SOCIETY FOR INFORMATION DISPLAY

UK & IRELAND CHAPTER

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Chairman's Report

Myrddin Jones

Welcome to the latest SID UK & Ireland chapter newsletter.

On the 26th April we held a very successful meeting at the Hauser Forum in Cambridge focusing on 'UK display innovations'. Naturally, the day had a strong Cambridge focus with companies such as Plastic Logic and Light Blue Optics talking about some of the latest innovations in plastic display development and holographic laser projections respectively. Key speakers from the University of Cambridge gave talks on Flexible Smectic A technology, Printable organic CMOS, Holographic projection with LCoS and Graphene technology. This was the first time for the SID in the UK to receive a talk on graphene and it opened many eyes to how this material could revolutionise the display industry. To balance the Cambridge focus, Sharp Laboratories introduced new functions that are being added to displays and BAE Systems talked on waveguide developments for head up displays. It was a great day and I'd like to thank all the speakers who made it happen.

Myrddin Jones

Looking forward, 'SID Organic Electronics UK 2012', a well-established two-day meeting, will be held on the 17th and 18th September at Imperial College, London. This year, the plenary speaker is Professor Mark E. Thompson, University of Southern California, co-discoverer of the Phosphorescent OLED and winner of the Jan Rajchman Prize 2006. The meeting will cover all aspects of organic semiconductors and their use in displays including OLEDs, OTFTs, OPVs, Materials, Oxides and Fabrication. Full details and bookings can be made on :

http://www.sid.org/Chapters/uki/UKIForthcomingMeetings2/IChome.aspx

We look forwards to meeting you at Imperial College on the 17th and 18th September.

The flagship event of next year will be **EuroDisplay 2013**, a research conference jointly organised by the Optical Group of the Institute Of Physics and our UK and Ireland Chapter of the Society for Information Display. The conference will be held at Imperial College, London between the 16th and 19th September 2013.

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Chairman's Report continued

The programme of **EuroDisplay 2013** consists of a Monday workshop on Organic Electronics, followed by the three-day symposium, which starts with plenary sessions and continues with two parallel sessions. Topics that will be covered include:

- European Display Research topical highlights
- Graphene, CNT and related technologies (Special Session)
- Metal Oxide and other Transparent Semiconductors
- Touchscreen, Haptic and Interactive Displays
- Green displays; low power, ambient light, low input and recycling
- Flexible, conformal and roll-to-roll processed displays
- Display materials; organic conductors and semiconductors, liquid crystals, optical films, filters and substrates
- Energy efficient lighting and backlighting
- OLED displays
- LCD technologies
- Organic transistors, circuits and backplanes
- Display applications; automotive, mobile, projection and microdisplays
- 3D displays and technologies

SID Organic Electronics UK 2011, organised by the UK & Ireland Chapter of the SID, was held at Imperial College London on 5th and 6st of September, 2011. It was the fifth Organic Electronics meeting held at Imperial, and covered all aspects of the area including organic light-emitting diodes (OLEDs) for lighting and displays, organic thin-film transistors (OTFTs) for backplanes and circuits, organic photovoltaics (OPVs) for power generation, organic photonics for lasing and telecommunications, semiconducting polymers, small molecules and fullerenes, dielectrics and conductors, oxides and hybrid

A dedicated website for EuroDisplay 2013 is already live on https://www.eventsforce.net/iop/frontend/reg/thome.csp?pageID=117149&eventID=286&eventID=286

We welcome your participation and support to make this event a success.

Finally I'd like to thank you for being a member of the SID. Just to remind you of the many advantages of being a member including:

- Free access to SID's extensive archive of publications and past conference digests, with current and past issues available, searchable, and online.
- Stay on top of the latest research and advances in display technology via Journal of SID and the technical digests from the many SID conferences. These are also searchable, with free access for SID members.
- Stay informed of industry developments and events through Information Display Magazine, free for SID members.
- Lower registration fees at key display-industry events world-wide.
- Networking - over 5,000 members in industry and academia consisting of your prospective colleagues, sponsors, suppliers, customers - and competitors.
- On-line FREE access to the SID member directory - only available to members.

If you've not renewed your membership yet this year we invite you to do so online on our corporate website www.sid.org

SID ORGANIC ELECTRONICS UK 2011

Report on the two-day meeting at Imperial College, London on 5-6 September 2011

By Alasdair Campbell

devices, device and circuit modelling, and printing and fabrication methods.

The meeting was opened by the organiser and Conference Chair Dr Alasdair Campbell, who welcomed the speakers and delegates.

The Plenary Address was given by Professor Stephen Forrest from the University of Michigan on **OLEDs for Lighting: Can They Ever be Bright Enough?** Steve is co-discover of the phosphorescent OLED (PhOLED) and co-founder of Universal Display Corporation (UDC). He is currently Vice President of Research at the University of Michigan. He first stated that 20% of all electricity generated is used in lighting. The use of OLED technology has now reached the level where Samsung is moving towards fabricating 30 million displays/month. To use white emitting phosphorescent OLEDs (WOLEDs) for lighting requires a lifetime >10,000 hours, 100% internal quantum efficiency (IQE), a high surface luminance of 800 – 2000cd/m^2, an acceptable quality white of CRI >70, or a high quality white of CRI >80. UDC have now achieved a 100lm/W WOLED and although blue is still an issue, green and red PhOLED lifetimes (to 50%) are now about 1 million hours.

Dr Soeren Steudal

The cost of moving to large-area devices is still an issue, but currently WOLEDs can achieve 0.50USD/kLumen. Different strategies have been approached for white emission. The stacked OLED (SOLED) has a longer lifetime but a more complex multilayered structure. fluorescent/phosphor-escent WOLEDs involve blue fluorescent and green and red phosphorescent emitters. The structure involves an exciton generation zone from which excitons diffuse into the blue, then green, then red layers respectively, so that blue emitting singlet excitons and green and red emitting triplets excitons are used.

One issue in PhOLEDs is the efficiency roll-off as drive current and brightness increase. Modelling of pulsed OLED operation can explain this by triplet-triplet, triplet-polaron and singlet-triplet annihilation at the high polaron and exciton densities found in the devices. One strategy is to use fluorescent OLEDs with a triplet management layer to remove triplet excitons. In this device you no longer get high brightness roll-off, and the luminance decay due to exciton and polaron annihilation events no longer happens under pulsed driving. Another issue which impacts efficiency is optical outcoupling. Using a low-index grid (LIG) patterned on ITO increases forward light emission by x1.32, and a microlens array by x1.68. Using both, leads to an improvement in forward light emission of x2. Glancing angle SiO_2 deposition for the LIG results in tilted columns which can further improve outcoupling.

A final issue which impacts lifetime is temperature. PhOLEDs heat-up, green and red emitting devices at 24°C rising to 34–36°C. This is very much to do with the thermal conductivity of the air surrounding the devices, and in white PhOLEDs lifetime is proportional to temperature. The ultimate lifetime limit is the creation of mid-gap defect states, resulting in an energy gap size driven lifetime where two particle interactions lead to luminance loss. However, white SOLED panels at LT70 have now reached approximately 30,000 hours at 2000cd/m^2. Also, the current luminaire efficiency of WOLEDs has now reached an impressive 52lm/W at 3000cd/m^2. These results indicate the strong potential of large area PhOLED lighting.

The first invited presentation was on **Roll-able AMOLED display with organic TFTs** by Dr Soeren Steudal, IMEC. Moving from rigid LCD to flexible AMOLED represents a double challenge: the need to go from rigid to flexible, and from light-shutter to emissive. For flexible substrates, there is high temperature foil (>250°C) such as polyimide and metal. Issues are cost, roll-ability and transparency. For low temperature foil (<150°C) such as PET or PEN, issues are dimensional stability and limited display material usage. IMEC, Holst and Polymer Vision have jointly developed a

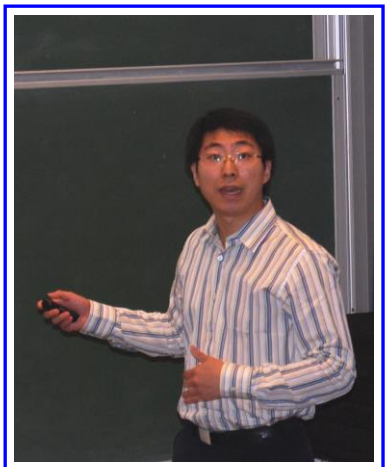
display fabricated on a wafer-based process. The emissive elements are 200cd/m^2 85dpi RGB top-emitting small molecule OLEDs from Fraunhofer IPMS. The required drive current, determined by the mobility and dielectric capacitance of the TFT, is 2μA per RGB pixel. The bottom contact, top gate TFTs consist of a 100nm thick high k ALD Al_2O_3 dielectric and polycrystalline pentacene. The TFTs are then encapsulated in parylene and 400nm of PVP before being connected to the OLED via Ag connections. The TFTs have a mobility of 0.4-0.9cm^2/Vs before and 0.3-0.4 cm^2/Vs after deposition of the other layers. Bias stability is critical, and the TFT turn-on voltage shifts by < 0.1V after 10,000s. In the current fabrication process, pixel yield is about 70%. Impressively, after being rolled up across a 7.5mm cylinder 3,300 times there is no noticeable degradation of the display performance, indicating impressive flexibility and robustness.

The second invited presentation of the meeting was given by Professor John de Mello, Imperial College London on **Transparent electrodes for Plastic Electronics**. The first part of John's presentation was on solution-processable, low-temperature replacements for ITO, which can be deposited on plastic at temperatures up to 150°C. Ag nanowires (NWs) form a mesh with a conductivity of 10ohms/square and a high transparency. The mesh forms too rough a surface for devices, and needs to be planarised with 150nm of PEDOT/PSS. P3HT:PCBM OPVs using this electrode achieved a power conversion efficiency (PCE) of 2.0% compared to an ITO/PEDOT:PSS reference device of 3.6%. Additionally, inverted OPVs with the structure Ag NWs/200nm TiO_2/P3HT:PCBM/MoO_3/Ag achieved a PCE of 3.5%, compared to an ITO/TiO_2 reference device of 3.5%.

The second part of the talk was on interlayer lithography. This is a photolithographic lift-off process where active material is spin-coated on resist, and then UV exposure and lift-off leaves patterned active material on surface stuck to the substrate by crosslinked resist. This technique has been used to pattern PEDOT:PSS, CNTs and graphene. Single wall CNTs patterned on flexible PEN using SU8 gave very good adhesion with a resistivity of 75ohms/square. Reduced graphene oxide has also been patterned on glass and converted at 500°C to graphene. By transferring with a PMMA stamp, it was possible to form the source and drain in n-type PCBM and p-type diF-TESDAT OTFTs and complementary inverters.

Dr Bodo Wallikewitz

After the lunch break, the afternoon session started with an invited talk given by Dr Jonathan Halls, Solar Press on **Solar Press: New Approaches to Low Cost Printed Photovoltaics**. Solar Press are focused on accelerating the commercialisation of OPVs, developing an innovation portfolio of IP and know-how and out-sourcing and supplying knowledge. Cost is the primary driver and OPVs offer potential for the lowest cost solar power as they are R2R processable. Current development focus is on solar lighting for the developing world. There are 300-400 million households not on the grid and population is outstripping electrification. Solar Press are using gravure to develop the printing of P3HT/PCBM OPVs. They find that a low concentration/high molecular weight additive gives the best efficiency compared to a high concentration/low molecular weight additive. They additionally use wire bar coating, non-chlorinated solvents and printed Ag ink electrodes. Process scale-up will involve moving to R2R, while device scale-up involves moving to modules. Modelling of modules shows that the crucial issue is the most resistive layer. There is a substantial voltage drop across cells for edge-only connections, and this problem becomes more significant as area increases. The solution is to raise electrode conductivity by using a conducting grid, thus decreasing the series resistance. This was followed by a presentation by Dr Bodo Wallikewitz, University of Cambridge, UK on the **Investigation of Triplet Dynamics in Fluorescent, Polymer Light-Emitting Diodes**. Bodo has been investigating the role of non-emissive triplet excitons in fluorescent F8BT PLEDs using photoinduced absorption. By looking at pulsed PLED operation, he showed that the triplet density rises with time after the device is switched off due to intersystem crossing, but then decays due to triplet-triplet annihilation.



Dr Zhenlin Wu

Dr Zhenlin Wu, Imperial College London then gave a talk on **Magnetic Properties of Manganese Phthalocyanine Thin Films for Spintronic Applications**. MnPC can potentially be used in magnetically-controlled current spin-valves. Zhenlin has been

growing films using low-pressure organic vapour phase deposition, and reported their ferromagnetic properties.

After the tea and coffee break, the next invited talk was **Printable Electronics at BASF** presented by Dr Roger Pretot, BASF. In 2010 BASF's sales were €63 billion and R&D expenditure was €1.5 billion. BASF are tracking the global megatrends. These include organic electronics devices such as OLEDs (for lighting and displays), OPVs and OFETs, where their focus is the science of materials and interfaces. Key features are performance, uniformity, processability and stability. BASF's new generation of semiconductors (polymers) have bulky moieties in the backbone to stop crystallization. They can achieve very low surface roughness, very good wetting, very uniform performance linked to a low domain size and can be used in a wide range of different solvents for printing.

Dr Steve Tierney

This was followed by a presentation titled **Boron Subpthalocyanine Chloride as an Electron Acceptor for High Voltage Fullerene Free Organic Photovoltaics** by Nicola Beaumont, University of Warwick. Nicola reported that C60 gives a low open-circuit voltage with the majority of donor materials, is not good for tandem cells, and can have oxidation/degradation issues. Replacing C60 with boron subPC gives a very high open-circuit voltage and a PCE of 2.9% when used in a vacuum-sublimed OPV with tetracene as a donor material.

The last talk of the day was an invited presentation by Dr Steve Tierney, Merck on **High performance polymer semiconductors for organic photovoltaics**. Steve described how the 3rd generation of organic solar cells (OPVs) are not only for mobile devices but also for large-area, building-integrated PV systems. As such, they must be flexible, light-weight, printable and coat large areas. The cost target is 0.3-0.5€/W, compared to inorganic PVs of 0.76USD/W. Merck will be a major supplier of OPV materials, and are currently developing PCBM type acceptors (a joint partnership with Nano-C Inc, USA), polymer donors and ZnO/Titania interfacial layers. Now at 6% efficiency with non-chlorinated solvents, their next target is high efficiency in modules, with appropriate cost at about 2015. Ease of coating is as important to customers as charge carrier mobility, and the doctor blade is used as a standard spreading technique for 200nm thick OPV layers. Merck's D4600 polymer / PCBM blend can perform as well in inverted cells as the standard cell configuration, and recent rapid progress in donor polymer development has moved efficiencies towards 7%.

The first day then closed with the poster session and a drinks and nibbles reception. Nearly 20 posters were presented by authors from a number of UK Universities including Imperial, Sheffield, Nottingham Trent, QMUL and Warwick, as well as NPL, Printed Electronics Ltd, Keeling & Walker Ltd, CDT and Merck. Topics covered all aspects of organic electronics. The winner of the Best Student Poster Prize for PhD students supported by Merck was Darren Watters with a poster titled **Carbazole and thienyl benzo [1,2,5]thiadiazole based polymers with improved open circuit voltages and processability for application in solar cells**. The winner of the Plastic Electronics DTC MRes Best Student Poster Prize supported by CDT was Joseph Shaw with a poster titled **Fabricating organic nanostructures**. Ossila Ltd, Sheffield also had an industry stand presenting their range of organic electronic support products.

The second day opened with an invited talk by Dr Uwe Vogel, IPMS Fraunhofer on **Bi-directional OLED microdisplays: Technology, Design, Applications**. Uwe is in the Business Unit focused on Microdisplay & Sensors, with the multimedia mobile display as the driving force. They have developed a Microdisplay based on an OLED light source on CMOS with electronics feature integration and sensor integration using embedded photodetectors. The microdisplay consists of a highly-efficient top-emitting white p-i-n OLED (from Novaled AG) on the CMOS wafer using a transparent top cathode of Ag, Al or Yb. This is then encapsulated and covered with a colour filter giving a total thickness of <1.5mm. It can then be used as a

Poster Sessiom

mobile head-mounted display (HMD) and/or micro projection display. In addition, Si photodetector pixels have been integrated onto the CMOS chip next to the OLED pixels, allowing bi-directional operation as a sensor or detector. Optical cross-talk can be dealt with, allowing simultaneous detection and display. In the HMD application, it can simultaneously display information and track (both conscious and unconscious) eye movements. In addition, they have a project developing a VGA 640x480 bi-directional OLED microdisplay with HMD optics for near-to-eye projection, with an optical sensor on the display measuring both distance and inclination.

After this, was a presentation **Heteroleptic bis-cyclometalated iridium(III) complexes for OLEDs** by Dr Etienne Baranoff, Ecole Polytechnique Fédérale de Lausanne. He reported the synthesis of a white metal complex emitter with a broad, single emission band between 450-750nm with CIE coordinates (0.28,0.36). For broad emission the LUMOs on the main and ancillary ligands must be close in energy. For a single isomer complex they have managed to achieve a 40 cd/A OLED.

Etienne Baranoff

This was followed by the second invited presentation of the day on **Organic blend semiconductors for high performance thin-film transistor applications** by Dr Thomas Anthopoulos, Imperial College London. For applications, display backplanes require unipolar (n- or p-type) OTFTs while the peripheral circuitry requires both n- and p-type OTFTs. Mobility requirements are 10^{-2}cm^2/Vs for e-Paper displays, 1cm^2/V for LCD and 1-10cm^2/Vs for standard RFID and AMOLED. In 2011, several publications have shown solution-processed OTFTs with mobilities of 10cm^2/Vs, exceeding that of α-Si. For OTFTs, polymers are soluble, easy to process, give good device uniformity, but have a lower mobility. Alternatively, small molecules tend to be anisotropic, polycrystalline, solution processing is more difficult, but give higher performance. Using a polymer – small molecule blend combines processability and uniformity with high performance. He has used diF-TESADT and TIPS-pentacene blended with the polymers PS and PTAA in a bottom contact/top gate configuration, achieving OTFTs with a low turn-on voltage, negligible hysteresis, low bias instability and excellent air stability. By optimising the small molecule/polymer blend ratio to 40-60% by weight and using thiol SAMs to lower contact resistance, he was able to achieve a uniform mobility of 4-6cm/Vs and an on/off ratio of 10^6. Recently, he has also begun to explore this blend approach using new n-type small molecules, achieving a mobility of 0.1cm^2/Vs.

After the morning coffee break, Jonathan Reveney from Stanford University, USA gave an invited presentation titled **Disorder and charge trapping in organic semiconductors**. Charge-carrier mobility in polycrystalline organic semiconductors is intimately related to microstructure. The charge transport bottlenecks in microstructure are: degree of crystallinity; texture (orientation relative to substrate); crystallite/grain size; crystallite quality; paracrystalline disorder; and the variation in main lattice spacing. He has investigated the grain size, lattice parameter fluctuations and paracrystalline disorder in the small molecule TIPS-pentacene (typical mobility 0.5-5cm^2/Vs) and zzzzthe polymer pBTTT (typical mobility 0.1-1cm^2/Vs) using synchrotron X-ray diffraction techniques. The level of lattice parameter fluctuations and paracrystalline disorder are much larger for the polymer. This large disorder causes carrier localisation and increases the density of tail states in the energy gap. He concluded that in polycrystalline films of

Details:

http://www.sid.org/Chapters/uki/UKIForthcomingMeetings2/IChome.aspx

polymers, disorder is within the crystallites and it is this which determines charge transport via a disorde- related coherence length. In polycrystalline films of small molecules, it is instead the grain boundaries at the edges of crystallites which dominate performance and determine mobility.

Ian Hancox

This was followed by a presentation from David James of Imperial titled **Systematic Control of the Macro-scale Morphology in Organic Small-Molecule Thin Films using Zone-Casting**. Zone-casting from solution allows crystalline films of small molecules to be coated uniformly over large-areas (15cm x 15cm), with solution temperature, concentration and substrate speed being varied to optimise morphology. Using TIPS-pentacene, a mobility of 1.2cm^2/Vs parallel and 0.03cm^2/Vs perpendicular to the fabrication direction was achieved in bottom-contact, top-gate TFTs. The next presentation was **Utilizing n-type vanadium oxide films as hole-extracting layers for small molecule organic photovoltaics** from Ian Hancox, University of Warwick. MoOx and V_2Ox can be used as hole-extraction layers in ITO/metal oxide/ClAlPC/C60/BCP/Al OPVs. They can be deposited in a few seconds and have an optimum performance at a thickness of 5nm. Compared to bare ITO, the metal oxide layers increase the workfunction, as well as improving device stability and lifetime.

After lunch, the afternoon session started with an invited presentation titled **Novel Concepts for Stable Blue Light Emitting Materials and Devices** by Professor Emil List, TU Graz . Stability is still an issue in blue-emitting fluorescent polymers, blue polymer OLED lifetimes being much less than red or green devices. In blue-emitting polyfluorenes, degradation results in the appearance of a green emitting band at 2.3eV, shifting the overall emission colour from blue to white. This degradation occurs in the presence of oxygen with UV light, elevated temperatures or charge carriers. Synthesis of a model polymer with a fluorenone keto-defect, where a double bonded oxygen replaces the two alkyl side chains, shows this green emission. Emil showed four potential ways to avoid this green-band degradation and pixel colour shift: Firstly, to attach dendronic sidechains; secondly, use aryl-substituted ladder-type pentaphenylenes, although the synthesis is complex; thirdly, use poly-pyrenes, which have scaleable synthesis; and fourthly, 3D shape-persistent dendrimers. These methods avoid the potential defect and/or reduce exciton migration to the defect sites.

Mary O'Neill

This was followed by a presentation titled **Structural dependence of magnetic coupling in semiconducting cobalt phthalocyanine spin chains** by Michele Serri, Imperial College London. These materials have application in spintronic spin-valves and memories, as well as spin-aligned injection electrodes for fluorescent OLEDs. Michele has been growing metal PCs by thermal vapour deposition, forming single crystals or chains by stacking in columns, and exhibiting different paramagnetic and antiferromagnetic properties.

The final presentation of the meeting was an invited talk on **Semiconducting Nematic Liquid Crystals: Photovoltaics & Photoembossing** by Professor Mary O'Neill, University of Hull. Mary has been investigating photoreactive liquid crystals called reactive mesogens consisting of two photo-reactive endgroups attached by spacer units to a functional conjugated molecular core with charge transporting or light emitting properties. These materials can be photo-embossed into gratings and other structures by irradiating thin films with patterned light, which have application as distributed feedback organic lasers or directional OLEDs. Crosslinking with uniform polarised light results in mesogens parallel to the light direction becoming preferentially excited, resulting in that orientation being locked in by crosslinking, with neighbouring molecules align in the same direction. It is possible to achieve grating-separation periods down to 265 nm and peak-to-trough depths of up to 140nm. OPVs have additionally been fabricated using blends of

these materials, achieving a PCE of 1.4%.

The prizes for the best poster awards were then announced by the Conference Chair. Following a final tea and coffee break the meeting was closed and delegates departed.

CONFERENCE CALENDAR

SID 50th ANNIVERSARY CELEBRATION

and One-Day Technical conference

Displays and Technologies for the Future

September 29th 2012

LatinDisplay 2012-09-11

IDRC 2012

November 26-30th

Mackenzie – SP – Brazil

The 19th International Display Workshop

In conjunction with **Asia Display 2012-09-11**

Kyoto International Conference Centre, Japan

4th Workshop on LIQUID CRYSTALS FOR PHOTONICS

December 9-11 2012 Hkust, Hong Kong

EL 2012

December 10-14 2012-09-11

Lam Woo International Confernece Centre, Hon Kong

The Programme of the conference consists of a Monday workshop on Organic Electronics, followed by the three-day symposium, which starts with plenary sessions and continues with two parallel sessions. A table top exhibition will be run along side this conference, for more information or to book a stand please contact jenny.bremner@iop.org

Topics:

- European Display Research topical highlights
- Graphene, CNT and related technologies (Special Session)
- Metal Oxide and other Transparent Semiconductors
- Touchscreen, Haptic and Interactive Displays
- Green displays; low power, ambient light, low input and recycling
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- Organic transistors, circuits and backplanes
- Display applications; automotive, mobile, projection and microdisplays
- 3D displays and technologies

1st call for papers 17 August 2012 **Registration 1st May 2013**