
IOP | Institute of Physics

Printing and Graphics Science Group

NEWSLETTER

September 2014

Issue no. 8



Timsons T-flex 508 flexographic press for functional printing at the Welsh Centre of Printing and Coating, Swansea University. Image credit: Alan Hodgson

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Welcome

Welcome to the 2014 edition of the Printing and Graphics Science Group Newsletter. This issue contains reports on meetings organised by the Group over the past year as well as other events of interest. A summary of forthcoming meetings is also included.

We have seen changes to the Committee membership since the last Newsletter: we welcomed Martyn Cherrington to the Committee in January and later this year Alan Hodgson will step down as Group Chair. I would like to take this opportunity to thank Alan for his invaluable work and contribution to the Group during his time as both Chair and Honorary Secretary.

Following a successful conference in 2013, our student conference will again be organised this year in collaboration with the Knowledge Transfer Network. The UK Plastic Electronics Research Conference will take place over two days in December at the University of Manchester. Submissions for oral and poster presentations are welcome, please see page 21 for details.

Our annual 'Science of Inkjet and Printed Drops' meeting will take place on the 11th November, and there is still time to submit poster presentations for this event. Our second conference on bioprinting will also be held in November, and will focus on the applications of 3D printing in this area. Details of these and other meetings will be uploaded to our website <http://pgs.iop.org> as they become available. Our Group pages on LinkedIn and Facebook are also regularly updated with news items and details of upcoming events.

We are always keen to receive items for the Newsletter that may be of interest to our readers. If you have conference reports, details of upcoming events or other material, we would love to hear from you.

Anna Fricker
Newsletter Editor

Message from the Chair

Hi folks,

Welcome to the Group Newsletter. The Group has been involved in a lot of events this year so thanks to all who helped out. And a special thank you to all who have contributed to the newsletter this year.

Through this year Roy Gray has continued involvement as Group Treasurer. In addition to compiling this newsletter Anna Fricker has continued as Hon. Secretary as well, in preparation for taking over as Chair later this year. I would like to take this opportunity of thanking them both for their support and contribution this year.

This year I complete the maximum number of years service allowed as an IoP Group Officer and will therefore be stepping down as Chair. For me one of the enduring successes during this time has been our involvement with our student contingent and the refocusing of the direction of the group to be more congruent with current research focus in Printing and Graphics Science. A key deliverable in this has been the development of our annual Student Conference. This past year has seen significant development of this in association with The KTN. The partnership with The KTN on events such as this will hopefully allow us to expand our reach further.

The emerging topic of Printed Electronics continues to provide a significant part of the Group events. However, this is not our exclusive focus and we are always open to new ideas; let one of the committee know your thoughts. As an example our "Science of Inkjet & Printed Drops" meeting goes from strength to strength.

The Group Committee remains open to new members and we particularly welcome more students and early career scientists. The networking is good and we can give you experience and support in organising meetings and events. We conduct most of our committee meetings by telephone conference but will pay travel expenses for the occasional face to face meeting. Talk to one of the present committee if you are interested.

Since the last Newsletter we have taken part in a number of events in these areas and you can find reports on all of these in this edition. Check out more on the Group and its events on <http://pgs.iop.org>.

Thanks again to all for the support through my tenure on the Group Committee. And I look forward to seeing you at future events.

Cheers,

Alan

*Alan Hodgson
Departing Chair, Printing and Graphics Science Group
August 2014*

Committee Membership 2013-2014

Chair

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Mr Martin Gouch

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Mr Trevor Lambourne

University of Leeds

Dr Davide Deganello

University of Swansea

Prof. Ian Hutchings

University of Cambridge

Dr Leszek Majewski

University of Manchester

Reports from Recent Group Events

Science of Inkjet and Printed Drops

6 November 2013

IOP, London, UK

The conference was held at the Institute of Physics in London. This was the 6th annual conference in this series and continues to grow. This year there were 6 invited speakers and 64 delegates. The following is a summary of the talks.

One key point in the early presentations is that noise seems to be a parameter that is useful to explore in these systems.

Initial conditions, modal analysis and breakup length of continuous liquid jets

Prof Javier Garcia, University of Seville, Spain

Lord Rayleigh explained why capillary jets are unstable – surface tension is the leading force in the break up into drops. This can be understood through a temporal analysis of the jet and this is what was done by Rayleigh in 1878. This analysis is also used when modelling this break up.

The group at Seville examined systematic deviations from the Rayleigh model. This follows on from the work of Berger in the 1980s who noted that a number of groups had detected deviations from this model. The authors of this work explained these deviations as a combination of dominant and sub-dominant modes in drop formation. This explains the behaviour in the transient and mature modes.

Stochastic forces (statistical thermal motions) were used to explain the break up of linear jets when other perturbation forces were absent. Another appearance of Maxwell's demon!

This was a great presentation where the concepts were explained with a beautiful analogy with football and plentiful references to the Spanish National team!

The University of Seville is working in collaboration with University of Cambridge in this field. They have checked their model against experimental observables with the Cambridge group and the fit was shown to be good.

Breaking of single and compound liquid jets: electrostatic, electrokinetic and surfactant effects

Prof Demetrios Papageorgiou, Imperial College, London

Demetrios is from the Department of Mathematics at Imperial. His presentation concentrated on the surfactant effects – he has a huge amount of material in this

area. This group has evidently also worked on electrostatic features such as Taylor cones – high curve features from radial fields.

The presentation started with the linear stability of liquid jets and the theoretical tools to explore this were explored. The presentation then moved on to model jet pinching and to model the experimental evidence on filament break up of very viscous fluids.

The work discussed the Marangoni effect as a pressure produced by a surfactant concentration gradient on a jet. This results in surfactant being swept away from the pinch region.

Progress and problems in predictive modelling of drop deposition dynamics

Dr Mark Wilson, University of Leeds

This work illustrates the use of numerical modelling – effectively virtual experimentation. Once again Leeds are working with Cambridge on this work. Mark models drop formation as a zero thickness interface using finite element analysis as a surface mesh. This lattice Boltzmann method can be used to model blood flow and wetting of porous media.

This presentation moved into drop deposition which in some respects is more complex as there is a 3 phase contact line. In particular the complexity is magnified for rough surfaces. One important application of these model is at the interface in curtain coating as it can be used to explain air entrapment. Mark cited the work done on curtain coating design where they worked to increase coating speed without the inclusion of air bubbles. The work derives a relationship between a “wetting parameter” and the static contact angle.

Mark is also modelling drop coalescence, knowledge of which is essential for inkjet fabrication. The message is that knowledge of contact angle hysteresis is crucial for this work. The model looks to be capable of a realistic prediction of the footprint of coalesced drops.

At present this work is an engineering solution. The aim is to move this into a more user friendly system for use in industrial coatings.

Splashing and inkjet

Prof Frits Dijkstra, University of Twente, Netherlands

Frits is ex-Philips research and is a great presenter at events like this. At this meeting, he started with his conclusion – splashing of ink when it impacts a surface is not an issue. However, as the discussion progressed this really only holds for drop on demand onto solid surfaces. The large fast drops from some continuous inkjet systems, plus wet-on-wet impacts could be a different issue.

His discussion centred around drop dispensing from piezo drop on demand inkjet heads employing Helmholtz resonator ink systems that use a “throttle” constrictor. He made the interesting observation that with these systems the following equation usually applies.

$$(\text{drop velocity})/(\text{drop frequency} \times \text{drop radius}) = \text{approximately } 1$$

Fritz charted the evolution of the science of inkjet dispensing through Newton, Hooke, Boyle, Rayleigh etc., explaining the effectiveness of air bubbles in damping the dispensing action.

Inkjet printing at the heart of sensors and diagnostics

Dr Laura Gonzalez-Macia, University of West of England

The presentation started with some background to printed biosensors. In 1987 the first of the screen printed biosensors arrived. Inkjet printing entered this application area in the 1990s.

This group are using polyaniline as the basis for the sensor material. Their synthesis is designed to produce nanoparticles instead of the expected long fibres by the use of a combination of 2 surfactants. They need nanoparticles for inkjet printing and they use multiple printed layers onto a gold coated substrate to gain the necessary thickness and flatness.

They started with ammonia sensors and moved on to the SIMS project (Smart Integrated Miniaturised Sensor system) going on at UWE. SIMS aims to integrate sensors, displays, power and circuitry into one sensor system. The demonstrator won an award at LOPE-C 2013.

Commercial opportunities and barriers for inkjet

Steve Temple, Templetech Ltd

Steve charted the evolution of inkjet as a production printing technique. He noted that inkjet had now effectively taken out flatbed screen printing and is now working on the litho print market. However, there remain some impediments to progress that were charted here.

One issue is that material dispensing seems stuck at a level below 1 μ l/sec per nozzle. Replenishment of the fluid in the chamber seems to be the issue. Other issues to be addressed are pigment content for coverage and satellite drop issues. The good news on this is that simulations are now providing visions of real event with high accuracy.

As we move on to Digital Fabrication the printing of continuous lines and smooth structures are key issues to address. However, it does look promising. Steve finished with the fact that 33 Xaar 1001 heads have the materials throughput of a medium scale injection moulding machine!

Poster session

Claire Bourdin of Domino Printing presented a poster “Development of an intelligent indicator for inkjet technology”, part of the IsaPack project. This part of the project consists of inkjet printing a photochromic dye as a part of a time-temperature indicator. There are still issues to be addressed with the permanence of the dye once printed.

Kai Hsiao of University of Cambridge presented his work on the use of inkjet printing rat cells using an inkjet system. The aim is to further the target of using such systems for regenerative medicine.

Dr Alan Hodgson

UK Plastic Electronics Research Conference 2013

10-11 December 2013

Loughborough University, UK

For a number of years the Institute of Physics Printing and Graphics Science (PGS) Group has held a 1 day Student Conference in December. This year the event was extended to 2 days, devoted entirely to Plastic Electronics and held in partnership with the Electronics, Sensors and Photonics Knowledge Transfer Network (ESPKTN). We also received support from the Engineering and Physical Sciences Research Council (EPSRC) and publicity from +Plastic Electronics magazine.

The meeting this year was most ably organised and chaired by Dr Martyn Cherrington of ESPKTN and Dr. Davide Deganello from the PGS and Swansea University. The papers this year were of a uniformly high standard.

The Student Conference is an annual event that allows early years researchers to present their work in a friendly, supportive forum. It is not intended that the work be necessarily complete for presentation and it therefore the event gives an early snapshot of the work being undertaken in key UK groups working in this field. As with the event last year it shows the breadth of work being undertaken in the area of printed electronics.

Imperial College had a strong contingent at this meeting. Their Centre for Plastic Electronics aims to integrate and coordinate printed electronics activity at Imperial. They have a Corporate Affiliates Programme to stimulate commercially focussed interactions, giving the opportunity to network with staff and students alike. Imperial also host the Centre for Doctoral Training in Plastic Electronics.

There were 78 people pre-registered for this event.

KEYNOTE – EPSRC and Plastic Electronics Research in the UK

Derek Gillespie, Senior Portfolio Manager for ICT at the EPSRC

This presentation covered Electronics Systems Research in the UK, covering societal trends such as ubiquitous information and connectivity and tremendous growth and change. He cited the ESCO report (Electronic Systems Community) as a document of particular influence within government.

There are a number of key points in this report that is pertinent to Plastic Electronics.

- The authors note the use of flexible plastic and printed technologies to enable new functionality. A later section notes that this could be an enabling technology for Electronic Systems.

- The implementation strategy envisages closer ties with "leading UK players in vertical market sectors". An Electronic Systems Technology Group is to be created to work with these vertical sectors. One role of this will be to comment on disruptive technologies such as plastic electronics, graphene and 3D printing.
- An emphasis on appropriate Centres for Doctoral Training.

Manufacture of printed electronics devices for revolutionary applications

Sharjil Siddique, Plastic Logic

Plastic Logic produce flexible displays with small format manufacturing in Cambridge and Gen 3.5 scale (1.5m square) in Dresden. As a part of this process they deposit a dielectric using flexo printing. They also do a lot of physical testing of displays. The displays are around 50 μ m thick and are highly bendable.

Plastic Logic have some impressive flexible displays and are now moving from e-ink to OLED. They are also involved with ISORG to make plastic image sensors for smart surfaces.

Conventional and microwave assisted processing of Cu loaded ICAs for electronic interconnect applications

Geoffrey Qi, Loughborough University

This work aims to prepare novel isotropic electrically conductive adhesives (ICAs). These are widely used in electronic packaging applications.

Ag is widely used in such applications. It has good electrical conductivity but is expensive. Cu however is lower cost but is usually covered in an insulating layer of CuO. Geoffrey has been acid etching the particles to remove the CuO then adding a self assembling monolayer to protect from further oxidation. This monolayer can be removed using a heating step in 2 possible ways.

1. Conventional heating – described as outside in.
2. Microwave heating – described as inside out. They use a thermal imaging camera to monitor cure temperature.

The latter route gives Cu with a surface conductivity of $0.7 \times 10^{-4} \Omega/\text{sq}$. This is claimed to be as good as that achieved with conventional Ag based ICAs. These ICAs can be used as adhesives or applied through stencil printing.

Alkyl chain and polymer backbone modification in thieno[3,2-b]thiophene based diketopyrrolopyrrole polymers for high performance OPV and FET applications

Iain Meager, Imperial College London

In a polymer based solar cell the donor material (in this case the Diketopyrrolopyrrole) is intimately mixed with an acceptor material (in this case an electron rich fullerene) in a blend known as a built heterojunction. The polymer absorbs the sunlight to create an electron / hole pair – an exciton. If this exciton diffuses to a donor/acceptor boundary within its short lifetime the electrons and holes can be separated, transported to the respective electrodes and used to produce a photocurrent.

Diketopyrrolopyrrole (DPP) is widely used in organic semiconductors and in this case for photovoltaic (PV) work. Iain has been functionalising DPP using branched chain alkyl groups on the nitrogen. These give enhanced solubility.

Iain has also been working on increased branching point distance up to 3 carbon – carbon bonds. A strong correlation was shown between increases in crystallinity and performance. The work is funded by Solvay and BASF.

Scalable droplet flow techniques for the controlled synthesis of semiconducting polymers

James Bannock, Imperial College London

This paper gained one of the IoP PGS awards for the presentation and showed a depth of work at Imperial on both PV and droplet flow reactors.

The motivation for the work was to reduce the cost of PV materials which needs a move from batch to flow chemistry production. One of the issues cited for marginally soluble materials in flow reactors is pipe work blockage. To reduce this issue Imperial are conducting the reactions in droplets in a carrier liquid. James' work involves developing a droplet flow method to create uniform micro-dispersions consisting of a monomer, catalyst and carrier such as Perfluoropolyether (PFPE).

KEYNOTE: National Centre for Printable Electronics

Jon Helliwell, CPI

CPI are one of 7 High Value Manufacturing Centres in the UK and have received £35mi in government funding since 2009. They have manufacturing capability up to GEN2 scale. CPI houses 100 people, 50 of which are embedded SMEs in incubator space. They also have an open access clean room facility.

Jon highlighted their Integrated Smart Systems programme using the PragmatIC / DeLaRue demonstrator as an example. This programme used a bespoke Nilpeter

press featuring litho, screen, flexo and gravure units running at 60m/min. They are now looking at high speed pick and place to complement this.

A Near Field Communications (NFC) project has just been funded to initiate a supply chain and they are looking into atomic layer deposition techniques for PV barrier layers.

Automated spray Deposition for plastic electronics

Kirsty Roy, Imperial College London

Kirsty was investigating the use of an artist's air gun for spray deposition. It is a cheap, fast and scalable solution processing technique. However, it is hard to get uniform, reproducible and smooth films this way. Kirsty was seeking to address this weakness.

As expected an automated gun under computer control was found to give much greater reproducibility. They have tried to address surface smoothness issues by a subsequent stamping process. Results were mixed.

The work started by applying ZnO and the choice of this inorganic is interesting. It is air stable and can be used to confer some level of protection to an underlying more sensitive organic component. This could be a good method for nanowire applications. Kirsty reported that by varying the temperature at which deposition takes place, it is possible to change the particles' direction of orientation.

Controlling large area film formation and drying for printed polymer OLED devices

Ben Mogg, Swansea University

He is working with CDT and is flexo printing from aromatic solvents. As a result the films dry quickly, including on the printing plate!

Ben is investigating the deposition of polymeric solutions using various techniques including spin-coating. He is interested in the drying kinetics of these solutions for both single layer and multilayer films that may incorporate different solvents.

Laser additive manufacturing of 3D embedded plastic circuit board using holographic optics

Adam Hou, Loughborough University

Laser writing of 3D polymer structures conventionally uses Nylon-12 beads. These structures have issues such as voids resulting from poor heat transfer. The Gaussian beam profile also causes problems such as Marangoni flow.

The group at Loughborough are using a holographic optical element (HOE) to equalise the beam profile. They have tried this system using a polyethylene powder with a silver ink. The HOE modified beam gives cleaner conductive lines.

Thermal ejection is also an issue with heated voids, where the void causes the surface to burst away. Modifying the beam to a “tuning fork” profile was shown to reduce this.

Manufacturing multilayer thin films for photovoltaics

Ruth Cherrington, Warwick University

The aim of this project is to move away from spin coating using inkjet dispensing. The inks included in this work so far include nanoparticle silver, ZnO and two polymeric solutions. Jetting performance for these inks is variable. Ruth is now working on ink formulation and mitigating surface roughness.

KEYNOTE: Chris Jones from Novalia

Chris was showcasing the Bluetooth connectivity piano demonstrator at this meeting. The individual layers are printed onto PET sheets using a flexo process. A small watch battery is used to run Bluetooth connectivity to an iPhone. The Bluetooth connectivity is done through an industry standard Bluetooth chipset integrated onto the print.

Dynamics of polymer blend film formation during spin coating

Youmna Mouhamad, Sheffield University

Spin coating is often used for material deposition in the OLED, organic solar cell and biotechnology spaces. There can be issues controlling the morphology of the film and particularly the applied thickness.

Youmna illustrated the use of specular reflection measurements using a HeNe laser, detectors and cameras to measure film thickness. Working at a set geometry the system monitors successive maxima and minima in the reflection intensity as the film thickness changes. Youmna is also interested in modelling the behaviour of the film and applying these models to the reflectivity data.

Enhanced light-harvesting in organic optoelectronic devices via ‘nanopinballing’ and polymer refractive index patterning

George Richardson, Imperial College London

The work illustrated the production of micro-replicated features first from a silicon master then from a micro-sphere array. Patterning into organic layers is limited by the low refractive index differences that can be produced. Hybrid (organic / inorganic) give higher capability.

The features are being evaluated using goniometry and this group are building the optical toolset to evaluate such features. His poster “Refractive index patterning for polymer photonics” gained an IoP award for the poster.

Continuous flow synthesis of fullerene bis-adduct acceptors

Barnaby Walker, Imperial College London

Barnaby was using the same type of flow reactor as James Bannock – see above. However, instead of using droplets in a carrier his synthesis can use continuous flow. He is looking to functionalise Fullerene to break the symmetry of the C60 cage structure.

This illustrated how synthetic chemistry can add to conferences on Printed Electronics. Next year we intend to get the Royal Society for Chemistry involved in this meeting.

The effect of interlayer work function on the recombination dynamics in OPV

Scot Wheeler, Imperial College London

Scott noted the instability of PEDOT:PSS to water. He is looking at alternative metal oxide interlayers for OPV, noting that these layers are important for overall PV performance. These interlayers can also have useful barrier capability too, shielding the PEDOT:PSS from environmental water. Scot is particularly interested in looking at the Fermi-level splitting and recombination dynamics at electrodes.

KEYNOTE: Andromachi Malandrak from Merck Chemicals

Andromachi is a Research Scientist from the Performance Materials group at the Merck Chemicals Southampton research centre. The presentation showed some interesting organic photodetector materials and these will be extended into the NIR in the future. These materials are water sensitive.

Truxenone-based non-fullerene acceptors for OPV

Sarah Holliday, Imperial College London

This was another example of both the work going on with electron acceptor materials for OPV and the extent of work being conducted at the Imperial Doctoral Training Centre.

This project is being run in collaboration with BASF. The aim is to spoil the planar nature of the molecules to inhibit the crystallisation process. Without this the materials form a mass of highly monoclinic crystals which inhibits acceptor performance. This a compromise as too much bulking also spoils their performance.

Controlling molecular orientation: exploiting the dipole-dipole interaction between molecules and ferroelectric substrates

Alexandra Ramadan, Imperial College London

The work is looking at ferroelectric substrates such as LiNbO₃, which can be grown as thin films. The work is investigating the use of phthalocyanine molecules on these. Although the common CuPc has no dipole moment the VOPc analogue has. Alexandra is using XRD to examine the orientation of these molecules when deposited on a ferroelectric substrate.

In-situ probing of molecular order in P3HT:PCBM blends by resonant raman spectroscopy

Joseph Razzell, Imperial College London

The work is investigating the use of Raman spectroscopy to probe the OPV blend structure. It was shown to be useful in investigating the annealing process too. Changes in the molecular order were measured using Raman spectroscopy and were found to improve with heating. The technique was also shown to be useful in detecting phase transitions.

The use of superposition rheology in functional printing

James Claypole, Swansea University

The work started by examining the different ways to test shear rheology. James is investigating Newtonian and non-Newtonian fluids including gelatine. Superposition rheology seems to be an interesting technique to characterise silicon inks and 2 part resins.

KEYNOTE: Chris Rider from the EPSRC Centre for Innovative Manufacturing in Large Area Electronics

There are 16 UK Centres for Innovative Manufacturing. Chris leads the Large Area Electronics centre which consists of contributions from Cambridge, Imperial, Manchester and Swansea universities.

Organic semiconducting: insulating blends for field-effect transistors

Alberto Scaccabarozzi, Imperial College London

The aim of the work is to improve the physical characteristics of organic semiconductors by blending them with other polymers, without spoiling their electrical characteristics.

Alberto was applying the polymer blends using Mayer bar coating. He was using a 3PHT semiconductor and found that the trick is to get the 3PHT to crystallise out before the polyethylene in the blend. The polyethylene can improve the physical

properties but can also change some of the electrical properties in a useful direction.

Singlet exciton fission in unconventional systems

Andrew Musser, Cambridge University

Thermalisation was stated as a basic problem in PV – lots of the absorbed energy ends up as heat. Singlet exciton fission is a potential route to bypass this issue. So far this has only been demonstrated for Pentacene systems. There is a need here for singlet exciton fission sensitisers. However, the physics of this process is not yet fully understood.

This paper received one of the IoP PGS presentation prizes. This is potentially a game changing technology.

Flow synthesis of silver nanowires for low cost and high performance transparent conducting electrodes

Thomas Phillips, Imperial College London

OPV often uses a transparent ITO front electrode. The presentation started by showing that for printed OPV the ITO pattern is about 50% of the bill of materials. The key thing is to minimise sheet resistance and maximise light throughput.

This group believes that the next step for OPV is the use of silver nanowire technology. But at the moment this is about 3 times the cost of ITO. The nanowires are extended pentagonal prisms and to drive down cost there is a need to encourage this crystal habit during polyol synthesis. This was another example of the use of the Imperial flow reactor technology illustrated in previous papers. In this case they use a 1mm diameter tube and can synthesise up to 150mg / channel / hour.

The nanowires are characterised using dark field optical microscopy. After optimisation of the process they can produce pure product and control the wire width and length too.

KEYNOTE: Printed Electronics Ltd, Dr. Neil Chilton

Neil illustrated his talk with some of the silver, copper and gold metallic inks they have jetted through a modified Epson P50 printer. He then went on to describe the SIJ Technology inkjet system. This was described as easily capable of 5µ track and gap features but (as yet) only with a single nozzle. Two systems are known to be coming to the UK, one for Cambridge and one for Manchester.

High precision inkjet printing of single nanowire field effect transistors for plastic electronics

Greg Rigas, University of Surrey

Greg is working with various nanowires (silver, silicon etc) with the aim of making connections to individual wires using inkjet technology. The work is being done in collaboration with NPL.

Novel room temperature laminate technology to enable the mass manufacture of flexible Organic Electronics

Daniel Bryant, Swansea University

Daniel discussed the SPECIFIC project which aims to put low cost PV onto metal substrates. As a part of this they need a low cost front electrode and took a transparent pressure sensitive adhesive and blended it with PEDOT:PSS. The result is low cost adhesive film for PV applications. He made the point that percolation theory says you need a certain concentration of conductive "islands" to join up to make a conductor.

Roll-to-roll vacuum fabrication of organic electronics

Ziqian Ding, Oxford University

Ziqian is using flash evaporation techniques to make transistors.

Welsh Centre for Printing & Coating, Swansea University

Davide Deganello, WCPC

They had printed 70 μ m silver lines by flexo printing as a part of the Fast2Light FP7 project. This used a nano silver ink, cured in 2 seconds using NIR radiation giving 2-3 times bulk silver resistivity. They are now moving on with an Optomec aerosol printer which can give fine lines of <10 μ m width.

WCPC are now getting into antibody printing. Davide believes these should have security print applications as they are difficult to copy.

Spray printed nanoscale materials for large area flexible touch-screens

Shrawan Kumar Jha, Imperial College London

The work concentrates on materials as a replacement for ITO on capacitive touch screens.

Polymer degradation in inkjet printing

Joseph Wheeler, Manchester University

OMIC in Manchester have developed hyper-branched polymers that are less prone to degradation issues in continuous and drop on demand inkjet formulations. These have potential utility in conductive polymer ink.

A novel scanning technique for evaluating printed electrode performance

Peter Greenwood, Swansea University

Peter has been looking at the Scanning Vibrating Electrode technique, commonly used to measure corrosion on metal. This could be a way of visualising fine printed conductive lines.

KEYNOTE: Haydale, David Gibbs

David described the plasma functionalisation route used at Haydale. They now have 2 screen printable conductive Graphene inks. One gives $<10 \Omega/\text{sq}$, the other $20 \Omega/\text{sq}$.

Graphene and layered nanomaterial inks for electronics

Richard Howe, Cambridge University

The Cambridge Graphene Centre perform liquid exfoliation followed by ultracentrifuge treatment. The centrifuge can be used to concentrate the dispersion too. They then do inkjet printing and Mayer bar coating onto PET and aim to widen these deposition techniques to include screen and flexo printing.

Development of graphene inks as transparent electrocatalysts for dye sensitised solar cells

Jenny Baker, Swansea University

The NMF solvent works well for the Graphene platelets from Haydale but PV cells made from this material have poor performance. It looks like residual solvent is blocking the catalytic sites and it takes a 450°C heat treatment to remove this. As a result Swansea are investigating water based inks.

Dr Alan Hodgson and Anna Fricker

Forthcoming Group Events

Advances in Photovoltaics

16 September 2014

IOP, London, UK

Organised by the IOP Ion and Plasma Surface Interactions Group and co-sponsored by the PGS Group

<https://www.iopconferences.org/iop/555/home>

This one day meeting provides a forum to help assess the current state of the art. It brings together a list of distinguished invited speakers whose expertise covers the range of photovoltaic technologies.

The conference programme and registration details are available at the link above.

Ultra-High Barriers for Plastic Electronics

24 September 2014

IOP, London, UK

Organised by the Knowledge Transfer Network and co-sponsored by the PGS Group

<https://connect.innovateuk.org/web/plastic-electronics/events-view/-/events/14588396>

This is a one day technical conference on the advances in the production and characterisation of ultra-high barriers for plastic electronics. The programme is available at the link above.

Science of Inkjet and Printed Drops

11 November 2014

28 Portland Place, London, UK

<https://www.iopconferences.org/iop/594/home>

This annual meeting will cover all aspects of the generation, deposition and behaviour of liquid droplets, together with applications in graphical printing as well as printed electronics, novel materials processing and 3-D printing. The conference programme consists of six invited talks and a poster session, details are available at the link above.

Poster presentations

Authors wishing to submit an abstract to be considered for poster presentation can view the abstract guidelines on the website. The deadline is 14th October 2014.

Registration

The early registration deadline is 14th October 2014 and registration closes on 6th November 2014.

Advances in 3D Printing Technology for Medical and Biological Applications

18 November 2014

Swansea University, UK

Organised in collaboration with the Welsh Centre for Printing and Coating

This conference will cover all aspects of 3D printing of materials for biological and medical applications, such as replacement bone scaffolds, wound dressings and monitoring devices. Please keep an eye on the PGS website or contact Davide Deganello (d.deganello@swansea.ac.uk) for further information about this event.

UK Plastic Electronics Research Conference 2014

December 2014

Manchester University, UK

Organised jointly by the PGS Group and the Knowledge Transfer Network

Following a successful conference in 2013, the IOP Printing and Graphics Science Group's annual student conference will again be organised in collaboration with the Knowledge Transfer Network as a two day conference dedicated to students: the UK Plastic Electronics Research Conference.

Presentations are sought at postgraduate level on any subject related to printed, plastic, organic and large area electronics. Potential topics could comprise, but are not restricted to, recent developments in applications, materials and processing. Examples include OLEDs, OPVs, smart packaging, printed biosensors, developments in printing technologies and research into the underpinning physics of printing.

The conference will be an opportunity for students to present their work and meet others from around the country who are working in similar fields. As a gathering of leading industry and academic contributors, it will offer potential for professional development and possible collaborations.

Funds are available to cover basic travel expenses for speakers. Further details are available at the link above.

Other Events of Potential Interest

IARIGAI 41st Annual Conference

7-10 September 2014

Swansea, UK

<http://iarigai-swansea.org/>

30th International Conference on Digital Printing Technologies and Digital Fabrication (NIP30)

7-11 September 2014

Philadelphia, Pennsylvania, USA

<http://www.imaging.org/ist/Conferences/nip/index.cfm>

10th Colour Conference

11-12 September 2014

Genoa, Italy

<http://www.gruppodelcolore.it>

Plastic Electronics Conference

7-9 October 2014

Grenoble, France

<http://www-large-area-electronics.eng.cam.ac.uk/event/plastic-electronics-conference/>

AIMCAL Web Coating & Handling Conference

19-22 October 2014

Myrtle Beach, South Carolina, USA

<http://www.aimcal.org/events/web-coating-and-handling-conference/2013/conference/overview.aspx>

22nd Color and Imaging Conference (CIC22)

3-7 November 2014

Boston, Massachusetts, USA

<http://www.imaging.org/ist/Conferences/cic/index.cfm>

Printed Electronics USA 2014

19-20 November 2014

Santa Clara, USA

<http://www.idtechex.com/printed-electronics-usa/pe.asp>

RPS Good Picture 2014: Imaging Features

13 December 2014

London, UK

<http://www.rps.org/events/2014/december/13/good-picture-2014-imaging-features>

Innovations in Large-Area Electronics

3-4 February 2015

Cambridge, UK

<http://www-large-area-electronics.eng.cam.ac.uk/>

Electronic Imaging 2015

8-12 February 2015

San Francisco, CA

<http://www.imaging.org/ist/Conferences/ei/index.cfm>

Large-area, Organic & Printed Electronics Convention (LOPEC)

3-5 March 2015

Munich, Germany

<http://www.lopec.com/>

Printed Electronics Europe 2015

28-29 April 2015

Berlin, Germany

<http://www.idtechex.com/printed-electronics-europe/pe.asp>

Awards

PGS Group Awards

The PGS Group makes two awards each year.

Student Presentation Prizes

These prizes are open to all research students currently undertaking work at a university in the UK or Ireland, leading to a PhD or Masters degree, who present their work at the annual Printing and Graphic Science Group Student Conference. The Group will award two prizes of £50 for the best Student Presentations.

All presentations given at the Group's Student Conference will be considered for this year's prizes. For more information on this year's conference please see our group calendar. The 2013 Student Presentation Prizes were awarded as follows.

James Bannock, Imperial College London

'Scalable Droplet Flow Techniques for the Controlled Synthesis of Semiconducting Polymers'

Andrew Musser, University of Cambridge

'Singlet Exciton Fission in Unconventional Systems'

A certificate for the best poster presentation was also awarded to George Richardson, Imperial College London for his poster on *'Refractive Index Patterning for Polymer Photonics'*.




James Bannock and Andrew Musser receiving their prizes at the 2013 UK Plastic Electronics Research Conference

Group Prize

The Printing and Graphics Science Group of the Institute of Physics awards an annual prize to an individual or organisation that has contributed a significant theoretical or practical application of physics in the area of printing and graphics science.

The 2013 Group Prize was awarded to Dr Laura Gonzalez-Macia and Professor Tony Killard of the University of the West of England for their paper '*Inkjet Printing at the Heart of Sensors and Diagnostics*'.

Research Student Conference Fund

The banner features a top section with a black background and white text that reads "Supporting research students". Below this is a grayscale image of a complex, fibrous network. The main body of the banner has a light gray background with the title "Research Student Conference Fund" in large, bold, black font. Below the title, there are three lines of text: "Providing financial support to research student members, to attend international conferences and major national meetings.", "Apply for up to £250 during the course of your PhD.", and "Applications are considered on a quarterly basis and should reach the Institute by: 1 March, 1 June, 1 September or 1 December". At the bottom of the main body, it says "For further information see www.iop.org or contact supportandgrants@iop.org". The bottom section of the banner has a black background with the text "IOP Institute of Physics" in white.

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IOP Institute of Physics

Further information may be found at the following link.

http://www.iop.org/about/grants/research_student/page_38808.html

Other Information

PGS Group on LinkedIn, Facebook and Twitter

The Group has pages on the LinkedIn, Facebook and Twitter social networking sites which are regularly updated with news items and details of upcoming events. We look forward to seeing you there.

LinkedIn

<http://goo.gl/B0mds>

We can be found by searching for the 'Printing and Graphics Science' group on LinkedIn or by following the link above. You will need to be a member of LinkedIn to view the page.

Facebook

<http://goo.gl/vX0kC>

We can be found by searching for the 'Printing and Graphic Science Group' on Facebook or by following the link above. There is no need to be a Facebook member to view the page.

Twitter

https://twitter.com/PGS_IOP

The PGS Group is now on Twitter @PGS_IOP.

This newsletter is also available on the web and in larger print sizes

The contents of this newsletter do not necessarily represent the views or policies of the Institute of Physics, except where explicitly stated.

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