



ICDT 2017

2017国际显示技术会议

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I See Display Trend

ICDT Proceedings

Content

Session 1:	ICDT Business Conference	1
Session 2:	ICDT Seminar	1
Session 3:	Opening Remarks / Plenary Session 1	1
Session 4:	Plenary Session 2	2
Session 5:	OLED Materials 1 (OLEDs)	2
Session 6:	AR & VR 1 (AR&VR)	5
Session 7:	Key materials for flexible display and electronics (E-paper and Flexible Displays)	7
Session 8:	Manufacture of TFT Device, Array, and Circuits 1 (Display Manufacturing)	10
Session 9:	TFT Circuit and Display Driving (Active-Matrix Devices)	12
Session 10:	Organic TFTs (Active-Matrix Devices)	15
Session 11:	Quantum Dots materials (Emissive Displays)	16
Session 12:	New Structure TFT and Backplane Technology (Active-Matrix Devices)	18
Session 13:	New TFT Applications (Active-Matrix Devices)	19
Session 14:	New Material TFTs (Active-Matrix Devices)	21
Session 15:	micro-LED (Emissive Displays)	23
Session 16:	QD PL (Emissive Displays)	28
Session 17:	OLED Device 1 (OLEDs)	29
Session 18:	OLED Display 1 (OLEDs)	31
Session 19:	Display Module Manufacturing for All Display Technologies (Display Manufacturing)	33
Session 20:	Applications of 3D Display (Display Applications)	34
Session 21:	Printed inorganic TFTs & electronics (Active-Matrix Devices)	36
Session 22:	Liquid-Crystal Technology 1 (Liquid-Crystal Technology)	39
Session 23:	Liquid-Crystal Technology 2 (Liquid-Crystal Technology)	41
Session 24:	Display Measurement 1 (Display Measurement)	44
Session 25:	Display Measurement 2 (Display Measurement)	46
Session 26:	Electronic paper 1 (E-paper and Flexible Displays)	49
Session 27:	Electronic paper 2 (E-paper and Flexible Displays)	51
Session 28:	Color Vision and Color Rendering (Applied Vision)	52
Session 29:	High Performance Metal Oxide TFTs (Active-Matrix Devices)	52
Session 30:	Flexible TFTs and Displays (Active-Matrix Devices)	54
Session 31:	QLED (Emissive Displays)	56
Session 32:	Visual Healthy (Applied Vision)	58
Session 33:	OLED Device 2 (OLEDs)	60
Session 34:	OLED Materials 2 (OLEDs)	62
Session 35:	AR & VR 2 (AR & VR)	65
Session 36:	Touch sensor technology & touch panel process (Touch and Interactive Displays)	67
Session 37:	Vehicle Displays	69
Session 38:	Display Applications 1 (Display Applications)	71
Session 39:	Display Material and Component Manufacturing (Display Manufacturing)	73
Session 40:	Manufacturing Equipments for All Display Technologies (Display Manufacturing)	74
Session 41:	Novel Displays (Display Systems)	76
Session 42:	Printed OLED Materials (Printed Displays)	78
Session 43:	TFT Reliability (Active-Matrix Devices)	80

Session 44:	Manufacture of TFT Device, Array, and Circuits 2 (Display Manufacturing)	82
Session 45:	Liquid-Crystal Technology 3 (Liquid-Crystal Technology)	84
Session 46:	Flexible OLEDs and key material technology (E-paper and Flexible Displays)	85
Session 47:	Flexible Electronics (E-paper and Flexible Displays)	87
Session 48:	Display Electronics	89
Session 49:	OLED Display 2 (OLEDs)	91
Session 50:	Lighting and Emissive Materials	93
Session 51:	Novel Interactive Displays (Touch and Interactive Displays)	96
Session 52:	Laser Projection Display and Key Devices & Applications (Projection)	98
Session 53:	Display Applications 2 (Display Applications)	100
Session 54:	Manufacture of LCDs and other Non-Emissive Display Panels (Display Manufacturing)	102
Session 55:	Manufacture of OLEDs and Other Emissive Display Panels (Display Manufacturing)	104
Session 56:	Processing and Devices of Printing Display 1 (Printed Displays)	105
Session 57:	Processing and Devices of Printing Display 2 (Printed Displays)	107
Session 58:	Performance Optimization of Display system (Display Systems)	109
Session 59:	Poster Session	110
Author Index	128

Session 1: ICDT Business Conference

Session 2: ICDT Seminar

S2.1

Advanced TFT

Fundamentals of Thin-film Transistor Technologies for Modern Displays

XiaoJun Guo (郭小军)

Shanghai Jiao Tong University

S2.2

Quantum Dots & Related Displays

Highly Efficient and Stable Quantum Dot Light-emitting Diodes Produced by Ink-jet Printing

Lei Qian (钱磊),

TCL Corporate Research

S2.3

Printing Displays

Overview of Printed Display

Zheng Cui (崔铮),

Suzhou Institute of Nano-tech and Nano-bionics, Chinese Academy of Sciences

S2.4

AR&VR&MR

Yi-Pai Huang (黄乙白),

National Chiao Tung University

Session 3: Opening Remarks / Plenary Session 1

S3.1

Future of OLED Displays

邓青云, Ching W. Tang

University of Rochester and Hong Kong University of Science and Technology

S3.2

History and Trend of Flat Panel Display Development in Mainland China (中国大陆平板显示发展历史与趋势)

欧阳钟灿 Zhongcan Ouyang

Institute of Theoretical Physics, Chinese Academy of Sciences

S3.3

Versatile Chromophores and Triplet Emitters for Efficient Optoelectronic Functions

任咏华 Vivian Wing-Wah YAM

University of Hong Kong

S3.4

Technology Advancement in Flexible Displays

程章林 Jang Lin, Chen

Industrial Technology Research Institute(ITRI)

S3.5

Tentative title: Oxide TFT Backplanes for OLED Displays

Arokia Nathan

Cambridge University

S3.6

The Future TV is Here, It's OLED

SY Yoon

LG Display

S3.7

Challenges for New OLED Display Era

Toshiaki Arai

JOLED

Session 4: Plenary Session 2

S4.1

New frontiers in LCDs

Shintson Wu

University of Central Florida

S4.2

Recent progress in photoalignment technologies

郭海成 Hoi Sing KWOK

Hong Kong University of Science and Technology

S4.3

Latest development of high-performance OLED material suitable for printing fabrication

Takeshi Yamada

Sumitomo Chem

S4.4

Advances in Next Generation Display Materials

Kathleen O'Connell

Dow Chemical

Session 5: OLED Materials 1 (OLEDs)

S5.1

***Invited:* TADF Materials for High Efficiency OLEDs**

Ken-Tsung Wong

Department of Chemistry National Taiwan University

Abstract: Organic molecules with efficient thermally activated delayed fluorescence (TADF) are emerging as attractive emitters in OLEDs because of the achievable 100% internal quantum efficiency. In this talk, our recent works on acridine-based TADF materials will be presented. One of this series TADF materials exhibits nearly 100% photoluminescence quantum yield, excellent thermal stability, and a horizontal dipole ratio of 83%, leading to extremely efficient blue organic EL with external quantum efficiency (EQE) of ~37%. In addition, efficient and tunable blue-green to yellow TADF emitters capable of generating OLED EQEs of >31% are developed adopting acridine as donor unit and CN-substituted benzene, pyridine and pyrimidine as acceptor units will also be reported. These materials permit one to systematically probe the influence of different acceptor strengths and also the influence of tunable conformations (twist angles) within the acceptor moieties through controlling the orientation of asymmetric heteroaromatic ring relative to the donor component. TADF can also be achieved by exciplex formed through intermolecular charge transfer between a hole-transporting material and an electron-transporting material. Some efficient OLEDs based on exciplex system will also be presented.

Key Words: thermally activated delayed fluorescence (TADF); intramolecular/intermolecular charge transfer; exciplex; horizontal orientation.

S5.2

Invited: TADF Phosphides

Hui Xu

Heilongjiang University

Abstract: Recently, we reported a series of phosphine-containing materials for thermally activated delayed fluorescence (TADF) diodes. 2,2',4-Tris(di(phenyl)phosphoryl)-diphenylether (DPETPO) as electroactive high-energy-gap host material endowed to its DMAC-DPS-based devices with the best results among true-blue TADF diodes reported so far, including the record efficiencies with maxima of 23.0% for external quantum efficiency (EQE), the smallest EQE roll-off of 15% at 1000 cd m⁻² and the excellent color purity with emission peak at 464 nm and CIE coordinates of (0.16, 0.21). A novel spirocyclic phosphine oxide host SFXSPO was further constructed on the basis of short-axis linkage strategy, giving rise to the extremely twisted, rigid and asymmetric conformation, as well as highly disordered molecular packing in its solid states. As the results, SFXSPO successfully provided the state-of-the-art performance to its full-color devices, e.g. the record EQE of 22.5% and 19.1% and int of ~100% for its yellow TADF diodes and single-host full-TADF complementary nearly-white devices, respectively.

Key Words: TADF; Phosphide; Host; Emitter; Electron-Transporting Materials

S5.3

Invited: Thioxanthone Derivatives and Their Application for OLEDs

Ying Wang^{1,2,*}

¹Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, No. 29 Zhongguancun East Road, Haidian District, Beijing, 100190, P. R. China; ²University of Chinese Academy of Sciences, Beijing, 100049, P. R. China;

Email: wangy@mail.ipc.ac.cn

Abstract: Thermally activated delayed fluorescent (TADF) emitters based on pure organic aromatic compounds aroused much attention in that an internal quantum efficiency of 100% can be achieved by taking advantage of the efficient

up-conversion of the triplet excitons. Novel TADF emitters based on thioxanthone unit, TXO-TPA and TXO-PhCz, were reported. Both emitters exhibited high fluorescent efficiency and small energy gap between the triplet and singlet (ΔE_{ST}), affording the high efficient up-conversion process from triplet states to singlet states. Their application in the high performance organic light emitting diodes were investigated in detail. Novel phosphorescent host based on thioxanthone unit with TADF was also reported. The host with TADF can be used to reduce the efficiency roll-off of red and yellow light phosphorescent OLEDs. These results made thioxanthone derivatives promising for the application in the future organic flat panel display and solid-state lighting.

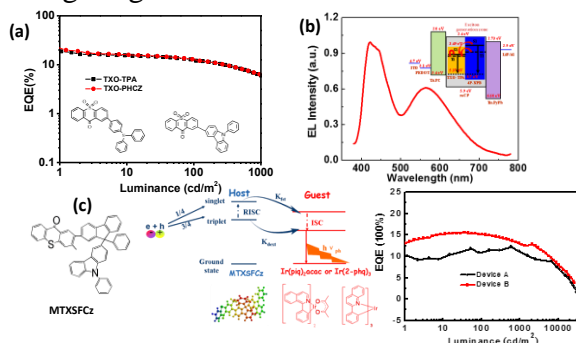


Figure1. (a) Chemical structure of TXO-TPA and TXO-PhCz (inset) and device performance of OLEDs based on them; (b) EL spectra of multilayer white OLEDs; (c) Chemical structure of MTXSFCz and their device performance of red and yellow phosphorescent OLEDs.

Key Words: Thioxanthone derivatives; Thermally activated delayed fluorescence (TADF); Organic light emitting diodes

References:

- [1] H. Uoyama, K. Goushi, K. Shizu, H. Nomura, C. Adachi*, *Nature* 2012, 492, 234-238.
- [2] S. Ishijima, M. Higashi, H. Yamaguchi*, *J. Phys. Chem.* 1994, 98, 10432-10435.
- [3] H. Wang, L. Xie, Q. Peng, L. Meng, Y. Wang*, Y. Yi, P. Wang*, *Adv. Mater.* 2014, 26, 5198-5204.
- [4] H. Wang, L. Meng, X. Shen, X. Wei, X. Zheng, X. Yi, Y. Wang*, P. Wang*, *Adv. Mater.* 2015, 26, 5198-5204.
- [5] L. Meng, H. Wang, X. Wei, X. Lv, Y. Wang*, P. Wang, *RSC Adv.* 2015, 5, 59137-59141.
- [6] L. Meng, H. Wang, X. Wei, J. Liu, Y. Chen, X. Kong, X. Lv, P. Wang, Y. Wang*, *ACS Appl. Mater. Interfaces* 2016, 8, 20955-20961.
- [7] L. Xie, G. Ge, Y. Chen, H. Wang, X. Kong, X. Wei, J. Liu, Y. Yi, B. Chen, P. Wang, Y. Wang*, *J. Mater. Chem. C* 2016, Accepted.

S5.4

Invited : An alternative way to use the triplet energy of fluorescent dye in OLED via an external iodide

Xing Xing, Mengying Bian, Bo Qu, Zhijian Chen and Lixin Xiao* (肖立新)

State Key Laboratory for Mesoscopic Physics and Department of Physics, Peking University, Beijing 100871, China

Tel.:86-10-62767290, E-mail: lxxiao@pku.edu.cn

Abstract: An unusual heavy atom effect has been identified in an organic light emitting device (OLED) containing polyvinylcarbazole (PVK) as the host, the red fluorescent dye DCM2 as the emitter, and non-emitting 1,8-diiodooctane (RI) as a heavy atom source instead

of a rare metal. The intensity of electroluminescence (EL) of DCM2 changes with the concentration of RI, with a maximum EL intensity obtained for DCM2 at a concentration of 0.25% of RI. Photoluminescence (PL) spectra of PVK–DCM2 films show increased singlet emission from DCM2 in the presence of iodide at 12 K. The enhanced fluorescence induced by iodide is caused by energy transfer from both the singlet and triplet states of PVK to the singlet states of DCM2. These results suggest an alternative way to use the triplet energy of fluorescent materials with external heavy atoms rather than conventional phosphorescent dyes containing rare heavy metal atoms.¹ The energy levels and proposed energy transfer processes are shown in Figure 1.

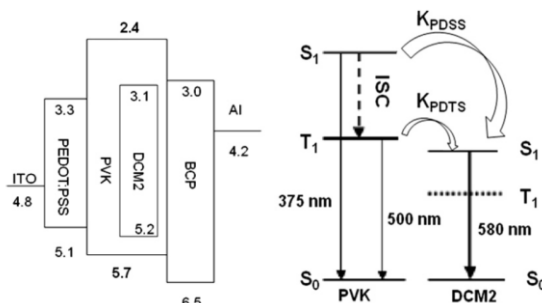


Fig. 1. The energy levels and proposed energy transfer processes in the OLEDs.

In addition, we present an in-depth understanding of the essential differences of organic small-molecule thin films at the molecular level via vacuum deposition and solution processes for organic light-emitting diodes (OLEDs).² The result reveals that tris(4-carbazoyl-9-ylphenyl)amine (TCTA) molecules show highly oriented arrangements, that is, face-to-face π - π stacking, in vacuum-deposited films, unlike the randomly arranged molecules in spin-coated films, which is the essential reason for the higher efficiency of a vacuum-deposited OLED compared with that of a solution-processed counterpart, consistent with the calculation results.

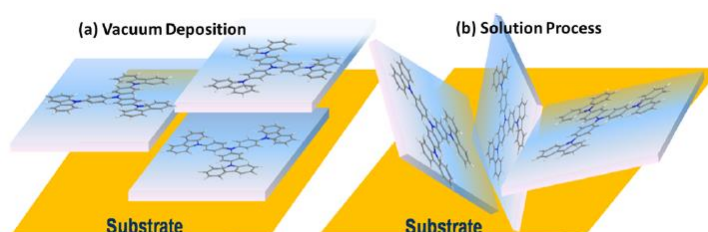


Fig. 2. Diagram of the molecular arrangement in a TCTA film via vacuum deposition (a) and spin coating (b).

Acknowledgment: This work was financially supported by the National Key Basic Research and Development Program of China (Grant No. 2016YFB0401003) and NSFC (Grant Nos. 61575005, 11574009).

References:

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Session 6: AR & VR 1 (AR&VR)

S6.1

Invited: True 3D realization in the see-through type head-mounted display with complex amplitude modulation

Zhiqi Zhang

Beijing Institute of Technology

Abstract: A monocular 3D see-through type head-mounted display (3D-STHMD) is designed by using the complex amplitude modulation technique. It can present true 3D images to the human eye to avoid the accommodation-vergence conflict. The optical experiments demonstrated that the designed system has continuous and wide depth cues with dynamic display ability.

Key Words: Three-dimensional image acquisition; Heads-up displays; Holographic display; Real-time holography

S6.2

***Invited:* Novel Head-UP Displays (HUD) and Human Interface for Vehicles by Employing AR Technology**

Lijun Wang

Dream World Technology (Beijing) Inc.

Abstract: Combining the head-up displays(HUD) with augmented reality(AR) technologies will help make driving even more safe, comfortable and intelligent. AR-HUDs augment the view of drivers with virtual informations such as the navigation map, traffic conditions and warning signals from the advanced driving assistant systems(ADAS). Drivers can see all the important informations and interact with the vehicles without their eyes moving away from the road ahead. Digital-light projection, low-cost laser source and high dynamic range(HDR) imaging are key enabling technologies for future AR-HUGs.

Key Words: Head up displays(HUD) for vehicle; Augmented Reality(AR); Digital light projection(DLP); High Dynamic Range(HDR)imaging.

S6.3

***Invited:* Perception Intelligence in VR/AR and AI**

感知智能在 VR/AR 及人工智能中的关键作用及产业化实现

Allen Fan Lu 陆凡

Senscape Technologies 触景无限

Abstract: VR/AR is part of Artificial Intelligence, especially in concept and technologies of interactive display between people and computers. However, other than cognition and feedback, perception intelligence is dragging the development of AI due to difficulties in technologies and industrialization. Currently, most of perception computing and deep learning are carried out in computer servers or in the cloud; as the rapid development in robots, drones, surveillance cameras, VR/AR, and other wearable smart devices, perception intelligence in an embedded environment is badly needed. Jointly developed with Intel/Movidius, Senscape is offering a complete solution of embedded perception intelligence. The technologies and solutions are breakthroughs for artificial intelligence in industrialization and make the developments of smart devices much easier.

Key Words: perception; VR/AR; AI; Intel; Movidius; Senscape

S6.4

***Invited:* 3D Augmented Reality based Minimally Invasive Surgical Navigation and Precision Intervention**

Hongen Liao

Department of Biomedical Engineering, School of Medicine, Tsinghua University, Beijing, China

Abstract: Rapid technical advances in medical imaging, including its growing application in therapy and invasive/interventional procedures, have attracted

significant interest in the close integration of interdisciplinary research. Image-guided surgery is a general term used for any surgical procedure with indirect vision to realize the minimally invasive diagnosis and treatment. Most of the medical image used for the surgical navigation system is displayed as a set of two-dimensional sectional images or computer generated three-dimensional (3D) models and often placed in a nonsterile field from surgeon. This forces the surgeon to take extra steps to reconstruct the 3-D information of the object in their mind and match the guidance information on the display with the actual anatomy of the patient. We developed a novel medical autostereoscopic image named Integral Videography (IV). The IV technique can provide geometrically accurate 3D images and reproduces motion parallax without using any supplementary viewing devices or tracking devices. Furthermore, the development of relative image overlay techniques makes it appear that the 3D vision is inside the patient's body, and enables a medical augmented reality environment for minimally invasive navigation and precision intervention. This lecture will also introduce our latest research results on high-quality see-through surgical guidance system.

Key Words: Augmented Reality; Minimally Invasive Surgery; 3D

S6.5

Invited: Applications of VR & Medical Visualization in Healthcare Simulation.

Xiaotian Yan

Tellyes Scientific Inc.

Abstract: VR and Medical Visualization technology are widely used in healthcare simulation that based on Flat-panel LCD Displayer. 1: The systems based on VR technology, which used for nursing or surgery skill training, need to establish software framework, choose suited rendering engine, physics engine, emerging software with solid manikins. For example, PICC, the Lumbar puncture training system, the laparoscopic surgery training system etc. 2: The Radiology, Anatomy and Surgery training system, which adapt 3D engine can support Volume rendering, achieve 2D and volume rendering for DICOM series, real-time 3D model knifing, virtual ultrasound probing, GPU heterogeneous computing, can be used for patient's radiology diagnosis training, anatomy or surgery training. For example: the anatomy Table, the Imaging Workstation, the Neurosurgery training system and so on. The trainee can acquire experience in both too kinds of systems. They can promote their operation skills in virtual reality software as the same as in real clinical operation environment.

Key Words: VR; physics engine; Volume rendering; GPU heterogeneous Computing; real-time 3D model knifing

Session 7: Key materials for flexible display and electronics (E-paper and Flexible Displays)

S7.1

Invited: Flexible Display Technology Trend & Market Status

Jerry Kang(Minsu Kang)

IHS Markit

Abstract: Display panel suppliers have tried various type of flexible displays with various technologies (EPD, LCD, OLED), and recently flexible AMOLED became

the most popular flexible display solution. Flexible AMOLED has the superior optical characteristics & innovative flexibility than any other display technologies, but currently there are only a few panel suppliers which are mass-producing it. IHS Markit forecast that there would be more panel suppliers which can start to mass produce flexible AMOLED in a few year, especially in China.

On the other hands, some of panel suppliers are still suffering from overcoming the technologic barrier because manufacturing flexible AMOLED technology is basically different with conventional display technologies. In this status, IHS Markit analyzed which suppliers are preparing & which technology they are in development, and also how the flexible AMOLED will compete with conventional display technologies. In this speech, we would summary the panel suppliers strategies & technology of flexible AMOLED, and would like to help the audience to prepare the changes of display market & technology.

Key Words: flexibel display; electrophoretic display (EPD); liquid crystal display (LCD); organic light emotting diode (OLED); market analysis; technology trend

S7.2

***Invited:* Recent Progress of Polymer Substrate for Flexible Display**

Yi Zhang

Sun Yat-sen University

Abstract: As opposed to the more prevalent traditional flat screen displays used in most electronics devices, flexible display is another revolutionary technology which would totally change our daily life. It has become hot-topic in the fields of academic and industry. Among them, flexible substrate, as the sustain and protection component, it's overall properties have great influence to the preparation process, quality and life-time of the devices. So the development of novel high-performance polymer-base flexible substrate have attract great attention at home and abroad, to meet the requitment of pratical applications in flexible display. Here, we would like to introduce recent progress of polymer substrate for flexible display, and recent advances on high-performance polyimide in our group.

Key Words: flexible display; polyimide; flexible substrate; research progress

S7.3

***Invited:*Flexible Electronics Printing Technology & Materials**

Luhai Li

Beijing Institute of Graphic Communication; Beijing Engineering Research Center of Printed Electronics

Abstract: Printed electronics (PE) has emerged as one of the key technologies not only for electronics but also for all kinds of electrically controlled machines and equipment. PE is a technology that merges electronics manufacturing and text/graphic printing. By this combination, one can manufacture high-quality electronic products that are thin, flexible, wearable, lightweight, of varying sizes, ultra-cost-effective, and environmentally friendly. Based on the properties of flexible electronics, especially on the field of flexible display driving electrode, both functional materials and pringting/coating technologys are investigated by people. The nano silver conductive ink and graver /flexo/macro contact/micro grauvre pringting of flexible such as E-paper electrode are investigated in Beijing Engineering Research Center of Printed Electronics. It was found that many the properties of printed flexible electrode was defined by many factors, such as the shape of printing plate, press and ink composition. At the same time, ink transfer rate is must be calculated. By the

application of nano silver ink and combined with nanotube and PEDOT:PSS, some transparent conductive film (Surface resistance $8.4\text{--}11\Omega/\square$) and RFID electrode were printed (Pass rate $\geq 99.6\%$, and they could be identified over 1 meter.).

Key Words: flexible electronics, printed electronics, printed electrodes nano silver inks

S7.4

Invited: Perovskite Light-Emitting Diodes based on Solution-Processed, Self-Organized Multiple Quantum Wells

Jianpu Wang and Wei Huang

Key Laboratory of Flexible Electronics (KLOFE) & Institute of Advanced Materials (IAM), Jiangsu National Synergetic Innovation Center for Advanced Materials (SICAM), Nanjing Tech University (NanjingTech), 30 South Puzhu Road, Nanjing 211816, P.R. China

Abstract: Solution-processed light-emitting diodes (LEDs) are attractive for applications in low-cost, large-area lighting sources and displays. Organometal halide perovskites can be processed from solutions at low temperatures to form crystalline direct-bandgap semiconductors with intriguing optoelectronic properties. However, their electroluminescence (EL) efficiencies are limited by either exciton quenching in the two-dimensional (2D) perovskites or imperfect film morphologies in the three-dimensional (3D) perovskites. Here, we demonstrate that strikingly high-efficiency, room-temperature EL can be achieved from solution-processed hybrid perovskite films consisting of self-organized multiple quantum wells (MQWs) with an energy cascade. The perovskite MQW films deposited at low temperatures exhibit uniform morphology and high photoluminescence (PL) efficiencies resulting from efficient cascade energy transfer between the quantum wells. LEDs based on perovskite MQWs show peak external quantum efficiency (EQE) up to 11.7% (internal quantum efficiency, IQE, $\sim 52\%$) at a current density of 38 mA cm^{-2} and a radiance of $23\text{ W sr}^{-1}\text{ m}^{-2}$, representing the highest efficiency for perovskite-based LEDs. Remarkably, the solution-processed device exhibits impressive high-power performance, i.e. 5.5% of wall-plug efficiency at a current density of 100 mA cm^{-2} , which is more efficient than state-of-art vacuum-deposited organic LEDs at this high current density. By changing the halide compositions, the LED emission spectrum can be tuned from near infrared to visible range. Moreover, the stability of the MQW LEDs is improved by two orders of magnitude compared with 3D perovskite-based LEDs. Our study shows that perovskite MQWs are promising as a new class of solution-processed emitters for LEDs.

Key Words: LED, Perovskites, Multiple quantum well, solution process

Reference:

[1] N. Wang et al., Nature Photonics, 10, 699 (2016)

S7.5

Invited: Flexible Sensors

Shoujun Li (李守軍),

Kangdexin Composite Material Group

Session 8: Manufacture of TFT Device, Array, and Circuits 1

(Display Manufacturing)

S8.1

Invited: Ink-jet print high-conductive silver electrode in AOS TFT Array

Honglong Ning, Jianqiu Chen, Ruiqiang Tao, Yicong Zhou, Caigui Yang, Wei Cai, Zhennan Zhu, Jinglin Wei, Zeke Zheng, Rihui Yao[†], Miao Xu, Lei Wang, Linfeng Lan and Junbiao Peng

Institute of Polymer Optoelectronic Materials & Devices, State Key Laboratory of Luminescent Materials & Devices, South China University of Technology, Guangzhou 510640, China

[†] Corresponding author email: yaorihui@scut.edu.cn

Abstract: Printing technologies have recently attracted lots of interests owing to their eco-friendliness, direct patterning, low cost, and roll-to-roll manufacturing processes. High-conductive electrode is of great significance for Amorphous Oxide Semiconductor Thin Film Transistors (AOS-TFT). In recent years, silver (Ag) ink has been investigated as an alternative approach to low-cost, high-conductivity, printable conductors compared with other inks such as poly anilines, Cu ink, and Au ink. In this report, Ag electrodes were printed onto the glass substrate through an inkjet printer with a print head driven by piezoelectricity (Fujifilm Dimatix, DMP2800, Santa Clara, California, USA). The electrodes were curing at different temperatures. As shown in Fig 1, a lot of holes were detected by SEM when the electrodes cured in a relatively higher temperature (over 150°C) because of organic solvent removing and silver nano-particle aggregating, and the resistivity of Ag electrodes decreases as the increasing of the curing temperature. Finally we've obtain high-conductive and compact silver electrodes with resistivity about $4.2 \times 10^{-8} \Omega$, which could serve as Source/Drain electrodes of AOS-TFT. For a further research, we have developed S/D electrodes array to study the possibility of large area printing electronic device. From Fig 2, we can see the S/D electrodes array is of good uniformity, and the minimum bus line and channel width is about 36 μm and 19 μm . The area of TFT driver unit is about 562 $\mu\text{m} \times 547 \mu\text{m}$. It could enable a display with a resolution of about 16.7 PPI as calculated. It shows the potential that the printed electrode for AOS-TFT can realize not only high conductivity and good uniformity but also big size and process compatible to the present mass product line.

Key Words: ink-jet printing; silver ink; high conductivity; AOS-TFT; array

Acknowledgments:

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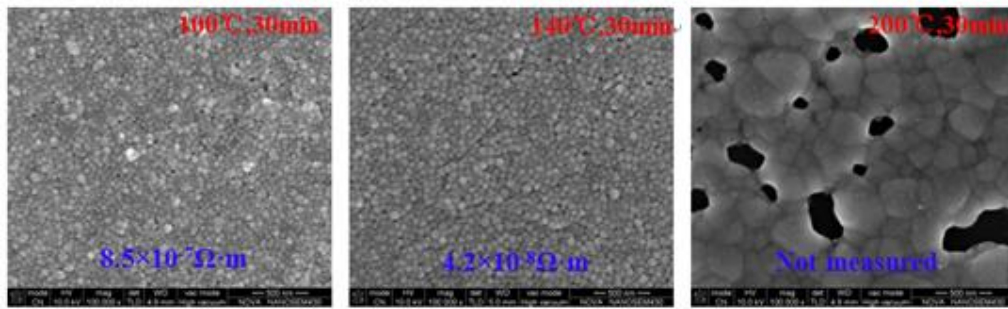


Fig 1. Ag electrodes curing at different temperatures

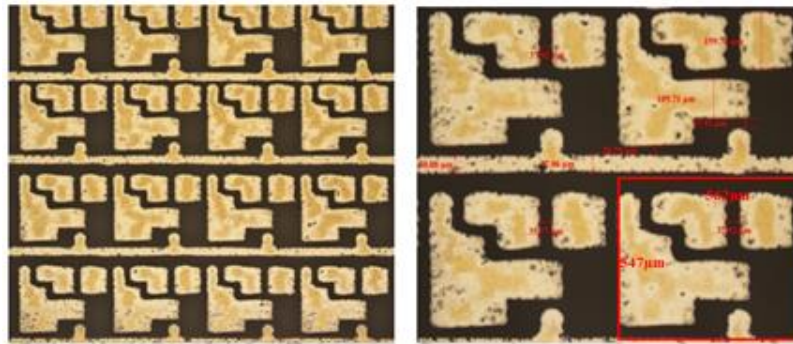


Fig 2. S/D electrodes array for Amorphous Oxide Semiconductor Thin Film Transistors.

S8.2

Invited: Application of Array Tester in AMOLED Manufacturing

Junfeng Li

Kunshan Govisionox Optoelectronics Co., Ltd.

Abstract: Due to the long manufacturing lead time, dramatically increased process complexity compared with AMLCD, and the variety of defect types for AMOLED panel, it is meaningful but challenging to explore an effective inline inspection method during AMOLED manufacturing. This presentation will focus on two types of mainstream inline inspection techniques, namely, non-contact voltage type and full contact current type array testers. We elaborate the demand and challenge of new inspection technology in AMOLED manufacturing, in terms of inspection accuracy, product design, and running cost as well.

Key Words: component; Array Tester; AMOLED; inspection; manufacturing

S8.3

Invited: New kinds of TFTs and Novel Applications based on TFTs

Yanzhao Li

BOE Technology Group Co. Ltd.

Abstract: This report first summarize the current status of thin-film transistors (TFTs), including amorphous Si (a-Si: H), low temperature polycrystalline silicon (LTPS), oxide TFTs, etc. and its corresponding spec parameters from present and future application needs in various kinds of market fields. To meet these demands, we will shortly discuss about the physical principles hidden within different kinds of TFTs and then to try to give some conclusions. We also discuss about the development trends for the TFT technology.

S8.4

Invited: The properties of Cu metallization based on Cu alloy buffer layer for the applications in thin film transistor(TFT)

Zhinong Yu, Ruihuang Ren, Jian Gao, Jin Chen, Xuyang Li, Wei Xue

School of Optoelectronics and Beijing Engineering Research Center of Mixed Reality and Advanced Display,
Beijing Institute of Technology, Beijing 100081, China E-mail address:
znyu@bit.edu.cn

Abstract: With the rapid development of high-resolution thin film transistor liquid crystal displays (TFT-LCDs), copper (Cu) has received considerable attention due to its lower resistivity in comparison with that of the pure aluminum (Al), which helps to increase the transmission speed of digital signals and reduce the power consumption. However, copper thin films exhibit poor adhesion to semiconductors; and copper atoms may diffuse into the semiconductors, resulting in reduction in reliability. In this report, such Cu alloy thin film as CuCa or CuMgAl was used as a diffusion barrier for copper metallization, and the properties of Cu film as functions of the fabrication parameters of Cu alloy buffer layer were investigated in view of adhesion, diffusion and electronic properties. The bilayer of Cu film and Cu alloy buffer layer was etched as an electrode line with a much-desired taper angle and a little critical dimension bias in one etching step by wetting method. The TFT with the Cu/CuCa electrodes demonstrated comparative electronic properties with the conventional electrodes due to the superior performances of the Cu/CuCa electrodes with the desired adhesion, specific resistance and taper angle despite no annealing process.

Key Words: Thin Film Transistor; Cu Metallization; Diffusion Barrier; Adhesion; Electrodes

S8.5

***Invited:* Lessening the Tails in Four-Mask Process of G8.5 LCDs by Structure Design and Process Improvement**

Xiaodi Liu (刘晓娣),

Shenzhen China Star Optoelectronics Technology Co., Ltd.

Session 9: TFT Circuit and Display Driving (Active-Matrix Devices)

S9.1

***Invited:* High-Speed Coulmn Driver IC for High-Resolution, High-Frame-Rate Displays**

Byong-Deok Choi

Hanyang University

Abstract: The display format and the frame frequency does not cease to increase for high-quality LCDs and OLED displays. Recently, ultra-high-definition (UHD) displays lead the commercial TV markets, and the format will increase to quad UHD in the foreseeable future. Moreover, to reduce the motion-blur effect, the frame frequency is increased from 60 to 240 Hz. A well-known issue for realizing a high-resolution and high-frame-frequency displays is the driving time reduction. The driving time for each row line is decreased inverse-proportionally to the format and frame frequency, thus the data driving speed should be increased. For example, the driving speed of a UHD 240 Hz display should be increased to 12 times higher than that of a FHD 60 Hz display. In this talk, we will extensively analyze the speed reduction factors on a panel driving path, and discuss the methods to enhance the driving speed. Especially, we introduce low-power, high-speed, slew-rate-enhanced

buffer amplifiers for column drivers [1-3] and compare the performance of the amplifiers.

Key Words: high-resolution; high-frame frequency; driving speed; slew-rate enhancement; row-line time;

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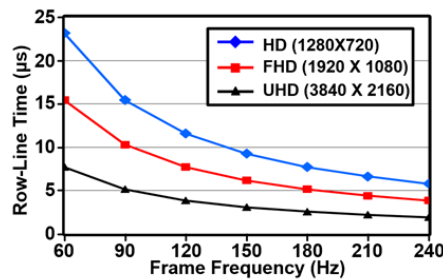


Fig. 1. Row-line time versus frame frequency.

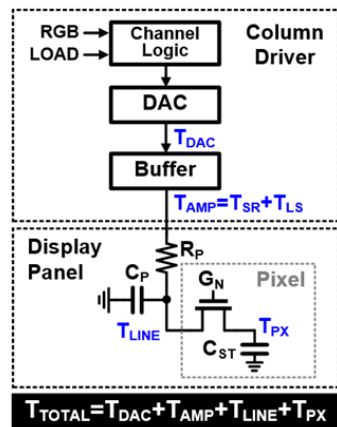


Fig. 2. Speed reduction factors on a driving path.

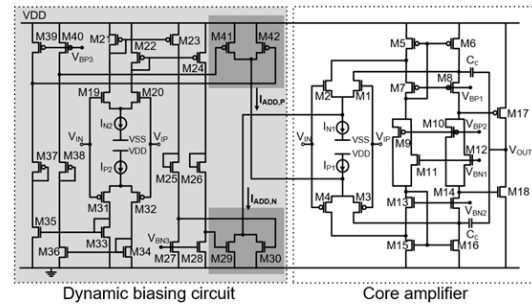


Fig. 3. Schematic of a slew-rate enhanced amplifier [1].

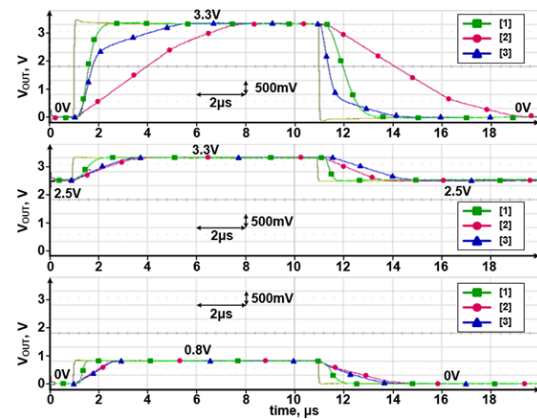


Fig. 4. Measured waveforms of buffer amplifiers [1].

S9.2

Invited: Design of 5.5 inch IGZO TFT FFS In-Cell Touch Panel

Mingxin Wang

CEC-Panda Group

Abstract: At present, the Amorphous Indium Gallium Zinc Oxide Thin Film Transistor (a-IGZO TFT) has attracted more and more attention. Compared with the traditional silicon-based TFT, IGZO have their respective advantages, for example, the manufacturing cost is lower compared to LTPS TFT, and the process is easy to control. This paper introduced the design of 5.5 inch FHD In-cell panel based on IGZO technology, and shows the demo of this design. We briefly introduced the key structure of self-capacitance multiple in-cell touch. In the paper, we analyze the problem caused by parasitic capacitance in the producing, and the solutions of this are described.

Key Words: IGZO; In-cell Touch; projected capacitive; FFS

S9.3

Invited: Robust Gate Driver Circuit Design with a-Si:H TFTs

Congwei Liao

School of Electronic and Computer Engineering, Peking University

Abstract: Amorphous silicon thin film transistor (a-Si:H TFT) technology is still playing dominant role in flat panel display nowadays. Due to its mature manufacturing process and decent electrical characteristics, there are many new application field for a-Si:H TFTs . Rather than switching element in active matrix, a-Si:H TFTs is still capable of building logic and sensing circuits. Among these applications, integrated gate drivers are increasingly popular with both mobile and TV displays for narrow bezel and low cost. However, reliability issue of gate driver with a-Si:H TFTs is still of great concern. Although many previous publications declare that function of gate driver can still be guaranteed after long stressing time, it is worth pointing that these experiments were carried out using only limited gate drivers units. In additions, mechanism of gate driver failure after stress testing is rarely discussed up to date.

In this paper, different biasing methods of pull-down TFTs to enhance gate driver reliability is compared for the first time, for example, bipolar biasing, quasi-constant trans-conductance biasing, and conventional constant voltage biasing. In additions, reliability measurement of a-Si:H gate driver with 2160 stages for 55-inch UHD TV panel is carried out. And failure mechanism of gate driver caused by clock bus lines is analyzed in detail.

Key Words: gate driver; reliability; TFT; narrow bezel

S9.4

Invited: A New Pixel Compensation Circuit for AMOLED Display

Siming Hu

KunShan Govisionox Optoelectronics Co., LTD Kunshan New Flat Panel Display Technology Center Co. Ltd

Abstract: An active matrix organic light emitting diode (AMOLED) pixel circuit is proposed for improving the image quality of the display, which can compensate the threshold voltage caused by the LTPS process. Simulation results shows that the current variation through OLED decreases to 10% comparing with the conventional pixel structure when the threshold voltage of the driving TFT varies from -0.3 V to 0.3 V. The circuit is verified with SPICE simulation by using LTPS P-type and N-type TFT models. We also measure single pixel circuits to verify non-uniformity compensate ability of circuits, and the uniformity of the new pixel for all gray level are better than the conventional 2T1C.

Key Words: AMOLED; LTPS; pixel circuit; threshold voltage compensation

S9.5

Stability Analysis of a-IGZO Thin Film Transistors Applied in Integrated Gate Driver of Narrow-border LCD Panel

Hongtao Huang, Chao Dai, Zhijun Wang

Nanjing CEC Panda FPD Technology Co., Ltd. NO. 7, TianYou Road, QiXia District, Nanjing, China 210033

Abstract: The reliability of integrated gate driver monolithic (GDM) in liquid crystal displays (LCDs) depends on the electrical properties of thin film transistors (TFTs). By the process of bottom-gate inverted-staggered a-IGZO TFTs with etch stop layer, 5.5" FHD narrow border (1.0 mm) fringe-field-switching (FFS) LCD panels were

manufactured. The properties variation of a-IGZO TFTs is firstly investigated considering device sizes and the role of organic passivation layer, followed by the degradation of a-IGZO TFTs under voltage bias stresses. The results indicate that the threshold voltage shifts in different degrees depending on the device dimension, current, temperature, humidity and especially the irradiation. More results are carried out by monitoring the performance change of GDM's TFTs in a 5.5" FHD LCD panel after reliability experiments. Rather than a simple summation of the device stress conditions, the real operation environment of GDM's TFTs in LCD panel is much more complicated, leading to a different degradation behavior from that observed in stress experiments. It makes the design of GDM circuits an intricate task when taking the complex degradation of TFTs into account. Some ideas and perspectives are given in the end to overcome this challenge, in the direction of improving a-IGZO TFT stability and refining the GDM circuit design.

Key Words: a-IGZO TFTs; GDM; stability, voltage bias stress; reliability analysis; narrow border

Session 10: Organic TFTs (Active-Matrix Devices)

S10.1

Invited: High performance printed organic thin film transistors for flexible display

Yong-Young Noh,
Dongguk University, Korea

S10.2

Invited: Molecular Design toward High Mobility Organic Semiconductors

Yanhong GENG

School of Materials Science and Engineering, Tianjin University

Abstract: The performance of organic thin-film transistors (OTFTs) has been significantly improved owing to the development of new organic semiconductors and new device structures and processing methods. The progress for the design and synthesis of high mobility semiconductors in our group will be introduced. Via rational molecules design, we have developed organic heteroacene-type semiconductors for vacuum deposited OTFTs with hole mobility above $20 \text{ cm}^2/\text{V}\cdot\text{s}$, alkyl-substituted phthalocyanines for solution processed OTFTs with hole mobility approaching $1 \text{ cm}^2/\text{V}\cdot\text{s}$ and n-type unipolar donor-acceptor (D-A) conjugated polymers for solution processed OTFTs with electron mobility above $4 \text{ cm}^2/\text{V}\cdot\text{s}$.

Key Words: Organic semiconductors; organic thin-film transistors; mobility

S10.3

Invited: High Performance OFET Package for Printed Organic Electronics

Joseph Hsiao/Mi Zhou

BASF

Abstract: Organic field-effect transistor(OFET) is a promising candidate for the flexible displays and electronics in the future, due to its unique feature on the low process temperature and inherent ultra-flexibility. Besides the excellent performance, the low manufacturing cost and equipment investment could be achieved by solution process and low thermal budget. In this presentation, we would like to present the significant progress made with BASF's material package and novel process

techniques. Full stack OFET devices are developed with industrial-relevant process, and the homogeneity is verified for mass production. In addition, novel photopatternable materials are created to reduce processing steps and simplify the manufacturing process. For front-planes technologies requiring higher field-effect mobility, we further present our new semiconductor materials offering mobility of up to $4\text{cm}^2/\text{Vs}$, feasible for application in backplanes for LCD and approaching requirements for OLED displays.

Key Words: OFET; organic transistor; solution process; photo-patternable; high performance organic semiconductor

S10.4

***Invited:* OLCD: Scalable large area, low cost and high performance conformable plastic LCD**

Paul Cain

Flex Enable

Abstract: Organic electronics will play a pivotal role in enabling flexible displays that break form factor constraints of glass and unlock new product applications and use cases.

In particular, organic LCD (OLCD) technology opens a new avenue for LCD – it enables glass-free, conformable, high performance displays with TFT performance beyond a:Si, combined with a low manufacturing cost that is driven directly by the uniquely low temperature process (sub $100\text{ }^\circ\text{C}$) afforded by OTFT.

The presentation will describe the attributes of OTFT and the benefits of using plastic instead of glass. It will reveal why OLCD is inherently suitable for mass production and the value it brings to specific applications and markets.

Key Words: plastic LCD; flexible displays; OTFT; flexible electronics

Session 11: Quantum Dots materials (Emissive Displays)

S11.1

***Invited:* High Performance Quantum Dot Materials for Quantum-Dot Light-Emitting Diodes (QLEDs)**

Yixing Yang

TCL Corporate Research

Abstract: Recent progress of quantum dot (QD) materials designed for new generation QLEDs display application was reported. While we have already demonstrated conventional Cd-based red, green and blue QDs with high performance in terms of narrow and efficient photoluminescence (PL) emission, high color gamut and high EL performance, we were also searching for alternative candidates as appropriate emissive materials for QLEDs, including Cd-free QDs and quantum well quantum dots (QWQDs). Although these new types of QD materials currently have inferior performance than the conventional Cd-based QDs, they have potential advantages such as environmental friendly and good solid state film performance.

Key Words: Quantum dot; QLEDs; Cd-based QDs; Cd-free QDs; QWQDs

S11.2

***Invited:* Quantum-dot Light-emitting diodes based on copper-based semiconductor nanocrystals**

Aiwei Tang

Beijing Jiaotong University

Abstract: In this talk, we would like to present our recent progress in the synthesis of copper-based semiconductor nanocrystals and their applications in the quantum-dot light-emitting diodes. Bright copper-based semiconductor nanocrystals including Cu-In-Zn-S or Cu-In-Zn-Se nanocrystals were synthesized via a heating-up method, and the emission color could be tuned by varying the Cu content. The different-colored Cu-based nanocrystals were used as emissive layers to fabricate quantum-dot light emitting devices (QLEDs) via a solution-processed technique, in which TFB and ZnO were used as hole-transporting and electron-transporting layers, respectively. Besides, we also incorporated high quality yellow QDs to fabricate organic-inorganic hybrid white light-emitting devices. By adjusting the annealing temperature of ZnO nanoparticle film, the electroluminescence spectra could be tailored from blue emission to white light emission without any efficiency decrease, and the CIE coordinate of the white light is (0.32, 0.33) with a high CRI up to 90.

Key Words: Quantum-dot light-emitting diodes; Copper-based nanocrystals; White emission

S11.3

Invited: Recent progress on quantum dots based light-emitting diodes in my group

Zhan'ao Tan, Tai Cheng, Zhibing Wang, Shengli Jin, Fuzhi Wang
North China Electric Power University, Beijing 102206, China
tanzhanao@ncepu.edu.cn

Abstract: Since the colloidal quantum dots (QDs) have been utilized as novel fluorescent materials in early 1980s, great efforts and rapid progresses have been made during the last 30 years in QDs based solid-state lighting and flat-panel display technologies. A principal character of QDs is the quantum confinement induced tunability of their emission color (from UV, visible, to near-infrared wavelengths) through precise control of their size and composition. QDs based light-emitting diodes (QD-LEDs) are featured with pure and saturated emission colors with narrow bandwidth. Moreover, QD-LEDs offer durability combined with the efficiency, flexibility, and low processing cost. Herein, we will present our recent progress on QD-LEDs including the strategies for high performance blue QD-LEDs through balance the charge injection, heavy-metal-free QD-LEDs, and the possibility for flexible RGB QD-LEDs.

Key Words: Quantum dot based light-emitting diodes; charge injection; heavy-metal free

S11.4

Invited: One-pot Synthesis of highly luminescent and stable $\text{CH}_3\text{NH}_3\text{PbBr}_3$ Quantum Dots assisted with amine functional silane

Hong-Shang Peng*, Mu Yang,
School of Science, Minzu University of China
Email: hshpeng@bjtu.edu.cn

Abstract: Recently, organometal halide perovskites ($\text{CH}_3\text{NH}_3\text{PbX}_3$, $\text{X} = \text{I}, \text{Br}, \text{Cl}$) QDs have emerged as revolutionary semiconductor materials, by virtue of the merits of low cost and superior charge-transfer properties, in high-performance lighting and display systems. However, a number of obstacles lie ahead for their further commercialization, such as low production yield, and low stability against temperature and moist air. In this report, we present a one-pot synthesis of highly

luminescent and stable $\text{CH}_3\text{NH}_3\text{PbBr}_3$ QDs encapsulated by silica. More interestingly, the silica-coated perovskites QDs exhibit an abnormal orthorhombic phase, which is thought to be unstable for perovskites at room temperature.

Key Words: $\text{CH}_3\text{NH}_3\text{PbBr}_3$; Quantum Dots; Luminescence; Silica coating

Session 12: New Structure TFT and Backplane Technology (Active-Matrix Devices)

S12.1

Invited: High mobility, scalable and transparent fin-like thin film transistors based on self-aligned in-plane silicon nanowires array

Jimmy Wang¹, Mingkun Xu¹, Zhaoguo Xue¹, Xiaoxiang Wu¹, Ping Feng¹ and Linwei Yu^{1,*}

1. School of Electronic Science & Engineering, and Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, China,

E-mail: yulinwei@nju.edu.cn

Abstract: Flat-panel liquid-crystal displays (LCD) are omnipresent in a variety of consumer electronics, entertainments, personal computers and mobile devices, where higher resolution and superior cost-to-performance ratio are always preferred. In this work, a matrix of fin-like TFTs are fabricated based on self-aligned polycrystalline Si nanowires (SiNWs), which are produced at low temperature (<350 °C) via a new catalyst-guided in-plane growth strategy proposed in our previous works [1-8], with a high-yield and precise position control of the nano-channels over one-inch-square area. Thanks to the crystalline nature and fin-like gating profile of the nanowire channels, a high hole mobility of $>100 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$ and an excellent subthreshold swing of only 163 mV/decade have been achieved from an amorphous Si thin film technology. More excitingly, the precise arrangement of the nanowire channels makes it possible to implement transparent TFT circuitry. These results highlight the important potential of the in-plane SiNWs in establishing a readily scalable, cost-efficient and high performance TFT technology paradigm for high generation flat panel displays.

Key Words: in-plane Si nanowires; self-alignment; fin-TFT; thin film deposition

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S12.2

Invited: Elevated-Metal Metal-Oxide Thin-Film Transistor: A New Device Architecture Allowing Improved Performance Metrics

Man Wong

Department of Electronic and Computer Engineering, the Hong Kong University of Science and Technology

Abstract: The resistivity of zinc oxide-based semiconducting thin films was found to depend on not only the conditions of its thermal annealing but also the oxygen-permeability of the cover film during the heat-treatment. Based on the knowledge gained from an extensive investigation of this phenomenon, a new device architecture is proposed, and dubbed “elevated-metal metal-oxide (EMMO) thin-film transistor (TFT)”. After a heat-treatment process in an oxidizing atmosphere, conductive source and drain regions spontaneously populated by donor-defects are formed, while the defects in the channel region are simultaneously passivated. The latter is responsible for the extremely low off-state leakage current exhibited by an EMMO TFT. Compared with a conventional TFT with a channel-protecting etch-stop layer, an EMMO TFT inherently accommodates an etch-stop/passivation layer while preserves the same gate-drive and the small device foot-print of a conventional back-channel etched TFT. EMMO TFTs built on both popular indium-gallium-zinc oxide and a higher mobility metal-oxide semiconductor as the active layers have been demonstrated. All exhibited good performance metrics, and stability against a variety of environmental and electrical stress.

Key Words: thermal annealing; metal-oxide semiconductor; thin-film transistor

S12.3

***Invited:* Enhanced Bias Illumination Stress Stability of Vertical Field Effect Transistors for AMOLED Displays**

Bo Liu

nVerpix, LLC

Abstract: The carbon nanotube enabled vertical field effect transistor technology continues to show great promise for enabling cost effective manufacturing of large screen AMOLED displays. A QVGA AMOLED prototype using the technology was demonstrated at the SID’s 2016 San Francisco Display Week and won the I-Zone award for best prototype. The architecture features important, desirable advantages over the conventional lateral channel TFTs. The readily obtained and controllable short channel length, and multiple mechanisms responsible for a strong gate field lever arm, makes a broad range of amorphous organic semiconductors useful as the channel material, despite their low charge carrier mobility. The vertical architecture also gives the devices a much greater immunity to bias stress instability than the conventional lateral channel TFT. As we report here, these features also permit an enhanced bias illumination stress stability under both positive gate bias stress (PBIS) and negative gate bias stress (NBIS) conditions. The physics that underlies these advantages in device stability will be discussed.

Key Words: Active-matrix Devices; Novel Material TFTs and Processing Techniques; Novel Active-Matrix Backplanes

S12.4

***Invited:* Development and trend of new display backplane technology**

Wei Yang (杨维),

BOE Technology Group Co. Ltd.

Session 13: New TFT Applications (Active-Matrix Devices)

S13.1

***Invited:* Organic thin film transistors for high-performance biosensors**

Feng Yan

Department of Applied Physics, The Hong Kong Polytechnic University

Abstract: Organic thin film transistors have shown promising applications as sensors. Solution-gated organic transistors normal have no gate dielectric and the gate voltages are applied directly on the solid/electrolyte interfaces or electric double layers near the channel and the gate, which lead to very low working voltages (about 1 V) of the transistors. On the other hand, the devices can be easily prepared by solution process on flexible substrates because of the much simpler device structure compared with that of a conventional field effect transistor with several layers. Many biosensors can be developed based on the detection of potential changes across solid/electrolyte interfaces induced by electrochemical reactions or interactions. The devices normally show high sensitivity due to the inherent amplification function of the transistors. In this talk, I will introduce several types of biosensors studied by our group recently, including DNA, glucose, dopamine, uric acid, cell, and bacteria sensors, based on solution-gated flexible organic electrochemical transistors. The biosensors show high sensitivity and selectivity when the devices are modified with functional nano-materials (e.g. graphene, Pt nanoparticles) and biomaterials (e.g. enzyme, antibody, DNA) on the gate electrodes or the channel. The organic transistors are expected to find more important applications in the future. (use style: Font:Times New Roman, Font Size: 10 pt.)

Key Words: thin film transistor; biosensor; organic semiconductor; flexible electronics

S13.2

Invited: Emerging Non-Display Applications of Thin-Film Transistors

Kai Wang

Sun Yat-sen University

Abstract: As a fundamental building block of large area electronics, thin film transistor (TFT) and its relatives have enjoyed an exciting era of development and implementation. Its dominant application-flat panel display has grown to be a multi-billion-dollar industry that continues booming. However, the potential of TFT in non-display applications has been rarely explored and not yet matured. In this talk, some emerging non-display applications of TFTs in particular, sensors will be addressed. These applications are based on architecture of dual-gate TFT where its top gate is field-coupled. Optical-, mechanical-, and thermal-field-coupled dual-gate TFTs are investigated while magnetic-, biological-, and chemical-field-coupled TFTs will be conceptualized. The applications of field-coupled dual-gate TFTs including indirect conversion X-ray imaging, fingerprint sensors, fluorescent biosensors, tactile sensors, energy harvesting, and temperature sensors will be briefly covered. With designing and optimizing device structures, high sensitivity and wide dynamic range can be achieved. I will also elucidate device physics, device and circuit models, and structure-performance relations as well as key issues in device fabrication and process integration. From this study, it is anticipated that field-coupled dual-gate TFT technology can potentially go far beyond flat panel display applications and foster new opportunities in Internet of Things (IOTs) and neuromorphic engineering.

Key Words: dual-gate TFT; field-coupled transistor; sensor; IOT; neuromorphic engineering.

S13.3

All Solution Processed Low Voltage Organic Thin-film Transistors for Ubiquitous Sensors

Jiaqing Zhao, Wei Tang, Linrun Feng and Xiaojun Guo

National Engineering Laboratory for TFT-LCD Materials and Technologies, Department of Electronic Engineering, School of the Electronic Information and Electrical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China (x.guo@sjtu.edu.cn)

Abstract: The utilization of organic thin-film transistors (OTFTs) as vapor or pH sensing elements in low power consumption applications offers a promising opportunity for the next-generation electronic productions in environment monitoring, food security supervision and Internet of Things. To satisfy the critical requirements of these applications, the low-cost construction of flexible OTFT devices with bias stressing stability in low power consumption sensing system is highly desired. In this work, it was shown that by reducing the subgap density of states (DOS) at the channel, all solution processed low voltage OTFTs were demonstrated on flexible polyethylene naphthalate (PEN) substrates. Stable electrical properties after either being placed for weeks or continuously prolonged bias stressing for hours in ambient air are achieved for the un-encapsulated OTFTs with the channel being exposed to the ambient air, paving the way for further ubiquitous sensors. Then, on the one hand, the individual OTFT device was incorporated into a battery-powered (3.7 V) electronic system for continuously ammonia vapor sensing in ambient air with a small power consumption of ~50 nW. On the other hand, an integrated pH sensor tag was fabricated with two low voltage OTFTs, an extended gate OFET for sensing and the other OTFT as the load to convert the current signal to a voltage output, for pH sensing. The pH sensor tag was able to be operated in a low voltage battery-powered (3.3 V) electronic system for reliable pH sensing. In conclusion, this work provides a competitive technology platform for ubiquitous sensor applications by combining the advantages of fully printable OTFTs in low cost and scalability on large area and flexible surfaces and those of conventional electronics in high performance and high integration density for complex and accurate signal processing.

Key Words: All solution processed; organic thin-film transistor (OTFT); low power consumption; sensing system; pH sensing; ammonia vapor sensing

Session 14: New Material TFTs (Active-Matrix Devices)

S14.1

***Invited:* Ubiquitous Design of Organic-Inorganic Heterojunctions Toward More High Performance Field Effect Transistor Applications**

Chao Jiang

National Center for Nanoscience and Technology, CAS Center for Excellent in Nanoscience, Beijing 100190, China

Abstract: A hybrid structure of organic-inorganic hetero-junctions has been highly expected to realize more flexible design of functional devices in opto-electronics and electronics for ubiquitous applications in reality. Especially, with tremendous increasing of novel materials, the novel device applications are coming true. Here, we present several examples to illustrate the possible strategy of design in phototransistors and ambipolar transistors.

Organic/Perovskite hybrid thin film transistor photodetectors consist of C8BTBT

molecular film and $\text{CH}_3\text{NH}_3\text{PbI}_3$ film prepared by two-step vacuum deposition. By implementing perovskite $\text{CH}_3\text{NH}_3\text{PbI}_3$ film onto the organic active layer, the organic/perovskite hybrid photodetector exhibited a photoresponsivity of 33 A/W and fast response time and well gate tunable ability. Improvement of photodetection performance is attributed to the balance between light absorption in perovskite layer and an effective transfer of photogenerated carriers entering from perovskite into organic C8BTBT channel.

Secondly, as showing large potentials for applications in integrated logic circuits with low power dissipation, wide noise margins, and higher robustness, ambipolar transistors have attracted widely attentions in recent. Here, we utilize IGZO and organic semiconducting material--DNTT, to fabricated ambipolar transistors. The transistors show balance mobility for n- and p-type channels, in addition, ideal reliability was observed in the prolonged bias stress test. Converters based on above were also built up, which showed promising behaviors with gain value as high as 30. The organic-inorganic hybrid heterostructures may open up a path way for the flexible design of functional devices and its integrations.

S14.2

Invited: Challenges for carbon nanotube thin film transistors

Xuelei Liang

Key Laboratory for the Physics and Chemistry of Nanodevices and Department of Electronics,

Peking University, Beijing, 100871, China

Email: liangxl@pku.edu.cn

Abstract: Carbon nanotube thin film transistors (CNT-TFTs) have shown high on/off current ratio, high current density and superior carrier mobility with ease of large scale production at low temperature on both flexible and rigid substrates. These advantages make CNT-TFTs strong competitors to those currently commercialized TFT technologies in the field of macroelectronics, such as display backplane electronics, flexible electronics, bio-chemical sensors, solar cells and others. However, most of the efforts on the research and development of CNT-TFTs were carried out in research laboratories, and there are still many challenges before it being commercialized. In this presentation, we will report progress on the CNT-TFT technology in our group, and also discuss the challenges from the aspects of the CNT materials production, the fabrication process of the CNT-TFTs, and the device performance. Though the CNT-TFT technology is not yet ready for commercialization, it arrives at a critical status of being transferred from lab to industry, and the challenges could be overcome by close collaboration between research institutes and manufacturers in the near term.

Key Words: carbon nanotube; thin film transistors; challenge;

S14.3

Invited: 2D Materials: from fundamental research to thin-film transistor applications

Wenzhong Bao(包文中),

Fudan University.

S14.4

Invited: Printable high-performance sc-SWCNT inks and application in printed p-type and n-type TFTs and circuits on PET substrates

Jianwen Zhao, Zheng Cui

Printable Electronics Research Centre, Suzhou Institute of Nanotech and nano-bionics, Chinese Academy of Sciences, No. 398 Ruoshui Road, SEID, Suzhou Industrial Park, Suzhou, Jiangsu Province, 215123, PR China

*Email: jwzhao2011@sinano.ac.cn; Zcui2009@sinano.ac.cn

Abstract: Printed thin film transistors (TFTs) are the core elements to construct various printed devices and systems, including backplanes for OLED, LED and QLED displays, and E-paper, printed logic gates and circuits, biologic and chemical sensors, and artificial electronic skin. Performance of printable inks, especially semiconductor inks, is critical for high-performance TFTs. Semiconducting SWCNTs (sc-SWCNTs) have been become a promising semiconductor for printed TFTs, especially for flexible printed TFTs, since SWCNTs show excellent electrical properties, solubility, flexibility, high chemical and physical stability, and process temperatures compatible with flexible substrates[1-4]. In this work, we developed a valid approach to selectively wrap large-diameter semiconducting single-walled carbon nanotubes from commercial SWCNTs using organic conjugated compounds and achieved more than 20 high-performance sc-SWCNT inks. High-performance printed p and n-type SWCNT TFTs, CMOS inverters and ring oscillators were constructed on PET substrates using sorted sc-SWCNT inks. The effective mobility and on/off ratio of flexible printed TFTs can be up to $30 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$ and 10^6 at operation voltage of $\pm 2 \text{ V}$. The gains of printed inverters and the frequency of printed oscillators on PET substrates can reach 30 and 3.3 kHz, respectively. At the same time, we demonstrated the great potential of using SWCNT TFTs for high-performance OLED displays. It might pave the way of using sorted sc-SWCNTs for future display applications.

Key Words: printed flexible electronics; sorted semiconducting carbon nanotube; printed TFTs; n-type; p-type; and printed circuits

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S14.5

Invited: Interface and Surface Passivation of Germanium Junctions for High Speed Flexible Electronics

Chi Liu(刘驰),

Institute of Metal Research (IMR), Chinese Academy of Sciences.

Session 15: micro-LED (Emissive Displays)

S15.1

Invited: Current status and issues of QLED displays

Changhee Lee,

Seoul National University.

S15.2

Invited: A high-performance full-color micro display based on quantum-dot aerosol jet technology

Huang-Yu Lin,¹ Chien-Chung Lin,² Wing-Cheung Chong,³ Zhaojun Liu,^{3,4} Kei-May Lau,³ and Hao-Chung Kuo^{1*}

1 Department of Photonic & Institute of Electro-Optical Engineering, National Chiao Tung University, 1001 University Road, Hsinchu 30010, Taiwan

2 Institute of Photonic System, College of Photonics, National Chiao-Tung University, No.301, Gaofa 3rd Rd., Guiren Dist., Tainan City 71150, Taiwan

3 Department of Electronic and Computer Engineering, Hong Kong University of Science and Technology, Kowloon, Hong Kong

4 School of Electronic and Information Engineering, Sun Yat-sen University, China

* hckuo@faculty.nctu.edu.tw

Abstract: Currently, the light utilization efficiency (LUE) of LCD display is still lower than 2.8 %. Most passive components such as color filters can absorb a large portion of emitted photons from LED backlight. Thus the display needs to be operated at more than ten times of the required power in order to meet the expected output luminescence. The RGB quantum dots (QDs) can be a great alternative candidate to realize full color display and solve the low light utilization efficiency problem in LCD system. The QDs possess unique properties such as high quantum yield, size-dependent emission wavelength, and narrow emission FWHM. This study reports a full-color LED based display by combining UV micro-LED arrays with 282 pixels per inch (PPI) in full color by RGB QDs via aerosol jet printing technology.

Key Words: micro LED; quantum dot; light emitting diode; micro display

Figure 1 (a) show the PL spectra of the three types of QD in toluene under a 365 nm excitation. Different peaks at 450 nm, 535 nm, and 630 nm can be observed, respectively. The alphabets (NCTU) logo fabricated by the aerosol jet process is as shown in Fig. 1(b). The strokes are with the linewidth of 33 μ m and 14 μ m, respectively. The standard multiple quantum well (MQW) LED structure was grown on the sapphire substrate and a 30 μ m by 90 μ m mesa for each micro-LED pixels were formed via micro-LED array fabrication process shown in elsewhere. Figure 2 shows the micro-LED array with the fully processed metal connection. The emission wavelength of the UV LED pixels is 395nm. After the fabrication was finished, the RGB QD was mixed with xylene to prepare the spraying solution of 5mg/mL concentration and the aerosol jet printing system was used to spray the RGB QDs on the micro-LED array sequentially, as shown in figure 2(b)-(f). The driving current of each LED is 20 mA and the spectra with and without DBR were taken as shown in Fig. 3(a). After DBR structure was added, the strong reflection band successfully suppressed the 395nm peak of the UV LED and increased the RGB intensities by 194 % (blue), 173 % (green) and 183 % (red). Figures 3(b) demonstrated the micro-LED array with QDs in full operation. The resolution of our current display is 282 pixels per inch (PPI) in full color. The maximum color gamut that can be covered by our RGB QDs and its area is 1.52 times of the NTSC 1976 standard gamut (dash-dot line) as shown in Fig. 3(c).

Supplementary information

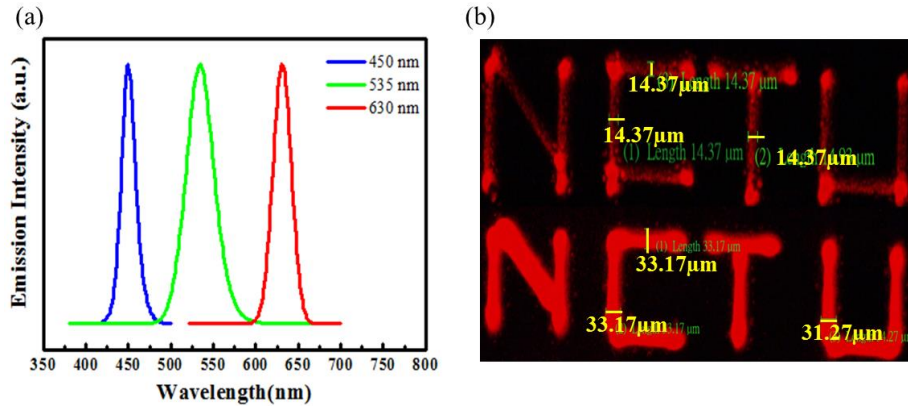


FIG. 1. UV-visible absorption and PL emission spectra of QDs with the emission colors of (a) blue, green and red, and (d) the NCTU logo printed by the aerosol jet technology with the red QDs.

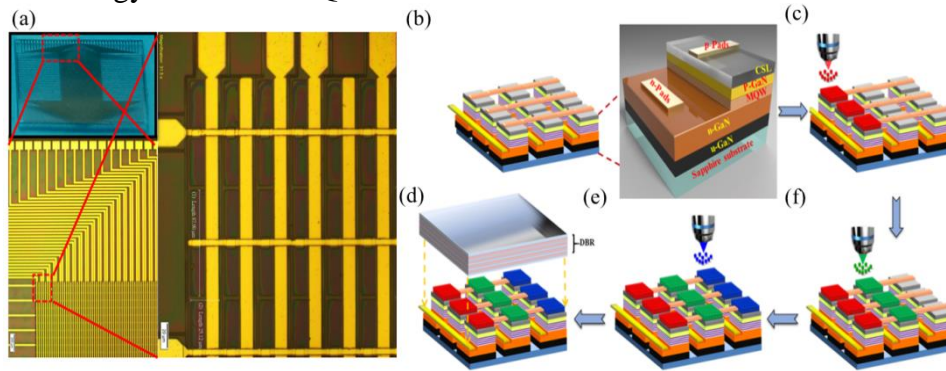


FIG. 2. (a) The micro-LED array with the pixel size of $30\mu\text{m} \times 90\mu\text{m}$. (b)-(f) The process flow of the aerosol jet printing of RGB QDs on micro-LED array.

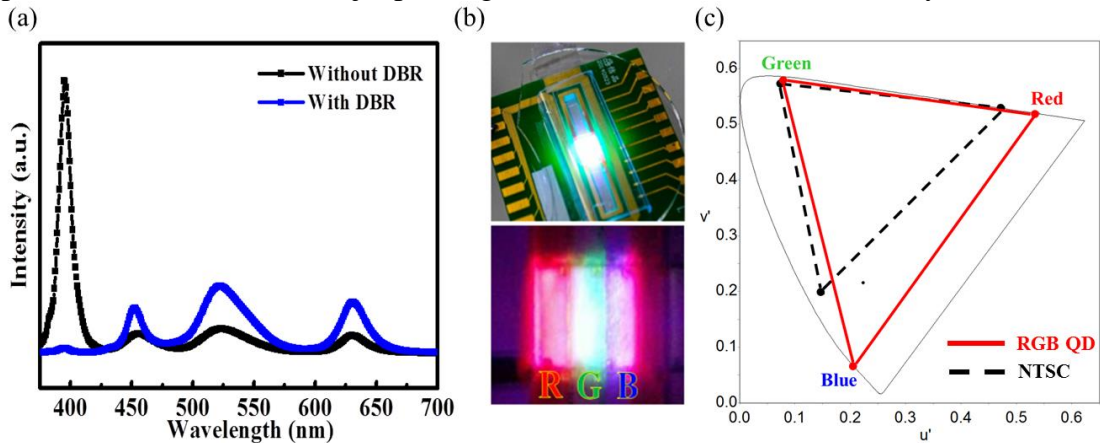


FIG. 3. (a) The emission spectra with and without the DBR. (b) The jet-printed RGB QDs LED display in operation and representative image of RGB pixels in bottom. (c) The CIE 1976 color space chromaticity diagram of the QD display technology and NTSC standard gamut.

S15.3

Invited: GaN-based micro-LEDs for micro-display and visible light communication

Pengfei Tian

Fudan University

Abstract: This talk will discuss novel GaN-based micro-LEDs for applications in micro-display and visible light communication, and the key electrical and optical

characteristics of micro-LEDs. The fabrication, characteristics, and applications of micro-LEDs on Si and flexible substrates will be demonstrated. We will present free space non-line-of-sight visible light communication using a micro-LED, which is suitable for practical communication, and high-speed underwater communication using a low power micro-LED. The size has significant effects on the sidewall defects, current spreading, heat dissipation, junction temperature, and carrier recombination of micro-LEDs, and therefore the characteristics of current versus voltage, quantum efficiency, modulation bandwidth, and aging are strongly related to the micro-LED size. Ambient temperature effect on the micro-LED characteristics will be also analyzed. Investigations of these physical mechanisms benefit the applications of micro-LEDs in micro-display and visible light communication.

Key Words: micro-LED; micro-display; visible light communication; efficiency; modulation bandwidth

S15.4

Invited: Micro-LEDs: Homogeneous and Heterogeneous Integrated Devices of Light Emitting Diodes and Driving Circuits

Zhaojun Liu

Sun Yat-sen University

Abstract: In the past several years, LEDs have gradually substituted cold cathode fluorescent lamps (CCFLs) as the backlight of liquid crystal displays (LCDs) because of better luminous efficiency, longer lifetime and wider color gamut. Although many technologies have been developed to reduce the power consumption, extremely low light utilization efficiency (LUE) in LCD panels renders further power reduction difficult. Micro-LEDs, self-emitting devices without the need of backlight units, are suitable for many applications such as novel displays. Micro-LED displays have the potential to enhance the capabilities of LCDs and OLED displays with its excellent performance in many different aspects, particularly high LUE, simplicity of optical modules without backlight unit, long lifetime and excellent visibility under bright day-light.

Our group has been working on micro-LED technologies since 2006. We have reported the design and fabrication of high pixel per inch (PPI) micro-LED displays with red, green blue and UV colors by integrating monolithic LED micro-arrays and active matrix substrates using Flip-Chip technology. A CMOS active matrix driving scheme was designed to provide sufficient drive capability and individual controllability of each LED pixel. The micro-LED displays had 400×240 pixels on a single chip with PPI (Pixel per Inch) up to 1700. The emission wavelengths were 630nm, 535nm, 445nm and 380nm, respectively. The red, green and blue micro-LED displays can be used to form a novel full-color direct-view display. The UV LEDoS micro-display could be used for modulated visible light communication systems or for data-modulated photo-pumped organic semiconductor devices.

Key Words: Micro-LEDs; Active Matrix; novel displays; LEDs; heterogeneous integration; homogeneous integration

S15.5

Invited: The applications of LED/OLED micro-display devices in VR/AR light-field display systems

Lilin Liu

School of Electronics and Information Technology, Sun Yat-Sen University

Abstract: Compared with those non-self-emissive micro-displays (such as LCOS,

DMD, DLP etc.), OLED/LED-based micro-display devices take the advantages of the inherent large divergence angle, which guarantees a homogeneous light intensity distribution on the spectrum plane, i.e. a necessary condition for successful time multiplexing. In this talk, I will present several innovative technologies developed by our research groups in the area of 3D display by employing OLED micro-displays. (1) A novel multi-view 3D display system with continuous motion parallax by using a group of planar aligned OLED micro-displays, taking the merit of full display resolution and a thin optical structure, offering great potentials for portable or mobile 3D display applications. (2) A 360° all-around multi-view 3D display system by using coarse-pitch circular-aligned OLED micro-displays. (3) A novel super-multi-view (SMV) technology combining time-/spatial-multiplexing based on planar-aligned OLED micro-displays. The horizontal interval between adjacent sub-viewing-zones is as small as 1.6mm, bringing perfect 3D viewing effects. (4) Through shrinking the optical structure of the project 3 into a thin space, the SMV further gets implemented on portable display terminals, such as smartphone. (5) A proof-of-concept head-mounted light field VR/AR system based a novel exit pupil division multiplexing theory. For all these projects, the visual fatigue accompanying those conventional stereoscopic technologies are relieved greatly, especially for 3D display with a large depth. Finally, requirements on performances of OLED micro-displays for better 3D experiences are discussed. The advantages of LED micro-display over OLED micro-displays in VR/AR applications are talked.

Key Words: LED/OLED microdisplay; light-field VR/AR; super multi-view technique(SMV); portable display terminals.

S15.6

Invited: Active Matrix Micro LED Display Based on Digital Modulation Silicon Backplane

Chen-Hsien Chu,

Jasper Display Corporation (JDC)

S15.7

Fully-Integrated Active Matrix Programmable UV and Blue Micro-LED Display System-on-Panel (SoP)

Ke Zhang, Deng Peng, Zhaojun Liu*

Sun Yat-sen University Carnegie Mellon University Joint Institute of Engineering,
School of Electronics and Information Technology, Sun Yat-sen University,
Guangzhou, China

Sun Yat-sen University Carnegie Mellon University Shunde International Joint
Research Institute, Shunde, China

Department of Electronic & Computer Engineering, Hong Kong University of
Science and Technology

E-mail: liuzhaojun@mail.sysu.edu.cn

Abstract: High pixel per inch (PPI) and high resolution micro-LED displays are attracting more and more attentions. The increasing pixel number requires a large amount of connecting pads and brings huge difficulties to micro-LED system design and lowers power efficiency as well. So it is urgent to integrate row and column driving circuits onto the micro-LED panel. Here we report a fully integrated active matrix programmable micro-LED system on panel (SoP). The micro-LED SoP has a resolution of 60×60 and pixel pitch of 70μm. With the fully integrated scan and data circuits, the number of bonding pads was greatly reduced from 136 to 28 and large

areas were saved. The micro-LED SoP was achieved by integrating micro-LED arrays with silicon-based PMOS driving panel using fine-toned flip-chip bonding technology. The micro-LED SoP panel was mounted on an external driving board and representative characters were displayed successfully.

Key Words: System on panel, micro-LED display, active matrix

Session 16: QD PL (Emissive Displays)

S16.1

Invited: QD-LCD vs. OLED: The Battle for the Next Mainstream TV

Zhongsheng Luo (罗忠升),

Greater China & Applications Engineering, Nanosys Inc, Milpitas, CA, USA.

Abstract: With the fast advance of new display technologies, premium TVs have delivered picture quality that has never been seen before by incorporating high resolution for extraordinary clarity, higher color volume for realistic colors and high dynamic range (HDR) for a life-like viewing experience. QD-LCD and OLED are the two leading technologies in the race for ultimate picture quality. QD-LCD technology has its advantages in combining superior color performance with all other advancements, including peak brightness, in LCD technologies while OLED technology has its advantages in its emissive nature which brings strengths in key areas such as deep black level and wide viewing angles. We believe that the next mainstream TVs will all be coming from one of these two technologies. This paper presents detailed comparison of these two technologies from their performance and limitations to cost and supply and discusses which technology will be the most likely winner for the next mainstream TVs. The data shows that as the only OLED technology feasible for TV application, WOLED technology still faces many challenges in serving as a mainstream, such as low efficiency, prone to image burn-in, limited supply and high manufacturing cost. On the other hand, although still limiting by LCD technology, QD-LCD has kept improving upon its own weakness and as a result, we predict QD-LCD will become the market share leader for the next mainstream TVs.

Key Words: Quantum Dots (QD), color volume, QD-LCD, HDR, OLED, WOLED, TV

S16.2

Invited: Halide Perovskite Quantum dots: Potential Alternative Materials for Display Applications

Haizheng Zhong

Beijing Key Laboratory of Nanophotonics and Ultrafine Optoelectronic Systems, School of Materials Science & Engineering, Beijing Institute of Technology, Beijing, 100081, China.

E-mail: hzzhong@bit.edu.cn

Abstract: Colloidal quantum dots are excellent solution-processable luminescence materials for high-color-quality solid-state lighting and flat panel displays. They are emerging “upstart” in the commercialized TV market. The future of quantum dots to reach mainstream status strongly relies on the developing of low cost materials. Halide perovskites quantum dots with tunable and narrow band emissions are rising as alternative candidates for display applications. We recently developed the colloidal synthesis of $\text{CH}_3\text{NH}_3\text{PbX}_3$ quantum dots and explored their applications in the fabrication of wide color gamut white light-emitting diodes and electroluminescence

device. Furthermore, we also developed an in-situ fabrication strategy for $\text{CH}_3\text{NH}_3\text{PbX}_3$ quantum dots embedded polymer composite films and demonstrate the prototype display system. In addition, we will also discuss the future challenge for the applications.

Key Words: quantum dots; halide perovskite; electroluminescence; composite films; backlights.

S16.3

***Invited:* Emerging Photoluminescent Quantum Dot and Quantum Rod Displays**

Kai Wang

Southern University of Science and Technology

Abstract: With advantages of wide color gamut (narrow FWHM), size-dependent emission wavelength, flexible, printable and low cost, quantum dot (QD) and quantum rod (QR) displays are emerging in displays. For photoluminescent application, the next challenges concerning QD/QR are suggested to be new luminescent nanocrystals with narrower emission, higher long-term operational stability and polarized emission. In this study, we present emerging photoluminescent QD and QR displays technologies, including highly stable QD composites based on luminescent microspheres technology integrated with micro packaging for on-chip QD-LED, precise optical and thermal modeling of QD composites and QD-LED, QR based Active Luminance Enhancement Film (ALEF) and Perovskite nanocrystals film with strong polarized and narrow FWHM emission for wide color gamut and low power consumption display, and related QD-LED devices and modules for high quality displays and lighting applications. PL QD/QR display technology will rejuvenate LCD technologies in terms of color.

Key Words: quantum dot; quantum rod; perovskite; photoluminescent; on-chip QD-LED; active luminance enhancement film; displays;

Session 17: OLED Device 1 (OLEDs)

S17.1

***Invited:* OLED Micro-displays for Virtual Reality (VR) & Augmented Reality (AR)**

Amal Ghosh,
eMagin Corp.

Abstract: Organic Light Emitting Diode (OLED) based displays are beginning to enter the main stream display and television market. OLED based Head mounted displays (HMD) are a major part of wearables, particularly near-to-the-eye displays. The brightness of the displays is critical for many applications including Augmented (AR) and Virtual Reality (VR). eMagin's recent efforts to develop high brightness OLED microdisplays will be presented.

S17.2

***Invited:* Development of High EQE OLEDs: from Efficient Internal Generation to External Extraction**

Chung-Chih Wu^{1,*}

¹ Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan

*wucc@ntu.edu.tw

Abstract: To achieve ultimately high external quantum efficiencies of OLEDs, OLED

materials and device architectures that can achieve high internal quantum efficiencies and high optical out-coupling efficiencies are equally important. In the paper, we will present some of our recent works on OLED materials and devices that can provide ideal internal quantum efficiencies and high optical out-coupling efficiencies. For instance, in addition to presentation of some efficient (blue to red emitting) phosphorescent emitters, a few series of TADF emitters having highly efficient PL and EL properties will be discussed. For instance, extremely efficient blue organic EL with external quantum efficiency (EQE) of ~37% is achieved in a conventional planar device structure, using a highly efficient TADF emitters that simultaneously possesses nearly unitary (100%) photoluminescence quantum yield, and strongly horizontally oriented emitting dipoles (with a horizontal dipole ratio of 83%). On the other hand, we will also show that judicious use of low-index active organic materials and transparent electrodes in OLEDs, together with OLED emitters with preferentially horizontal emitting dipoles, can effectively enhance optical coupling both into substrate and directly into air. As a result, OLED EQEs of up to 39% had been achieved with the simple planar device structure, while EQE of 64-65% had been achieved further with adopting simple external extraction schemes.

Key Words: OLED; internal quantum efficiency; light out-coupling; phosphorescence; TADF.

S17.3

***Invited:* Laser nanofabrication for advanced OLEDs**

Hong-Bo Sun, Yan-Gang Bi and Jing Feng

State Key Lab on Integrated Optoelectronics, Jilin University

Abstract: Light management is crucial for the performance of organic light-emitting devices (OLEDs), and microstructures have played important roles in light management through manipulating the generation and propagation of photons in materials. We have investigated systematically the fabrication of microstructures by laser in OLEDs and their effects on improving the device performance. By precisely designing geometry of microstructure and selecting dielectric material property, we can effectively control the efficiency of light transmission, extraction, scattering, or reflection in OLEDs. The electroluminescent characteristics of OLEDs with laser nanofabricated microstructures have been effectively improved by the excitation and outcoupling of the optical modes inside devices, such as waveguide and surface plasmon-polariton modes. Laser nanofabrication technology is also applied to fabricate the stretchable OLEDs. The stretchable OLEDs with an ordered-buckling profile have been obtained by the laser-programmable buckling process, which not only creates options for the design and fabrication of the device but also allows the stretch-release cycles to be controlled. The strained OLED luminous efficiency (70 cd/A under 70% strain) is the largest to date and the OLEDs can accommodate 100% strain while exhibiting only small fluctuations in performance over 15,000 stretch-release cycles.

Key Words: laser nanofabrication; microstructures; OLEDs; surface plasmon-polariton; stretchable OLEDs.

S17.4

***Invited:* Transient electroluminescence of Organic Light-Emitting Diodes**

Suling Zhao*, Peng Wang, Chengwen Zhang, Bo Qiao, Dandan Song, Zheng Xu

Key Laboratory of Luminescence and Optical Information, Ministry of Education, Beijing Jiaotong University, Beijing 100044, China

Institute of Optoelectronics Technology, Beijing Jiaotong University, Beijing 100044, China

Email: slzhao@bjtu.edu.cn.

Abstract: Transient electroluminescence (EL) measurement has been proven to be an effective and profitable method for the study of information on injecting carriers. When organic light emitting devices (OLEDs) are driven by the pumping signal of the periodic square wave, instead of being driven by DC bias as usual, the devices provide a delayed luminescence after the end of the forward bias pulse. Transient EL can be used to analyze the formation of excitons in host–guest systems, energy transfer processes, and carrier transportation in OLEDs. In this work, we fabricated solution-processed OLEDs using a thermally-activated delayed fluorescent (TADF) emitter 1,2,3,5-tetrakis(carbazol-9-yl)-4,6-dicyanobenzene (4CzIPN) and studied the corresponding transient EL decay of this system. A reverse pulse was applied to the devices with a delay time of 10 μ s behind the forward bias. The doped devices showed an accelerated EL decay under the reverse bias, while the device without 4CzIPN experienced a partial increase when the reverse pulse was on. The joining of the reverse bias sped up the dissociation of the exciton in 4CzIPN formed under a forward bias. If the exciton of 4CzIPN is formed by the energy transfer from the interfacial exciplex exciton, the transient EL intensity form of the devices doped with 4CzIPN should depend on that of the device without 4CzIPN. The difference in the EL decay from doped and undoped devices means that the energy transfer is not the main process for the emission of 4CzIPN, especially in highly-doped devices. Therefore, it is concluded that the main mechanism of the electroluminescence of the 4CzIPN-doped system is the direct recombination of the injected carrier of 4CzIPN.

In addition, transient EL can be used to study the charge accumulation OLEDs. OLEDs containing an insulating layer of poly(methyl methacrylate) (PMMA) with the thickness of 2, 6, 8, 10nm have been prepared and investigated. The emission mechanisms of the device are analyzed considering transient and AC EL measurements. We show that charges are stored in the PMMA layer as surface charges and bulk charges. The former contribute to the occurrence of EL spike, and the latter can be released to emit light under reversed voltage more than 2V because they are immobile unless under the stronger reversed field. When operating under AC stress, we not only obtain the EL peak from injection charges under forward voltage, but also obtain another peak, whose peak point lies in -0.2V. It turns to originate from stored charges so they become beneficial instead of weakening EL for reusing to produce light. All the results pave the way to realize AC driven OLEDs devices using these stored charges, to uncover the AC EL mechanisms and to improve their EL performance.

S17.5

TBD

Huaping Li (李华平)

ATOM Nanoelectronics

Session 18: OLED Display 1 (OLEDs)

S18.1

Invited: Inkjet Printing for OLED TV on Large-Area Glass

Jeff Hebb

Kateeva, Inc.

Abstract: Cost-effective mass production of OLED TVs requires scale-up of the manufacturing process to panel sizes of Gen 8 or larger, including the formation of the RGB active layers. The RGB active layers for consumer products made on smaller glass sizes are formed using thermal evaporation through a fine metal mask. However, thermal evaporation has critical technical limitations which prevent it from being scaled to panel sizes large enough to make cost-effective OLED TVs.

Inkjet printing (IJP) is today's most promising alternative to thermal evaporation for OLED TV manufacturing. Historically, though, IJP has presented its own set of challenges (e.g., pure process environment, particles, print-mura). In response, Kateeva developed a unique RGB pixel printing technology that successfully addresses the challenges. In fact, many of the enabling technologies in Kateeva's RGB IJP system have already been proven in mass production for OLED thin film encapsulation. Additional innovations were implemented to enable successful RGB pixel printing.

This presentation will describe Kateeva's RGB pixel printing system. Special focus will be applied to the advanced technologies pioneered by Kateeva that enable IJP for OLED TV mass production.

Key Words: inkjet printing; OLED; RGB pixels

S18.2

Invited: Enabling OLED Technologies for TVs: PHOLEDs and OVJP

Pete Liu

Universal Display Corporation

Abstract: We present enabling OLED Technologies for supporting TVs by the following three topics:

OLED Market Overview and Technology Outlook

Active matrix organic light-emitting diode (AMOLED) displays are rising fast, wider use in end-market consumer electronics devices. OLED TV's greatly outperform LCD's by the features of lower bill of materials, better Performance and superior aesthetics. In this topic, we will explain why our proprietary UniversalPHOLED materials and technology provide strong performance benefit to enable greater energy efficiency, increases lifetime and reduces requirements for heat dissipation components.

UDC Corporate Overview and Phosphorescent OLED Performance for TVs

In this topic, we will demonstrate superior PHOLED performance to support OLED (TV) development and commercialization. UDC is inventing, developing and commercializing the emissive layer materials (Dopant + Host) and design/fabricate PHOLED devices to deliver materials, device design and supporting data to target roadmap specs. We will also share the outlook for red, green and yellow emitters which have significant more runway to improve.

New OLED Technologies in R&D for TVs

We will introduce a novel dry printing technology (OVJP) technology to enable RGB sub-pixel OLED TV design.

Key Words: component; OLED; Phosphorescence; TV

S18.3

Invited: Approach to AMOLED display market

Kouji Hane

ULVAC, Inc.

Abstract: Display industry is now at a large turning point, within future 2~3 years,

growth of LCD market for mobile & TV will stop and forecast to be replaced by OLED panels. After a Korean manufacturer releasing a 55 inch AMOLED-TV to the market back in Jan 2012, AMOLED display market has been growing by and with the key features such as: “Deep Black” which is the key for the frame contrast “High response speed”, “Thin hardware”, “Curved (flexible) display” ULVAC believes that “display flexibility” and “low manufacturing cost” is the key for continued growth of the AMOLED display market. As a key player in this industry, ULVAC is approaching this market multilaterally with Hardware / Process / Material know-how to realize high productive equipment capable to process large substrates in good film uniformity. The presentation aims to introduce ULVACs OLED equipment line-up and feasibility to meet the requirements in the display industry. The presentation aims to introduce ULVACs OLED equipment line-up and feasibility to meet the requirements in the display industry.

S18.4

Invited: Metal-oxide backplane Integration challenges for OLED TV applications

Nino Zahirovic

Ignis Innovation Inc

Abstract: Metal-oxide semiconductor technology is the backplane technology of choice for large area AMOLED TV displays. Metal-oxide backplanes have the advantage of scalability and high mobility but suffer from some significant challenges including negative bias instability, non-uniformity, voltage threshold shift, thermal instability, light sensitivity and hysteresis. All of these issues can be significant barriers to widespread adoption of metal-oxide backplanes for OLED displays.

External compensation technology, championed by Ignis Innovation Inc., has enabled one display manufacturer to bring products to market while others still struggle. This talk outlines the optimal application of external compensation technology to solve the challenges of metal-oxide backplanes for OLED TV applications. Particular attention will be paid to which problems must be solved by process optimization and which problems can be tackled effectively by application of external compensation.

Key Words: OLED TV; External Compensation; Metal Oxide

Session 19: Display Module Manufacturing for All Display Technologies (Display Manufacturing)

S19.1

Invited: Module bonding process technology about high resolution and display quality

Dankui Wang

BOE Technology Group Co., Ltd.

Abstract: With the high resolution and display quality, it is necessary to improve module bonding process. It is introduced fine pitch and COG mura solution in the paper. According to fine pitch, it is presented in detail including ACF, drive IC and bonding equipment accuracy. Conducting ball size in ACF, IC bump pitch and equipment are the three main factors effecting fine pitch bonding. In regard to COG Mura resolution, it is stated intensively about UV bonding process and equipment

design, which process temperature and pressure are lower than normal bonding and low-degree ACF bonding to solve the COG Mura fundamentally.

摘要: 随着液晶面板的解析度和显示画面品质要求的提高,对模组的 Bonding 工艺提出了更高的要求,本文重点说明了 bonding 工艺如何解决 fine pitch 和 COG mura。对于 fine pitch Bonding 解决方案从 ACF 材料、IC 及设备三个方面进行了详尽的说明,包括 ACF 导电粒子大小及结构、IC Pitch 的管控以及设备精度的提升等。对于 COG Mura 的改善方法,除了采用低温 ACF 材料和 Bonding 温度的管控以为,本文重点讲述了 UV Bonding 的工艺及设备。

S19.2

Invited: Development of novel diamond cutter wheels for display glass cutting

Wenlin Tang (唐文林),

北京沃尔德金刚石工具股份有限公司.

S19.3

Invited: Prospects of Automotive Touch Technology

Fred Wu(吴锡淳)

Shantou ultrasonic display co., LTD

Email: xichunwu@goworld-lcd.com

Direct: 86-754-89893820, **Mobile:** 13229663961

Abstract: Automotive capacitive touch screen develop very fast in past 3 year, Now many models using capacitive touch screen as their basic configuration, more and more capacitive touch screen are applied in different vehicle. Let's talk about technical progress in the past, and what new technology will apply in automotive CID successfully in the future.

摘要: 车载电容触摸屏在过去的 3 年飞速发展,如今很多车型已经将电容屏作为标配,越来越多的车型使用电容触摸屏,探讨车载触摸屏在过去的取得的技术进展,以及未来会有哪些新技术会成功应用到车载 CID 上。

Session 20: Applications of 3D Display (Display Applications)

S20.1

Invited: LC-lens Array for 3D Applications

Yi-Pai Huang(黄乙白)

National Chiao Tung University

Abstract: Liquid crystal lens (LC-lens) array was utilized in many 3D applications, such as 3D Display, 3D endoscope, and 3D light field microscope. This presentation will cover the fundamental of LC-lens, and followed by its 3D applications. Finally, a newly developed LC-lens arrays that can be locally controllable, switchable, focus-tunable, orientation rotatable functions will be presented. Comparing with conventional plastic lens array, which was usually placed in 3D or light field system, the proposed LC-lens array has higher flexibility of electrically changing its focal length.

S20.2

Invited: 360 °Realistic 3D Image using Direct Light Scanning Method

光线扫描法实现 360 度真实三维图像

Xiaodi Tan

Beijing Institute of Technology

Abstract: The 360 degree realistic 3D displays should have to develop for the purpose of observing objects from free viewpoints with multiple people. A Direct Light Scanning Method is proposed in this paper. In the method, a high-density directional 3D motion image can be obtained easily with only one SLM. The 3D display system employed this method by a new-type of named “Holo-Table” is also demonstrated. The features of these displays are not only in 360 degree large views angles but also high density of views. Because of these features, viewers can see the 3D scene from any directions with smooth motion parallax. In addition, a method of creating the 360 degree parallax images from a real object, which are taken by a scanning camera, is introduced, and the 3D image with smooth motion parallax from any directions can be displayed. According to the principle of Holo-Table display, the processing methods of these images are discussed. The effective parameters of the 3D images are demonstrated, too.

Key Words: display; 3D display; 3D component; holography.

S20.3

***Invited:* A naked eye 3D LCD with 2D/3D switchable property**

Yanna Xue

BOE Technology Group Co., Ltd

Abstract: The autostereoscopic display with a liquid crystal panel attached onto a liquid crystal has been developed successfully and has the ability to switch between 2D display mode and 3D display mode. In order to acquire the high quality 3D display, the precise pitch of the parallax barrier and the stack height are calculated through view distance and interpupillary distance. We divided the pitch of the parallax barrier into several slits equally by transparent ITO electrode which adjust eye tracking effectively and then achieved almost perfect uniformity of view image brightness and dynamic viewing angle.

Key Words: autostereoscopic display; 2D/3D switchable property; parallax barrier; eye tracking

S20.4

***Invited:* Three-dimensional light-field display and it's medical applications**

Xinzhu Sang

Beijing University of Posts and Telecommunications

Abstract: Real time light field display with 90×90 viewpoints and the frame rate above 40 fps is demonstrated. The backward ray casting algorithm is used to render the medical volume data in real time. Four different kinds of medical data are applied for testing the validity of our scheme, and real time interactive 3D light field display is presented. Experimental results shows the viewing angle for the full-parallax light-field display can reach $40^\circ \times 40^\circ$ and the rendering efficiency can reach 30-40 fps for common medial volume data.

Key Words: light field information capturing; light field display; virtual capturing; real capturing

S20.5

A Multi-layer 3D Display Method Based on Depth Map

Chen Xiaoxi

University of Electronic Science and Technology of China

Abstract: In order to obtain the real 3D display, two multi-layer display methods

were done. 1. We calculated the light field using a few images of different view, and obtain the attenuation image by the least square fitting. 2. We design the algorithm that can calculate the attenuation images of the multi-layer display from only two images (the texture image and the depth map image of the object) . The display system include the multi-layer liquid crystal device module , multi-channel driver module and high brightness backlight. Finally we give the experimental results of two methods which show our display system has the good 3D effect.

Key Words: Multi-layer; 3D display; light field; depth map;

S20.6

Light field display optimization based on eye-tracking

Lu Haiming

Research Institute of Information Technology, Tsinghua University

Abstract: Virtual reality technology has developed rapidly and can provide good immersion. However, long-time use of virtual reality glasses may bring fatigue and dizziness to users, which is mainly caused by “accommodation-convergence conflict” . As for now, light field display could ease the “accommodation-convergence conflict” by providing a display performance similar to the real physical environment, which has received extensive attention and research. At present, because of the fact that light field display requires a huge amount of computing and transmission bandwidth, it is hard to achieve a full light field reconstruction scene. In consideration of the knowledge that human eyes are usually only aware of a limited field of view, we can achieve weighted optimization of spatial light field by using eye-tracking techniques. Meanwhile, by providing high-resolution images in the target area of user’s eyes while low-resolution images in others, we can optimize the algorithmic complexity and compress the amount of data significantly. Hence, the proposed method can help to achieve high subjective light field image quality with less resource consumption.

Key Words: virtual reality; accommodation-convergence conflict, light field display; eye-tracking

Session 21: Printed inorganic TFTs & electronics (Active-Matrix Devices)

S21.1

***Invited:* Recent Developments of Digital Printing Technologies for Flexible Electronics and Displays**

Jinguo Yang

Kunshan Govisionox Optoelectronics Co. Ltd

Abstract: Digital printing technologies have been applied to deposit functional materials to form patterns on flexible substrates to make flexible electronics and displays. In this talk, I will first review the recent research and development of digital printing technology for fabrication of flexible electronics and displays, and discuss the advantages and challenges of digital printing technology in comparison to conventional IC technologies and other non-digital based printing methods. Next I will introduce our research in digital printing technologies and printed samples.

Key Words: digital printing; flexible electronics; displays

S21.2

Invited: Low-temperature high-performance p-type oxide thin-film transistors via solution process

Fukai Shan

College of Electronic & Information Engineering, Qingdao University, Qindao 266071, China

Abstract: Solution-processed p-type oxide semiconductors have recently attracted increasing interests for the applications in low-cost optoelectronic devices and low-power consumption complementary metal-oxide-semiconductor circuits. Achieving high performance p-type oxide thin-film transistors (TFTs, that have an advantage over n-type TFTs since the TFT supplies hole current for the anode of the organic light emitting device without affecting the drain current in the saturation mode) will definitely promote a new era for electronics in rigid and flexible substrates, away from silicon. Herein, several novel solution-based approaches (i.e. vacuum annealing, polyol reduction, and complex reaction in precursor solution) were adopted to fabricate p-type metal oxide (i.e. Cu_xO and NiO_x) thin films.[1-4] To investigate their applications as hole-transporting semiconductor layers in transistors, the bottom-gate, top-contact TFTs were constructed. The electrical properties of the fabricated TFTs, together with the characteristics of oxide thin films, were systematically investigated as a function of annealing temperature. By introducing high-k gate dielectrics, the electrical performance, especially the hole mobility, of devices was improved significantly. Meanwhile, the operation voltage could be reduced to only several volts, which is promising for portable and low-power consumption electronics.

Key Words: solution process; p-type oxide semiconductors; thin-film transistor; low-operation voltage

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S21.3

Invited: Fully Printed Metal-Oxide Thin-Film Transistors

Linfeng Lan

South China University of Technology

Abstract: In this report, metal oxide thin-film transistors (TFTs) were successfully fabricated with a inkjet printer without any photolithography steps. The fully printed TFT devices in the array exhibited excellent electron transport characteristics with a maximum mobility of $11.7 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$, negligible hysteresis, good uniformity, and good stability under bias stress. The new route lights a general way toward fully inkjet-printed metal oxide TFT arrays.

Key Words: inkjet printing; metal oxide; thin-film transistors; surface-energy pattern

S21.4

***Invited:* Electrohydrodynamic printing and its application in TFTs and electronics**

YongAn Huang

State Key Laboratory of Digital Manufacturing Equipment and Technology, Huazhong University of Science and Technology, Wuhan, 430074, China

Abstract: The uniformity, resolution and material compatibility are the critical challenges for ink-jet printing techniques. An electrohydrodynamic printing technique is presented to print solution with large viscosity range into micro/nano-fibers with high deposition accuracy. Then the jetting fiber is stretched through a moving substrate, by which the deposited fiber can be continuously tuned from 20 μm to 200 nm. This method is able to use a large nozzle to deposit high-resolution fiber-arrays by near-field localization. This method can directly deposit micro/nano-structures over a large flat area in the form of arrays and complex patterns, in a programmable, rectilinear, and individually controlled manner. Additionally, a directly printed self-similar serpentine fibers can be incorporated to enhance the stretchability. The electrohydrodynamic printing is utilized to deposit fine mask for small-channel TFTs and fabricate aligned 3D hierarchical Ag/ZnO nano-heterostructure arrays for highly selective NO₂ gas sensors. The electrohydrodynamic printing can fabricate TFTs and electronics, avoiding expensive and complicated multi-step lithography processes, and removing the requirements of transfer printing.

Key Words: flexible electronics; ink-jet printing; electrohydrodynamic printing; thin-film transistors; flexible sensors

S21.5

***Invited:* Inkjet Printing Oxide Thin Film Transistor Array with Polymer-Doped Metal Nitrate Aqueous ink**

Shaojing Wu, Qing Zhang, Zheng Chen,* Zheng Cui

Printable Electronics Research Centre, Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences

Email: zchen2007@sinano.ac.cn

Abstract: The printed oxide thin film transistor (TFT) spacing should be small enough for its application in backplane of high resolution display. The maximum spreading size of ejected droplet on substrate depending on substrate wettability and ink formulation, is critical limitation in the TFT spacing. We first investigated printing metal oxide dot array through 10pL nozzle with metal nitrate aqueous solution on hydrophobic substrates that are used to reduce the spacing. Along with the reducing of spacing, however, the dried dots became very small, making the film is too thick for high performance TFT. Decreasing the concentration of metal salt only led to very slowly film thinning because the dots became smaller. To reduce the film thickness on the hydrophobic substrate, the polymer of polyvinylpyrrolidone (PVP) was added in the ink. By this approach, we printed PVP-doped indium oxide TFT array of the smallest spacing of 50 μm , coupling with mobility in excess of 4 cm² V⁻¹ s⁻¹ and current on-to-off ratio more than 10⁷.

Key Words: solution process; printed electronics; indium oxide; IGZO; doping;

Session 22: Liquid-Crystal Technology 1 (Liquid-Crystal Technology)

S22.1

***Invited:* Can a Field-Sequential-Color LCD Become a Future Eco-Display?**

Fang-Cheng Lin

National Chiao Tung University

Abstract: By sequentially displaying three primary-color field-images, a field-sequential-color LCD (FSC-LCD) gets rid of color filters to yield color images. It has a high resolution, high image saturation, and lower power consumption. However, an issue limits its commercial application is color breakup, which degrades the image quality and leads to discomfort in human eyes. This paper introduces Stencil-FSC methods to overcome color breakup.

Stencil-FSC methods incorporate the local-color-backlight-dimming technology to gather the most luminance in a multi-color field and reduce the luminance of the residual field-image to effectively suppress color breakup. For practical applications, we developed the Stencil-FSC methods at 240Hz, 180Hz and 120Hz field rates to effectively suppress color breakup for large-sized TFT-LCD applications. For more efficiently suppress color breakup, we further proposed the Edge Stencil-FSC method utilizing a global backlight controlling and could much reduce the computational complexity and make an FSC technologies more promising for medium/small-sized display applications.

Key Words: color breakup; color filterless; field-sequential-color; Stencil-FSC

S22.2

***Invited:* Curved LCD Design and Limited**

ChangJian yu

Shenzhen China Optoelectronics Technology Co., Ltd

Abstract: Along with TV technology developing, High-end TV tend to be ultra large size, ultra-slim and curved design. Curved TV has been paid great attention for more natural and realistic visual experience due to circular arc shape. Optimizing curvature design of curved LCD TV is discussed in this paper, which is invested from the aspects of light leakage and glass fracture analysis. Furthermore, we comprehensively research curved LCD TV in aspects of mechanical, optical and reliable design. Based on this, we successfully developed and demonstrated 110-inch curved LCD TV and 55inch ultra-slim(3.9mm) curved LCD TV.

Key Words: Curved LCD TV; Ultra large size; Ultra-silm, Finite element analysis

S22.3

***Invited:* The Process Influence of TFT-LCD Low Frequency Mura**

Liu Cheng Ming

InfoVision Optoelectronics (Kunshan) Co., Ltd.

Abstract: TFT-LCD is widely used in varied application and display quality has higher and higher requirement to people. In order to satisfy different operation frequency range, image quality at low frequency especially should be concerned. Uniform LC alignment is indispensable in LCD, and photo-alignment process is one technology to form liquid crystal alignment grooves in IPS (In-Plane Switch) LCD by

apply polarized UV irradiation. However, UV exposure treatment will simultaneously damage TFT device that produces photo generated electrons and electronic migration on amorphous silicon layer. The TFT leakage current will lead to poor image quality. At low frequency, mixed-charge phenomenon is easily occurred between neighboring scan line due to longer gate switching time, parts of off pixels re-charging then enhance striped Mura appearance. In this study, we discuss process influence and electronic driving effect of low frequency Mura. The results show that: 1. Apply thermal treatment after UV irradiation can improve low frequency Mura; 2. Extend the Out Enable time (Gate close to Source close time difference), reducing gate high voltage (V_{gh}), and increasing GOA circuit static operating point voltage (V_{SS_Q}) can effectively resolve low frequency Mura.

Key Words: Photo-alignment; Low frequency Mura; Leakage current

S22.4

Invited: Hybrid view angle liquid crystal display

Zhongfei Zou

InfoVision Optoelectronics(Kunshan) Co.,Ltd.

Abstract: Hybrid view angle liquid crystal display which can switch between wide view angle and narrow view angle was developed. The device was design by three electrodes using positive nematic liquid crystal. There are common electrode and slit pixel electrode on bottom substrate. There are two separated electrodes on the top substrate. In wide view angle mode, the LC is driven by fringe filed between common and pixel electrode, this mode is similar with fringe filed switch. In the narrow view angle mode , there is an vertical filed between the separated electrode and common electroe except the fringe field. The LC tilt angle are increased and the view angle decrease. The separated electrode pattern on the top substrate is design based on diving mode, the polarity of each separated electrode is simillar with bottom pixel. 12.5inch hybrid view angle liquid crystal display was developed, the wide view angle is larger than 85 degree and the narrow view angle is 40 degree.

Key Words: liquid crystal display; wide view angle; narrow view angle; view angle switch

S22.5

LED Matrix Design for Field Sequential Color LCDs

Tang Jing-lang, Zhang Yu-ning*, Shen Zhong-wen, Chu Hai-long

School of Electronic Science and Engineering, Southeast University, Jiang Su, Nanjing, 210096, China

*Email: zyn@seu.edu.cn

Abstract: Field-sequential-color displays can have high spatial resolution and low power consumption because the color filters are not needed, leading to increased light transmission. But the LCD suffers from color breakup, which reduces image quality. In this paper, a backlight consisting of a matrix of light-emitting diodes (LEDs) was developed to effectively suppress the perceived color breakup by controlling the backlight temporally and spatially and significantly save power because it haves no color filter and uses local dimming.The backlight colors are locally desaturated according to the local image content, so the color difference between fields is reduced, which have a significant effect on the perceived color breakup.The results indicate the resolution of LEDS improve the supression of color breakup,yet,increase cost and waste power consumption.

Key Words: Field-sequential color; Color backlight; Local dimming

Session 23: Liquid-Crystal Technology 2 (Liquid-Crystal Technology)

S23.1

Invited: Cholesteric Liquid Crystals for Optofluidic Microlasers

Lu-Jian Chen^{*, a}

^aDepartment of Electronic Engineering, Xiamen University, Xiamen, Fujian 361005, China

* Email: Lujianchen@xmu.edu.cn

Abstract: Bottom-up fabrication of 3D photonic structures with unique optical properties is currently a burgeoning area of research. In this context, cholesteric liquid crystals (CLCs) hold great promise and opportunities in optics and photonics owing to the self-organization of LC molecules into helical superstructures when chirality is introduced. The investigation of dye doped CLCs (DDCLCs) emulsions as optofluidic microlasers and CLC fingerprint textures as beam-steering grating device is of our particular interest. [1-5] Recently, tunable DDCLC microlasers in the form of a core-shell structure, operating in band-edge mode, have been successfully fabricated by glass capillary based microfluidic technology. [1] The incorporation of water-dispersible Fe₃O₄ magnetic nanoparticles in the inner aqueous phase endows the DDCLC microlaser with magnetically transportable capability by taking advantage of the immiscibility with the middle CLC oil phase. [2] By simply varying the diameter of end-pumping beam, namely tuning the DDCLC gain area, several mode resonances, including distributed feedback (DFB), Fabry-Pérot (FP) and whispering gallery (WG) modes, can be robustly constructed and excited in an individual DDCLC microshell, due to the unique material characteristics of DDCLC and geometrical structure of microshell.

Key Words: cholesteric liquid crystals; microlaser; microfluidics; optofluidics

Reference:

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S23.2

Invited: Double-layer templated cholesteric liquid crystal film

Yong Li, Dan Luo*

Department of Electrical & Electronic Engineering, Southern University of Science and Technology, Xueyuan Road 1088, Nanshan District, Shenzhen, Guangdong, 518055, China

*Corresponding author: luo.d@sustc.edu.cn

Abstract: We demonstrate cholesteric liquid crystal films based on cholesteric liquid crystal and mesogens. Different materials from anisotropic materials such as nematic liquid crystals to isotropic materials have been refilled to polymer scaffolds with helical structure. Reflectance of over 80% has been achieved by double-layer structure consisted of both right and left cholesteric liquid crystal film, where the reflection bandwidth of these films can be dramatically narrowed with the reduced birefringence of refilled materials. The temperature effect on linewidth of films is also studied. A full-color reflective display is experimentally demonstrated based on these flexible reflective films that are refilled with small birefringence liquid crystals. The applications of these cholesteric liquid crystal films include flexible reflective display, sensors, color pixels in digital photographs, printing and colored cladding of variety of objects.

Key Words: cholesteric liquid crystal; helical structure ;polymer

S23.3

Invited: Micro Display and Digital Spatial Light Modulator (SLM) Using Electro-Optics Platform

Chun-Wei Tsai

Jasper Display Corporation (JDC)

Abstract: Electro-optics Platform is the main concept of Jasper Display Corp. (JDC) to develop various applications. These applications are based on our X-on-Silicon technologies, for example, X-on-Silicon technologies could be used on Liquid Crystal on Silicon (LCoS), Micro LED on Silicon (μ LEDoS), OLED on Silicon (OLEDoS), and Cell on Silicon (CELLoS), etc. LCoS technology is applied to Micro Display, Spatial Light Modulator (SLM), Dynamic Optics, Wavelength Selective Switch (WSS), Holographic Display, Microscopy, Bio-tech, 3D Printing and Adaptive Optics, etc. In addition, μ LEDoS technology is applied to Augmented Reality (AR), Head Up Display (HUD), Head-mounted Display (HMD), and Wearable Devices. A digital modulation is the use of Pulse Width Modulation (PWM) on LC to create gray scale and phase level. The operation in time domain has greater Root Mean Square (RMS) voltage accuracy for finer gray scale and its over drive feature also increases the response time of Spatial Light Modulator (SLM). The stability of LC response to digital modulation in SLM is still a challenging work even diffraction efficiency is not sensitive to the stability. But the zero order and noise of higher order arise from the imperfection of phase profile, for clean and high quality diffraction result the stability improvement is still one of the important topic in digital modulation.

Key Words: digital modulation; micro display; spatial light modulator

S23.4

Invited: Properties of Nano-Phase-Separated LCs with Fast Response

Toru Fujisawa

DIC Corporation Fine Synthesis Technical Group 4

Abstract: Through our research activity relating to the variety of liquid crystalline

substances to be used for practical LCDs, our attention has been focusing on polymer stabilized liquid crystals to achieve a breakthrough in performance of a LCD. We have succeeded in the development of Nano-Phase Separated Liquid Crystals (NPS-LCs) characterizing fast decay time accelerated by anchoring forces of polymer network in vertical aligned polymer stabilized NLCs. NPS-LCDs are fabricated by formation of vertical aligned polymer network in a liquid crystal layer with a phase separation process induced by a UV photo-polymerization. The decay time drastically decreases in the range from 5 ms of the host liquid crystals to 0.3 ms by the enhancing effect of interaction between the polymer network and the liquid crystals. Meanwhile, the transmittance is decreased by the enhancing effect of polymer network. The reasons to reduce transmittance are related to decreasing effective birefringence of host liquid crystals and deteriorating an inclining alignment of liquid crystals at on-state. To improve the transmittance, we have introduced photo alignment materials into polymer network to avoid disordering alignment of liquid crystals and an increasing birefringence of host liquid crystals. Detailed elector-optical properties will be reviewed and discussed.

Key Words: Nano-phase separated LCs; Fast decay time; Polymer network; Photo-polymerization induced phase separation; Polymer/liquid crystal composite materials

S23.5

***Invited:* New RM and room temperature nematic RM for application**

Chaoyuan Chen

Jiangsu Hecheng Display Technology Co. Ltd

Abstract: RM is applied widely in display or optical film. For example, to enhance PS-FFS mode performance or for special optical functions, etc. It is reported that the contrast ratio of FFS mode is successfully enhanced by polymerized RM mixed in liquid crystal at -20°C. HCCH have been developed some new structure RMs, and these RMs polarized at room temperature can also enhance FFS mode contrast ratio. Many disadvantages which occurred at -20°C, can be avoided. RM is usually operated at the temperature above melting point in the process of manufacturing optical film. But RM is sensitive to heat, then lead to narrow operating window. HCCH have been developed room temperature nematic RM materials successfully. These RM materials can be operated at room temperature in the optical film manufacturing process. So the disadvantages of high temperature process will be avoided, and energy can be saved.

Key Words: RM; RM structure; Liquid crystal; Room temperature RM

S23.6

Market demand and technology development of color photoresist

Chen Tang; Lin Li; Ming Zhao; Zhuo Zhang**

Fuyang Sineva Material Technology Co., Ltd.; No.1 Tianzhushan Road, Yingzhou Zone, Fuyang, Anhui, China

Abstract: With rapid development of FPD industry, color photoresist is facing huge market demand that will reach 21.32 kL in 2018, however which has mostly been controlled by foreign manufactures from Japan and South Korea because of high technical barriers. Recently a few domestic enterprises increase the investment, break the technical barriers and gradually realize the industrialization, which plays an important role to reduce the price of color photoresist and keep the development of FPD industry healthy and sustainable. High color image quality of display products needs high performance of color photoresist to achieve the most vivid and accurate

colors. This article will focus on the analysis of market demand and the future development directions of color photoresist technology, such as wide color gamut, high transmittance, high contrast ratio, high resolution, low outgas, low temperature process and low tack time.

Key Words: color photoresist; wide color gamut; high transmittance; high contrast ratio; high resolution; low outgas; low temperature process; low tacktime

Session 24: Display Measurement 1 (Display Measurement)

S24.1

Invited: Development of the optical calibration facility for displays in NIM

Chen Chi

National Institute of Metrology

Abstract: Development of a calibration facility for spectro-radiometric, colorimetric, reflective, gray to gray response time and goniometric measurements of displays, display colorimeters has been completed at the National Institute of Metrology (NIM). An overview of the facility and results of the characterization measurements are presented. The results show that the facility is capable of measuring colors of different time of emitted sources with an expanded uncertainty 0.002 for chromaticity (x,y) and 2.5% for luminance°(Y). The new calibration services from NIM are designed to reduce the uncertainty of color measurements using commercial instruments to a level approaching that of the NIM reference instrument. The assesement of the reflective properties of the visual display by the approach of complete 2 dimensional bidirectional-reflectance-distribution-function profiles. The response time properties of the display under different gray levels are measured under an expanded uncertainty 5% in our lab. we reviewed a variety of quantities and the resultes were compared with CMS (Taiwan) and some standard references required for the display calibration are present as well.

Key Words: display metrology; colorimeter; response time; reflective

S24.2

Invited: VR 顯示器的動態殘影的量化技術

Kerson Wang (王科順)

i-boson

摘要: VR 顯示器目前最被關注的問題，在於動態影像移動時，殘影的嚴重程度。本次報告主要要介紹波色科技所發展出來 VR MPRT 技術，可量化此現象，給 VR 顯示器發展廠商一個參考指標。介紹包括動態殘影的量測原理；影響動態殘影的因素；VR 的動態殘影的問題

S24.3

Invited: Key performances characterization of spectral radiance meter

Cherry Li

EVERFINE Corporation

Abstract: A spectral radiance meter (SRM) measures the spectral radiance of an object and the photometric and colorimetric quantities can be calculated. It has been widely adopted in optical measurements of displays due to its comprehensive functions and no spectral mismatch problem, and sometime it is even used as a working reference to calibrate filter type luminance meters or colorimeters. Therefore,

it is necessary to verify the accuracy of a SRM so as to make sure the quantities obtained in different labs or for different types of displays comparable. However, the characterization and calibration of SRMs haven't been standardized, and there are only some standards on filter type luminance meters or spectro-radiometers, which are far from enough to give the users or instrument manufacturers guidance for the application of SRM. Based on these standards, this paper will investigate the key performances of SRM that affect the luminance and color measurements of displays, for example the directional response and surround field factor, linearity, polarization, focusing distance related to luminance measurements, and wavelength accuracy, bandwidth, stray light, wavelength accuracy related to spectral measurements. Further, the calibration of a SRM will be discussed so as to make sure the quantities traceable to SI unit.

Key Words: Spectral radiance meter; key performances; characterization; calibration

S24.4

Invited: The Radiation Safety Assessment Method for Home-Used Laser Projection Displays

Wang Feixia, Li Xiaohua*, Jin Cenqin

School of Electronic Science and Engineering, Southeast University, Jiang Su, Nanjing, 210096, CHN

*Email: lxh@seu.edu.cn

Abstract: Home-used laser projection displays have plenty of advantages, such as wide color gamut, high brightness, long life and so on, which have been considered to be one of the best choices for home-used large-screen displays in future. However, due to the high energy density of laser, the optical radiation safety of laser should be studied and analyzed. The radiation safety assessment methods for home-used laser projection displays are reviewed referring to existing international standards, such as safety of laser products (IEC 60825) and photobiological safety of lamps and lamp systems (IEC 62741) series, as well as ICNIRP guidelines [1-6]. The mainstream home-used laser projection displays are introduced, and the differences of radiation exposure hazards to eyes between pure laser sources and laser phosphor hybrid sources are analyzed. The measurement methods and calculation procedures for optical radiation safety of the home-used laser projectors are proposed.

Key Words: Optical Radiation Safety; Home-used Laser Projection Displays; Display Measurement; Laser Phosphor Hybrid Sources; Pure Laser Sources

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S24.5

Invited: Measurements of OLED Key Optoelectronic Properties

Yang Yang

EVERFINE Corporation

Abstract: OLED display has grown rapidly for its larger gamut, higher dynamic range and efficacy compared with the traditional LCDs. And it is highly necessary to measure OLED optoelectronic properties, including relationships among current, voltage, external quantum efficacy, color coordinates, and luminance. The present paper introduced the measurements of these properties in details. Firstly, an adjustable voltage/current supply was used to achieve accurate control of OLED chips. Then a luminance meter having a range between 0.0001 cd/m² and 1,000,000 cd/m² was applied to collect both the extremely dark and bright lights from OLEDs. Moreover, a spectroradiometer was used instead of filtered sensor to measure the spectral power distribution of OLEDs and calculate color coordinates precisely.

Key Words: OLED; Optoelectronic Property; Measurement method

S24.6

Invited: The measurement methods research for HDR display performance

Wu Weihua

National Testing and Inspection Center for Radio and TV Products

Abstract: This paper introduces the specifications of the HDR curves (including PQ and HLG curve) which are adopted by ITU standards, and analyzes the theories of TV which can display the HDR signal. On the basis of them, puts forward some key display performance items, and introduces testing signal and methods of measurements in detail. And then analyzes the test results. Discusses the methods of measurement focus on contrast, proposes several methods of measurement, and discusses the differences and importance among them.

Key Words: HDR; methods of measurement; contrast

Session 25: Display Measurement 2 (Display Measurement)

S25.1

Invited: Measurement Issues and International Standardization for Electronic Displays

Tongsheng Mou

Zhejiang University

Abstract: The new quantification methods of the display performance are proposed along with the development of new display devices, such as 3D displays, transparent displays, laser projection displays and near-eye displays. The optical measurement plays an important role in the assesment of display quality. In this paper, the measurement issues corresponding measurement of optical performance, visual quality and image quality for electronic display devices are presented. The related standardization items are also introduced.

Key Words: Measurement Issues; Standardization; IEC TC110

S25.2

Invited: Optical Measurement of Display Light Units

Kalil Kalantar

SENSING Optronics Co., Ltd

Abstract: Display light units are main parts in LCD modules, which include back light units and front light units. The optical performance of the LCD modules, especially as the luminance, chromaticity and their uniformity, color gamut and luminous efficacy are closely dependent on the light units. And also, the effects on display performance come from the matching between them. Therefore, a project team was established in IEC TC110 for drafting the standards on optical measuring methods of display light units. This paper focuses on the back-light units, and introduces the measuring methods of optical parameters including uniformity, chromaticity coordinates, viewing angle. The measuring methods for beam profile, optical origin, chromaticity, and other special parameters of LED light devices are also included.

Key Words: Display light units; LED light bar; optical measurement

S25.3

Invited: Study on standards for evaluative methods of display based on user performance

Yunhong Zhang

China National Institute of Standardization

Abstract: Based on ISO 9241-304-2008" User performance test methods for electronic visual displays", user performance for different kinds of phones' screen were tested and contrasted by the method of visual searching task, at the same time visual fatigue and comfort level were evaluated. The test samples including anti-reflection screen, anti-glare screen, circular polarized screen and linear polarized screen and so on. There were 20 subjects participating in the experiment each other. It turned out that method of user performance evaluation was highly of consistency with that of visual fatigue and comfort evaluation, which also proved that method of visual searching task was applicable to user experience evaluation.

Key Words: Mobile phone screen; User performance; Visual fatigue; Comfort

基于用户绩效的显示器测评方法标准研究

摘要: 依据 ISO 9241-304-2008 标准, 利用视觉搜索任务进行几种不同类型手机显示屏用户绩效比较测评, 同时辅之以视疲劳及舒适度进行测评, 实验结果表明用户绩效评价方法与视疲劳及舒适度评价方法结果具有高度一致性。实验结果证明, 该标准中的视觉搜索评价方法对显示器用户体验评价具有适用性。

关键词: 手机显示器; 户绩效; 视疲劳; 舒适

Application of cognitive neuroscience on evaluation of display user experience

Abstract: User experience of different kinds of 3D displays and 2D displays were tested and evaluated by various experimental paradigms in cognitive neuroscience, and displays were used either for a short time or for a long time. And it indicated that experimental paradigms in cognitive neuroscience were applicable and sensitive to evaluation of display user experience.

Key Words: display; cognitive neuroscience; cognitive function

认知神经科学在视觉显示器用户体验评价中的应用

摘要: 利用不同的认知神经科学实验范式对不同类型 3D 显示器及 2D 显示器用户体验进行比较测评研究, 其中显示器的使用时长有短期的也有长期的。实验结果表明, 认知神经科学的一些实验范式对显示器用户体验评价具有适用性和敏感

性。

关键词：显示器，认知神经科学，认知功能

S25.4

Study of Brain Response During Watching Stereoscopic Display Using an Oddball Task Evoked Event-Related Potential

Peng Ye^{1,2}, Xiang Wu^{3,*}, Dingguo Gao³, Haowen Liang², Jiahui Wang², Shaozhi Deng^{1,2}, Ningsheng Xu^{1,2}, Juncong She^{1,2}, Jun Chen^{1,2*}

¹ State Key Laboratory of Optoelectronic Materials and Technologies, Guangdong Province Key Laboratory of Display Material and Technology, School of Electronics and Information Technology, Sun Yat-sen University, Guangzhou, China

² State Key Laboratory of Optoelectronic Materials and Technologies, Sun Yat-Sen University, Guangzhou, China

³ Department of Psychology, Sun Yat-Sen University, Guangzhou, China

* Email: stscjun@mail.sysu.edu.cn; rfwuwux@gmail.com

Abstract: Binocular disparity is one of the important factors related to the discomfort when watching the stereoscopic display. The event-related potential (ERP) provides measurement of the brain response to stimulus, e.g. images, which could be used for investigating the brain response to stereoscopic contents possessing different disparities. In this talk, we will introduce the recent results in our lab on the ERP study using an oddball task during watching stereoscopic display. Excessive binocular disparity could intensify the discomfort, and limiting the binocular disparity within the “comfort zone” is thus an important guide line for producing comfortable stereoscopic contents. Using an oddball task and recording the EEG meanwhile, we obtained the high-level attention related brain responses, i.e. the DP3 signals, and compared this signal (1) between viewing comfortable stereoscopic contents and 2D contents and (2) between viewing comfortable stereoscopic contents with different disparities. The result revealed that (1) the comfortable stereoscopic contents elicited the DP3 signal with delayed latency and enhanced amplitude over anterior scalp, compared to the 2D contents; (2) the DP3 signals elicited by the comfortable stereoscopic contents possessed delayed latency for larger binocular disparity, with the same amplitude for different disparities.

Key Words: stereoscopic display; binocular disparity; discomfort; comfort zone; ERP; DP3

S25.5

OLED de-mura system

Chen Ting

Color Space Technology Inc

Abstract: Screen burn-in mura is a permanent discoloration of areas on OLED caused by cumulative non-uniform usage of the pixels. Frequently using APP with no-moving text, graphics and flags can create a permanent ghost-like image Mura. Blue color OLED degrades much faster than green and Red color OLED. Which cause color shift mura after a period of application. A kind of de-mura system is designed to calibrate not only the screen burn-in mura but also the color shift mura. The de-mura system includes a signal generation unit, an image pickup unit and a control unit. The signal generation unit display test pattern on the OLED screen. The image pickup unit including a high resolution 2D matrix chromameter can capture CIE 1934 XYZ of each OLED pixels and distinguish the uneven light output of each pixels. The control unit control the entire system procedure and generate luma correction data to make

screen uniform and color correction data to let screen output true color. Both brightness correction data and color correction data will be compressed and save inside the display memory. Display control circuit uses these correct data to realize de-mura function.

Key Words: de-mura, 2D matrix chroma-meter; OLED screen burn-in; uniformity correction; Tristimulus adjustment

S25.6

Conoscopic measurements for displays – advantages and limitations

Bob Liu

TechnoTeam Bildverarbeitung GmbH, Germany

Abstract: Measurements with conoscopic lenses together with ILMDs (Imaging Luminance/Color Measuring Devices) can support the characterization of displays and materials during the R&D and production process. Using a conoscopic lens the angular dependence of luminance/color can be measured with only a single measurement. Using different geometrical relations between the device under test, the conoscopic lens and different illumination conditions a lot of display and material properties can be measured with one or a few measurements only. The article shows the working principle of conoscopic lenses in detail. Furthermore the measurement of the angular dependent luminance/color, the angular dependent contrast and the measurement of selected angular dependent material properties (e.g. transmission and reflection characteristics of glasses) are presented. For all applications the advantages and limitations of the conoscopic lens measurements are explained to suggest the right fields of application for this measurement method.

Key Words: ILMD (Imaging Luminance Measuring Devices); conoscopic lens; BSDF; HUD (Head-Up display); virtual reality displays

Session 26: Electronic paper 1 (E-paper and Flexible Displays)

S26.1

Invited: Recent progress in colored video electro-fluidic display technology

Yong Deng^{1,2}, Biao Tang¹, Alexander Victor Henzen¹, Guofu (G.F.) Zhou^{1,2,3*}

1 Institute of Electronic Paper Displays, South China Academy of Advanced Optoelectronics, South China Normal University, Guangzhou 510006, P.R. China.

2 Shenzhen Guohua Optoelectronics Tech. Co. Ltd., Shenzhen 518110, P.R. China

3 Academy of Shenzhen Guohua Optoelectronics, Shenzhen, 518110, P.R. China

(*email: guofu.zhou@m.scnu.edu.cn)

Abstract: Electro-fluidic display (EFD) technology is one of the most attractive technology with full color, video capability and flexibility. In the past few years, although much work has been done aiming at fully understanding the fundamental mechanism behind, the industrialization of EFD technology still presents many challenges, including production cost, manufacturing yield and device reliability. To address the challenges above, lots of R&D activities including work on materials, processing, modeling, driving and flexibility have been completed. These achievements have largely promoted the maturity of this technology. In this paper I will give an overview on the recent progress on this technology.

Key Words: Electro-fluidic technology; video; color e-paper

S26.2

Invited:The design considerations for full-color e-paper

Bo-Ru Yang*, Yu-Cheng Wang, and Li Wang

State Key Lab of Opto-Electronic Materials & Technologies, Guangdong Province Key Lab of Display Material and Technology, School of Electronics and Information Technology, Shunde International Joint Research Institute, Sun Yat-Sen University, Guangdong 510275, P. R. C.

*E-mail: paulyang68@me.com

Abstract: Electrophoretic display, as a reflective display technology, has several advantages such as good flexibility, low power consumption and good sunlight visibility. With paper-like performance, monochromatic EPD has been widely applied to E-paper applications including E-book, electronic price label and smart watch, that motivated the research of full-color to carry vivid and complete image information. To achieve full-color EPD, we proposed a feasible method by spatially deploying dual-particle microcapsules with different color to defined areas as shown in Figure 1. This method avoided the decrease of reflectivity by adding color filter, the redesign of different colloidal system by using color dye as well as the difficult manipulation scheme in multi-particles electrophoretic system.

Key Words: Electrophoretic display; Full-color; Transfer process

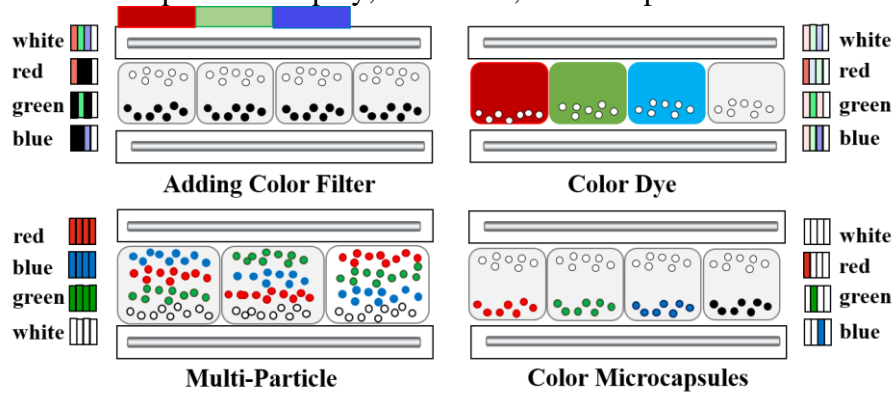


Figure 1. Full-color EPD strategies

Then, a facile transfer method was introduced to realize this proposed structure including three steps as shown in Figure 2. Firstly, the microcapsules were coated onto a PDMS stamp filling the micro-cupped portion that formed a spatial array of microcapsules. In the second step, the deployed microcapsules were transferred onto a temporary PDMS substrate with surface energy adjustment. Finally, they were transferred onto PET or other substrates. Finally, a full-color EPD was obtained by repeating these steps as shown. The measured color gamut reached 19.1% NTSC.

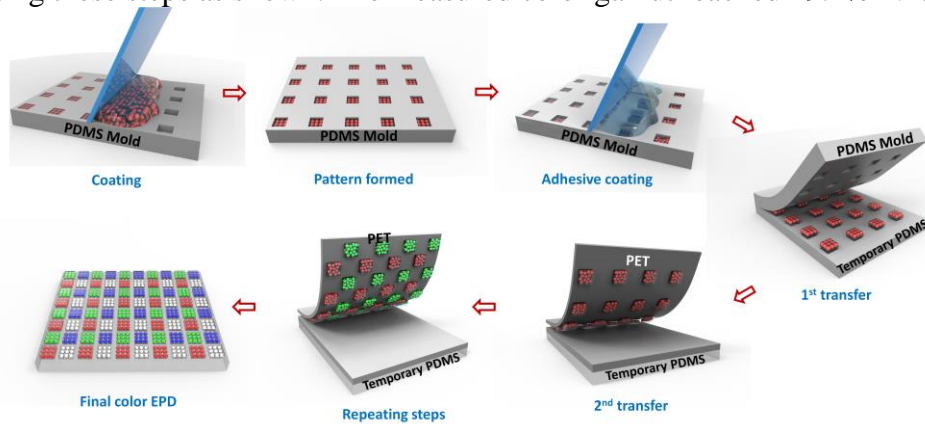


Figure 2. The transfer process

S26.3

Invited: New Applications of Electronic Paper Display Technology

Xidu Wang

Guangzhou OED Technologies, Inc.

Abstract: Electronic paper is well known as a perfect technology for reading, but as a reflectivity and bi-stable technology, it could not only be used in electronic reader but in many aspects. Some new applications will be showed in this paper, and potential applications are also discussed after some characteristics of E-Paper are improved.

Key Words: Electronic Paper (E-Paper) ; Contrast Ratio(CR); Response Time(RT); Greyscale; Ghosting.

Session 27: Electronic paper 2 (E-paper and Flexible Displays)

S27.1

Invited: Next Applications of e-Paper

Makoto Omodani,

Tokai University

S27.2

Invited: Kapok Fibers containing Functional Materials

Shuichi Maeda

Tokai University

S27.3

Invited: R&D Status of E-Paper & Flexible Displays at Chiba Univ., Japan

Akira Suzuki

Chiba University

Abstract: Our Chiba Univ. in Japan is quite unique and famous to have Imaging Science Department, which has been doing research and development on “E-Paper & Flexible Displays” since around 2002. Recently, we have announced several interesting papers about the following three main technologies. They are 1. “Reflective Electrochromic Displays”, such as, Color Organic Electrochromic Display and Ag Electrodeposition-Based Device, 2. “Dual-mode Display (DMD)” consisting of both emissive mode and reflective mode, and 3. “Stretchable and Flexible Electrophoretic Display”. Some of them have received “Best Paper Award Winners” of IDW2012-2015. In this presentation, they will be summarized and then introduced to develop for the practical use of some applications. Regarding these technologies, even though we have already been collaborating with Japanese big companies, we are still open and welcome to collaborate to develop with any other enterprises or companies except in Japan.

Key Words: E-Paper; Flexible displays; Electrochromism; Silver deposition; Electrophoretic displays; Stretchable EPD

Session 28: Color Vision and Color Rendering (Applied Vision)

S28.1

***Invited:* Diffraction efficiency distribution of output grating in HWD**

Ao Liu

Southeast University

S28.2

***Invited:* See-through Image Blurring of Transparent Displays: Diffraction Calculation and Pixel Structure Evaluation**

Zong Qin(秦宗)

National Chiao Tung University

Abstract: Diffraction-caused blurring issue of transparent display's see-through images has been addressed these years, however, there have been little studies proposing how to calculate diffracted images and evaluate the influence of pixel structure. In this paper, firstly, a systematic method is introduced to calculate chromatic see-through images, which takes background and viewing distances into consideration to correct Fresnel diffraction. High accuracy of the calculation method is experimentally validated. Then a series of diffracted see-through images are calculated by adopting different sample images with different pixel structures and viewing conditions. Based on these images, several state-of-the-art image quality assessment (IQA) algorithms are tested, and multiscale structural similarity (MS-SSIM) is demonstrated to have the highest Pearson linear correlation coefficient (PLCC) and consequently, the most adapted for see-through images. Finally, the influences of aperture ratios, resolutions, and pixel geometries of transparent displays on subjective see-through image quality are evaluated based on MS-SSIM and general image databases, and they are revealed to affect the quality from the most significantly to the least.

Key Words: Transparent display; diffraction; see-through image; image quality assessment; pixel structure

Session 29: High Performance Metal Oxide TFTs (Active-Matrix Devices)

S29.1

***Invited:* Scaling AMOLED displays to high resolution**

Paul Heremans

IMEC, Belgium/Holster Center, Netherland

S29.2

***Invited:* Transparent Megahertz Circuits from Solution-Processed Composite Thin Films**

Lei Liao (廖蕾)

Wuhan University

S29.3

Invited: Development of 98 inch 8K4K Oxide TFT-LCD with UV2A Technology

Liufei Zhou (周刘飞)

Nanjing CEC Panda FPD Technology Co., Ltd.

Abstract: We developed 98" 8K4K TFT-LCD panel using IGZO and UV2A technology, which shown excellent optical performance, such as high transmittance, omni view angle, ultra-high contrast ratio, and faster response time, etc. IGZO TFT has advantages for large-sized, high resolution and high frame frequency TV panel design. Furthermore, gate multi-scan technology is developing with 1G1D to increase the transmittance further.

Key Words: UV2A; IGZO; ultra high definition; pixel; charging time

S29.4 (Withdrawn)

A 31-in UD AM-OLED Display using self-aligned top gate IGZO TFTs

Meng Yanhong

Shenzhen China Star Optoelectronics Technology Co., Ltd

Abstract: We fabricated self-aligned top gate IGZO TFTs with two structure, light shielding metal floating and un-floating, respectively. It is found that the floating light shield induced DIBL effect, and the un-floating light shield structure TFT show good switching properties, including an averaged mobility of $9.17\text{cm}^2/\text{Vs}$, a threshold voltage of 0.52V, and a subthreshold gate swing of 0.25V/dec. Finally, a 31-inch UD(3840×2160 , pentile) AM-OLED TV was developed by using self-aligned top gate IGZO TFTs with the un-floating light shield structure.

Key Words: AM-OLED; IGZO; Top gate TFTs

S29.5

High Performance Oxide TFTs and Displays

Rongsheng Chen^{1,2}, Sunbin Deng², Zhihe Xia², Meng Zhang², Wei Zhou², Man Wong², and Hoi-Sing Kwok²

1. School of Electronic and Information Engineering, South China University of Technology,

Guangzhou, China

2. State Key Laboratory on Advanced Displays and Optoelectronics Technologies, Department of Electronic and Computer Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

E-mail: chenrs@scut.edu.cn, sdengaa@connect.ust.hk

Abstract: The advancement of displays towards large area and ultrahigh definition claim thin film transistors (TFTs) with higher electrical performance, uniformity and stability. The most prevalent a-IGZO is theoretically limited by its composition and randomness, and seems insufficient to provide demanded mobility ($> 20\text{ cm}^2/\text{Vs}$). Binary ZnO suffers from instability issues that related to native defects. We propose the ITO-stabilized ZnO thin film with less native defects, and introduce a novel hybrid-phase microstructure, where nanocrystals are embedded in an amorphous matrix. The proposed thin film can provide relatively high mobility and stability. Following a sufficient study on microstructural and electrical properties of hybrid-phase ITO-stabilized ZnO thin films, both staggered bottom-gate and top-gate TFTs with this optimal ITO-stabilized ZnO channel layers are fabricated, and exhibit a fairly high electrical performance especially in field-effect mobility and subthreshold swing. Additionally, the electrical performance of devices is proved to be spatially uniform and stable.

Key Words: Thin-film transistors; hybrid-phase microstructure; ITO-stabilized ZnO.

S29.6

***Invited:* High Performance Thin-film Transistors with Hybrid-phase ITO-stabilized ZnO Active Channel Layer**

Rongsheng Chen (陈荣盛)

South China University of Technology

S29.7

Development of Cu BCE-structure IGZO TFT for High PPI 31-inch 8K4K GOA LCD Display

Shimin Ge

Shenzhen China Star Optoelectronics Technology Co., Ltd.

Abstract: A 31-inch 8K4K GOA LCD panel was developed by employing Cu BCE-structure IGZO TFTs backplane. To achieve Cu BCE-structure IGZO TFTs with excellent device characteristics and reliability is crucial for a high PPI GOA LCD. Since it is very difficult to avoid the back channel damage from the source/drain wet etch process, the condition of the back channel is a main issue for the BCE-structure device characteristics. The characteristics and reliability of the a-IGZO TFTs can be improved by modifying the passivation layer and optimizing the selection of copper acid and PFA material. The reliability of the optimized device showed ΔV_{TH} shift of +1.42V and -0.67V after 2000s of +/- 30V 80 °C BTS respectively, which made great contribution to the stable function of GOA circuit. Thus, an excellent image quality of 31-inch 8K4K IGZO GOA LCD was obtained.

Key Words: BCE; a-IGZO TFT; 8K4K; GOA

Session 30: Flexible TFTs and Displays (Active-Matrix Devices)

S30.1

***Invited:* Highly Robust Oxide TFTs on Polyimide Substrate**

Jin Jang

ADRC, Kyung Hee Univ.

Abstract: Plastic AMOLED displays are of increasing attention recently for mobile applications. The TFT backplane on polyimide (PI) substrates are widely used for flexible smartphone and smart watch displays. We developed a nonlaser detach process of PI substrate from carrier glass by using a GO/CNT buffer which is being used for highly robust oxide TFTs and TFT circuits in our lab [1]. The bulk accumulation oxide TFTs exhibiting both high on-currents and uniform threshold voltage can be applied to high resolution displays and high speed TFT circuits. In this talk I will review our recent research results on TFTs and TFT circuits on PI substrates. We have also developed highly robust TFTs using TFTs in neutral plane [2] and high mobility a-IGZO TFTs on PI substrate by introducing top interface engineering [3]. The performance, electrical stability and mechanical stability will be introduced at the conference.

Key Words: Flexible TFT Backplane; Oxide TFT; Rollable Displays; Highly stable TFT

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3. S. Lee, J. Shin and J. Jang, "Top interface engineering of flexible oxide thin-film transistors by splitting active layer" Advanced Functional Materials" In press.

S30.2

Invited: Flexible IZO-based Thin-Film Transistors on Paper Substrates

Qing Wan, Feng Shao, Ping Feng

School of Electronic Science & Engineering, and Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210093, China

Abstract: Paper electronics represents a newly raised concept that includes various types of electronic devices and circuits on paper. Recently, cellulose nanofibers (CNFs) have gained increasing interest due to their high mechanical strength, flexibility, biodegradability and renewability. Herein, we reported multi-gate indium-zinc-oxide-based homojunction electric-double-layer (EDL) thin film transistors (TFTs) with CNFs as the gate dielectrics. Solution-processed CNTs electrolytes films showed a extremely high specific capacitance (C_i) of $3.5 \mu\text{F}/\text{cm}^2$ at 1.0 Hz. A field-effect mobility μ_{FE} of $26 \text{ cm}^2/\text{V} \cdot \text{s}$, a threshold voltage of $\sim 0.52 \text{ V}$, and a sub-threshold swing of $86 \text{ mV}/\text{dec}$ were obtained. Resistor-loaded inverters (NOT gate) were demonstrated both in abottom gate mode and an in-plane gate mode. Logic AND operation was realized in a device with two in-plane gates. Most significantly, the universal logic NAND was experimentally demonstrated with one transistor/one resistor structure by combining the NOT and AND logics.

Key Words: Cellulose nanofibers; Oxide thin-film transistors; Paper electronics.

S30.3

Invited: Current Status and Opportunities of OTFT Technologies

Xiaojun Guo

Shanghai Jiao Tong University, China

Abstract: Attributed to its advantages of super mechanical flexibility, very low temperature processing, and compatibility with low cost and high throughput manufacturing, the organic thin film transistor (OTFT) technology is able to bring electrical, mechanical and industrial benefits to a wide range of new applications by activating non-flat surfaces with flexible displays, sensors and other electronic functions. Despite both strong application demand and these significant technological advances, there is still a gap to be filled for OTFT technology to be widely commercially adopted. This paper provides a comprehensive review of the current status of OTFT technologies ranging from material, device, process, and integration, to design and system applications, and clarifies the real challenges behind to be addressed. The first challenge is to develop OTFT material stacks capable of producing high performance, stable and uniform OTFTs in large area compatible processes. The second one would be how to define standard material stacks, device /integration architectures, and manufacturing processes to allow the whole community to work on the common issues, and also reduce the entry barrier for the design community. How to balance the device performance and the large low cost manufacturability is also important to meet the application requirements. Finally, with a near-overwhelming list of applications (both existing and new markets), focused

applications needs to be defined. To address these challenges, the whole community needs clear application and technology roadmaps and also standards in terms of materials, device/integration structures and processes to work together.

Key Words: Flexible electronics; printed electronics; organic thin film transistor (OTFT); displays; sensors; hybrid integration

S30.4

***Invited:* High mobility organic semiconductor materials for applications in dynamically flexible displays**

Simon Ogier

NeuDrive Limited

Abstract: Dynamically flexible displays (DFDs) require all components of the display to remain functional during repeated bending cycles of the device. Robustness of the transistor backplane is determined largely by the materials used in the construction with existing inorganic semiconductors struggling to meet the high strain values required for rollable or foldable portable display devices. Organic semiconductor (OSC) technology has been shown to be a good candidate for this application due to the inherent flexibility of the organic materials, and the low temperature processing enables a wide range of thin plastic substrate to be chosen for the DFD.

NeuDrive Limited is developing of a range of solution processable active and passive materials suitable for DFD backplanes based on the FlexOSTM OSC small molecule and binder technology. These material sets enable uniform (~5% standard deviation) transistor performance with high linear mobility ($>4\text{cm}^2/\text{Vs}$) for channel lengths of less than 10 microns. This presentation will describe the materials' properties and the low temperature (115 °C) fabrication process to incorporate them in display and other flexible device applications.

Key Words: organic transistor; organic semiconductor; flexible display; high mobility

S30.5

***Invited:* A Novel Flexible LTPS Capacitance Compensating Method for Luminance Uniformity**

Yanqin Song (宋艳芹)

Kunshan GoVisionox OptoElectronics

Session 31: QLED (Emissive Displays)

S31.1

***Invited:* Towards high-performance quantum-dot light-emitting diodes**

Yizheng Jin

Center for Chemistry of High-Performance & Novel Materials, State Key Laboratory of Silicon Materials, Department of Chemistry, Zhejiang University, Hangzhou 310027, People's Republic of China

Email: (yizhengjin@zju.edu.cn)

Abstract: Quantum dots are a unique class of emitters with size-tunable emission wavelengths, saturated emission colors, near-unity luminance efficiency, inherent photo- and thermal- stability and excellent solution processability. In the past few years, efficiency and lifetime of quantum-dot light-emitting diodes (QLEDs) achieved tremendous progresses. These encouraging facts foreshadow the commercialization of

QLEDs, which promises an unprecedented generation of cost-effective, large-area, energy-saving, wide-color-gamut, ultra-thin and flexible displays. Here we review our activities associated with QLEDs, including material chemistry of charge-transporting layers and optimization and mechanism studies of prototype devices. We also identify a few key challenges facing the development of active-matrix QLED displays.

Key Words: Quantum dots; light-emitting diodes; display

S31.2

Invited: QLED Device Structures for Display Application

Zhuo Chen

Material and Device Research Institute BOE Technology Group Co., Ltd.

Abstract: Electroluminescent quantum dot light emitting diode (QLED) is now considered as one of the potential next generation display technologies. QLEDs has the advantages of narrow and tunable emission peak, high color gamut, potentially high stability and low cost. Now most of QLED literatures studied bottom-emission structure. However, bottom-emission structure leads to low aperture ratio in the display panel. The low aperture ratio requires very high brightness for the EL part, thus leading to high current density and high heat, which is a great challenge to TFTs and ICs in PM and AM devices. In order to achieve high aperture ratio, especially in high-PPI display, top-emission structure is required. Different from top-emission OLED, QLED features solution process, narrow emission peak from quantum dots, and ZnO nanoparticle electron transporting layer (ETL). So the design and preparation of top-emission QLED devices are facing new challenges. This presentation will discuss the challenges and some solutions in developing top-emission QLED devices.

Key Words: quantum dot light emitting diode; top-emission; challenge

S31.3

Invited: Design and Fabrication of High-efficiency and Long lifetime Quantum Dot Electroluminescent Devices

Fan Cao and Xuyong Yang*

Key Laboratory of Advanced Display and System Applications, Education of Ministry, Shanghai University, 149 Yanchang Road, P. R. China 200072

Email: yangxy@shu.edu.cn

Abstract: Light-emitting diodes based on colloidal quantum dots (QLEDs) have recently received considerable attention for the next generation lighting and displays thanks to their narrow emission linewidth, spectrum tunability, high efficiency and low-cost solution-processing techniques. In the past few years, the rapid advances in device performance have been achieved. However, the operating lifetime of QLEDs still cannot meet the practical applications. Solution-processed metal-oxides with the advantages of excellent stability, visible transparency, cost effectiveness and controllable morphologies and interface structures of thin films show the great potential for long operating lifetime optoelectronic devices. In this report, we will present our latest advances in improving the device stability of QLEDs by using solution-processed metal-oxide carrier transport layers.

Key Words: QLEDs; quantum dots; metal-oxides; display; operating lifetime

Acknowledgements : The research is supported by National Natural Science Foundation of China (Nos. 51675322 and 61605109), The National Key Research and Development Program of China (No. 2016YFB0401702), and The Program for Professor of Special Appointment (Eastern Scholar) at Shanghai Institutions of Higher

Learning (No.TP2015037).

S31.4

Invited: Efficient Quantum Dot Light-Emitting Diodes with Novel Structures

Shuming Chen*

Dept. of Electronic & Electric Engineering, Southern University of Science and Technology

Email: chen.sm@sustc.edu.cn

Abstract: Colloidal quantum dot light-emitting diodes (QLEDs) are recognized as promising candidates for next generation displays. In this talk, we will review our recent progress on QLEDs, particularly emphasizing the influence of device structures on the performance of QLEDs. Various device structures including top-emitting, microcavity, inverted, tandem, transparent, full-solution vacuum-free processed QLEDs will be talked. Charge balance is carefully optimized in these structures. In addition, we show that the defect concentration of ZnO significantly quenches the emission and thus reduces the performance of QLEDs. By substituting the problematic ZnO with $\text{Zn}_x\text{Mg}_{1-x}\text{O}$, the efficiency of QLEDs can be largely improved. With the strategies mentioned above, our recently developed vacuum-free processed tandem QLEDs exhibit current efficiency and external quantum efficiency (EQE) over 100 cd/A and 23.5%, respectively.

Key Words: QLEDs; Device Structures; Charge Balance; Tandem; Vacuum-free Processed

S31.5

Invited: Highly Efficient and Stable Quantum-Dot Light-Emitting Diodes (QLEDs)

Weiran Cao

TCL Corporate Research

Abstract: During last two decades, advances in colloidal quantum dot materials and device architectures have led to the performance of quantum-dot light-emitting diodes (QLEDs) comparable to those of organic light-emitting diodes (OLED), which makes QLED as one of potential competitors in the field of next generation displays. Despite these great progresses, performance of QLED still lags behind that of the requirements for display products, especially for the color of blue. Besides the development of higher quality quantum dot materials, to better understand the device physics and to design device architectures more suitable for QLEDs are essential to further improve the efficiency and stabilities of QLEDs, which can push forward the realization of next-generation full-color displays based on QLEDs.

Key Words: quantum dots (QDs); light-emitting diodes; efficiency; life-time

Session 32: Visual Healthy (Applied Vision)

S32.1

Invited: The application of Bayesian adaptive method in human contrast sensitivity function measurement

Fang Hou

Wenzhou Medical University

S32.2

***Invited:* Application of cognitive neuroscience on evaluation of display user experience**

Yunhong Zhang

China National Institute of Standardization

Abstract: User experience of different kinds of displays were tested and evaluated by various experimental paradigms in cognitive neuroscience, and displays were used for about a month. There were two group of subjects participating in the experiment, and one group was experimental group, the other group was control group. The results showed that there were significant different between the two group on the cognitive reaction and visual cognitive ability on the several different cognitive neuroscience experiments. And it indicated that experimental paradigms in cognitive neuroscience were applicable and sensitive to evaluation of display user experience.

Key Words: Display; Cognitive neuroscience; Cognitive function; Tracking experiment

S32.3

***Invited:* Visual fatigue following long-term visual display terminal work under different light sources**

Wang Lili

Display Center, School of Electronic Science and Engineering, Southeast University

Abstract: Although visual display terminals have been used in office work for many years, research on the effect of long time work using them is still insufficient. Also, the impact of a LED light source for all day work is not clear. In this paper, the visual fatigue caused by long-term VDT work under fluorescent and LED luminaires was investigated through subjective reports of symptoms, ophthalmological parameters and physiological signals. The results show that visual fatigue becomes more serious with increasing time spent at VDT work. Compared to fluorescent luminaires, the LED luminaires produced significantly greater near point accommodation, blink amplitude and oxygen saturation but less dry eye symptoms, less best corrected distance visual acuity and less high-frequency electrocardiogram power as time passed. Based on the data derived from the experiment, a model for evaluating visual fatigue under has been developed based on five ophthalmological parameters and three physiological signals. A simplified model based on one ophthalmological parameter and one physiological signal is also proposed. Both models show a high correlation with subjective data, and are confirmed by a validation experiment.

Key Words: visual fatigue; LED light source; fluorescent luminaires; ophthalmological parameters; physiological signals

S32.4

***Invited:* The Design of the Calibration System of the Display Flicker**

Xinhong Liu

国家平板显示产业计量测试中心（苏州）

S32.5

***Invited:* Real-time modulation of eye dominance in human**

Jiawei Zhou

Wenzhou Medical University

Abstract: Information from the two eyes is combined in the visual cortex in the brain. There is a distribution of eye balances or preferences with most normal adults having

a balanced input from each eye and a minority exhibiting dominance for one eye or the other. This is called eye dominance. Here, for the first time, we show that ocular dominance plasticity can be changed in real-time in the adult human by varying the spatial image content of movies seen dichoptically by the two eyes over a period as short as 2.5 hours. This modulation in ocular dominance is not simply a consequence of reduced interocular correlation (e.g. synchronicity) or overall contrast energy, but due to the amplitude reductions of specific image components in one eye's view. Our results provide a mean to induce binocular plasticity in adults, suggesting a revolutionary new approach that offers hope for restoration of binocular function in both children and adults with binocular disorders either as a stand-alone treatment or when used in conjunction with emerging binocular training therapy.

Key Words: Sensory eye dominance, dichoptic movie, image filtering

Session 33: OLED Device 2 (OLEDs)

S33.1

Invited: Large-scale nanotechnology for New generation Sunlight-like and High purity OLED (8:30-8:50)

Jianhua Zhang

Shanghai University

S33.2

***Invited:* High Efficiency White OLEDs by Exciplex Engineering**

Dongge Ma

Institute of Polymer Optoelectronic Materials and Devices, State Key Laboratory of Luminescent Materials and Devices,

South China University of Technology, Guangzhou, China

Abstract: White organic light-emitting diodes (WOLEDs) are highly attractive in the fields of solid-state lighting. Here we firstly demonstrate an efficient and universal strategy to achieve highly efficient all-fluorescence WOLEDs and fluorescence/phosphorescence hybrid WOLEDs by exciplex engineering. The constructed exciplex exhibits not only efficient property of host for red, yellow and green fluorescent and phosphorescent emitters, but also excellent blue emitter itself. Accordingly, we successfully fabricate all-fluorescence WOLEDs and fluorescence/phosphorescence hybrid WOLEDs by doping conventional fluorescent or phosphorescent emitters into the resulting exciplex host. The two-color fluorescent WOELDs show the forward-viewing external quantum efficiency of 20.8% and power efficiency of 75.4 lm W^{-1} , whereas the two-color fluorescence/phosphorescence hybrid WOLEDs then emit the maximum external quantum efficiency of 28.3% and power efficiency of 102.9 lm W^{-1} , and remain 26.9% and 73.5 lm W^{-1} at 500 cd m^{-2} and yet as high as 25.8% and 63.5 lm W^{-1} at 1000 cd m^{-2} , respectively. Furthermore, the fabricated three-color hybrid WOLEDs yielding a high color rendering index of 86, an external quantum efficiency of 29.4% and a power efficiency of 75.5 lm W^{-1} . It is expected that the exciplex engineering will open an efficient avenue to precisely allocate excitons, and finally producing high-performance WOLEDs for next-generation solid state lighting technology

Key Words: OLED; white emission; exciplex enigneering; all fluorescence; hybrid

S33.3

Invited: Flexible OLEDs on Outcoupling Enhanced Plastics

Jianxin Tang*

Institute of Functional Nano & Soft Materials (FUNSOM), Soochow University, Suzhou, CHINA

Abstract: Flexible organic light-emitting diodes (OLEDs) hold great promise for future bendable display and curved lighting applications. One key challenge of high-performance flexible OLEDs is to develop new flexible transparent conductive electrodes (TCEs) with superior mechanical, electrical and optical properties. Indium-tin-oxide (ITO) electrode is the most widely used TCE in optoelectronic devices due to its excellent electrical conductivity and light transmission, but the high-temperature fabrication and the brittle nature under repeated bending condition hinder its application on flexible plastic substrates. An additional drawback of using ITO in flexible OLEDs on plastic substrates is the limited light outcoupling efficiency due to the severe trapping loss of the internally emitted photons.

Herein, we demonstrate a new strategy to achieve a powerful transparent conductive electrode on plastic substrate that combines a quasi-random nanostructured optical coupling layer and an ultrathin metal alloy conduction layer [1,2]. The optimum electrical conductivity, optical manipulation capability, and high tolerance to mechanical bending are realized in this composite electrode, which is favorable for the fabrication of ITO-free flexible OLEDs with state-of-the-art performance on low-refractive-index plastic substrate. The angularly and spectrally independent boost in light outcoupling of white emission is obtained by minimizing the waveguide mode, metallic electrode-related microcavity effect and surface plasmonic loss due to the integrated quasi-random outcoupling structure in the composite electrode[3-5]. The resulting white flexible OLED exhibits the high enhancement in efficiency, e.g., external quantum efficiency of 47.2% and power efficiency of 112.4 lm/W. In addition, this composite electrode has a scalable manufacturing potential in large-area flexible electronic systems.

Key Words: Flexible OLED; light outcoupling; transparent conductive electrode

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S33.4

Invited: High efficiency OLED based on ultra-thin emission layer

Shuai Yang, Jun Liu, Xindong Shi, Meijun Yang, Gufeng He*

National Engineering Lab for TFT-LCD Materials and Technologies, and Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai 200240, People's Republic of China

Abstract: Ultrathin non-doped emission layer (EML) has been employed in both inverted and top-emission organic light-emitting diodes (OLEDs). Compared to

conventional device, the inverted OLED with 0.5 nm undoped EML exhibits significantly larger external quantum efficiency (EQE), due to effective energy transfer from the excited host to the emitter. According to the atomic force microscopy image of EML, the 0.5 nm emitter sandwiched by two hosts can be considered as the emitter doped in two hosts. The inverted device with intentionally doped ultrathin EML (1.5 nm) exhibits the maximum EQE of 31.1%, which is attributed to optimized charge balance and preferred horizontal orientation of emitter. In top-emission OLED, an ultrathin EML can take full advantages of the cavity standing wave condition in a microcavity structure. Much higher out-coupling efficiency has been observed compared to conventional doped EML with relatively wide emission zone. A further investigation on dual ultrathin non-doped EMLs separated by a special bi-layer structure demonstrates better charge carrier balance and improved efficiency. The resulting device exhibits a high efficiency of 125.0 cd/A at a luminance of 1000 cd/m² and maintains to 110.9 cd/A at 10,000 cd/m².

Key Words: OLED; ultra-thin EML; inverted; top-emission

S33.5

Non-Doped White Organic Light-Emitting Diodes with Nearly 20% External Quantum Efficiency

Shengfan Wu

Soochow University

Abstract: Up to the present, white organic light-emitting diodes (WOLEDs) have already been shown to have very high external quantum efficiencies (EQEs) of above 20%. However, considering the complicated device configuration, poor reproducibility in doping systems and relatively high manufacturing cost, there is an urgent need to simplify the device structures and lower its cost. For previously demonstrated non-doped WOLEDs, the additional spacers in-between the UEMs usually enhance the complexity of the devices, as well as introduce new interfaces which may cause a mismatch of energy level with neighboring UEMs. To overcome the above problems, we propose a newly designed non-doped WOLED. By completely removing the spacers, our device not only significantly improves the device efficiency, but also simplifies the fabrication process. The spacer-free structure exhibits a very high current efficiency (CE) of 56.0 cd A⁻¹ and power efficiency (PE) of 55.5 lm W⁻¹, and at the same time achieves a warm white emission with color coordinates of (0.33, 0.46) at a current density of 2.5 mA cm⁻². The color balance could be actively tuned by the thickness of the respective UEMs in a much simpler and controllable way. Our results represent an advance in non-doped WOLED and, more importantly, achieve the highest efficiency in UEM based WOLEDs.

Key Words: white organic light-emitting diodes; ultrathin emitting layer; spacer-free structure

Session 34: OLED Materials 2 (OLEDs)

S34.1

***Invited:* Design and Modulation of Excited State in Organic Electroluminescence Materials**

Shitong Zhang,¹ Yu Gao,¹ Haichao Liu,¹ Bing Yang,¹ and Yuguang Ma²

¹ State Key Laboratory of Supramolecular Structure and Materials, Jilin University, Changchun 130012, China

2 State Key Laboratory of Luminescent Materials and Devices, South China University of Technology, Guangzhou 510640, China
(yangbing@jlu.edu.cn)

Abstract: Excited state plays an important role in photoluminescence (PL) and electroluminescence (EL) properties of organic light-emitting materials. Charge-transfer (CT) state is beneficial to harvest triplet exciton utilization in fluorescent organic light-emitting diodes (FOLEDs) by efficient reverse intersystem crossing. However, the CT-dominated emissive state seriously decreases PL efficiency in such materials. Our strategy is to combine both locally-excited (LE) state and CT state into hybridized local and charge-transfer (HLCT) state, aiming at a balance between high PL efficiency and high exciton utilization. As a result, a quasi-equivalent hybridization is obtained in TBPMCN, and its nondoped OLED exhibited a very high performance: a pure blue emission with a CIE(0.16, 0.16), a high EQE of 7.8% and a high exciton utilization of 97% without delayed component. Furthermore, the excited state properties were systematically investigated in donor-acceptor (D-A) system using time-dependent density functional theory. The hybridization and de-hybridization processes between LE and CT states were evolved with an increasing distance between donor and acceptor. What is more, HLCT state composition can be finely modulated by D-A strength, linkage, etc. Using HLCT conception, we achieved high-efficiency blue, green, red and even NIR luminescent materials and their FOLED devices. In a word, the excited state modulation could be a practical way to design low-cost, high-efficiency FOLED materials.

Key Words: HLCT state; donor-acceptor; OLEDs; PL efficiency; exciton utilization

Reference:

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S34.2

Invited: New routes to breakthrough the 25% upper limit of internal quantum efficiency of OLEDs

Ablikim Obolda, Qiming Peng, Mang Zhang, and Feng Li

State Key Laboratory of Supramolecular Structure and Materials, Jilin University, Changchun, P.R. China E-mail: lifeng01@jlu.edu.cn

Abstract: Almost 30 years have passed since the invention of OLED by C. W. Tang. During the long time of development of OLEDs, there are so many materials and devices that were reported. Although the diversity of materials and devices can be nearly infinite, their light-emitting modes can be by far summarized as only three: i) emission from singlet exciton corresponding to the fluorescent materials; ii) emission from triplet exciton corresponding to the phosphorescent materials; iii) emission from singlet exciton converted from triplet exciton corresponding to the TADF, HLCT, TTA materials. Different from the above mentioned light-emitting modes, recently, we reported a new type OLED whose emission comes from the doublet exciton [1, 2].

In this kind of OLEDs, organic open-shell molecules, neutral pi radicals, are used as the emitter. For the open-shell molecule, there is only one unpaired electron in the highest singly occupied molecular orbital (SOMO). When this electron is excited into

the lowest singly unoccupied molecular orbital (SUMO), the SOMO is empty. Thus, its transition back to the SOMO is always spin-allowed in despite of its spin state. TTM-1Cz, a kind of photoluminescent radical [3], was used as the emitter to fabricate the OLEDs. After optimizing the structure of the OLEDs, the newest results are: the EQE is more than 4 %, which is very high for the deep-red devices without using the phosphorescent materials; the creation ratio of doublet exciton is nearly 100%. Our results pave a new promising way to obtain 100 % internal quantum efficiency of OLEDs.

If time is enough, I'd like to introduce a new possible mechanism to upconvert triplet to singlet exciton, which we called triplet-polaron-interaction (TPI) induced upconversion. It is verified that this route is very beneficial to obtain the blue OLED with very high performance [4].

Key Words: open-shell molecules; doublet excitons; blue OLEDs; triplet-polaron-interaction; upconversion

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S34.3

Invited: Novel organic electronic materials and its highly efficient electronic devices

Silu Tao(陶斯禄)

University of Electronic Science and Technology of China

S34.4

Invited: Operational stability enhancement in organic light-emitting diodes with novel electron transport materials

Wenzheng Gao, Hongtao Fan, Huixian Zhou, Zhiyang Li, Shu Jing, Yiwen Li, Xueyan Ren

Beijing Eternal Material Technology Co., Ltd., Beijing, China

Abstract: With the development of OLED technology, the device lifetime are one of the important concerns of commercial materials selection. The accumulation of electron in the light-emitting layer is one of the important factors affect the lifetime. In this report, we designed and synthesized a series of novel electron transport materials (ETM), which can improve the device lifetime (LT_{95}) effectively by 92% compared to that using Bphen as ETM. Moreover, these compounds have specific groups which could interact with Liq to enhance the ability of injection and have high T1 (>2.6 eV) to prevent the spread of the excitons, both of these can ensure good photoelectric performance of device together.

Key Words: Organic light-emitting diode; electron transport materials; lifetime

S34.5

Invited: New Host Materials Based on carbazole for High-performance OLED

Xialei Lv, Wenzhi Zhang, Jianghong Tan Shaoqing Zhuang, Lei Wang*

Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, Wuhan 430074, P. R. China.

Email: wanglei@mail.hust.edu.cn;

Abstract: Carbazole, as a famous hole-transporting unit, has been used in the designing of OLED materials extensively. Here, we mainly introduced a series of new host materials based on carbazole, 1, 5-diazacarbazole, 5'H-spiro[fluorene-9,7'-indeno[2,1-b]carbazole]. Firstly, by conjugating the different electron-deficient group (bezoimidazole, 1, 2, 4-thiadiazole) to carbazole, excellent bipolar host material has been synthesized and them exhibit high performance in blue, green and red phosphorescent device; Secondly, a novel electron deficient, high triplet energy moiety 1, 5-diazacarbazole (NCz) was designed, synthesized and firstly introduced to the constructing of phosphorescent host materials; Finally, four spiro-based materials based on 5'H-spiro[fluorene-9,7'-indeno[2,1-b]carbazole] were designed and investigated, when them was used as host materials for TADF emitter, the orange device exhibit a high EQE of 20.8 %; when it was used as blue TADF emitter, a high EQE of 23.1% blue device was achieved.

Keywords: host materials , carbazole, 1, 5-diazacarbazole, 5'H-spiro[fluorene-9,7'-indeno [2,1-b] carbazole], OLED

Session 35: AR & VR 2 (AR & VR)

S35.1

Invited: VR/AR Audio Technologies and Standardization: Review, Latest progress and Tendency.

Pan Xingde

Wavarts Technologies Co., Ltd.

Abstract: 3D Audio is an key part of virtual reality and augmented reality. This report review the history of 3D Audio technologies, including the theories, algorithms, standards and engineering applications; discuss the technical requirement and features of 3D audio in virtual reality and augmented reality; introduce the latest developments, technical trends and the standardization of 3D audio for virtual reality and augmented reality.

Key Words: 3D Audio; virtual reality; augmented reality; HRTF; AVS; IEEE; MPEG

S35.2

Invited: Light-Field Information Capturing and Display

Xinzhu Sang

Beijing University of Posts and Telecommunications

Abstract: Large size light filed spatial information capturing and display with 8100 viewpoints are presented. Virtual light field information capturing and light field information coding for the light field display are realized with the the backward ray-tracing technique and the reverse perspective technique. Real three-dimensional light field information is captured with the lens ray and the object lens, and the captured light field information is processing and coding based on the depth map and elemental images. Real time 50 cm×28cm light field display with 90×90 viewpoints and the frame rate above 40 fps is demonstrated .

Key Words: light field information capturing; light field display; virtual capturing; real capturing

S35.3

Invited: Evaluation and Standardization of Optical Properties of Virtual Imaging Devices

Tongsheng Mou

Zhejiang University

Abstract: The optical images of AR/VR virtual devices are different from traditional real images. The light beam of each pixel of the image emits through exit pupil of the virtual imaging optics. The imaging plane of traditional display is the 2D image in the rectangular coordinate system, while the virtual image in the AR/VR system is characterized in a certain angular field. In this paper, an angular coordinate system is introduced to evaluate the optical characteristics of AR/VR virtual image. And an aperture which is matched with the actual viewing condition is applied to evaluate the photometric and colorimetric quantities, and FOV. The detailed methods are presented for evaluation of the virtual image performance. Recently, a new project has been established in IEC TC110 for optical measurement of the virtual image, and measuring methods are presented.

Key Words: Virtual imaging devices; angle coordinates; effective FOV

S35.4

Invited: Quantification of Luminance and Chromaticity for Apparent Images in Virtual Reality

Chenzi Xu

SENSING Instruments Co., Ltd

Abstract: The quantification of apparent images is a very important issue in the virtual reality (VR). The traditional luminance meters in the market are not suitable to be applied in optical performance measurement of the VR apparent image. The large entrance pupils of the imaging lens of the current luminance meter would bring unacceptable errors. And the pupil location is also not matched with VR imaging devices. The exit pupil of virtual imaging optics is generally only ten centimeters apart from the VR lens. In this paper, a new geometry for VR image quantification is introduced. The new luminance meter combines the high accuracy array spectroradiometer and CCD imaging camera to determine the luminance and chromaticity of the apparent image.

Key Words: Apparent images; entrance pupil; Virtual Reality

S35.5

Invited: AR integral imaging 3D displays based on holographic optical element

Qiong Hua Wang

Sichuan University

Abstract: This talk will introduce a conventional integral imaging (II) augmented reality (AR) 3D display based on holographic optical element (HOE), an AR double-side II 3D display based on HOE and a floating II AR 3D display based HOE.

Key Words: 3D display, AR, integral imaging, holographic optical element

S35.6

A 3D Interaction Technique for Augmented Reality on Smart Glasses

Keyu Wang, Chao Ping Chen*, Lei Zhou, Yishi Wu, Bing Yu, and Yang Li

Smart Display Lab, Department of Electronic Engineering, Shanghai Jiao Tong

University, Shanghai, China

Email: ccp@sjtu.edu.cn

Abstract: We propose a 3-dimensional (3D) interaction technique for augmented reality (AR). Our interaction technique is implemented on a smart glasses that is equipped with a depth camera. A stable performance has been achieved with low CPU and memory usage. At first, virtual 3D objects are created and rendered by Unity 3D. By wearing smart glasses, the users are able to see these virtual 3D objects being overlaid to the real world and interact with them with their hands. The depth camera detects the certain region surrounding the virtual objects. Once something, such as user's hands, appears and moves in the region of interest (ROI), the motion vector map of ROI will be calculated using blob matching algorithm. Key features such as position and direction of the moving blobs are extracted for classifying the type of manipulation. After feature extractions, support vector machine (SVM) is adopted to convert the motion into three manipulations including translational move, rotation and zooming.

Key Words: 3D interaction; augmented reality; computer vision; smart glasses; depth camera

Session 36: Touch sensor technology & touch panel process (Touch and Interactive Displays)

S36.1

Invited: A stack of bendable touch sensor for bendable AMOLED display

Liu Zhen

BOE Technology Group Co., Ltd

Abstract: In this paper, we meet growing demand for flexible touch sensor used in flexible displays and wearable devices, and present a thinner stack of bendable touch sensor with silver nanowire for flexible AMOLED display panel. A 4.35-inch flexible touch sensor integrated with circle polarizer is fabricated with thickness of touch sensor reduced to 10 μm . Transparent conductive film of silver nanowire named TCTF (transparent conductive transfer film) marketed by Hitachi Chemical is also used for better preformation of bending test. Normal touch detection is achieved after 10^5 folding operations with curvature radius of 3mm. This stack of bendable touch sensor with silver nanowire can be used for flexible even foldable smartphone, tablet, and wearable device etc.

Key Words: Touch sensor; silver nanowire; flexible; circle polarizer; AMOLED

S36.2

Invited: High strength technology apply to OGS by adopting OC0 process

Zeng Ting, Shao Xibin, Guo Zongjie, Hu Ming, Xie Taofeng, Zhang Ming, Zhang lei, Gu Xiaofang, Xie Xiaodong

DBG\Chief technology officer organization\Touch Development Dept.

Abstract: The paper is proposed that the full-coating OC(Over Coating: transparent organic materials), which is also called OC0 layer, is used to strengthen OGS (one glass solution) surface strength itself after black matrix process during Sensor. From the mechanism analysis, the OC0 Layer could decrease the film stress focus on the glass, in particular, ITO sputtering gives rise to the main stress to influence OGS

surface strength and then makes products surface strength enhanced obviously. The experiment shows that adding OC layer after black matrix process can improve surface strength of the laminated OGS products and the surface strength will be better with increasing the thickness of OC0 layer. The free-ball experiment shows the falling-height of the product with a lamination of LCM and OGS , also called TTL, with the full-coating OC were used to the soda lime glass is above 59 cm, however without the layer, the height is below 20cm. The paper is suggested that slimming OC0 thickness ($<0.8\mu\text{m}$) significantly sloved the product optical problem-Rainbow issue caused by ITO sputtering at high temperature ($\geq 230^{\circ}\text{C}$); When OC0 thickness exceed over $0.8\mu\text{m}$, we can adopt lower temperature ($<180^{\circ}\text{C}$) ITO sputtering to eliminate rainbow. We also need to optimize the n-K of SiN_xO_y layer to adjust the TTL products chromaticity and pattern shadow. Therefore, Tx/Rx achieved the technical innovation of OC0 design with adding the layer and optimum material of OC0 at the same time. It is also the first time that adding the full-coating OC layer after black matrix process is applied in the mass production.

Key Words: OGS; OC0 layer; Rainbow; surface strength; SiN_xO_y index matching

S36.3

Invited: High strength technology applying to OGS by adopting OC0 process

Ting Zeng

BOE Technology Group Co., Ltd

S36.4

***Invited:* Graphene-Ag nanohexagonal platelets-based ink with high electrical properties at low sintering temperatures**

Piao Liu

Hunan LEED Electronic Ink Co., Ltd.

Abstract: Printed-electronics inks belong to a class of novel functional conductive inks that can be used to form high-precision conducting lines or circuits on various flexible substrates. Previous studies have reported conductive inks produced by the reduction and membrane separation method for use in flexible devices. However, it remains a challenge to synthesize conductive inks with high electrical properties at low sintering temperatures, which restricts their range of applications. Herein, we prepare inkjet-printed patterns of conductive inks consisting of Ag nanohexagonal platelets (AgNHPs) as the main component and containing graphene (GE) in different contents. It is found that GE improves the electrical conductivity of the patterns when sintering is done at relatively low temperatures. For instance, when the GE content is 0.15 mg/mL , the resistivity is the lowest. When sintering is done at 150°C , the resistivity ($2.7 \times 10^{-6}\ \Omega\text{ cm}$) of the GE-AgNHPs conductive ink (GE: 0.15 mg/mL) is 14% of that of the AgNHPs conductive ink; on the other hand, after sintering at 50°C , this ratio is 2%. This study on GE-AgNHPs conductive inks sintered at low temperatures should further the development of flexible touch screens.

Key Words: Ag nanoparticles; graphene; conductive ink; electrical properties

S36.5

***Invited:* Application of Novel Conductive-Film Materials in Display Module and Mobile Phone**

Zhen Yu(于甄)

Zhangjiagang Kangde Xin Optronics Material Co., Ltd(张家港康得新光电材料有限

公司)

Abstract: Set up in August 2001, KDX is listed on the Shenzhen Stock Exchange. We specialize in the development strategy of new materials, taking the entire industry into consideration and macro-ecology. We own four business departments: advanced high polymer materials, emerging smart displays, internet applications and new energy automobiles. including preparation of nano-silver conductive film and the successful preparation of flexible touch panel, late integrated barrier film, cover film, high dielectric film, polymer decorative film, to develop excellent performance flexible optical films and devices for flexible display in the future.

S36.6

Invited: Embedded Ag Mesh Electrodes for Polymer Dispersed Liquid Crystal Devices on Flexible Substrate

Yanhua Liu

Soochow University; SVG Optronics, Co., Ltd.

Abstract: An embedded Ag mesh transparent conductive electrode (TCE) on flexible substrate, which is suitable for polymer dispersed liquid crystal (PDLC) device, is demonstrated. With the combination of soft ultra-violet nanoimprinting lithography and scrape technique, it offers parallel processing with high resolution (10000dpi), as well as remarkable simplicity and fully controllable flexibility to tailor the transmittance and sheet resistance. While being able to achieve maximum transmittance 60% in the on state and the minimum 0.1% in the off state, the PDLC smart window displays low sheet resistance (5.58 $\Omega/\text{sq.}$) under low driven voltage (30V) safe for human. The main advantage of adoption of PDLC as an optically scattering element lies in the fact that there needs no mechanical part for in situ tunability. An enhancement factor of 50 of the diffraction intensity is observed experimentally. The embedded Ag mesh TCE for PDLC device has an environmentally-friendly additive manufacturing process inherently. Compared to existing solutions, the fabricated sample shows superior performance in both optoelectronic and mechanic characteristics. We envision that the embedded Ag mesh TCE will enable economically widen application of PDLC devices on flexible substrate.

Key Words: Transparent conductive electrode; polymer dispersed liquid crystal; Ag mesh; soft nanoimprinting.

Session 37: Vehicle Displays

S37.1

Invited: Displays for Avionics Applications

Kalluri R. Sarma

Honeywell Aerospace Advanced Technology

21111 N. 19th Avenue, Phoenix, AZ 85036, USA

Tel: 602-436-6415, email: kalluri.r.sarma@honeywell.com

Abstract: High performance wide viewing angle AMLCDs were developed and used in commercial avionics applications for the first time starting early 1990s, in B777 aircraft. Since then AM LCD has been the technology of choice for aerospace cockpit applications ranging from air transport, business jet, regional jets, helicopters and general aviation. In this presentation we will first discuss the requirements of cockpit displays in general, and relevance of new and emerging display technology

developments for enhancing cockpit display capabilities in particular. We will then discuss the recent advances in AM LCD, AM OLED, and Flexible display technologies supporting superior video image quality with greatly expanded color gamut, SWaP (size, weight and power) attributes, flexible form factors, sensor integration, operation and under broad range of environmental conditions and ruggedness.

Key Words: Avionic Displays, Cockpit Displays, Displays for Avionics, Rugged displays

S37.2

Invited: Bending Stress research on Automotive Curved TFT LCD

Longwei Yang, Xiaosong Song, Xiaoping Sun, Xiongping Li

Technology Development Department, Shanghai Tianma Micro-electronics, Co., Ltd.

Abstract: With rapid development of automotive display, diversified tendency is more and more obvious. One of research subjects will come in particular through curved display inspired by the consumer electronic. Curved display could improve the integration in the dashboard and bring modernity and originality in the car. However, bending stress results in a bottle neck on technology, process and material to realize the curve of TFT LCD. This work focuses on stress research and simulation, presenting a more accurate model for theoretical formula and bending stress analysis. Based on ANSYS workbench simulation results and optimized boundary conditions, a series of verification experiments were carried out, which gives insights into Corner MURA, CTP material and lamination process.

Key Words: Bending stress; Corner MURA; Curved display; CTP;

S37.3

Invited: The future automotive display

Steven Tian

Tianma Microelectronics Co., Ltd

Abstract: The display used in automotive have some differences of the others used in personal computer or mobile phone, such as reliability, long lifetime, wide temperature operation, good optical performance, and low cost.

With the advent of new technologies, new infrastructure and highly automated functions, especially the HMI, automotive is not only a vehicle, but also become to “the 3rd living space”, people spend more time in automotive. The safe and comfort of the automotive will be promoted to the higher level in future, and the future automotive interiors will be changed more even looked weird now, but they are greatly influenced by new display technologies, so there will be more requiring to the display. This paper will briefly describe the development tendency of the automotive display.

Key Words: Automotive displays; LCD; OLED; HMI; Heads-Up Display (HUD); 3D

S37.4

Invited: A Novel Emissive Projection Display (EPD) for Vehicle Glass, Digital Signage and AR Applications

Ted Sun

Sun Innovations Inc.

Session 38: Display Applications 1 (Display Applications)

S38.1

Invited: Development of Free-Form LCD for Automotive Applications

Yang-Bing Yu

BOE Technology Group Co., Ltd.

Abstract: As vehicular displays is updating continually, there is more need to make free form and narrow border display panel to match the automotive trim perfectly. For this sake, this paper introduces the design concept of 0.9 mm narrow border free form display technology based on BOE self-developed 12.3 inch automotive free-form curved cluster. Gate driver IC is placed at the same side as source driver IC, and multi layer trace layout in panel is applied to get narrow free form border. Zigzag pixel arrangement and arc black matrix are applied to get free form border. Besides, glass slimming is applied to make curved display's image quality more perfect. At the same time, Stressful, thermal and optical simulation have been done to analyse and forecast the whole performance of the free-form curved display module. At last we also presented some counter measures to alleviate or avoid the common failure issues.

Key Words: Automotive; Free-form; Curved; Narrow border.

S38.2

Invited: Anti-press ability study on smartphone lcd

Qin Feng, FU Jiong-liang, XIA Zhi-qiang, JIAN Shou-fu, JIN Lu

Shanghai AVIC Optoelectronics Co., Ltd, Shanghai 201108, China

Abstract: With the popularity of mobile phone OEMs CoverLens-LCM full lamination products, especially the popular 3D Touch technology and mobile phone thinning tendency, mobile phone GUI become diversified. Consumers need to press the screen for different pressure operation, which the anti-press ability on the LCD screen put forward new requirements. The traditional liquid crystal display full lamination products in the presence of external force shows that the edge of the area, such as the shape of the water ripple, affecting the display effect . In this paper, through the analysis of force and experimental factors, and establish a reliable evaluation system, and finally find the key factors. In this paper, the design and optimization of illumination Spacer with the consideration of process capability are summarized, as well as the contribution of the glass thinning and asymmetric thickness matching to the mobile phone panel.

Key Words: anti-press; full lamination; 3D Touch; thinning; force

S38.3

Invited: Processing technology and application of bar display based on TFT-LCD

Li Quan

Shenzhen China Optoelectronics Technology Co., Ltd

Abstract: This paper exhibited a simple and low-cost processing method of bar-display screen based on TFT-LCD, and the existing issues in the process of product development, such as LC bubble, failure of polarizing plate, vertical bright and dark lines, were solved. The sealant with low viscosity would be chosen to solve the LC bubble issue . The original polarizing plate was removed and replaced by a new polarizer suited to use of bar display, and since then, the issue of polarizer failure was solved. In order to decrease the ratio of vertical dark line, the A-Com line in the edge of cutting was compulsory removed. The development of bar display technique

based on TFT-LCD in the commercial display, though our research, will be enormously promoted.

Key Words: Bar display; TFT-LCD; Commercial display; Issues

S38.4

Invited: A New Method of Display Application based on Adaptive Theory

Zhiyong Ren

Tianma Micro-electronics Co., Ltd

Abstract: In order to extend the working time of portable equipment, using adaptive theory to deal with the display modularization which is aimed at the problem of large power consumption of display device [5], so as to reduce the power consumption of the display device and make the portable device get longer working hours. Through the overall analysis of the data, the overall display is in partition control and the display data is in block control, which contains the backlight and display data coordination and complementation. This mode can not only enhance the dynamic effects of the active area of the display, and can effectively reduce the part of the static energy consumption. Simulation and experimental results show that this mode can significantly reduce the power consumption of the display under the existing technology, and its working time can be increased by 30% compared with the general display effect. It has obvious advantages compared with the MIP (Memory in Pixel) in terms of process complexity.

Key Words: LCD; Oxide; Sub-Pixel Algorithm; Power Consumption

S38.5

Invited: A novel low power reflective LCD development

Wang Lei

Tianma micro-electronics group

Abstract: As the rapid development of information technology and the increasing trends of information exchanging and demanding, more and more people frequently use a variety of portable devices. Accordingly, it is inevitable to face the topic of low power consumption, low cost ,high visibility under the sunlight and so on. In this paper, based on the low cost a-Si:H TFT process, the reflective display technology had been developed, and it used the method of optimizing the pixel design, increasing the storage capacity and reducing the leakage current. These methods improve the holding ratio of the pixel, when the case of longer holding time, so as to achieve low frequency driving and low power consumption. By using the above technology, the 4.4inch VGA reflection display has been fabricated. Under the condition of 8bit color depth, the driving frequency can be reduced to 10Hz, and the power consumption had been reduced by 86% compared with the traditional design. Using 1bit color depth, driving frequency can be reduced to 1Hz or less, the corresponding power consumption can be reduced to uW level, which is suitable for smart wearable devices.

Key Words: Liquid crystal display; low cost; low power consumption; reflective display; smart wearable technology

Session 39: Display Material and Component Manufacturing (Display Manufacturing)

S39.1

Invited: The Development of Emerging LCD with Black Photo Spacer Application

Minggang Liu, Chengliang Ye, Chengzhong Yu, Yanxi Ye, Zhuming Deng, Gang Liu, Yunglun Lin, Chungyi Chiu and Chiayu Lee

Shenzhen China Star Optoelectronics Technology Co., LTD, Shenzhen, Guangdong, China.

Abstract: We present a LCD demon with Black Photo Spacer (BPS) technology which is a wide potential technology to save cost in the emerging LCD industry. The BPS can reduce the step of process by merging the BM and PS process. Besides, with designing BM/PS (BPS) on array in this technology, it is suitable to satisfy curved and flat panel on the same time with sharing one layout. In this paper we discussed the designs and process controls on the triple type BPS, and then we studied the optical performances about the AA and border areas. At the end a demon with BPS technology was demonstrated.

Key Words: BPS; process saving; curved display



Size	Resolution	Tr%	CR	NTSC
28"	1366*768	6.58%	6468	68.6%

Figure 1. A 28" demo of BPS technology and its optical results

S39.2

Invited: Reliability impact of residual reactive mesogen at PS-VA mode

Gang Wen

Shijiazhuang Chengzhi Yonghua Display Material Co., LTD

Abstract: To improve the image sticking performance of PS-VA, a series of experiments with different UV curing conditions are designed to investigate the influence of RM residual amount on image sticking. It shows that the RM residual which could be controlled by UV process is related to image sticking performance. As known, ion density is a factor of image sticking issue, based on analysis the relationship between ion density and RM residual amount, a technology to reduce the probability of image sticking at PS-VA mode is also studied. Furthermore, a new method is provided to improve the image sticking performance by designing different

mixture concepts which affect the RM residual.

Key Words: PS-VA; image sticking; RM residual amount; Ion density; liquid crystal

S39.3

Invited: Colorless Polyimide for LCD Substrate Application (9:10-9:30)

CJ Chen (陳志榮)

CHIMEI CORPORATION

S39.4

Invited: Mechanism analysis of air pocket in the color film on array LCD display

Lei Ma, Ying Yan, Jia-xing Ma, Bing-jie Liao

*Shenzhen China Star Optoelectronics Technology Co., Ltd., Shenzhen, Guangzhou, China

Abstract: The color film on array (COA) structure technology is used in the FPD industry becoming more and more popular, but there are still some restrictions on the process control, such as the air pocket issue. In this paper, air pocket generated mechanism was investigated, includes the COA structure microscopic morphology, color resist thermal stability and outgas composition, and which was analyzed by the instruments including scanning electron microscope (SEM), thermal gravimetric analysis(TGA), laser Raman spectrophotometer and so on. And then it is proposed that the air pocket issue can be solved the process and materials's improvement. The test results show that the gas composition of air pocket is strongly correlated with the color resist outgas, it can lead to product air pocket. This issue can be effectively improved by optimizing the process of the passivation layer and reducing the source of the color resist outgas.

Key Words: color film on array technology; color resist; outgas; air pocket

Session 40: Manufacturing Equipments for All Display Technologies (Display Manufacturing)

S40.1

Invited: Inkjet Printing Technology For Next Generation Display

Takayuki Harada

Nakan Techno Co., Ltd

Abstract: As we can see, the development speed of high resolution LCD is rapidly progressing,

and recently, the use of 4K for TV is spreading to the market, even now the next generation 8K is in progress for mass production.

We are manufacturing the printing EQ for forming PI alignment layer, which is important process of LCD.

We developed INKJET printing EQ, which is realizing Higher-definition printing more than the conventional flexo printing EQ.

Please let us introduce our printing technology which is realized by overcoming technical challenge for high resolution printing and also by our INKJET EQ.

S40.2

Invited: Overview of Image Restoration Technique for Flat Panel

Mike Zheng

Wuhan Jingce Electronic Technology Co.,Ltd.

Abstract: Along with a strong demand for large-size panels and to avoid the negative effect of Mura on the quality of panels, the image restoration technique has been widely applied in the production. At the same time, further researches on this technique arise. Such kind of technique is based on the idea of capturing the images of the panel in different colors and grayscale, followed by the calculation of the intensity distribution of Mura. And then it is converted into the compensation data which TCON can read, and finally the TCON restores the images in real-time. In the paper, some image restoration systems are introduced, and the advantages and challenges of the technique are described as a discussion and conclusion.

Key Words: Image restoration; Mura intensity distribution; Real-time restoration of TCON

S40.3

Invited: Unveiling New Inspection & Repair Technology in Display Manufacturing Process ; airSEM & Auto Repair

Yeo Hong Yoon (尹汝洪)

Charm Engineering Co., Ltd.

S40.4

Invited: Enabling OLED Displays by applying Semiconductor Yield Methods

Xuena Zhang, Peter Nunan

Applied Materials

Abstract: Modern high resolution mobile display manufacturing requires greater emphasis on defect reduction and critical dimension (CD) control. Increased PPI leads to smaller killer defects, which can't be classified using optical techniques. As PPI scales and display area grows (A_c), killer defect density (D_o) increases exponentially. Using Poisson Yield model, $e^{-(D_o A_c)}$, yield will be a challenge. Similar challenges during the 90's in semiconductor industry necessitated inline SEM defect analysis and CD measurement. Today, 100% of semiconductor processes are inspected and measured using SEM. Optical inspection combined with SEM review enabled Moore's Law scaling for the past 20 years. In development, DOE methodology and tighter SPC limits in manufacturing lead to the need for in line SEMs which provided more accurate analysis and measurement capability without breaking the substrate! Introducing inline SEM Semiconductor yield methods to display will enable high yielding reliable OLED displays.

AKT Electron Beam Review (EBR) system combines proven Semiconductor inline SEM capability with AKT's large-scale vacuum platform. EBR brings semiconductor SEM capabilities to display to quickly determine root cause of killer defects. Multiple leading display makers are benefiting from AKT's EBR, resulting in faster yield ramps and fewer yield excursions.

Key Words: OLED; Display manufacturing; Defect reduction; SEM

半导体良率方法成就 OLED 显示

高解析 OLED 和 LCD 显示制造亟待控制缺陷和关键尺寸。高 PPI 导致影响良率的缺陷 (D_o) 指数增长, 与日益增大的显示面积 (A_c) 让良率 $= e^{-(D_o A_c)}$ 大幅降低。半导体在 90 年代引入 SEM 应对类似挑战, 实现摩尔定律, 发展至今 SEM 控管 100% 的工艺制程。

EBR (在线 SEM) 拓展半导体 SEM 技术到显示业, 结合 DOEs, SPC 等, 更快更精准的确定产品致命缺陷和分析缺陷根源。EBR 用半导体良率方法缩短良率

爬坡和控制良率异常，正助力多家世界知名显示企业，成就柔性 OLED 显示的开发和制造。

S40.5

Invited: Intelligent manufacturing of LCD factory

Shi Chao Zhang (James)

Nanjing CEC Panda FPD Technology Co.,Ltd.

Abstract: To adapt to the demand of development of manufacturing industry, intelligent manufacturing technology is an inevitable trend of the development of advanced manufacturing technology in the future and also is an important guarantee for China to achieve the transformation from manufacturing to manufacturing power. Nanjing CEC Panda FPD Technology Co., Ltd., as a professional enterprise engaged in R & D, manufacturing and sales of LCD , was put into operation in March 2015, the world's first G8.5 production line using IGZO technology. The company achieves the LCD of the whole process of digital production which puts enterprise resource management system as the core operating platform, and integrates Product lifecycle management system, computer integrated manufacturing system, quality management system, automatic warehouse management system, Supplier of electronic data interaction platform, customer relation management, Virtual cloud desktop system, Human resource management system and the other production and management system. Currently, the company is actively studying a road to converse from the digital factory to the intelligent factory, and then upgrade to the intelligent production, in order to seize the commanding heights of industrial development.

Key Words: intelligent manufacturing system; IGZO; ERP; PLM; CIMS; QMS; WEB-EDI

Session 41: Novel Displays (Display Systems)

S41.1

Invited: Flexible Clocking For Modern Pixel-Driven Displays (8:30-8:50)

Liming Xiu (修黎明)

BOE Technology Group Co., Ltd.

S41.2

Invited: Real time efficient pedestrian detection

Hai Jun Su

BOE Technology Group Co. Ltd.

Abstract: Pedestrian detection is an important research subject in the field of computer vision. Automatic detection of pedestrian can be widely used in advanced driver assistant system, intelligent robot and intelligent security monitoring. Based on the ACF detection algorithm, a differential channel feature algorithm is proposed to improve the accuracy of weak classifiers. In order to further improve the detection speed, this paper also gives a method of training soft cascade threshold, which improves the acceleration performance of soft cascade. Experimental results show that the proposed algorithm greatly improves the detection accuracy, and the detection speed reaches 14.6fps using just a single cpu thread.

Key Words: Pedestrian detection; Adaboost; HOG; Difference Channel

S41.3

Ultra High Definition 3D Medical Display Technology

Geng Lihua, Leng Changlin, Yin Xinshe, Wei Chuang, Zhou Chunmiao, Zhang Xiao, Li Xiaoyu

Internet of Things and Artificial Intelligence Institute, BOE Technology Group Co., Ltd.

Abstract: BOE 3D medical monitor realizes 3D stereoscopic display of 4K UHD (Ultra-High-Definition, 3840x2160) resolution, conforms to the medical display standard DICOM, and can be applied to endoscopic surgery, medical teaching and so on. The monitor employs the system architecture of FPGA + SoC (Field Programmable Gate Array + System on a Chip) to achieve 4K 3D video data processing and acceleration, thereby improving data processing speed and efficiency. Additionally, in order to ensure image quality, the optimized image up-scaling algorithm stretches image resolution. Besides, glass thinning process is used to enhance 3D viewing angle, so that up and down viewing angle can arrive 32 ° ^{32°}. This paper focuses on the 3D medical display system architecture and key technologies, including high-definition image up-scaling technology and 3D viewing angle enhancing technology.

Key Words: 3D Display; UHD; FPGA

S41.4

Invited: Ultra-High-Definition 3D Medical Display Technology

Chuang Wei (卫创)

BOE Technology Group Co., Ltd.

S41.5

Invited: Fiber Optic Transmission System For 8K UHD

Lu Tong, Hong Wang, Changlin Leng, Weiqing Guo, Shu Wang

BOE Technology Group Co., Ltd.

Abstract: Recently the high resolution and large size terminal have become the inevitable trend in display market due to the customer demands on high video quality and fast development of video technology. However, the existing signal connection and transmission technologies are complex and slow for the ultra high resolution signal. The pixels for existing highest resolution 8K UHD (8K Ultra-High Definition) is 16 times more than the FHD (Full High Definition) and 4 times more than the 4K UHD. As the 8K UHD requires up to 16 lanes DVI-D (Digital Visual Interface-Digital) or 4 lanes HDMI2.0 (High-Definition Multimedia Interface 2.0) to transmit the video signal due to its wider bandwidth. This paper presents a novel signal processing system for 8K UHD with only a single fiber optic cable, which is essential for ultra high resolution system based on simple interface and small board. Our design utilize FPGA systems to reduce the conventional 16 lanes DVI into a single fiber optic cable. The entire system leads to a much simplified and fast transmission.

Key Words: 8K; fiber optic; FPGA; power integrity; signal integrity

S41.6

Invited: Research of Visible Light Communication Method Based on Display Panel

Yingyi Li

BOE Technology Group Co., Ltd.

Abstract: The traditional communication method is facing many security challenges

and the available band for it is very limit. As the extended popularization of LED lighting, the research of VLC (visible light communication) has become an attractive alternative to radio frequency communication and has brought the opportunity for it being adopted in short-distance communication applications. This research has proposed a creative method which VLC signal emission is based on a display panel. Within the reported visible light communication plans, the most common way is to use LED as the transmitter, photosensitive structure as the receiver. In this research every pixel is used as a single data transmission channel, a mobile device camera as a receiver to capture the pictures, so that to realize the high-speed data transmission between the display panel and the smart mobile devices. The principle of the method will be discussed and the result on picture quality will be given in this presentation. In addition to the above, other reported screen-to-camera communication methods will be summarized in this presentation.

Key Words: visible light communication; data transmission channel; display panel based signal emission

Session 42: Printed OLED Materials (Printed Displays)

S42.1

Invited: Novel luminescent dyes enabling new solution-based AMOLED technology

Yuguang Ma

State Key Laboratory of Luminescent Materials and Devices, South China University of Technology,

Abstract: As the luminescent dyes have an electroactive feature, they can spontaneously be deposited on the electrode surface to form patterned luminescent films. We reported herein a novel use of thin-film transistor(TFT) combined with these novel luminescent dyes to process pixel in active-matrix organic light-emitting diode (AMOLED) displays. This is a maskless RGB color patterning method, that is based on an electrochemical polymerization (EP) reaction of luminescent RGB dyes on the interface of electrode and electrolyte solution, where TFTs provide a “switch” current signal to control EP process and address the dye deposition on selected pixel. By optimized designs and experiments involving dye precursors for EP(RGB precursors), electrode modification(1~2nm Au layers), and TFT’ s parameters(gate voltage), high-quality RGB light-emitting films and devices have been realized..

Key Words: TFT; AMOLED; electrochemistry

S42.2

Invited: Inkjet printed OLED & QLED based on cross-linkable materials

Zheng Cui

Suzhou Institute of Nanotech and Nanobionics, Chinese Academy of Sciences

Abstract: Cross-linkable inks of electron and hole transport materials have been developed. Inverted green and blue phosphorescent OLEDs have been fabricated by inkjet printing and solution process. High external quantum efficiencies (EQEs) of 12.1% and 12.8% were achieved for the green and blue phosphorescent OLEDs, respectively. The maximum current efficiencies are 40 cd/A and 26 cd/A, which are among the best in the literature. The cross-linkable materials are also combined with inkjet printed quantum dots as the emission material for making QLED. At less than 9 volts driving voltage, the emission intensity QLED is over 4000cd/m². Work on

inkjet printed driving electrodes for flexible passive matrix OLED will also be presented.

Key Words: printed display; OLED; cross-linkable materials; quantum dots; QLED; inkjet printing

S42.3

Invited: Development of Advanced Materials for Printed OLED Displays

David Flattery

E.I. DuPont de Nemours & Co., Inc.

Abstract: OLED televisions have received glowing reviews since their introduction around 3 years ago; however, significant market penetration has not been achieved. The most often-cited cause of this sluggish growth is the high price of the OLED panels, which is a consequence of their high manufacturing cost. Many panel makers are aggressively pursuing an alternate manufacturing process utilizing printing for the deposition of the first three OLED material layers which promises to dramatically reduce both fixed and variable cost of the panels through lower capital investment and dramatically reduced material consumption. As the process nears commercial viability, manufacturers and material suppliers are working to produce printed devices with performance competitive with the incumbent evaporated devices through optimization of both the materials and the process conditions. This talk will update developments in processibility and intrinsic material performance that close the gap between demonstrated performance and current targets. In particular, printed blue device data with narrow luminance spectra to match preferred top-emission architectures together with long lifetime will be updated.

Key Words: OLED materials; printed displays; lifetime

S42.4

Invited: Ink Formulation for Inkjet Printed OLED Displays

Hsin-Rong Tseng, Gaelle Bealle, Christoph Leonhard, Anja Jatsch, Leticia Garcia Diez, Peter Levermore, Edgar Böhm, Herwig Buchholz

Merck KGaA, Frankfurter Strasse 250, Darmstadt, 64293, Germany

hsin-rong.tseng@merckgroup.com

Abstract: Ink formulation development with the aim of providing high quality inks for inkjet printed OLED display manufacturing is reported in this paper. OLED inks enabling a high degree of film formation control are in focus. This is especially crucial for top-emission device architectures. Flat film formation is achieved and relative device performances are reported. Very low particle contamination is necessary for good device performance. Thus OLED inks having extreme low particle count are reported. These inks are ready for scale up for printed OLED display manufacturing.

Key Words: OLED; display; inks; film formation; particle

S42.5

TBD

Huaping Li (李华平)

ATOM Nanoelectronics

S42.6

Layer formation of polymer yellow inks in inkjet-printing process

Tang Qian, Ye Yun, Zhou Xiongtu, Guo Tailiang

Fuzhou University

Abstract: We studied the layer formation and characteristics of droplets in inkjet-printing process using polymer yellow material (PDY-132) on glass and flexible substrates. The commercially available materials were widely used by spin coating in the past, but seldom to be reported on its formulation for inkjet printing. Stable droplets of 10-100 pl could be jetted with a mixed-solvent ink. A standard stack of ITO/PEDOT: PSS/ PDY-132/Ba/Al were applied to this study. The uniform layers were formed either in $58 \times 164 \mu\text{m}^2$ pixels with banking or in 1×1 to $5 \times 5 \text{ mm}^2$ areas without banking, under plasma pretreatment and post-vacuum drying and baking. We determined the best distances between two droplets placed onto different substrates according to the size of droplets. The layer uniformity influenced by drying process was discussed. The light efficiencies of the devices were 3-5 Cd/A. High reliability and long lifetime of the material encourages us to develop low-cost flexible OLED digital signage by inkjet-printing process.

Key Words: inkjet printing, layer formation, flexible digital signage

Session 43: TFT Reliability (Active-Matrix Devices)

S43.1

Invited: The Reliability Issues and Progress in Foldable Amorphous InGaZnO and LTPS TFTs

Ting-Chang Chang

Department of Physics, National Sun Yat-sen University

Abstract: Recent reliability issues and progress in foldable amorphous InGaZnO (a-IGZO) and low-temperature polycrystalline silicon (LTPS) TFTs are reviewed in this talk. Firstly, the electrical characteristics variation of a-IGZO TFTs after undergoing different bending radius are demonstrated. The mechanical stress-oxygen vacancies generation model is proposed by our group and further verified by UV light simulation. Secondly, the endurance of flexible LTPS TFTs after undergoing 100,000 iterations mechanical bending at $R=2\text{mm}$ is investigated. It performed abnormal parasitic current path and severe threshold voltage degradation after bending. By utilizing the mechanical stress simulation, the non-uniform stress in the gate insulator is distinctly observed. This stress results in defects in the gate insulator and leads to a non-uniform degradation phenomenon. Both of the performance and reliability in thin-film transistors (TFTs) would be affected. Thirdly, the flexible substrate possess both high coefficient of thermal expansion (CTE) and low thermal conductivity. These material properties would lead to electrical characteristics variation while comparing to the devices fabricated on glass substrate. Lastly, after understanding the exact degradation mechanism and its location in flexible TFTs that undergo mechanical stress, accurate designs rules and improved devices structure are proposed and fabricated by our group for enduring mechanical stress.

Key Words: component; formatting; style; styling; insert

S43.2

Invited: Reliable n-channel Four-Terminal LTPS TFTs

Mingxiang WANG

Soochow Univ.

Abstract: In the operation of LTPS TFTs based circuits, reliability of TFTs is a concerned issue due to various DC/AC voltage stresses. It is shown that steep gate

voltage pulse switching can induce severe dynamic degradation of TFTs, which would be even worsen if a DC drain bias was presented. We show that a conventional low-doped-drain (LDD) structure, which is known to be effective to improve the DC hot carrier reliability, can also reduce the dynamic degradation of LTPS TFTs. While a newly proposed novel four-terminal TFT where a counter-doped lateral terminal is designed to attach to the channel, is shown to have much superior performance to the conventional LDD TFTs in suppressing the dynamic degradation. In four-terminal TFTs, either the substrate terminal is grounded or biased to a low voltage, they will have much higher immunity to the dynamic degradation than conventional LDD TFTs. Besides, four-terminal TFTs can also reduce the kink current in the output characteristic and reduce the DC HC degradation of TFTs. Degradation suppression can be explained based on the non-equilibrium PN junction degradation model.

Key Words: LTPS TFTs; four-terminal; dynamic hot-carrier degradation; non-equilibrium PN junction model

S43.3

Invited: Development of Highly Reliable Amorphous In-Ga-Zn-Sn-O TFTs with BCE structure.

H. Goto, M. Ochi, A. Hino, K. Nishiyama*, K. Hayashi, T. Kugimiya, and H. Kanamaru*

Kobe Steel, Ltd., JAPAN

*Kobelco Research Institute, Inc., JAPAN

Abstract: In the materials design of amorphous oxide semiconductors for thin-film transistor (TFT) application, the balance between the electron mobility and the stress reliability in TFT performances should be considered with maintaining the compatibility with the TFT processes such as back channel etching (BCE). For that purpose, the selection of material elements and the optimization of the metal compositions on the basis of the evaluation of electronic state are especially important. We have developed amorphous In-Ga-Zn-Sn-O thin films as a solution of the issues above and examined the characteristics of TFTs with BCE structure. Moreover, as the methods of monitoring the electronic states of amorphous oxide semiconductor film, we will demonstrate the optimization of the TFT performances by the microwave photoconductivity decay (m-PCD) and photoinduced transient spectroscopy (PITS).

Key Words: In-Ga-Zn-Sn-O; back-channel-etch; m-PCD; Oxide semiconductor

S43.4

Invited: Low Frequency Noise model For Thin-Film Transistors Considering Power-Law Mobility Parameter

Hongyu He and Shengdong Zhang

School of Electronic and Computer Engineering, Peking University Shenzhen Graduate School, Shenzhen 518040, China

Email: hongyuhe2018@yahoo.com, zhangsd@pku.edu.cn

Abstract: The low frequency ($1/f$) noise model is presented for both amorphous IGZO and organic thin-film transistors (TFTs). The power-law parameter is considered to describe the carrier-concentration-dependent mobility for the drain current model. The drain current noise power spectral density (PSD) is derived from Ghibaudo's carrier number fluctuation model due to the flat-band voltage fluctuation. It is found that, the parameter clarifies the relationship between the drain current noise PSD and the drain current, and the interface trap states density is extracted, accurately. The traditional McWhorter's carrier number fluctuation model and Hooge's mobility

fluctuation model can not describe the $1/f$ noise characteristic for the TFTs, accurately.

Key Words: thin film transistor (TFT); low frequency noise; mobility; trap states

S43.5

Suppression of Light Induced Instability of BCE InGaZnO Transistors and Panel Flicker Improvement for 32-in. 8K4K LCD

Longqiang Shi

Shenzhen China Star Optoelectronics Technology Co., Ltd.

Abstract: Illumination instability of BCE IGZO TFT was studied in this paper. It was found that the distance between island-in IGZO and gate electrode is larger than $2\mu\text{m}$ (P2) could be able to resist light induced device deterioration effectively. We also found that P4 was an optimum distance for flicker performance compared to P2 design, the flicker level of P2 and P4 is 25dB and 11dB respectively. Finally, a high performance 32-inch 8K4K IGZO LCD was successfully demonstrated based on all the study above.

Key Words: BCE IGZO; Illumination stress; 8K4K; Flicker

Session 44: Manufacture of TFT Device, Array, and Circuits 2 (Display Manufacturing)

S44.1

One Solution of Cu Oxidation of Source/Drain On SiNx, SiO₂ Dielectric in BCE IGZO TFT

Bifen Lin *, Xianwang Wei*, Shimin Ge* , Rui Zhao

*Shenzhen China Star Optoelectronics Technology Co., Ltd, Guangdong, China

*TCL Corporate Research, Guangdong, China

Abstract: This letter investigates the Cu oxidation behavior of source/drain layer on SiNx, SiO₂ dielectric in BCE IGZO TFT. The Cu oxidation appears easily when etching the via hole at the bonding lead area between gate and source layer which the gate insulator is SiNx, SiO₂. It has gibbose residues at the via hole edge after dry etching process, the sharp corner can be much more higher after Cu film is deposited on it, then the passivation layer can not cover Cu film perfectly, the H₂O and O₂ in the air oxidize the Cu film. By increasing the dry etching pressure from 30mT to 140mT, the gibbose residues can be removed. It also explains the difference of taper angle at different locations of the same hole leads to the orientation of Cu oxidation, and it can be improved by increasing the distance of two adjacent holes when designing the mask of photo process.

Key Words : Cu oxidation; SiNx, SiO₂ dielectric; gibbose residues

S44.2

Electrical Characterization of In-Ga-Zn-Sn-O Thin-Film Transistor With a Self-Aligned Top-gate Structure

Jerry Li*, Yuhao Zhai*, Xiaobo Hu*, Huahua Yu*, Wei Huang*, Wei Cao*, Tony Sun*, Shijian Qin*, Can Lee*, Frank Wang*

*Shenzhen China Star Optoelectronics Technology Co., Ltd, Guangdong, China

**TCL Corporate Research, Guangdong, China

Abstract: Recently, amorphous oxide semiconductor material has been widely used

in large size flat display, especially, amorphous indium gallium zinc oxide (α -IGZO) has attracted most attention of people, because it has several main properties, including its low-temperature process, low threshold voltage, high mobility and good uniformity of large size preparation, and it has used in many applications: optical waveguides, optoelectronic devices, ultraviolet/violet light emitting diodes, backplane of flat panel displays. The stability and reliability of α -IGZO TFT structure become the research highlights of current research, especially the reliability of negative bias stress (NBS). Among α -IGZO thin film transistor (TFT) structures, up to now, α -IGZO bottom-gate structure TFTs have been generally developed for active matrix liquid crystal displays (AMLCD) and active matrix organic light emitting displays (AMOLED). Nevertheless, the bottom-gate TFT structure has a high parasitic capacitance due to gate-source/drain overlap, a poor device scalability, and the degradation of drain current resulted from gate-source/drain misalignment. On the contrary, the top-gate TFT structure which has many significant advantages, is suitable for the realization of large size flat-panel display applications. Furthermore, the self-aligned TFT structure process involves some difficulties of photolithography misalignment issues, the development of a self-aligned top-gate structure is rather essential. Also, there are several reports that Indium-Gallium-Zinc-Tin-Oxide (α -IGZTO) TFTs exhibited a comparably high stability as compared with α -IGZO TFTs. Herein, We propose a self-aligned top-gate amorphous gallium indium zinc oxide thin film transistor (α -IGZTO TFT) formed by using He or Ar plasma treatment. The TFTs with He plasma treatment exhibited the comparable electrical performance. We also compare IGZTO to the IGZO TFTs, and the α -IGZTO TFT reveals a high uniformity and a lower threshold voltage shift of 0.5 V is obtained, which is less than the threshold voltage shift of 1.1 V of α -IGZO TFT under the negative bias stress (NBS) with same stress time of 2000s.

Key Words: α -IGZTO TFT; top-gate; high stability

S44.3

Novel 3-Mask TFT Technology with ITO Lift-Off Enhancement Process for First Worldwide 28" HVA AM-LCD TV

Hongyuan Xu

Shenzhen China Star Optoelectronics Technology Co., Ltd.

Abstract: A 3-masks technology has been developed by a new mask design named large area half-tone mask (LA-HTM) and a new process named treatment enhanced ITO lift-off (TEIL). The risk points of the LA-HTM design were discussed and solved. By using this technology, the transmittance of LCD panel was improved and the lift-off efficiency was enhanced. The ITO pattern after stripping is very smooth and regular. TFT device fabricated by TEIL technology exhibits the same electrical characteristics performance as traditional non-lift-off one. Lastly, the first 28" HVA-AMLCD panel of 3mask was successfully fabricated. This novel 3-Mask TFT technology is the most suitable for mass production so far.

Key Words: 3mask; large area half-tone mask (LA-HTM); treatment enhanced ITO lift-off (TEIL)

S44.4

The Effects of Different Gate Insulator Deposition Power on Top Gate IGZO TFT Properties

Macai Lu

Shenzhen China Star Optoelectronics Technology Co., Ltd.

Abstract: Deposited power is a key factor of PECVD gate insulator deposition, which has great effects on the gate insulator and the electrical properties of top gate IGZO TFT. In this paper, We would introduce the properties of different gate insulator deposited power on top gate IGZO TFT fabricated, the power we studied was 600W/800W/1000W/1200W/1400W/1800W/2200W in G4.5 equipment. Finally, we fabricated a good electrical property top gate IGZO TFT with the gate insulator deposition power of 1400W. Mobility=14.7 cm²/V.S. Subthreshold Swing(SS) =0.31V/dec, Threshold Voltage (V_{th}) =2.01V, ΔV_{thNBTS} = -0.085V (NBTS, Bias=-30V, Temp=80 °C ,2000S), ΔV_{thPBTS} =+2.57V (PBTS, Bias=30V, Temp=80°C,2000S) .

Key Words: Top Gate; IGZO TFT; Deposited Power

Session 45: Liquid-Crystal Technology 3 (Liquid-Crystal Technology)

S45.1

The study of an display device and materials for black-and-white reflective bistable display

Wenming Han

Jiangsu Hecheng Display Technology Co., Ltd.

Abstract: Black-and-white reflective bistable display devices have been widely used in display devices, such as electronic shelf label, electronic papers, and handwriting tablet, due to their features of energy saving, and reading experience close to that of traditional black-and-white papers. Several cholesteric liquid crystal materials with high Δn are described in this paper, and used to prepare black-and-white reflective bistable display devices, to realize both higher contrast and lower refresh voltage.

Key Words: Bistable; Reflective; High optical anisotropy; Cholesteric; Black-and-white; High contrast; Low refresh voltage

S45.2

Preparation and Functional Properties of Pleochroic Dichroic Dyes for Use in Nematic Liquid Crystals

Xiaolian Li*, Zhaofen Wang

Email: xlianli@dlut.edu.cn

State Key Laboratory of Fine Chemicals, Dalian University of Technology

Abstract: Dichroic dyes play an important role in the color liquid crystal displays because of their characteristic structure and the ability of being chemical modified. Guest-host liquid crystal displays have many advantages, such as displaying information in excellent colour, good contrast ratio, a large viewing angle, high brightness and the need for only one or no external polarizers at all, so they can't lead to excessive energy loss of beaming light and low brightness. A novel series of dichroic dyes have been synthesized by introducing substituents group to 1-site and 2-site of the anthraquinone. We have synthesized red, yellow, and blue dichroic dyes. These anthraquinone dyes were mixed into guest-host type black dichroic dyes for applying in GH-LCDs. Our recent progress of dichroic dyes for liquid crystal displays, including the absorption spectrum, dichroism, the solubility and the light stability in liquid crystal is reviewed in detail. The order parameter of dye molecules

in liquid crystal were determined. The future trend in synthesis and functional applications of dichroitic dyes for liquid crystal colour display is proposed.

Key Words: dichroitic dyes; light stability; anthraquinone dyes; colour liquid crystal display

Acknowledgments: We are grateful to the National Natural Science Foundation of China (21576043), supported by “the Fundamental Research Funds for the Central Universities”

S45.3

Using 1Domain pixel design to improve the transmittance rate of UV2A

Yu Zhang

Shenzhen China Star Optoelectronics Technology Co., Ltd, Guangdong,

Abstract: 1Domain pixel design UV2A has been proposed by changing the way of exposure and it has high transmittance rate performance due to the disappearance of the dark lines in pixel. In order to compare the optical performance of 1Domain/4Domain, we prepared the 32HD 1Domain/4Domain panel. We have investigated the transmittance rate, visual angle and reliability of 1Domain/4Domain, to prove that 1Domain pixel is practicability in TV panel. Although the 32HD image quality is not very good due to the grid line, it is proved that the high resolution panel can effectively avoid the generation of the grid. And finally, a method to improve the quality of 1Domain TV is proposed.

Key Words: UV2A; transmittance rate; 4Domain, 1Domain; high resolution

Session 46: Flexible OLEDs and key material technology (E-paper and Flexible Displays)

S46.1

***Invited:* A Novel Design of Magnet Array for Solving Mask Deformation**

Jian XU

Tianma Micro-electronics Co., Ltd.

Abstract: Divided masks are used to form film of designed pattern during evaporation process. Although both ends of divided mask is usually welded on the frame, it still has severe deformation due to its gravity. Various attempts have been made to solve this issue, e.g., assembling magnet array on the other side of glass substrate so as to pull ferromagnetic mask against gravity. A novel design of magnet array, called Halbach array, is employed to solve mask deformation due to gravity in this article. Through adjusting magnet arrangement, size, and property, a uniform magnetic force on the mask can be achieved to balance its gravity in relatively larger range. This article derived the equations of magnetic force exerted on ferromagnetic mask by magnet array. It allows us to optimize the magnet array to obtain appropriate magnetic force distribution. The numerical simulation indicates that, comparing with conventional magnet array, the magnetic force from Halbach magnet array has smaller fluctuation and slower decay rate, which is beneficial for evaporation process. Therefore, it is a promising method to solve the mask scratching resulting from rapid change in magnetic force from conventional magnet array.

Key Words: Halbach magnet array; Uniform magnetic force; Mask deformation

S46.2

***Invited:* Design of Coil Assembly for Solving Mask Deformation**

Yaoyang Liu

Tianma Micro-electronics Co., Ltd.

Abstract: Deformation of shadow masks utilized in OLED manufacturing may affect the homogeneity of thin film, resulting in deviation from the designed pattern and hence various defects. A new design of coil assembly is proposed to solve mask deformation due to its gravity. In this method, the superposition of uniform intensity magnetic field and uniform gradient magnetic field is yielded by combining Helmholtz coil and anti-Helmholtz coil. As a result, even magnetic force is exerted on the ferromagnetic mask to counterbalance its gravity. The main advantage of this method is that magnetic force varies slowly with vertical shifting. Both numerical simulation and theoretical derivation for circular and square coil assembly were carried out to evaluate the feasibility of this proposal. Ampere-turns of both coils can be adjusted so that the exerted force balances the mask gravity. Theoretical derivation predicted the critical ampere-turns, which is consistent to the result from numerical simulation. In this case, the resultant force applied on the mask is controllable. Therefore, mask can approach glass substrate at a slower speed and avoid related negative influences.

Key Words: Coil assembly; mask deformation; magnetic field gradient; uniform magnetic force

S46.3

Invited: A new design of metal lines with high mechanical reliability used for flexible AMOLED

Kun HU

Kunshan New Flat Panel Display Technology Center Co., Ltd, Kunshan, Jiangsu, P.R.China 215300 Kunshan Govisionox Optoelectronics Co., Ltd

Abstract: Active matrix organic light emitting diode (AMOLED) has been widely used in display field especially in flexible displays. The metal lines in flexible AMOLED play a critical role in flexible displays. For example, the micro-cracks in the metal lines lead to the electrical failure of the TFT device in AMOLED. The mechanical reliability of metal lines should be fully improved. In this article, various metal lines were designed and the mechanical reliability of metal lines was studied by cyclic bending test and simulation method. It is found that when the metal line is designed to be thin and smooth, the stress in metal lines can be effectively decreased, leading to the high mechanical reliability of metal lines.

Key Words: Mechanical reliability; Metal line; bending test; Simulation method.

S46.4

Invited: High Performance of Flexible AMOLED Display with BCE structure

Lei Wang^{1,2}, Miao Xu^{1,2}, Junbiao Peng¹

²Institute of Polymer Optoelectronic Materials and Devices South China University of Technology, Wushan Road 381#, Guangzhou, 510640, China

¹Guangzhou New Vision Opto-Electronic Technology Co., Ltd, 2nd Floor A1 Building, Huangpu District, Guangzhou, 510730, China

E-mail: mslwang@scut.edu.cn, Tel: +86-20-32203886, Fax: +86-20-32203818.

Abstract: We report a high performance foldable and rollable AMOLED display with 300 ppi (real RGB) driven by oxide thin film transistors (TFTs) based on a polyimide (PI) substrate (Fig. 1). No new defects appear on the display after 100,000 times bending with radius of curvature at 3 mm. In the oxide TFT, the Lanthanide rare earth doped In-Zn-O (Ln-IZO) is employed as the key active layer to improve the mobility

and stability. The fabricated Ln-IZO TFT with BCE process exhibits a high field-effect mobility of $\sim 40 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$, a subthreshold swing of 0.13 V/dec, and an Ion/Ioff ratio of 10^9 . Meanwhile, Al_2O_3 film prepared by the method of atomic layer deposition (ALD) is used as the encapsulation of AMOLED display.

Key Words: Foldable AMOLED; Rollable AMOLED; Oxide TFT; High Mobility; BCE Structure

S46.5

Invited: Printed Organic Thin-film Transistors: Fabrication Method and Performance Assessment

Chuan Liu

Sun Yat-sen University, Guangzhou, China

Abstract: Large area organic thin-film transistors (OTFTs) have multiple functional layers and rely on careful design of printing methods including shearing, spin-coating, screen-printing, and etc. We have coated multiple layers of semiconducting organic crystals, conducting nanowires or nanoparticles, and insulating hybrid dielectrics, on flexible substrates into high-resolution patterns. The channel length of OTFTs is down to $1 \mu\text{m}$, as fabricated by simple surface treatment and shearing without inkjet printing. However, the non-ohmic contact injection at the metal-organic interface leads to non-ideal device performance, placing obstacles in assessing the device performance and especially carrier mobility. We have developed quantitative tools to understand and extract parameters of those OTFTs with non-ideal performance. It turns out that the device performance of printed OTFTs with mobility at $0.3 \text{ cm}^2/\text{Vs}$ in $1 \mu\text{m}$ device and $7 \text{ cm}^2/\text{Vs}$ in $100 \mu\text{m}$ device, which overwhelms that of amorphous silicon and is hopeful to drive OLEDs.

Key Words: Organic thin-film transistors, printing, performance assessment

Session 47: Flexible Electronics (E-paper and Flexible Displays)

S47.1

Invited: Printing approach to making flexible stretchable wearable electronics

Zheng Cui

Suzhou Institute of Nanotech and Nano-bionics, Chinese Academy of Sciences

Abstract: Printed electronics represents a paradigm shift in electronic manufacturing. Though printing does not have the resolution comparable to microlithography patterning, it has the advantages of making electronics in large area, to be flexible and at low cost. It is an additive manufacturing with less waste of materials, less pollutants and less energy consumption. The talk will give a brief overview of what is printed electronics, the classification of printing fabrication processes and key technologies involved in printed electronics. The main focus of the talk will be the work carried at PERC to make flexible, stretchable and wearable electronic systems by printing instead of conventional lithographic patterning approach. Some recent results will be presented.

Key Words: Printed electronics; flexible electronics; stretchable electronics; wearable electronics

S47.2

Invited: Silver Nanowire Transparent Conductive Films fabricated by High-output, Large-scale R2R Coating Process for Flexible Electronics

Junliang Yang

Research Center in Changsha, Lucky HuaGuang Graphics Co., Ltd; School of Physics and Electronics, Central South University

Abstract: Flexible transparent conductive films (TCFs) are attracting much attention due to the extreme development of flexible electronics and wearable electronics. The conventional flexible TCFs indium tin oxides (ITO) deposited on polymer substrate such as polyethylene terephthalate (PET) and polyimide (PI) are not ideal candidates for highly flexible or rollable applications because of the limited fixed curvature and the easy crack after bending, which would dramatically make the sheet resistance increase by several orders of magnitude. Silver nanowire (AgNW) is an emerging TCF technology for potentially replacing conventional flexible ITO/polymer TCFs. In this presentation, we will introduce our research progress on AgNWs TCF and the high-output, large-scale roll-to-roll (R2R) fabrication, as well as its application in flexible electronics such as touch panel, display, solar cells, etc.

Key Words: Silver nanowires; transparent conductive film; flexible electronics; flexible display; touch panel

S47.3

Invited: TBD

Dongming Sun

Institute of Metallurgy, Chinese Academy of Sciences

S47.4

Invited: Flexible Sensors and Systems with Low-Dimensional Nanostructures

Guozhen Shen

State Key Laboratory for Super-lattices and Microstructures, Institute of Semiconductors, Chinese Academy of Sciences

Abstract: Over the last few decades, advancements in flexible electronics have spread across an expansive area ranging from the development of fundamental transistors, different kinds of sensing devices, and flexible organic light-emitting diode displays in various kinds of flexible substrates. This academic interest in flexible electronics will continue for some years, which is driven by the growing demand for electronics permitting lightweight design, portability, and low manufacturing cost as compared to their rigid substrate counterparts, and supported by techniques for the ceaseless miniaturization of individual elements in microelectronics.

In this talk, we will briefly introduce the most recent progress of flexible sensors designed in our group. We will first introduce our work on design and fabrication of single functional sensors including flexible photodetectors, pressure sensors, and then the multifunctional sensing systems, consisting of flexible sensors and flexible energy units, will be discussed, including flexible supercapacitor-integrated sensing systems, flexible lithium-ion battery integrated sensing systems, etc. Studies found that the performance of the designed systems exhibited stable sensing performance, in consistent with the conventional one driven by the external power source, demonstrating the feasibility of the flexible integrated sensing systems, which are promising for further large-scale and integrated applications.

Key Words: component; flexible; sensors; nanostructures; systems

S47.5

When Conventional Clothes and Wearables Become Indistinguishable

A Bold Look At The Inflexion Point In Wearable Displays

WALLEN MPHEPO

xShuu Technologies [UAB LARIAN LT]

Abstract: The experimental work in this paper demonstrates how display knowhow was applied to an industry that has yet to be disrupted by advances in flexible information display technologies. The herein work demonstrates that wearable displays from head to toes is no longer a buzz word, but a reality. A reality that is not only here to stay but even wins purely fashion awards on a global scale including in fashion capitals such as Milan, Italy. Which is where our wearable display eyewear frames, designer handbags, designer high heel shoes whose patterns and colors can be controlled via a smartphone app to match the user's outfit ensemble won the Grand Prize. Thus we shall present the wearable display fashion products here plus the research work behind their realization and hereby invite the reader to bear witness to this inflexion point. URL links to videos of the actual products in action will also be provided. If the reader cannot distinguish these wearable display products from conventional ones while they are in their selected desired static states it is by design.

Key Words: Display applications, flexible displays, flexible electronics, wearable, wearable display, fashion.

Session 48: Display Electronics

S48.1

***Invited:* The research of 3D touch technology based on capacitance touch panel**

Zhu Qiwen

Southeast University - School of Electronic Science & Engineering

Abstract: Nowadays, touch panel technology has become the most important human-computer interaction technology. Based on Atmel's maxTouch technology and Eclipse software, this paper proposes a simple algorithm, which can achieve the detection of distance between finger and the screen when the finger is close to the screen and complete the prediction of the touch point according to the self-capacitance value and Hover data. Besides, when touch event occurs, this algorithm can distinguish it into "Pop" and "Peek", just on the basis of pressure. This algorithm does not need to change the hardware of the touch panel device and achieves the function of 3D Touch. The result of repeated tests verifies the accuracy of the algorithm.

Key Words: Touch panel; 3D Touch; Self-capacitance; Hover data; Recognition algorithm

S48.2

***Invited:* A Fast TFT Threshold Voltage Sensing Method Based on Iterative Feedback**

Jianhang Fu

Shenzhen China Star Optoelectronics Technology Co., Ltd

Abstract: In this paper, we present a fast TFT threshold voltage sensing method based on iterative feedback. The sensing method is implemented on 3T1C pixel structure. One can cancel sensing error by iterative correction of sensing condition according to the sensed voltages. Using this method allows one to determine accurate relative TFT

threshold voltage V_{th} of each pixel in an AMOLED display under short time. With the accuracy of TFT relative V_{th} threshold voltage, we compensate the driving data with algorithm to significantly improve the uniformity of AMOLED display. This method is validated both on simulation and CSOT 31-inch AMOLED display.

Key Words: OLED; threshold voltage; sensing time; compensation

S48.3

***Invited:* A Brightness-Compensable Driving System for AMOLED Displays**

Yang Jinguo

Kunshan Govisionox Optoelectronics Co.,Ltd

Abstract: A brightness-compensable driving system is proposed in this work. The compensation unit built in driver IC can detect the voltage drop along ELVDD line, after which adjustment signal will be fed back complementing into Vdata signal to avoid problems of uneven brightness and gamma shift resulted from ELVDD voltage drop. Real device test results show that the proposed design can effectively keep the display brightness unchanged when ELVDD is unstable. This driving method makes it possible to achieve high brightness uniformity and stability over large area, which is essential for large-area displays with high brightness and high ppi.

Key Words: AMOLED; Brightness compensation; Driver IC; Driving system

S48.4

***Invited:* An Adaptive Contrast Enhancement of Image Using Multi-Scale Histogram Representation**

Jin Yufeng

Shenzhen China Star Optoelectronics Technology Co., Ltd

Abstract: New methods are presented to enhance images using histogram equalization. The methods include multi-scale fusion function to make local LUT with global information, and Gaussian filter function is applied to reduce hardware cost. Furthermore, one self-adaptive parameter is also employed to optimize the enhancement performance for different kinds of images.

Key Words: Histogram; Local Contrast; Multi-scale; Gaussian filter; Adaptive Parameter; HDR

S48.5

***Invited:* A Novel Driving Architecture for 280 ppi 8K4K TV Panel Using High-Mobility IGZO Technology**

Xiao-Long Chen, Ming-Jong Jou, Yi-Chien Wen, Meng Wang, Yang Zhao, CK Zhang, Chung-Yi Chiu

Shenzhen China Star Optoelectronics Technology Corporation. Guangming District, Shenzhen, Guangdong, China

E-mail:chenxiaolong01@tcl.com

Abstract: CSOT (China Star Optoelectronics Technology) has launched 8K4K LCD IGZO display system, because IGZO process is easy to apply for large size display with affordable cost. The display has diagonal size of 32 inch and its pixel density is 280 ppi (pixel per inch). The CSOT 8K4K IGZO display system consists of 2 FPGA boards for TCON (timing controller), data remapping, frame rate control, wide color gamut and high contrast ratio, etc.

Key Words: LCD; IGZO; 8K4K; pixel density; TCON

S48.6

Digital-analog-syncretized drive strategy for high definition LED microdisplays

Yuan Ji
Shanghai University

Abstract: Microdisplays are one of the most important devices in the near-to-eye systems like the head-mounted displays (HMD), smart glasses and other augmented reality applications. The microdisplay based on the LED is attracting because of its high brightness, stability and low cost. For the LED microdisplay with high resolutions and high refresh rates, the traditional digital drive method requires very high data bandwidth, and the traditional analog amplitude modulation strategy requires digital-to-analog converter (DAC) with high accuracy and high conversion speed, which is hard to implement. We propose a digital-analog-syncretized drive strategy to balance the merits and demerits of the digital drive and analog drive method. A full high definition (FHD) LED microdisplay driving circuit adapting to this drive strategy is designed and simulated. The experimental results show that the digital-analog-syncretized drive method can reduce the data bandwidth effectively. The grayscale levels can reach higher than 256 and the frame refresh rate reaches above 100Hz. As a result, the display resolution and refreshed rate is enlarged compared with the traditional full digital drive method, and the accuracy of the pixel current is improved compared with the traditional analog drive method.

Key Words: LED microdisplay; digital-to-analog converter; full high definition; digital-analog-syncretized drive strategy

Session 49: OLED Display 2 (OLEDs)

S49.1

Invited: Technologies for small and medium-sized AMOLED display

GuanZhen Peng

Tianma

Email: dz_peng@tianma.cn

Abstract: AMOLED continues to draw attention for the next generation of display technology because of its myriad advantages over other displays. Higher resolution, smaller form factor and lower power consumption are three main requirements in the mobile displays, which needs faster development and manufacturing capability to meet these requirements for OLED displays. In this presentation, Tianma would like to share the latest technical updates to meet the market needs. Moreover, the technical requirements for flexible – wearable displays will also be introduced followed by our AMOLED production and future capacity plan.

S49.2

Invited: Why is OLED in explosive growth and BOE' challenges in this war

Na Li

BOE Technology Group Co. Ltd.

Abstract: For the most of terminal brand adopt OLED panel, OLED show explosive growth. Serious contradiction between the supply side: more than 99% of the supply from S company. Imbalance between supply and demand shows in the market. Until 2020, after considering all possible new capacity, the gap is nearly 100 million. It indicates the flexible production can form scale supply in October 2017 and January 2018. Until 2020, the capacity of BOE in flexible supply can account for 35%.

Key Words: component; OLED, explosive growth, challenge

S49.3

Invited: Realization of Al₂O₃/MgO laminated structure at low temperature for thin film encapsulation in organic light-emitting diodes

Min Li, Miao Xu, Jianhua Zou, Hong Tao, Lei Wang, Zhongwei Zhou, Junbiao Peng
Institute of Polymer Optoelectronic Materials and Devices, State Key Laboratory of Luminescent Materials and Devices, South China University of Technology, Guangzhou 510640, PR China
Guangzhou New Vision Optoelectronic Co., Ltd., Guangzhou 510530, PR China
E-mail: limin@newvision-cn.com

Abstract: A laminated structure of Al₂O₃ and MgO deposited by atomic layer deposition (ALD) is used to realize a thin film encapsulation technology in organic light-emitting diodes (OLEDs). This film was targeted for achieving an excellent barrier performance. As the thickness of MgO layer increased from 0 nm to 20 nm, the physical property was transformed into crystalline state from the amorphous state. The optimized cyclic ratio of ALD Al₂O₃ and MgO exhibited very lower water vapor transmission rate (WVTR) of 4.6×10^{-6} g/m²/day evaluated by Calcium (Ca) corrosion method at 60 °C & 100% RH, owing to the formation of a terrific laminated structure. The top-emitting OLEDs encapsulated with laminated Al₂O₃/MgO show longer operating lifetime under rigorous environmental conditions. These improvements were attributed to the embedded MgO film that served as a modified layer to establish laminated structure to obstruct the gas permeation, as well as a scavenger to absorb the water molecular that alleviating the hydrolysis process of bulk Al₂O₃ material.

Key Words: organic light-emitting diodes; atomic layer deposition; thin film encapsulation; scavenger

S49.4

Invited: Development progress of Foldable AMOLED

Li Lin

Kunshan New Flat Panel Display Technology Center Co., Ltd.

Abstract: AMOLED on plastic substrates was expected to be the best candidate of a foldable display. For small bending radius display modules, however, the development of module process technologies and stress resistance materials is still an essential and challenging research subject. Here, we discuss our recent work on a foldable full function AMOLED module. A 7 inch flexible AMOLED display was fabricated using thin 3) Circular Polarizer and Touch Sensor. Pencil hardness of Cover window film's anti-scratch layer is 5H. The module can be folded with bending radius 3mm. In addition, touch panel technologies applied on this module are discussed.

Key Words: Foldable; On-cell Touch; AMOLED module

S49.5

Invited: Flexible OLED Encapsulation: TFE with ALD, Testing Method

Xing Wei Ding

Shanghai University

Abstract: Given their various advantages, organic light-emitting diode (OLED) devices have a promising future in the field of displays. As OLED is very sensitive to water vapor and oxygen, main factors affecting the service life of OLED are water and oxygen which permeate into the devices. Therefore, encapsulation technology is of great importance to OLED. With the development of display technology, flexible displays, which are light, unbreakable and foldable, are likely to replace glass substrates which are widely used currently. However, as flexible displays cannot bear

high temperature, it is particularly important to develop low-temperature thin-film encapsulation technology for flexible displays. This report introduces the structure design of encapsulating thin film prepared on the basis of ALD technology, and characterizes the WVTR of thin films by using the WVTR tester developed independently by our center (based on Ca Membrane electrical test method).

Session 50: Lighting and Emissive Materials

S50.1

Invited:

QiuHong Hu

Zhejiang Tricolor Photoelectric Technology Co., Ltd.

S50.2

Invited: Characteristics of road lighting and driving recognition

HuJiangbi, GaoXiaojuan

Beijing university of technology

Abstract: Many researches have focused on the effect of road lighting luminance on driving recognition. However, light source has many kinds of characteristics, such as color temperature and color rendering index, which play roles in improving the driving recognition efficiency. This paper proposed three characteristics, color temperature, color rendering index and luminance of road lighting to study the relationship between the characteristics of road lighting and driving recognition. 15 light combinations were designed, composed by 5 color temperatures and 4 color rendering indexes under 8 different kinds of light luminance. 12 test drivers were selected to conduct the static recognition experiment on the grey objective in different lighting environments and the change law of the driver's recognition time for the target under different characteristics of light sources was obtained. The results indicated that increasing the value of light color rendering index or color temperature can improve the visibility without the increasing of the luminance. That is the luminance needs of drivers for static recognizing the grey objective is different under different light color rendering index or color temperature and that is higher when dynamic driving. The result can provide support in designing and operating of road lighting.

Key Words: characteristics of light sources; road lighting; recognition time

S50.3

Invited: A Color Temperature Adjusting Method Based On Fuzzy Neural Network

Lv Tu

Hefei BOE display Lighting Co. Ltd.

Abstract: With the wide use of electronic products such as cell phones and personal computers, the retina blue light hazard and visual fatigue phenomena are becoming more and more serious. To solve these problems, this paper provides a color temperature adjusting method based on fuzzy neural network. The method combines fuzzy control and artificial neural network algorithm. It doesn't need accurate mathematical model. It can automatically adjust the color temperature according to surrounding environment, and reduce the blue light from the light source to a certain extent. Meanwhile, this method has the advantages of high precision and strong

robustness. MATLAB simulation results show that the method can effectively adjust the color temperature in real time.

Key Words: Back Light; color temperture; fuzzy neural network; FPGA

S50.4

Invited: Research on Tunnel Lighting Based on Visual Physiology

Xin Xu, Tongsheng Mou,
Zhejiang University

S50.5

Long persistence phosphors applied to Electrophoretic Displays

Hui-Jiuan Chen, Xiaogang Chen, Shuai Xiao, Jingshen Qiu, Bo-Ru Yang*

SYSU-CMU Shunde International Joint Research Institute, School of Electronics and Information Technology, State Key Lab of Optoelectronic Materials and Technologies, Guangdong Province Key Laboratory of Display Materials and Technologies, Sun Yat-Sen University, Guangzhou, 510275, People's Republic of China.

*Corresponding author, Bo-Ru Yang, paulyang68@me.com

Abstract: The long persistence phosphors particles (LPPs) are used as a new type of electrophoretic particles (EPs) for electrophoretic display, which has great potential to solve the problem of electronic paper can not be displayed independently in darkness. The figure 1 shows the dynamic model of long persistence phosphors, under photo excitation, a portion of the electrons are excited to emit fluorescence (transition 1), The other electrons transitions to the conduction band and is released from the trap energy level after the necessary energy is obtained, which results in long-time luminescence (transition 2). After modified, the dispersibility of the LPPs is improved, as figure 2 shows. The long persistence phosphors particles after modified can show green under light and in darkness as show in figure 3. The sizes of modified long persistence phosphors particles are from 5 to 8 μm . Their ζ potential value is -89 mV, which is enough to migrate in the electrophoretic ink liquid by the driving of an electric field. The display performance of the particles in fluorescent electronic ink devices has been characterized under the bias of 30V.

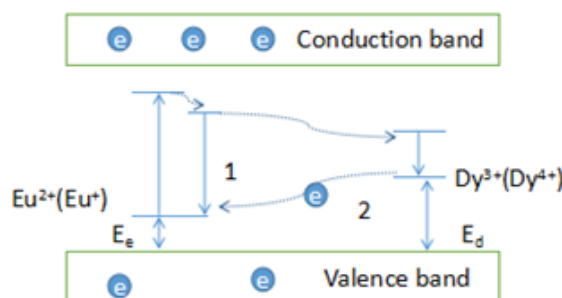


Figure 1. The dynamic model of long persistence phosphors

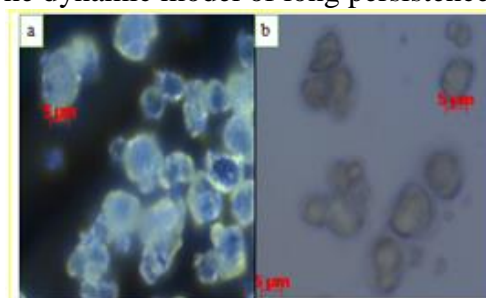


Figure 2. the long persistence phosphors under the optical microscope (a) before modified and (b) after modified

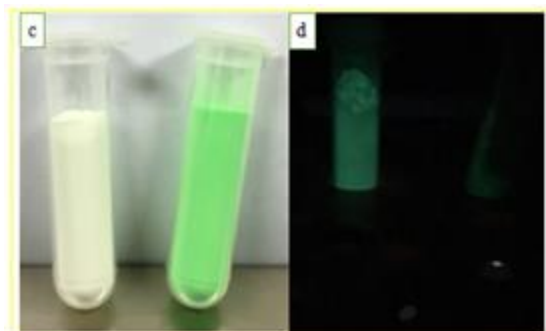


Figure 3. the optical images of LPPs and general EPs under light (c) and in the dark (d).
Key Words: Fluorescent particles; Electrophoretic display; Long afterglow luminescence

S50.6 (To Poster Session)

Synthesis and Characterization of ZnMoO₄ phosphor powders doped with Light Rare Earth Sm

Yang Yang, Tao Lu, Deng Peng, Zhaojun Liu *

Sun Yat-sen University Carnegie Mellon University Joint Institute of Engineering, School of Electronics and Information Technology, Sun Yat-sen University, Guangzhou, China

Sun Yat-sen University Carnegie Mellon University Shunde International Joint Research Institute, Shunde, China

E-mail: liuzhaojun@mail.sysu.edu.cn;

Abstract: Micro-LEDs technology has reduced the pixel pitch size from millimeter to micron in display applications, which considerably improved the resolution and definition. Besides, micro-LED can be employed as white-light backlight source of micro-display device based on blue or ultraviolet (UV) micro-LED excitation method. And orange red phosphors are key materials to increase backlight source color rendering index. This paper mainly investigated the synthesis and characterization of ZnMoO₄: Sm³⁺ phosphors for micro-LED backlight source by high temperature solid phase method. X-ray diffraction method (XRD) was employed to analyze the phosphors structure. The results showed ZnMoO₄: Sm³⁺ phosphors doping structure is in accordance with the structure of pure ZnMoO₄ phosphor. Besides after fluorescence spectrometry analysis of samples, we also investigated the trend of the spectrum and how concentration of Sm³⁺ affects the performance of phosphor luminescence.

Key Words: micro-LED backlight source; orange red phosphors; X-ray diffraction; phosphor luminescence

S50.7

Mesoporous Aluminum Hydroxide as a High Quantum Yield Blue Phosphor for UV Pumped White Light-Emitting Diodes

Bingkun Chen^{1,2*}, Andrei S. Susa², Claas Reckmeier², Stephen V. Kershaw², Yongtian Wang¹, Bingsuo Zou¹, Haizheng Zhong¹, and Andrey L. Rogach^{2*}

1. Beijing Engineering Research Center of Mixed Reality and Advanced Display, School of Optoelectronics, Beijing Institute of Technology, Beijing, 100081, China

2. Department of Physics and Materials Science & Center for Functional Photonics (CFP), City University of Hong Kong, Hong Kong S. A. R.

Abstract: Nano-sized aluminum hydroxide as an abundant and inexpensive material with wide photoluminescence spectra can be used as blue phosphor in UV pumped

white light-emitting diodes, however, low photoluminescence quantum yields limit its potential applications to a great extent. Here, we developed a single-source precursor decomposition strategy in tube furnace system to fabricate highly emissive aluminum hydroxide phosphors with quantum yield to 69 %. The aluminum hydroxide samples exhibit nano-layered and amorphous microstructure. Optical properties and structure characterizations were performed to identify the source of photoluminescence and the reason of enchanted emission of our samples, which is, F⁺ center and carbon-related defect contributing to UV (388 nm) and blue (450-520 nm) emission region would be enhanced by surface electron-donating hydroxyl groups and benefited from nano-layered and amorphous microstructure. We further demonstrated blue aluminum hydroxide phosphors as color converting materials for UV pumped light-emitting diodes. Furthermore, we combined blue aluminum hydroxide phosphors with red CuInS₂ based nanocrystals to fabricate white light-emitting diodes, and high color rendering index of ~91 has been achieved.

Key Words: component; aluminum hydroxide; rare-earth free; blue phosphor; UV WLED

Session 51: Novel Interactive Displays (Touch and Interactive Displays)

S51.1

Invited: Design and application of photosensitive sensor

Rui Xu, Haisheng Wang, Chunwei Wu, Yingming Liu, Xiaoliang Ding, Pinchao Gu, Changfeng Li, Wei Liu, Pengpeng Wang, Qingrong, Ren, Yu Wen

Abstract: Optical sensor is a kind of important application in sensor technology, It is a very important research how to convert light into electrical signals and then into the image for display. The method of the photosensor design, and the affection of different light intensity on device characteristics were analyzed in this paper, and finally we found out the direction of the optimized photosensor, and we conclude some measures how to optimized the characters of optical-sensitive sensor. And then the optical-sensitive sensors can be applied in glass or flexible matrix display factory, such as fingerprint identification or X - ray detection applications.

Key Words: optical-sensitive sensor; P-I-N

S51.2

Invited: Electrostatic Tactile Display with Localized Multiple Sensations

Hiroshi Haga

Development Division, NLT Technologies, Ltd.

Abstract: We have developed an electrostatic tactile display that presents localized sensations with multiple kinds of sensations in conjunction with visual objects on an LCD. The tactile display panel consists of a glass substrate, row and column electrodes made of indium tin oxide (ITO) on the substrate, and an insulator layer that covers the electrodes. By applying AC voltage signals to the electrodes, fluctuating electrostatic force is generated between the finger and the electrodes, which induces fluctuation of dynamic friction when the finger slides across the surface. In order to create localized sensation, beat phenomenon which arises from the combination of voltage signals between the row and column electrodes is used. The beat frequency is designed so that the frequency of the dynamic friction fluctuation is in the range

where our tactile sensory system has high sensitivity. In contrast, the driving frequency of each electrode is set to be over 1000 Hz so that the frequency of the dynamic friction fluctuation is in low sensitivity, which avoids unwanted sensations along the electrodes. For creating multiple kinds of sensations, the beat frequency is modulated using a frequency-variable voltage source. Developed prototype shows the potential of our tactile display.

Key Words: tactile display; electrostatic force; beat phenomenon; multi touch; user experience; multiple kinds of sensations

S51.3

***Invited:* Force sensing integrated display module developed for the industrial products**

Liang Liu

Tianma Micro-electronics Co., Ltd.

Abstract: As more and more smart phones allow users to interact with an application programs by force input on the display module, the demand of this kind of user interaction in an industrial product is increasing. Generally, display modules used in the industrial product have larger thickness and size, and require higher mechanical reliability than those in smart phones. We present a 7-inch display module demo with sensors added on the border of cover glass, which can sense the force applied on the display module by probing the strain. Our module has a force output of 0 ~ 1024 levels with SNR of 42 at 500gf force applied and is believed to be suitable for the industrial product.

Key Words: strain; force touch; industrial display module

S51.4

Human-computer Interaction Based on Eye Tracker and Gesture Recognition

Zhou Meng

Display R&D Center of Southeast University

Abstract: A vision-based EYE-FINGER-POINTER human-computer interaction system with a single camera is proposed in this paper, in which the cursor coordinate is calculated according to eyesight and fingertip. In this system, the captured image is analyzed to detect the user's dominant eye through the AdaBoost algorithm based on haar-like features and index fingertip through fingertip identification algorithm based on polygonal approximation method and the convexity and convexity defects. Cursor position is obtained by calculating the geometric relationship between the coordinates of the user's eye and the index fingertip. The accuracy of the system is studied by simulating the influence of distance of face and hand to the camera. Consequently, a friendly and natural interaction system is achieved as an alternative of the traditional mouse or touch panel input system.

Key Words: coordinate positioning; eye tracker; hand detection; human-computer interaction

S51.5

Light Filed Render and Optimization for Measurable 3D Depth Perception Interaction

Renjing Pei

State Key Laboratory of Management and Control for Complex Systems, Institute of Automation, Chinese Academy of Sciences

Abstract: The main benefit of 3D display over 2D display, beyond the obvious ability

to create a more lifelike character with perception of depth, is that different depth-scenes of sight presentation on 3D display device can be controlled by adjusting the disparity structure of multiview content for a realistic visual experience. However, most of the existing approaches are often reproducing a sub-optimal multiview content for inferior 3D display productions, like shifting each view image respectively by computing disparity separately. But the errors of disparity acquisition make it extremely hard to maintain a smooth motion parallax. Recently, a dense light filed controlling method solved the rough-shifting disparity problem by adjusting the slope of linear structures in epi-polar plane image (EPI). However, the view images in the each re-building dense light filed are usually severely twisted due to the discrete rendering for each EPI, and cannot be measurable. As a result, no turnkey solution exists for reproducing high quality 3D light filed for accurate depth perception interaction. In this paper, through minimizing a global spatially regularized energy functional in a novel non-convex optimization framework, we introduce a novel approach to render and optimization light filed playing up to users' depth perception requirements through a voice interaction system, based on a RGBD inputting image, aiming at controlling measurable visual presentations with fidelity 3D scenes.

Key Words: measurable depth perception; light filed rendering; epi-polar plane image; non-convex optimization component

S51.6

Integrated display assembly: from embedded touch to display-based fingerprint sensor

Kimi Lin

IHS Markit

Abstract: Embedded touch types are mature for high end and mid-range smartphone segments as well as offer form thinner stack, fewer materials (adhesive between cover glass and sensor), and simpler supply chain. The cost gap between embedded touch and add-on touch is shrinking. Most brands adopt 20%-40% portions of their demands. IHS Markit estimated that embedded touch will likely grab more than 50% shares in 2016. Furthermore, AMOLED on-cell will account for 26.4% in 2017, surpass In-cell LCD 24.2% for the first time. On the other hand, fingerprint module is becoming a standard configuration of smartphone. There are capacitance and ultrasonic two major technology roadmap for fingerprint module. However, we expect that the fingerprint feature can be integrated into display in the near future. I will expound the market trends about embedded and display-based fingerprint in this topic.

Key Words: integrated; embedded touch; capacitance; ultrasonic; fingerprint; display-based fingerprint

Session 52: Laser Projection Display and Key Devices & Applications (Projection)

S52.1

Invited: Influence of unite size of diffuser on speckle contrast in laser projector

Y. Yuan, T. Fang, Y. Bi*

The Research Center of Applied Laser, Technical Institute of Physics and Chemistry of the Chinese Academy of Sciences, Beijing 100190

Abstract: Laser speckle is observed when coherent light is reflected or transmitted

through a diffuser, which has a bad effect on the quality of image. When a diffuser illuminated by lasers, a lot of sub light sources would be produced and intervene with each other, then produces different speckle patterns. In the exposure time, the superposition of these different speckle patterns can reduce speckle contrast. As we know, the structure of the diffuser affects speckle patterns, such as the focus of micro lens, the number of micro unites and the size of diffuser. In this paper, the relationship between the size of the scattering particles and the number of speckle patterns has been theoretically analyzed. Experimentally, we have measured speckle contrast using different diffuser.

Key Words: Laser Speckle; Unite Size of Diffuser; Speckle Contrast

S52.2

Invited: Influence of Light integral rods to the speckle diversity in laser projector

T. Fang, Y. Yuan, Y. Bi

The Research Center of Applied Laser Technology, Technical Institute of Physics and Chemistry of the Chinese Academy of Sciences, Beijing 100190

Abstract: Speckle effect can be reduced by speckle pattern diversity in laser projector. speckle pattern diversity is generally obtained with laser beams pass through the moved diffuser surface, thus speckle contrast can be reduced by multiple independent speckle pattern overlay in the human eye integral time. In practical projector a light rod integrator is placed in optical system to produce a uniform optical field, but after laser beams are homogenized within a rod integrator , the speckle pattern independence can be affected. In this paper, speckle pattern diversity method is further analyzed and discussed, and the effect of light integral rods to speckle pattern is investigated.

Key Words: Light integral rods; speckle contrast; speckle pattern diversity

S52.3

Invited: The influence of optical system on speckle measurement and a speckle measurement method based on the characteristics of human eye

Minyuan Sun^{1,2}, Tao Fang¹, Yong Bi¹

1 Technical Institute of Physics and Chemistry, CAS

2 Academy of Opto-electronics, CAS

Abstract: The speckle in laser display device can be classified as subjective speckle which was consisted of the speckle pattern on screen by projector lens and the speckle pattern on retina by human eye. Usually a camera was used to measure the speckle and the result was introduced inevitable errors due to the difference of the imaging system parameters such as aperture, focal length, pixel size and so on. In this article, we discussed the influence of the optical system parameters on speckle contrast and speckle size in imaging system and proposed a speckle measurement scheme according to the characteristics of human eye.

Key Words: laser display; speckle; human eye

S52.4

Invited: The research of the speckle effect reduction based on LCOF

DD Wang, T Fang, Y Bi*

The Research Center of Applied Laser, Technical Institute of Physics and Chemistry of the Chinese Academy of Sciences, Beijing 100190

Abstract: In the technology of laser projection display, the speckle effect could result in the poor quality projection screen. This article described a method using liquid core

optical fiber (LCOF) to eliminate the speckle in laser projection display technology and discusses its mechanism. For researching the effect of speckle suppression, images with 520nm laser passing through a 2m LCOF as light source captured by a CCD image acquisition card were analyzed and compared with images without LCOF. The results of experimental comparison shows that the speckle effect of the laser projection screen modulated by LCOF could be effectively reduced

Key Words: Laser Projection Display; Liquid Core Optical Fiber; Speckle

S52.5

Invited: Research on Large Color Gamut and Multi Primary Display Based on Laser Display Technology

ZHANG Wen-ping, BI yong, GAO Wei-nan, FANG Tao, SUN Min-yuan, WANG Dong-dong, XU Zu-yan

Technical Institute Physics and Chemistry, CAS

Abstract: The trend cannot be blocked. BT.2020 color space is defined as the image signal color gamut standard of 4K/8K by ITU (International Telecommunication Union), two times of BT.709. The new color space puts forward higher requirements for UHD display devices. At present, a new generation of display technology-Laser display is a good choice. To display the new color gamut, further more, to get closer to the color space of the nature, Three primary and Multi Primary of laser display became the most important topics among display. This paper will study the Multi Primary display(MPD) color management method, and the four Primary display about color gamut, brightness, color temperature, laser parameters and time sequence modulated waveform of lasers. An appropriate timing modulation mode of the MPD is explored.

Key Words : Laser Display Technology; Large Color Gamut; MPD

S52.6

Invited: The study of three-LCOS laser projection display with RGB LD source

Wei Nan Gao(高伟男)

The Research Center of Applied Laser, Technical Institute of Physics and Chemistry of the Chinese Academy of Sciences, Beijing 100190

Abstract: In this article, three Liquid Crystal on Silicon (LCOS) laser projection using RGB laser diodes (LD) as the light sources is designed and demonstrated. The laser diodes, as the perfect light source, which are suitable for the excellent image quality display with high resolution, high brightness, large color domain coverage ratio. The laser module used by tricolor LD with high efficiency cooling setup is optimized and applied to the laser projection. And the laser beam shaping for three LCOS optical engine is also designed and fabricated. The development of the tricolor LD projection with three LCOS may promote the research and application with all LD laser source.

Key Words: laser display; RGB LD; three LCOS; laser beam shaping

Session 53: Display Applications 2 (Display Applications)

S53.1

Invited: AMOLED for Wearable Application

J. J. Lih

AU Optronics

S53.2

Invited: The Development of 5.5 inch FHD Flexible AMOLED Display

Donglun Yang (杨东伦)

Everdisplay Optronics (Shanghai) Limited (和辉光电)

Abstract: Flexible AMOLED display is the megatrend in the next-generation display market. Everdisplay Optronics (Shanghai) Limited (EDO) has been working on flexible AMOLED in the last 4 years. Recently, curve-type 5.5 inch FHD flexible AMOLED display prototype with full-structure was developed and its performance of optics and mechanics has reached the mass-production level. EDO also made great effort to decrease the front-view border. With the help of the bezel, the border can't be watched from front side, thus achieving "0-Border Display"

Key Words: AMOLED, Flexible display, curved, narrow border

S53.3

Invited: Sensors Using Semiconductor Display Technology

Lin Jiaqiang

BOE TECHNOLOGY GROUP CO., LTD

Abstract: Photovoltaic materials are widely used in sensing technology. Combined them with semiconductor display technology, we can make photo-sensor array and apply TFTs to control each sensor in the array. Thus we can measure the light density at each pixel and hence get a complete image with high resolution. Also the array can be made as large as a display. This can be benefited from large size image applications, like medical imaging systems, non-destructive test equipments, security inspection facilities, etc. In this paper we introduce some photovoltaic materials and show the performance and applications of an amorphous silicon based negative-intrinsic-positive structure photodiode array.

Key Words: sensor; photovoltaic; photodiode array

S53.4

Invited: A Privacy Liquid Crystal Display

Bo Hai

Shenzhen China Optoelectronics Technology Co., Ltd

Abstract: At present, a lot of common privacy LCD make image can't display by removing the CF Polarizer, Then use the external Polarizer such as polarized sunglasses to watch image. But it have two problems, One is the privacy effect is very poor. Because the Polarized sunglasses are very popular, the other one is when our head rotates the image quality will became bad. So this paper mainly solve above two problems. In this article, we use quarter wave plate to design a new privacy lcd. Someone else cannot watch the lcd under normal viewing environment, only use the specific device to watch the lcd. So the special lcd can effectively protect privacy. And the cost is low, easy to mass production.

Key Words: Privacy lcd; Quarter wave plate; VT curve; Contrast ratio

S53.5

Invited: See-Through Near-Eye Displays for Vision Correction

Chao Ping Chen, Lei Zhou, Yishi Wu, Keyu Wang, Bing Yu, and Yang Li

Smart Display Lab, Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai, China

Email: ccp@sjtu.edu.cn

Abstract: See-through near-eye display (NED) is a key component of augmented

reality. Unlike flat panel displays, NED is wearable and very close to the eyes. Therefore, not just the optical performance of the displays but also the vision acuity of the users needs to be considered. Unfortunately, with current NED solutions, users, who are more or less visually impaired, are required to wear extra eyeglasses. If doing so, both the user experience and device performance will be deteriorated, as the device becomes bulky and the eyes are further from the exit pupil. As an alternative, users can choose to wear contact lens or even contact-lens-like NED. But for aged people, it might not be a wise option for their eyes are dry and the removal of the contact lens is not quite convenient. Motivated by the above issue, we propose several compact designs of see-through NEDs, which feature a pair of corrective lenses coated with multiplexed volume holograms. With our designs, for those who have refractive anomalies, extra eyeglasses or contact lens are no more needed. Based on numerical simulations, field of view, modulation transfer function, and distortion have been studied.

Key Words: augmented reality; near-eye display; vision correction; volume hologram

Session 54: Manufacture of LCDs and other Non-Emissive Display Panels (Display Manufacturing)

S54.1

Advanced Molybdenum Rotary Sputtering Targets for Metal Layer Deposition in TFT-LCD Fabrication

Dr. Hennrik Schmidt

Plansee (Shanghai) High Performance Material Ltd.

Abstract: Molybdenum rotary sputtering targets manufactured by powder metallurgical processes have advantages in deposition rate and arcing behavior compared to sprayed or non-deformed material. With pressing, sintering, and deformation the microstructure, density, and texture are optimized for thin film deposition. The presentation will cover some comparison of different manufacturing routes for molybdenum based rotary targets.

Optimizing the target geometry depending on the erosion profile is one of the keys to increase target utilization for rotary sputtering targets. So called “dog-bone” shaped targets have currently only limited application in PVD equipment for TFT-LCD metallization. Combining of a recently developed new deformation process with optimized dog-bone geometry result in advanced molybdenum targets (TigerBone®).

Key Words: physical vapor deposition; rotary sputtering target; powder metallurgy

S54.2

***Invited:* Tigerbone target, higher utilization rate solution**

Qiyu Zhao

PLANSEE

S54.3

***Invited:* A found and analysis of the PS mode**

Weimin Zhang

Shenzhen China Star Optoelectronics Technology Co., Ltd.

S54.4

Invited: TOYO COLOR's challenge for the color-gamut expansion of color filter

Kenro, Sunahara 砂原建朗

Toyo Color CO.Ltd

Abstract: We Toyo Color Co. have synthesis technology to make various colorants. And also have molecular design and structure modification technology of colorant for adjusting the absorption wavelength. In order to stabilize the pigment particle and to make it easier to disperse, we apply chemical treatment technology to the particle surface. Not only with these color material technologies, but also with polymer technology/radiation curing technology of the Toyo Ink Group, we keep solving various problems of color resist from the customers.

In this presentation, I'd like to introduce our challenge for the color-gamut expansion of color filter, like DCI, BT2020, that is the future trend of flat panel display development.

私どもトヨーカラー社は様々な色素合成技術を有するとともに、吸収波長の調整のための分子修飾・構造改変技術を有している。また顔料結晶の粒子形態を整える技術とその粒子を安定化させるため、及びより分散し易くするために粒子表面にケミカル的な処理を施す技術を有している。更にはこれらの色材技術に加えてポリマー技術 / R C の技術を東洋インキグループ内に有しており、カラーフィルター用レジストインキに要求される様々な課題解決を色材からレジストまで一貫した設計で達成している。

今回は今後のパネルトレンドであるDCI・BT2020など高色域化へ向けたカラーフィルター用レジスト開発を紹介する。

S54.5

Invited: The study of HVA Process Conditions Influence Pressed Recovery Time of Panel

Gui Ning Ren (任贵宁)

Shenzhen huaxing photoelectric co., LTD(深圳华星光电有限公司)

Abstract: In this paper, it is found that the pressed recovery time of HVA panel is connected with different process conditions for liquid crystal display. The process conditions contain UV curing voltage, UV curing time, UV curing temperature and stage temperature at RM second reaction. Changing these process conditions appropriately can make the pressed recovery time of HVA panel faster.

Key Words: pressed recovery time, UV curing voltage, UV curing time, UV curing temperature

S54.6

The Property Differences of Copper Thin Films Deposited by One-step and Multi-step DC Magnetron Sputtering Technique

Hui Xia

Shenzhen China Star Optoelectronics Technology Co., Ltd.

Abstract: To match the products such as large-size and high-resolution TFT-LCD, the thicker Cu films with lower resistance are needed. A comparative study of microstructural and electrical properties of the Cu films with different thickness (420-1040nm) deposited by one-step and multi-step dc magnetron sputtering technique is presented in this paper. To investigate the influence of the deposition method on the substrate temperature, we use the temperature profiling systems to get the temperature curve during deposition. The results showed that the multi-step

method can get Cu films with lower roughness and smaller grain size due to the lower rise of temperature of the substrate. With increasing film thickness, the resistivity and stress of the films deposited by multi-step dc magnetron sputtering technique is more stable than those deposited by one-step method. In production, the lower rise of the temperature of the substrate also reduces the requirements and impact on the machines. It provides guide to Cu process for large-size and high-resolution TFT-LCD.

Key Words: Copper Thin Films; DC Magnetron Sputtering; Thickness; One-step; Multi-step; Roughness; Residual Stress; Resistivity; Resistanc; temperature curve

Session 55: Manufacture of OLEDs and Other Emissive Display Panels (Display Manufacturing)

S55.1

Invited: Development of Fabrication Processes for Main Defects in AMOLED Displays

Lu Wang

Shanghai Tianma AM-OLED Co., Ltd.

Abstract: Recent development of fabrication processes has been explained in this paper, which increases the yield rate in AMOLED displays. Defects such as the dot defect, the line defect and Mura kill when the panel lights up. Defects in layers during the process have been reduced by developing the mechanical device, chemicals and other processes to eliminate main defects on the panel. For bright dots, process improvement helps the most. Chemical and process changing both give important contribution to dark dots. Mura benefits from the mechanical device and processes optimizing. We will present detailed defects, analysis and progress in fabrication processes below.

Key Words: AMOLED displays; dot defects; Mura; process improvement

S55.2

Invited: An overview of high resolution AMOLED display's process

Chunxia Li

Shanghai Tianma AMOLED Co., Ltd

Abstract: High resolution products become more and more popular in AMOLED field, but it is restricted by OLED process. Color mixture and shadow effect account for a high proportion of OLED defect in high resolution products. The kernel of OLED process is mask simulation, fine metal mask (FMM) tension and evaporation. We analyzes the issue in the high resolution AMOLED process around three points above, and also discuss how to solve these problems in this overview.

Key Words: High resolution process; AMOLED; Fine metal mask; Simulation; Evaporation

S55.3

Invited: FMM Solution For High Resolution OLED Manufacutre

Gao Xiaoping

Anhui Tatfook Optoelectronics Technology CO.,LTD

Abstract:

1. Brief introduction of OLED evaporation process.

2. What is FMM and how it used in OLED evaporation?
3. The bottleneck of FMM development.
4. Brief introduction of some kinds of traditional technologys of FMM producing.
5. Our solution on high PPI FMM

Key Words: OLED evaporation; FMM; traditional technology of FMM; high PPI

S55.4

***Invited:* The Application of Oxide TFT in Small-Size AMOLED Display: From Simulation to Realization**

Lei Zhou

New Vision Optoelectronic Co., Ltd.

Tel: 18520661060

Email: zhoulei@newvision-cn.com

Abstract: Power consumption of display panel is critical for mobile consumer-electronic devices due to a limited battery capacity. We develop a power model of the AMOLED display and analyze the power contribution of TFT, OLED and VDD line drop. Both theoretical analysis and calculation are derived from TFT mobility, OLED luminous efficiency, pixel aperture ratio and VDD line drop. The TFT mobility from $0.1\text{cm}^2/(\text{V s})$ to $10\text{cm}^2/(\text{V s})$ is a bottleneck of display power. Metal Oxide TFT may be more suitable for AMOLED display since relatively high mobility and low fabrication temperature. High luminous efficiency of OLED and top emission structure can decrease power consumption abundantly. Furthermore, we fabricate a 2.2 inch flexible AMOLED display panel with a maximum power of 0.135W at the brightness of 535 cd/cm^2 .

Key Words: Active-matrix organic light-emitting diode (AMOLED); mobility; luminous efficiency; power consumption; flexible



Lei Zhou was born in Xiangyang, China in 1987. He received the B.Sc. degree in Microelectronics in 2010 and the M.Sc. degree in Microelectronics and solid-state electronics in 2013 from South China University of Technology, Guangzhou, China. In 2013, he joined Guangzhou New Vision Optoelectronic where he worked on AMOLED display panel design. Now he is the department manager of AMOLED panel design and he is responsible for circuit simulation, TFT panel layout, display circuit driven, demo exhibition, and display panel testing. His research interests include new pixel design, AMOLED display, touch sensor, TFT model and flexible circuit based on metal oxide thin-film transistors.

Session 56: Processing and Devices of Printing Display 1 (Printed Displays)

S56.1

***Invited:* Full color polymer light emitting Display**

Junbiao Peng*, Juanhong Wang, Congbiao Jiang, Zhiming Zhong, Zhanhao Hu, Lei Ying, Wei Xu, Jian Wang

Institute of Polymer Optoelectronic Materials and Devices State Key Laboratory of Luminescent Materials and Devices South China University of Technology

* psjbpeng@scut.edu.cn

Abstract: Polymer light emitting display (PLED) is normally fabricated by using ink-jet printing technique. It has advantages in low coat and large area during mass production. PLEDs may be used in the field of cell-phones and TV sets and attract much attention. So far, OLED display (based on small molecule) is fabricated by using vacuum thermal evaporation technology to make organic thin films in industrial production. However, low key material utilization efficiency and high cost are still bottlenecks for its widely application. Solution process, such as using inkjet printing technique to fabricate polymer films, is a promising technology for making large area, low cost, and green manufacture display. For the solution process, many key problems are still to be solved, such as, high performance polymer materials, ink formulation, high quality film process, cathode preparing by printing technique. In this presentation, I would talk about the development of our research group in polymer ink formulation, high film preparing and PLED display process.

S56.2

***Invited:* Research on full colour OLED display based on advanced Ink-jet printing technology**

Jingyao Song

Guangdong Juhua Printed display Technology Co., Ltd

Abstract: Printing OLED technology has a huge potential to achieve superb image quality, product differentiation and cost competitiveness. All major display players around the world have dedicated so many efforts to realize this next generation display technology. In order to overcome technical difficulties, massive studies has been carried on our printed OLED development, e.g. pixel definition layer (BANK layer) research, materials evaluation, device architecture optimization, ink jet printing technology development, film formation processes, panel fabrication study, etc. Based on above investigation, a full colour 4.8 inch printed OLED display has been demonstrated with ink-jet printed HIL/HTL(or IL)/R、G、B layers and deposited ETL/EIL and cathode. With this demo-display, Guangdong Juhua printed display technology Co., Ltd, a joint venture between China Star Opto-electrical technology (CSOT) and Tianma Micro-electronics(Tianma), has present its dedication and technology advantage on Printed OLED research, as well as its vision to push this advanced ink jet printing technology to future market. Acknowledgement: we would like to thank CSOT and Tianma sincerely for their fully supports on our R&D activities.

Key Words: Ink jet printing; OLED; printing technology; device architecture; pixilation

S56.3

***Invited:* New Solution Processable QLED Device with Inkjet Printing**

Xiangwei Xie*, Yang Liu**, Yixing Yang*, Weiran Cao*, Lei Qian*, Fushan Li**, Dong Fu

*TCL Corporate Research, Shenzhen 518052, China

**Institute of Optoelectronic Display, Fuzhou University, Fuzhou 350002, China

Abstract: Quantum dot light emitting diode (QLED) has been widely studied because of its attractive electro-optical properties for display application. Based on the solvent-dispersion nature of the quantum dots, many solution processes were introduced to develop QLED devices, especially for the patterning methods of quantum dots emissive pixels. Inkjet printing (IJP) is a preferred technology to

fabricate QLED devices since it is easily to pattern pixels individually. In this study, a QLED prototype device with printed HIL/HTL/QD-EML/ETL stack was demonstrated. The QLED device was printed on a pre-patterned bank substrate with 72.3PPI, which is corresponding to the 60 inch UHD TV. The mutual influence of ink formulation, printing process and substrate character is discussed.

Key Words: Quantum dot light emitting diode; QLED; ink jet printing; pixelation

S56.4

Invited: Inkjet-printed QLEDs for display applications

Zhen Changgua

NajingTechnology Corporation LTD

Abstract: High quantum yield, narrow emission bandwidths, spectral tunability, and compatibility with solution process enable quantum dots a bright future in display applications: lightweight, lower cost, thinner and flexible panels are very possible in the near future. Nevertheless, challenges of efficiency and lifetime, especially of blue QLEDs need to be addressed to further enhance the performances of displays based on quantum dots. Furthermore, high through-put low-cost process techniques such as inkjet printing, transfer printing are required for long-term success of QLED displays in the market.

Key Words: inkjet printing; QLED; display

Session 57: Processing and Devices of Printing Display 2 (Printed Displays)

S57.1

Invited: Important technologies of Ink Jet system for OLED display fabrication

Teruyuki Hayashi

Tokyo Electron Limited

Abstract: We developed the Gen. 8.5 ink jet (IJ) system for the large size OLED display. We reported the advantages of ink jet process (IJP) and the important technologies for MURA/Defect free panel fabrication by IJP.

As the method for large size OLED display fabrication, IJP has many advantages in comparison with conventional vapor deposition method. At first, by increasing the printing head units, the fabrication of OLED display by IJP can be easily scaled-up to the large mother glass size. Second, we expect that electrical short failure between anode and cathode electrodes by particle contamination is reduced by IJP, because IJP is based on soluble process. At last, OLED material utilization efficiency of IJP is higher than vacuum evaporation process, because OLED materials are not printed in the area except pixel by IJP at all. Therefore we expect low fabrication costs by IJP.

The swath-mura caused by IJ head variations, the ink mixed color issue in dry process and the oval-mura issue in baking process were already resolved by IJP equipment technologies. Those technologies were applied to develop the TELTM's Gen. 8.5 IJ system.

Key Words: OLED; Inkjet; MURA/Defect free; Dry process

S57.2

Invited: Inkjet Printing for Next Generation Display Technology

Xiao Chen

S57.3

Versatile printing technology for efficient use of OLED materials

Marcel Grooten, James Peng

DoMicro BV, Eindhoven, The Netherlands

Abstract: The development of printing technology for manufacturing OLED displays is getting more and more interest now the need for a more efficient use of materials is rising.

Therefore, in advanced display R&D institutes much work is done on subjects such as InkJet Printing (IJP) and Laser Induced Thermal Imaging (LITI), next to work on printed electronics, electrospinning for touchscreen applications. For enabling a rapid progress in these areas, versatile equipment is needed. Furthermore, it is important to anticipate on the industrialization aspects of OLED mass production based on printing processes.

This paper presents an advanced industrialization approach enabling inline mass manufacturing of OLED displays with IJP or LITI. A dedicated inline layout for process steps from the backplane to the layer deposition up to the encapsulation is shown. The layout includes a versatile cluster with three printers as well as tools for exposure, layer deposition, wet etching and encapsulation.

We conclude with recommendations on how a manufacturing process for printed displays can best be matured and developed.

Key Words: printing displays, OLED industrialization, inline display manufacturing, flexible electronics & display

S57.4

Viscosity of emissive organic inks for inkjet-printed OLED

Lv Shanhong, Ye Yun, Kang Dongru, Wang Jiangsheng, Tang Qian, Guo Tailiang

Fuzhou University

Abstract: Inkjet printing technology is a non-vacuum process and can achieve a drop-on-demand mode to bring droplets of ink with low viscosity on accurate positions on substrates. This process is very promising for manufacturing low-cost OLED displays. In this paper, we investigate 5 different solvents of making emissive organic inks for inkjet-printed OLED, among them 3,4-dimethylanisole acts as a starting point. With respect to the jetting stability without clogging the nozzle as well as the variations in drop volume, speed and jetting straightness, we find out a mixed-solvent ink for polymer yellow material (PDY-132). The viscosity of the ink as a function of temperature has been studied in order to optimize inkjet-printing process. Using this process, an OLED device of ITO/PEDOT:PSS/emissive organic layer/Ba/Ag was fabricated. Moreover, the electrical and luminescent properties of OLED devices were examined through I-V and V-L characteristics. The results showed that an appropriate ink viscosity could improve the printing process, and finally influence on the performance of OLED devices.

Key Words: Ink-jet printing; viscosity; OLED devices; inks

Session 58: Performance Optimization of Display system (Display Systems)

S58.1

Invited: OLED luminance degradation delay based on equivalent lifetime method

Rui Fan¹, Zhentao Tu¹, Xiaoning Zhang^{1*}, Taijiun Hwang², Pengfei Liang², Limin Wang²

1.Key Laboratory of Physical Electronics and Devices of the Ministry of Education, Xi'an 710049, China

2. Shenzhen China Star Optoelectronics Technology Co., Ltd. Shenzhen, China

Abstract: Life degradation is one of the primary issues influencing OLEDs display performance. OLEDs luminance degradation calculation is the premise to precisely compensate luminance so as to prolong OLEDs life. Currently degradation measurement under constant drive current is unable to be put into practice. Thus, equivalent lifetime method to estimate the luminance degradation degree and improve the lifetime of the OLEDs was proposed. The equivalent lifetime was calculated by converting the display time at different luminance with the same degradation degree with ascertained luminance decay curve. Luminance degradation of OLEDs dynamic display can be obtained to compensate luminance. The calculation accuracy can reach 99.98% and lifetime can extend 13.3%.

Key Words: OLEDs; equivalent lifetime method; dynamic degradation estimating; compensate luminance

S58.2

Invited: Optimization of luminance compensation to delay OLED degradation

Rui Fan¹, Shidong Xia¹, Zhentao Tu¹, Xiaoning Zhang^{1*}, Taijiun Hwang², Pengfei Liang², Limin Wang²

1.Key Laboratory of Physical Electronics and Devices of the Ministry of Education, Xi'an 710049, China

2. Shenzhen China Star Optoelectronics Technology Co., Ltd. Shenzhen, China

Abstract: Optimization of maximum and minimum compensation degree are to meet the actual hardware driver, display uniformity and prolong OLEDs lifetime when compensating luminance to delay OLEDs degradation. According to display uniformity optimize minimum compensation degree, the number of compensation limited by IC driver ability and actual degradation extent will affect hardware resources. Compensation number and effect of OLEDs life extension are analyzed to optimize maximum compensation degree. To OLEDs decay curve with initial luminance 5000 nits, luminance maximum and minimum compensation degree were optimized. OLEDs lifetime is 3074 hours without compensation, and it can be prolonged 28 percent after optimized compensation, in which luminance was compensated to 83% when degradation degree was 75%.

Key Words: OLEDs; optimization; compensate luminance; maximum and minimum compensation degree

S58.3

Invited: The improvement of light intensity by using multilayer ZnO films and the research of array driving circuit on HfOx film light emitting device

YU Bo-jiang, LIU Ling-guang, LIN Yuan-yuan, ZHANG Xiao-ning*

Key Laboratory of Physical Electronics and Devices of the Ministry of Education, Xi'an 710049, China

Abstract: The light emitting device composed of HfO_x high-k dielectric with different numbers of ZnO nanolayers has been fabricated and studied. To explore the relationship between light emitting characteristics and ZnO nanolayers, four kinds of ZnO nanolayer samples based on p-type silicon substrate were prepared and the properties of light emitting intensity, I-V characteristics, spectrum and surface profiles were measured. The experimental results showed that light intensity was improved with increase of the number of ZnO nanolayers, but the range of emission spectrum stayed the same. This phenomenon can be explained by the mechanism that multilayer ZnO film can make the ZnO fully diffuse in the HfO_x layer which favorable for the formation of the current paths and helpful to the luminous intensity increase. The research of array driving circuit was also explored. Through FPGA controlling, array finally displayed some simple symbols.

Key Words: Light emitting devices; Dielectric breakdown; Broad band light; ZnO-HfO_x film; Array driving circuit

S58.4

Invited: The influence of annealing heating rate on a-IGZO TFTs electric properties

He Zhanga, Xiaoning Zhang^{*, a}, Tao Xue^{b, a}, Lingguang Liu^a, Chunliang Liu^a

^aKey Laboratory of Physical Electronics and Devices of the Ministry of Education, Xi'an Jiaotong University, Xi'an 710049, P.R.China

^bCollege of Electrical and Engineering, Shannxi University of Science and Technology, Xi'an 710021, P.R.China

* E-mail:znn@xjtu.edu.cn

Abstract: The annealing processes with different heating rates on the amorphous Indium-Gallium-Zinc-Oxide (a-IGZO) thin film and thin film transistors (TFTs) were investigated. In N₂ ambient, annealing treatment with various heating rates including 0.1 °C/s, 1 °C/s, 10 °C/s, 20 °C/s and 50 °C/s were carried. The experimental results indicate that the electrical properties of a-IGZO TFTs including saturation current, carrier mobility, threshold voltage, and the ON/OFF current ratio were improved with the decrease of annealing heating rate. Compared with other annealing heating rates, the heating rate of 0.1 °C/s can make the a-IGZO TFT have the best properties such as saturation current $\sim 2.2 \times 10^{-4}$ A, carrier mobility ~ 13.2 cm²/V •s, threshold voltage ~ -3.4 V, subthreshold swing ~ 0.3 V/decade, and ON/OFF current ratio $\sim 6.3 \times 10^6$. The images of atomic force microscope (AFM) show that the slower annealing heating rate can reduce the roughness of a-IGZO films effectively, which leads a decrease of effective contact resistance between a-IGZO layer and S/D electrodes and achieve more uniform distribution of electric field, promote the TFT electric properties.

Key Words: a-IGZO TFT; anneal; heating rate; electric properties

Session 59: Poster Session

S59.1

A Liquid Crystal Lenticular Lens with High Cell Gap for Naked-eye 3D Display

Chun-Ge Yuan

SHENZHEN CHINA STAR OPTOELECTRONICS TECHNOLOGY CO.,LTD.

Abstract : A 32inch switchable autostereoscopic display using Liquid-crystal-Lenticular lens(LC lens) technology was fabricated. Dual driving system was established for split screen with independent switchable 2D/3D. In order to obtain the larger view angle and the smaller error function(EF), the cell gap of the LC lens was designed 21.35 μ m.

Currently, the normal TV panel in the market which cell gap is just about 3.5 μ m, however, in the LC lens with the high cell gap, the height of the photo spacer(PS) is almost eight times than the normal one, and the quality of a single drop of liquid crystal increased ten times than the normal one. So this LC lens with high cell gap has been achieved through improvements about the production of high photo spacer(PS) and the LC filled by one drop(ODF) process.

Finally, combining a LCD with 7680*4320 2D resolution, we obtained a 32inch switchable autostereoscopic display with good 3D quality, and verified the feasibility of the design and manufacturing process.

Key words : 3D/2D; Autostereoscopic; Switchable; LC lens;

S59.2

Metal contact effect on the performance and scaling behavior of carbon nanotube thin film transistors

Jiye Xia, Guodong Dong, Boyuan Tian, Qiuping Yan, Han Zhang, Xuelei Liang and Lianmao Peng

Key Laboratory for the Physics and Chemistry of Nanodevices and Department of Electronics,

Peking University, Beijing, 100871, China.

Email: 1301111170@pku.edu.cn

Abstract: Metal-tube contact is known to play an important role in carbon nanotube field-effect transistors (CNT-FETs) which are fabricated on individual CNTs. Less attention has been paid to the contact effect in network type carbon nanotube thin film transistors (CNT-TFTs). In this talk, we demonstrate that contact plays an even more important role in CNT-TFTs than in CNT-FETs. Although the Schottky barrier height at the metal-tube contact can be tuned by the work function of the metal, similar to the case in CNT-FETs, the contact resistance (R_c) forms a much higher proportion of the total resistance in CNT-TFTs. Interestingly, the contact resistivity was found to increase with channel length, which is a consequence of the percolating nature of the transport in CNT films, and this behavior does not exist in CNT-FETs and normal 2D Ohmic conductors. Electrical transport in CNT-TFTs has been predicted to scale with channel length by stick percolation theory. However, the scaling behavior is also impacted, or even covered up by the effect of R_c . Once the contact effect is excluded, the covered scaling behavior can be revealed correctly. We believe the findings in this paper will strengthen our understanding of CNT-TFTs, and even accelerate the commercialization of CNT-TFT technology.

Keywords: carbon nanotube; thin film transistors; contact effect; scaling behavior

S59.3

Edge Effect Induced Hump Phenomenon in Amorphous In-Ga-Zn-O Thin-film Transistors under Negative Bias Stress

Jianwen Yang,¹ Po-Yung Liao,² Ting-Chang Chang,^{2,a)} Qun Zhang,^{1,b)}

¹Department of Materials Science, National Engineering Laboratory for TFT-LCD Materials and Technologies, Fudan University, Shanghai 200433, China

2Department of Physics, National Sun Yat-Sen University, Kaohsiung 80424, Taiwan

a) Electronic mail: tcchang3708@gmail.com

b) Electronic mail: zhangqun@fudan.edu.cn

Abstract: The stability of the amorphous InGaZnO (a-IGZO) thin film transistors (TFTs) is insufficient, as it is sensitive to light, environment and bias stress. Improving the stability of a-IGZO TFTs to obtain better quality display has been an important research content. The negative bias stress (NBS) stability of a-IGZO TFTs with back-channel-etched process was investigated in this paper. The hump phenomenon appeared in the transfer characteristics along with a negative shift of threshold voltage. The magnitude of the parasitic current increases with the measured temperature, indicating that high temperature can induce more charge injection. Furthermore, this magnitude is independent on the channel width and bias voltage, illustrating that the parasitic channel originates from the holes trapping near the IGZO edges. The greater the bias voltage, the faster the hole injection, thus forming a more negative threshold voltage.

Key words: IGZO; hump; negative bias stress (NBS); thin-film-transistor (TFT).

S59.4 (Withdrawn)

Photoelectric properties and application prospect in display of MOFs

YiBiaoYin

Shenzhen China Star Optoelectronics Technology CO.,LTD

Shengfan Wu

Soochow University

Chen Ting

Color Space Technology Inc

Shilongqiang

Shenzhen China Star Optoelectronics Technology Co., Ltd.

Abstract: Metal-Organic Framework(MOFs) as a new organic-inorganic hybrid materials, has been widely used in the filed of photoelectric. By adjusting the kinds of metal ions and organic ligands' ratio and concentration, and combined with appropriate preparation methods can be constructed with different photoelectric properties of MOFs. And it can be used for light sensing, electroluminescence, photoluminescence , photovoltaic materials and other optoelectronics filed. At present, the display technology is in rapidly change stage, micro-LED, OLED, QLED and other future display technology is rapidly rising, photoelectric materials has become one of the bottlenecks restricting its development. MOF as a new kind of photoelectric materials,combined with the photoelectric properties of organic and inorganic, its unique and rich photoelectric properties have great value in the display industry research and application,and it's expected to become the breakthrough of future display technology.

Key words: Metal organic frameworks; Photoelectric properties; Display technology

S59.5

Effects of Calcium Doping on Zinc Oxide Thin Film Transistors

Wen Yu^{1,2}, Dedong Han^{2*}, Junchen Dong², Yingying Cong², Shengdong Zhang^{1,2*}, Xing Zhang² and Yi Wang²

1Shenzhen Graduate School, Peking University, Shenzhen 518055, China

2Institute of Microelectronics, Peking University, Beijing 100871, China

Abstract: High-performance calcium doped zinc oxide thin film transistors (Ca-ZnO TFTs) were successfully fabricated at low temperature. It was shown that the

sputtered Ca-ZnO films are in nanocrystal phase. The characteristics of Ca-ZnO TFTs with 3 wt % Ca content and Ca-ZnO TFTs with 10 wt % Ca content were compared. The results suggested that the Ca-ZnO TFTs (10 wt %) exhibit better electrical performances with the saturation mobility of 55.7 cm²V⁻¹s⁻¹, subthreshold slope (SS) of 0.124 V/dec, Ion/Ioff of 4.67×10⁹. In this work, we also demonstrated that the incorporation of Ca into ZnO thin film could be an effective method to reduce defects in active layer and to increase electron mobility of TFTs. The role of Ca could act as a suppressor on the growth of the columnar structure and a superior oxygen binder. Therefore, Ca-ZnO TFT will be promising for application in the next generation displays.

Keywords: Calcium doped zinc oxide (Ca-ZnO); thin film transistor (TFT); low temperature process; oxygen partial pressure.

S59.6

Fingerprint-Sensor-Integrated Display Technology Based on Three-Dimensional Dual-Gate Photosensitive Thin-Film Transistors

Huimin Li^{1,2}, Hai Ou³, Jun Chen³, Shaozhi Deng³, Ningsheng Xu³, and Kai Wang^{1,2,3*}

1SYSU-CMU Joint Institute of Engineering, School of Electronics and Information Technology, Sun Yat-sen University, Guangzhou, China

2SYSU-CMU Shunde International Joint Research Institute, Foshan, China

3Guangdong Province Key Laboratory of Display Material and Technology, School of Electronics and Information Technology, Sun Yat-sen University, Guangzhou, China

*Email: wangkai23@mail.sysu.edu.cn

Abstract: With increasing demands on mobile pay with high security, fingerprint sensor has been widely used for user's identification in mobile devices such as cell phones and tablets. However, almost all mobile devices in the market with fingerprint authentication unanimously utilize a discrete capacitive fingerprint sensor and only offer single fingerprint identification with limited security. Together with growing customers' favor on a lighter, thinner, and smarter handset, a fingerprint-sensor-integrated display with multiple fingerprints' identification is needed. We here propose an integrated fingerprint sensor technology that restructures the existing display-pixel driver a-Si:H thin-film transistor (TFT) into a three-dimensional dual-gate photosensitive FIN-TFT as an optical imager to detect light reflected from the fingerprints on the surface of the display panel. In order to fulfill dual functions of display driving and fingerprint imaging, a new pixel circuit is designed and a dual-mode operation is implemented by using a touch-initiated switch. Accordingly, a general design methodology and computer-aided-design (CAD) tool for pixel design will be presented along with detailed analysis in noise, sensitivity, and dynamic range. Further, we plan to design, fabricate, and evaluate a prototype 128×128 sensor array to enable fingerprint-sensor-integrated display applications.

Key words: Active matrix liquid crystal display; 3-D dual-gate photosensitive TFT; Fingerprint-sensor-integrated display; a-Si:H

S59.7

Research on the effects of different doping methods on Top Gate IGZO TFT

Yakov deng

Shenzhen China Star Optoelectronics Technology Co., Ltd.

Abstract: Doping has great influence to the electrical property of Top Gate IGZO TFT. By doping the activelayer of IGZO with N₂O Plasma, we find the true reason

that affects the electrical uniformity of whole substrate. Furthermore, By Doping the S/D of IGZO With AL /Ar/SiNx/ He/ No doping, We have systematically summarized how does the doping of S/D effect the Mobilty/SS/Vth/NBTS and PBTS of device. By optimizing the doping method, we have fabricated a device with good electrical uniformity and good electrical properties. With threshold voltage shift of 18 points less than 1V, Mobility=8.6 cm²/V.S; Subthreshold Swing(SS) =0.26 V/dec ;Threshold Voltage (V_{th}) =3.03V, ΔV_{th}=1.88V (NBTS, Bias=-30V, T=80 °C ,5160S) , ΔV_{th}=4.88V (PBTS, Bias=30v, T=80 °C ,5160S) .

Key words: Top-Gate; IGZO TFT; Doping

S59.8

Study of thin film properties and stress of Amorphous Si-Doped SnO₂

Honglong Ning, Xianzhe Liu, Hongke Zhang, Jianqiu Chen, Xiaoqing Li, Kuangkuang Lu, Rihui Yao[†], Miao Xu, Lei Wang, Linfeng Lan and Junbiao Peng
Institute of Polymer Optoelectronic Materials & Devices, State Key Laboratory of Luminescent Materials & Devices, South China University of Technology, Guangzhou 510640, China

[†] Corresponding author email: yaorihui@scut.edu.cn

Abstract: Flexible devices have drawn much attention in the display. The performance of flexible devices are easily affected with stress. The research of film stress is critical. In this paper, the effect of intrinsic stress on the structure and physical properties of SiSnO (STO) films was investigated. The as-deposited films were in a state of tensile stress, and the value of stress increased exponentially with increasing annealing temperature. The tensile stress can suppress the crystallization and widen the optical band gap of STO film, and also reduce the defects in STO film. The STO TFTs can exhibit better electrical performance with a saturation mobility of 6.7 cm²/Vs, a high I_{on}/I_{off} ratio of 7.34 × 10⁷, a steep sub-threshold swing of 0.625 V/decade, and a low trap density of 7.96 × 10¹¹ eV⁻¹cm⁻² at annealing temperature of 450 °C.

Key words: intrinsic stress; Si-doped SnO₂; amorphous oxide semiconductors

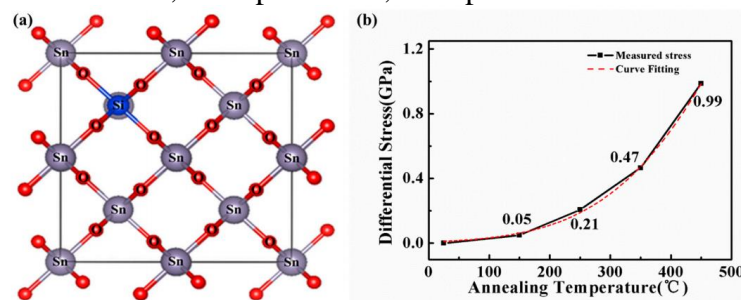


Figure 1. (a) The schematic structure of STO films; (b) The differential stress of STO films annealed at different temperatures. The red dash line represents an exponential curve fitting well with the experimental data.

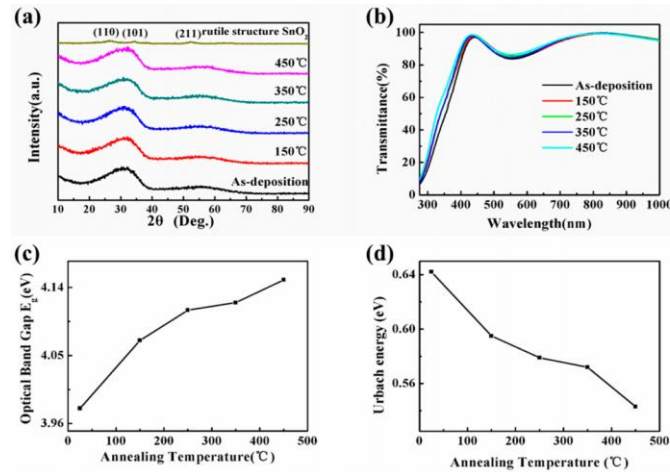


Figure 2. (a) XRD patterns, (b) transmittance, (c) band gap (E_g), and (d) Urbach energy (E_u) of 200nm thick STO thin film annealed at different temperatures.

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S59.9

Compatibility of a-IGZO Thin Film Transistors with Fabrication Process of ZnO Nanowire Field Emitter Arrays

Xiaojie Li, Xiaoming Chen, Zhipeng Zhang, Hai Ou, Juncong She, Shaozhi Deng, Ningsheng Xu, Jun Chen*

State Key Laboratory of Optoelectronic Materials and Technologies, Guangdong Province Key Laboratory of Display Material and Technology, School of Electronics and Information Technology, Sun Yat-sen University, Guangzhou 510275, China.

*E-mail: stscjun@mail.sysu.edu.cn

Abstract: Large area ZnO nanowire field emitter arrays (FEAs) is promising for application in X-ray source, electron beam lithography, field emission display, etc. Thin film transistors are used as active driving device for FEAs in order to lower driving voltage and stabilize emission current. Because the fabrication of the ZnO nanowire FEAs requires a high temperature process, whether the TFT can be compatible with the process becomes an important issue. In this study, ZnO nanowire FEAs integrated with a-IGZO TFTs were fabricated. Bottom-gate, inverted-staggered a-IGZO TFTs with a drain-offset were fabricated on glass substrate. ZnO nanowire FEAs were fabricated using a thermal oxidation method with a typical process temperature of 470 °C. It is found that the characteristics of the a-IGZO TFT degraded due to the high temperature process. The off-current increased to $\sim 1 \times 10^{-7}$ A and on/off ratio decreased to ~ 10 due to the formation of excess carriers in channel. A post-annealing process (350 °C in the N₂) is introduced to reduce the off-current. The effect of duration of the post-annealing process on the off-current is studied. The results show that off-current decreases as the annealing time increases. After 3-hour post-annealing process, the off-current decrease to $\sim 4 \times 10^{-11}$ A. The characteristics of the a-IGZO TFT after post-annealing process are sufficient for driving the ZnO nanowires field emitters. The post-annealing effectively solved the compatibility issue

of a-IGZO TFT fabrication process with that of ZnO nanowire FEAs.

Key words: a-IGZO TFT; FEAs; ZnO nanowires

S59.10 (Withdrawn)

Effect of VR on Blood Pressure and Heart Rate

Sheng-Xue Gu, Qiong-Hua Wang, and Wu-Xiang Zhao*

School of Electronic and Information Engineering, Sichuan University,
Chengdu 610065, China

(*Corresponding author: qhwang@scu.edu.cn)

Abstract: An experiment is designed to investigate the visual experience for watching video clips and playing games presented by VR display, and the participants' blood pressure and heart rate are measured by a sphygmomanometer. 16 participants, all college students with strong ability to accept new technology, respectively experience 2 VR video clips and 3 VR games. Four of these participants are patients with arrhythmia. The data obtained are used to analyze the effect of a fully immersed VR environment on the heart rate and blood pressure. The results reveal that video clips and games that contains rapid rise and fall are easy to cause high blood pressure and heart rate disorder, especially the patients with arrhythmia. One participant appears unable to persist and stop the experience halfway. And the results further reveal that VR video and games have a great potential threat to people with heart rate problems and blood pressure problems.

Key words: VR; blood pressure; heart rate; sphygmomanometer.

S59.11

Improved performance of Al₂O₃ passivated a-IGZO TFT with copper electrodes

Ning Honglong, Hu Shibei, Lu Kuankuan, Tao Ruiqiang, Yao Rihui†, Xu Miao, Wang Lei, Peng Junbiao

Institute of Polymer Optoelectronic Materials & Devices, State Key Laboratory of Luminescent Materials & Devices, South China University of Technology, Guangzhou 510640, China

† Corresponding author email: yaorihui@scut.edu.cn

Abstract: Next generation display techniques require high mobility thin film transistor (TFT) and low resistivity bus line to meet the demand for high resolution (\geq UHD), large size (≥ 80 inch) and fast frame rate (≥ 480 Hz). Amorphous Indium-Gallium-Zinc Oxide (a-IGZO) thin film transistors (TFTs) are widely used in production for their high mobility, good uniformity and low cost. Copper (Cu), which is an attractive electrode material for its low resistivity ($1.7 \mu\Omega\cdot\text{cm}$), is taken into consideration in RC-delay reduction. In mass fabrication, bus line and source/drain electrodes (S/D) are fabricated synchronously. In consequence, it's essential to carry out the research of Cu S/D on a-IGZO TFTs.

In this work, we fabricate Cu-contact a-IGZO TFT with an aluminum oxide (Al₂O₃) layer deposited on the back channel by radio frequency magnetron sputtering and an inverted staggered structure, as shown in Figure 1. The TFT having an Al₂O₃ layer shows an improved μsat of $9.9 \text{ cm}^2/\text{Vs}$, V_{on} of -1 V , SS of 0.21 V/decade and $I_{\text{on}}/I_{\text{off}}$ ratio of ~ 108 . Further studies have shown that the bombardment by the energetic particles involving sputtering process appears to play a beneficial role in the improved performance of TFTs. This improvement is due to the modification of the a-IGZO channel to reduce the concentration of oxygen vacancy sites and/or the average oxygen vacancy sites, thereby increasing the carrier concentration and decreasing the density of the trap sites, as revealed in the improved performance. It is proposed that

the sputtering process can not only passivate a-IGZO channel TFT without using an etch stop layer but also compensate the degraded performance caused by Cu diffusion since the process improves device performance.

Key words: copper interconnect, a-IGZO, Al₂O₃ passivation

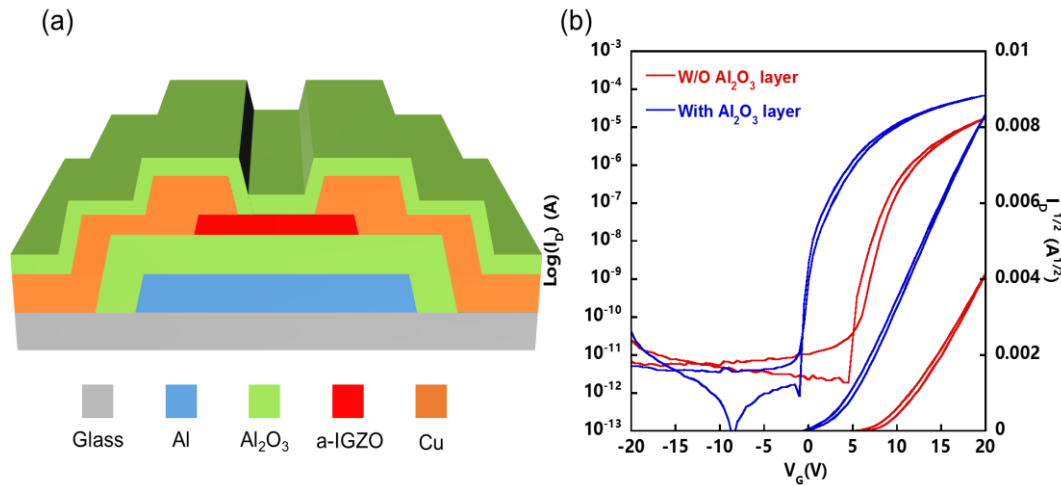


Figure 1 (a) Schematic of the TFT structure; (b) Transfer characteristics of a-IGZO TFTs

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S59.12

The heating investigation of absorption microwave by silver nanowires for transparent conductive films

Hui-Juan Chen, Zhiyang Xuan, Duohua Xu, Jingshen Qiu, Bo-Ru Yang*

SYSU-CMU Shunde International Joint Research Institute, Sun Yat-Sen University, Guangzhou, 510275, People's Republic of China, School of Electronics and Information Technology, State Key Lab of Optoelectronic Materials and Technologies, Guangdong Province Key Laboratory of Display Materials and Technologies.

*Corresponding author, Bo-Ru Yang, paulyang68@me.com

Abstract: Silver nanowires (AgNWs) are widely used in the preparation of transparent conductive film. However, the poor connection between nanowires leads to higher sheet resistance, which will reduce the conductivity of the film. In this work, the sheet resistance of AgNW networks was optimized through microwave irradiation treatment and the thermal effect of microwave irradiation on AgNW was reported. As shown in the figure 1, the nonpolar solvent as base solvent yields a tiny temperature increase, upon microwave irradiation, even if the microwave power reaches 800W, the temperature change of base solvent is less than 2K. Through the curve of AgNW in figure 1, when the power increased to 800W, the heat generated by AgNW can increase by about 90%, but the heat generated by base solution just increased by nearly 5%. From the curves in figure 2, AgNWs absorb the energy of microwave irradiation and transform the energy into heat, when the concentration increased by 100%, the heat also increased by about 100%. As shown in Table I, the sheet

resistance of AgNW thin film decrease by nearly 13%-22% after microwave irradiation.

Keywords: Silver Nanowire; Microwave; Sheet resistance

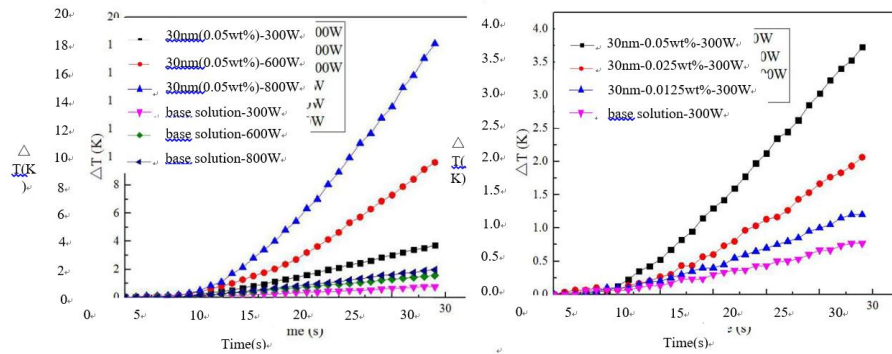


Figure. 1 Solvent was exposed to microwave irradiation.

Figure. 2 Solvent was exposed to microwave irradiation at 300W.

TABLE I. RESISTANCE BEFORE AND AFTER MICROWAVE IRRADIATION OF AgNW FILMS.

Glass substrate	Sample1	Sample2	Sample3
Before R(Ω/sg)	646	737	672
After R(Ω/sg)	500	638	523

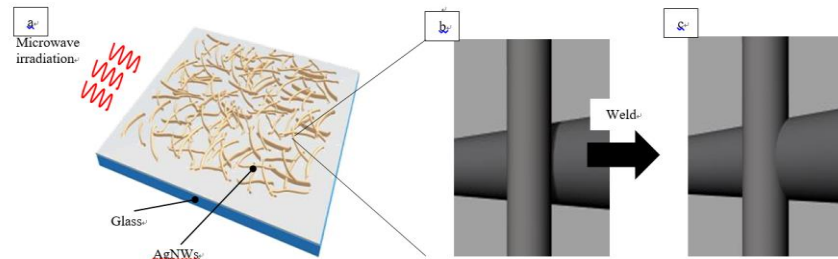


Figure. 3 The effect of microwave irradiation for transparent conductive film. (a)transparent conductive film under microwave irradiation. (b)AgNW before microwave irradiation treatment. (c)AgNW after microwave irradiation treatment.

S59.13

Criteria for uniform color space and the effect on color image processing on high dynamic range display systems

Jingyu Fang

Huawei Technologies Co.,Ltd.

Abstract: High dynamic range uniform color spaces (HDR-UCS), such as ICtCp from Dolby and zICaCb from Zhejiang University & Huawei, have been proposed and they aim to achieve more efficient coding, processing, and representing of HDR contents. The performance and merits of those recently published HDR-UCS were evaluated in this study. A novel test pattern was designed using a set of visually uniform color samples from Munsell color order system. It was used for quantitative evaluation of hue linearity and visual uniformity within each HDR-UCS. Consequently, zICaCb outperforms ICtCp in lightness and hue domains, since design of the perceptual quantizer curve appears to lack of visual uniformity, inspite of an advantage of color coding efficacy. Specifically, the average color difference between scale adjusted in zICaCb and ground truth Munsell color is 2.3 CIELAB units while that for ICtCP is around 10.7 CIELAB units. However, performance of zICaCb in chroma domain was not reaching that of ICtCp. The average color difference of zICaCb is shown around 2.1 CIELAB units, while ICtCp around 1.1 units. This may be due to its undesirable color shifting in low-chroma region.

Key-words: high dynamic range; uniform color space; color image processing;

S59.14

The Investigation of Photo-alignment Polyimide material structure For In-plane Liquid Crystal Technology

Wei Ren*, Chung-Ching Hsieh*, Yong-Chao Zhao*, Ren-Tang Zhao*, Yan-Jun Song*, Xiang Li*, Yu Zhang*, Chun-Ge Yuan*, Chung-Yi Chiu, Chia-Yu Lee*

*Shenzhen China Star Optoelectronics Technology Co., Ltd, Guangdong, China

Abstract: The in-plane switching (IPS) liquid crystal display (LCD) mode in large size TV display have been one of important modes because of its various merits such as high transmittance. A new photo alignment material for fringe field in-plane switching (IPS) liquid crystal display has been presented and it has good alignment performance. It realizes alignment by irradiating linearly polarized light with wavelength of 313nm, however 313nm Cross-link Photo alignment not only by linearly polarized UV exposure but also should be P2UV improve Image sticking performance. We have investigated Polyimide only by linearly polarized UV exposure with improvement polyimide material structure. An excellent cell Process flow less and Manufactures cost less property can be achieved by optimized polyimide material structure. This optimized material realizing photo alignment is based on photo Cross-link of 313nm. The excellent optical property and good photo alignability can be obtained only by once LPUV exposure.

Key-word: Photo alignment, LPUV 313nm, Cross-link

S59.15

The Light Path Simulation For Single Liquid Crystal Lens Based on ZEMAX

YANG Lan, WANG Minshuai, XU GongQin, CAI Xiaomei, ZOU WeiDong, GUO Tailiang,^{2*}

(1. College of Science, Jimei University, Xiamen 361021, China;

2. College of Physics and Information Engineering, Fuzhou University, Fuzhou 350002, China;)

Abstract: Liquid crystal lens is a kind of novel optical-electrical micro-nano devices which combines the micro-lens fabrication techniques and good opto-electrical characteristic of liquid crystal material. In order to solve difficult issues in conventional autostereoscopic display technology, such as 2D / 3D communion, the liquid crystal lens had been applied widely. Based on via Fermat's principle and ZEMAX optical design software, the focusing and converging imaging capability characteristic about a single-layer structure and double lens structure of the liquid crystal lens be contrasted. It is shown that two-layer structure of the liquid crystal lens is able to realize better focus range with an effective focus length (EFL) as long as 7.643mm and improved image quality.

Key-words: autostereoscopic display; Liquid Crystal; ZEMAX; optical design software;

S59.16

Ultrathin Channel and Large-area MoS₂ Thin Film Transistors (TFTs)

Xi Liu, Heshen Wang, Zhaojun Liu*

Electrical Computer Engineering, Carnegie Mellon University, Pittsburgh, PA.

SYSU-CMU Joint Institute of Engineering, School of Electronics and Information Technology, Sun Yat-sen University, Guangzhou, China.

E-mail: liuzhaojun@mail.sysu.edu.cn;

Abstract: Owing to the direct bandgap and ultrathin channel thickness, two-dimensional semiconductor materials have stimulated a lot of interests. However,

the study of implementing two dimension materials for thin film transistors (TFTs) is lacking. The key issue is to synthesize large area of high quality MoS₂ thin film. Here we report a synthesis that can produce centimeter area of MoS₂ thin film with high coverage and superior uniformity. The Raman spectrum and Photoluminescence proved the MoS₂ thin film has few-layer structure. The TFTs fabricated using the product have on-off ratio around 10⁵. The devices can be further improving by using high-k dielectrics. The large-area few-layer MoS₂ material provides a high possibility of novel displays with transition metal dichalcogenides (TMDs) thin film transistors.

Key-words: System on panel, micro-LED display, active matrix

S59.17

Fabrication and properties of patterned ZnO arrays prepared by inkjet printing

Kang Dong-ru, Ye Yun*, Lv Shan-hong, Wang Jiang-sheng, Guo Tai-liang

Abstract: Inkjet printing technology has drawn tremendous interest for its low material consumption, high patterned layer flexibility and reduced processing procedures. In this paper, patterned ZnO arrays were obtained by inkjet printed ZnO seed layer and electrochemical deposited ZnO arrays. Firstly, the sol-gel precursor ink was prepared through dissolving zinc acetate dihydrate in anhydrous 2-methoxy-ethanol. The ink was sonicated to prevent from agglomeration and clogging of nozzle. Then, the ZnO seed layer was inkjet printed into a desired pattern formation on the substrate. Finally, ZnO arrays were growth from patterned layer by electrochemical deposition. The morphology and structure characteristics of as-prepared ZnO arrays were investigated by scanning electron microscope (SEM) and X-ray diffraction (XRD), respectively. And their field emission properties were also studied. The results showed that the proposed process could grow ZnO arrays in patterned seed layer. The ZnO arrays based on inkjet printing was a promising field emission materials.

Key-words: Inkjet printing; precursor ink; ZnO seed layer

S59.18

Fault Isolation and Failure Analysis Study in the State-Of-Art Thin-Film Transistor

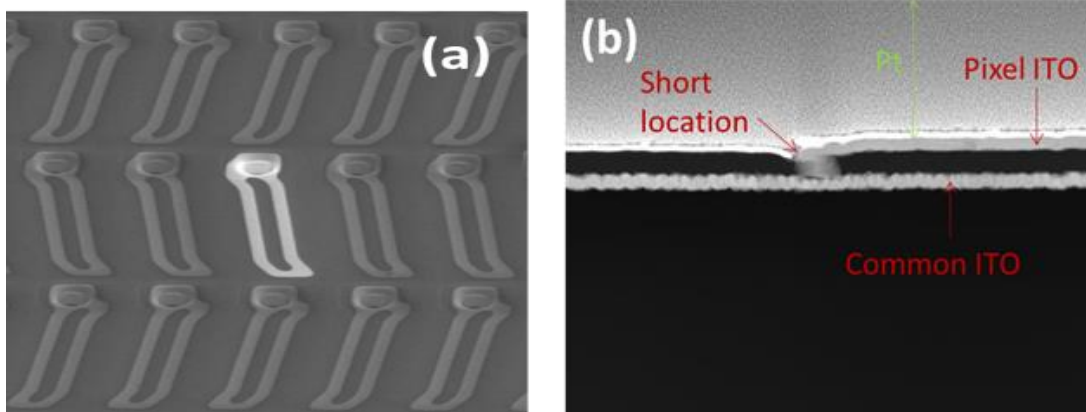
Chao Fu, Younan Hua and Xiaomin Li

WinTech Nano-Technology Services Pte. Ltd.

10 Science Park Road, #03-26 & #03-28, The Alpha, Singapore Science Park II, Singapore 117684

Phone: (+65-67777354) No. Fax: (+65-67772462) No. Email: fuchao@wintech-nano.com

Abstract: In this work, we discussed the fault isolation method for Thin-Film Transistor (TFT). Many defects in TFT can be directly observed by optical microscope; however, for some defects, they are not visible in either optical microscope or SEM, which makes the fault isolation very challenging. We demonstrated that OBIRCH can be used to find the defect location in the leakage/short type TFT failure. The TFT is so fragile that the laser power and biasing voltage have to be very carefully controlled to avoid damaging the TFT. After identifying the defect location by OBIRCH hot spot, the following TEM analysis has successfully captured the defect.



Key-words: Failure Analysis, FIB, TEM, EMMI, OBIRCH,

S59.19

Design of Active Matrix Micro-LED Displays with Time Sequential Gray-Scale Methods

Tao Lu, Yang Yang, Ke Zhang, Zhaojun Liu *

Sun Yat-sen University Carnegie Mellon University Joint Institute of Engineering, School of Electronics and Information Technology, Sun Yat-sen University, Guangzhou, China

Sun Yat-sen University Carnegie Mellon University Shunde International Joint Research Institute, Shunde, China

E-mail: liuzhaojun@mail.sysu.edu.cn;

Abstract: Micro-LED has attracted increasing attention for its obvious advantage of self-emission, long lifetime, low power consumption. AM (active matrix) driving circuits is one of the best candidates for driving which can effectively eliminate the crosstalk issues with higher driving capability and lower power consumption. One of the classic AM circuits was 2T1C which requires at least two transistors (addressing transistor M1 and driving transistor M2) and a storage capacitor. Scanning signals and data signals were also used to control the illumination of the LED pixels. Besides, the data signal can be “memorized” in the storage capacitor, leading to a continuous desired current. However the I-V characteristic of active matrix addressed micro-LED was nonlinear, while there is a linear correlativity between the current and the luminance of micro-LEDs. As a result, it is difficult to achieve gray scale. In this paper, we proposed a time sequential method based on 2T1C voltage controlled current source(VCCS) of AM circuits. The light frame can be divided to a 5-bit (Pulse Width Modulation)PWM frame,including PWM16/8/4/2/1. Then, after implementing different combination of the 5-bit frame, gray-scale of the displays can be achieved by the integral of time. In this way, micro-LED display can be effectively realized.

Key-words: Micro-LED display, active matrix, 2T1C, gray scale

S59.20

Alcohol-Soluble Quantum Dots: Enhanced Solution Processability and Charge Injection for Electroluminescence Devices

Shuai Chang, Haizheng Zhong

Beijing Institute of Technology

Abstract: General and versatile ligand exchange routes are developed for converting non-polar solvent soluble quantum dots to alcohol-soluble. Through ligand exchange, long-chain methyl-terminated oleylamine on quantum dots' surface can be substituted

by the short-chain hydroxyl-terminated 6-mercaptohexanol, enabling their dispersibility in polar organic solvents including methanol, ethanol and dimethylformamide. The resulted alcohol-soluble quantum dots maintained their optical properties and perfectly fit the requirements for solution processed electroluminescence devices. Furthermore, by replacing the processing solvent from normally toxic non-polar solvents to less toxic alcoholic solvents, the alcohol-soluble quantum dots are promising materials towards green manufacturing. Light emitting diode based on the alcohol-soluble quantum dots eclipsed their counterparts made from non-polar solvent soluble quantum dots. The improvement of device performance is ascribed to decreased energy barriers and increased charge injection rate between charge transport layer and the emitting layer. The hydroxyl-terminated alcohol-soluble quantum dots provide a new materials platform for the design of high efficient quantum dot light emitting diodes, and also enable an alternative route to achieve RGB display devices.

Key-words: ligand exchange; alcohol-soluble; quantum dot light-emitting diodes; solution processability; charge injection

S59.21

Investigation of Pulse Oxygen Saturation Measurement

Based on Multi-Wavelength Micro-LED Array

Lihuan Qin, Zhaobin Xiong, Ke Zhang, Zhaojun Liu *

Sun Yat-sen University Carnegie Mellon University Joint Institute of Engineering, School of Electronics and Information Technology, Sun Yat-sen University, Guangzhou, China

Sun Yat-sen University Carnegie Mellon University Shunde International Joint Research Institute, Shunde, China

E-mail: liuzhaojun@mail.sysu.edu.cn;

Abstract: Dual-wavelength(red and infrared) LEDs are traditionally used for pulse oxygen saturation measurement on the base of Lambert-Beer law. However there is still an urgent need for a comprehensive, high efficiency, and low power consumption method for multiple light-delivery and detection deep into the tissue. Most reported studies were limited to test only two major hemoglobin in the body and failed to simulate other trace hemoglobin, leading to an incomplete test results. Here, we proposed a novel approach to the design of probes comprising of 4×4 micro-LED arrays due to its obvious advantage of long lifetime, small size, low power consumption and high brightness. The array includes eight kinds of light($\lambda \sim 606-980nm$) so that the emission wavelength can be tuned to stimulate a variety of hemoglobin, especially for the carboxyhemoglobin and methemoglobin which are in very low concentration in the blood . Photodetector was utilized with dynamic spectroscopy method to measure more data about hemoglobin through the reflected light. The measurement errors will be reduced effectively and consequently a more accurate result of the body's oxygen saturation can be obtained. This novel design is compact and can be attached onto a flexible film. It is suitable for mobile medical devices and brings greatly convenience to the biomedical engineering.

Key-words: Pulse oxygen saturation, multi-wavelength, micro-LED array, dynamic spectroscopy

S59.22

Large-Area and Flexible Transfer-Printed Pixelated-addressable Micro-LED Displays

Deng Peng, Ke Zhang, Zhaojun Liu *

Sun Yat-sen University Carnegie Mellon University Joint Institute of Engineering,
School of Electronics and Information Technology, Sun Yat-sen University,
Guangzhou, China

Sun Yat-sen University Carnegie Mellon University Shunde International Joint
Research Institute, Shunde, China

E-mail: liuzhaojun@mail.sysu.edu.cn;

Abstract: Currently micro-LED displays for large-area outdoor/indoor screens were fabricated by sequentially transferring and bonding single LED pixel to passive- or active-addressable backplanes. Such approach has better alignment accuracy and stability between micro-LED pixels and contact pads on backplane. However, it is not appropriate for mass production because of its poor efficiency and complicated manufacturing process. In this paper, we proposed a large-area and flexible transfer-printed approach for micro-LED displays based on wafer-level integration. Fabricated micro-LED array which is originally adhered to blue tape was expanded isotropically by chip expanding machine. Then the array was transferred to an ultraviolet (UV) dicing tape for further expansion to match the welding positions of target substrate. Convertible pitches of the micro-LED arrays can be obtained by fine-tuning the stretching parameters when repeating this procedure. Then the micro-LED arrays were transfer-printed onto predesigned passive-matrix or active matrix backplane. Anisotropic conductive films (ACF) were employed to connect electrodes of the micro-LED array and metal contacts of the backplane. Compared with traditional methods for fabricating micro-LED displays, this more reliable and higher throughput method has great potential for high performance large-area flexible/inflexible micro-LED panels.

Key-words: Flexible transfer-printed, micro-LED displays, anisotropic conductive film

S59.23

Design of Three-dimensional Micro-LED Display System

Zhaobin Xiong, Lihuan Qin, Deng Peng, Zhaojun Liu*

Sun Yat-sen University Carnegie Mellon University Joint Institute of Engineering,
School of Electronics and Information Technology, Sun Yat-sen University,
Guangzhou, China

Sun Yat-sen University Carnegie Mellon University Shunde International Joint
Research Institute, Shunde, China

E-mail: liuzhaojun@mail.sysu.edu.cn;

Abstract: Traditional three-dimensional (3D) LED displays have many disadvantages to present a real-dimensional scene because of their large pixel pitch and poor color mixture. In this paper, we proposed a design of $8 \times 8 \times 8$ RGB 3D micro-LED display system based on chip on film (CoF). Each pixel of the 3D micro-LED display system contains a red, a green and a blue (RGB) micro-LED chip. And the RGB micro-LED chips were bonded onto the transparent thin film circuit plank using anisotropic conductive adhesive (ACA) with a pixel pitch of 3 mm. After the integration, a layer-row-dot (LRD) scanning scheme was employed to address each pixel of the 3D micro-LED display, which can minimize the number of periphery driving chips. The system can dynamically and statically display characters, images and animations, and even can be applied for wearable devices. It provides a theoretical and practical basis for the further development of 3D display and future wearable equipment.

Key-words: micro-LED, three-Dimensional display, thin film circuit plank

S59.24

Study on color electrophoretic nanoparticles modified by CTAB and SDBS for electrophoretic display applicationson

Hui-Juan Chen , Meng-Qi He , Di-An Lin , Jie-Fang Huang , Bo-Ru Yang*

SYSU-CMU Shunde International Joint Research Institute, Sun Yat-Sen University, Guangzhou, 510275, People's Republic of China, School of Electronics and Information Technology, State Key Lab of Optoelectronic Materials and Technologies, Guangdong Province Key Laboratory of Display Materials and Technologies.

*Corresponding author, Bo-Ru Yang, paulyang68@me.com

Abstract: The Fe_2O_3 nanoparticles nanoparticles was successfully prepared by modifier to improve the electrophoretic properties and dispersionability in organic medium. Cationic surfactant Hexadecyl trimethyl ammonium Bromide (CTAB) and anionic surfactant sodium dodecyl benzene sulfonate (SDBS) were used as the surface modifier. The results showed that the ξ potential of the particles modified with different concentration modifiers is different, for the same type of electrolytes, higher concentration of the modifier is, the greater ξ potential would be. The dispersity and sedimentation of the modified Fe_2O_3 nanoparticles in tetrachloroethylene, silicone oil, Isopar G, Isopar H and Isopar M were also studied. It has been observed that in these dispersion medium, the electrophoretic particles modified by CTAB and SDBS had the lowest sedimentation rate and the best dispersibility in Isopar G.

Key-words: Nanoparticles modifiedparticles, Electrophoretic display, Color electrophoresis devices

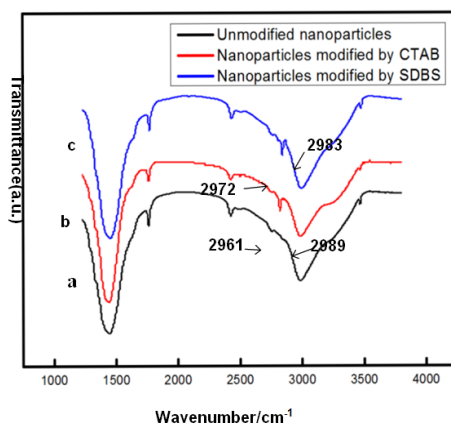


Figure .1 FT-IR of (a) unmodified nanoparticles (b) nanoparticles modified by CTAB (c) nanoparticles modified

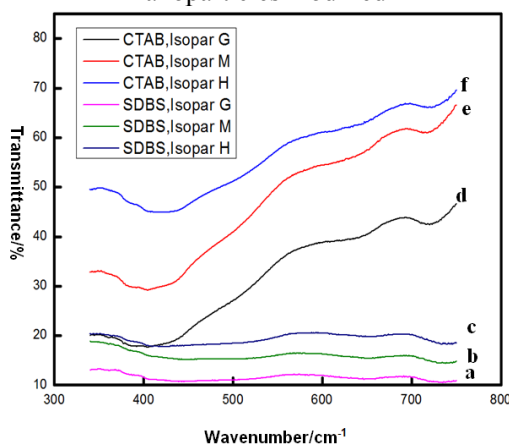


Figure.2 Transmittance of nanoparticles modified by SDBS in (a) Isopar G (b) Isopar H (c) Isopar M and nanoparticles

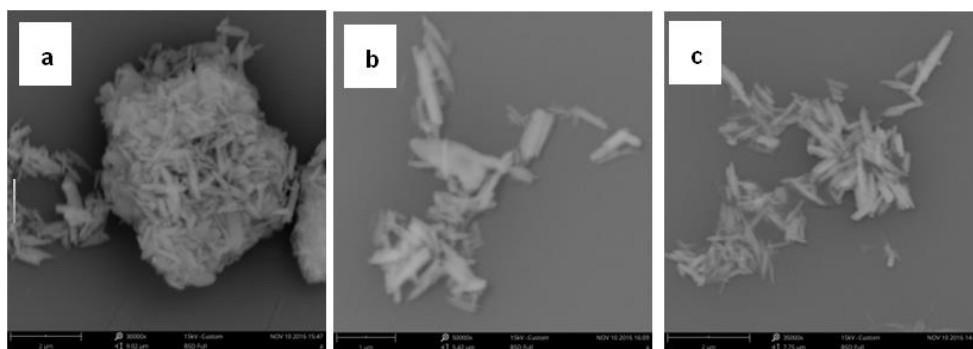


Figure. 3 SEM images of (a) raw material (b) modified by CTAB (c) modified by SDBS

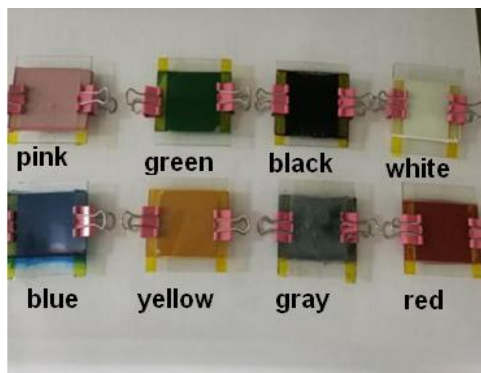


Figure .4 Color electrophoresis devices

In Figure 1, The absorption peak of methyl group and methylene group in CTAB is 2846 cm^{-1} and 2919 cm^{-1} , and the absorption peak of methyl group and methylene group in CTAB is 2840 cm^{-1} and 2906 cm^{-1} . The final analysis conclusion: the surfaces of the Fe_2O_3 nanoparticles were modified by CTAB, SDBS. In Figure 2, the modified particles had the lowest transmittance in Isopar G, indicating that the modified particles had the best dispersibility in Isopar G.

S59.25

Using Poly styrenesulfonate to Modify Red Electrophoretic Particles

Hui-Juan Chen, Sai-Sai Xue, Cheng-Lin Liu, Jing-Shen Qiu, Bo-Ru Yang*

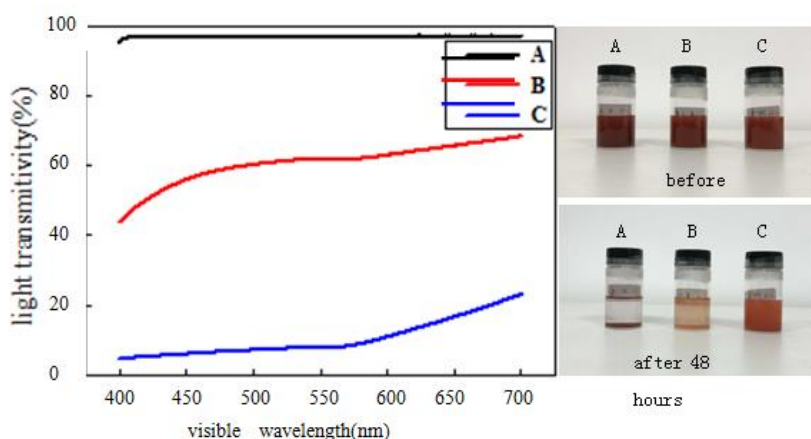
School of Electronics and Information Technology, State Key Lab of Optoelectronic Materials and Technologies, Guangdong Province Key Laboratory of Display Materials and Technologies, SYSU-CMU Shunde International Joint Research Institute, Sun Yat-Sen University, Guangzhou, 510275, People's Republic of China.

*Corresponding author, Bo-Ru Yang, paulyang68@me.com

Abstract: In order to study the color electrophoretic particle surface modification, an approach was designed and used to modifying red electrophoretic particles based on Fe_2O_3 particles for Electronic Inks. Compared with organic particles, inorganic particles have better optical properties, more stable chemical properties, and are low cost. Since the surface properties of inorganic particles are mostly hydrophilic, surface modification is essential to use inorganic particles as electrophoretic particles. In the proposed method, these Fe_2O_3 nanoparticles were encapsulated by Poly styrenesulfonate (PSS). In addition, the electrophoretic suspension was also targeted designed based on Isopar H. The experimental results showed that the electrophoretic suspensions were more resistant to sedimentation after modifying the particles and designing the suspension. And the zeta potential of the Fe_2O_3 nanoparticles increased

from 11mv to 66mv, which demonstrated that it was an effective approach to modify the Fe₂O₃ particles. The method can be used not only for red electrophoretic display but also for electrophoretic display of other colors.

Key-words: Electronic Particles, Fe₂O₃ nanoparticles, Chromatic display



A: unmodified particles were dispersed in Isopar H
 B: unmodified particles were dispersed in designed suspension
 C: modified particles were dispersed in designed suspension

Fig. 1 Sedimentation of comparative experiments



Fig. 2 Color electrophoresis devices

Table. 1 Zeta potential of the samples

Sample	Zeta Potential(mv)
A	11
B	32
C	66

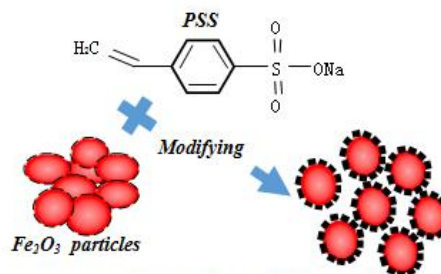


Fig. 3 The process of modifying

S59.26

Study of carrier adjusting layer on electroluminescent and ultraviolet detective properties of organic optoelectronic integrated device

Dianli Zhou *

School of Optoelectronic Information University of Electronic Science and Technology of China (UESTC)*

E-mail: dlzhou@outlook.com

Abstract: Organic optoelectronic integrated device (OID) with ultraviolet (UV) photodetective and electroluminescent (EL) properties was constructed by using four kinds of organic materials with various film thicknesses as carrier adjusting layer (CAL). The effect of CAL on the performance of OID was studied via energy level regulation, simulation of optical density distribution and charge transport analyses. Three orders of magnitude in UV-detectivity from 10¹⁰ to 10¹² Jones, and five folds of luminance from 3000 to 23000 cd/m², were achieved by optimizing the species and thickness of CAL materials. We found that the energy level and thickness of CAL play important roles on the improvement of EL and UV detective properties. On one hand, the energy difference of highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) between hole transport layer and active layer has a significant effect on the EL property through adjusting hole injection and

passivating leaking current processes. On the other hand, the optimized CAL thickness is beneficial to enhance the distribution of optical density in the active layer, leading to more photocurrent generation for high UV detective property. Meanwhile, the CAL can trap leaking electrons to decrease the dark current for high detective performance. Moreover, both high EL and UV detective properties of OID can be simultaneously achieved by emulating calculation the carrier transport length of CAL.

Key-words: organic optoelectronic integrated device; organic light-emitting diodes; organic photodetectors; carrier adjusting layer

S59.27

Color-tunable OLEDs based on Exciton Adjusting Layer

Run Wang *

University of Electronic Science and Technology of China(UESTC)

E-mail: wangrun_uestc@163.com

Abstract: A series of voltage-controlled color-tunable organic light-emitting devices (OLEDs) based on exciton adjusting layer (EAL) are fabricated. The structure of the devices is ITO/NPB/FIr6/EAL/(t-bt)2Ir(acac)/Bphen/Mg:Ag. Three different charge transport materials including mCP, TAPC and TPBi as exciton adjusting layer is inserted between blue and yellow emissive layers, respectively. Comparing three kinds of EBL, the luminescent characteristics and color-tunable properties of the devices are investigated. The device consisting of mCP EBL color coordinates from (0.38, 0.41) to (0.21, 0.32) with the resultant current and power efficiency varied from 36.2 to 3.7 cd/A and 26.4 to 2.2 lm/W at 2500 to 15450 cd/m², which exhibited the broadest color tuning range. Meanwhile, the device based on TPBi EBL shows the opposite color-tuning sequence and slightly higher tuning voltages.

Key-words: organic light-emitting devices (OLEDs); color-tunable property; exciton adjusting layer.

Author Index

A		<i>F. Gao</i>	<i>S31.3</i>	<i>J. J. Liu</i>	<i>S53.1</i>
<i>A. F. Lu</i>	<i>S6.3</i>	<i>F. Hou</i>	<i>S32.1</i>	<i>J. Jang</i>	<i>S30.1</i>
<i>A. Ghosh</i>	<i>S17.1</i>	<i>F. K. Shan</i>	<i>S21.2</i>	<i>J. Kang</i>	<i>S7.1</i>
<i>A. Nathan</i>	<i>S3.5</i>	<i>F. Wu</i>	<i>S19.3</i>	<i>J. L. Chen</i>	<i>S3.4</i>
<i>A. Obolda</i>	<i>S34.2</i>	<i>F. X. Wang</i>	<i>S24.4</i>	<i>J. L. Yang</i>	<i>S47.2</i>
<i>A. Suzuki</i>	<i>S27.3</i>	<i>F. Yan</i>	<i>S13.1</i>	<i>J. Li</i>	<i>S44.2</i>
<i>A. W. Tang</i>	<i>S11.2</i>	G		<i>J. M. Wang</i>	<i>S12.1</i>
<i>Ao Liu</i>	<i>S28.1</i>	<i>G. L. Hua</i>	<i>S41.3</i>	<i>J. P. Wang</i>	<i>S7.4</i>
B		<i>G. N. Ren</i>	<i>S54.5</i>	<i>J. Q. Lin</i>	<i>S53.3</i>
<i>B. Chen</i>	<i>S50.7</i>	<i>G. Wen</i>	<i>S39.2</i>	<i>J. Tang</i>	<i>S22.5</i>
<i>B. D. Choi</i>	<i>S9.1</i>	<i>G. Z. Peng</i>	<i>S49.1</i>	<i>J. W. Yang</i>	<i>S59.3</i>
<i>B. Hai</i>	<i>S53.4</i>	<i>G. Z. Shen</i>	<i>S47.4</i>	<i>J. W. Zhao</i>	<i>S14.4</i>
<i>B. J. YU</i>	<i>S58.3</i>	H		<i>J. W. Zhou</i>	<i>S32.5</i>
<i>B. Lin</i>	<i>S44.1</i>	<i>H. Z. Ga</i>	<i>S58.4</i>	<i>J. X. Tang</i>	<i>S33.3</i>
<i>B. Liu</i>	<i>S25.6</i>	<i>H. B. Sun</i>	<i>S17.3</i>	<i>J. Y. Fang</i>	<i>S59.13</i>
<i>B. Liu</i>	<i>S44.1</i>	<i>H. Cheng</i>	<i>S50.5</i>	<i>J. Y. Xia</i>	<i>S59.2</i>
<i>B. Liu</i>	<i>S12.3</i>	<i>H. G. Liao</i>	<i>S6.4</i>	<i>J. Yuan</i>	<i>S48.6</i>
<i>B. R. Yang</i>	<i>S26.2</i>	<i>H. Goto</i>	<i>S43.3</i>	<i>J. Zhao</i>	<i>S13.3</i>
C		<i>H. Haga</i>	<i>S51.2</i>	K	
<i>C. C. Wu</i>	<i>S17.2</i>	<i>H. He</i>	<i>S43.4</i>	<i>K. Hu</i>	<i>S46.3</i>
<i>C. Chi</i>	<i>S24.1</i>	<i>H. Huang</i>	<i>S9.5</i>	<i>K. J. Hane</i>	<i>S18.3</i>
<i>C. Fu</i>	<i>S59.18</i>	<i>H. J. Bi</i>	<i>S50.2</i>	<i>K. Kalantar</i>	<i>S25.2</i>
<i>C. G. Yuan</i>	<i>S59.1</i>	<i>H. J. Chen</i>	<i>S59.12</i>	<i>K. Lin</i>	<i>S51.6</i>
<i>C. H. Chu</i>	<i>S15.6</i>	<i>H. J. Chen</i>	<i>S59.24</i>	<i>K. O'Connell</i>	<i>S4.4</i>
<i>C. H. Lee</i>	<i>S15.1</i>	<i>H. J. Chen</i>	<i>S59.25</i>	<i>K. R. Sarma</i>	<i>S37.1</i>
<i>C. J. Chen</i>	<i>S39.3</i>	<i>H. J. Su</i>	<i>S41.2</i>	<i>K. Sunahara</i>	<i>S54.4</i>
<i>C. J. Yu</i>	<i>S22.2</i>	<i>H. L. Ning</i>	<i>S8.1</i>	<i>K. T. Wong</i>	<i>S5.1</i>
<i>C. Jiang</i>	<i>S14.1</i>	<i>H. L. Ning</i>	<i>S59.8</i>	<i>K. Wang</i>	<i>S35.6</i>
<i>C. Li</i>	<i>S24.3</i>	<i>H. L. Ning</i>	<i>S59.11</i>	<i>K. Wang</i>	<i>S13.2</i>
<i>C. Liu</i>	<i>S46.5</i>	<i>H. M. Li</i>	<i>S59.6</i>	<i>K. Wang</i>	<i>S16.3</i>
<i>C. Liu</i>	<i>S14.5</i>	<i>H. P. Li</i>	<i>S17.5</i>	<i>K. Wang</i>	<i>S24.2</i>
<i>C. P. Chen</i>	<i>S53.5</i>	<i>H. P. Li</i>	<i>S42.5</i>	<i>K. Zhang</i>	<i>S15.7</i>
<i>C. Tang</i>	<i>S23.6</i>	<i>H. R. Tseng</i>	<i>S42.4</i>	L	
<i>C. W. Liao</i>	<i>S9.3</i>	<i>H. S. KWOK</i>	<i>S4.2</i>	<i>L. C. Ming</i>	<i>S22.3</i>
<i>C. W. Tang</i>	<i>S3.1</i>	<i>H. S. Peng</i>	<i>S11.4</i>	<i>L. F. Lan</i>	<i>S21.3</i>
<i>C. W. Tsai</i>	<i>S23.3</i>	<i>H. Schmidt</i>	<i>S54.1</i>	<i>L. F. Zhou</i>	<i>S29.3</i>
<i>C. Wei</i>	<i>S41.4</i>	<i>H. Xia</i>	<i>S54.6</i>	<i>L. H. Li</i>	<i>S7.3</i>
<i>C. X. Li</i>	<i>S55.2</i>	<i>H. Xu</i>	<i>S44.3</i>	<i>L. J. Chen</i>	<i>S23.1</i>
<i>C. Y. Chen</i>	<i>S23.5</i>	<i>H. Xu</i>	<i>S50.7</i>	<i>L. J. Wang</i>	<i>S6.2</i>
<i>C. Z. Xu</i>	<i>S35.4</i>	<i>H. XU</i>	<i>S5.2</i>	<i>L. L. Liu</i>	<i>S15.5</i>
D		<i>H. Y. Lin</i>	<i>S15.2</i>	<i>L. L. Wang</i>	<i>S32.3</i>
<i>D. D. Wang</i>	<i>S52.4</i>	<i>H. Z. Zhong</i>	<i>S16.2</i>	<i>L. Liao</i>	<i>S29.2</i>
<i>D. Flattery</i>	<i>S42.3</i>	J		<i>L. Lin</i>	<i>S49.4</i>
<i>D. G. Ma</i>	<i>S33.2</i>	<i>J. B. Peng</i>	<i>S56.1</i>	<i>L. Liu</i>	<i>S51.3</i>
<i>D. K. Wang</i>	<i>S19.1</i>	<i>J. F. Li</i>	<i>S8.2</i>	<i>L. M. Xiu</i>	<i>S41.1</i>
<i>D. L. Yang</i>	<i>S53.2</i>	<i>J. G. Yang</i>	<i>S21.1</i>	<i>L. Ma</i>	<i>S39.4</i>
<i>D. Peng</i>	<i>S59.22</i>	<i>J. G. Yang</i>	<i>S48.3</i>	<i>L. Qian</i>	<i>S2.2</i>
<i>D. R. Kang</i>	<i>S59.17</i>	<i>J. H. Fu</i>	<i>S48.2</i>	<i>L. Qin</i>	<i>S59.21</i>
<i>D.M. Sum</i>	<i>S47.3</i>	<i>J. H. Zhang</i>	<i>S33.1</i>	<i>L. Quan</i>	<i>S38.3</i>
F		<i>J. Hebb</i>	<i>S18.1</i>	<i>L. Shi</i>	<i>S43.5</i>
<i>F. C. Lin</i>	<i>S22.1</i>	<i>J. Hsiao</i>	<i>S10.3</i>	<i>L. Tong</i>	<i>S41.5</i>

L. Tu	S50.3	S. M. Hu	S9.4	X. P. Guo	S55.3
L. W. Yang	S37.2	S. Maeda	S27.2	X. T. Yan	S6.5
L. Wang	S46.4	S. Ogier	S30.4	X. W. Ding	S49.5
L. Wang	S38.5	S. T. Zhang	S34.1	X. W. Xie	S56.3
L. Wang	S55.1	S. Tian	S37.3	X. XU	S50.4
L. X. Xiao	S5.4	S. Wu	S4.1	X. Z. Sang	S35.2
L. YANG	S59.15	S. Wu	S33.5	X. Z. Sang	S20.4
L. Zhen	S36.1	S. X. Gu	S59.10		Y
L. Zhou	S55.4	S. Y. Yoon	S3.6	Y. A. Huang	S21.4
	M	S. Yang	S33.4	Y. B. Yin	S59.4
M. C. Lu	S44.4		T	Y. Deng	S26.1
M. G. Liu	S39.1	T. Arai	S3.7	Y. deng	S59.7
M. Grooten	S57.3	T. C. Chang	S43.1	Y. G. Ma	S42.1
M. K. Zheng	S40.2	T. Chen	S25.5	Y. H. Geng	S10.2
M. Li	S49.3	T. Fang	S52.2	Y. H. Liu	S36.6
M. Lin	S44.4	T. Fujisawa	S23.4	Y. H. Yoon	S40.3
M. Omodani	S27.1	T. Harade	S40.1	Y. H. Zhang	S25.3
M. Wong	S12.2	T. Hayashi	S57.1	Y. H. Zhang	S32.2
M. X. Wang	S43.2	T. Lu	S59.19	Y. Jin	S48.4
M. X. Wang	S9.2	T. S. Mou	S35.3	Y. Li	S23.2
M. Y. Sun	S52.3	T. S. Mou	S25.1	Y. Meng	S29.4
M. Zhou	S51.4	T. Sun	S37.4	Y. N. Xue	S20.3
	N	T. Yamada	S4.3	Y. P. Huang	S2.4
N. Li	S49.2	T. Zeng	S36.3	Y. P. Huang	S20.1
N. Zahirovic	S18.4		V	Y. Q. Song	S30.5
	P	V. W.-W. YAM	S3.3	Y. Wang	S5.3
P. Cain	S10.4		W	Y. X. Yang	S11.1
P. F. Tian	S15.3	W. H. Wu	S24.6	Y. Y. Li	S41.6
P. Heremans	S29.1	W. Han	S45.1	Y. Y. Liu	S46.2
P. Liu	S18.2	W. L. Tang	S19.2	Y. Y. Noh	S10.1
P. Liu	S36.4	W. M. Zhang	S54.3	Y. Yang	S50.6
P. Ye	S25.4	W. MPHEPO	S47.5	Y. Yang	S24.5
	Q	W. N. Gao	S52.6	Y. Yuan	S52.1
Q. Feng	S38.2	W. R. Cao	S31.5	Y. Z. Jin	S31.1
Q. H. Hu	S50.1	W. Ren	S59.14	Y. Z. Li	S8.3
Q. H. Wang	S35.5	W. Yang	S12.4	Y. Zhang	S7.2
Q. Tang	S42.6	W. Yu	S59.5	Y. Zhang	S45.3
Q. W. Zhu	S48.1	W. Z. Bao	S14.3		Z
Q. Wan	S30.2	W. Z. Gao	S34.4	Z. A. Tan	S11.3
Q. Y. Zhao	S54.2		X	Z. B. Xiong	S59.23
	R	X. Chen	S48.5	Z. C. Gua	S56.4
R. Fan	S58.1	X. Chen	S20.5	Z. C. Ouyang	S3.2
R. Fan	S58.2	X. Chen	S57.2	Z. Chen	S31.2
R. Pei	S51.5	X. D. Liu	S8.5	Z. Cui	S47.1
R. S Chen	S29.5	X. D. Pan	S35.1	Z. Cui	S42.2
R. S. Chen	S29.6	X. D. tan	S20.2	Z. Cui	S2.3
R. Xu	S51.1	X. D. Wang	S26.3	Z. F. Zou	S22.4
	S	X. H. Liu	S32.4	Z. J. Liu	S15.4
S. C. Zhang	S40.5	X. J. Guo	S30.3	Z. N. Yu	S8.4
S. Chang	S59.20	X. J. Guo	S2.1	Z. Q. Zhang	S6.1
S. J. Li	S7.5	X. J. Li	S59.9	Z. Qin	S28.2
S. L. Tao	S34.3	X. L. Liang	S14.2	Z. S. Luo	S16.1
S. L. Zhao	S17.4	X. l. Lv	S34.5	Z. Ting	S36.2
S. Lv	S57.4	X. Li	S45.2	Z. W. ping	S52.5
S. M. Chen	S31.4	X. Liu	S59.16	Z. Yu	S36.5
S. M. Ge	S29.7	X. N. Zhang	S40.4		