japan), 2. Ritsumeikan University (Japan)

In this paper, we propose a gesture input method around a smart-phone. Each gesture is detected by a distance-measuring sensor array attached to the side of a smartphone. We evaluated the accuracy of gesture recognition, and obtained an average accuracy of about 92.9% when identifying six distinct gestures.

INPp1 - 5L An Evaluation and Reduction of the Coupling Noise in Pen-Based Touch Screen Display

**Ying Kan Yang¹, Tzu Jung Tien¹, Wei Shan Yu¹, Meng Wei Shen¹, Wen Bin Wu¹, Wen Ching Tsai¹*

1. AU Optronics Corporation (Taiwan)

Here we report the quantitative analysis of coupling noise in AHVA mobile display. Moreover, some approaches for reducing the coupling noise are demonstrated. The addition Vcom compensation circuit and moderate thickness of passivation layer is introduced to diminish the coupling noise.

INPp1 - 6L Development of a User Interaction System that Presents Relevant Information Based on Gaze Line

**Takahide Otomo¹, Shinya Mochiduki¹, Eriko Ishii², Yuko Hoshino¹, Mitsuho Yamada¹*

1. Tokai University (Japan), 2. Kagoshima Prefectural College (Japan)

We developed a new user interaction system using non-contact eye tracking device. This is a system that extracts and uses words that are estimated to be of interest to the user from a web page, based on the gaze point and gazing time automatically. This article describes this system.

INP

14:30-17:00

Main Hall

**Poster VHFp3/INPp2:
Ergonomics of Interaction Technologies**

**VHFp3/
INPp2 - 1 Wearable Stick-Slip Display on Fingertip to Reproduce Rubbing Sensation**

**Honoka Haramo¹, Vibol Yem¹, Yasushi Ikei¹, Makoto Sato¹*

1. Tokyo Metropolitan University (Japan)

We developed a wearable stick-slip display using a rotating cylindrical contactor to reproduce friction sensation during rubbing a material. This paper introduces the mechanism of our device and a method to reproduce sensation of rubbing a silicon rubber or a wood based on the data measured by a force sensor.

Also presented in Innovative Demonstration Session (see p. 280)

**VHFp3/
INPp2 - 2 The Research of Touch Performance for Huge Displays**

**Kyungmok Mo¹, Sinhu Choi¹, Seungwon Jung¹*

1. LG DISPLAY (Korea)

In this study, we research the major touch performance evaluation methods for touch-applied products on large displays and examine the studies that reflect cognitive evaluation and visual characteristics. Based on this, I would like to suggest an appropriate quantitative indicator of touch performance by investigating the environment where large touch products are utilized.

**VHFp3/
INPp2 - 3 A New Athlete Performance Analysis Method Using
4K Video and Wireless Eye Movement Measurement
Device**

**Takuya Sarugaku¹, Yasuyoshi Kobayashi¹,
Reiko Koyama¹, Shinya Mochiduki¹, Mitsuho Yamada¹*

1. Tokai University (Japan)

It is thought that analyzing line-of-sight movement during sports may provide insight into exceptional athletic skill. In this study, we propose a method to analyze the athlete's performance using the athlete's line of sight measured by a wireless eye movement measurement device, and his/her movement taken by 4K images.

17:20-18:50

Room 206

INP4: Haptic Technologies (2)

Special Topics of Interest on Automotive Displays

Chair: Masashi Konyo (Tohoku University)

Co-Chair: Vibol Yem (Tokyo Metropolitan University)

INP4 - 1 *Invited* Sensory Illusion beyond Real Haptics

17:20

**Norio Nakamura^{1,2}*

1. AIST (Japan), 2. Miraisens, Inc. (Japan)

'DigitalHaptics™' is the world first invention of illusionary haptics technology, developed originally by AIST based on Neuro Science. It realized many miracle haptics such as Pushing, Pulling, Texture, and Softness in the Air, and theoretically enables the almost all kinds of haptic feeling, as same as visual composition of RGB.

**INP4 - 2 *Invited* Wearable Tactile Device for Fingertip
Interaction with Virtual World**

17:45

**Vibol Yem¹*

1. Tokyo Metropolitan University (Japan)

Author developed a wearable tactile device mounted to the fingertips for interaction with objects in the virtual environment. The device can provide sensations of pressure, low-frequency vibration and forward-flexion illusionary force in thumb, index and middle fingers by electrical stimulation; and high-frequency vibration and skin deformation by mechanical stimulation.

Also presented in Innovative Demonstration Session (see p. 281)

**INP4 - 3 *Invited* Input and Output Interaction Technologies
for Flexible Touch Panels**

18:10

**Ki-Uk Kyung¹*

1. KAIST (Korea)

This talk will introduce recent technologies for polymer based sensors and actuators. Polymer based tactile sensors support functions of detecting multiple contact forces as well as touch positions. Flexible actuators may provide haptic cues to users.

INP4 - 4L
18:35

8.4 Tactile Touch Display Using Segmented-Electrode Array as Both Tactile Pixels and Touch Sensors

**Takuya Asai¹, Hiroshi Haga¹, Shin Takeuchi¹, Harue Sasaki¹, Koji Shigemura¹*

1. Tianma Japan (Japan)

We developed an electrostatic-tactile touch display using a segmented-electrode array as both tactile pixels and touch sensors. This structure allows presenting real localized tactile textures in any shape. A driving scheme in which the tactile strength is independent of the grounding state of the human body was also demonstrated.

Also presented in Innovative Demonstration Session (see p. 281)

Author Interviews
18:50 - 19:20

INP

I-DEMO (Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters

Thursday, Nov. 28, 2019

11:40 – 15:40

Main Hall (1F)

Sapporo Convention Center

KEYNOTE EXHIBITION

The human-centered automotive cockpit HMI that will be introduced in the keynote address, and mass-produced vehicles equipped with actual display devices will be exhibited, along with other individual devices.

Main Hall (1F)

Sapporo Convention Center

Friday, November 29

9:00-10:35	Room 206
INP5: AR/VR Interactive Technologies <i>Special Topics of Interest on AR/VR and Hyper Reality</i>	

Chair: Takamichi Nakamoto (Tokyo Institute of Technology)
 Co-Chair: Shunsuke Yoshimoto (University of Tokyo)

**INP5 - 1 *Invited* Utilization or Elimination of Mona Lisa Effect
 9:00 for Eye Contact with Characters**

**Hironori Mitake¹, Hsueh Han Wu¹, Taro Ichii¹,
 Kazuya Tateishi¹, Shoichi Hasegawa¹
 1. Tokyo Institute of Technology (Japan)*

Interactive characters as digital signage are becoming popular. Eye contact from the character in appropriate situation may cause sense of awareness from the character, and attract people attention. Also, widely used planar display cause Mona Lisa effect. We focused on positive and negative aspect of the effect, and created novel way to enable eye contact from characters to viewers, which is utilizing or eliminating the Mona Lisa effect.

Also presented in Innovative Demonstration Session (see p. 281)

**INP5 - 2 *Invited* Olfactory Display and its Application
 9:25**

**Takamichi Nakamoto¹
 1. Tokyo Institute of Technology (Japan)*

An olfactory display is a device to present smells. We have studied multi-component olfactory display to generate a variety of smells. Our recent model consists of multiple micro dispensers and a surface acoustic wave atomizer. Both desktop-type and wearable type olfactory displays together with their contents were developed.

**INP5 - 3 *Invited* Electromechanical Impedance Tomography
 9:50 for Soft Tactile Sensor**

**Shunsuke Yoshimoto¹
 1. The University of Tokyo (Japan)*

This study introduces a tactile sensing technology based on a tomographic approach with conductors for imaging of pressure distribution. The proposed technology enabled designing the soft tactile sensor, characterized by high positional accuracy, adjustable sensitivity and range, and a relatively simple fabrication process.

INP5 - 4
10:15

**An Interactive Holographic Light-Field Display
Color-Aided 3D-touch User Interface**

**Ivan Alexis Sanchez Salazar Chavarria¹,
Tomoya Nakamura¹, Masahiro Yamaguchi¹*

1. Tokyo Institute of Technology (Japan)

The author's group previously demonstrated a holographic light-field display with a 3D touch interface, based on the detection of scattered light by the user. That interface is now improved by realizing real-time interactivity and the implementation of 3D motion detection using the color information captured by an RGB sensor.

Author Interviews

12:10 - 12:40

Supporting Organizations:

Holographic Display Artists and Engineers Club (HODIC), The
Optical Society of Japan

State of the Technologies in Expression Association

Technical Committee on Haptics, System Integration Division, The
Society of Instrument and Control Engineers

Technical Group on Information Sensing Technologies, ITE

INP

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers
selected from those presented at IDW '19.

IDW'19 Award winners will be announced on the
IDW website: <https://www.idw.or.jp/award.html>

EXHIBITION

12:40 – 18:00 Wednesday, Nov. 27

10:00 – 18:00 Thursday, Nov. 28

10:00 – 14:00 Friday, Nov. 29

Main Hall (1F)

Sapporo Convention Center

Free admission with your registration name tag

Innovative Demonstration Session

Thursday, November 28

11:40 - 15:40

Main Hall

Innovative Demonstration Session

- AIsp2/
VHFp6 - 1** **Automatic Selection of Preferable Tone-Mapping Method Based on Deep Learning**
**Hirofumi Sasaki¹, Keita Hirai¹, Takahiko Horiuchi¹*
 1. Chiba University (Japan)
- 3DSA3/
3D3 - 1** **Depth Range Control in Visually Equivalent Light Field 3D (VELF3D) Display**
**Munekazu Date¹, Shinya Shimizu¹, Hideaki Kimata¹*
 1. Nippon Telegraph and Telephone Corporation (Japan)
- 3DSA7/
3D7 - 4** **Air Floating Image Based on a Dihedral Corner Reflector Array**
**YUKI MAEDA¹*
 1. Parity Innovations Co. Ltd. (Japan)
- LCTp5 - 8L** **Electro-Optical Properties and Stabilities of Polymer Network Liquid Crystal Films with Polymer Wall Structure**
**SeYong Eom¹, Da-Som Yoon², Tae-Hoon Kwon¹, Soon-Bum Kwon^{1,2}*
 1. Hoseo University (Korea), 2. NDIS Corporation (Korea)
- LCT5/
FMC5 - 3** **17-inch Laser Backlight LCD with 8K, 120-Hz Driving and BT.2020 Color Gamut**
*Yoichi Asakawa¹, Ken Onoda¹, Hiroaki Kijima¹, *Shinichi Komura¹*
 1. Japan Display Inc. (Japan)
- AMD4 - 1** **Active-Matrix Driven Flexible mini-LED Displays Based on High-Performance Organic Single-Crystal TFTs**
**Jun Takeya^{1,2}*
 1. The University of Tokyo (Japan), 2. Organo-Circuit Inc. (Japan)

- AMD6 - 2 Development of High Mobility Top Gate IGZO-TFT for Automotive OLED Display**
**Yujiro Takeda¹, Aman Mehadi¹, Shogo Murashige¹, Kazuatsu Ito¹, Izumi Ishida¹, Shinji Nakajima¹, Hiroshi Matsukizono¹, Naoki Makita¹*
 1. SHARP Corporation (Japan)
- AMD7 - 4L Low-Temperature IGZO Technology on Transparent Plastic Foil by Atmospheric Spatial Atomic Layer Deposition**
*Corné Frijters^{1,2}, Roy Verbeek¹, Gerard de Haas¹, Tung Huei Ke³, Erwin Vandenplas³, Marc Ameys³, Jan-Laurens van der Steen¹, Gerwin Gelinck^{1,4}, Eric Meulenkamp¹, Paul Poodt^{1,2}, Auke Kronemeijer¹, *Ilias Katsouras¹*
 1. TNO/Centre (Netherlands), 2. SALDtech B.V. (Netherlands), 3. imec (Belgium), 4. Eindhoven University of Technology (Netherlands)
- FMC4/ LCT4 - 1 High-Resolution (1,000 to over 3,000 ppi) Full-Color "Silicon Display" for Augmented and Mixed Reality**
**Hidenori Kawanishi¹, Hiroaki Onuma¹, Masumi Maegawa¹, Takashi Kurisu², Takashi Ono², Shigeyuki Akase¹, Shinji Yamaguchi¹, Naoto Momotani², Yusuke Fujita¹, Yuhei Kondo², Kentaro Kubota², Toshimi Yoshida¹, Yuta Ikawa¹, Tsuyoshi Ono², Hiroyoshi Higashisaka², Yasuaki Hirano², Shinsuke Anzai¹*
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- FMC6 - 3 Novel Chromakey Technology with Polarizer and Retardation Film**
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- OLED3 - 1 Development of Long Lifetime and High Performance OLED Display with Wide Temperature Range**
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**Kazuya Furuta¹, Yuji Sakamoto¹*
 1. Hokkaido University (Japan)

- 3Dp1/ 3DSAp1 - 16 Multiview Image Correction for Visually Equivalent Light Field 3D Display**
**Takasuke Nagai¹, Munekazu Date¹, Shinya Shimizu¹, Hideaki Kimata¹*
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- VHF3/ DES3 - 1 VR Headset with Human-Eye Resolution**
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- VHFp3/ INPp2 - 1 Wearable Stick-Slip Display on Fingertip to Reproduce Rubbing Sensation**
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- PRJ4 - 3 New Concept Ultra Short Throw Projector for Consumer**
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- PRJ6/ AIS3 - 2 Vertical View Human Action Recognition from Range Images**
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- EP2/ DES4 - 5L High-Performance and Low-Power Full Color Reflective LCD for New Applications**
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 1. Japan Display Inc. (Japan)
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**Yusuke Yamazaki¹, Hironori Mitake¹, Akihiko Shirai², Shoichi Hasegawa¹*
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- INP4 - 2** **Wearable Tactile Device for Fingertip Interaction with Virtual World**
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- INP4 - 4L** **8.4" Tactile Touch Display Using Segmented-Electrode Array as Both Tactile Pixels and Touch Sensors**
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H. Kim	Kyungpook National Univ.
J. Kim	ETRI
S. Kim	Korea Telecom
S. Kim	KIST
Y. Kim	Korea Radio Promotion Assn.
H. Kimata	NTT
J. Kwon	Samsung Display
B. Lee	Seoul Nat. Univ.
Y. Lin	Theia Tech.
J. Liu	Feng Chia Univ.
O. Matoba	Kobe Univ.
S. Min	Kyung Hee Univ.
D. Miyazaki	Osaka City Univ.
G. Park	Seoul Nat. Univ. of S&T
J. Park	Hanyang Univ.
J. Park	ETRI
M. Park	ETRI
Z. Qin	Nat. Chiao Tung Univ.
H. Saito	Keio Univ.
D. Sakamoto	Hokkaido Univ.
J. Seo	ETRI
Y. Seo	Sogang Univ.
J. Son	Konyang Univ.
W. Su	Nat. Changhua Univ. of Education
Y. Takaki	Tokyo Univ. of A&T
C. Tsai	DOE
K. Wang	Ibosen Tech.
W. Woo	KAIST
H. Yamamoto	Utsunomiya Univ.
J. Yang	Nat. Cheng-Kung Univ.
S. Yano	Shimane Univ.

H. Yoshikawa Nihon Univ.

Special Topics of Interest on AR/VR and Hyper Reality

Facilitator: Y. Oyamada Tottori Univ.

Program Committee:

LCT	S. Oka	Japan Display
FMC	H. Yamamoto	Utsunomiya Univ.
3D	M. Tsuchida	NTT
VHF	T. Shibata	Tokyo Univ. of Social Welfare
PRJ	K. Ohara	Marubun
DES	Y. Oyamada	Tottori Univ.
INP	Y. Sugita	Sharp
3DSA	K. Yamamoto	NICT

Special Topics of Interest on Automotive Displays

Facilitator: K. Morita Chuo Univ.

Program Committee:

LCT	K. Miyachi	JSR
FMC	H. Yamamoto	Utsunomiya Univ.
OLED	K. Kishino	Idemitsu Kosan
3D	M. Tsuchida	NTT
VHF	Y. Imai	Mitsubishi Elec.
PRJ	K. Ohara	Marubun
DES	K. Morita	Chuo Univ.
INP	Y. Sugita	Sharp
3DSA	K. Yamamoto	NICT

Special Topics of Interest on Micro/Mini LEDs

Facilitator: T. Honda Kogakuin Univ.

Program Committee:

LCT	K. Miyachi	JSR
AMD	K. Nomoto	Sony
FMC	H. Kato	Sharp
PH	N. Miura	Meiji Univ.
MEET	J. Moon	Shizuoka Univ.

Special Topics of Interest on Quantum Dot Technologies

Facilitator: T. Ikuta JNC

Program Committee:

LCT	S. Oka	Japan Display
FMC	T. Nonaka	Merck PM
PH	N. Miura	Meiji Univ.
OLED	T. Tsuji	Nippon Steel Chem. & Material
MEET	J. Moon	Shizuoka Univ.

SUPPORTING MEMBERS (as of October 15, 2019)

EIZO Corporation
 JAPAN BROADCASTING CORPORATION
 JNC Corporation
 Merck Performance Materials Ltd.
 Tianma Japan, Ltd.
 TOKYO ELECTRON LIMITED
 ULVAC, Inc.
 Zeon Corporation

FINANCIAL SUPPORTING ORGANIZATIONS (as of October 15, 2019)

Applied Materials, Inc.
 Japan Display Inc.
 NICHIA CORPORATION
 Sharp Corporation
 Sony Corporation

EXHIBITORS: COMPANIES (as of October 15, 2019)

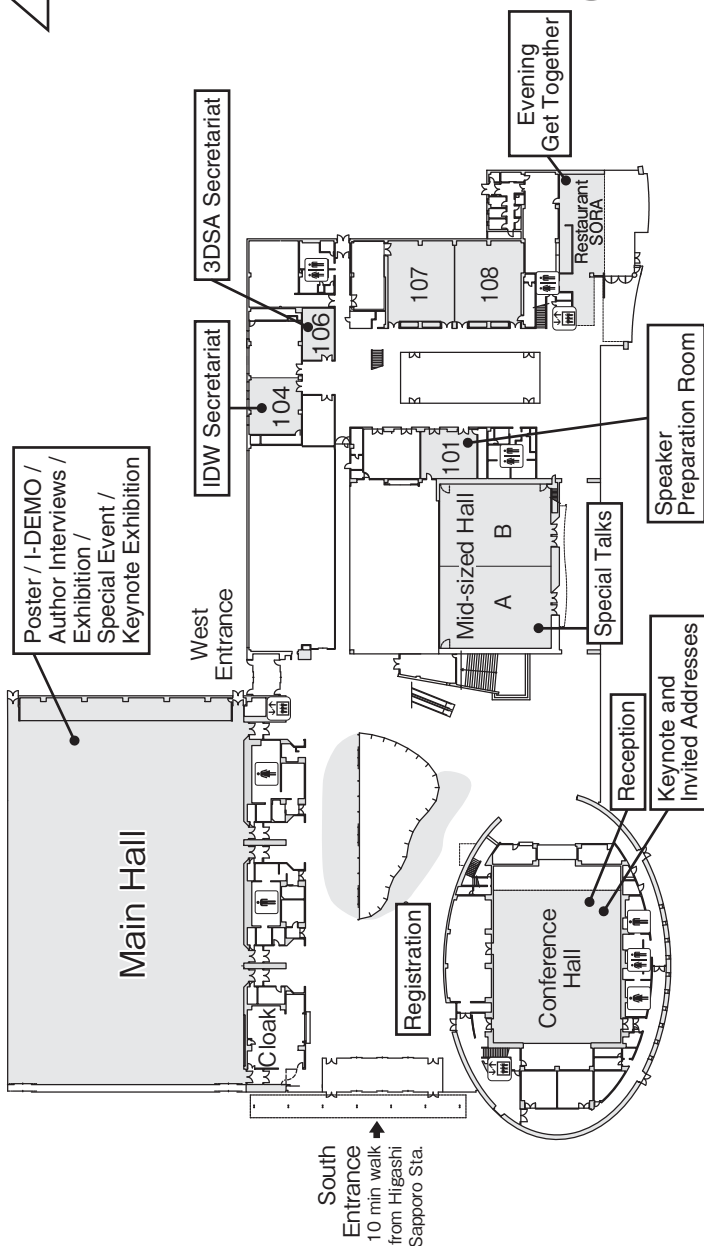
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IDTechEx
ITOH OPTICAL INDUSTRIAL CO., LTD.
KYOSHIN COMMUNICATIONS Co., Ltd.
Mitsubishi Chemical Corporation
Nagase ChemteX Corporation
OPTO DESIGN INC.
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OXIDE Corporation
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Tosoh Corporation
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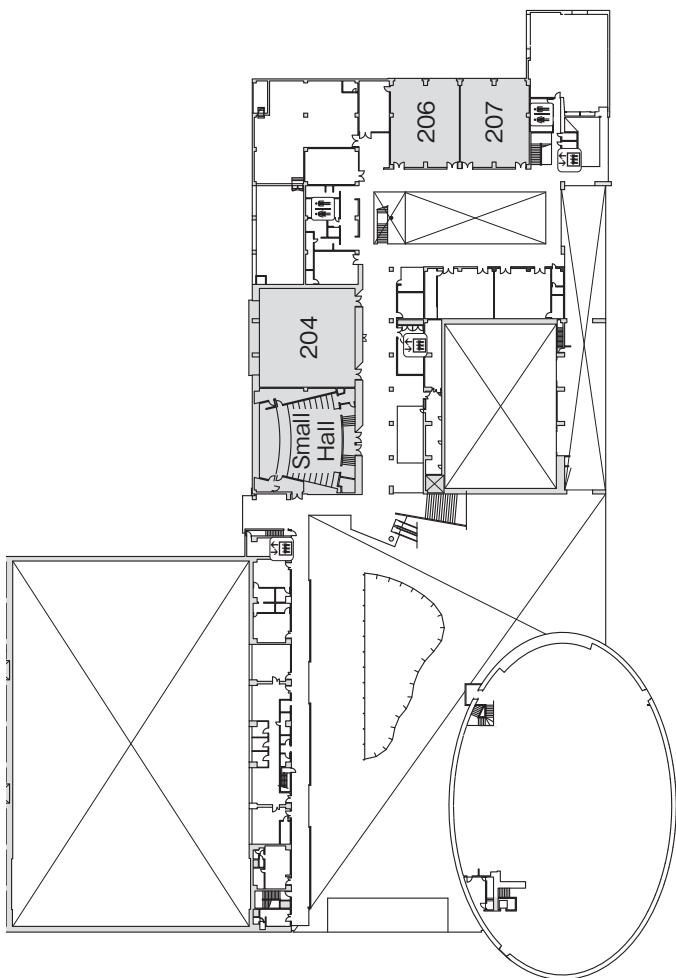
EXHIBITORS: UNIVERSITIES (as of October 15, 2019)

Dept. of Optical S&T, Fac. of Eng., Tokushima Univ.
Electron Device Eng. Labs., Graduate School of Sci. & Eng.,
Univ. of Toyama
Liquid Crystal Device Lab., Nagaoka Univ. of Tech.
Mutsu Lab., Ryukoku Extension Ctr., Ryukoku Univ.
Yamamoto Lab., Utsunomiya Univ.

FLOOR MAP

1F





MEMO

Reception

Wednesday evening
Nov. 27, 2019
19:20 – 21:00
Conference Hall (1F)
Sapporo Convention Center
See page 15 for details

IDW '19 Tutorial in Japanese

Organized by SID Japan Chapter
Tuesday, Nov. 26, 2019
13:00 – 17:50
Small Hall (2F)
Sapporo Convention Center
Detailed information will be announced at
<http://www.sid-japan.org/>

Evening Get-Together with Wine

Tuesday, Nov. 26, 2019
18:00 – 20:00
Restaurant “Sora” (1F)
Sapporo Convention Center
Sponsored by
International Display Workshops
General Incorporated Association
See page 15 for details

IDW '19 Workshop Timetable

	1F						2F				1F			
Date	Lobby	Conference Hall	Mid-Sized Hall A	Mid-Sized Hall B	Room 107	Room 108	Small Hall	Room 204	Room 206	Room 207	Main Hall			
Tue., Nov. 26	Registration 17:00 - 20:00	Evening Get - Together at Sora (1F) 18:00 - 20:00												
Wednesday, November 27	Registration 8:00 - 18:00	Opening, Keynote & Invited Addresses 9:20 - 12:30												
		Lunch												
			VHF1 13:40 - 15:10	AMD1 13:40 - 15:15	LCT1 13:40 - 15:00	PRJ1/FMC1 13:40 - 15:05	3DSA1/3D1 13:40 - 15:05	OLED1 13:40 - 15:00	INP1 13:40 - 14:56	DES1 13:40 - 15:00	Exhibition 12:40 - 18:00			
		Break												
			VHF2 15:20 - 16:45	AMD2 15:20 - 16:45	LCT2 15:20 - 16:50	FMC2 15:20 - 16:40	3D2/3DSA2 15:20 - 16:40	OLED2 15:20 - 16:40	AIS1/INP2 15:20 - 16:35	DES2 15:20 - 16:40				
		Break												
		VHF3/DES3 17:00 - 18:30	AMD3 17:00 - 18:35	LCT3 17:00 - 18:00	FLX1/FMC3 17:00 - 18:30	3DSA3/3D3 17:00 - 18:20	OLED3 17:00 - 18:25	AIS2 17:00 - 18:25	EP1 17:00 - 18:35					
			Special Talks 18:30 - 19:10								Author Interviews 18:30 - 19:00			
Break														
Reception at Conference Hall (1F) 19:20 - 21:00														
Thursday, November 28	Registration 8:00 - 18:00	MEET1 9:00 - 10:30	FMC4/LCT4 9:00 - 10:20	AMD4 9:00 - 10:20	EP2/DES4† 9:00 - 10:38	PRJ2† 9:00 - 10:38	3D4/VHF4/3DSA4 9:00 - 10:20	OLED4 9:00 - 10:35	INP3 9:00 - 10:15				Exhibition 10:00 - 18:00	
		Break												
											Author Interviews 10:40 - 11:10	LCTp,AMDp,FMCp, PHp,OLEDp,MEETp, 3Dp,3DSAp, 10:40 - 13:10		Innovative Demonstration Session 11:40 - 15:40
											LCTp,AMDp,FMCp, PRJp,VHFp,EPP, DESp,INPp,FLXp, AISp,3Dp,3DSAp 14:30 - 17:00			
		MEET2 17:20 - 18:40	VHF5 17:20 - 18:40	FLX2 17:20 - 18:30	EP3 17:20 - 18:20	PRJ3 17:20 - 18:40	3DSA5/3D5 17:20 - 18:40	OLED5 17:20 - 18:40	INP4 17:20 - 18:50					
											Author Interviews 18:50 - 19:20			
Friday, November 29	Registration 8:00 - 13:00	MEET3 9:00 - 10:20	LCT5/FMC5 9:00 - 10:35	AMD5 9:00 - 10:30	FLX3 9:00 - 10:15	PRJ4 9:00 - 10:35	3D6/3DSA6 9:00 - 10:20	OLED6 9:00 - 10:15	INP5 9:00 - 10:35			Exhibition 10:00 - 14:00		
		Break												
		MEET4 10:40 - 11:40	LCT6 10:40 - 12:10	AMD6 10:40 - 12:15	FLX4 10:40 - 12:15	PRJ5 10:40 - 12:20	3DSA7/3D7 10:40 - 12:00	PH1 10:40 - 11:55	FMC6 11:00 - 11:40					
											Author Interviews 12:10 - 12:40			
	Lunch													
		MEET5 13:20 - 14:40	VHF6 13:20 - 14:45	AMD7 13:20 - 14:40	DES5 13:20 - 14:35	PRJ6/AIS3 13:20 - 14:35	3D8/3DSA8 13:20 - 14:40	LCT7/FLX5 13:20 - 14:50	FMC7 13:20 - 14:20					
		Break												
		MEET6 15:00 - 16:20	VHF7 15:00 - 16:25	AMD8 15:00 - 16:25	DES6/AIS4 15:00 - 16:10	PRJ7/LCT8 15:00 - 16:20	3DSA9/3D9 15:00 - 16:20	FLX6 15:00 - 16:00	FMC8 15:00 - 16:20					
										Author Interviews 16:30 - 17:00				

† Including Short Presentations

IDW '19 Session Navigator

	Wednesday, November 27				Thursday, November 28						Friday, November 29					
	PM			A.I.	AM	A.I.	AM Poster	PM Poster	PM	A.I.	AM		A.I.	PM		A.I.
	13:40~	15:20~	17:00~	18:30-19:00	9:00~	10:40-11:10	10:40-13:10	14:30-17:00	17:20~	18:50-19:20	9:00~	10:40~	12:10-12:40	13:20~	15:00~	16:30-17:00
3D/Hyper-Realistic Displays 3DSA2019	Small Hall			Main Hall	Small Hall	Main Hall	Main Hall	Main Hall	Small Hall	Main Hall	Small Hall		Main Hall	Small Hall		Main Hall
	Holography 1*	Holography 2*	Light Field 1*	A.I.	Illusion*	A.I.	Posters	Posters	Light Field 2*	A.I.	Distinguished Display*	Virtual Reality 1*	A.I.	Virtual Reality 2*	Data Compression*	A.I.
Active-Matrix Displays	Mid-Sized Hall B			Main Hall	Mid-Sized Hall B	Main Hall	Main Hall	Main Hall			Mid-Sized Hall B		Main Hall	Mid-Sized Hall B	Mid-Sized Hall B	Main Hall
	Foldable Technology of OLED Displays	High Resolution Display	Driving Technology of Micro/Mini LED Displays	A.I.	Emerging TFTs	A.I.	Posters	Posters			Oxide TFT: Device Fundamentals	Oxide TFT: Device Application	A.I.	Oxide TFT: Fabrication Process	Advanced Driving Technology for High-quality Display	A.I.
Artificial Intelligence and Smart Society	Room 206			Main Hall				Main Hall						Room 108	Room 107	Main Hall
		Smart Society & Information Display*	AI & Information Display	A.I.				Posters						A.I.*	Image Processing*	A.I.
Display Electronic Systems	Room 207		Mid-Sized Hall A	Main Hall	Room 107	Main Hall		Main Hall						Room 107		Main Hall
	8K Systems	Driving Technology	Virtual Reality*	A.I.	Advanced Electronic Paper Displays & Systems*	A.I.		Posters						Video Coding	Image Processing*	A.I.
Emissive Technologies							Main Hall					Room 204	Main Hall			
							Posters					Phosphors & Devices	A.I.			
e-Paper			Room 207	Main Hall	Room 107	Main Hall		Main Hall	Room 107	Main Hall						
			Emerging Electronic Paper Displays	A.I.	Advanced Electronic Paper Displays & Systems*	A.I.		Posters	Electrochromic Devices	A.I.						
Flexible Electronics			Room 108	Main Hall				Main Hall	Mid-Sized Hall B	Main Hall	Room 107		Main Hall	Room 204		Main Hall
			Advanced Materials & Components for Flexible Electronics	A.I.				Posters	Stretchable & Flexible Devices	A.I.	Printed TFT Technologies	Wearable Sensors & Devices	A.I.	Flexible LCDs*	Advanced Process & Evaluation for Flexible Electronics	A.I.
Human Factor	Mid-Sized Hall A			Main Hall	Small Hall	Main Hall		Main Hall	Mid-Sized Hall A	Main Hall				Mid-Sized Hall A		Main Hall
	Image Quality & Measurements	Ergonomics for Automotive Applications	Virtual Reality*	A.I.	Illusion*	A.I.		Posters	Physiological & Psychophysical Factors	A.I.				Ergonomics for Display Applications I	Ergonomics for Display Applications II	A.I.
Interactive Technologies	Room 206			Main Hall	Room 206	Main Hall		Main Hall	Room 206	Main Hall	Room 206		Main Hall			
	In-Cell Touch Panels & Fingerprint Sensors	Smart Society & Information Display*		A.I.	Haptic Technologies (1)	A.I.		Posters	Haptic Technologies (2)	A.I.	AR/VR Interactive Technologies		A.I.			
Liquid Crystal Science & Technologies	Room 107			Main Hall	Mid-Sized Hall A		Main Hall	Main Hall			Mid-Sized Hall A		Main Hall	Room 204	Room 108	Main Hall
	Evaluation Techniques	LC Flat Diffractive Optics	Advanced LCD Technologies	A.I.	Micro LED Display*		Posters	Posters			High Performance 8K LCDs	New LC Applications	A.I.	Flexible LCDs	Eyewear*	A.I.
Manufacturing, Process & Equipment	Room 108			Main Hall			Main Hall	Main Hall			Mid-Sized Hall A		Main Hall			
	AR/VR*	Metrology & Manufacturing	Advanced Materials & Components for Flexible Electronics	A.I.			Posters	Posters			High Performance 8K LCDs		A.I.			
Materials & Components					Mid-Sized Hall A			Main Hall				Room 206	Main Hall	Room 206		Main Hall
					Micro LED Display*			Posters				Retardation Management	A.I.	Quantum Dot	Advanced Material	A.I.
MEMS					Conference Hall	Main Hall	Main Hall		Conference Hall	Main Hall	Conference Hall		Main Hall	Conference Hall		Main Hall
					Novel Materials, Fundamental Components & Process Technologies	A.I.	Posters		EL Quantum Dots Technologies	A.I.	Emerging Quantum Dots & Nanotechnologies (1)	Emerging Quantum Dots & Nanotechnologies (2)	A.I.	Micro/NanoDisplays & Nanotechnology Application (1)	Micro/NanoDisplays & Nanotechnology Application (2)	A.I.
OLED Displays & Organic Devices	Room 204			Main Hall	Room 204	Main Hall	Main Hall		Room 204	Main Hall	Room 204		Main Hall			
	OLED Devices	OLED Material	OLED Display	A.I.	QD Material & Devices	A.I.	Posters		OLED Optical Design	A.I.	OLED Advanced Technologies		A.I.			
Oxide-Semiconductor TFT											Mid-Sized Hall B		Main Hall	Mid-Sized Hall B		Main Hall
											Oxide TFT: Device Fundamentals	Oxide TFT: Device Application	A.I.	Oxide TFT: Fabrication Process		A.I.
Projection & Large Area Displays	Room 108			Main Hall	Room 108	Main Hall		Main Hall	Room 108	Main Hall	Room 108		Main Hall	Room 108		Main Hall
	AR/VR*			A.I.	Optical Components	A.I.		Posters	Image Quality & Display Devices	A.I.	Projection Mapping & Lighting	Automotive Display	A.I.	A.I.*	Eyewear*	A.I.

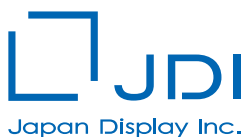
A.I.: Author Interviews

*: Joint Session

IDW '19 Special Topics of Interest Navigator

			AR/VR & Hyper Reality					Automotive Displays				Micro/Mini LEDs				Quantum Dot Technologies			
			Mid-Sized Hall A(1F)	Room 107(1F)	Room 108(1F)	Small Hall(1F)	Room 206(2F)	Main Hall(1F)	Mid-Sized Hall A(1F)	Room 108(1F)	Room 206(2F)	Main Hall(1F)	Conference Hall(1F)	Mid-Sized Hall A(1F)	Mid-Sized Hall B(1F)	Main Hall(1F)	Conference Hall(1F)	Room 204(2F)	Room 206(2F)
Wed., Nov. 27	PM	13:40			PRJ1/FMC1: AR/VR 13:40 - 15:05						INP1: In-Cell Touch Panels & Fingerprint Sensors 13:40 - 14:56								
		15:20		LCT2: LC Flat Diffractive Optics 15:20 - 16:50					VHF2: Ergonomics for Automotive Applications 15:20 - 16:45										
		17:00	VHF3/DES3: Virtual Reality 17:00 - 18:30											AMD3: Driving Technology of Micro/Mini LED Displays 17:00 - 18:35					
		Special Talks 18:30 - 19:10 Mid-Sized Hall A																	
Thu., Nov. 28	AM	9:00								INP3: Haptic Technologies (1) 9:00 - 10:15			FMC4/LCT4: Micro LED Display 9:00 - 10:20				OLED4: QD Material & Devices 9:00 - 10:35		
		10:40												FMCp1: Poster 10:40 - 13:10				FMCp2/PHp2/ OLEDp2: Posters 10:40 - 13:10	
	PM	14:30					DESp3/DESp4 14:30 - 17:00				DESp5 14:30 - 17:00								
		17:20			PRJ3: Image Quality & Display Devices 17:20 - 18:40					INP4: Haptic Technologies (2) 17:20 - 18:50						MEET2: EL Quantum Dots Technologies 17:20 - 18:40			
Fri, Nov. 29	AM	9:00				INP5: AR/VR Interactive Technologies 9:00 - 10:35										MEET3: Emerging Quantum Dots & Nanotechnologies (1) 9:00 - 10:20			
		10:40			3DSA7/3D7: Virtual Reality 1 10:40 - 12:00				PRJ5: Automotive Display 10:40 - 12:20						MEET4: Emerging Quantum Dots & Nanotechnologies (2) 10:40 - 11:40				
	PM	13:20			3D8/3DSA8 Virtual Reality 2 13:20 - 14:40							MEET5: Micro/NanoDisplays & Nanotechnology Application (1) 13:20 - 14:40					FMC7: Quantum Dot 13:20 - 14:20		
		15:00			PRJ7/LCT8 Eyewear 15:00 - 16:20								MEET6: Micro/NanoDisplays & Nanotechnology Application (2) 15:00 - 16:20						

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