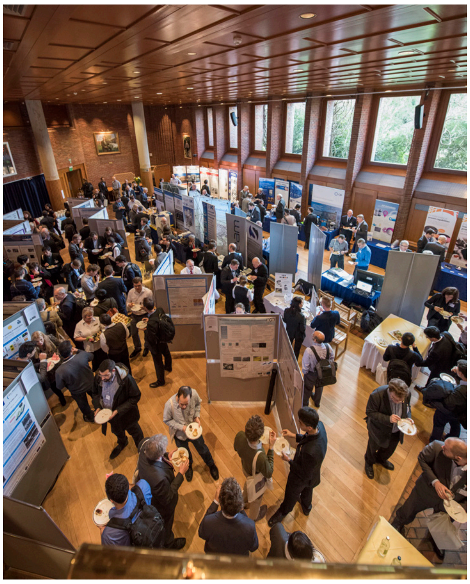

Innovations in Large-Area Electronics Conference

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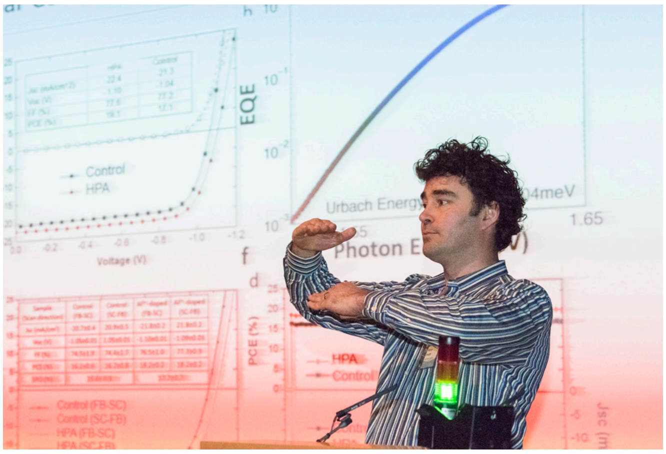

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TABLE OF CONTENTS

2 CONFERENCE PROGRAMME

4 KEYNOTES

7 PLENARY ADDRESS

8 SESSION 1: MATERIALS

14 SESSION 2: MANUFACTURING 1

20 SESSION 3: BIOELECTRONICS

26 SESSION 4: ENERGY HARVESTING & STORAGE

31 SESSION 5: IOT & SENSOR TECHNOLOGIES

36 SESSION 6: MANUFACTURING 2

41 SESSION 7: FLEXIBLE HYBRID SYSTEMS

46 WORKSHOP: E-FIBRES/E-TEXTILES

49 POSTER PRESENTATION

Conference Programme Day 1

08:30- 09:00	Registration, tea/coffee on arrival	
09:00 – 10:10	Conference opening (plenary) • Welcome by Dr Luigi Occhipinti, Conference Chair • Introduction by Chris Rider, EPSRC Centre Director • Keynote address: Prof. Zhong Lin Wang, Georgia Tech *Nanogenerators for self-powered flexible electronics and piezotronics for active human-machine interfacing*	
10:10 – 10:40	Tea/coffee, posters and exhibition	
10:40 – 12:45	Session 1: Materials 1. Invited speaker: Dr Hagen Klauk, Max Planck Institute *Megahertz flexible low-voltage organic thin-film transistors* 2. Invited speaker: Dr Pawel Miskiewicz, Merck Chemicals *Performance materials* 3. Dr Sean Butterworth, Promethean Particles *Novel industrial scale continuous production of silver and copper nanoparticles for conductive inks* 4. Dr Georgios Liaptsis, CYNORA *Improved stability of blue TADF emitters with EQE > 10% to replace fluorescent blue emitters* 5. William R Taube Navaraj, University of Glasgow *Metal-assisted chemical etched Si nanowires for high-performance Large Area Flexible Electronics*	Session 2: Manufacturing 1 1. Invited speaker: Dr James Semple, Imperial College London *Engineering the world's largest nanofeature for fast, printed diodes on plastic* 2. Dr Kornelius Tetzner, Imperial College London *Rapid fabrication of solution-processed metal oxide transistors via photonic processing at room temperature* 3. Dr Dimitris Karnakis, Oxford Lasers *Ultrafast laser processing for organic thin film transistor manufacturing* 4. Thomas Cosnahan, University of Oxford *Vacuum flexographic patterning of sacrificial oil for organic transistor aluminium contacts* 5. Thomas Kolbusch, Coatema GmbH *Process technologies for printed electronics: an overview of the latest trends and developments*
12:45 – 14:15	Lunch, posters and exhibition	
14:15 – 16:20	Session 3: Bioelectronics 1. Invited speaker: Prof. Róisín Owens, École des Mines de Saint-Étienne *Upping the ante for organic bioelectronics; integration with 3D tissue models* 2. Invited speaker: Prof. Fabio Biscarini, Università di Modena e Reggio Emilia *Electrolyte-gated organic field effect transistors: fundamentals and applications to biosensing* 3. Invited speaker: Dr Daniel Chew, Galvani Bioelectronics (a GSK subsidiary) *Road mapping bioelectronic medicine – neural interface applications* 4. Invited speaker: Dr Mark Fretz, CSEM *ACTION - ACTive Implant for Optoacoustic Natural sound enhancement* 5. Dr John Hardy, Lancaster University *Multiphoton Fabrication of Bioelectronic Biomaterials for Neuromodulation (MFBBN)*	Session 4: Energy Harvesting & Storage 1. Invited speaker: Dr Manuel Pinuela, Drayson Technologies *Intelligent IOT networks for future cities* 2. Invited speaker: Dr Claudio Marinelli, Eight19 *Commercialising organic photovoltaic – manufacturing and applications* 3. Dr Jeff Kettle, Bangor University *Accelerated testing for predictive ageing in organic solar cells for outdoor applications* 4. Dr Harrison Lee, Swansea University *Large area organic photovoltaic module for indoor applications* 5. Dr Stuart G. Higgins, Imperial College London *Overcoming the challenges of using organic diodes for energy harvesting*
16:20	Poster reception	
19:00	Transport to dinner venue	
19:45	Gala dinner at Downing College	

Conference Programme Day 2

08:30 - 09:00	Tea/coffee	
09:00 – 10:10	Plenary session Chair: Dr Luigi Occhipinti, University of Cambridge • Welcome to day 2 by Chris Rider, EPSRC Centre Director • Plenary address: Dr Jon Helliwell, CPI *The innovation process: practical support for the Large Area Electronics community* • Keynote address: Dr Gregory Whiting, Google [X] *Printed, flexible and transient electronics for distributed systems*	
10:10 – 10:40	Tea/coffee, posters and exhibition	
10:40 – 12:45	Session 5: IOT & Sensor Technologies 1. Invited speaker: Dr Daniel Tate, University of Manchester *Low power OFET based sensors for IoT applications* 2. Invited speaker: John Biggs, ARM *PlasticARM: challenges in flexible printed VLSI* 3. Dr Iyad Nasrallah, University of Cambridge *Low-voltage polymer transistors for high-performance solution-processed complementary analogue amplifiers on foil* 4. Dr Gianluca Bovo, CDT *Solution processed organic photodetectors and integrated sensors* 5. Dr Tiziano Agostinelli, FlexEnable *Security tags Enabled by near field Communications United with Robust Electronics (SECURE)*	Session 6: Manufacturing 2 1. Invited speaker: Dr Catherine Ramsdale, PragmatIC *Moving towards mass manufacture* 2. Invited speaker: Prof. Rhodri Williams, Swansea University *Advanced Rheological Characterisation of functional inks for printed electronics (PE) applications yields improved prediction of line width accuracy and electrical performance* 3. Invited speaker: Prof. Luis Pereira, Universidade Nova de Lisboa *Printed oxide nanoparticles based devices on paper substrates* 4. Prof. Carlos Bufon, Brazilian Nanotechnology National Laboratory *Three-dimensional organic conductive networks embedded in paper for flexible and foldable devices* 5. Raj Bhakta, North Carolina State University *Direct-jet printed flexible interconnects on films and textiles*
12:45 – 13:45	Lunch, posters and exhibition	
13:45 – 15:50	Session 7: Flexible Hybrid Systems 1. Invited speaker: Dr Ton van Mol, Holst Centre *Imperceptible electronics* 2. Dr Michael Renn, Optomec *3D printing of flexible and stretchable interconnects* 3. Dr Aoife Celoria, Novacentrix *Smart wearables and stretchable/ultra-flexible electronics* 4. Dr Abhijeet Sangle, University of Cambridge *2D printed flexible and scalable thermoelectric power generators for wearable applications* 5. Dr Fernando Castro, National Physical Laboratory (NPL) *Challenges in testing the reliability of printed and flexible electronics*	Workshop: E-Fibres/e-textiles • Workshop keynote: Prof. Jong Min Kim, University of Cambridge *1D Nanofibre Electro-Optic Networks (1D-NEON)* 1. Invited speaker: Dr Paolo Canonico, SAATI *e-textile and Strategic Innovation and Research agenda for European textile and clothing industry* 2. Invited speaker: Mark Pedley, SmartLife Inc. *Wellbeing without walls* The presentations will be followed by a panel discussion moderated by Dr Luigi Occhipinti
15:50 - 16:00	Concluding remarks (Dr Luigi Occhipinti, Conference Chair)	

Prof. Zhong Lin Wang

GEORGIA TECH

Nanogenerators for self-powered flexible electronics and piezotronics for active human-machine interfacing

Zhong Lin Wang
School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta USA
Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing, China

ABSTRACT

Developing wireless nanodevices and nanosystems is of critical importance for sensing, medical science, environmental/infrastructure monitoring, defense technology and even personal electronics. It is highly desirable for wireless devices to be self-powered without using battery. Nanogenerators (NGs) have been developed based on piezoelectric, trioboelectric and pyroelectric effects, aiming at building self-sufficient power sources for mico/nano-systems. The output of the nanogenerators now is high enough to drive a wireless sensor system and charge a battery for a cell phone, and they are becoming a vital technology for sustainable, independent and maintenance free operation of micro/nano-systems and mobile/portable electronics. An energy conversion efficiency of 55% and an output power density of 500 W/m^2 have been demonstrated. This technology is now not only capable of driving portable electronics, but also has the potential for harvesting wind and ocean wave energy for large-scale power application. This talk will focus on the updated progress in NGs.

For Wurtzite and zinc blend structures that have non-central symmetry, such as ZnO, GaN and InN, a piezoelectric potential *(piezopotential)* is created in the crystal by applying a strain. Such piezopotential can serve as a “gate” voltage that can effectively tune/control the charge transport across an interface/junction; electronics fabricated based on such a mechanism is coined as *piezotronics,* with applications in force/pressure triggered/controlled electronic devices, sensors, logic units and memory. By using the piezotronic effect, we show that the optoelectronc devices fabricated using wurtzite materials can have superior performance as solar cell, photon detector and light emitting diode. Piezotronics is likely to serve as a “mechanosensation” for directly interfacing biomechanical action with silicon based technology and active flexible electronics. This lecture will focus on the updated progress in the field and its expansion to 2D materials.

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BIOGRAPHY

Dr. Zhong Lin (ZL) Wang received his PhD from Arizona State University in 1987. He now is the Hightower Chair in Materials Science and Engineering and Regents' Professor at Georgia Tech, and Director and Chief Scientist, Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing. Dr. Wang has made original and innovative contributions to the synthesis, discovery, characterization and understanding of fundamental physical properties of oxide nanobelts and nanowires, as well as applications of nanowires in energy sciences, electronics, optoelectronics and biological science. His discovery and breakthroughs in developing nanogenerators establish the principle and technological road map for harvesting mechanical energy from environment and biological systems for powering a personal electronics. His research on self-powered nanosystems has inspired the worldwide effort in academia and industry for studying energy for micro-nano-systems, which is now a distinct disciplinary in energy research and future sensor networks. He coined and pioneered the field of piezotronics and piezo-phototronics by introducing piezoelectric potential gated charge transport process in fabricating new electronic and optoelectronic devices. This breakthrough by redesign CMOS transistor has important applications in smart MEMS/NEMS, nanorobotics, human-electronics interface and sensors. Dr. Wang's publications have been cited for over 96,000 times. The H-index of his citations is 151. Dr. Wang was elected as a foreign member of the Chinese Academy of Sciences in 2009, member of European Academy of Sciences in 2002, fellow of American Physical Society in 2005, fellow of AAAS in 2006, fellow of Materials Research Society in 2008, fellow of Microscopy Society of America in 2010, and fellow of the World Innovation Foundation in 2002. He received 2016 Outstanding Achievement in Research Innovation award, Georgia Tech; 2016 Distinguished Scientist Award from (US) Southeastern Universities Research Association; 2015 Thomas Router Citation Laureate in Physics; 2014 Distinguished Professor Award (Highest faculty honor at Georgia Tech); 2014 World Technology Prize in Materials; 2014 the James C. McGroddy Prize for New Materials from America Physical Society, 2013 ACS Nano Lectureship award, 2012 Edward Orton Memorial Lecture Award and 2009 Purdy Award from American Ceramic Society, 2011 MRS Medal from the Materials Research Society, 1999 Burton Medal from Microscopy Society of America. Details can be found at: www.nanoscience.gatech.edu

Dr Greg Whitting

GOOGLE [X]

Printed, Flexible and Transient Electronics for Distributed Systems

ABSTRACT

Electronic systems that can be widely distributed are useful for a range of applications including environmental sensing, human performance and health monitoring, energy generation and storage, and data security. Printing is an effective method for the fabrication of such systems as it enables large-area coverage, mass customization, integration of multiple materials with mechanically flexible substrates, and potentially enables an inclusive, distributed manufacturing model.

This presentation will provide an overview of recent work carried out at PARC, A Xerox Company, into printed electronic devices and systems. Using printing techniques a variety of components can be fabricated entirely from solution-based inks, including circuits, power sources, sensors, memory and a range of passives. From these components, completely printed sensor systems can be fabricated directly onto flexible substrates providing useful functionality with a high degree of design freedom. For application where functionality is limited by the properties of printed circuits, pre-fabricated silicon-based microelectronic components can be combined with the printed devices to achieve sensor systems with more complex capabilities such as RF communication or high resolution analogue-to-digital conversion. In addition to these printed and hybrid devices a parallel digital electrostatic fluidic microassembly technique, capable of positional and orientational control of small objects (such as microelectronic dies), has also been developed, and potentially provides a method for print processing of complex materials and devices.

Another useful function for distributed systems is physical transience. An approach for achieving controllably transient electronic systems based on stress-engineered glass substrates that rapidly disintegrate when triggered, fragmenting and dispersing the substrate and any thin electronic components processed onto it will also be described.

BIOGRAPHY

Greg is currently a member of the Rapid Evaluation Team at Google[X], where he carries out early stage work in a wide range of areas in order to develop large scale projects that address high impact problems.

Prior to joining X, Greg was at the Palo Alto Research Center (PARC) from 2008-2016, where he managed the Novel Electronics Group. His work focused on materials and processes for unconventional electronic systems – such as those that may be mechanically flexible and conformable, large area, widely distributed, controllably transient or manufactured using printing techniques, in order to address applications in areas including distributed sensing, wearable electronics, environmental monitoring, data security, and additive manufacturing.

From 2006-2008 he worked for Cambridge Display Technology, studying organic field-effect transistors, polymer/polymer blend photovoltaics, and polymer light-emitting diodes. Greg received a Ph.D. from the University of Cambridge in 2007 where his research focused principally on solar cells and field-effect transistors formed using surface-initiated polymer films. He received a B.S. degree from the University of California, Berkeley in 2002 where he studied solution processed polymer/nanoparticle solar cells.

Greg has co-authored over 20 peer reviewed journal articles, holds 16 US patents, and his research has been covered by various media outlets including the New York Times, and IEEE Spectrum. He is an active member of a number of societies including the MRS and is an executive committee member of the AVS. His awards include a Flexi award from the FlexTech Alliance, a top performer award from DARPA, and he is a 2016 National Academy of Engineering Frontiers of Engineering participant.

Dr Jon Helliwell

CPI

The Innovation Process: Practical Support for the Large Area Electronics Community

ABSTRACT

The presentation will describe the Innovation Process using experience gained by CPI over the last eleven years. It will then describe how CPI uses its approach to Innovation process to provide practical support to companies operating in the sector, illustrating this with the experiences of real companies.

BIOGRAPHY

Dr Jon Helliwell, a chemist by training, is the Business Unit Director for Printable Electronics at CPI. He is also CEO of one of the CPI spin out companies, Primary Dispersions Limited

He has spent most of his career in the ceramic and mineral processing industries, becoming the Technical Director for Cookson Matthey's global Zircon business. He then became the Technical Director for Johnson Matthey's Structural Ceramics business, where he was responsible for its Research and Development portfolio. He joined CPI in 2005, managing the Low Carbon Energy Development Centre in CPI, prior to joining the CPI Printable Electronics team.

Jon has a proven record in new product introduction, business representation and business development and possesses extensive team skills and management experience at all levels. He sits on the Advisory Board of the Centre for Sustainable Chemical Processes at Durham University and he was an Advisory Group member on the EPSRC Delivery of Sustainable Hydrogen Supergen projects.

Dr Hagen Klauk

MAX PLANCK INSTITUTE

Megahertz Flexible Low-Voltage Organic Thin-Film Transistors

Hagen Klauk
Max Planck Institute for Solid State Research, Stuttgart

ABSTRACT

Organic thin-film transistors (TFTs) can typically be fabricated at temperatures of about 100 ºC or less and thus not only on glass or polyimide substrates, but also on inexpensive and optically transparent types of plastics, such as polyethylene naphthalate (PEN), and even on paper. In some of the more advanced applications for organic TFTs, such as the integrated row and column drivers of active-matrix flat-panel displays or image sensors, the TFTs may need to be able to control electrical signals of a few volts at frequencies of a few megahertz. This can be achieved by aggressively reducing all transistor dimensions, *i.e.*, the channel length, the parasitic gate-to-source and gate-to-drain overlaps, and the gate-dielectric thickness. For this purpose, we have developed a process in which the TFTs are patterned using high-resolution silicon stencil masks and in which a 5-nm-thick hybrid gate dielectric is employed. With this process, bottom-gate, top-contact organic TFTs with channel lengths as small as 0.5 μm and gate-to-contact overlaps as small as 5 μm can be fabricated on flexible PEN substrates. Owing to small thickness of the gate dielectric, the TFTs can be operated with voltages of about 2 to 3 V. For 11-stage unipolar and complementary ring oscillators based on TFTs with a channel length of 1 μm and a gate overlap of 5 μm, we have measured signal propagation delays per stage as short as 420 ns and 6.6 μs, respectively, both at a supply voltage of 3 V.

BIOGRAPHY

Hagen Klauk received the PhD degree in electrical engineering from the Pennsylvania State University in 1999. From 2000 to 2005 he was with the Polymer Electronics Group at Infineon Technologies in Erlangen. Since August 2005 he has been head of the Organic Electronics group at the Max Planck Institute for Solid State Research in Stuttgart, Germany.

Dr Pawel Miskiewicz

MERCK

Performance Materials

Pawel Miskiewicz, Stephen Bain, Irina Afonina, Aurelie Morley, Toby Cull, Andromaki Malandraki, Lichun Chen
Merck Chemicals Ltd., Chilworth Technical Centre, University Parkway, Southampton SO16 7QD, UK

ABSTRACT

Merck has been actively researching Organic Electronic materials since the year 2000 with the objective to enable mass production of plastic electronic devices.

In this paper we present two selected activities: organic thin film transistors (OTFT) and organic photodetectors (OPD).

We demonstrate how the co-development of organic semiconductors, passive materials and formulations together with process optimisation enable the manufacture of high performance OTFT arrays suitable for mass production of display backplanes. These materials can be either printed or patterned using photolithographic process to fabricate OTFT's with mobilities exceeding that of amorphous silicon.

In similar approach we present recent progress on materials for OPD devices, addressing applications such as x-ray detectors, blood oximetry and touchless interaction where they offer unique benefits over current solutions.

BIOGRAPHY

Pawel Miskiewicz has a PhD in chemistry. After postdoctoral research he joined Merck Chemicals UK working on various projects related to Printed Electronics in the UK and USA. From 2015 he became R&D Manger of Hybrid Electronics team.

Dr Sean Butterworth

PROMETHEAN PARTICLES

Novel Industrial Scale Continuous Production of Silver and Copper Nanoparticles for Conductive Inks

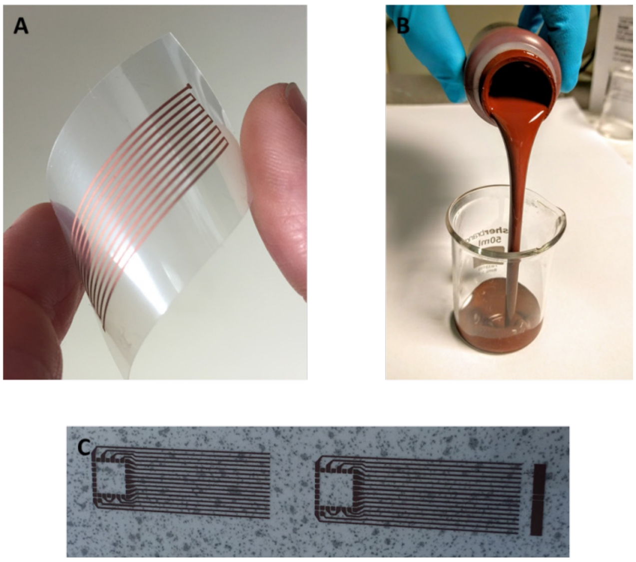
Sean Butterworth[1] and Pete Gooden[1]
[1] Promethean Particles Ltd, 1 Genesis Park, Midland Way, Nottingham, NG7 3EF, UK

ABSTRACT

Promethean Particles design and develop bespoke inorganic nanoparticle dispersions by continuous hydrothermal synthesis. Promethean are currently commissioning the world's largest continuous hydrothermal reactor system capable of producing multiple materials at ton scale. The Promethean reactor technology allows for the continuous production of large volumes of copper and silver nanoparticles in relatively benign solvents with no observable oxide impurity. The Promethean process works by heating a solvent (water or alcohol) stream which is then mixed in a counter current fashion with a metal salt stream. This allows for rapid precipitation of particles at the mixing interface. Promethean has been ramping up production and focusing on process optimisation and can now produce low cost copper and silver dispersions for formulating into functional inks.

Working with customers these materials have been formulated into inkjet printing inks using a Dimatix DMP printer which display good conductivity of ~50 mΩ/□.

Promethean Particles hope to become a global leader in the dispersions market for functional inks.



A, showing laser sintered copper track on PET, B, showing 60 wt. % copper dispersion and C, showing inkjet printer and sintered copper tracks on PET

BIOGRAPHY

Dr Sean Butterworth obtained his PhD from Manchester University working in the Organic Materials Innovation Centre (OMIC) in polymer colloid science and has been working in the area of nanoparticle dispersions for 8 years with a focus on process optimisation and functional ink development. Sean has working at Promethean for 4 years as a senior research scientist and heads up printed electronics development at Promethean.

Dr Georgios Liaptsis

CYNORA

Improved Stability of Blue TADF Emitters with EQE > 10% to Replace Fluorescent Blue Emitters

Dr. Georgios Liaptsis
CYNORA GmbH, Werner-von-Siemens-Straße 2-9, 76446 Bruchsal, Germany

ABSTRACT

With the purpose to enable curved and flexible displays, the mobile display market is strongly shifting towards organic light emitting diode (OLED) technology. Hence, the demand on highly efficient OLED emitters is growing with focus on reduced power consumption. At the same time decreasing the sub pixel size to increase display resolution is common target. Today, OLED emitters which combine high efficiency and lifetime are limited to green and red. For blue, only stable fluorescent emitters with a limited efficiency are available. Therefore, new approaches of blue emitters with increased efficiencies and stability are needed.

CYNORA´s approach to fulfill this gap is based on thermally activated delayed fluorescence (TADF) technology to provide efficient and stable blue OLED emitters. TADF emitters facilitate a theoretical internal quantum

efficiency of 100% like their phosphorescent counterparts. That is four times higher than for conventional fluorescent systems. This efficiency enhancement is utilized by harvesting both triplet and singlet excitons for the emission of light.

CYNORA has recently made significant progress in the development towards highly efficient and stable deep blue emitting TADF materials. Device EQEs (external quantum efficiency) exceeding 10% at an electroluminescence center wavelength of λ < 480 nm and a lifetime > 300 h (LT_{80} at 500 cd m^{-2}) were achieved. While our materials are designed for thermal evaporation, they are also compatible for solution processing as is or via slight chemical modifications.

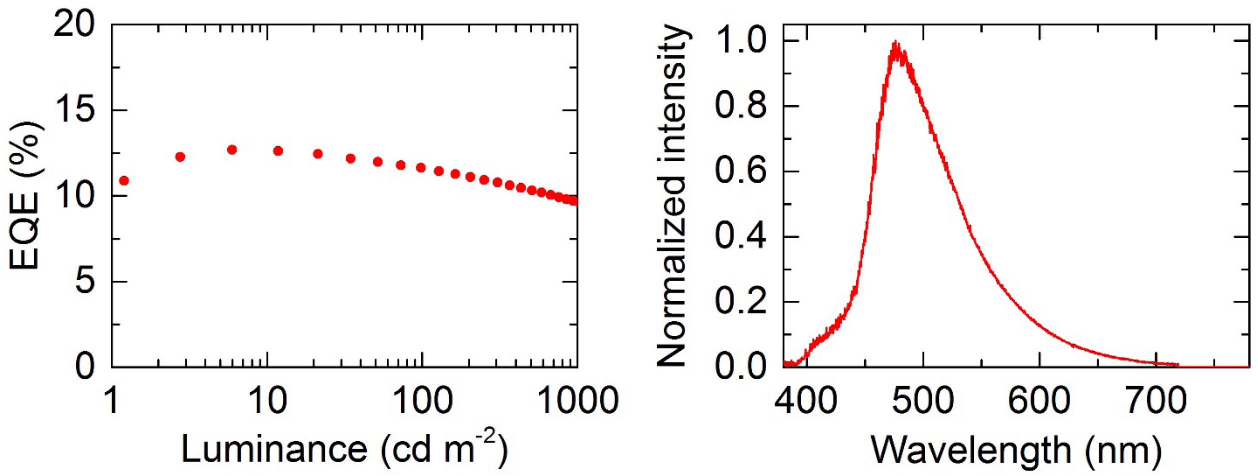


Figure 1. Optoelectronic characteristics of an OLED with TADF emitter: At an electroluminescence center wavelength of λ = 478 nm and a luminance of 500 cd m^{-2}, an external quantum efficiency of > 10% is achieved.

BIOGRAPHY

Dr. Georgios Liaptsis received his PhD in 2012 from the Chemistry Department of the University of Cologne (Meerholz Group), Germany. During his thesis with the title: "Synthesis of Crosslinkable Organic Seminconductors and Application in Solution Processed OLEDs" he explored the structure-property-relations of several material classes for OLEDs. Since 2013 he joined CYNORA where he executed positions in R&D and business development. Meanwhile, as the team leader of the device group, he is responsible for the stack development at CYNORA GmbH.

William Taube Navaraj

UNIVERSITY OF GLASGOW

Metal-assisted Chemical Etched Si Nanowires for High-Performance Large Area Flexible Electronics

W. Taube[δ], D. Shakthivel[δ], C. García Núñez[δ], F. Liu[δ], D. Gregory[Δ], R. Dahiya[δ,*]
[δ]Bendable Electronics and Sensing Technologies Group, School of Engineering, University of Glasgow, UK
[Δ]School of Chemistry, University of Glasgow, UK

ABSTRACT

Silicon (Si) nanowires (NWs) are considered important building blocks for high-performance flexible and large-area electronics (LAE). Attributes such as bendability, mobility, ability to achieve high on/off current ratio and suitability for device fabrication make Si-NWs suitable candidates for applications in electronics, optoelectronics, photonics, photovoltaics, sensing and wearable technologies [1-3]. Functionalized or non-functionalized Si-NWs based large area arrays over flexible substrates could be used both as sensing material as well as switching devices. Synthesis of single crystalline doped Si-NWs, controlled NW transfer process and the fabrication of NW field-effect transistors (FETs) are the key steps to realize these applications. Here we present the fabrication and characterisation of flexible NWs based FETs using a cost-effective Si-NWs synthesis and transfer process.

Metal-assisted chemical etching (MACE) is considered as one of the cost-effective techniques for the synthesis of single crystalline Si-NWs. This top-down approach uses bulk single crystalline wafer as a starting material for the synthesis of Si-NWs. First, the catalyst metals with nanosized circular patterns are prepared over Si wafer surface and then the wafer was immersed in an etching solution consisting of HF and H_2O_2. The advantage of this technique is the ability to synthesize Si-NWs at wafer scale, with good control over doping, NW size and NW-to-NW spacing. This approach is favourable for printing of Si-NWs over large areas and non-conventional surfaces. In the current work, Si NWs were synthesised using Nano Sphere Lithography (NSL) patterning followed by MACE process (Fig. 1(e, f)). Close-packed assembly of silica nanospheres (NSs), deposited by dip-coating method, act as a mask for Ag catalyst. The initial dimension of NSs determines the pitch of the nano-mesh (Fig. 1(c,d)). Reactive ion etching (RIE) is carried out subsequently to shrink the NSs to desired dimensions which eventually determines the diameter of resulting NW. Si NWs are synthesised in the diameter range of ~100 nm, lengths up to hundreds of microns, and printed over flexible substrates at defined locations. NW FETs were fabricated (Fig.1(g)) and their performance was studied through current-voltage (I-V) characteristics. This research sets a platform to realize high performance electronics over flexible large-area materials using inorganic nanostructures.

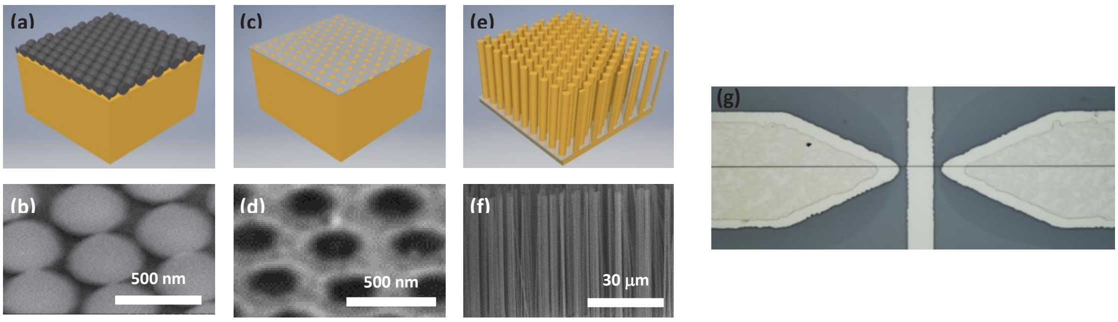


Fig. 1. 3D schematic illustrations and micrographs of the MACE process flow and fabricated NW FET. (a,b) Assembly of silica NSs over Si wafer. (c,d) Preparation of Ag catalyst nanomesh. (e,f). MACE Si NWs. (g) Optical image of the NW FET from MACE process.

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[3] D. Shakthivel, C. García Núñez, and R. Dahiya, “Inorganic semiconducting nanowires for flexible electronics,” United Scholars Publications, 2016.

BIOGRAPHY

William R Taube Navaraj received his B.E. degree in Electronics and Communication Engineering from Anna University-Thiagarajar College of Engineering in 2009 and M. Tech. degree in Advanced Semiconductor Electronics from Academy of Scientific and Innovative Research (AcSIR) in 2011. Before joining University of Glasgow for his PhD, he was working as a Scientist in Sensors and Nanotechnology Group at CSIR-Central Electronics Engineering Research Institute (CEERI), Pilani, India's pioneer research institute in the area of electronics. His current research interests include flexible electronics, nano-electronic devices and technology, tactile sensing, sensors-to-devices-to-systems, 3D printing prosthetics/robotics. He has won CSIR-QHS Fellowship, best paper awards in international conferences, Department Topper during Masters' Degree, Child scientist award from NCSTC-DST, District Topper in Higher Secondary Exams, Anna Award from Govt. of Tamil Nadu and several prizes in various engineering projects and robotics events. He is a student member of IEEE-UK, IEEE-EDS Society, IEEE Sensors Council, IEEE Nanotechnology Council, member of IET-UK, associate member of IE (India), life fellow of OSI.

Dr James Semple

IMPERIAL COLLEGE LONDON

Engineering the world's largest nanofeature for fast, printed diodes on plastic

James Semple, Dimitra Georgiadou, Gwenhivir Wyatt-Moon, Thomas D. Anthopoulos
Centre for Plastic Electronics and Department of Physics, Imperial College London

ABSTRACT

Reliably engineering nanoscale features for large area electronics (LAE) remains a bottleneck in the field and, if overcome, would allow for significant progress in many respects. For instance, large area fabrication of nanogap electrodes alone could be advantageous for the facile production of chemical sensors, light sensors, strain sensors and energy harvesting antenna arrays. Furthermore, downscaling device dimensions has the effect of improving device frequency performance. This is critical as the printed semiconductors employed for LAE have an inherently poor intrinsic frequency response, owing to their microscopic disorder.

Herein, we present advances in the scale up of adhesion lithography (a-Lith), an unparalleled nanogap electrode fabrication technique. Unique to a-Lith are the abilities to employ mismatched metal electrodes (e.g. aluminium and gold) separated on the order of nanometers, and to carry out the process on hundreds of electrode sets in parallel on a variety of substrates, including plastic. Specifically, we detail advances in minimising gap dimensions to below 10 nm, increasing uniform gap fabrication yields to > 90 % and boosting the width of the nanogaps up to 1 m, to achieve unprecedented aspect ratios in excess of 100,000,000 (the world's largest nanofeature).

Finally, we demonstrate the results of implementing these nanogap electrode structures as building blocks for high frequency printed ZnO Schottky diodes. Such diodes have been shown to operate into the GHz regime with significant output power, and thus could find applications in rectifier circuits for flexible radio frequency identification (RFID) technology and thus as an enabler for the internet of things (IoT).

BIOGRAPHY

Dr James Semple is a Research Associate at the Centre for Plastic Electronics and Department of Physics in Imperial College London. He is working under the supervision of Prof. Thomas Anthopoulos on the EPSRC Centre's PLANALITH project. The project focuses on optimising device structures to enable high frequency printed diodes for radio frequency identification (RFID) applications. James received his PhD in Physics from Imperial College in 2016, on the topic of large-area plastic nanoeletronics, with a focus on electronic devices based on adhesion lithography. Prior to that, he received his BA in Physics from Trinity College, Dublin, with projects focused on the mechanical and optoelectronic properties of solution processed two dimensional composite materials. His research interests include printed radio frequency Schottky diodes, photodetectors and memory devices, based on planar electrode device architectures.

Dr Kornelius Tetzner

IMPERIAL COLLEGE LONDON

Rapid fabrication of solution-processed metal oxide transistors via photonic processing at room temperature

K. Tetzner, Y.-H. Lin, T. D. Anthopoulos
Department of Physics and Centre for Plastic Electronics, Imperial College London, South Kensington, London SW7 2AZ, United Kingdom

ABSTRACT

The use of solution-based fabrication processes for the realization of (opto-)electronic devices and circuits based on metal oxide semiconductors has become an attractive alternative to conventional manufacturing technologies allowing for the reduction of manufacturing costs by large-area production. Field-effect mobilities of metal oxide transistors are already well beyond those of amorphous silicon and the performance of such devices is steadily increasing due to material and process optimization. However, still the limiting factor in the fabrication process is the annealing step of the metal oxide semiconductor involving high curing temperatures typically beyond 200 °C for prolonged periods of time in order to achieve optimum charge transport properties. This makes the use of low-temperature substrates unfeasible and also hampers rapid throughput during production. To overcome these issues several recent studies reported the use of flash lamps for the rapid conversion of the electroactive films as a promising approach. However, to date, all reports involving photonic-based processes are solely restricted to experiments carried out on silicon substrates and neither glass nor plastic substrates have been used so far which show completely different thermal properties.

Here we report the fabrication of solution-processed metal oxide transistors where the precursor material layer is rapidly converted to its stable metal oxide semiconductor state using a high power xenon flash lamp. Using this technology we are able to demonstrate low operating voltage (≤2 V) n-channel indium oxide (In_2O_3) and zinc oxide (ZnO) transistors with electron mobilities of 1.7 cm^2/Vs and 6 cm^2/Vs, respectively. Although, this level of performance is comparable to reference devices fabricated via conventional thermal annealing at 250 °C for >20 min, photonic processing is extremely rapid with low thermal budget. The later make photonic processing attractive for high throughput manufacturing of metal oxide electronics on temperature sensitive substrate materials such as plastic. Besides the electrical characterization the influence of the high intensity flash exposure on the surface topography and elemental composition of the resulting semiconductors is investigated by atomic force microscopy and x-ray photoelectron spectroscopy. Finally, through the use of numerical modelling, we are able to analyse the temperature profile within the layer stack and its evolution with time. The calculations reveal a remarkable increase of the temperature beyond 1000 °C in less than 1 ms within the metal oxide layer during each light pulse while the temperature of the backside of the substrate is found to remain unchanged and close to room temperature. Our work demonstrates the tremendous potential of photonic processing for the rapid manufacturing of metal oxide electronics on arbitrary substrate materials.

BIOGRAPHY

Kornelius Tetzner studied electrical engineering at the Technische Universität Berlin where he received the degree of a graduated engineer (Dipl.-Ing.) in 2008 and doctor of engineering (Dr.-Ing.) in 2014, respectively. During his PhD studies he worked as a research assistant at the Technische Universität Berlin from 2009-2014 focusing on the use of semiconducting liquid-crystalline polymers for large-area fabrication of electronic devices and circuits. In 2015 he started working as a research associate at Technische Universität Dresden working on additive patterning processes of organic/inorganic materials for flexible electronics. In the same year he was awarded with a Marie-Curie fellowship and became a research associate at Imperial College London under the supervision of Professor Thomas Anthopoulos. His current research focuses on the realization of complementary integrated circuits combining organic and inorganic semiconductors into a hybrid approach by using solution-based deposition techniques.

Dr Dimitris Karnakis

OXFORD LASERS

Ultrafast Laser Processing for Organic Thin Film Transistor Manufacturing

D. Karnakis[1] R. Geremia[1], N. Bellini[1], S. Norval[2], G. Fichet[2]
[1] Oxford Lasers Ltd, Unit 8 Moorbrook Park, Oxfordshire, OX11 7HP, United Kingdom
[2] FlexEnable Ltd, 34 Cambridge Science Park, Cambridge, CB4 0FX, United Kingdom

ABSTRACT

There is a plethora of high volume patterned printing technology options for manufacturing organic thin film transistors (OTFT) and other logic circuitry on flexible substrates. Most of these technologies such as photolithography, nanoimprint lithography, flexographic printing, etc. are already in use, utilising a series of well established, distinct advantages. But such techniques and associated hardware are carefully optimised for batch processing only. Hence, they are unsuitable for low volume pilot production, which is much needed for device prototyping, due to their inherent limitations around cost, number of development steps and cycle time, etc. At present, reliable, low cost, adaptable soft tooling techniques are critically needed to help open up niche markets in flexible electronics. Digital fabrication technology such as inkjet and laser is increasingly bridging this gap bringing new tools and manufacturing advantages to the engineer's and scientist's toolbox.

Laser ablation using diode-pumped solid state (DPSS) lasers is such a direct-write digital technology, which combined with CAD design software and motion automation such servo CNC axes, reel-to-reel and/or optical scanning axes becomes a highly versatile development and pilot production tool offering design flexibility for surface patterning. Ultrafast lasers in particular unlock a further advantage by offering the opportunity for "cold laser processing" i.e. nanometre scale selective layer processing below the materials' melt points based on photomechanical rather than thermal evaporative ablation mechanisms. Such processing can guarantee true selective patterning of ultrathin layers like those encountered in OTFT processing with diffraction limited optical resolution, no damage to stack under layers and maintaining sufficient feature quality, edge control and position accuracy (single micrometre scale) as those delivered by traditional photolithography.

In this paper, we will present recent successful results of flexible display backplane manufacturing (source/drain patterning and via interconnection drilling, Fig.1) with different picosecond and femtosecond ultrafast DPSS lasers. We will discuss the merits of optimum choice of laser wavelength and laser pulse duration to unlock the valuable low temperature "stress-assisted ablation" mechanism and support all this with robust electrical performance measurements from fully working OTFT stacks on demonstrator flexible displays built with such a method.

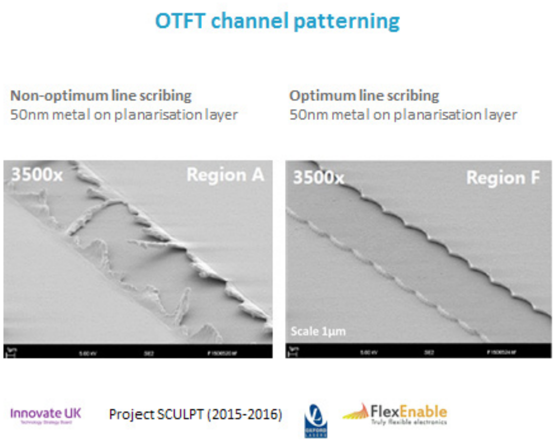


Fig.1 Examples of OTFT laser patterned source/drain electrodes with optimum and non-optimum laser conditions

This work was part funded by Innovate UK, grant agreement 315222, project SCULPT

BIOGRAPHY

Dimitris Karnakis (PhD, Hull University) is currently Technical Manager for R&D Projects at Oxford Lasers Ltd (UK) having previously held the positions of Applications Engineer and Project Leader for laser micromachining systems since 2003. He is responsible for collaborative research and technology development for advanced laser micro/nanofabrication applications and increasingly involved in new business development. Dimitris has 25 years' experience in laser technology having earlier worked at Exitech Ltd (Oxford), Japan Atomic Energy Research Institute (Osaka) and Hull University (Hull). Dimitris is currently interested in ultrathin layer patterning, advanced laser beam shaping, laser transfer LIFT printing and conductive material sintering as well as ultrafast laser processing of dielectrics.

Thomas Cosnahan

UNIVERSITY OF OXFORD

Vacuum Flexographic Patterning of Sacrificial Oil for Organic Transistor Aluminium Contacts

ABSTRACT

Patterning was identified by the OE-A 2015 6th edition roadmap as a key challenge for flexible technology. Combining precision patterning with high throughput roll-to-roll systems is an important area of research for large area electronics, be it photovoltaics, displays, or organic electronics. This research has investigated flexography printing in vacuum to create organic thin film transistors.

Flexography is a roller based printing system which has already been used to pattern solvent based organic and inorganic layers of transistors. In this work the rotary flexographic process has been optimised to pattern a sacrificial oil onto a plastic web, on top of which aluminium is thermally evaporated to form the source and drain of common gate top contact transistors. This deposition process requires a lower latent heat of

vaporisation of the oil than the thermally evaporated metal, in order that the patterned oil is evaporated as the metal vapour condenses on the substrate. The process is already used industrially e.g. for decorative and holographic applications. Our investigation of its suitability to the fabrication of functional devices requires a clear understanding of the process mechanics and materials requirements.

A custom built flexographic printing set-up has been created within a vacuum deposition system, with control over the process factors, such as nip force. A coating drum rotating within a small vacuum chamber is wrapped with polymer substrate or devices on polymer, and the web moves past the printing head followed by metallization. This paper will report how the equipment can be used to modify the printing parameters during optimisation experiments and also to create devices to improve our understanding of the process. The results from the optimisation of process parameters, such as nip force, oiling and process speed, provide an insight into flexography ink transfer dynamics. We report quantitative assessment of the printed patterns using image analysis. The results are discussed in relation to understanding from solvent based flexography.

To achieve metal evaporation patterning, using the custom built flexographic printer, first the sacrificial oil was metred onto the relief pattern of a silicone flexo print roller in ambient conditions. The silicone print head was a sleeve of polydimethylsiloxane which had the relief features created from diamond saw cut silicon. Next, under vacuum, the flexo roller/process drum nip force was varied to remove killer defects and achieve the best line edge.

We will report on use of this aluminium metallisation process applied to organic thin film transistors, with a molybdenum tri-oxide carrier injection layer. The patterned transistors were compared to control transistors patterned with masks, as has been the historic standard procedure outside a roll-to-roll process.(1) Using aluminium as a source drain contact is a beneficial advance in organic transistor production. This is due to the lower materials cost compared to the previous use of gold. The encouraging results demonstrate the applicability of this flexographic process to metallizing any pattern on vacuum processed high end applications.

1. Abbas G a., Ding Z, Assender HE, Morrison JJ, Yeates SG, Patchett ER, et al. A high-yielding evaporation-based process for organic transistors based on the semiconductor DNTT. Organic Electronics. 2014 Sep;15(9):1998–2006.

BIOGRAPHY

I read Materials Science and Engineering at Imperial College London for four years (MEng). I conducted research projects into theoretical infrared energy harvesting and, for my master's research, the laser cleaning of plastics for conservation purposes. This research was in collaboration with the Victoria & Albert Museum and the City and Guilds of London Art School. I am now in my 3rd year of my DPhil research in the Department of Materials, University of Oxford, researching patterning using the vacuum roll-to-roll industrial-scale facilities at Oxford University.

Thomas Kolbusch

COATEMA COATING MACHINERY GMBH

Process technologies for Printed Electronics: And overview of the latest trends and developments

Thomas Kolbusch, Dr. Klaus Crone, Dr. Nico Meyer

ABSTRACT

The IoT or IoE is suposed to be multi billion dollar market in the next years. 5G networks and the rapid growth of cloud data storage will impact the whole society and will make data measurement, collection and storage the market of the future. A huge part will be software and data storage, but there is also a need for new type of hardware components.

Here the products named under Printed Electronics provide the promise to supply the trillions of devices needed for the internet of everything. Printed sensors in R2R processes, hybrid systems and fully integrated devices with sensor, display, memor and, wireless data transfer have the promise of being low cost, disposable and give freedom of design.

The author will describe in his talk the needed R2R core technologies like coating, printing and laminating. A deeper look is taken into processes like UV nanoimprint lithography and thermal nanoimprint Lithography, laser patterning and high accuracy registration control for these processes.

BIOGRAPHY

Thomas Kolbusch is Vice President of Coatema Coating Machinery GmbH, an equipment manufacturing company for coating and printing solutions located in Dormagen, Germany. Since 1999 he is working for Coatema Coating Machinery GmbH in different positions. His responsibilities are marketing, sales and business development.

He is member of the board of directors of the OE-A (Organic Electronics Association). In the OE-A he leads a working group which is dedicated to “Up-scaling Production – from Lab to Fab” and is chairman of the Lopec exhibition which is world largest event on printed electronics.

He is member of the board of directors of COPT.NRW which is a local association in Germany on printed electronics.

Thomas studied Business Economics at the Niederrhein University of Applied Sciences and got his degree as business economist in 1997. He worked for 3M, Germany and the alpi GmbH in Germany, before starting at Coatema GmbH.

Prof. Roisin Owens

ÉCOLE DES MINES DE SAINT-ÉTIENNE (EMSE)

Upping the ante for organic bioelectronics; integration with 3D tissue models

R. M. Owens, Dept. of Bioelectronics, Ecole des Mines de St. Etienne

ABSTRACT

The development of electrical techniques for monitoring of biological phenomena is a field that is fast gathering pace. Advantages of electrical techniques are manifold, including the fact that they are label-free, and have the potential to be very efficient transducers, since the signal measured is already in an electrical readout format. Electronic methods for live-cell sensing can be applied to applications involving extracellular recording of electrical activity from electrically active cells (neurons/myocytes), but also for monitoring of non-electrically active cells and tissue assemblies. We have successfully demonstrated the use of conducting polymer (CP) devices for monitoring a variety of in vitro models with the goal of developing physiologically relevant systems with integrated monitoring for use in diagnostics, toxicology or drug development.[1,2] [3] CPs are 'smart materials' that have gained considerable attention of late for their use in interfacing with tissues in vivo and in vitro.[2] Mixed ionic/ electronic conduction, along with an ideal biocompatible surface and soft tissue-like mechanical properties, have contributed to the successful use of this material for integration with biological components. One key advantage of these materials is their amenability for processing in a variety of formats, including in 3D scaffolds.[4] A second major advantage of CPs is their compatibility with high resolution imaging, allowing correlation of electrical data with time lapse imaging of the cells in real time.[5] In this presentation I will show recent work on the integration of both microfluidics and 3D tissue models with CPs to allow real time monitoring of cellular function.

[1] M. Huerta, J. Rivnay, M. Ramuz, A. Hama, R. M. Owens, *Appl. Vitro Toxicol.* **2016**, *2*, 17.

[2] X. Strakosas, M. Bongo, R. M. Owens, *J. Appl. Polym. Sci.* **2015**, *132*, 41735.

[3] M. Huerta, J. Rivnay, M. Ramuz, A. Hama, R. M. Owens, *APL Mater.* **2015**, *3*, 30701.

[4] A. M.-D. Wan, S. Inal, T. Williams, K. Wang, P. Leleux, L. Estevez, E. P. Giannelis, C. Fischbach, G. G. Malliaras, D. Gourdon, *J. Mater. Chem. B* **2015**, *3*, 5040.

[5] M. Ramuz, A. Hama, J. Rivnay, P. Leleux, R. M. Owens, *J Mater Chem B* **2015**, *3*, 5971.

BIOGRAPHY

Róisín Owens is an Associate Professor in the Department of Bioelectronics at the Centre Microélectronique de Provence. She received her BA in Biochemistry at Trinity College Dublin, and her PhD in Biochemistry and Molecular Biology at Southampton University. In her early postdoc work she specialized on biochemical aspects of infectious diseases, including enteric pathogens and tuberculosis, but then moved into novel therapeutics (for rhinovirus) using protein engineering and development of new technologies for pathogen detection. A continued interest in novel engineering technologies for biological applications led her to the field of organic bioelectronics. Her current research centers on application of organic electronic materials for monitoring biological systems in vitro, with a specific interest in understanding the biotic/abiotic interface. She has received several awards including the European Research Council starting and proof of concept grants, a Marie Curie fellowship, and an EMBO fellowship. In 2014, she became principle editor for biomaterials for MRS communications (Cambridge University Press), and she serves on the advisory board of Materials research express (IOP publishing) and Journal of Applied Polymer Science (Wiley). She is author of 50+ publications).

Prof. Fabio Biscarini

UNIMORE/SCRIBA NANOTECNOLOGIE SRL

Electrolyte-gated organic field effect transistors: fundamentals and applications to biosensing

Michele Di Lauroa, Marcello Bertoa, Carlo Augusto Bortolottia, Marcello Pintia, Andrea Cossarizzab, Michele Zolic, Fabio Biscarinia
a) Life Sciences Dept., Università di Modena e Reggio Emilia, Modena , Italy.
b) Dipartimento di Scienze Mediche e Chirurgiche Materno-Infantili e dell'Adulto, Università di Modena e Reggio Emilia, Modena , Italy.
c) Dipartimento di Scienze Biomediche, Metaboliche e Neuroscienze, Università di Modena e Reggio Emilia, Modena, Italy.

ABSTRACT

Organic field effect transistors (OFET) in aqueous environments can be operated as ultra-sensitive biosensors, transducers of electrical and electrochemical signals from cells, and stimulators for electroactive cells. Their applications range from detection of biomarkers in bodily fluids to implants for bidirectional communication with the central nervous system. They are used in diagnostics, loco-regional treatments and theranostics. Several OFET layouts have been demonstrated to be effective in aqueous operations, which are distinguished either by their architecture or by the respective mechanism of doping by the ions in the electrolyte solution. In this work we discuss the chemical-physics of the electrolyte-gated OFET (EGOFET). We show how the substrate plays the role of a second bottom gate, whose potential is actually fixed by the pH/composition of the electrolyte and the gate voltage applied. The presence of the substrate can be exploited to modulate the capacitive coupling of the electrolyte solution with the semiconductor by almost one order of magnitude. We also show that this device, operated as a biosensor for a primary inflammatory citokine, i.e. TNF-alpha, responds super-exponentially in current vs analyte concentration in the sub-nM range, whereas it responds linearly at concentrations greater than 1 nM. We unify the two regimes by introducing the changes of the density of states of the organic semiconductor (pentacene in our case) upon the change of the electro-chemical potential caused by the adsorption of TNF-alpha. We finally show that the response is modulated by the gate voltage applied, and that is possible to measure the association binding constant of the antibody-antigen recognition, the molar free energy, and the electrostatic contribution to the free energy from the analysis of the transfer curves. This work is supported by MIUR IT/SE Strategic Project Poincaré and UNIMORE FAR 2015 Project PRODE.

BIOGRAPHY

Fabio Biscarini is Full Professor of General Chemistry and Nanobiotechnologies at Università di Modena e Reggio Emilia. He was CNR Research Director at CNR-ISMN and Professor of Nanotechnology at Alma Mater-Università di Bologna. He graduated cum laude in Industrial Chemistry at Università di Bologna, and received a PhD in Chemistry at University of Oregon. His research spanned theory of STM, thin film growth phenomena, self-organization, unconventional nanofabrication and organic electronics. He is currently studying fundamental aspects of organic field effect transistors and developing organic bioelectronics biosensors of inflammatory biomarkers and implantable devices for regenerative treatment of Parkinson's disease. He is inventor of 19 patents and 230 publications. He has founded two spin-off companies. He coordinated more than 30 EU and National projects. He received the 2007 EU-Descartes Prize, the 2012 Sapio Prize for Industrial Research, and he is fellow of the Royal Society of Chemistry (UK) since 2004.

Dr Daniel Chew

GALVANI BIOELECTRONICS (A GSK SUBSIDIARY)

Road mapping bioelectronic medicine – neural interface applications

BIOGRAPHY

Dr Daniel Chew leads the neural Interfacing development, and in vivo delivery efforts, at the Stevenage site in the UK, and directs the laboratory work conducted there. The Galvani Bioelectronics laboratory, drives early stage feasibility studies of autonomic nervous system neuromodulation, across a pipeline of disease indications. Work centres around exploring the fundamentals of nerve physiology, and optimising ways to interact with the disparate anatomy. This involves the pursuit of ex vivo and in vivo electrophysiology methods, while driving the process of development of mechanically and electrically compliant neural interfaces for patients. Daniel's team manages a portfolio of external academic and industrial collaborations focused on driving research into novel and future interface architectures, materials, and therapeutic modalities. Our team collaborates extensively with our worldwide academic consortium; to develop, assist, and enable surgical and electrophysiological technical development and talent expansion. Daniel's prior academic career was focused on understanding the dynamics of the peripheral nervous system, developing pre-clinical in vivo neurosurgical models, and novel interface design and application.

Dr Mark Fretz

CSEM

ACTION - ACTive Implant for Optoacoustic Natural sound enhancement

ABSTRACT

The EU-project ACTION builds on the recent discovery that relatively low levels of pulsed infrared laser light are capable of triggering activity in hair cells of the partially hearing (hearing impaired) cochlea and vestibule. So far the excessively large volume of optical fibre systems and external light sources used for animal studies prevented the practical use of this discovery for long term animal research devices or for human grade implants. ACTION aims to develop a self-contained, smart, miniaturised system to provide optoacoustic stimuli directly from the electrode array of a cochlear implant. In-vivo measurements in guinea pig confirmed our hypothesis that the generated compound action potentials are indeed explained by the optoacoustic effect in the cochlea: IR-light from a tiny VCSEL- absorbed by a small volume of the cochlear fluid- generates heat and causes this volume to expand quickly. The volume/pressure change propagates through the cochlea and stimulates the hair cells.

A new miniaturised device sufficiently small for in-vivo chronic cat experiments will be available by the end of the project. The external part is a belt-worn box which runs autonomously for at least 24 hours. Acquired data is transferred wirelessly to a nearby computer. Two insertable stimulators have been fabricated: The first device is suitable for short term in-vivo tests (less than 29 days) and is based on a commercially available flexible PCB. The VCSEL is directly attached. The entire device is coated with a layer of silicone. The second device is exclusively made of biocompatible materials. The VCSEL is hermetically sealed inside a sapphire box. This device has slightly larger dimensions and was, therefore, not tested in in-vivo trials.

BIOGRAPHY

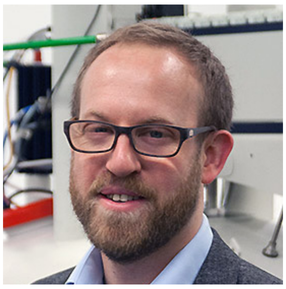
Mark is a senior R&D research engineer and project manager at CSEM and has been a member of the Optics & Packaging group since November 2012. He worked on and managed numerous projects concerning electronic and medical packaging as well as optical systems such as long-term implantable pressure sensors, fabrics inspection systems for looms and gas flow sensors.

Previously, Mark worked for Implant Systems, NICTA, in Australia from 2009 to 2012, where he focused on biocompatibility and –stability issues of spinal cord stimulator leads, and gained insight into developing long-term implantable devices.

Mark received his Diploma in Physics from the Federal Institute of Technology Zurich (ETHZ) in 2005 and a PhD from the University of Neuchâtel, Switzerland, in 2009 for his work on 'Flip Chip Bonding Technologies for Hybrid Integration' conducted at CSEM from 2005 to 2009. He was involved in developing novel packaging concepts for electronic devices and in testing new micro-joining techniques.

As a master student, Mark researched in the field of photorefractive crystals for laser beam quality improvement, which is a branch of nonlinear optics.

He co-authored several patents (some pending) concerning medical and electronic packaging, (co-) wrote several publications and presented at various conferences.



Dr John Hardy

LANCASTER UNIVERSITY

Multiphoton fabrication of bioelectronic biomaterials for neuromodulation (MFBBN)

Academics: John Hardy[1] and Frances Edwards[2]
Affiliations: 1) Lancaster University. 2) University College London.
Industrial Partners: GlaxoSmithKline, Kanichi Research Services Ltd.

ABSTRACT

Electromagnetic fields affect a variety of tissues (e.g. bone, muscle, nerve and skin) and play important roles in a multitude of biological processes (e.g. nerve sprouting, prenatal development and wound healing), mediated by subcellular level changes, including alterations in protein distribution, gene expression, metal ion content, and action potentials. This has inspired the development of electrically conducting devices for biomedical applications, including: biosensors, drug delivery devices, cardiac/neural electrodes, and tissue scaffolds. It is noteworthy that there are a number of FDA approved devices capable of electrical stimulation in the body, including cardiac pacemakers, bionic eyes, bionic ears and electrodes for deep brain stimulation; all of which are designed for long term implantation. Polymers are ubiquitous in daily life, and conducting polymers (e.g. polyaniline, polypyrrole, poly(3,4-ethylenedioxythiophene)) have shown themselves to be capable of electrically stimulating cells. Furthermore, when implanted in mammals their immunogenicities are similar to FDA-approved polymers such as poly(lactic-co-glycolic acid) (PLGA), supporting their safety in vivo. These preclinical studies suggest that conducting polymer-based biomaterials are promising for clinical translation.

The aim of this proposal is to use multiphoton fabrication to print conducting biomaterials for use as neural electrodes, characterize their physicochemical and electrical properties, and to validate the efficacy of the bioelectronic devices to interact with brain tissue ex vivo in collaboration with Frances Edwards at UCL Neuroscience. Clinically approved electrodes are manufactured from inorganic materials (e.g. titanium nitride, platinum, and iridium oxide), however, their mechanical properties are far from those of soft tissues in the central and peripheral nervous system, and such mechanical mismatch leads to local tissue inflammation and their encapsulation in fibrous scar tissue that impedes the successful function of the neural electrode (in some cases this necessitates the application of up to 7V to stimulate the nerve tissue which leads to tissue damage). The development of neural electrodes with biomimetic chemical and mechanical properties is highly attractive as it may facilitate the widespread use of such electronic devices. We present our progress so far in this endeavour facilitated by a Pathfinder Award.

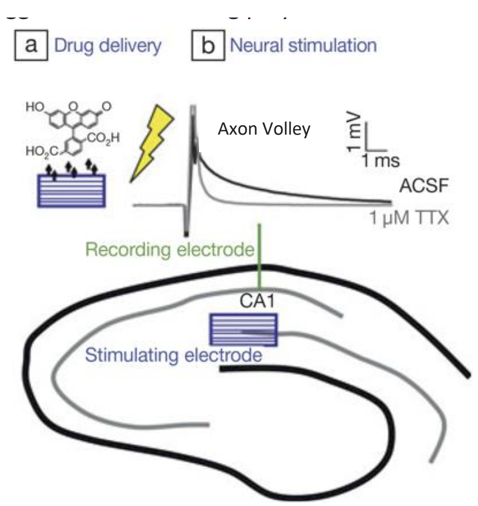


Figure 1: Conducting polymer-based electrode prepared by multiphoton fabrication for application as a neural electrode. Collaboration with Frances Edwards at UCL Neuroscience. Hardy, *J. Mater. Chem. B*. **2015**, 3, 5001.

BIOGRAPHY

John Hardy is a 50th Anniversary Lecturer in the Department of Chemistry and Materials Science Institute at Lancaster University. He obtained his first degree from the University of Bristol, and his PhD from the University of York working with Professor David Smith on supramolecular materials. He moved to Strasbourg in France to work on supramolecular materials with Professors Jean-Marie Lehn and Jack Harrowfield, to Bayreuth in Germany to work on silk protein-based biomaterials with Professor Thomas Scheibel, to the United States to work on organic bioelectronics for neuromodulation, drug delivery and tissue engineering with Professors Christine Schmidt (Austin, TX; Gainesville, FL) and David Kaplan (Boston, MA), and to Northern Ireland to work on light-responsive drug delivery systems with Professor Colin McCoy. He has published multiple papers and patents, serves on the Editorial Board for the International Journal of Molecular Sciences and Future Science OA, and kicked off his independent career developing materials that respond to electricity, light and magnetism for biomedical applications in Lancaster in August 2015.

Dr Manuel Pinuela

DRAYSON TECHNOLOGIES

Intelligent IOT networks for future cities

ABSTRACT

Drayson Technologies is an Internet of things (IoT) platform company using wireless charging technology and machine learning software to create smart sensor networks that deliver tangible business value for our customers and at reduced costs. We enable energy-efficient and cost-effective IoT intelligent data collection and analysis, which reduces the cost of deploying, owning and running IoT networks. We are making the IoT easy by deploying our core technologies, FreevoltTM and SensyneTM.

FreevoltTM is an innovative, patented and patent-pending wireless charging technology that provides trickle charging for the IoT sensor devices using recycled radio frequency (RF) energy harvested from existing wireless and broadcast transmissions such as microwave, cellular, WiFi and Digital TV when sufficient RF density is available, and inductive power transfer (IPT) using a dedicated transmitter.

SensyneTM is our proprietary software platform for building complete end to end IoT solutions that uses machine learning algorithms to provide the 'brain' of the network.

SensyneTM integrates seamlessly with our hardware technology, FreevoltTM, to provide an end-to end highly energy-efficient IoT platform that reduces the cost of installation and operation of IoT networks.

Two of the products we have created demonstrate these technologies. CleanSpaceTM is our first commercial application and the world's first IoT air pollution monitoring network that uses portable, personal air pollution smart sensors (the CleanSpaceTM Tag) to track exposure to air pollution (specifically carbon monoxide) in real-time and to crowd-source that data via a smartphone app to provide insights and maps to avoid pollution hotspots. It uses a machine learning and connected smart sensors to create the most advanced map of air pollution to enable people to "see the air they breathe" and to help enterprises and municipalities implement projects that improve air quality. Aura is a temperature and air quality monitoring system for buildings, facilities and asset management. Aura's end-to-end sensor network offers the ability to measure the near real-time temperature and air quality in offices or retail spaces. It optimises building monitoring efficiency and provides a cleaner working environment for people. It enables reduced monitoring costs, easier and robust compliance, as well as improved service levels and ease of installation.

Our company showcases a complete sensor solution combining an optimized hardware sensing platform (including a state of the art CO sensor) with an innovative self-powering technology and a complex, customizable software management view providing data insight to what is broadly known as the IoT world.

BIOGRAPHY

In 2009 Manuel Pinuela started his PhD in Electrical Electronic Engineering at Imperial College London developing systems for inductive power transfer and ambient RF energy harvesting. Both technologies have won awards in international conferences and are published in IEEE journals.

After more than five years of developing new technologies, as the CTO of Drayson Technologies, Manuel believes that technologies such as wireless power transfer will simplify our lives and completely modify the way we interact with the systems that surround us.

Dr Claudio Marinelli

EIGHT19

Commercialising organic photovoltaic – manufacturing and applications

ABSTRACT

Eight19 design, develop & manufacture energy harvesting solutions incorporating our unique flexible organic solar technology. In its transition from from research and development to manufacturing and commercialisation, Eight19 has combined vertical integration with the outsourcing of selected process steps to achieve volume capacity and device performance adequate for real world applications, while minimising the requirement for capital investment. The talk will describe technical challenges and achievements, as well as a range of near-term market opportunities.

BIOGRAPHY

Claudio has more than 25 years experience in business development and technology commercialisation. Previous roles include Senior Photonic Engineer in Silicon Valley (Luxnet Corp.), Open Innovation Director and Business Management Director in Nokia, as well as investor, founder and BD Director in UK ventures, including Applied Graphene Materials plc. Claudio holds a degree in Physics (University of Trieste, Italy), a PhD in Electronic Engineering (University of Bristol) and an MBA from the Judge Business School (University of Cambridge).

Dr Jeff Kettle

BANGOR UNIVERSITY

Accelerated testing for predictive ageing in organic solar cells for outdoor applications

Dr Jeff Kettle*, Mr Vasil Stoichkov, Mr Dinesh Kumar, School of Electronics, Bangor University, Wales, UK
* presenter and corresponding author

ABSTRACT

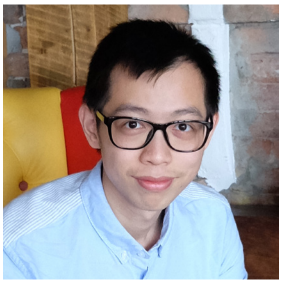
Accelerated Life Testing (ALT) is normally used to provide information on 1) a products failure mechanisms and/or 2) expected life in the field. Generally, ALT data analysis is separated into two distinct forms. Firstly, qualitative tests are used to compare the relative stability of products or to meet specific standards. Quantitative accelerated life tests are used for predictive ageing and tries to quantify this through the application of mathematical models. Currently, most ALT of organic photovoltaics (OPVs) in the literature is based on 'ISOS consensus standards,' which were devised by the OPV academic community to enable consistency when reporting lifetimes in literature. These are qualitative tests that are normally performed on small samples with the specimens subjected to a single severe level of stress, or multiple stresses (max. of 2), and limited to only one type of time-varying stress.

In this presentation, I will try to show how standard life test models can be applied to OPV modules to relate degradation in an indoor test chamber to data obtained outdoors from testing facilities at Bangor University. The degradation related to temperature, humidity, irradiance and thermal change has been studied. The results indicate that consensus test protocols (i.e. ISOS standards) do not provide a good enough range of stress conditions to accurately fit life test models to and therefore, additional testing data is needed. Multiple stress testing (i.e. light with additional factors such as temperature and humidity) is also required as OPV degradation is often related to the interaction between environmental stress factors.

Whilst the focus of this presentation will be on OPVs, many of the principles discussed are relevant to other plastic electronic products such as displays and sensors etc.

BIOGRAPHY

I received my PhD in 2008 and took up a position as a senior lecturer at Bangor University in 2012. I have previously worked at Alcatel SEL AG, Germany and 2 spin out companies and under the supervision of Prof Michael Turner and Prof Song at University of Manchester. Since starting at Bangor University in October 2011, I have secured £1.5m funding specific to solar cells and printed electronics from a variety of sources (Interreg, Royal Society, European Commission). I am a P-I on a Pathfinder project "stable Nanowires" which is funded from the large area electronics consortium. My expertise lies manufacturing and testing semiconductor devices, reliability studies and device modelling. I have published over 40 articles since beginning his PhD in 2006, all in peer review journals . I have also given several presentations at major international conferences including an invited talk on 'Accelerated testing of OPVs' at the ninth international summit on organic solar cell stability.



Dr Harrison Lee

SPECIFIC

Large area organic photovoltaic module for indoor applications

Harrison K. H. Lee,[1] Zhe Li,[1] James R. Durrant,[1,2] and Wing C. Tsoi[1]
1 SPECIFIC, College of Engineering, Swansea University, SA1 8EN, Swansea, UK
2 Department of Chemistry, Imperial College London, SW7 2AZ, London, UK

ABSTRACT

Different benchmark polymer based organic photovoltaic (OPV) systems, namely P3HT, PCDTBT, and PTB7, are tested as donor materials in blend with fullerene derivatives for comparison under artificial indoor lighting condition. We found that PCDTBT devices outperform the others generating 13.9 μW/cm^2 at a low light level of 300 lux, which corresponds to 16.6 % power conversion efficiency. To date, it is the highest record for polymer based OPV cells tested under low light level condition. This high power output density is comparable to other inorganic PV technologies such as silicon and gallium arsenide suggesting that OPV could be a promising candidate for indoor applications. Also, surprisingly, PTB7, the highest performing system under one sun, is not the highest performing systems under low light level. To explain the difference of their performance between under one sun and under low light, several device properties were studied. Based on these findings, we can conclude the criteria of selecting OPV systems for low light applications. A large OPV module, 14 cm by 14 cm with 100 cm^2 active area, is demonstrated and tested for real applications using PCDTBT as the active material.

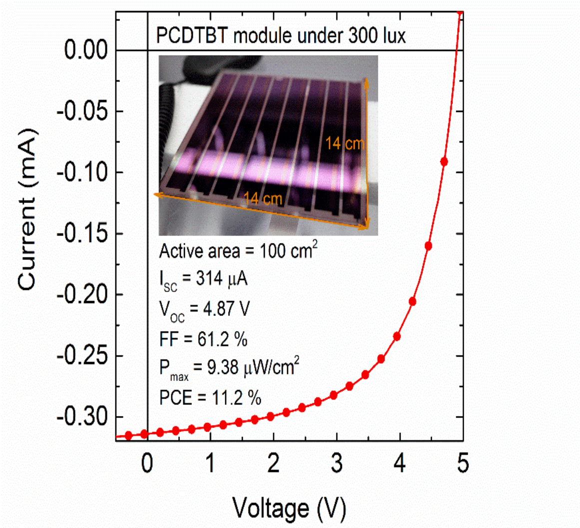


Figure 1 Current density-voltage (*J-V*) characteristic of a 14 cm by 14 cm PCDTBT:$PC_{71}BM$ module. The photo and the performance of the module are showed in the inset.

BIOGRAPHY

Harrison Lee is a Technology Transfer Fellow in SPECIFIC Swansea University in the photovoltaic group led by Prof. James Durrant.

Dr Stuart Higgins

IMPERIAL COLLEGE LONDON

Overcoming the challenges of using organic diodes for energy harvesting

Stuart G. Higgins*, Henning Sirringhaus
Optoelectronics Group, Cavendish Laboratory, JJ Thomson Avenue, Cambridge, CB3 0HE
*Present address: Department of Materials, Imperial College London, London, SW7 2AZ

ABSTRACT

One of the original selling points of organic electronics is the concept of cheap manufacturing. In particular radio-frequency identification (RFID) was seen as a promising target market, as organics have a clear manufacturing advantage that undercuts the normal silicon-based systems. But realising organic RFID tags has struggled due to the need for organic circuits capable of operating fast enough to rectify the high frequency radio signal (13.56 MHz) into a DC voltage.

To compound problems further, it's not just speed that you need to worry about. Not only does the rectifying circuit need to operate quickly, it also needs to provide sufficient current to power up the internal circuitry of the RFID tag. And it needs to be sustain that current during operation.

I will present the challenges organic electronics face for energy harvesting and RFID applications, and how through careful material choices and by understanding real-world power requirements, it's possible to produce organic diodes for high performance rectifying circuits, unlocking the potential for manufacturing fully organic RFID tags.

BIOGRAPHY

Dr Stuart Higgins worked on the Innovate UK funded project 'Security tags Enabled by near-field Communications United with Robust Electronics' (SECURE) within the group of Professor Henning Sirringhaus. He currently works on the microfabrication of innovative materials and devices for biomedical applications with Professor Molly Stevens at Imperial College London. He completed his PhD on organic transistors and complementary circuits with Professor Alasdair Campbell also at Imperial College London.

Dr Daniel Tate

UNIVERSITY OF MANCHESTER

Low power OFET based sensors for IoT applications

D. J. Tate1, E. Danesh[1,2], V. Tischler[1], S. Faraji[1,2], L. A. Majewski[3], K. C. Persaud[2], M. L. Turner[1]
1. OMIC, School of Chemistry, University of Manchester, M13 9PL, UK
2. School of Chemical Engineering and Analytical Science, University of Manchester, M13 9PL, UK
3. School of Electrical and Electronic Engineering, University of Manchester, M13 9PL, UK

ABSTRACT

Solution processed, printed electronics is an attractive and realistic alternative for the manufacture of large area inexpensive electronic devices such as flexible displays, RFID tags and environmental sensors.

Whereas traditional inorganic electronics require processing at high temperature and low pressures, organic electronics can be processed under ambient conditions, enabling manufacture on plastic substrates, desirable for their low cost, lightweight and mechanical flexibility.

Recently, organic field-effect transistor (OFET) sensors have attracted considerable attention due to their customizability through chemical structure modification, low-temperature processing, intrinsic mechanical flexibility and compatibility with large area manufacture. Such features, coupled with multiparametric data acquisition and signal processing provide OFETs with great potential as low-cost yet reliable sensors

Herein, we report the fabrication of a gas sensor array based on a fully solution processed bottom-gate bottom-contact organic field-effect transistor operating at low voltage (< 3 V). The sensor was fabricated on polyethylene naphthalate (PEN). Contact electrodes were patterned with a commercial nanoparticle ink via inkjet printing. A high-k/low-k bilayer dielectric was employed in order to achieve high dielectric capacitance as well as favourable interfacial contact at the dielectric poly(3,6-di(2-thien-5-yl)-2,5-di(2-octyldodecyl)-pyrrolo[3,4-c]pyrrole-1,4-dione)thieno [3,2-b]thiophene) (DPPTTT) interface.

To demonstrate the utility of our sensor array platform we evaluated the performance of the sensor towards ammonia due to the relevance in environmental and healthcare monitoring applications. The response of the sensor was measured as a change in source drain current upon exposure to a range of environmentally relevant ammonia concentrations (0.3 – 50 ppm, 0-80% RH) and was able to detect ammonia at concentrations as low as 600 ppb, 80% RH.

BIOGRAPHY

Dr Daniel Tate is a postdoctoral researcher at the Organic Materials Innovation Centre (OMIC), University of Manchester, currently working on iPESS, one of EPSRC Centre's flagship projects. Prior to taking up this appointment, Daniel worked at OMIC with Professor Michael Turner developing chemical field effect transistor sensors. He gained his PhD at the Centre for Molecular Nanoscience, University of Leeds, under the supervision of Professor Richard Bushby on the synthesis and uniaxial planar alignment of discotic liquid crystals for field effect transistors. Daniel continued this theme during a 1-year post doc with Professor Bushby, followed by a position with Professor Andrew Nelson, University of Leeds, developing aqueous electrochemical sensors.

John Biggs

ARM

PlasticARM: challenges in flexible printed VLSI

ABSTRACT

The projected market for the Internet of Things (IoT) is vast with some predicting an installed base of over 20Bn "things" by 2020 (Gartner). However, this opportunity also presents some significant challenges to the silicon based electronics industry, such as design cost, NRE and form factor, that can perhaps be more easily met by flexible ICs.

PlasticARM is a "blue sky" research project that is looking into the viability of building very cheap (disposable?) ARM based microcontrollers using state of the art thin film transistors on a flexible plastic substrate.

This presentation will draw on the experience of established VLSI design techniques that have been used in the silicon based electronics industry for many years to outline the challenges and opportunities that may lie ahead in fully exploiting the cost benefits of thin film flexible ICs.

By looking back at the developments in silicon ICs over the last few decades some interesting comparisons can be made with recent developments in thin film flexible ICs that may allow future predictions to be made.

BIOGRAPHY

John Biggs has been involved with ARM developments since 1986 and co-founded ARM Ltd. in 1990. After a number of years working as a VLSI design engineer he went on to form ARM's Design Methodology Group in 1995. John works as a Consultant Engineer in ARM's research group focusing on the development of advanced methodologies for the low-power deployment of synthesisable ARM IP. He holds a BSc in Electronic and Electrical Engineering from the University of Manchester and is currently chair of the IEEE1801 (UPF) work group.

Dr Iyad Nasrallah

UNIVERSITY OF CAMBRIDGE

Low-voltage Polymer Transistors for High-Performance Solution-Processed Complementary Analogue Amplifiers on Foil

Vincenzo Pecunia, Iyad Nasrallah, Atefeh Amin, Henning Sirringhaus

ABSTRACT

We present the development of low-voltage, flexible analogue operational amplifiers using complementary technology. The operational amplifiers consist of two-stage amplification with differential inputs.

Optimised polymer-based and metal-oxide transistors are used for p- and n-type transport, respectively. Using high-k dielectrics we are able to operate at a battery-compatible power-supply voltage of 5V, with gains of above 60dB below 8V supply voltage, and power dissipation of 11μW. To the best of our knowledge, this is the highest performing two-stage operational amplifier reported to date.

The high performance of our operational amplifier circuit meets the requirements of many aspired state-of-the-art applications, enabling battery-powered smart-sensing applications in healthcare, environmental monitoring, smart packaging, and wearable electronics.

BIOGRAPHY

Dr. Iyad Nasrallah is currently a Research Associate working with Prof. Henning Sirringhaus at the Cavendish Laboratory, University of Cambridge, UK. He holds an MEng in Electronic Engineering with Nanotechnology from the University of York, UK. He completed his PhD under the supervision of Prof. Henning Sirringhaus at the University of Cambridge where he worked on characterizing and improving device stability of organic field-effect transistors. His work was conducted in collaboration with an industrial partner. Iyad's current research interests are in the methods of integrating organic circuitry into state-of-the-art electronic applications using novel materials and fabrication processes.

Dr Gianluca Bovo

CDT

Solution processed organic photodetectors and integrated sensors

ABSTRACT

Organic photodetectors (OPDs) have received an increased level of attention over the past few years. The relative ease of processing devices via solution phase as well as the performance and cost tuneability according to application requirements make them promising alternative devices to their in organic contenders. Jointly with Sumitomo Chemical, CDT have developed materials and device architectures in order to address applications where there is a clear benefit of using OPDs. Materials capable of a wide spectral response from the visible to the near infrared(NIR) region have been developed. The devices we have developed are fabricated by coating films in ambient conditions on glass or flexible substrates from non halogenated solvents. These can be deposited via various coating methods, for example by spin coating, inkjet printing or slot die coating as well as many others. The design and performance of these devices will be presented with an emphasis on tailoring the device structure and performance toward specific application requirements. For applications that require low light level illumination conditions, increasing the signal-to-noise ratio of the OPD devices is paramount. To address this, we have developed devices with low dark current levels. A device with dark currents as low as 10pA/mm2 at-10V and with a weak dark current dependence on reverse bias will be presented ass how shown in figure1. An example of the integration of an OPD with OLEDs will also be presented. A flexible pulse-oximeter

(figure2) consists of red and NIR OLEDs integrated with an OPD on a single substrate. The benefit of using organic devices in such applications as well as the principle operation of the pulse-oximeter will be described.

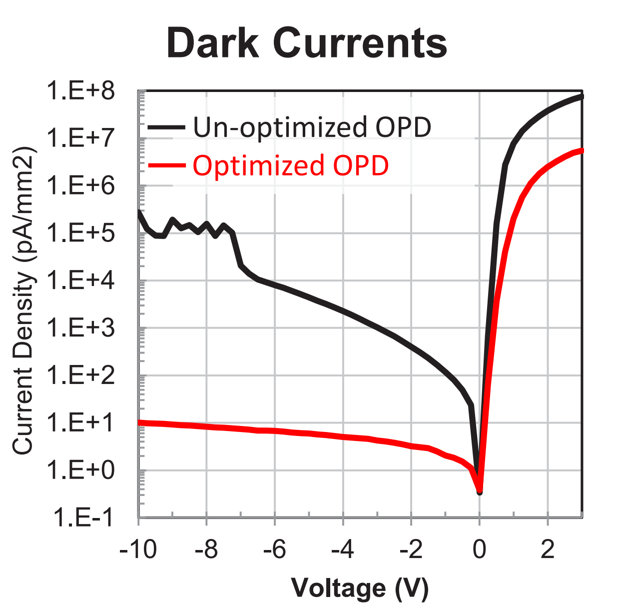


Figure 1

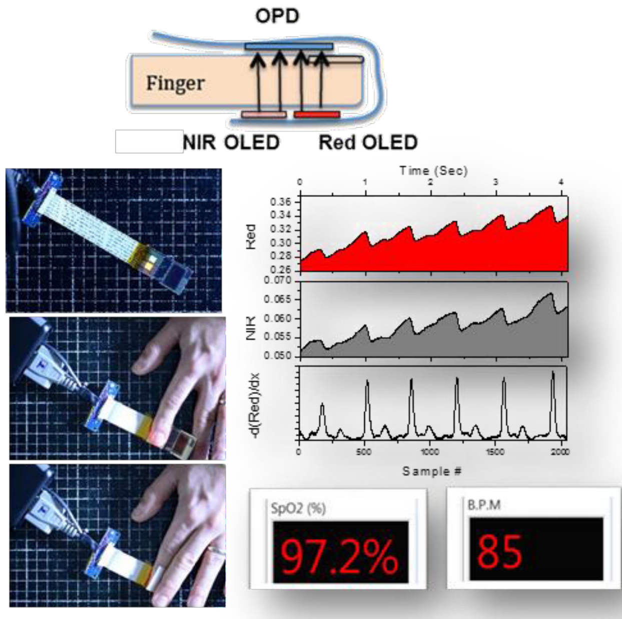


Figure 2

BIOGRAPHY

Gianluca earned his BSc and MSc in Materials Science from University of Padua (Italy) in 2009 and 2011 respectively, where he worked for one year on the integration of plasmonics with high electron mobility transistor structures for bio-sensing applications. He then moved to Imperial College London where he completed a PhD in Physics under the supervision of Prof Paul N. Stavrinou and Prof Donal D.C. Bradley on the processing, characterisation and device application of spin crossover polymers in photonics and electronics. He joined CDT in 2015 where, as a scientist, he has been working on the device development of organic photodetectors and integrated systems.

Dr Tiziano Agostinelli

FLEXENABLE

Security tags Enabled by near field Communications United with Robust Electronics (SECURE)

ABSTRACT

In this contribution, we will report on the performance of FlexEnable TFT technology in the security label market, based on research carried out within the Innovate UK-funded project SECURE (Security tags Enabled by near field Communications United with Robust Electronics) in collaboration with University of Cambridge and commercial partner De La Rue.

In this project, printed electronics in the form of high quality organic rectifiers and organic transistor logic circuits were integrated to produce a display-equipped RFID tag to be wirelessly powered at 13.56 MHz

and used in secure and innovative packaging concepts. The tag is low-cost and flexible and consists of a user input, a logic operation, an output display and a communication function. The demonstration of such functionality opens up new methods for manufacturing complex systems on flexible substrates by integrating a low density component with the RF antenna and the low power display and a high density component with the logic circuit and the rectification diodes.

The outcome of the project is a demonstrator manufactured using FlexEnable's production line in Cambridge and diodes fabricated at University of Cambridge. Significant part of the work focussed on the development of high-performance organic rectifying diodes for the energy harvesting block as well as reducing the operating voltage for organic logic circuits using FlexEnable's scalable manufacturing processes.

SECURE demonstrator with energy harvesting and logic foils bonded on PCB

NFC Communication

User Input

Display output

BIOGRAPHY

Dr Tiziano Agostinelli is Senior Design Engineer at FlexEnable Ltd. He received Laurea degree and PhD in Electrical Engineering from the Politecnico di Milano, Italy. Following post-doctoral years at Imperial College of London and Plastic Logic Ltd, he joined FlexEnable Ltd in 2015. He has over 10 years' experience working in the field of plastic electronics and he is author or co-author of more than 20 papers on peer-reviewed international journals. He is inventor or co-inventor of 3 patents filed/awarded. His expertise covers the device physics, modelling and process optimization of organic photodetectors, solar cells and thin film transistors. His current interests are the development of flexible backplanes and circuits for display and sensor applications.

Dr Catherine Ramsdale

PRAGMATIC

Moving towards mass manufacture

ABSTRACT

Flexible Electronics is moving ever closer to market reality and mass manufacturing. With this comes the need for a standardised design flow, controlled manufacture, high throughput testing and rapid failure analysis.

PragmatIC has recently announced funding for development of its FlexLogIC equipment under the EU Horizon 2020 SME Instrument Programme. FlexLogIC transfers PragmatIC's proven end-to-end flexIC production process, developed at the Centre for Process Innovation in Sedgefield, into a self-contained, fully automated, modular "fab-in-a-box" for high throughput manufacturing. FlexLogIC offers capacity for billions of flexICs at a capital cost between 100 and 1000 times lower than a silicon fab.

This presentation discusses the key considerations in moving PragmatIC's flexible electronics technology from R&D to mass manufacture and wider market adoption.

BIOGRAPHY

Dr Catherine Ramsdale is VP of Device Development at PragmatIC, based in Cambridge, (UK). She has more than 15 years experience in printed electronics research and development. Over 8 years at Plastic Logic she helped pioneer technologies for semiconductor devices on plastic, including successful transfer to manufacturing. She now leads the Device Group at PragmatIC, whose activities include; device design, modelling, test, reliability and failure analysis.

Catherine has a first in Physics from Imperial College and a PhD from the Cavendish Laboratory at Cambridge University, and is a named inventor on 12 patents.

Prof. Rhodri Williams

SWANSEA UNIVERSITY

Advanced Rheological Characterisation of functional inks for printed electronics (PE) applications yields improved prediction of line width accuracy and electrical performance

A. Holder[1], D.J. Curtis[1], J. Claypole[2], T.C. Claypole[2], D.T. Gethin[2], P. Cooper, P.R. Williams[1*]
1. Complex Fluids Research Group; 2. Welsh Centre for Printing and Coating
College of Engineering, Swansea University UK

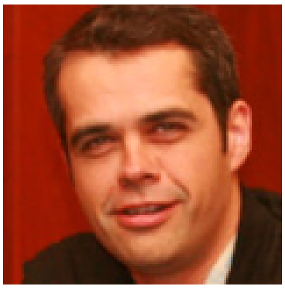
ABSTRACT

We report a new rheological characterisation technique based on Fourier transform mechanical spectroscopy in parallel superposition shear flow. Unlike established techniques such as small amplitude oscillatory shear (SAOS) in which no net deformation is experienced by the material, this new technique (FTMS-PS) provides measurements of key viscoelastic parameters (the superposition complex shear modulus $G^*_{//}$ and loss tangent $\tan\delta_{//}$ respectively) under conditions relevant to manufacturing flow processes. The frequency-multiplexing element of the new technique provides a basis for rapid measurements, thereby significantly reducing the mutation errors which are a feature of conventional measurements.

Validation of the new technique is reported with reference to model viscoelastic materials. Also reported are applications of the technique to functional ink systems (carbon-based and silver-based) over a wide range of solids concentration relevant to PE applications. Corresponding results of print trials demonstrate that both $G^*_{//}$ and $\tan\delta_{//}$ provide significant predictive capability in terms of (i) line width accuracy and (ii) electrical conductivity of printed lines. No significant predictive capability is achieved for these systems by corresponding measurements based on conventional rheometric methods. Moreover, we report how FTMS-PS provides a new basis for guiding potential cost-savings in terms of reduced energy costs and raw materials formulations costs for functional inks in PE applications.

BIOGRAPHY

Professor Rhodri Williams from Swansea University works in the fields of non-Newtonian Fluid Mechanics, rheology, haemorheology, nanotechnology and cavitation with special reference to process/chemical engineering instrumentation and theoretical developments relevant to the liquid state. In 2012 he was awarded an Enterprise Fellowship by the Royal Academy of Engineering for his development of new blood clot diagnostics and sensors. He is President of the British Society of Rheology (2013-2015) and lead author of over 130 papers. His work has also led to recognition though major awards from the Royal Society (Brian Mercer Award), the Institution of Chemical Engineers (IChemE) Industry Award for Innovation and Excellence, the Annual Award of the British Society of Rheology and the ICI/AkzoNobel Strategic Technology Award.



Prof. Luís Pereira

UNIVERSIDADE NOVA DE LISBOA

Printed oxide nanoparticles based devices on paper substrates

L. Pereira, L. Santos, P. Grey, J.T. Carvalho, D. Gaspar, E. Fortunato and R. Martins
CENIMAT/I3N, Departamento de Ciência dos Materiais, Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa and CEMOP-UNINOVA, Campus da Caparica, 2829-516 Caparica (Portugal)

ABSTRACT

The growing demand of new and sustainable consumer printed electronics led to the increased interest in electric and electrochemical devices on paper substrates. Here we present the wok resulting from recent research concerning the combination of oxide nanoparticles with cellulosic materials. First topic is related to nanostructured electrochromic printed films with controllable dual phase, which show an optical density 80% higher than amorphous ones, in parallel with improved coloration efficiency and response time (below

3s). Second topic to be addressed are printable inks based on commercial ZnO NPs mixed with some cellulose derivatives that were optimized to create printed channel layers at temperatures lower than 150 °C. This allowed the development of fully screen-printed EGTs with mobility above 1 $cm^2V^{-1}s^{-1}$ and on/off current ratio close to 10^4. Finally, the dual phase approach was used to prepare inks that can be written on paper, resulting in dense NPs matrix with sufficient interparticle connectivity to be used in hybrid handdrawn/printed UV-sensors, transistors and logic gates.

BIOGRAPHY

Prof. Luis Pereira was born in Lisbon, Portugal, in 1977. He received the Engineering degree in Materials Science in 2001 and has finished the Ph.D. in Microelectronics and Optoelectronics Materials in 2008 at Universidade Nova de Lisboa. His Ph.D. work was focused on polycrystalline silicon and high k dielectrics for TFT's application.

The expertise gained on oxide materials for electronics allowed focusing the pos-doc activities on the development printed inorganic nanostructured materials for chromogenic, electronic and electrochemical devices on paper and plastic substrates. He was involved in the team that demonstrated for the first time transistors made of oxides with paper as dielectric. He has authored and co-authored 156 publications in peer-reviewed journals and proceedings of the ISI with more than 3500 citations and has a H factor of 32.

He is currently a researcher at CENIMAT/I3N coordinating and participating in R&D projects and has been granted in 2015 with a Starting Grant of the European Research Council on the development of cellulose nanocomposites for paper electronics (New-Fun, project 640598). His current research interests are on the design and synthesis of 1D, 2D and 3D inorganic and hybrid nanostructures, chiral cellulose nanocomposites, functional micro and nanofibers and it integration on chromogenic, electronic and electrochemical devices.

Prof. Carlos Bufon

BRAZILIAN NANOTECHNOLOGY NATIONAL LABORATORY (LNNANO)

Three-dimensional organic conductive networks embedded in paper for flexible and foldable devices

Murilo Santhiago[1], Jefferson Bettini[1], Sidnei R. Araújo[1], Carlos C. B. Bufon[1,2,3]
[1]Brazilian Nanotechnology National Laboratory (LNNano), [2]Institute of Physics "Gleb Wataghin" (IFGW), UNICAMP, [3] Institute of Chemistry, UNICAMP.

ABSTRACT

Flexible and foldable devices have gain much attention in the field of low-cost electronics. Among the flexible materials used as substrates, paper is a very interesting candidate with several attractive advantages. For instance, paper is a natural polymer broadly available worldwide, lightweight, disposable, portable and foldable. Paper has, in addition, unique porous structure formed by cellulose fibers, which can drive solutions by capillary action. Here, we described the fabrication of three-dimensional (3D) polypyrrole conductive tracks through the porous structure of paper [1]. We combined paper microfluidics and gas-phase pyrrole monomers to chemically synthesize polypyrrole-conducting channels embedded in-between the cellulose fibers. By using the proposed method, foldable conductive structures can be created across the whole paper structure, allowing the electrical connection between both sides of the substrate. Our approach is a step forward towards the

development of 3D-electronic devices on paper. As a proof of concept, Top-Channel-Top (TCT) and Top-Channel-Bottom (TCB) conductive interconnections, as well as all-organic paper-based touch buttons are demonstrated. Our work essentially paves the way toward 3D fabrication of electrochemical devices [2], including sensors, capacitors and energy harvesting systems. Several devices can be manufactured in parallel and the fabrication process allows high-volume production.

Acknowledgements:
We would like to thank National Center for Research in Energy and Materials (CNPEM), Brazilian Nanotechnology National Laboratory (LNNano), CNPq and FAPESP

References:
[1] Murilo Santhiago, Jefferson Bettini, Sidnei R. Araújo, Carlos C. B. Bufon, ACS Appl. Mater. Interfaces 8, 10661(2016).
[2] Murilo Santhiago, John B. Widallys, Lauro T. Kubota, Charles S. Henry, Anal. Chem. 85, 5233 (2013).

BIOGRAPHY

Graduate in Physics at Heinrich-Heine Universität Düsseldorf (2006) in Germany. Group leader at the Institute of Integrative Nanosciences at the Leibniz Institute for Solid State and Materials Research Dresden in Germany (2008-2012). Coordinated the research group of nanostructured device´s at Chemnitz University of Technology (2010-2012). Currently is the head of the Laboratory for Functional Devices and Systems at the Brazilian Nanotechnology National Laboratory and professor in the graduate program of both Physics and Chemistry Institute at Campinas State University (Unicamp), Brazil.

Raj Bhakta
NORTH CAROLINA STATE UNIVERSITY

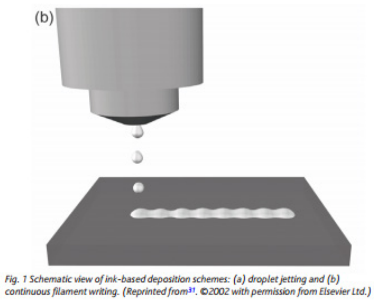
Direct jet printed flexible interconnects on films and textiles

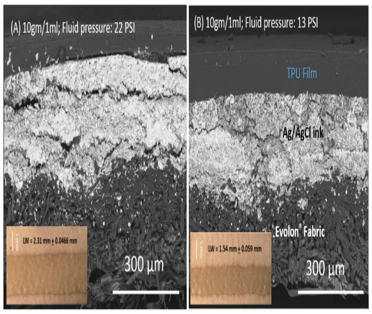
Raj Bhakta[1]; Joshua Gowin[1]; Rachel Foote[1]; Jesse S. Jur[1]
[1]Department of Textile Engineering, Chemistry, & Science; North Carolina State University, Raleigh, North Carolina, USA

ABSTRACT

Textiles provide a broad range of applications in electronics, particularly as a platform for integrating sensors and displays. A large driver for this momentum is wearable technology for fitness and health applications, as well as home textiles for internet-of-things (IoT) connectivity. Current materials methods, such as the use of conductive yarns, are limited in the ability to manufacture at large scale and breadth of materials function. Printed electronics offers an alternative technology roadmap for textile electronics. This research explores the fabrication considerations and subsequent characterization of printed flexible interconnects, sensors, and devices using a new direct-jet printing technology that enables roll-to-roll processing on large area fabrics. Direct-jet printing uses back pressure (<30 Psi) to deliver a conductive ink in the range of 20,000 cps through a nozzle positioned on a X-Y gantry stage (Figure A, *Lewis 2006*). Using this technology, Ag/AgCl conductive patterns at 1 mm resolution have been produced at speeds of 80 mm/sec with a resistance of 0.17 Ω/cm in a sinusoidal pattern of 16.8 cm total length (Figure D). Process design variables of fluid pressure and dispense velocity are examined with respect to ink viscosity. This is used to explore the ink penetration into nonwoven, knit, and woven materials (Figure B). The influence on these variables on the resistance is also determined. Flexible interconnects were direct-jet printed onto a heat-laminated thermoplastic polyurethane layer (TPU)

and encapsulated with another layer of the same onto a compression knit fabric of basis weight 0.0183 g/cm^2. An interconnect was also printed directly onto a cotton twill fabric of basis weight 0.0306 g/cm^2. Compared to screen-printed interconnects, direct-jet interconnects were printed at similar cost in ink (~ $0.00178/mm) but with minimal ink waste, no post processing clean up, and 4x times lower resistance. Next steps include large-area direct-jet printing onto a cut-and-sewn shirt to develop an electrocardiogram (ECG) smart shirt (Figure C).





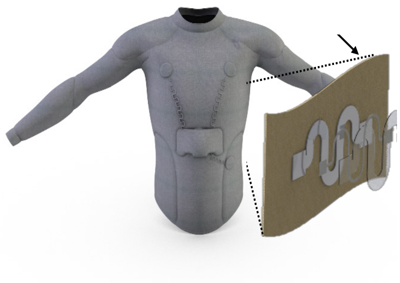


Figure A (above)

Figure B (above)

Figure C (above)

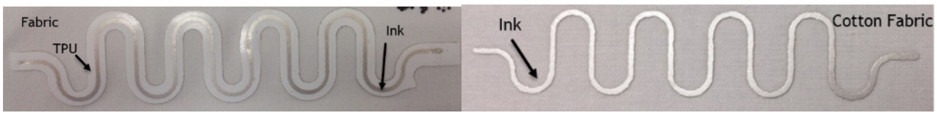


Figure D (above)

BIOGRAPHY

Raj Bhakta is currently a PhD student in the Fiber & Polymer Science program researching printed electronics on textiles for applications in wearable technology and internet-of-things.

Dr Ton van Mol

HOST CENTRE

Imperceptible electronics

ABSTRACT

For medical health care monitoring, devices are required which allow the user to wear them for several days, 24/7. Wear comfort is then key. In automotive industry, users a relooking for a seamless blend of aestethics, function and intuitive user interfaces. We will discuss that a new generation of flexible and stretchable electronics, these needs from two important industries can be met.

BIOGRAPHY

Ton van Mol graduated with honors from Eindhoven University of Technology in Chemical Technology in 1997, and received his PhD in the area of Thin film technology in 2001. He worked at Sandia National Laboratories (Livermore) as visiting scientist and joined TNO in 2003 as senior scientist in the area of flexible solar cells. In 2005, Ton helped set-up the open innovation initiative between IMEC and TNO called Holst Centre, where he had various roles, such as Program Manager and Business Development Director before he took the role as managing director in 2013.

Dr Michael Renn

OPTOMEC, INC

3D Printing of Flexible and Stretchable Interconnects

Michael Renn, Ph.D., Optomec, Inc
2575 University Ave, Suite 135, St. Paul, MN USA

ABSTRACT

Flexible hybrid circuits typically require interconnecting rigid bare silicon or packaged die to a flexible circuit board. Flexing these assemblies can cause extreme stress on the electrical connections, especially near the edge of the chip where it mates with the substrate. Much of the stress can be relieved by first printing an elastic fillet at the base of the chip to form a flexible ramp leading to the surface. Metal ink traces can then be printed along the ramp to connect between the board and chip I/O. Aerosol Jet® is an ideal printing tool for precision deposition of polymeric and metal inks in this 3D application. It is a non-contact, high resolution printing technology that is compatible with a wide range of conductive, insulating, and resistive materials. We will present the printing of robust, flexible and stretchable 3D interconnects with line and space below 50 micrometers and good stability under thermal cycling. We also present the printing of passive electronic components and sensors.

BIOGRAPHY

Dr. Michael Renn is the Chief Technology Officer and Director of the Advanced Applications Laboratory at Optomec. He holds a B.A. degree from Lawrence University and a Ph.D. from the University of Virginia in physics. Dr. Renn was a postdoctoral fellow at the University of Colorado and an Assistant Professor at Michigan Technological University prior to joining Optomec in 1999. He and his team are responsible for materials, process, and applications development for Optomec's Aerosol Jet technology.

Dr Aoife Celoria

NOVACENTRIX

Smart wearables and stretchable/ultra-flexible electronics

ABSTRACT

Rapid evaluation of physiological conditions offers huge advantages to personnel in areas such as emergency medical response and professional sports, and would allow continuous monitoring of physiological health, as well as possibilities for immediate treatment of serious injuries. High fidelity real-time diagnostics allowing simultaneous detection and comparison of several biological markers would allow profiling of an athlete's health during training to avoid any excess force on their physiology. It could also provide medical personnel with a more direct treatment path to enhance survival rate of patients.

Bio-sensing in human perspiration can provide a non-invasive pathway to such diagnostics. For example, continuous monitoring of sweat lactate during exercise can benefit health and fitness applications of an athlete or patient. In this abstract, we outline wearable chemical sensors that utilize the expertise and access to high performance tools at NovaCentrix.

Some lactate sensors currently employed rely on finger-stick blood draws which are intrusive and inconvenient for an athlete or patient during physical activity, as well as causing distress to some. We wish to develop wearable chemical sensors, capable of real-time, on-body monitoring of this biological target to yield immediate information on the wearer. We shall demonstrate this, through printed electrochemical sensors over flexible (and thus wearable) substrates.

The conformal geometry of a sensor over skin is vital for monitoring biomarkers. The sensor must also withstand repeated mechanical stress from the wearer and still function within a very small error. This can enable unobtrusive sensing to detect physiological targets, and perhaps even environmental targets.

NovaCentrix inks capitalize on advanced materials and formulation expertise to provide a variety of options for specific applications, as well as the ability to tune factors such as conductivity, stretchability and solderability, towards a variety of printing techniques. These capabilities allow us to develop suitable materials towards electrochemical sensors that will conform to the physical and chemical requirements outlined in previous paragraphs. Add to this, the design of our inks specifically for use with low-temperature substrates including paper and plastics so that the convenience of a disposable biosensors can fully be realized. Solderability can be a significant advantage in the ease of combining a sensor to a reader. At NovaCentrix, inks have been developed to couple this feature with stretchability and bendability in order to address the physical demands of an on-body sensor.

Finally, the deployment of PulseForge, our photonic curing tool, allows us to thermally process inks over temperature sensitive substrates without damaging them. The use of such substrates significantly reduces the cost of each sensor thus rendering them available to a much wider (and lower budget) market.

BIOGRAPHY

Aoife Celoria has a Ph.D. in Physical Chemistry from the University of Oxford where she specialized in the integration of ionic liquids for commercial toxic gas sensors. She held postdoctoral fellowships at UC San Diego and UT Austin where she focused on the development of electrochemical systems including solid-state batteries and field-deployable sensors. She currently serves on the applications development team at NovaCentrix, where she is developing new photonic curing processes in support of NovaCentrix's core business of selling photonic curing tools and conductive inks for printed electronics.

Dr Abhijeet Sangle

UNIVERSITY OF CAMBRIDGE

2D printed flexible and scalable thermoelectric power generators for wearable applications

Abhijeet Sangle[1,*], Anuja Datta[1], Vijay Narayan[2] and Sohini Kar-Narayan [1,*]
[1]Department of Materials Science and Metallurgy, University of Cambridge, Cambridge, CB3 0FS, United Kingdom
[2]Department of Physics, Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

ABSTRACT

Thermoelectric power generation has emerged as one of the most attractive energy harvesting techniques, especially after wearable electronics started garnering attention from electronics companies worldwide. With a gamut of electronic devices such as mobile phones, portable wearable media players, smart watches, smart glasses, activity monitors and other health monitors becoming integral parts of contemporary lifestyle, there is a pressing need for uninterrupted electrical power to run these gadgets. While battery technology has improved considerably over the years with increasing power densities achieved, the exponential rise in the number of gadgets a person carries leaves much to be desired. This is where wearable, light weight, flexible thermoelectric power generators can make up for the power demand of these gadgets.

Bi_2Te_3 and Sb_2Te_3 are very well-established thermoelectric power generating materials with excellent figures of merit. However, the paucity of these materials in the earth's crust and expensive solid state traditional top-down fabrication techniques make them uneconomical to use in bulk or even in film forms. Whereas, if used sparingly by fabricating nanostructured power generators with cheap techniques, these materials can address the power demand of the wearable gadgets at least partially, if not fully. Nanostructuring also allows for reduced thermal conductivity, much desired for thermoelectric power generators, by increased scattering of the phonons from the interfaces and surfaces of the nanostructures.

Bi_2Te_3 and Sb_2Te_3 based p- and n- type thin wires (~10 µm in width) are directly printed on flexible polyimide sheets using aerosol jet printing technology employing bespoke water and polymer-based inks with optimised stoichiometric proportions. The lines of p and n type materials are placed parallel and alternate to each other, as shown in Figure 1. The lines are joined at alternate ends by Ag lines, also printed by the aerosol jet printer

using an Ag nanoparticulate ink, to create (p-n-p-n-p...)- type series electrical connections to build up significant DC bias in response to a thermal gradient. With a sustained thermal gradient across the two ends of the lines, a sustained DC bias is developed which can be used to charge/power wearable gadgets.

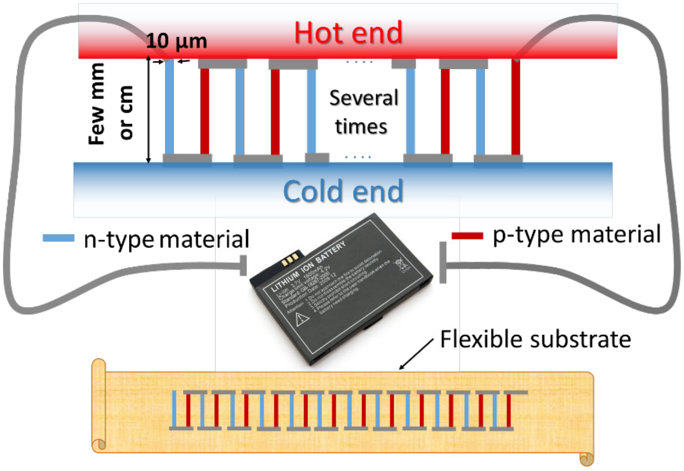


Figure 1: Schematic diagram showing the 2D printed flexible and scalable thermoelectric power generators.

BIOGRAPHY

I work as a Post-Doctoral Research Associate with Dr. Sohini Kar-Narayan at Department of Materials Science and Metallurgy, University of Cambridge. I am researching on aerosol-jet printed, flexible thermoelectric energy harvesters using bespoke inks of inorganic and hybrid (organic-inorganic materials). I completed my Ph. D. in Materials Science from University of Cambridge in July 2016. During my Ph.D., I worked on self-assembled columnar oxide nanocomposite films for different applications such as resistive random access memory (ReRAM), photoelectrochemical (PEC) water splitting, tunable RF devices and thermoelectric power generation. I graduated from Indian Institute of Technology (IIT) Bombay in 2011 with a 5-year dual degree (B. Tech. + M. Tech.) in Metallurgical Engineering and Materials Science with a specialisation in Ceramics and Composites. I come from the historic city of Aurangabad in the state of Maharashtra, India.

Dr Fernando Castro

NATIONAL PHYSICAL LABORATORY

Challenges in testing the reliability of printed and flexible electronics

Fernando A. Castro*, James C. Blakesley, Martin Wickham
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ABSTRACT

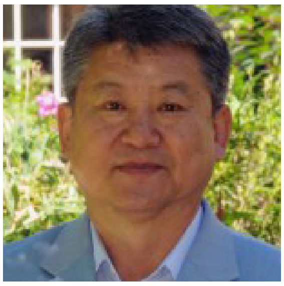
One of the key challenges when bringing a novel product to market is to demonstrate reliability and estimate lifetime. In established industries this is achieved through accelerated tests designed to induce degradation modes that the product is likely to experience in service. For materials that are not yet in the market place, such as many new printed and flexible electronics, validated accelerated tests need to be created to ensure manufacturer and consumer confidence. Requirements for reliability tests will be application dependent.

However, some aspects, such as environmental and mechanical stability, will be of importance to most applications of printed and flexible electronics.

At the National Physical Laboratory we have been developing a range of in-situ and ex-situ measurement methods to allow not only the identification but also the characterisation of the origin of degradation and failure modes. In this presentation we will show how reliability tests can be designed for specific applications, both at the R&D materials development phase and the product level phase. This will be followed by presentation of two case studies. The first will demonstrate a unique environmental stability testing rig which can control the atmospheric H_2O and O_2 content within a sample chamber to the part-per-million level, as well as illumination intensity, temperature and electronic stress, in an arrangement that allows the detailed study of the degradation of organic semiconductor materials and devices under highly controlled and reproducible conditions. Evaluation of degradation modes in printed solar cells will be demonstrated. The second case study will demonstrate the importance of in-situ and reliable testing of mechanical stress in flexible electronics. In-situ electrical measurement during bending and tensile stress of flexible transparent electrodes will be presented and discussed. The importance and the progress towards standardisation in this area will be highlighted.

BIOGRAPHY

Dr Fernando Castro is a Principal Scientist and the Science Area Leader for Electronic and Magnetic Materials at NPL, where he supports industry through world class measurement science and modelling. He has a PhD in Physics and 15 years of experience in printed and flexible electronics. He is a Fellow of the Institute of Physics, has over 50 publications, has delivered over 30 invited talks in 11 countries and is a regular reviewer for over 23 peer review scientific journals. Dr Castro is also Chair of the Technical Working Area 36 “Organic Electronics” of the international pre-normative organisation VAMAS, acts as UK Expert within the International Electrotechnical Commission (IEC) TC 119 - Printed Electronics, is a member of the Steering Committee of the European Energy Research Alliance JP Photovoltaics and is an Associate Editor of the scientific journal Science and Technology of Advanced Materials.



Prof. Jong Min Kim

UNIVERSITY OF CAMBRIDGE

1D Nanofibre Electro-Optic Networks (1D-NEON)

Jong Min Kim, Professor of Electrical Engineering (1944)
EE Div, Dept of Engineering, 9JJ Thomson Ave, Cambridge, UK

ABSTRACT

This speech presents the current and future nanotechnology, especially focusing on the convergence of nano with electronics, photonics, and energy/bio areas. Nano-electronics will cover the graphene and carbon nanotubes, and their applications in flexible, transparent and printable electronics, and transistors for future applications. Nano-photonics will include quantum-dot (QD) displays/lighting and other applications such as including QD solar cell.

New concept of energy harvesting and flexible battery, fragrance generation system, large area active hologram and photonics crystal for future devices, textile electronics including smart lighting energy devices, and e-skin and sensor network will be presented.

These convergence technologies also focus on new medical imaging areas, non invasive medical detection, and healing patch and else for industrial applications.

BIOGRAPHY

Professor Jong Min Kim was formerly Senior Vice President and Vice President in Samsung Electronics Corporate R&D Centre, Korea for 13 years. Now, he is Professor of Electrical Engineering of Department of Engineering at University of Cambridge. He was Chair of Electrical Engineering at University of Oxford from 2012-2015. Professor Kim had previously held a variety of senior technology positions at the Samsung Group including Display, Materials, Energy and Electronics research/developments. Professor Kim had managed several tens of millions of dollars per annum for major projects in Samsung for 17 years. His research is described in more than 300 journal papers (including 8 Nature/Science, and Nature family journals), 250 publications on the Technical Digest and proceedings with around 100 keynote/invited speech at major international conference, and 253 patents (153 international patents). He received a number of awards: Best Paper Award, the Gold Prize Award by Samsung Group Chair, Prime Minister Awards (2001), Awards by Minister of Science (2000), and recently Awards by Minister of Knowledge/Economy (2012) from the Korean government. He was responsible for a number of world first inventions: carbon nanotube (reported variously in Science, Nature, etc. One paper is with more than 1,000 citation); transparent and flexible graphene electrodes (Nature 2009, with more than 3,000 citations) and quantum dot based LEDs and displays (Nature Photonics, Cover Article, 2009 and 2011, Nature Comm'13), LED on glass (Nature Photonics, Cover Article, 2011), CNT network Transistors (Science 2008 and Nature Communications 2011), and many others.

Paolo Canonico

SAATI

e-textile and strategic innovation and research agenda for European textile and clothing industry

ABSTRACT

Over the next 10 years, new challenges await the textile and clothing Industry in Europe. The constant flow of new textile materials with better performance and smart functionalities will not stop, digitisation and clean high-tech manufacturing technologies will become the norm in textile factories and value chains, resource efficiency and circularity will make the industry and its products more sustainable and new growth markets in sectors such as health and sports, transport and energy, entertainment and fashion look for innovative textile solutions.

E-textiles for smart structures, functional interiors or smart wearable systems is one of the main topics listed in Research Priorities of SIRA (Strategic Innovation and Research Agenda), and involves all the value chain, from fibre, yarn and fabrics producers to sensors and system integrations developers.

With ongoing collaboration between textile industry, materials sciense, electronics, medical technology, and end users of smart textiles the integration possibilities of electronics in textile application are constantly widening.

BIOGRAPHY

Dr Paolo Canonico holds a degree in Mechanical Engineering from the University of Naples. He has 20 + years project management experience and R&D activities on advanced technologies and materials at international level among Universities and industries. Since 2008, he is Global and R&D Director of Saati group, with responsibility for production of all production sites, Technical Office and Research & Development. Paolo has authored numerous patents and publications. Since January 1, 2012 he is Chairman of the ETP (European Technology Platform of technical textiles and clothing), based in Brussels.

Mark Pedley

SMARTLIFE

Wellbeing without Walls

ABSTRACT

Wireless technologies, assistive medical devices, remote ambulatory monitoring, coupled with the evolution of IoT technologies are recognised globally as the current and future platforms critical to managing the global squeeze on healthcare budgets. These technologies allow people to monitor their wellbeing in their own homes and at a distance from conventional care institutions.

The adoption of these technology solutions relies mainly on three factors: (i) ease of use for all parties, (ii) low cost of purchase and operation, plus (iii) robust, repeatable and reliable data. In addition, personalization, patient discretion, and other technological considerations (power consumption, charging, and the rate of technological advancement) are all challenges that must be overcome. If these human and technology factors can be aligned, the delivery of healthcare outside conventional building estate scenarios may prevail.

Since 2004, Smartlife has been developing and testing various means of garment-based bio-metric data capture to deliver both real-time and time logged wellbeing monitoring. Our demonstrations at this conference will share with all interested parties just how 'normal' wellbeing without walls has actually become.

BIOGRAPHY

As founder and Chief Innovation Officer of Smartlife®, Mark is recognised for injecting innovation, entrepreneurial flair and foresight into a business with a worldwide appetite for success. As an inventor with a number of Patents, he has knowledge and experience of intellectual property, material sciences and garment based wearable technologies.

The opportunity to create a platform technology, personalise it to meet the needs of both individuals and established markets such as HealthCare, Military, Wellbeing and Sports, whilst building partner and shareholder value, are the drivers behind Mark's professional activities.

Mark's passion and enthusiasm for ideas, innovation, entrepreneurship and networking is focused on appreciating new and emerging technologies to secure the best financial returns. Past enterprise successes coupled with commitment to, and belief in, the people who deliver cutting edge innovation, create a repeatable formula.

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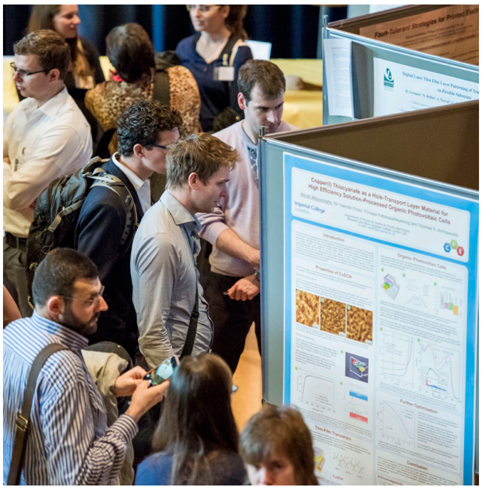

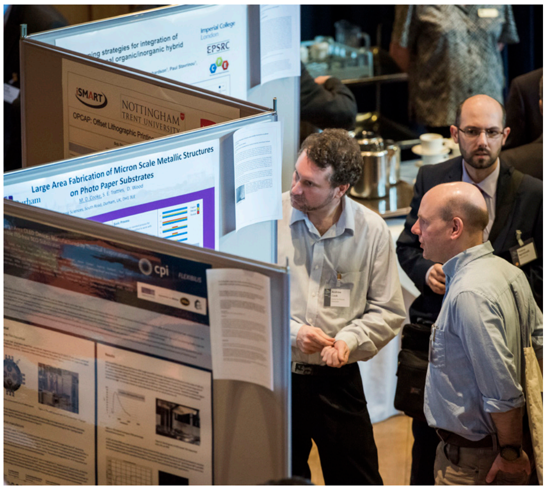

POSTER PRESENTATION

1: Organic Synergisms: Eumelanin/PEDOT(PSS) integration for ITO-free electrodes in bioelectronics and nanomedicine

Ludovico Migliaccio,[1,2] Salvatore Aprano,[1] Luca Iannuzzi,[1] Maria Grazia Maglione,[1] Paolo Tassini,[1]Carla Minarini,[1] Paola Manini,[2] Alessandro Pezzella[2]
[1] ENEA Agenzia Nazionale per Le Nuove Tecnologie lEnergia e lo Sviluppo Economico Sostenibile, SSPT-PROMAS-NANO, C.R.Portici, Portici, NA, Italy
[2] Università degli Studi di Napoli Federico II - Department of Chemical Sciences, Via Cintia n.4, Napoli, Italy

ABSTRACT

Organic Bioelectronics applications are largely dictated by the chemical nature of the materials that transduce signals across the biotic/abiotic interfaces1. Among the available materials for functional biocompatible interfaces, the human pigment eumelanin is currently gaining increasing interest.This black insoluble pigment of human skin, hair, eyes and nigral neurons (neuromelanin),2 featuring unique assortment of chemical physical properties3,arises biogenetically from the aminoacid tyrosine via the oxidative polymerization of 5,6-dihydroxyindole (DHI) and/or 5,6-dihydroxyindole-2-carboxylic acid (DHICA)2,3. Two main obstacles hampered a full exploitation of eumelanin based devices: (i) the actual eumelanin insolubility in any solvents, preventing easy processability of the pigment as well as the devices fabrication; (ii) its low conductivity, limiting both the range of possible working potential and functional applications.To improve the electrical performances of the eumelanin thin films, a clear-cut approach lies in the hybridization with a suitable conductive counterpart. In this view, π-conjugated molecules featuring conductive pathways appear a key choice in the production of new organic materials for electronic (nano)devices.

Here, we present the first (at the best of our knowledge) preparation of an eumelanin-PEDOT blend, featuring valuable functional and processing properties, like easy films preparation, high adhesion, good electrical conductivity and biocompatibility. The hybrid was characterized by chemical, physical, electrical and morphological analysis.The biocompatibility and toxicity was investigated in view of its potential exploitation as bio-interface material.

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BIOGRAPHY

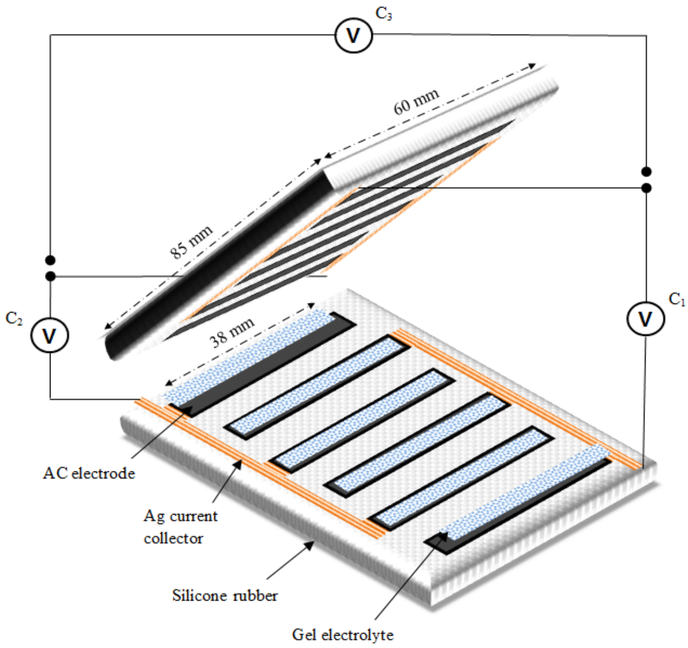
Alessandro Pezzella received his Ph.D. in Chemistry in 1997. He has carried out research mainly in the field of 5,6-dihydroxyindole polymerization, melanin pigment characterization, and oxidative behavior of phenolic compounds. More recently, his interest is focusing on the applications of bioinspired polymers (melanins and eumelanins)in organic electronics and bioelectronics. His research activity has produced some 100 publications including international and national patents, research papers, reviews, and book chapters.

2: A Study of 3D Printed Flexible Supercapacitors onto Silicone Substrates

Milad Areir, Yanmeng Xu, David Harrison and John Fyson
Department of Design, College of Engineering and Physical Sciences, Brunel University London, Uxbridge, UB8 3PH, UK

ABSTRACT

The rapid development of flexible energy storage devices is crucial for various electronics industries. A highly flexible supercapacitor was manufactured by 3D printing onto a silicone substrate. In this study, the supercapacitor fabricated is an electrochemical double layer capacitor (EDLC). It is a great challenge to fabricate multiple material layers of the EDLC in one rapid and accurate deposition process. The fabricated structures were composed of a twelve electrode which could be configured in a number of different ways in one block module (see Figure). The electrochemical performance of the devices showed near ideal cyclic voltammetry (CV) curves without distortion at fast scanning rate. The flexible EDLCs can be used in flexible electronics with different patterens, sizes and resolutions using 3D printing technology, and have the potential to be applied in many applications such as wearable technology and building.



BIOGRAPHY

A. Milad is currently a Ph.D. candidate in design at the Brunel University London, UK. received the B. Sc. degree in electrical engineering from Bright Star University of Technology, Libya in 2004 and the M. Sc. degree in instrumentation and control from Taxila University, Pakistan in 2007. research interests include energy storage materials and 3D printing technology.

3: Printed nanowires for applications in magnetoelectric sensors and energy harvesters

Chess Boughey, Michael Smith, Yeonsik Choi & Sohini Kar-Narayan*
Department of Materials and Science and Metallurgy, University of Cambridge, UK

ABSTRACT

Aerosol jet printing and template–assisted electrodeposition are both low–temperature, fast, simple and scalable growth techniques which have been used in this work to fabricate a magnetoelectric (ME) composite device with possible future applications as either a sensor or an energy harvester. ME composite devices convert magnetic fields into electrical energy via strain coupling of the ferromagnetic and piezoelectric components i.e. via magnetostriction and the piezoelectric effect. In this work, ferromagnetic nickel nanowires were first grown via electrodeposition within a nanoporous anodized alumina template and subsequently released from the template and dispersed in a solution of the piezoelectric polymer; polyvinylidene fluoride trifluoroethylene (P(VDF-TrFE)). Using this as an ink for aerosol jet printing, one can print a ME film. One device architecture attempted in this work is a fully-printed flexible device where interdigitated electrodes are printed first using a silver nanoparticle ink on a plastic substrate followed by deposition of the NW dispersion on top using the same printing process, see figure 1. After annealing and poling steps, the ME device has the potential to be tested as either a magnetic field sensor or a vibrational / magnetic energy harvesting device or both.

Aerosol jet printing is a relatively new deposition technique compared to other printing technologies where an aerosol of an ink is generated and a sheath gas is used to focus a jet of the ink onto a substrate. The advantages of this technique compared to ink-jet printing for example, include a wider range of compatible inks both conductive and dielectric with a wider range of viscosities. It is also possible to print a variety of nanowire-based inks of other materials such as piezoelectric and thermoelectric and carbon nanotubes, amongst others.

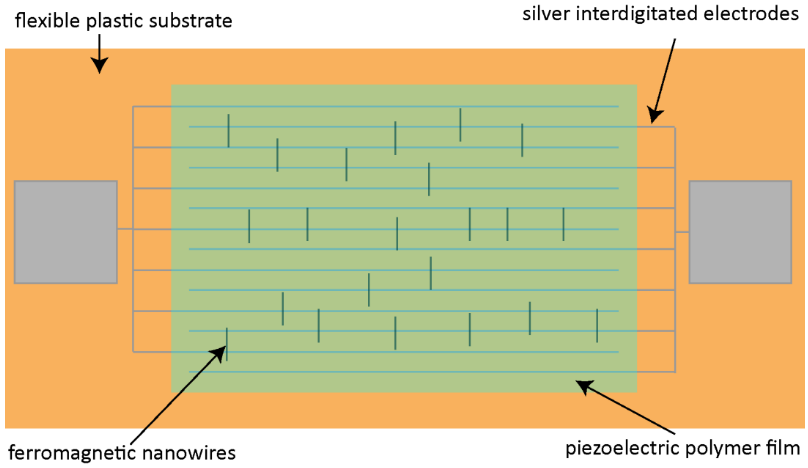


Figure 1: example of a fully printed magnetoelectric device based on a composite ferromagnetic nanowire – piezoelectric polymer based ink.

BIOGRAPHY

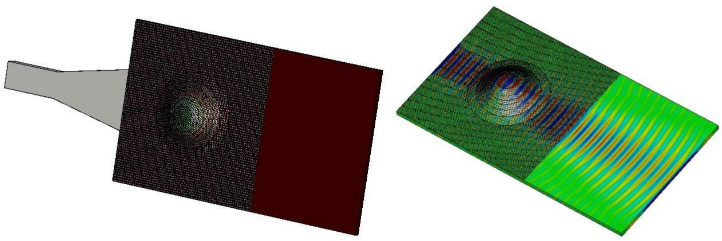
Chess Boughey is a 3rd year PhD student in the Kar-Narayan group in the Department of Materials Science & Metallurgy at the University of Cambridge and his research focuses on electrodeposited nanowires and other scalable fabrication techniques for piezoelectric nanogenerators and magnetoelectric energy harvesters and sensors. He is funded by the nanoscience and nanotechnology centre for doctoral training (EPSRC) as well as benefiting from their supervisor's ERC starting grant. His undergraduate degree was in physics from Imperial College London where they specialized in gravure printed organic field effect transistors in their final year.

4: Control of guided and space waves by meta-surfaces

Luigi La Spada and Yang Hao

ABSTRACT

A huge interest in manipulating waves has grown: the possibility to control electromagnetic waves (in terms of guided propagation and space radiation) is crucial for several application fields [1]. Although the topic has been studied in the past, new research ideas emerged, including the use of meta-surfaces, artificially designed planar materials with sub-wavelength dimensions. The main advantage is the possibility to accurate modify at will: amplitude, phase and polarization of both electric and magnetic field components [2]. Recently, several techniques have been proposed ranging from microwave to optical frequencies [3]: in particular, array of pillars/crossed slit structures [4] metallic patches [5], optical scatters [6], hologram imagers [7], thin films [8] and nanocomposites [9]. All such works aimed to control modes phase and consequently manipulate their propagation, by engineering the dimensions of unit elements within the array. Although all such examples address specific issues, they are restricted to certain geometries and shapes. A more generic approach is still missing. The aim of this work is to present a new design technique for arbitrary meta-surface structures to design devices by linking their geometrical parameters with specific required electromagnetic characteristics. To validate and test the proposed approach, an example for surface wave cloaking is numerically and experimentally reported, (in the frequency range 8-12 GHz) showing good performance in terms of polarization/source independence and broadband behaviour.



(a) (b)

Fig1: (a) Structure under study and (b) surface wave cloaking device in action

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BIOGRAPHIES

Prof. Yang Hao received the Ph.D. degree from the Centre for Communications Research (CCR) at the University of Bristol, U.K. in 1998. From 1998 to 2000, he was a postdoc research fellow at the School of Electrical and Electronic Engineering, University of Birmingham, U.K. In May 2000, he joined the Antenna and Electromagnetics Group, Queen Mary, University of London, London, U.K. first as a lecturer and was promoted to Reader in 2005 and to Professor in 2007.

He currently leads a £4.6M EPSRC QUEST programme grant on transformation electromagnetics and microwave metamaterials. He is a management board member of Cambridge Graphene Center, which has attracted over £25M funding from UK EPSRC. Over the years, he developed several fully-integrated antenna solutions based on novel artificial materials to reduce mutual RF interference, weight, cost and system complexity for security, aerospace and healthcare. He developed, with leading UK industries, novel and emergent gradient index materials to reduce mass, footprint and profile of low frequency and broadband antennas. He also co-developed the first stable active non-Foster's metamaterial to enhance usability through small antenna size, high directivity, and tuneable operational frequency. He coined the term 'Body-centric wireless communications', i.e. networking among wearable and implantable wireless sensors on the human body. He was the first to characterize and include the human body as a communication medium between on-body sensors using surface and creeping waves. He contributed to the industrial development of the first wireless sensors for healthcare monitoring, digital plaster antennas and textile antennas. Professor Hao is a strategic advisory board member for Engineering and Physical Sciences Research Council (EPSRC), where he is committed to championing RF/microwave engineering for reshaping the future of UK manufacturing and electronics.

Dr. Luigi La Spada received his bachelor's degree, summa cum laude, in Electronics Engineering from the University of Roma Tre, Rome, Italy, in 2008.

In 2010, he received his master's degree, summa cum laude, in Information and Communication technology from the University of Roma Tre.

From 2011 to 2013, he was with the Department of Applied Electronics, University of Roma Tre, where he worked as a PhD student (scholarship winner) at the Doctoral School in Engineering in the Biomedical Electronics, Electromagnetics, and Telecommunications section. In 2013, he was with the Department of Electrical and Systems Engineering, University of Pennsylvania (Philadelphia, USA), as Visiting Researcher.

In 2014, he received his PhD in Electronic Engineering and from March 2014, he was employed as a Postdoctoral Research Assistant in the School of Electronic Engineering and Computer Science at Queen Mary University of London. Here, he works with Professor Yang Hao in the Antennas and Electromagnetics research group, as part of the QUEST project.

His main research interests are microwave, terahertz, and optical applications of complex media and metamaterials; design of miniaturized sensors and antennas based on metamaterial technology; biological and biomedical applications of plasmonic nanoparticles; analysis and synthesis of planar metamaterials and radiating elements for sensing and telecommunications applications.

5: SIMLIFT: Towards single micron LIFT technology

D.Beynon*, B.Clifford*, R.Geremia ^, D.Karnakis^, D.Deganello*
* WCPC, Swansea University, Swansea, UK
^ Oxford lasers, Didcot, Oxfordshire, UK

ABSTRACT

Laser Induced Forward Transfer (LIFT) is a key enabling technology for large area processing of printed electronics capable to print a wide range of materials rapidly and digitally. A major barrier for large scale implementation & adoption of the technology is the current achievable printing resolution, commonly reliably limited to the tens of micron. SIMLIFT is an EPSRC CimLAE Pathfinder project aiming to overcome current limits proposing a transformative development of the technology, refining its resolution to a new reliable level towards single micron resolution.

In LIFT, a donor substrate ink carrier is locally irradiated by a short pulse laser causing the transfer of material from the donor layer to a receiving substrate. The donor layer and laser processing are keys for precision patterning. To address the challenge of reliable single micron patterning, SIMLIFT will analyse the effect of varying thin film donor deposition processes (namely spin coating, blade coating, forward roll coating) on the donor film morphology and resulting transfer; it will explore the interaction with varying laser pulse duration that dictates the physical ejection mechanism (namely from nanosecond, picosecond, to femtosecond level duration pulsed lasers). The accuracy of laser processing will be further explored through the novel integration of new microlens arrays for affordable accurate digital patterning.

For the first time influencing parameters will be systematically analysed and compared at a dimensional scale close to that of the laser wavelength; introducing novelty both in donor deposition & laser processing, with the exploration of forward roll coating as a new LAE compatible donor layer deposition method. Gains are expected through the new adoption of microlens arrays for accurate digital patterning by lasers. This research will provide a new insight and scalable technological solutions leading to unique enhancement of the technology to SIMLIFT for large scale adoption of technology for digital processing

The pathfinder project joins together academic and industrial partners to give a unique combination of skills; the project will include the Welsh Centre for Printing and Coating (Swansea University), a leading research centre in printing and printed electronic, with the key partnership and support of Oxford Lasers Ltd, a leading British Industrial laser technology system integrator. The project will also benefit by the support and guidance of a dedicated industrial end-user advisory board.

BIOGRAPHY

Dr. Davide Deganello is an Associate Professor at the College of Engineering, Swansea University, where is deputy director at the Welsh Centre for Printing and Coating (WCPC). His research interests comprise the development of printing technologies and of functional materials for novel applications. For this goal, Davide's experience covers from large scale roll-to roll printing to one-off additive manufacturing, experience supported by study of material formulation, underlining rheology and CFD modelling. Since his first appointment at Swansea in 2011, Davide has developed a sustained program of research, inclusive of a number of Research Council, collaborative & industrial projects (in collaboration also with EPSRC Centre for Innovative Manufacturing in Large-Area Electronics) targeted to development of novel solutions and materials for energy storage, electronic, smart packaging, and biomedical applications. His research has led, together to a number of publications in high impact international journals, to patents and industrial investments.

6: Unveiling the potential of adhesion lithography towards development of plastic nanoelectronics

Dimitra G. Georgiadou, James Semple, Gwenhivir Wyatt-Moon and Thomas D. Anthopoulos
Physics Department, Imperial College London, London, United Kingdom

ABSTRACT

Adhesion lithography (a-Lith) is a patterning technique that is based on the modification of adhesion forces between two sequentially deposited metals by functionalising the surface of one of them with a suitable self-assembled monolayer (SAM)[1]. The final a-Lith patterned structure comprises two metals separated laterally by a nanogap of <15 nm (Figure 1). The competitive advantage of this technique is that it is simple and scalable with high throughput, while it can be applied in any type and size of substrates.

Recently, we demonstrated the scalability potential of a-Lith by developing a semi-automated system to perform the peeling of the second metal layer that critically defines the nanogap size and its quality and thus we maximised the process yield. Significant progress has been also achieved in applying a-Lith to plastic (flexible) substrates and different types of metals to create symmetric or asymmetric electrode structures.

The versatility offered by this simple patterning technique to manufacture any type of coplanar metal structures on the same substrate enables the simultaneous fabrication and statistical study of a great number of electronic devices by simply spin-coating the material of choice on top of the metal structures from its solution and applying low temperature thermal annealing to retain compatibility of the whole process with plastic substrates.

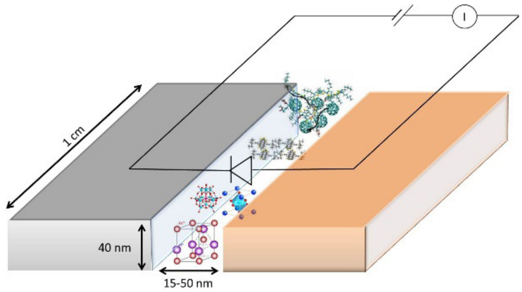

Figure 1. Schematic diagram of coplanar Au-Al asymmetric electrodes having a width of 1 cm, thickness of 40 nm and separated by a nanochannel (interelectrode distance) of 15-50 nm. Deposition of a suitable material in the nanogap and application of a bias between the electrodes allows current to flow from one metal to the other through the organic or inorganic material, that being the common underlying working principle of many electronic devices.

Herein, we will describe how deposition of a suitable functional material in the nanogap can give rise to a plethora of high performing nanoelectronic devices, such as radiofrequency Schottky diodes, nanoscale light-emitting diodes, photodetectors and ferroelectric tunnel junction memory devices. Emphasis will be placed on the different requirements posed by each application in terms of materials processing and electrodes geometry. Finally, we will showcase successful examples of proof-of-concept functional devices.

1. Beesley DJ, Semple J, Jagadamma LK, Amassian A, McLachlan MA, Anthopoulos TD*, et al.* Sub-15-nm patterning of asymmetric metal electrodes and devices by adhesion lithography. *Nature Communications* 2014, **5**.

BIOGRAPHY

Dr Dimitra G. Georgiadou is a Marie Skłodowska-Curie Research Fellow in the Experimental Solid State Physics group (EXSS) at the Blackett Laboratory, Imperial College London. Dimitra received her PhD in Photochemistry/Organic Electronics from the National Technical University of Athens. Before that she obtained a Master's Degree in Advanced Materials Science from the Technical University of Munich, Ludvig-Maximilians University of Munich and University of Augsburg. She has also gained industrial experience through internships in Procter&Gamble, Italy, and Schreiner Group, Germany. Dimitra is co-author of 40 publications in peer-reviewed journals (h-index: 14). Her research interests are the fabrication and optimisation of organic and hybrid electronic devices by applying novel materials concepts and alternative patterning techniques.

7: Inkjet printing of TiO_2 electron transport layers for application in 3rd generation organometal-halide photovoltaics

Anthony Lewis, Trystan Watson, Cécile Charbonneau, SPECIFIC – Swansea University, Bay Campus, Swansea, SA1 8EN

ABSTRACT

Since their discovery in 2012, photovoltaics (PV) utilising perovskite as an active layer have received a lot of attention and garnered many publications due to their high efficiencies (> 18%)1 and easy fabrication by solution processing.2 Once stabilised these devices could rival the efficiencies of established silicon solar cells and prove to be far cheaper for large scale manufacture under atmospheric conditions. Many device architectures have been envisaged, most of them including an electron transport layer (ETL) located between a transparent FTO-coated glass electrode and the perovskite active layer. This layer aims to convey electrons from the perovskite layer to the anode while preventing charge recombination phenomena. Typically, the ETL is applied via spray pyrolysis of a Ti-organo precursor at high temperature, spin coating, or by CVD/ALD under vacuum, followed by a high-T (500 °C) annealing step providing the TiO2 layer with adequate semiconductor properties. These methods, however, are either incompatible with lowering the cost of PV manufacturing (high T & vacuum) and/or do not always offer the technical versatility required for the deposition of fabrication of patterned layers which have a critical impact on the system performance PV modules.

Here we assess the application of inkjet printing for the fabrication of compact TiO2 ETLs using a PiXDRO LP-50 inkjet system. We also report on the printing of a novel aqueous colloidal ink containing anatase TiO2 nanoparticles (≈5 nm)3 which can be printed and further stabilised at 120 °C (Figure 1) or under UV radiation, an alternative to high-T processes. The morphological features and semiconducting properties of TiO2 nanoparticle ETLs deposited by inkjet printing are compared to films prepared using the conventional spray pyrolysis technique. The topography of the layers is assessed by FEG-SEM imaging, AFM and profilometry, the crystal phase and composition is determined by Raman spectroscopy and XPS quantitative analyses. The coverage yield of ETLs are characterised by cyclic voltammetry. Finally, all types of layers are implemented to the fabrication of lead-halide solar cells.

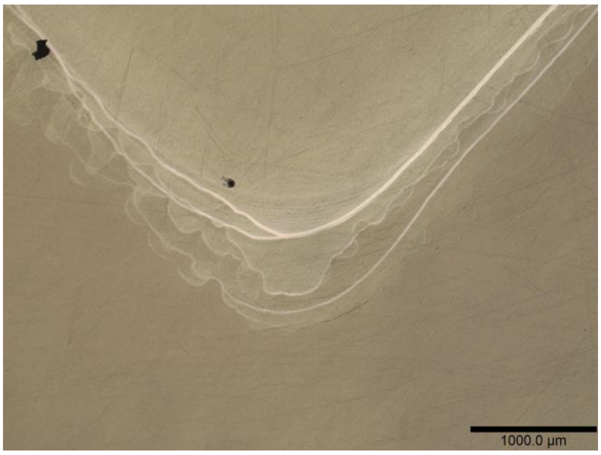

Figure 1. TiO2 nanoparticle precursor, deposited using inkjet printing over five passes.

1 Saliba, M. et al. Cesium-containing triple cation perovskite solar cells: improved stability, reproducibility and high efficiency. Energy Environ. Sci. 9, 1989–1997 (2016).

2 Burschka, J. et al. Sequential deposition as a route to high-performance perovskite-sensitized solar cells. Nature 499, 316–9 (2013).

3 Charbonneau, C., Holliman, P. J., Davies, M. L., Watson, T. M. & Worsley, D. A. Facile self-assembly and stabilization of metal oxide nanoparticles. J. Colloid Interface Sci. 442, 110–119 (2015).

8: Quality-Control of UV Offset Lithographically Printed Electronic-Ink by THz Technology

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a School of Electronics and Computer Sciences, Queen Mary University of London, Mile End Road, London E1 4NS, UK;
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c Department of Electronic and Electrical Engineering, University of Chester, Thornton Science Park, Chester CH2 4NU, UK, b.yang@chester.ac.uk

ABSTRACT

In this work, we present a novel quality-monitor method of inkjet-printed electronics based on terahertz (THz) sensing. Specifically, two different approaches are proposed, namely THz reflection spectroscopy and THz near-field scanning imaging (NSI). Sintered and un-sintered dielectric patterns printed on different flexible substrates are tested in both systems. THz reflection spectroscopy is firstly used to observe the broadband reflected spectra of the ink. The complex dielectric constants of the ink are quantitatively extracted to reveal ink quality as a whole. THz NSI is then proposed as a more localized and higher resolution investigation method. Intuitive near-field imaging of the ink quality in localized detail is achieved. The results show that THz sensing methods can clearly distinguish sintered and un-sintered printed pat- terns. This work will be of great significant and inspiration for the development of a real-time non-contact quality control system for large area printed electronic-inks.

BIOGRAPHY

Dr. Bin Yang received his MSc and PhD degrees in Electronic Engineering in 2004 and 2008 respectively from Queen Mary University of London (QMUL), UK. After his PhD, Dr Yang remained in the Antenna and Electromagnetics Group of QMUL as a Postdoctoral Researcher. In September 2013, he moved to the University of Bolton as a Lecturer and then joined the University of Chester as a Senior Lecturer in September 2015. His research includes the development of Terahertz (THz) measurement systems and the applications in material, biology and chemistry sciences.

9: Inkjet Flex: Roll to Roll Digital Inkjet Printing of Copper Based Circuits

Steven Bagshaw, CPI

ABSTRACT

The presentation will describe the recently installed capability at CPI, known as Inkjet Flex. Inkjet Flex allows clients to digitally print their own copper based circuit designs onto PET substrates in a roll to roll manner. The technology is ideal for the new product development of antennas, sensors, electrodes, flexible pcbs and many other printed electronics applications. CPI is providing the technology on an initial prototyping basis with a route to upscale to larger production volumes. Using Inkjet Flex the length of design can be printed in km and with a web width of 282.2mm

The talk will provide examples of the scientific challenges CPI faced to get the capability up and running alongside a diverse range of new product examples from academia, SMES and industry who are using the line to develop innovative applications from the UK.

BIOGRAPHY

Steven Bagshaw is responsible for the sales and project management of CPI's copper inkjet printing capability known as Inkjet Flex. Since the technology was acquired in 2015, Steven has created the online and offline sales channels alongside the implementation of the marketing and sales communication plan. Steven's expertise lies in the area of printed electronics and its role in the development of the internet of things and industry 4.0.

Previously Steven held marketing positions at CPI, where he was responsible for managing the marketing operations of CPI's printable electronics division. Steven's role was to provide an end user focus in the scale up and commercialisation of products and processes related to printable electronics. He has extensive knowledge in emerging technology areas such as intelligent print, printed lighting and enabling technologies such as materials integration and barrier encapsulation.

During his time at CPI Steven has a track record of delivering the successful dissemination of a number projects, including both commercial and collaborative research and development. Steven has also provided strategic marketing direction to a number of start-up companies in the field of printed electronics.

Prior to joining CPI in 2008, Steven graduated from Northumbria University with a Business Studies degree.

10: Controlling and assessing the quality of Aerosol Jet Printed features for large area and flexible electronics

Michael Smith, Yeonsik Choi, Chess Boughey, Sohini Kar-Narayan*
Department of Materials Science and Metallurgy, University of Cambridge, UK

ABSTRACT

Additive manufacturing promises to be the future of consumer device production 1,2. Patterning electronic circuits over large areas is of particular interest, especially given the advance of the 'Internet of Things' and the forecast of a dramatic increase in the number connected devices. Aerosol Jet Printing (AJP) is a relatively new additive manufacturing technique, capable of printing features down to 10 µm, which offers an alternative to traditional methods in this area such as inkjet printing. However, the relative infancy of the technique, along with the large number of variables, means that the process is not completely understood.

Previous studies have identified how some of the main parameters in AJP affect the morphology of a printed silver line 3. This work investigates some other, more subtle variables that nonetheless have a significant impact on the quality of deposition. An optical method to quantify two of the main aberrations in AJP is also presented and correlated to the deposition parameters and electrical properties of printed silver lines. Using flexible substrates, the bending performance is also assessed.

One of the key observations highlighted is the sensitivity of the process to the ink-substrate combination. As

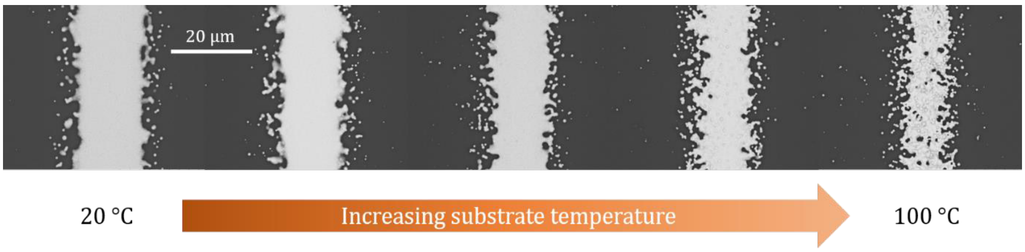

Figure 1 - The influence of substrate temperature on the morphology of an aerosol jet printed line

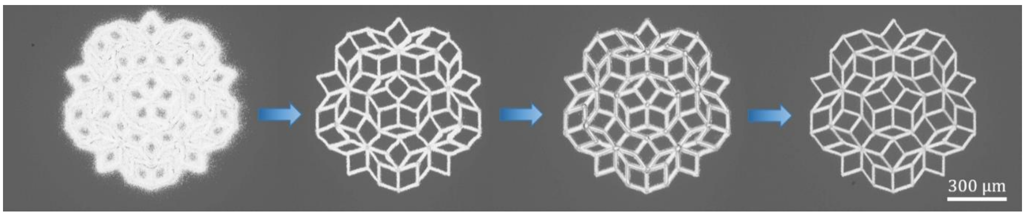

Figure 2 – An example of how aerosol jet deposition can be improved using the proposed framework

a result, a framework for arriving at an acceptable set of deposition parameters for any given application is devised by applying the conclusions reached from this work, as well as results determined elsewhere. It is hoped that this will allow more straightforward use of Aerosol Jet Printing to applications within large area and flexible electronics.

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2. O'Donnell J, Kim M, Yoon H-S. A Review on Electromechanical Devices Fabricated by Additive Manufacturing. J Manuf Sci Eng. 2016;139(1):10801. doi:10.1115/1.4033758.

3. Mahajan A, Frisbie CD, Francis LF. Optimization of Aerosol Jet Printing for High-Resolution, High-Aspect Ratio Silver Lines. ACS Appl Mater Interfaces. 2013;5(11):4856-4864. doi:10.1021/am400606y.

BIOGRAPHY

I am a second year PhD student in the Department of Materials Science and Metallurgy, University of Cambridge. I studied Natural Sciences for my undergraduate degree, also at Cambridge, with emphasis on the physical sciences and specialising in materials science towards the end of my degree. The principal research focus of my PhD is developing biological sensors using piezoelectric nanomaterials. My interest in large area electronics arises from using an aerosol jet printer to fabricate parts of these sensors, as well as other devices using similar materials.

11: Electrical Metrology for Printed Electronics

Adam Lewis and Martin Wickham
*adam.lewis@npl.co.uk, National Physical Laboratory, Teddington, UK

ABSTRACT

The printed electronics market doubled from 2014 to 2015 and a similar growth is predicted for 20161. There are numerous applications for printed electronics continually being explored and therefore it is important to have a method to evaluate the quality of the fabricated devices in order to maintain output quality and reduce wastage. Typically printed electronics are fabricated either on a roll-to-roll system or on a flat-bed printer system. The approach in our work is compatible with both of these common production methods. The electrical metrology is based on inductive sensors which is contactless and can be operated at high-speed.

Using inductive sensors, eddy currents are induced perpendicular to the magnetic flux and flow in closed loops. Eddy currents concentrate close to the surface near the excitation coil and the current density decreases exponentially with depth. This is because eddy currents flowing in the sample under test at any depth produce magnetic fields which oppose the primary field and hence reduce the net magnetic flux. The depth at which the eddy current density has decreased by 1/e is referred to as the standard depth of penetration (δ). The effect of frequency (f) on the standard depth of penetration can be approximated by (1), where μ and σ denote the magnetic permeability and electrical conductivity respectively.

$$\delta \approx \frac{1}{\sqrt{\pi f \mu \sigma}} \tag{1}$$

The frequency can be modified to vary the penetration depth and consequently the effect of thickness when measuring electrical conductivity. Here, we investigate the performance of the sensors operating at different frequencies. The results identified the optimum frequency of the sensors for the samples under test. The sensors have been demonstrated operating at high speeds, comparable with typical roll-to-roll printed speeds for printed electronics. Additionally we have developed a low-cost circuit to enable measurements at the

optimised frequency. Contactless inductive sensing using eddy currents can provide information on changes n the electrical properties of samples. This makes it feasible to measure the electrical properties which at present are not monitored in roll-to-roll printed electronics manufacture.

Figure 1 shows the responses from six inductive sensors, S1 to S6 (each operating at their resonant frequencies), to tracks of differing sheet resistivity. It can be seen that S4 gives the greatest response for the tracks measured. The response of S4 to the six tracks passing the sensor on a roller can be seen in Figure 2. Each track is printed twice, hence the response shows two peaks per detected track material. Tracks 2 and 4 had low sheet resistivity and so it was not possible to detect them at the frequencies tested, however the sensor has been shown capable of detecting tracks with a sheet resistivity <1.6 Ω/sq. which is suitable for many printed electronics applications.

Figure 1: Graph showing responses of sensors (S1-S6) to different track samples. Error bars denote standard error.

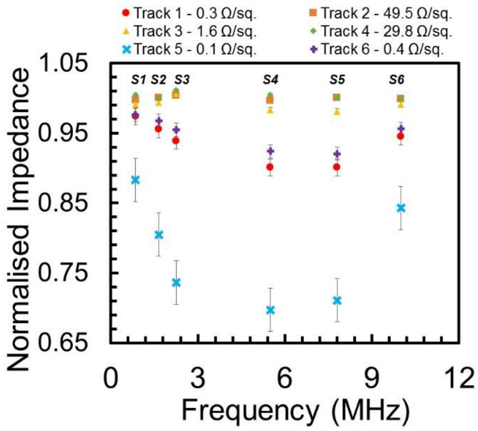
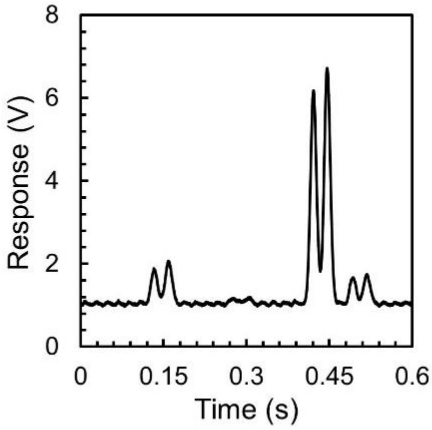


Figure 2: Response from Sensors S4 over a 0.6 s measurement time during which the 6 sample tracks (T1-T6) passed the sensors.



[1] D. Savastano, *'Printing and Electronics'* – Printed Electronics Now, March 2016

BIOGRAPHIES

Adam Lewis is a higher research scientist in the Magnetic Materials & Sensors Group at NPL. Adam's current research interests involve non-contact electrical characterisation of printed electronics. He is keen to implement intelligent measurement instrumentation into large-scale manufacturing. Adam in a member of the BSI AMT/009 committee which is responsive for the UK input into IEC/TC 119. He is also a member of the PELG (Plastic Electronics Leadership Group).

Martin Wickham is a Senior Research Scientist in the Magnetic Materials & Sensors Group at NPL and he has over 30 years' experience in electronics interconnection and reliability. His current interests are focused on high temperature interconnects, printed electronics, Sn whiskers and sustainability in electronics manufacturing. Current projects in high temperature electronics lifetime prediction include work with innovative conductive adhesives and sintered interconnects. Work in Sn whiskers includes mitigation using conformal coatings, electrostatic attraction, contact resistance measurement, oxide breakdown and whisker growth under electric fields. He is also currently involved in several projects to improve sustainability in the electronics industry including increasing the recyclability of printed circuit assembles. Recent work on printed electronics includes involvement in electrode development for increased sensor performance and reducing silver content in conductor inks.

12: Solution-Processed Co-planar Nano-Scale Photodetectors by Adhesion Lithography

Gwenhivir Wyatt-Moon, Dimitra G. Georgiadou, James Semple and Thomas D. Anthopoulos

ABSTRACT

As the resolution of devices in the electronics industry has hit the nanoscale, device fabrication costs have rapidly increased. Whilst commercial technologies such as photolithography are able to produce nanoscale feature size, they are costly and unsuitable for large area printable electronics. Research is now focusing on fabrication techniques that can reproduce this small size on flexible substrates without incurring such high costs, such as adhesion lithography (a-Lith). A-Lith is a novel, large scale fabrication technique for producing planar asymmetric nanogap electrodes. Devices have be created with aspect ratios >100000. The technique can be carried out in air and at low temperature making it ideal for the field of plastic electronics.

Here we show a-Lith used together with light sensitive, solution processable semiconductors to create photodetectors with large on/off ratios. This includes the use of Copper Thiocyanate (CuSCN), a visible-blind material, to create highly sensitive Schottky UV photodetectors, for use in different sensor applications including biological and environmental monitoring and analysis.

BIOGRAPHY

Gwen is a PhD Student within the Experimental Solid State Physics group at Imperial College London, under the supervision of Professor Thomas Anthopoulos. She is currently working on optimising the novel fabrication technique adhesion lithography (a-Lith), with particular focus on applications for optoelectronic devices such as organic light emitting diodes and photodetectors. Gwen gained her MRes in plastic electronics from Imperial College London and has previously worked for a medical devices company focusing on novel gas sensors and flow rheometry systems. Prior to this she gained her BEng in electrical engineering at Swansea University. Her current research interests include innovative fabrication techniques, materials, and devices for the plastic electronics field.

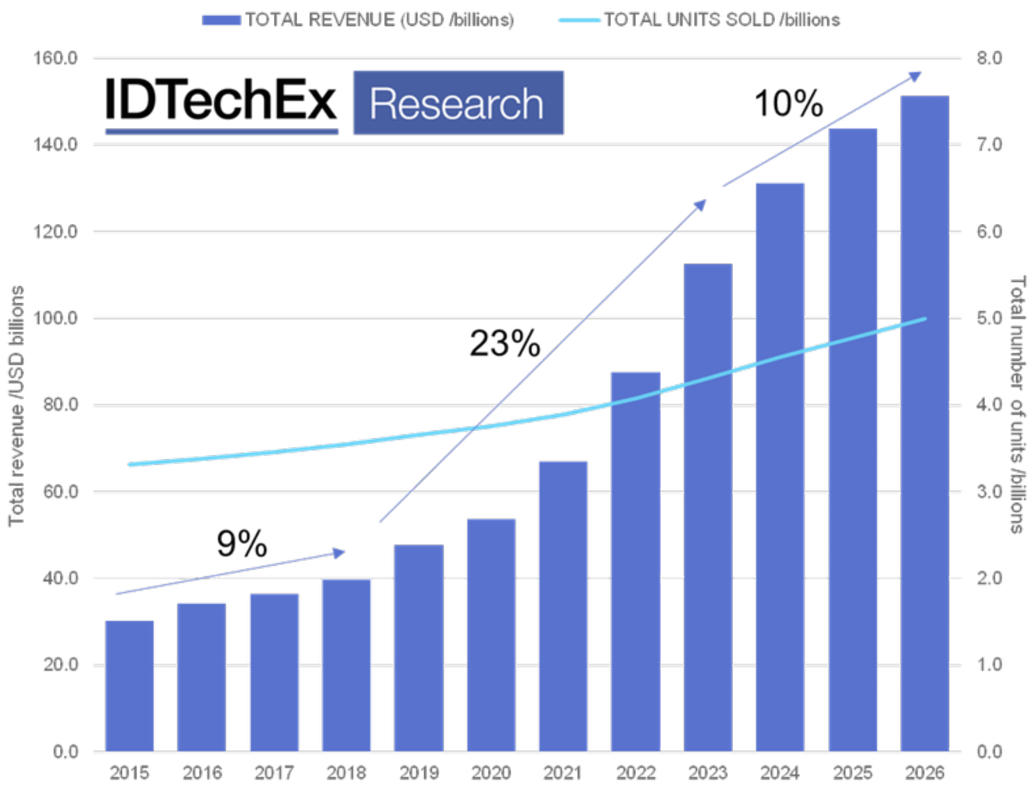
13: Market opportunities for Large Area Electronics

Guillaume Chansin, IDTechEx Research

ABSTRACT

This presentation will give an overview of the latest analysis from IDTechEx. In particular, it will cover the following aspects of large area electronics:

- The commercialization of organic electronics beyond OLED
- Status of flexible hybrid electronics
- How printed sensors can compete
- Technology trends in display industry
- Emerging applications in Wearables, Healthcare, and IoT



Global wearable technology forecast

BIOGRAPHY

Dr Guillaume Chansin is a Senior Technology Analyst at IDTechEx Research. Based in Cambridge (UK), he interprets the latest trends and market data in several industries, such as printed electronics, sensors, flexible displays and wearable electronics. His previous academic research includes three-dimensional fabrication with nanoimprint lithography and synthetic nanopore devices. Guillaume published several research papers in leading nanotechnology journals and received his PhD from Imperial College London. Before joining IDTechEx, he worked on the development of flexible e-paper displays at Plastic Logic. He is fluent in French and English and gives presentations in both languages. www.IDTechEx.com

14: Metal hexagonal grids and transparent conductors for OLEDs anode

Salvatore Aprano,[1] Luca Iannuzzi,[2] Ludovico Migliaccio,[3,4] Claudia Diletto,[4] Maria Grazia Maglione,[4]
Paolo Tassini,[4] Carla Minarini,[4] Paola Manini,[3] Alessandro Pezzella,[3] Alfredo Rubino.[1]
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[3] Università degli Studi di Napoli Federico II - Department of Chemical Sciences, Via Cintia n.4, Napoli, Italy
[4] ENEA - Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, SSPT-PROMAS-NANO, C. R. Portici, P.le E. Fermi n.1, Portici, NA, Italy

ABSTRACT

Large area organic light emitting diodes (OLEDs) are becoming very attractive devices for next generation of lighting applications. Anyway, the limited conductivity of the transparent anodic material (mostly ITO, indium tin oxide) leads to a lateral voltage drop along this contact, which reduces the current flow in this type of devices [1] so decreasing their performances. A simple way to overcome the low conductivity of the ITO, without

replacing it, and keep a good transparency of the anode, is to fabricate a metal grid on the ITO surface. In the literature, a hexagonal shape of the anodic metal grid is reported to have the lowest voltage loss [2] and the most established approaches to characterize it take into account the conductivity of the metal only [3]. In this work, various types of hexagonal metal grids have been prepared, using the lift-off method to define the metal lines, and coupled with ITO or PEDOT:PSS as the anodic material, measuring the resulting sheet resistance and optical transmittance. It has been observed that conductivity of the transparent conductor plays a key role in the behavior of these structures, and therefore the layout of the metal grids has to be tailored to obtain a good trade-off between electrical and optical properties and eventually use them in OLEDs.

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BIOGRAPHY

Laurea degree in Electronic Engineering (5 years course) at Università di Roma "Tor Vergata". In ENEA from 2000, with Laboratory of Nanomaterials and Devices (NANO). His interests have spanned from amorphous and polycrystalline silicon TFTs to organic devices, OLEDs, OTFTs, sensors, RFID, focusing on design, processing and characterization of materials, devices and circuits. He coordinated the ENEA scientific activities in Italian and European projects and has been responsible for the specifications and the purchase of complex and high value instrumentations and process systems. He is co-author of over 60 publications and communications to conferences and two patents. He is member of Organic and Printed Electronics Association (OEA), Photonics21 and Italian Association of Engineers.

15: Environmental Stability of the Density of States in Evaporated DNTT Films

Nor K Za'aba and D Martin Taylor
School of Electronic Engineering, Bangor University, Dean Street, Bangor, Gwynedd LL57 1UT, UK

ABSTRACT

The transfer characteristics of thin film transistors (TFTs) can be used to extract the density of states (DoS) in the semiconductor layer adjacent to the gate insulator. Of the several possible approaches, the most easy to use is the Grünewald approach, which has been used for both inorganic and organic TFTs. In the present work we have used the method to study the effects of relative humidity (RH) and temperature on the DoS in films of dinaphtho[2,3-b:2',3'-f] thieno[3,2-b]thiophene (DNTT) evaporated onto polystyrene as the gate insulator in bottom-gate topcontact TFTs.

Figure 1 shows transfer characteristics obtained following exposure for 30 minutes at each increasingly higher RH with temperature held at 20oC and the effect of 30 minute exposures to increasingly higher temperature with RH held at 10%. At higher RH VON shifts towards slightly more positive voltages with little or no hysteresis. The main effect of RH is to increase the OFF-currents possibly by creating current paths through moisture layers on the device and/or other insulator surfaces.

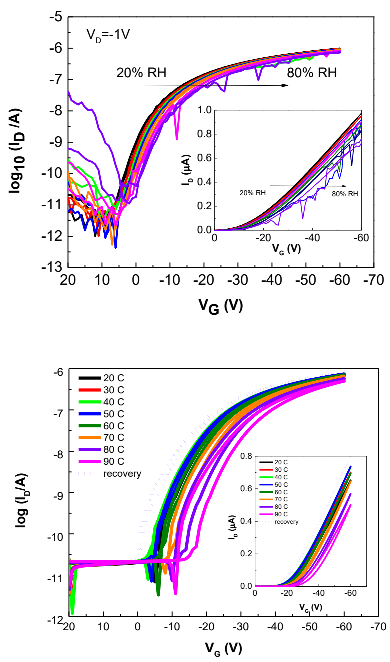

Fig 1 *Effect of RH at 20°C and temperature at 10% RH on the transfer characteristics*

Only minimal recovery was observed on reducing RH. On the otherhand, increasing temperature resulted in significant positive shifts in VON accompanied by increasing hysteresis and but with overnight recovery at lower temperature.

Figure 2 shows the density of states extracted from the transfer characteristics and plotted relative to the mobility edge, which we associated with the start of extended states at EV. The plots suggest that the main effect of RH and temperature is on the gate insulator. DNTT appears resilient to such changes and important feature in device applications.

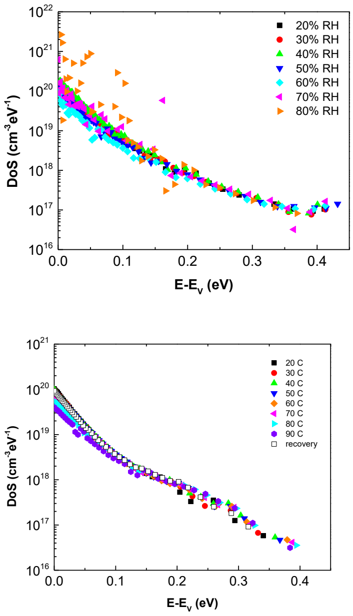

Fig 2 *Density of States in DNTT plotted relative to the mobility edge at E_V*

Acknowledgement

The authors are grateful to Dr J J Morrison, Manchester University for samples of DNTT. NKZ is grateful to MARA for the award of a PhD studentship.

BIOGRAPHIES

Nor Za'aba is currently in the third year of her PhD studies having obtained her first degree in Computational and Electronic Physics from University of Malaya. Some of the results from her PhD studies were reported in an oral presentation at the International Conference on Electronic Materials held in Singapore in July 2016

Martin Taylor is an Emeritus Professor at Bangor University. He has undertaken research into organic electronic devices for many years and has published papers on organic Schottky diodes, MIS capacitors, transistors and circuits. In his most recent paper with co-authors from SmartKem Ltd, he reported the shortest stage-delay time for a ring oscillator based on a solution-processed p-type semiconductor.

16: Refractive index patterning of molecular hybrid for photonics

Stefan Bachevillier1, Natalie Stingelin1,2, Paul Stavrinou1,3, Andreas Hafner4
[1] Centre for Plastic Electronics & Department of Materials, Imperial College London, SW7 2AZ, UK; [2] School of Materials Science and Engineering, Georgia Tech, GA 30332-0245, USA; [3] Department of Engineering Science, University of Oxford, OX1 3PJ, UK; [4] BASF AG, Basel BS, 4057, Switzerland

ABSTRACT

After the use of highly efficient but expensive inorganic optical materials, solutionprocessable polymers and hybrids have drawn more and more interest. Our group have recently developed a novel polymer-based hybrid optical material exhibiting an outstanding set of optical and material properties (Figure 1).

Even more remarkably, the refractive index can be tuned by either changing the inorganic content or locally via scalable patterning techniques. In this work, distinct methods will be presented. One of them, called hot-stamping can be used to fabricate waveguides (high refractive index core surrounded by lower index regions) as shown in Figure 2. These promising results open the way to solution-processed, high through- put and low-cost photonic structures.

Another part of this project is focused on reliable optical characterisation of these properties using a specific spectrometry method. This technique can be applied to non-destructive mapping of optical thin film properties but also to in situ annealing.

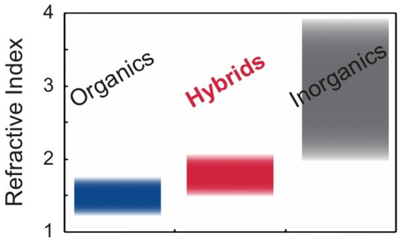

Figure 1. Refractive index ranges of different material categories in comparison with our tunable refractive index hybrid material.

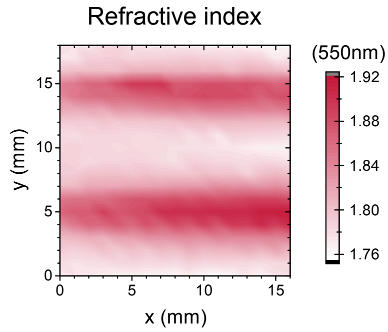

Figure 2. Refractive index mapping of hybrid thin film after hot stamping patterning.

BIOGRAPHY

Stefan Bachevillier is currently a PhD student at the department of Materials, Imperial College London within the Centre for Plastic Electronics and with Professors Natalie Stingelin and Paul Stavrinou as supervisors. Prior to this, he obtained a Master of Research at University of Bordeaux (IMS laboratory) and the degree of Engineer in Materials Science at ENSCBP of Bordeaux. During his Master's degree, he had the opportunity to conduct research at several research companies such as Nikon and Essilor International Joint Research Center (Tokyo, Japan), Cambridge Display Technology Ltd. and Plastic Logic Ltd.

17: Enhanced sensitivity for optical loss measurement in planar thin-films for light management

Hua-Kang Yuan, Imperial College London

ABSTRACT

Light management is to control the behaviour of light, often within or at the interface of optoelectronic devices. An organic-inorganic hybrid material benefits from processing advantages of organics and high refractive indices of inorganics. We focus on a titanium oxide hydrate system combined with common bulk polymers. In particular, we target thin-film structures of a few microns in thickness. A simple method of inplane patterning refractive index is a step towards waveguiding which would allow for a cut-back method approach (figure 1). Traditional Beer-Lambert approaches for measuring optical losses can only provide an upper limit estimate. This sensitivity is highly limited when considering the low-losses required for mid-range optical applications, on the order of 0.1 cm-1. For intensity based measurements, improving the sensitivity requires an increase in the optical path length. Instead, a sensitive technique suitable for simple planar thin films is required. A number of systems were modelled to measure optical losses in films of 1 micron thick in the visible region. The presented techniques utilise evanescent waves and total internal reflection to increase optical path length through the material. It was found that a new way of using prism coupling figure 2) provides the greatest improvement in sensitivity. In keeping the requirements on the material simple, this method for measuring loss is well suited to any future developments of new materials in thinfilm structures.

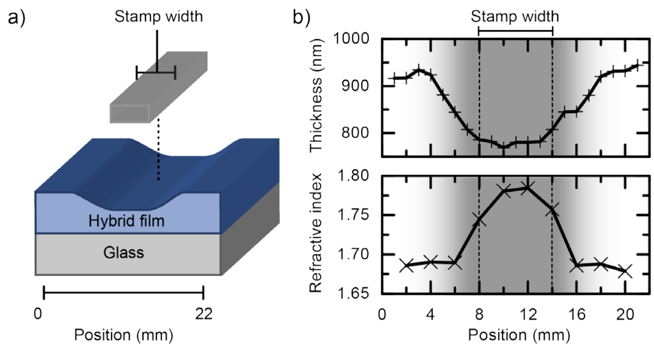

Figure 1. a) Schematic of annealed film. b) Index and thickness profiles.

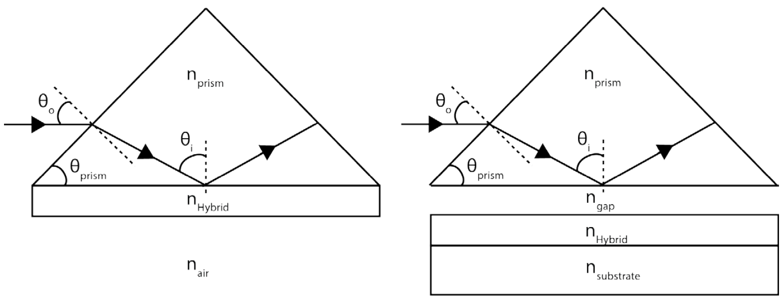

Figure 2. Prism coupling techniques for enhancing sensitivity of transverse loss measurements.

BIOGRAPHY

Hua-Kang (Kevin) Yuan is currently a PhD student of the Centre for Plastic Electronics at Imperial College London, supervised by Paul Stavrinou (University of Oxford) and Natalie Stingelin (Georgia Institute of Technology). This project is in collaboration with BASF, which is externally supervised by Andreas Hafner. Prior to this, Kevin was awarded an integrated BA and MSci undergraduate degree in Natural Sciences at the University of Cambridge, specializing in Physics.

18: Ambipolar charge transport in polymer blends for OFETs: Towards charge carriers balance control

Giovanni M. Matrone*[1], Alberto D. Scaccabarozzi[1,2], Natalie Stingelin[1]
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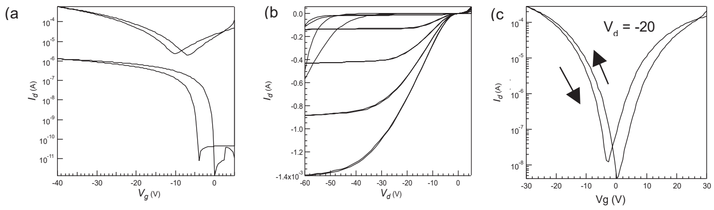
ABSTRACT

Generally, the nature of charge-carrier transport of polymer-based OFETs are manipulated through molecular-energy-level tuning, limiting injection of one type of charge carrier1. Ambipolar charge transport 2 can sometimes be desirable, including electronic applications such as complementary-like logic circuitry especially in light of development of bio-compatible devices. Although ambipolarity has been demonstrated to be an intrinsic property in organic materials, here we give evidence that it is possible to balance electron and hole mobility in OFET active layers1,2,3. In the attempt of investigating the transport properties of diketopyrrolopyrrole-thieno [3,2-b] thiophene copolymers (DPP-T-TT)) that standardly are used as hole-transporting polymer semiconductors but can display n-type behavior, we exemplify our approach controlling gate dielectric surface treatment4 and casting temperature in order to enhance n-type behavior. Blending DPP-T-TT with the insulator high-density polyethylene (HDPE)5,6 thereby assists realization of balanced charge carrier mobilities. We also demonstrate that it provides an additional tool to enhance the materials p-type mobility. Addition of a

commodity polymer will moreover allow fine-tuning of the mechanical properties, a feature that can be of great importance in the printing electronic area, assisting the deposition of more stable active layers.



Representative transfer (a) and output (b) characteristics of DPP-T-TT:HDPE 60:40 bottom-gate bottom-contact field-effect transistors. Source-drain voltages are -1V and -40V. Source-gate voltages in the outputs ranges from 0 V to -40 V with -10 V step. Ambipolar transfer characteristics (c), source-drain voltage is -20V.

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BIOGRAPHY

2013 - Bachelor in Science and Materials Engineering (University Federico II Naples ITA)

2015 – Master degree in Materials Engineering and Nanotechnology (Politecnico di Milano ITA)

2016 on – PhD student in Natalie Stingelin's group (Imperial College London) as an Early Stage Researcher in INFORM - Marie Sklodowska-Curie Innovative Training Network

19: Interconnection Technologies for Integration of Active Devices with Printed Plastic Electronics

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Department of Electrical and Electronic Engineering, Imperial College London, London SW7 2AZ, United Kingdom

ABSTRACT

Printed electronic circuits on low-temperature plastic substrates have enormous potential across a range of consumer markets including automotive windows, wearable devices, healthcare devices and smart labels. Many of these applications require a combination of both printed electronics, which offers large area and flexibility at low cost, and conventional silicon electronics which allows much greater functionality. Currently the main technique used for integrating silicon devices with plastic electronics is Isotropic Conductive Adhesive (ICA) packaging. With this approach, a conductive adhesive (typically a silver-loaded paste) is printed onto the substrate at sites where electrical connection is required. The silicon device is then placed in position, and the adhesive is cured. The same approach is also being used to mount flexible plastic electronic chips on plastic substrates. In this project we will investigate the use of Non Conductive Adhesive (NCA) packaging as an alternative route for integrating active devices on low-temperature substrates. With the NCA approach, electrical connections are mediated by conductive bumps on the active device, and the role of the adhesive is purely to pull these bumps into contact with the pads on the substrate. NCA packaging offers several advantages over ICA. Firstly it is more efficient at the point of assembly because it does not require selective deposition of the adhesive; instead the NCA is dispensed (or applied in film form) over the entire device area. Secondly, it inherently provides an underfill between device and substrate which improves reliability; thirdly it is scalable to finer interconnect pitches which will become important in the future. In addition to working on pure NCA packaging, we will also explore the feasibility of using thermosonic (TS) bonding to form metal-metal

micro-joints between the bumps and the substrate pads. TS bonding uses a combination of heat, pressure and ultrasonic energy to facilitate the formation of direct metal-metal bonds at lower temperatures and pressures than would be required for thermo-compression bonding. If a working process can be established for plastic electronics then it will provide more reliable interconnections than any purely adhesive-based approach.

Ultimately we envisage a combined thermosonic-adhesive (TA) process for plastic electronics in which a thermosonic bonding step is carried out during the NCA curing cycle – see Figure 1. The process comprises four steps: (1) apply NCA to plastic electronic substrate; (2) place and align active device; (3) apply pressure, heat and ultrasound as required to form TS bonds and cure NCA; (4) cool and withdraw pick-up tool.

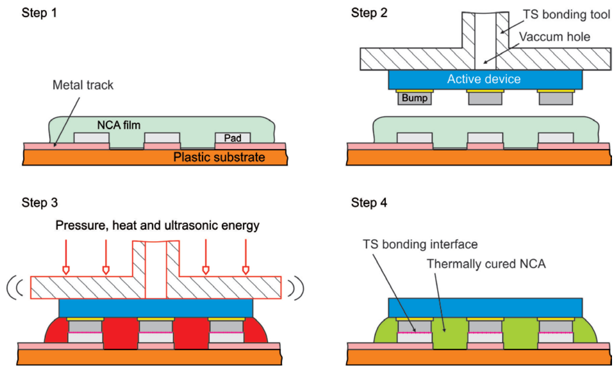

Figure 1. Thermosonic-adhesive packaging process combining NCA packaging and thermosonic bonding

BIOGRAPHIES

Dr Guangbin Dou is a Research Associate in the Department of Electrical & Electronic Engineering at Imperial College London. Dr Dou has a PhD in Electronics Manufacturing, with 9 years research experience in microsystems devices and microelectronics manufacturing. He has more than 25 high-quality publications, including journal papers published in Advanced Materials, Applied Physics Letters and CrystEngComm. He has delivered keynote speeches and invited talks on several occasions at international conferences and research institutions, and he has received an IEEE Outstanding Conference Paper award. Moreover, he has been awarded 2 patents, with one commercialised. He was a key researcher on the NASA InSight Mission to Mars where he was part of the team that has built the most accurate and reliable seismometers to date; these devices will be sent to Mars in 2018. Working on a NASA funded project has given him valuable experience in working to a strict project schedule, as well as knowledge of their reporting and logging to standards.

Professor Andrew S Holmes is Professor of Microelectromechanical Systems (MEMS) in the Department of Electrical & Electronic Engineering at Imperial College London. Professor Holmes has worked extensively on MEMS devices and fabrication technologies, and also on micro-assembly technologies for MEMS and electronics manufacturing. He has published around 150 journal and conference papers in these areas, including a number of invited papers at international conferences. He is a founding member of the Technical Coordination Committee on MEMS within the Industrial Electronics Society of the IEEE, and an Associate Editor of the IEEE Journal of Microelectromechanical Systems. He is also a co-founder and director of Microsaic Systems plc, an Imperial College spin-out company started in 2001 to exploit Imperial College MEMS research. The company, which has developed a bench-top mass spectrometer based on MEMS technology, was admitted to AIM in 2011.

20: Geometry considerations for printed Schottky diodes

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Electrical Engineering Division, University of Cambridge, 9 JJ Thomson Avenue, CB3 0FA, Cambridge, UK

ABSTRACT

Obtaining good rectification at high frequencies is a challenging task in printed electronics technology. A key factor which determines electrical characteristics is the device geometry in which the metal electrodes and semiconductor are arranged. We identified and studied several geometries of the electrodes and semiconductor to yield some design rules for producing an optimised rectifier. We used Athena to fabricate the structures and ATLAS for simulations, both of which are part of theSilvaco® software suite. IGZO was considered as the semiconductor while different metal work functions were studied to obtain rectification. It is found that, when the metal electrodes are placed out-of-plane with self-alignment instead of in parallel plate capacitor geometry, the obtained parasitic capacitances are minimised. This also leads to a high rectification ratio > 104 with leakage currents which are one order less for the thinnest semiconductor thickness studied. These simulated parameters are easily manufactured in printing technology.

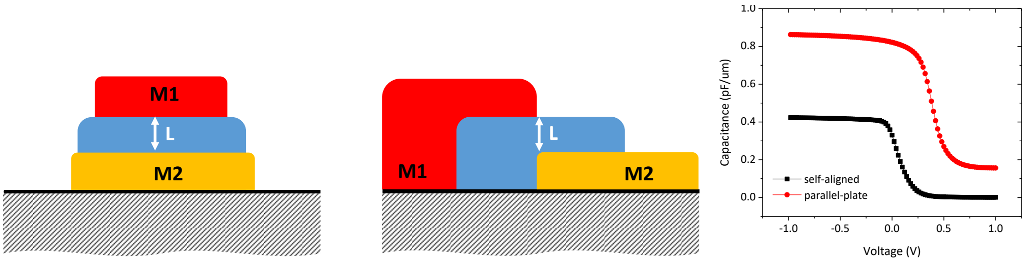

Figure. Schematic of two device geometries investigated: (left) parallel-capacitor, (right) self-aligned.

BIOGRAPHIES

Dr Sagade received his PhD in 2009 from Dr. B.A.M. University, India. After obtaining a DST-NANO India postdoctoral fellowship in 2010 he worked at JNCASR. He has also been part of the Horizon 2020 Graphene Flagship project at AMO GmbH Aachen, Germany. His research interests are in semiconductor device understanding, encapsulation, graphene and nanowire device fabrication.

Professor Flewitt received his PhD from the University of Cambridge in 1998, investigating the growth of hydrogenated amorphous silicon thin films using scanning tunnelling microscopy. His current research interests include inorganic thin film transistors and acoustic wave MEMS sensors. Of particular interest is the integration of silicon with plastics in devices and biological sensing devices based on surface acoustic wave devices.

21: Copper(I) thiocyanate (CuSCN) and its derivatives as hole-transport layer materials for large-area opto/electronics

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ABSTRACT

Recent advances in opto/electronics research have confirmed the enormous potential of copper(I) thiocyanate (CuSCN) as a universal hole-transport layer (HTL) for large-area applications. CuSCN is an inorganic, molecular, p-type semiconductor from the metal pseudohalide family, which combines excellent hole-transport properties with a wide bandgap (>3.4 eV) that facilitates high optical transparency [1]. Solution-processed CuSCN HTLs

have been demonstrated in perovskite-based solar cells, organic photovoltaic (OPV) cells, organic light-emitting diodes (OLEDs) and thin-film transistors (TFTs) [2]. CuSCN exhibits greater chemical stability relative to the acidic PEDOT:PSS [3] and is a low-cost alternative to Spiro-MeOTAD – materials employed as conventional HTLs in the literature. Therefore, this unique combination of attractive characteristics makes CuSCN an ideal HTL candidate for large-area applications.

Here we report on the optimisation of low temperature, solution-processed CuSCN-based HTLs, and present a novel derivative of CuSCN with similar hole-transport properties. First, the conductivity and Fermi level of CuSCN is modified with the addition of chemical p-dopants, and field-effect hole mobilities exceeding twice that of pristine CuSCN are observed in the optimised doped systems. Next, novel solution-processing schemes for CuSCN are explored, and alternatives to the standard n-alkyl sulphide solvents are demonstrated. These novel formulations were utilised to spin-cast CuSCN HTLs with superior field-effect hole mobilities (~0.1 cm2V–1s–1) and high uniformity over large-area substrates. The environmental stability of CuSCN HTLs and their suitability for ambient air solution-processing are also assessed. Finally, the synthesis of a novel wide bandgap semiconductor from the metal pseudohalide family is reported and a comprehensive investigation into its suitability as a next-generation HTL is presented. HTL deposition parameters are optimised using TFT measurements and a range of thin-film analysis techniques, such as AFM and XPS. Consequently, the tremendous potential of this family of inorganic compounds to replace conventional organic HTL materials is demonstrated.

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[3] A. Garcia, et al., Adv. Mater., 24, 5368, 2012.

BIOGRAPHY

Nilushi is a PhD candidate in the Centre for Plastic Electronics at Imperial College London. As the recipient of an EPSRC DTA funding award, she conducts research in Experimental Solid State (EXSS) Physics under the supervision of Professor Thomas Anthopoulos. She completed her undergraduate degree in Physics at University College London, where she also received the Corrigan Prize for experimental work, and two EPSRC funding awards for summer projects in Condensed Matter and Materials Physics. Prior to joining Imperial, Nilushi graduated with a research MSc in Atomic and Laser Physics from the University of Oxford, where she collaborated with theoreticians at the University of Cambridge on a non-linear optics project. She was a committee member of the Society for Information Display (SID) UK & Ireland Chapter for 2014-16, and the postgraduate representative of the EXSS research group at Imperial for 2015-16.

22: Printing Carbon Nanotubes Using Large-Area Fine-Feature Printer

Qingshen Jing1, Michael Smith1, Yeonsik Choi1, Nicolo Chiodarelli2, Michael De Volder2, Sohini Kar-Narayan1
1Department of Material Science and Metallurgy, University of Cambridge, UK
2Institute for Manufacturing, Department of Engineering, University of Cambridge, UK.

ABSTRACT

Carbon nanotubes (CNTs) have been proved promising as additives in battery electrodes, super capacitors and other electronics such as flexible or stretchable devices. Ways of making uniform CNT thin films have been mature and economic. Meanwhile, complex and fine pattern of CNT electrodes are desired to fulfil more complicated functions. Technologies of using a commercial printer to inkjet water/oil dispersed CNT solutions have been attempted however are hampered due to narrow range of solution viscosity permitted by printers.

Large-area fine-feature aerosol printer is a high-resolution rapid-prototyping equipment suitable for printing up electronic circuit with a widely ranged compatibility of ink materials, including conductive nanoparticles, polymers, insulators, adhesives, etchants, etc., with a work area as large as 175 mm x 200 mm.

We demonstrate this new technology in fabricating fine patterned CNT electrode through a fast and direct printing approaching. CNT inks can be prepared as either oil-based or water-based, with a minimum printing line approaching tens of micrometers. Various substrates including glass, silicon, PET, Kapton, PDMS are tested for the purpose of future applications in various situations requiring either rigid, flexible or stretchable features. In this work, we demonstrate an easy and straightforward approach in CNT electrode fabrication to meet both scientific and industrial requirements.

BIOGRAPHY

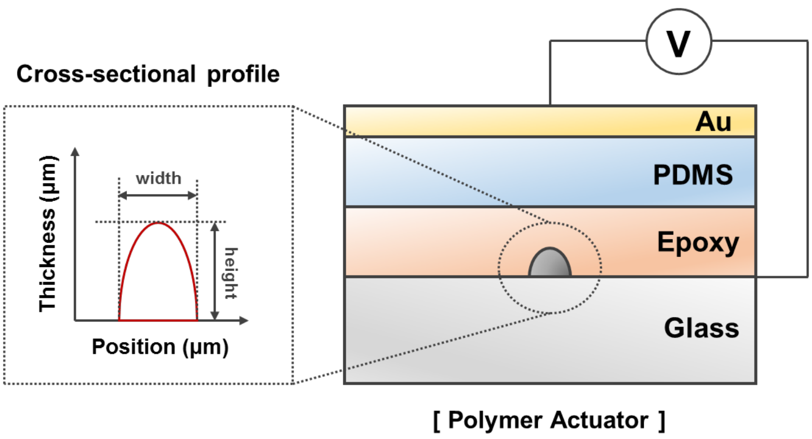
Being awarded with EU Marie Skłodowska-Curie individual fellowship since 2016, Dr Qingshen Jing is a research fellow in Department of Material Science and Metallurgy in University of Cambridge. He received his PhD from a joint PhD program held by both Peking University, China and Georgia Institute of Technology, USA. He has been focusing on nanogenerators in harvesting mechanical energy and active motion sensors during his PhD study. He is currently devoted in fabricating flexible and stretchable electronics using model technology including large-area fine-feature printer, etc.

23: Optimization of Aerosol Jet Printing for Highly Aligned Structural Actuable Polymer Surface

Yeonsik Choi†, I-Ting Lin†, Michael Smith, Chess Boughey, Tiesheng Wang, Stoyan K. Smoukov, and Sohini Kar-Narayan*
Department of Materials Science and Metallurgy, University of Cambridge, UK

ABSTRACT

Aerosol jet printing is a relatively new method for fabrication of printed electronics. This method is especially useful for easy control of the cross-sectional profile of printed lines, such as line width and thickness, using a number of process parameters.1 Engineered conductive lines can be used to change the surface morphology of polymer actuators. In this paper, the influence of the aerosol-jet-printed conductive line profiles on the actuation surface geometry of polymers is studied with the aim of creating highly aligned actuable elastomer structures. The focusing ratio and substrate temperature are varied to demonstrate different conductive line geometries. A systematic study of process conditions revealed that controlling the printed line profile influences the shape of the actuated surface. These results are used to develop an operability window for highly aligned actuable polymer surface.



Reference

1. Mahajan A, Frisbie CD, Francis LF. Optimization of Aerosol Jet Printing for High-Resolution, High-Aspect Ratio Silver Lines. ACS Appl Mater Interfaces. 2013, 5, 4856

BIOGRAPHY

Yeonsik Choi received his Bachelors degree (2009) and Masters degree (2011) from the Department of Materials Science and Engineering at Yonsei University in Seoul, Korea. Up to 2015, he worked at LG Chem. Ltd. R&D Center as a senior researcher for the development of the carbon nanotube based composite materials for electronic devices. He is currently a PhD student under Prof. Sohini Kar-Narayan at the University of Cambridge, UK. His Major research interest is the investigation of novel nanomaterials for application in triboelectric nanogenerators.

24: Soft-Blade Convective Self-Assembly, a Versatile Tool for Assembling and Ordering Organic/Inorganic Nanoparticles into Hierarchical Structures on Large Areas

Shengyang Chen[1], Paul Stavrinou[1,2], Natalie Stingelin[1,3], Ioan Botiz[1,4]
[1]Imperial College London (UK); [2]University of Oxford (UK); [3]Georgia Institute of Technology (US); [4]Babes-Bolyai University (Romania)

ABSTRACT

Convective self-assembly (CSA) is a method that can be used by depositing, in a controlled manner, nano- to micro-sized colloids onto a surface relief structure under the action of solvent evaporation and capillary forces. Conventional CSA methods require precise controls of various physical parameters, e.g., processing temperature, humidity, and deposition velocity. To overcome the sensitivity and complexity of conventional strategies, a soft-blade CSA method has been developed. As shown below, a polydimethylsiloxane (PDMS) replaces the role of the hard metal blade in a conventional blade-coating setup and is in direct contact with the surface relief structures. Due to the softness of the PDMS material, the surface relief structures are not damaged.

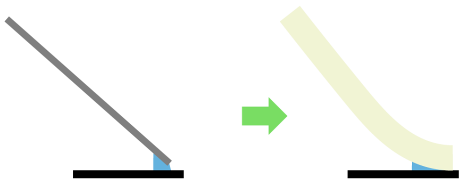


Figure 1 Conventional hard-blade method (left) and newly developed soft-blade method.

This soft-blade method turns out to be a very efficient method because it not only reduces the influences of processing parameters but also can be material-independent, i.e., different sizes of organic/inorganic material spheres were successfully deposited into the surface relief structures via this method. The final structure is mainly dependent on the dimensions of particle spheres and the surface relief structures. Fig.2 is an example of the final hierarchical structure, which consists of polyfluorene-co-divinylbenzene (polymer emissive material) particles and polystyrene gratings. What's worth mentioning is that this method has been proved to be able to produce homogeneous hierarchical structures on a substrate with the area up to 2x2 cm^2 so far, which is potential for large area production.

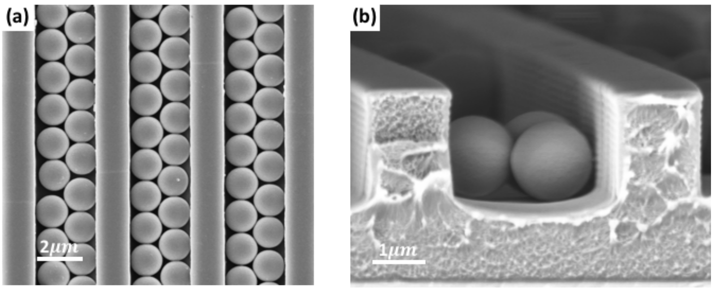


Figure 2 (a)Top-view and (b) cross-section view of SEM images of the hierarchical structure which consists of polyfluorene-co-divinyl-benzene particles and polystyrene gratings.

BIOGRAPHY

Mr Shengyang Chen is a PhD student in the Centre for Plastic Electronics (CPE), Imperial College London. Now he works with Prof Natalie Stingelin (Georgia Institute of Technology) and Prof Paul Stavrinou (University of Oxford). Shengyang graduated from the Beijing University of Chemical Technology with a first class B.Eng. in Polymer Science and Engineering in 2014. After that he continued his postgraduate study in Advanced Materials Science and Engineering in Imperial College London where he obtained a Distinction MSc degree. In 2015, he was awarded with Chinese Scholarship Council Scholarship and enrolled in the Plastic Electronics CDT programme. In 2016, he obtained a Distinction MRes degree and now works as a PhD candidate in Materials Department, Imperial College London.

His research projects mainly focus on two fields: (1) exploiting patterning strategies for integration of multifunctional organic/inorganic hierarchical structures and (2) the use of additives for breaking up phosphor aggregation in solution-processed organic light-emitting diodes (OLED).

25: Development of Scalable Methods for Printable Perovskite Photovoltaics

Harry Cronin[1,2], K. D. G. Imalka Jayawardena[2], Zlatka Stoeva[1], Martin Brown[3], Maxim Shkunov[2], S. Ravi P. Silva[2]
[1] DZP Technologies Ltd, Cambridge, UK; [2] University of Surrey, Guildford, UK; [3] Heraeus Noblelight Ltd., Cambridge, UK

ABSTRACT

Printable solar cells based on Perovskite absorber materials are on the verge of revolutionising the photovoltaics industry. However, challenges remain to be overcome in up-scaling this technology to leverage the advantages of large-scale printing, allowing rapid, low-cost deposition of large-area devices on flexible substrates. Here we present an overview of recent activity at DZP Technologies and our collaborators towards the upscaling of this promising technology.

One of the challenges in moving Perovskites towards large scale manufacture is the sensitive nature of the films to humidity during production, when produced using the standard one-step solution based method. It is known that humidity can lead to faster crystallisation and grain growth of the annealing Perovskite film, but here for the first time we report a systematic study of the combined effects of humidity and thermal annealing time, which is key information for moving towards up-scaled production. By fabricating Perovskite solar cells using different humidities and annealing times, we reveal the nature of the trade-off between these two variables, with the optimum conditions being a moderate level of humidity and a moderate annealing time. Based on these results we propose a strategy to reduce annealing times by control of humidity, which may allow for cost reductions in a future up-scaled printing process.

A further limitation is the use of costly electrode materials, which are often vacuum deposited, adding to cost and process complexity. We present results of our work on photo-curing of aqueous flake silver inks towards a low-cost, fully printable electrode material. While this technology is known to be of use in sintering nanoparticle

based systems, which benefit from significant melting point suppression compared with bulk material, larger flake inks are more challenging to sinter by this means owing to the higher required temperatures. We find that with photo-curing the conductivity of such inks approaches and in some cases matches that of typical nanoparticle inks. Furthermore, in an application employing screen printed silver lines, the yield of conductive patterns was increased from 46% untreated to 90% after photo-curing.

Finally we present initial results of Perovskite materials manufactured by a non-standard powder-based method, and a readily scalable slot-die printing process based on a blend of this material with various photo-active polymers. These initial results demonstrate the suitability of this method for upscaling and serve as a promising basis for future research.

BIOGRAPHY

Harry Cronin is an EngD research engineer working jointly at DZP Technologies in Cambridge and the University of Surrey. Harry received his MSci in Physics from Imperial College London and started his doctoral research in 2013. His research is focused on materials and process development for printed electronics, with a focus on printed solar cells.

26: Design of Metaferrites using Genetic Algorithms and Other Optimisation Techniques

By Philip Beal, QMUL EECS

ABSTRACT

Metaferrites are a class of metamaterials designed for the purpose of replicating the electrical properties of ferrite materials without actually using any, which could in some cases disrupt the function of devices due to the material's other properties. Additionally, metaferrites are customisable, allowing for bespoke materials with properties difficult or impossible to produce otherwise.

This work seeks to design novel metaferrites using a combination of genetic algorithms, machine learning and other optimisation techniques. If possible, it also seeks to construct a database of structures that will speed further endeavours in the area by quickly identifying which features correspond to a given set of parameters. So far, development of the design programs has been the primary output, with fabrication expected to be possible in the near future

BIOGRAPHY

Philip Beal is a PhD student studying Electronic Engineering at Queen Mary University of London under the supervision of Professor Yang Hao and Dr Khalid Rajab.

27: Magnetoelectronics on Bendable Ultra-Thin Si Chips

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ABSTRACT

The integration of magnetic elements into electronic devices, often referred to as magnetoelectronics, is an interesting development in flexible electronics. Here we present magentic devices (e.g. Hall Sensor and Giant Magnetoresistance (GMR)) on ultra-thin chips and our investigation realted to the effects of bending stress on these devices. The bending induced variations in device parameters are needed to improve device models and design the new generation of flexible magnetic sensors. We have recently presented the ending-induced stress

effects on ultra-thin cross-shaped magnetic sensors operating in CMOS technology, as shown in Fig. 1(a) [1]. In this work, the magnetic sensor's sensitivity and the offset drift have been analysed. The optimum geometry and thickness of the Hall sensor are the important parameters to be analysed to compensate any mechanical stress related effect on the performance of sensors. We also studied the vertical Hall sensor (VHS) on flexible substrate to obtain the optimum sensor device dimension and shape [2]. The chip has been mounted and wire bonded on two different polymeric substrates including VC and polyimide-based Flexible Printed Circuit board, as shown in Fig. 1(b). The optimal geometry of the Hall sensors on the chip has been investigated through simulations, which also consider the effect of mechanical stress on sensor performance. The results indicate degradation of performance by up to 2.5% when bending radius of curvature of the substrate changes from 10 to 25 mm.

The other aspect of our research on flexible magnetic device related to utilization of GMR-based sensorics, for example in magnetic read heads to boost the capacity and performance of magnetic data storage systems.

A schematic representation of random access memory (RAM) constructed with an array of GMR can be used for large area electronics, as illustrated in Fig. 1(c). Such giant magnetoresistive thin structures are chosen as the magnetic sensorics technology suitable for the development of flexible magnetoelectronics. The major economic impact from GMR is anticipated to come from nonvolatile magnetic computer memory. Our aim is to fabricate a wearable magnetic sensor based on giant magnetoresistance (GMR) that can be utilized in flexible electronics applications. For this purpose, we have fabricated a GMR multilayer stack composed of nickel (Ni) and titanium (Ti) layers as ferromagnetic and nonferromagnetic metals, respectively, rather than well-known cobalt (Co) and copper (Cu) multilayers. This well-known system relies on in-plane oriented magnetic moments and exhibits a high GMR ratio with moderate saturation fields. The results of this study will be presented in the conference poster.

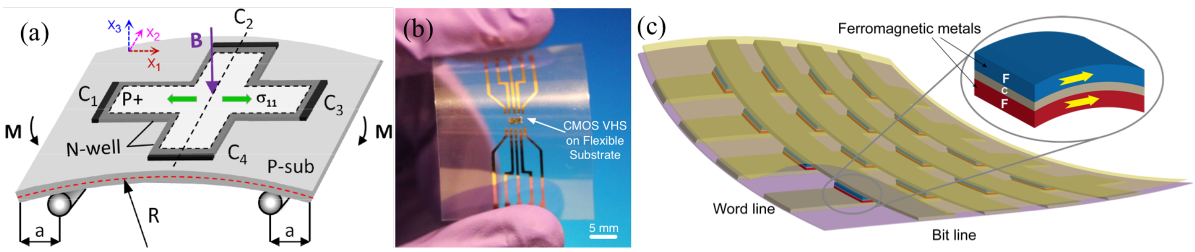

Fig. 1: (a) Horizontal magnetic Hall sensor in a four-point-bending (4PB) setup, (b) the VHS chip mounted on a PVC foil, (c) a schematic representation of random access memory (RAM) that is constructed of arrays of GMR which can be used for large area electronics.

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BIOGRAPHY

Dr Hadi Heidari, is a Lecturer at the University of Glasgow, UK, through the Joint Education Programme with the University of Electronic Science and Technology of China (UESTC), China. Prior to this position, he was a postdoctoral researcher at the Electronic and Nanoscale Engineering Division of the University of Glasgow, UK. His research interests are on device modelling, analog circuits and system design for flexible electronics applications. He completed the PhD degree in microelectronics from the University of Pavia, Italy, with the focus on development, design and testing of integrated CMOS sensor microsystems. He received the BSEE and MSEE degrees in 2005 and 2008, respectively. Dr Heidari served on the organizing committee of several conferences including social media chair of the IEEE Sensors 2017, social media chair of the IEEE SENSORS 2016, local organizing committee of the IEEE PRIME 2015, and organizer of special sessions in the IEEE ISCAS 2016 and 2017 conferences. He has published over 35 academic papers, supervised many MEng and BEng students, and acts as a reviewer for several journals and conferences. He received different paper awards at the IEEE ISCAS 2014, IEEE PRIME 2014, and the ISSCC 2016 conferences. He was a visiting scholar with the University of Macau, China, and McGill University, Canada.

28: Low-voltage electrospinning patterning of functional micro- and nano-fibres

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ABSTRACT

Applications of micro-nano fibrous structures are vital to a number of emerging technologies such as fibre-based sensors, filtration membranes, batteries, energy storage and a range of bioengineering technologies such as tissue scaffold implants, drug delivery and wound dressing. Electrospinning is a versatile technique for the construction of microfibrous and nanofibrous structures with considerable potential in the applications mentioned above. In the simplest form, electrospinning uses a high voltage of tens of thousands volts to draw ultra-fine polymer fibres over a large distance. However, the high voltage limits the flexible combination of material selection, deposition substrate, and control of patterns. Extending the capability of electrospinning, our work demonstrates a new ultra-low voltage continuous electrospinning patterning (LEP) technique. LEP utilizes solution dependent 'initiators', which reduces the applied voltage threshold to as low as 50 V, simultaneously permitting continuous fibre patterning. By incorporating with a microfluidic-based spinneret, LEP extends its applications in printing high performance conductive lines onto plastic substrates at mild temperatures. Compared to published literature using other printing techniques, the LEP patterned silver lines demonstrate improved aspect ratios for single pass lines. Post 90 °C heat treatment, the resulted silver lines show a conductivity value one order of magnitude smaller than its bulk counterpart, which is of comparable performance to other reported work requiring thermal treatments at temperatures exceeding 100 °C. In summary, the LEP technique reported here should open up new avenues in the patterning of bio-/ electronic-elements, and free-form nano- to micro-scale fibrous structures with a versatile range of materials, broadening the application scope of room temperature, solution-based direct-write fabrication techniques.

Acknowledgement

Thanks for the assistance from Yuan Yuan Hu and Lang Jiang from Cavendish Laboratory in performing the experiment.

BIOGRAPHY

Wenyu Wang acquired his Bachelor's degree in mechanical engineering from Tsinghua University (Beijing) in 2016, and then started a Ph.D. study at the University of Cambridge, focusing on biofabrication. His supervisor is Dr. Shery Huang. Wenyu has participated several research projects during his undergraduate period, ranging from precise processing of turbine blade to construction of a stereolithographic 3D printer, and has co-authored two EI articles. Now his research focuses on improving the functionality of additive manufacturing methods to enlarge the applications of the final products, like soft electronics and biocompatible device.

29: Monolayer graphene membrane device for bio-sensing applications

R. K. Gupta[a], U. Monteverde[a], Omar. M. Dawood[a,d], F. Hadi[a], J. Campbell[a], J. Sexton[a], L. Majewski[a], M. Missous[a], Dean Jackson[e], Robert J. Young[d], M. Migliorato[a], Neil Dixon[b,c]

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ABSTRACT

Single layer graphene, owing to its extraordinary electronic and chemical properties, offers the potential application for the fabrication of an ultra-sensitive biosensor and/or chemisensor [1]. Free standing (suspended) graphene sheet have shown high charge carriers mobility and large surface area for bio-or chemical interaction/ interface as compared to similar sized substrate supported graphene sheet [2,3]. Recently reported micron size free standing graphene beam based two terminal biosensors have achieved sensitive multiplexed detection of lung cancer tumor markers [4]. Graphene channel based three terminal devices - graphene field effect transistor (GFET), even with the limitations of low I_{on}/I_{off} ratio, exhibits characteristic parameter; charge neutrality voltage (VCN), which is very sensitive to the surface charge interacting with graphene channel. The charge sensing ability of suspended graphene based FET (SGFET) can be explored for an ultra-sensitive biosensor for biomarkers and pathogens in their physiological conditions or in an environment.

In this poster, we shall be showing the improved device structure and electrical results of an array based three terminal free-standing graphene devices (Fig. 1), in which graphene is suspended over micro-meter scale cavities with top and back gate contacts. The device uses conventional lithography and graphene transfer process for device fabrication. The end applications of this device shall be explored for an ultra-sensitive detection of DNA hybridisation and/or cardiac proteins.

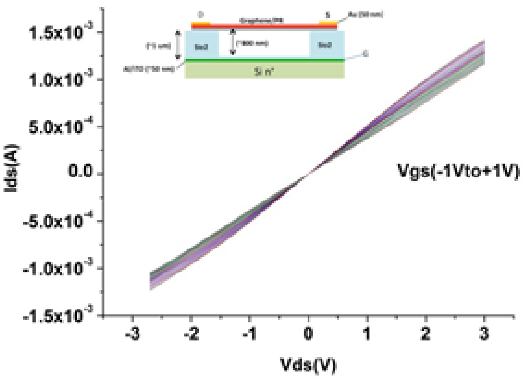

Fig. 1 Drain-Source current variations at different gate biasing (inset; Device cartoon)

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BIOGRAPHY

Rakesh obtained a Master's degree in Electronics from the University of Jammu, J&K, India, in 2002; later he received his MPhil degree in Micro and Nanotechnology from University of Cambridge, UK, in 2010. He had been a visiting research scholar at the Center for Nanotechnology and Astrobiology, NASA Ames research center, CA, USA, for 2013-14. There he was involved in the designing and testing of nano-biosensors for Astronaut's cardiac health monitoring.

In September 2015, Rakesh won the President Doctoral Scholar Award and is currently pursuing his doctoral research work on the fabrication of graphene membranes-based biosensors for an ultra-sensitive detection of biomarkers, in School of Electrical and Electronics Engineering, The University of Manchester.

30: Interfacial Engineering for High-Efficiency Polymer: Fullerene Solar Cells with Improved Stability

Sungho Nam[1,2], Jooyeok Seo[2], Hyemi Han[2], Hwajeong Kim[2], Youngkyoo Kim*[2], Donal D. C. Bradley*[1,3]
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ABSTRACT

Polymer solar cells with polymer:fullerene bulk heterojunction (BHJ) layers have been spotlighted in the field of green energy and flexible electronics due to their potential for low-cost fabrication of flexible plastic solar modules by employing continuous roll-to-roll processes. The polymer:fullerene solar cells have recently exhibited ca. 12 % power conversion efficiency (PCE) by utilizing new electron-donating polymers through device engineering. In addition to the material aspects, interfacial engineering between the electron-collecting buffer layers and the organic photoactive layers by insertion of an organic dipole interlayer has been proposed as a simple and scalable way to improve the overall solar cell performance. Despite recent progress, however, module efficiency and operating stability are still inferior to inorganic solar cells in the market leaving the need for further development. This presentation will introduce new polymeric interlayers for high efficiency polymer solar cells and discuss their enhanced stability under continuous illumination with solar light.

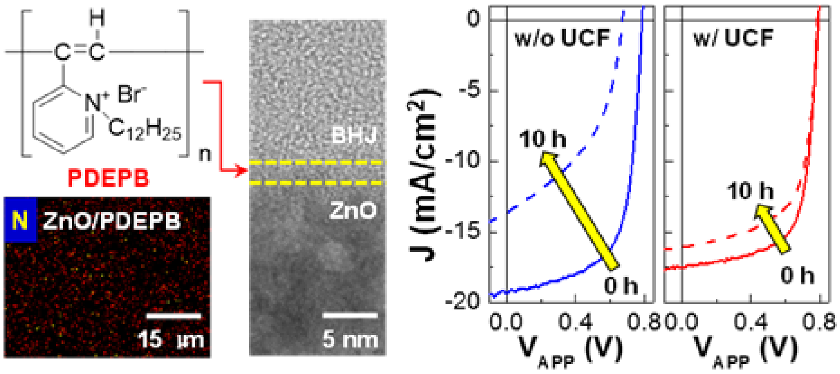

Figure 1. (left-side) Chemical structure of polyacetylene-based polyelectrolyte material, cross-sectional transmission electron microscope (TEM) image of device and nitrogen-mapping Auger electron microscope (AEM) image of ZnO/PDEPB layers. **(right-side)** J-V curves of devices under 10 h continuous solar simulated light (100 mW/cm2) without (w/o)/with (w/) a UV-cutoff filter (UCF).

31: Spray-cast multilayer perovskite solar cells with an active-area of 1.5 cm^2

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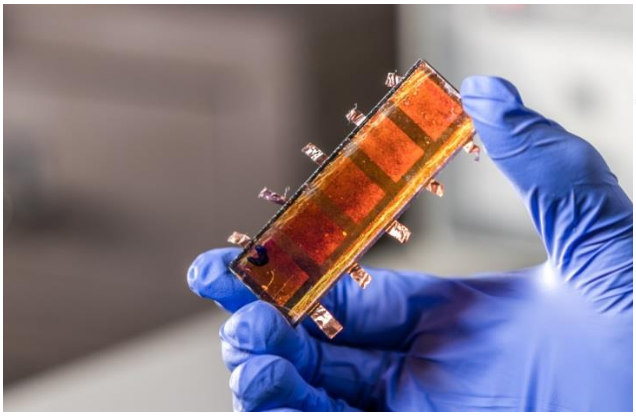
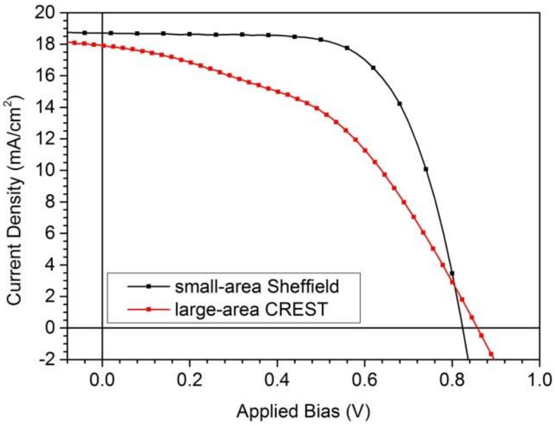
ABSTRACT

We utilise spray-coating under ambient conditions to sequentially deposit compact-TiO2, mesoporous-TiO2, CH3NH3PbI(3-x)Clx perovskite and doped spiro-OMeTAD layers, creating a mesoporous standard architecture perovskite solar cell (PSC). The devices created had an average power conversion efficiency (PCE) of 9.2% and a peak PCE of 10.2%; values that compare favourably with control-devices fabricated by spin-casting that had an average efficiency of 11.4 %. We show that our process can be used to create devices having an active-area of

1.5 cm2 having a certified efficiency of 6.6 %. This work demonstrates the versatility of spray-coating as well as its potential as a method of manufacturing low-cost, large-area, efficient perovskite devices.





BIOGRAPHY

James Bishop is a second year PhD student working under the supervision of Professor David Lidzey as a member of the Electronic and Photonic Molecular Materials (EPMM) group, based in the department of Physics and Astronomy, University of Sheffield. His research focuses on developing scalable manufacturing processes for perovskite based photovoltaics, with a particular focus on spray-coating as a means to deposit large area devices.

32: Spray coated zinc oxide for large area electronic applications

Tiago Carneiro Gomes[1,2], Neri Alves[2] and Jeff Kettle[1]
[1]Bangor University, Bangor, Wales, UK; [2]UNESP, Univ Estadual Paulista, Presidente Prudente, SP, Brazil

ABSTRACT

The potential application for metal oxide semiconductors in large area electronic has increased owing to the possibility for manufacturing flexible, transparent and lightweight devices from simple deposition techniques such as spray coating, inkjet-printing, screen-printing or roll-to-roll. Control of process parameters including coating and annealing conditions is important to achieve optimal and reproducible device performance parameters.

Within this context the zinc oxide (ZnO) is well known metal oxide semiconductor that has great potential due to its high charge carrier mobility, high optical transmittance in the visible spectrum and relatively good mechanical flexibility. In addition, it can be formed from pyrolysis at a reasonably low temperatures (150 - 450ºC), by spray coating from organic precursors. In this presentation, the electrical, optical and morphologic properties of spray coating ZnO films produced from a solution of zinc acetate dehydrated in methoxyethanol will be discussed. The influence of processing parameters such as concentration and annealing conditions will be discussed. In addition, the influence of these parameters upon surface roughness and transmission properties will be reported. Finally, the electron mobility is evaluated from thin film transistors, with values of up to 10^{-1} $cm^2/V.s$ reproducibly reached.

BIOGRAPHY

Tiago Carneiro Gomes is PhD student in Materials Science & Technology from UNESP, Brazil. Currently, he is visiting researcher in Bangor University, Wales and supervised by Dr. Jeff Kettle. His work is focused on processing and stability of ZnO transistors for sensor applications. His experience include the fabrication of the devices such as organic transistors, MIS capacitors and metal-oxide transistors using printing methods such as inkjet printing and spray coating.

33: Low-Cost Testing of Flexible Printed VLSI Prototypes

Jedrzej Kufel, ARM

ABSTRACT

Testing is one of the key challenges in the manufacturability of flexible and printed electronics. While reliability is a hot research topic, functional verification relies on methodologies well established in the silicon arena. Functional testing for plastic flexible chips however varies from cheap and simplistic breadboard prototyping to more expensive and sophisticated tester approach.

To develop testing capabilities for our PlasticARM flexible printed test chip we modified an off-the-shelf 3D printer to a low-cost semi-automatic wafer probe station. While this solution is not aimed at competing with high throughput testing, it offers an interesting alternative approach for R&D laboratories.

BIOGRAPHY

Dr Jedrzej Kufel joined ARM in 2014 and initially worked as part of IoTBU team, where he developed electronics for ARM mbed Wearable Reference Design. Recently, he moved to ARM Research and is currently a Senior Research Engineer. He focuses on design and test of plastic System-on-a-Chip. Jedrzej holds a MEng in Mechatronics and Robotic Systems from University of Liverpool and a PhD from University of Southampton.

34: Spray coating of graphene based capacitive touch sensors on a 3-dimensional surfaces

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ABSTRACT

Electronics on three dimensional (3D) curved surfaces is a rapidly emerging field with applications in the automotive and healthcare industries. Many of these application areas could require the large scale production of conductive coatings and films making spray coating a highly suitable deposition technique. Graphene inks are highly promising for applications in printed electronics such as in large area transparent conductive films (TCFs) [1]. In this work a graphene ink was produced by liquid phase exfoliation [2], a mixture of graphite flakes in ethanol/PEDOT:PSS is ultrasonicated and then subsequently centrifuged. Fundamental spray parameters such as temperature, surface tension and boiling point were investigated in order to optimise the production of morphologically uniform graphene films on polyethylene terephthalate (PET) substrates [3]. The formulated graphene ink is then applied to demonstrate spray coating of electrically and optically uniform graphene electrodes on a Perspex sphere, enabling a capacitive touch-sensitive and transparent 3D device. This work shows the viability of spray coating as an invaluable technique to realize conformal films on curved surfaces over large areas.

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[3] A. Lefebvre. Atomization and sprays. Hemisphere Publishing Corporation, 1988.

BIOGRAPHY

Tian Carey is a research student working towards a PhD in the EPSRC Centre for Doctoral Training in Graphene Technology. He is in the Cambridge Graphene Centre in the Electrical Engineering Division and a member of Pembroke College. He obtained an MPhil degree from the University of Cambridge, Department of Materials Science, after studying in Ireland at University College Dublin.

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