Innovations in large-Area Electronics Conference

23 JANUARY - 24 JANUARY 2018

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Day 1

Time	Programme	
08:30- 09:00	**Registration, tea/coffee on arrival**	
09:00 – 10:10	**Conference opening (plenary)** • Welcome by Dr Luigi Occhipinti, EPSRC Centre Outreach Manager • Introduction by Chris Rider, EPSRC Centre Director • Keynote address: Prof. John Rogers, Northwestern University *Hybrid Approaches to Large-Area, Flexible Electronics*	
10:10 – 10:40	**Tea/coffee, posters and exhibition**	
10:40 – 12:45	**Session 1: Large-Area Electronics Manufacturing 1** — Auditorium 1. **Prof. Elvira Fortunato**, New University of Lisbon, (invited) *Metal oxide materials as a sustainable and viable alternative to low cost electronics* 2. **Dr Adam Graham**, Centre for Process Innovation, *A novel, solution based process, allowing large area roll to roll printing of light emitting electrochemical cells creating large scale luminaires* 3. **Dr Dimitra Georgiadou**, Imperial College London, *Adhesion lithography: a material-agnostic approach to the fabrication of nanoscale electronic devices* 4. **Dr Thomas Kolbusch**, Coatema Coating Machinery GmbH , *Technology challenges and opportunities in UV and Thermal Nano Imprint Lithography Roll to Roll for flexible hybrid electronics.* 5. **Dr Paul Smith**, Xerox Research Centre Canada (invited), *Developments in Flexible Electronics at Xerox*	**Session 2: IoT & Sensor Technologies** — RF Pavilion 1. **Dr Iain Williams**, Department for Environment, Food and Rural Affairs, *Sensors and the future of environmental monitoring* 2. **Dr Woo Soo Kim**, Simon Fraser University, *A 3D-printed Integrated Electro-chemical Sensor System* 3. **Dr Suresh Garlapati**, University of Manchester, *Solution processed, low power organic field-effect transistor based sensors* 4. **Dr Iyad Nasrallah**, University of Cambridge, *Low-voltage Polymer Transistors for High-Performance Solution-Processed Complementary Analogue Amplifiers on Foil* 5. **Iain Sedgwick**, Rutherford Appleton Laboratory, *Design and Manufacture of Large Area Sensors for Scientific Applications*
12:45 – 14:15	**Lunch, posters and exhibition**	
14:15 – 16:20	**Session 3: Emerging Materials and Technologies** — Auditorium 1. **Dr Simon Ogier**, NeuDrive Ltd (invited), *High mobility, uniform performance organic semiconductor devices with applications in flexible displays and bio-sensor arrays* 2. **Mansoor D'Lavari**, Merck Chemicals Ltd, *Organic Electronics at Merck* 3. **Dr Chris Evans**, Peratech Holdco Ltd, 3*D Force Sensing Innovation* 4. **Alexandre Gaïtis**, Laboratoire des Composants Imprimés LITEN, *Stability and In Depth Characterization of Low-Voltage Organic Thin Film Transistors Based on Low-k/High-k Bilayer Dielectric* 5. **Prof. Andrea Ferrari**, University of Cambridge,(invited) *The Roadmap to Applications of Graphene and Related Materials*	**Session 4: Wearable and Flexible Hybrid Electronics** — RF Pavilion 1. **Jaap Lombaers**, Holst Centre (invited) *Large-Area Electronics: roads to implementation* 2. **Dr Francesca Bottacchi**, FlexEnable, *Scalable, low cost, conformable organic LCDs on plastic enabled by high-performance OTFTs* 3. **Dr Feras Alkhalil**, PragmatIC, *Phase change memory for flexible electronics* 4. **Prof. Ravinder Dahiya**, Glasgow University, *Electronic Skin with Energy Autonomy and Distributed Neural Data Processing* 5. **Dr Claudia Delgado Simao**, Eurecat (invited), *Conformable electronics: materials, processes and integration towards robust hybrid printed devices on stretchable substrates*
16:20 - 19:00	**Poster session and drinks reception**	
	Poster prize delivery	
	Gala dinner at Downing College (including transfer time to Cambridge)	

Day 2

Time	Programme	
08:30 - 09:00	**Tea/coffee**	
09:00 – 10:10	• Introduction to the conference and exhibition (day2) – Chris Rider • Plenary: Dr John Cocker, Centre for Process Innovation (CPI) *Trends in Healthcare: Opportunities for Printable Electronics* • Keynote Address: Dr Davor Sutija, Thin Film Electronics ASA, *Roll-based Manufacturing of NFC devices scaled to the Billions of Units enabling the Internet of Everything*	
10:10 – 10:40	**Tea/coffee, posters and exhibition**	
10:40 – 12:45	Session 5: Energy Harvesting — Auditorium 1. **Prof. Steve Beeby**, University of Southampton (invited) *Low temperature flexible materials for energy harvesting from textiles* 2. **Dr Wenzhuo Wu**, Purdue University, *Large-scale hybrid monolithic nanomanufacturing of liquid-solid heterojunction devices for self-powered smart skin* 3. **Dr Miguel Carrasco**, CDT ltd (invited) *Progress in printable energy harvesting and storage devices* 4. **Indrachapa Bandara,** University of Surrey, *Low Temperature Meso-Structured Flexible Perovskite Single Junction Solar Cells* 5. **Mathieu Bellanger**, Lightricity (invited), *Ultra-high efficient Photovoltaic Energy Harvester for wearable devices*	Session 6: Large-Area Electronics Manufacturing 2 — RF Pavilion 1. **Prof. Rodrigo Martins,** New University of Lisbon (invited), *Sustainable hybrid materials applied to flexible electronics* 2. **Chen Jiang**, University of Cambridge, *All-inkjet-printed low-voltage bias-stress stable organic thin-film transistors* 3. **Dr Daniel O'Connor**, National Physical Laboratory, *Metrology for large area electronics: a roadmap* 4. **Dr Bin Yang**, Chester University, *Quality-Control of UV Offset Lithographically Printed Electronic-Ink by THz Technology* 5. **Prof. Tim Claypole**, Swansea University (invited), *Advanced Rheology and its application to large area printed electronics*
12:45 – 13:45	**Lunch, posters and exhibition**	
13:45 – 15:50	Session 7: Large-Area Electronics Manufacturing 3 — Auditorium 1. **Dr Guangbin Dou**, Imperial College London (invited), *Interconnection Technologies for Integration of Active Devices with Printed Plastic Electronics* 2. **Dr João Manuel Carvalho Gomes**, CeNTI, *Development of interactive automotive interiors with integrated printed electronic solutions* 3. **Prof. Yu Liu**, Jiangnan University, *Development of Intelligent Hybrid Platform for Direct Printing of Functional Patterns at Large-scale Flexible Substrate* 4. **Dr Davide Deganello**, Swansea University, *SIMLIFT Optimisation of Laser Induced Forward Transfer Resolution through both coating and laser parameters* 5. **Dr Simon Tuohy**, Oxford Lasers, *High-Speed Selective Laser Sintering of Ag nanoparticle inks on Flexible Substrates*	Session 8: Workshop Bioelectronics/Biosensors — RF Pavilion 1. **Prof. George Malliaras**, University of Cambridge (invited), *Implantable electrophoretic devices for localized drug delivery* 2. **Prof. Xian Huang**, Tianjin University (invited). *Printed flexible sensors integrated with metal organic frameworks* 3. **Dr John Hardy**, Lancaster University, *Multiphoton fabrication of bioelectronic biomaterials for neuromodulation (MFBBN)* 4. **Prof. Luisa Torsi**, Università degli Studi di Bari "Aldo Moro" (invited) *Organic bioelectronics for bio-chemical detections at ultra-low detection limits* 5. **Panel discussion**: Biosensors and bioelectronics - opportunities in future diagnostics
15:50 - 16:00	**Concluding remarks (Dr Luigi Occhipinti, Conference Chair)**	

Professor John A. Rogers

NORTHWESTERN UNIVERSITY

Hybrid approaches to large-area, flexible electronics

ABSTRACT

Recent advances in semiconductor nanomaterials, high-speed assembly techniques and strategies for heterogeneous integration establish the foundations for unusual classes of electronics, characterized by levels of performance, functionality and area coverage that lie beyond those realizable with other approaches, established or emerging. The results provide access to a broad range of unique design options and associated application concepts. This talk summarizes the essential ideas and presents examples of their use in (1) emissive displays that exploit millions of interconnected, microscale inorganic light emitting diodes on glass substrates, (2) thin, flexible, brain-integrated silicon electronics for mapping neural function at high spatio-temporal resolution and (3) soft, stretchable, skin-integrated microsystems for wireless physiological monitoring in neonatal intensive care.

BIOGRAPHY

Professor John A. Rogers obtained BA and BS degrees in chemistry and in physics from the University of Texas, Austin, in 1989. From MIT, he received SM degrees in physics and in chemistry in 1992 and the PhD degree in physical chemistry in 1995. From 1995 to 1997, Rogers was a Junior Fellow in the Harvard University Society of Fellows. He joined Bell Laboratories as a Member of Technical Staff in the Condensed Matter Physics Research Department in 1997, and served as Director of this department from the end of 2000 to 2002. He then spent thirteen years on the faculty at University of Illinois, most recently as the Swanlund Chair Professor and Director of the Seitz Materials Research Laboratory. In 2016, he joined Northwestern University as the Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering and Medicine, with affiliate appointments in Mechanical Engineering, Electrical and Computer Engineering and Chemistry, where he is also Director of the newly endowed Center for Bio-Integrated Electronics. He has published nearly 600 papers and is co-inventor on more than 100 patents. His research has been recognized by many awards including a MacArthur Fellowship (2009), the Lemelson-MIT Prize (2011), and the Smithsonian Award for American Ingenuity in the Physical Sciences (2013). He is a member of the National Academy of Engineering, the National Academy of Sciences, the National Academy of Inventors and the American Academy of Arts and Sciences.

Dr. Davor Sutija

THIN FILM ELECTRONICS ASA

Roll-based manufacturing of NFC devices scaled to the billions of units enabling the Internet of Everything

ABSTRACT

The ubiquity of near-field communication (NFC) wireless protocol on smartphones creates an opportunity to add NFC-readable passive tags to disposable objects and packaging. Ultra-scale manufacturing of NFC circuitry on flexible substrates improves its shock-resistance and tolerance to shear and enables a variety of use cases, ranging from proximity marketing to secure delivery verification by consumers. By substituting printing for ion implantation, and rapid thermal processing for traditional annealing, electrical components and circuits containing up to thousands of transistors have been made using roll-compatible manufacturing steps. Millions of such printed NFC tags are currently in market, and starting in 2018, production will scale using a roll-based line to over seven billions of units annually. A new paradigm in large-area manufacturing is here, with up to a 100x lower capex per front-end die than traditional lithographic bulk-silicon processing.

BIOGRAPHY

Dr. Davor Sutija is CEO of Thin Film Electronics ASA. Prior to joining Thinfilm in January 2010, he was Senior Vice President, Product Marketing, at FAST (a Microsoft subsidiary) and founding CEO at SiNOR AS, a producer of electronic and PV-grade silicon ingots.

He was a board member for the Organic Electronics Association (OE-A) from 2012 through 2015, and has also served on the BoD of technology firms SensoNor, Birdstep, and Owera. He is currently a member of the Orbotech Advisory Board.

Dr. Sutija is a highly sought-after speaker and presents around the globe on topics including the Internet of Things, the convergence of the physical and digital worlds, and the future of smart packaging. He was a keynote speaker at Mobile World Congress 2015. Dr. Sutija graduated from the Jerome Fisher Management and Technology program at the Wharton School, and has a Ph.D. from the University of California, Berkeley, in Chemical Engineering. He was a Hertz Fellow at Lawrence Berkeley Labs.

Dr John Cocker

CENTRE FOR PROCESS INNOVATION LTD

Trends in healthcare: opportunities for printable electronics

ABSTRACT

Printable electronics offers the potential to add functionality to everyday objects at costs that are projected to allow widespread adoption. It offers the capability for new form factors allowing incorporation into applications that would be difficult in conventional technologies.

The benefits offered by printable and embedded electronics are being recognised in many sectors. Healthcare in particular is recognising the value offered by thin flexible functionality that can be incorporated into products or packaging to improve supply chain monitoring, diagnostics and imaging.

This presentation will provide an overview of some of the key trends and opportunities in the field.

BIOGRAPHY

John is the Business Unit Director at the National Printed Electronics Centre at CPI.

He has a DPhil in Chemistry and has spent most of his working career in industry with multinational chemical companies. He has extensive experience of new product development and introduction at DuPont, including leading global teams to identify opportunities and to develop electronics materials across a range of industrial sectors including photovoltaic, automotive and medical. He also worked with technology development companies to accelerate bringing product to market.

Professor Elvira Fortunato

NEW UNIVERSITY OF LISBON

Metal oxide materials as a sustainable and viable alternative to low cost electronics

ABSTRACT

Metal oxide electronic materials are quite attractive since they provide a large variety of different and possible applications due to the diverse spectrum of properties ranging from thin films to nanostructures.

Concerning applications they are becoming increasingly important in a wide range of applications like transparent electronics, optoelectronics, magnetoelectronics, photonics, spintronics, thermoelectrics, piezoelectrics, power harvesting, hydrogen storage and environmental waste management.

In terms of production tecnhiques rf magnetron sputtering has been well established and has demonstrated high performance devices, however these require complex high vacuum equipment which is a major drawback, especially if we are targeting low cost applications. In contrast, the solution process has many advantages such as large-area deposition, roll-to-roll capability, easy control of composition, atmospheric processing, and low cost.

In this work we will present some advances on solution based conductors, dielectrics and semiconductors all based on metal oxide and their application to electronic devices.

BIOGRAPHY

Elvira Fortunato is full professor in Materials Science Department of Faculty of Science and Technology of New University of Lisbon and she is the director of the Institute of Nanomaterials, Nanofabrication and Nanomodeling and of CENIMAT. She is member of the board of trustees of Luso-American Foundation (Portugal/USA, 2013-2020).

Fortunato pioneered European research on transparent electronics, namely thin-film transistors based on oxide semiconductors, demonstrating that oxide materials can be used as true semiconductors. In 2008, she earns in the 1st ERC edition an AdG for the project “Invisible”, considered a success story. In the same year she demonstrated with her colleagues the possibility to make the first paper transistor, starting a new field in the area of paper electronics.Fortunato published over 500 papers and during the last 10 years got more than 18 International prizes and distinctions for her work (e.g: Elvira Fortunato was awarded with the Blaise Pascal Medal from the European Academy of Sciences (2016). Since November 2016 she integrates the High Level Group for the Scientific Advise Mechanism of the European Commission. In 2017 she was awarded with the Czochralski medal from E-MRS in recognition of her achievements in the field of the Advanced Materials Science.

More information about Professor Elvira Fortunato can be found here (http://docentes.fct.unl.pt/emf).

Dr Adam Graham

CENTRE FOR PROCESS INNOVATION

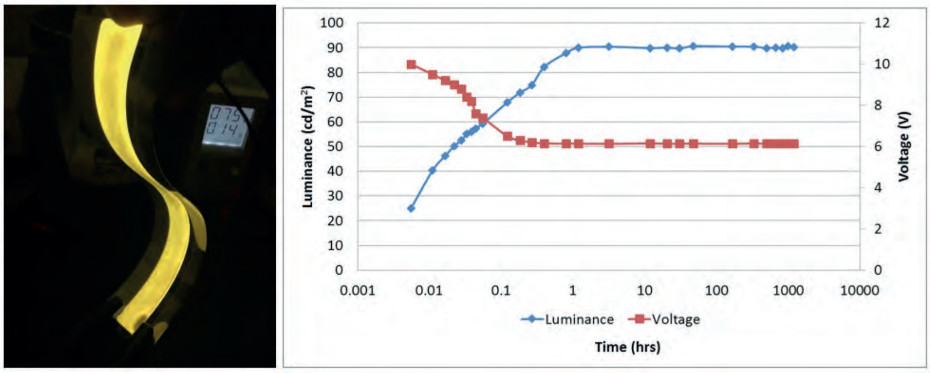
A novel, solution based process, allowing large area roll to roll printing of light emitting electrochemical cells creating large scale luminaires

Adam Graham, Dan Kolb, Alex Cole, Sean Bolton, Jon Gowdy (Centre Process Innovation)

ABSTRACT

A novel, solution based process has been developed allowing large area roll to roll printing of light emitting electrochemical cells (LEECs) to create luminaire devices on a large scale. A patterned ITO anode on flexible substrate is first coated with a PEDOT:PSS layer before a solution containing a light emitting polymer (LEP) and an Ionic Salt is coated over the top. The device is then completed by rotary screen printing of a patented silver ink cathode layer before the whole device is encapsulated with barrier film. Applying an electric field across the electrodes creates two doping fronts that form in the emissive layer from the ionic components. These grow to form a junction where electron hole recombination can then occur and light is emitted creating a self-assembled layered device. Following an initial light up stage, where the junction is formed under a higher voltage, typical LEEC devices have been shown to give a luminance of between 50 and 100 cd/m^2 at a running voltage of 6V lasting up to 1000 hours. Typical current densities of these devices are of the order 1 to 2 mA/cm^2

These devices are the first working roll to roll flexible LEEC devices to be produced in the world. Examples of large area high volume devices are in development. A typical production run would be printed at 3 m/min on 600mm wide substrate up to 1000m at a time.



An example of larger area 20cm x 30cm, flexible printed LEEC device (left). Luminance-Current-Voltage (LIV) characteristics over time of a typical yellow LEEC device run at a constant current density of 1mA/cm2 (right).

BIOGRAPHY

Dr Adam Graham; senior scientist at Centre for Process Innovation (CPI). I have worked in formulation and measurement of materials for organic electronics for over 9 years following a PhD characterising the force and touch sensing properties of quantum tunnelling composites. Further work then focussed on the material development and characterisation of LEECs/OLEDs along with application and exploitation of these devices. The development of the roll to roll tool and materials was primarily undertaken as part of an Innovate UK collaborative project; MAGENTA. Within the collaboration special recognition goes to Dan Kolb, Alex Cole, Jon Gowdy and Sean Bolton.

Dr Dimitra Georgiadou

IMPERIAL COLLEGE LONDON

Adhesion lithography: a material-agnostic approach to the fabrication of nanoscale electronic devices

Dimitra G. Georgiadou[1], James Semple[1], Gwenhivir Wyatt-Moon[1] and Thomas D. Anthopoulos[1,2]
1 Physics Department, Imperial College London, London, United Kingdom
2 Materials Science & Engineering, Division of Physical Sciences and Engineering, King Abdullah University of Science and Technology (KAUST), Kingdom of Saudi Arabia

ABSTRACT

The majority of the diode-based semiconductor devices, such as laser and light-emitting diodes (LEDs), Schottky diodes and rectifiers, photodiodes (PDs) and solar cells, rely on a vertical architecture, where the semiconductor is “sandwiched” between two asymmetric electrodes, i.e. with different work functions (Fig. 1a). However, coplanar architectures (Fig. 1b), especially when the two electrodes are separated by a nanometer sized gap, seem to possess an advantageous geometry for high speed applications. This is due to the lower resistance-capacitance (RC) constant and thus higher cut-off frequencies that can be achieved, since both film thickness and device active area can be minimised.

Despite the advantages presented by nanogap electrodes, namely to realise nanodevices with lower power consumption, faster speed and higher level of integration, their commercial exploitation has been hitherto impeded by technological bottlenecks, owing to the incompatibility of currently available fabrication techniques (e.g. e-beam lithography, scanning probe lithography) with industrial upscaling.

Adhesion lithography (a-Lith) has emerged as a viable alternative high throughput, low cost patterning technique to manufacture large aspect ratio (>100,000,000) coplanar asymmetric metal electrode nanogap (<15 nm) structures on a variety of substrate sizes and types, including plastic. The capabilities of this technique have been already exploited by our group and proof-of concept devices have been demonstrated.

In this work, we apply materials science concepts to the optimisation of a range of nanoscale electronic devices based on coplanar nanogap separated electrodes fabricated via a-Lith. These include Schottky diodes, capacitors, light-emitting diodes and photodiodes. We first address the technical and research challenges that arise from this particular device geometry, and then showcase routes toward overcoming them. It will be shown that both organic and inorganic materials can be deposited with plastic substrate compatible deposition methods, leading to high performance electronic devices.

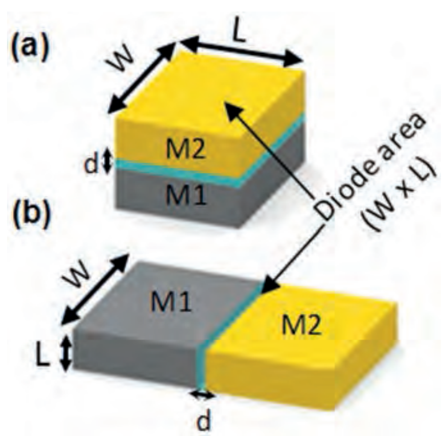


Fig. 1. Schematic diagram of (a) vertical and (b) coplanar diode architectures. A-Lith fabricated coplanar Au-Al asymmetric electrodes are separated by an interelectrode distance of about 15 nm. Deposition of a suitable material in the nanogap and application of a bias between the electrodes allows current 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.

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 43 publications in peer-reviewed journals (h-index: 16). Her research interests are the fabrication and optimisation of nanoscale electronic devices by applying novel materials concepts and alternative patterning techniques.

Thomas Kolbusch

COATEMA COATING MACHINERY GMBH

Technology challenges and opportunities in UV and thermal nano imprint lithography roll to roll for flexible hybrid electronics

ABSTRACT

The author describes the new technology of implementing nano imprint surface structures into R2R systems, like polymer films, stainless steel and flexible glass.

These surface structures can be used in optoelectronic systems, medical applications and printed electronics. Typical applications are light guides for display, light in and out-coupling structures for display, OLEDS and OPV, shark skin surface, lotus effect and microfluidics.

The R2R UV Nanoimprint technology, based on seamless sleeves on a roller which carry the nanoimprinted structure into the UV lacquer on the surface of flexible endless substrates, like polymer films, can be used in millions of different products very cost effectively.

The talk covers the whole spectrum of this new technology - from structures, the way of creating the structures, equipment technology and final products.

BIOGRAPHY

Thomas Kolbusch is Vice President of Coatema Coating Machinery GmbH, an equipment manufacturing company for coating, printing and laminating solutions located in Dormagen, Germany.He is member of the board of the OE-A (Organic Electronic Association) in Germany, a global association for printed electronics. He is member of the board of COPT.NRW, a local association in Germany.

He is active in the field of fuel cells, batteries, printed electronics, photovoltaics and medical applications. He organizes the international Coatema Coating Symposium since 16 years and represents Coatema in a number of public funded German and European projects.

Dr Paul Smith

XEROX RESEARCH CENTRE OF CANADA

Developments in flexible electronics at Xerox

ABSTRACT

What excites the scientists and engineers at Xerox about 3D printing and printed electronics is not so much making conventional things in a different way, but the possibility to make and commercialize things that were “unmake-able” before. Our work at Xerox is at the intersection of printed electronics and 3D printing, pushing the envelope towards producing unconventional objects by printing both form and function. Printing electronics and structure together opens up commercial opportunities in a range of important market areas.

XRCC has been the global materials development Centre for Xerox Corporation for the past 40 years and over the last decade, we’ve put our expertise to work commercializing a portfolio of materials for printed electronics and its integration into new devices. We have developed a broad range of materials from conductive inks to semiconducting polymers, organic dielectric materials and more. Our most recent work has been in developing these materials for printing functional device elements onto both flexible and conformal surfaces by leveraging the combination of printing systems with robotic motion control. This presentation will share new materials developments from our labs and how they are supporting Xerox’s SmartTag technology.

BIOGRAPHY

Paul Smith is Vice President of Xerox Innovation Group, the Centre Manager of Xerox Research Centre of Canada, and an Officer of Xerox Canada Inc. He leads the company’s Global Materials Research Centre, which is responsible for advanced materials research and development.

In partnership with the National Research Council of Canada, Dr. Smith spearheaded the creation of the Canadian Campus for Advanced Materials and Manufacturing – an exciting partnership between government and industry for leading-edge, world-class research and development in the commercialization of Advanced Materials in the field of devices for the Internet of Everything, printed electronics, additive manufacturing, automotive, aerospace and other critical sectors; pioneering an exciting field in the most exciting of times.

Dr. Smith received his PhD in the field of Chemistry from the University of Bath, England in 1991, was an NSERC Fellow from 1995 to 1997, and in 2001 received an MBA from the Rotman School of Management, at the University of Toronto. He is the first Chairman of the Canadian Printed Electronics Industry Association (now IntellliFlex) and is Chair of the Conference Board of Canada Council for Innovation and Commercialization. He serves on Canada’s Natural Sciences and Engineering Research Councils’ Committee on Research Partnerships. Dr. Smith is now a named inventor on 78 U.S, patents and has 16 publications

Dr Iain Williams

DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS

Defra presentation: Sensors and the future of environmental monitoring

ABSTRACT

The Department for Environment, Food and Rural Affairs (Defra) is the UK government department responsible for policy and regulations on environmental, food and rural issues. Our priorities include growing the rural economy, improving the environment and safeguarding animal and plant health.

Science in Defra provides evidence for decision-making, and Defra needs access to the right information at the right time and needs to be confident of the quality of that information. One of the fundamental functions of Defra science is the need to describe the state of the environmental systems of interest to the department (including biodiversity; (fresh and marine) water quality, air quality; and, animal and plant health) and to use this information and our understanding of the systems to predict the way in which they will respond to policy interventions and natural or societal pressures.

To do this we need a wide range of tools and techniques for environmental monitoring. These tools range from satellite Earth Observation monitoring to in situ environmental sensors and using experts and citizen science to record observations. The advances in sensing technology provide exciting opportunities potentially delivering a step change in the amount, timeliness and geospatial accuracy of data about the environment, and how we can access and use such data to enhance the environment and food and farming industries.

BIOGRAPHY

Iain Williams is Deputy Chief Scientific Adviser at the Department for Environment, Food and Rural Affairs (Defra). Previously Iain has held numerous scientific posts in government including UK's Home Office Science and Technology Counsellor in the British Embassy in Washington DC, Chief of Staff to the Home Office Chief Scientific Adviser, Head of Science Quality in Defra and research programme manager roles in horticulture, plant health and agri-environment.

Iain's research background is entomology, epidemiology and population dynamics having held research posts at Imperial College, London and the University of East Anglia.

Dr Woo Soo Kim

SIMON FRASER UNIVERSITY

A 3D-printed integrated electro-chemical sensor system

Yue Dong, and Woo Soo Kim*

School of Mechatronic Systems Engineering, Simon Fraser University BC Canada
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ABSTRACT

This presentation will discuss the design, fabrication and characterization of a 3D printed electro-chemical sensor circuit on Printed Circuit Board (PCB) for portable electro-chemical sensing applications. 3D printing technologies with conductive materials are investigated along with development of electro-chemical sensors and their system applications. An optimized Directly Ink Writing (DIW) technique is adapted in a novel 3D-PCB fabrication platform using silver nanoparticle ink. An electro-chemical circuit called potentiostat is designed and optimized from an open source circuit. Using the same 3D platform, a lactate sensor with 3-electrodes is printed on the flexible substrate. By being combined, the 3D printed sensor system demonstrates the electrochemistry test including cyclic voltammetry (CV) and amperometry. It is demonstrated that 3D-PCB technology can significantly accelerate the large-area fabrication process of conventional electronics, and merge its capability into electro-chemical applications.

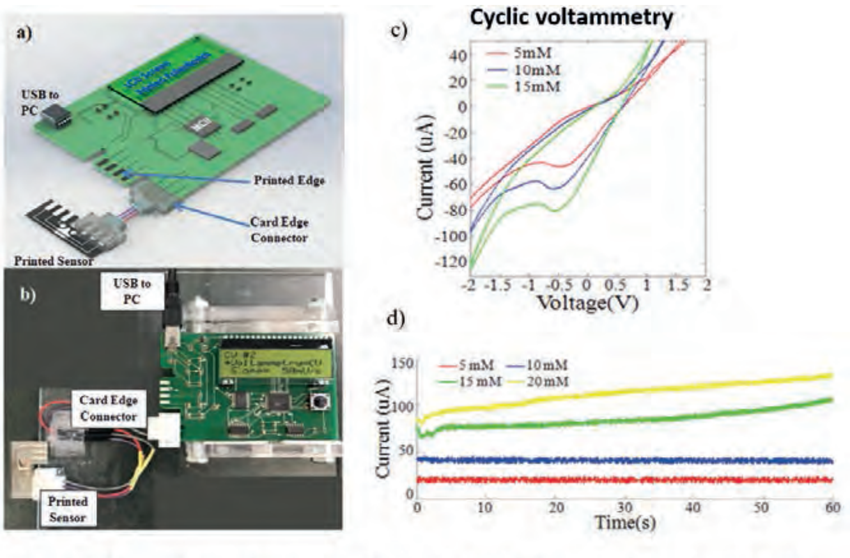

Figure: a) Design of sensor system, b) 3D printed sensor with potentiostat circuit, c) CV measurement, d) Current output from 3D printed sensor system.

BIOGRAPHY

Dr. Woo Soo Kim joined Simon Fraser University (SFU), located in British Columbia Canada, in September 2010 as a tenure-track Assistant Professor and promoted to tenured Associate Professor in 2016. Prior to joining SFU, he was a Senior Research Scientist in Xerox Corporation for two years after the period of a Post-doctoral Research Associate in Massachusetts Institute of Technology (MIT) for two and half years. He received BASc degree from the Yonsei University in 2001 and MASc and PhD degrees from the Korea Advanced Institute of Science and Technology (KAIST) in the Department of Material Engineering. He was the first rank recipient of Quadrant Award 2007, a PhD thesis competition. And he received Hanwha Corporation's Non-tenure Faculty Award in January 2016. His research interest is broad in the field of 2D and 3D printed electronics.

Dr Suresh Garlapati

UNIVERSITY OF MANCHESTER

Solution processed, low power organic field-effect transistor based sensors

S. K. Garlapati[1,2], S. Faraji[1,2], D. J. Tate[1], V. Tischler[1], 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
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ABSTRACT

Organic semiconductors based field-effect transistors (OFETs) have gained significant attention over the past few decades due to their attractive features such as low process temperatures, mechanical flexibility, light weight, and compatibility with all kinds (rigid and flexible) of substrates. Furthermore, they can be prepared by inexpensive solution processes over large areas (e.g. blade coating, printing, etc.), which makes them suitable candidates for various applications such as displays, radio-frequency identification (RFID) tags, and sensors, etc. OFETs are interesting for use as sensors because the weakly interacting π-conjugated molecules as semiconductors are sensitive to a variety of analytes and an array of devices can be selective to the detection of a desired analyte.

Here, we report solution processed OFETs for use as gas sensors to detect volatile organic compounds such as alcohols and esters. The OFETs were prepared on flexible polyethylene naphthalate (PEN) substrate and exhibit high field-effect mobility (≈ 1 $cm^2V^{-1}s^{-1}$) and operate at low voltages (≤ 3 V). The reproducibility of the manufacture process and the ambient and operational stability of the devices will be examined. The integration of the devices with conventional silicon electronics into a portable sensor system will be discussed.

BIOGRAPHY

Suresh Kumar Garlapati pursued his Masters in Metallurgical and Materials Engineering in Indian Institute of Technology Madras. During Masters he was awarded DAAD fellowship to purse Master's thesis in Karlsruhe Institute of Technology (KIT), Germany. He pursued his PhD on low temperature processing of printed oxide transistors and graduated in 2016. Currently he is in the University of Manchester as a postdoctoral researcher and working on organic field-effect transistors (OFETs) for gas sensing applications. His project goals include integration of OFETs with silicon microcontrollers in support of the work of EPSRC Centre for Innovative Manufacturing in Large Area Electronics at the Organic Materials Innovation Centre (OMIC).

Iyad Nasrallah

UNIVERSITY OF CAMBRIDGE

Low-voltage polymer transistors for high-performance solution-processed complementary analogue amplifiers on foil

Iyad Nasrallah, Moon Hyo Kang, Vincenzo Pecunia, 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 a Research Associate at the Optoelectronics Group, Cavendish Laboratory, University of Cambridge, UK. He is also a Research Fellow at Wolfson College, University of Cambridge, UK.

His research interests are in the fabrication and characterisation of low-voltage complementary flexible organic circuitry, for industrial applications. He focuses on novel, large-area fabrication techniques such as ink-jet printing of semiconducting materials. His other research interests are in device physics, most importantly the characterisation and improvement of operational and environmental stabilities of organic semiconductors.

Iyad completed his PhD at the Optoelectronics group, Cavendish Laboratory, University of Cambridge, working under the supervision of Prof. Henning Sirringhaus, and in close industrial collaboration with FlexEnable Ltd. He worked on characterising various charge trapping mechanisms within organic semiconductors, and developed methods to relieve them. Prior to this, Iyad received an MEng in Electronic Engineering with Nanotechnology from the University of York, UK.

Iyad currently works within the iPESS project at the EPSRC Centre for Innovative Manufacturing in Large-Area Electronics (CIMLAE), realising novel organic circuitry for signal conditioning in sensing applications.

Iain Sedgwick

RUTHERFORD APPLETON LABORATORY

Design and manufacture of large area sensors for scientific applications

Matthew Hart, John Lipp, Sion Richards, Iain Sedgwick, Paul Seller
Science and Technology Facilities Council, Rutherford Appleton Laboratory

ABSTRACT

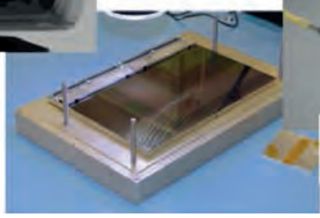
Scientific imaging can require sensor arrays of very large area, which presents challenges not present in the design of sensors for consumer applications. Often, this is due to the requirement to image X-rays, which cannot be focussed to the small focal plane of visible light sensors, but other applications (such as the detection of high energy particles) can require large detector areas as well.

In this paper, we present work undertaken on such detectors at the Rutherford Appleton Laboratory. Two different approaches to this work are described. Firstly, we will look at monolithic silicon CMOS sensors designed to cover large areas and present some examples of work completed in this area. Secondly, we will look at techniques for covering large areas with hybrid sensor tiles, and describe the manufacturing and assembly techniques needed for this.

The monolithic detector described here is the LASSENA sensor, a wafer scale device for use in X-ray applications such as non-destructive test and medical imaging. The sensor covers an area of 12.5 x 14.5 cm and has pixels to the edges on 3 sides, meaning that very large detector arrays can be constructed by assembling multiple sensors.

A hybrid approach is preferred when additional in-pixel processing or when alternative sensor materials are required. Multiple CMOS readout integrated circuits (ROICs) are placed on one plane and coupled with larger sensors on a parallel plane. A large area sensor can be realised by tiling multiple ROICs on a single sensor. The Large Pixel Detector (LPD) for the European X-ray Free Electron Laser (European XFEL) tiles many such hybrid modules in close proximity with minimal dead space between modules. This approach allows for tiling over unlimited areas and in the case of the LPD, has been used to create a detector with an active area of ~0.5m x 0.5m.

We will discuss the challenges of designing and manufacturing such systems, and present results from single devices and assemblies constructed from multiple devices. We will also highlight the merits and limitations of each approach.



A 2x1 LASSENA assembly (right) and an X-ray image of a lens (above). The imaging area is 25 x 14.5cm

A module of the LPD detector (above)

BIOGRAPHY

Iain Sedgwick has worked in the field of CMOS Image Sensors for scientific applications for almost 10 years and currently leads the CMOS Sensor Design Group at the Rutherford Appleton Laboratory in Oxfordshire. He has worked on several large area sensors during this period, and these have been used in both scientific experiments and commercial applications. In 2014, this work was spun out to form the X-ray imaging company vivaMOS. Further research areas of the CMOS Sensor Design Group are low noise performance, high frame rate imagers, radiation hardened devices and sensors with high time resolution.

Dr Simon Ogier

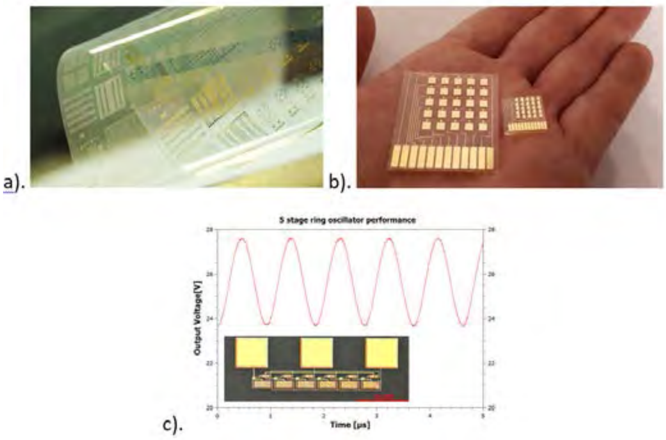
NEUDRIVE

High mobility, uniform performance organic semiconductor devices with applications in flexible displays and bio-sensor arrays

Simon Ogier, NeuDrive Limited, BioHub, Alderley Park, Macclesfield, SK10 4TG, U.K.
simon.ogier@neudrive.com

ABSTRACT

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



1. a). PEN substrate with OTFT based sensor and logic devices
b). OTFT extended gate sensor arrays
c). 5-stage ring oscillator with operating frequency of over 1MHz

NeuDrive develops OSC formulations based on small molecule soluble semiconductors and high permittivity semiconducting binders. These material sets enable uniform (<5% standard deviation) transistor performance with high linear mobility (>4cm^2/Vs) for channel lengths of less than 10 microns. This presentation will detail the device properties achieved with the formulations, the low temperature (115°C) fabrication process to make integrated circuits, and the application of OTFT to display backplane and biosensor devices.

BIOGRAPHY

Dr Simon Ogier graduated in Physics with Electronics and Instrumentation from Leeds University, UK in 1996 and completed a PhD researching Molecular Ion Channels as Novel Biosensors in 2000. Since that time, he has worked in the field of organic electronics, developing organic thin-film transistor technology within companies including Avecia, Merck, CPI and more recently with NeuDrive Limited. At CPI Simon had a major role in establishing the UK's National Printable Electronics Centre, housing a range of state-of-the-art fabrication equipment for pilot scale production of plastic electronic devices. Dr Ogier's current position as CTO of NeuDrive is responsible for the development of high performance organic semiconductor material technology for electronic applications such as dynamically flexible displays, sensors and logic devices. He has submitted 13 patents, authored 26 journal articles, and is an active member of the IEC TC119 standards committee for Printed Electronics.

Mansoor D’Lavari

MERCK

Organic electronics at Merck

Mansoor D’Lavari, William Mitchell, Mark James, Changsheng Wang, Pawel Miskiewicz, Stephen Bain, Aurelie Morley, Toby Cull, Lichun Chen, Nico Seidler, David Sparrowe

ABSTRACT

In recent years the demand for plastic electronic devices and materials has been increasing, through economic and demographic shifts in emerging markets and technological advancements. Merck, as a leading global producer of high quality, high-purity specialty chemical materials is actively invested in this fast growing market. Our materials are widely used in integrated circuits and devices, flat panel displays and light-emitting diodes.

In this paper we present some of our team’s recent activities focused on solution processable materials for high performance devices and their application in organic thin film transistors (OTFT) and organic photodetectors (OPD), from materials to prototype devices. We also demonstrate their unique advantages over currently available solutions and technologies.

BIOGRAPHY

After his studies (MRes) Mansoor D’Lavari started as an organic chemist at Key Organics Ltd in 1997. He then moved to Tripos Receptor Research in 2002 where he worked as medicinal research scientist. In 2010 he joined Merck (performance materials division) as an R&D Scientist in Chilworth, UK. He has worked on various projects relating to the field of organic electronics. Currently he holds an R&D project leader position within the Hybrid Electronics team.

Dr Chris Evans

PERATECH HOLDCO LTD

3D Force Sensing Innovation

Chris Evans
Peratech Holdco Ltd, Old Repeater Station, 851 Gatherley Rd., Brompton on Swale, N Yorks, DL10 7JH

ABSTRACT

Peratech has pioneered a new generation of force sensing components based on our proprietary range of QTC® (Quantum Tunneling Composite) additive-deposition inks that are compatible with flexible printed circuit material sets. This ability to integrate a nanomaterial-based composite with existing electronics, offers engineers and designers low-profile sensor constructions with simple integration and rapid prototyping needed to create the next generation force-touch user interfaces in a wide range of electronics products. Coupled with proprietary sensing circuit reference designs and software, incident loads from as low as 3gm to over 2kg can be monitored repeatedly and consistently.

In this paper we will describe the QTC® material system functionality, supported by a model for its mode of operation, together with options for application into a broad range of component designs, and a review of engineering methods for integration and assembly into products at the printed circuit and module levels.

The presentation summary will conclude with a discussion of the OEM product types currently in production or qualification in addition to new market segments with active developments requiring addition of dynamic force sensing to the capabilities for human to machine input.

BIOGRAPHY

Dr Chris Evans holds a BA in Natural Sciences and a PhD is Mechanistic Organic Chemistry from the University of Cambridge, he is a Fellow of the Royal Society of Chemistry. He is currently working with Peratech Ltd as a Staff Scientist guiding the materials development and deposition aspects of their force sensing technology. Career progression has combined technology and business development management roles working with the US based multinational companies 3M, Imation and MFLEX, together with UK companies including TTP and Xennia Technologies. Chris also is Managing Director of EvanMile Consulting Ltd.

Alexandre Gaïtis

LITEN

Stability and in depth characterization of low-voltage organic thin film transistors based on low-k/high-k bilayer dielectric

A. Gaïtis[1], M. Charbonneau[1], G. Ghibaudo[2], R. Coppard[1], C .Serbutoviez[1]
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[2] IMEP-LAHC, INPG – Minatec, 3 Parvis Louis Néel, CS 50257, 38016 Grenoble, France

ABSTRACT

One of the main key enabler for the development of the flexible circuit Large Area Electronics is low-voltage operation in order to allow compatibility with the conventional electronic components and low power consumption. In this paper we introduce a dielectric combining a low-k and a high-k material for the low-voltage organic thin film transistors (OTFTs). To fully evaluate this technology, we have conducted a full electrical characterization of the bilayer dielectric in capacitor and OTFT structures.

The bilayer is the preferred approach, to counter the negative impact of high permittivity material on the semiconductor's mobility. Here, the dielectric stack (~600 nm) is composed of a thin layer of commercially available low permittivity dielectric (k = 2.2 : D320 Lisicon from Merck) and a thick layer of poly(vinylidene fluoride-trifluoroethylene-chlorotrifluoroethylene from ARKEMA). This material is a relaxor ferroelectric polymer with a dielectric constant value reaching 24.7 for our selected composition. The resulting bilayer dielectric displays an intermediate dielectric constant and a greatly reduced hysteresis compared to the original high-k (Figure 3).

The thickness of the two layers may be optimized to access different operating voltage. In Figure 2 two different Proof of Concept (PoC) are presented for VDD= -5V and -3.3V and compared with a low-k reference of equivalent dielectric thickness. The PoC -3.3V transistors displayed low threshold voltage value (|Vth|< 0.7 V) enabling low operating voltage Figure 1 with a dielectric constant of 10.7. In order to evaluate the robustness of this process, device-to-device and foil-to-foil statistical evaluation will be presented.

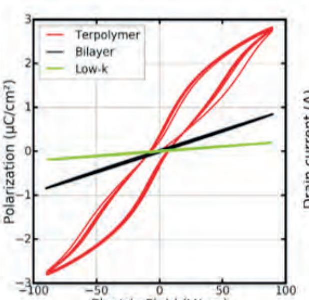


Figure 3 : Polarization profile for different dielectrics.

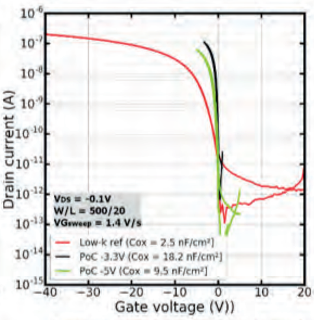


Figure 2 : Comparison of the Low-k reference, PoC-5V bilayer and PoC-3.3V bilayer OTFT's transfer-curves.

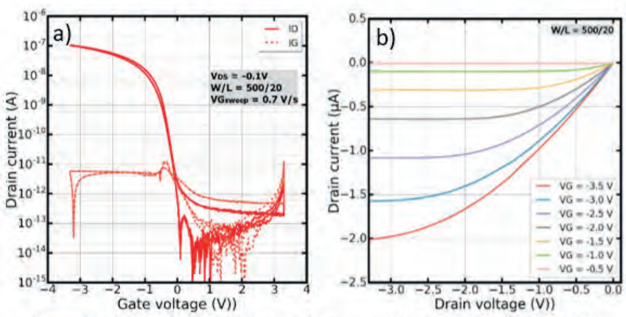


Figure 1 : a) Transfer and b) Output characterization for the low-Voltage OTFT.

In electronic circuit, transistors are mainly used in logical operation or addressing in actives matrix. Therefore, transistors need to withstand constant electrical stress. In order to assess the stability of this bilayer technology, we have monitored the evolution of the transistor's figures of merit through gate bias stress procedure. The measurement consisted in the application of +3.3V or -3.3Vo to the gate for a period of 10000 s and recording of the transfer curves (VDS = -0.1V) logarithmically spaced through the entire duration of the stress. The induced shift in the OTFTs figure of merit will be further discussed.

In conclusion, we propose here an evaluation of a low-voltage approach with materials ready for transfer in printed OTFT process flow and will present an in depth characterization of the resulting devices coupled to a statistical study.

BIOGRAPHY

After obtaining two Master's degree from "Bordeaux Graduate School of Chemistry, Physics and Biology" (ENSCBP, Bordeaux, France) and the University of Bordeaux (France) Alexandre Gaïtis was part of the material research team at FlexEnable (Cambridge, UK) for nine month. In April 2016 he started his PhD in electronic Organic at the CEA-LITEN (Grenoble , France) in partnership with IMPEC-LaHC (Grenoble, France).

Professor Andrea Ferrari

UNIVERSITY OF CAMBRIDGE

The roadmap to applications of graphene and related materials

ABSTRACT

Disruptive technologies are usually characterised by universal, versatile applications, which change many aspects of our life simultaneously, penetrating every corner of our existence. In order to become disruptive, a new technology needs to offer not incremental, but dramatic, orders of magnitude improvements. Moreover, the more universal the technology, the better chances it has for broad base success. The Graphene Flagship has brought together universities, research centres and companies from most European Countries. Significant progress has been made in taking graphene, related layered materials and hybrid systems from a state of raw potential to a point where they can revolutionize multiple industries. I will overview the progress done thus far and the future roadmap.

BIOGRAPHY

Andrea C. Ferrari is Professor of Nanotechnology at the University of Cambridge. He is the founding director of the Cambridge Graphene Centre and of the EPSRC Centre for Doctoral Training in Graphene technology. He is the chair of the Management Panel and the Science and Technology Officer of the EU Graphene Flaghip

Dr Jaap Lombaers

HOLST CENTRE

Large-area electronics: roads to implementation

Jaap Lombaers

ABSTRACT

Since its start in 2006 Holst Centre has been strongly involved in flexible and large-area electronics, with wearable devices as a leading application domain. Rather than choosing between technology push and market pull as driving force, Holst Centre has always worked in a mix of both. Working in 'shared mode' along roadmaps jointly defined with industry and academia allowed for building up generic technology platforms. Having concrete lead applications rather than a generic goals helped to accelerate the research and energize the teams. Once a generic platform technology was established, new roads to implementation were found by transfer and re-use to new application domains and to higher-TRL activities such as pilot lines. Managing the portfolio of activities and defining convincing propositions to industry continue to be key challenges in the management of the centre. I will illustrate the above by examples in barrier technology, OLEDs, flexible backplanes and circuits, healthcare patches and smart textiles and processes like atomic layer deposition.

BIOGRAPHY

Jaap Lombaers has a MSc degree in Industrial Design Engineering. He was researcher at TNO's Human Factors institute and next became consultant at Dutch Railroads. In 1987 he moved back to TNO in management of product development. In 1996 he became manager of the Product Development Division involving mechanical, electronics hardware and embedded software groups. In 2001 he became board member of TNO Industrial Technology.

In 2005 he co-founded and became managing director of Holst Centre, an research centre by imec and TNO on wireless sensors and large-area and flexible electronics.

In 2010 he co-founded Solliance, an initiative on thin-film photovoltaics operating along the joint innovation concept of Holst Centre involving TNO, ECN, TU Eindhoven (NL), imec, University of Hasselt (BE) and Forschungszentrum Jülich (DE).

In 2015 he co-founded Brightlands Materials Center, an initiative of TNO and the Province of Limburg on polymer-based innovations.

As of 2014 he is Director of TNO's business in the fields of flexible electronics (Holst Centre), thin-film photovoltaics (Solliance) and additive manufacturing / 3D Printing (AMSYSTEMS Centre). He has the following board positions:

- Member of the Boards of Solliance and of Brightlands Materials Centre and member of the Steering Committee of Holst Centre.
- Vice-chairman of the Organic Electronics Association (OE-A)
- Member of the Board of NanoNextNL
- Vice-president of Photonics21
- Member of the Steering Committee of EMIRI

Dr Francesca Bottacchi

FLEXENABLE LTD

Scalable, low cost, conformable organic LCDs on plastic enabled by high-performance OTFTs

ABSTRACT

Organic LCD (OLCD) technology opens a new avenue for LCD – it enables glass-free, conformable, high performance displays, combined with a low manufacturing cost that is driven directly by the uniquely low temperature process (sub 100°C) afforded by OTFT. This low cost process has been demonstrated on commodity plastics which have been integrated into highly functional plastic LCD modules. The process has been designed so it can be easily transferred into existing display factories providing a quick route to high production capacity and yields. With Truly Semiconductors becoming the first display maker to adopt OLCD, transfer of the manufacturing processes is now underway with mass production expected in late 2018.

In this presentation we report on the latest technical developments of OTFT and OLCD that allow these technologies to be industrialised and brought into products today. In terms of mobility, manufacturable OTFTs are now at least three times better than amorphous silicon, whilst having leakage currents nearly 1000X lower – both of which bring direct performance benefits to the display electro-optical performance alongside the benefits of flexibility.

The talk will explore the unique set of attributes OLCD brings to flexible displays that aren't possible with other flexible display technologies: large area scalability, low cost, and high brightness with long lifetime. Such attributes are necessary to serve markets such as automotive, consumer electronics, and digital signage.

Conformable 12.1" OLCD

BIOGRAPHY

Francesca Bottacchi has been working as Yield Engineer at FlexEnable Ltd since 2016. She received her BSc and MSc in Physics Engineering from Politecnico di Milano (Italy), and the PhD in Experimental Solid State Physics from Imperial College London. She has over 4 years' experience in the field of plastic electronics and her expertise covers carbon-based nanomaterials, device physics, processing, and characterization. She is currently working on yield improvement and failure analysis of OLCD, organic image sensors and OTFTs.

Dr Feras Alkhalil

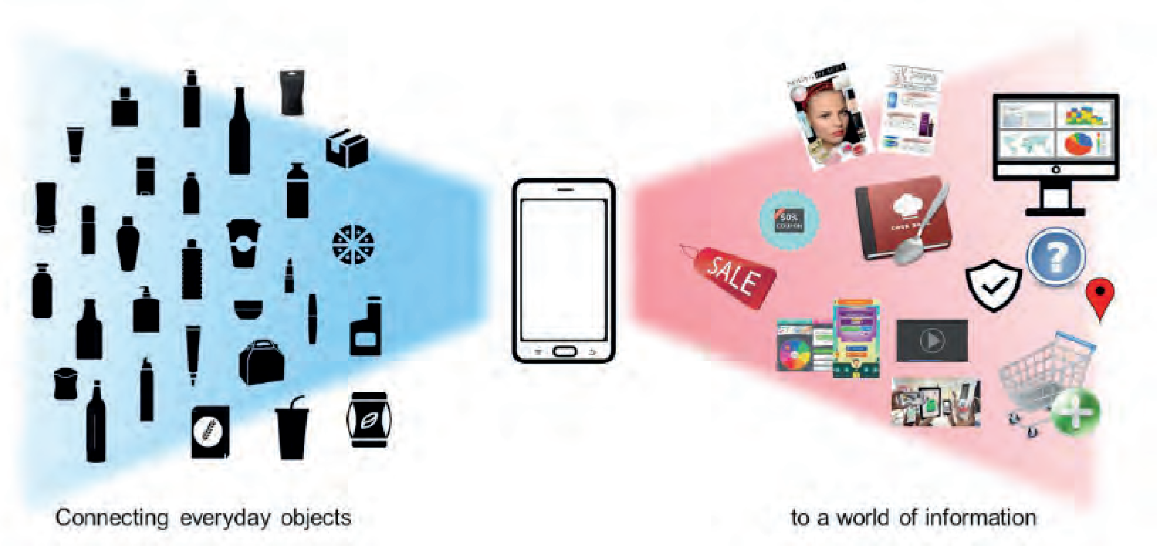
PRAGMATIC

Phase change memory for flexible electronics

F. Alkhalil[1], C. Ramsdale[1], Y.Y. Au[2], I. Zeimpekis[3], D.W. Hewak[3] and C.D. Wright[2]
[1] PragmatIC, Cambridge, CB4 0WH, UK
[2] Department of Engineering, University of Exeter, EX4 QF, UK
[3] Optoelectronics Research Centre, Univerity of Southampton, SO17 1BJ, UK

ABSTRACT

An increasingly prominent application space for flexible electronics is that of product identification and item level tagging. Such applications require a level of memory capability so that items or batches can be differentiated from one another. One route to memory is the inclusion of elements based on Phase Change Materials (PCM), that have large resistivity differences between states, are able to rapidly switch between states at comparatively low voltages and have long state retention times. We report here on the integration of PCM based WORM (Write Once Read Many) memory elements within PragmatIC's flexible electronics platform, discussing not only the circuit requirements but also the manufacturing considerations. The work was completed as part of project NEMATODE (InnovateUK Number: 132500) in collaboration with the Univerity of Exeter and the Univerity of Southampton. This work paves the way for item level tagging, opening up possibilities for brand protection, anti-counterfeiting, stock control, and cradle to grave tracking of consumer products.



Electronics in Everyday Objects

BIOGRAPHY

Dr Feras Alkhalil joined PragmatIC in September 2015 and leads PragmatIC's research team. Feras is a Visiting Fellow at Durham University, Department of Physics. He received his MSc and PhD from the University of Southampton in Microelectronics System Design and Solid State Electronics, respectively. From 2013 to 2015, he worked as a Research Fellow at the University of Southampton developing single electron transistor and quantum dot architectures with research laboratories and universities in the UK and Japan. He also held a lectureship, teaching Solid State Physics and Semiconductor Devices at the University of Southampton Malaysia Campus.

Professor Ravinder Dahiya

UNIVERSITY OF GLASGOW

Electronic skin with energy autonomy and distributed neural data processing

R. Dahiya*, W. Taube Navaraj, C. García Núñez, D. Shakthivel, F. Liu
Bendable Electronics and Sensing Technologies Group, School of Engineering, University of Glasgow, UK
*Correspondence to: Ravinder.Dahiya@glasgow.ac.uk

ABSTRACT

Harnessing technological advances to develop nature-inspired systems has led to many interesting solutions such as electronic skin (e-skin) with features mimicking human skin, as well as, imparting new functionalities beyond human skin's sensory level [1]. The major focus of e-skin research so far has been on the development of various types of sensors (e.g. contact, pressure, temperature, humidity, etc.) and their integration on large-area and flexible substrates. In this regard, two key challenges lie in realizing large-area e-skin: (1) processing of a large amount of data distributed over large areas, and (2) powering a large array of sensors. As an example, an estimated 45k mechanoreceptors (MRs) will be needed in about 1.5 m2 area to develop human inspired e-skin for robots. These sensory receptors process tactile data locally and require significant energy. Accordingly, flexible distributed tactile data processing and energy harvesting solutions are needed for an effective e-skin. Photovoltaics have shown one of the best performance for generating energy per unit area and are a promising candidate for e-skin [2]. Likewise, a neuromimicking approach could help to acquire and process sensors data locally as it leads to a significant downstream reduction in the numbers of neurons transmitting stimuli in the early sensory pathways in humans [3].

In this work, we show our recent research on e-skin (Figure 1) addressing above challenges through the development of a nanowire (NW) based neural field effect transistor (v-NWFET) as a basic building block for neural-mimicking data processing (Figure 1(a)) and an energy-autonomous e-skin achieved by integrating graphene based transparent touch sensors to photovoltaic cells (Figure 1(d)). The heterogeneous integration of various materials led to achieving such functionalities. Nanomaterials such as graphene and Si NWs are considered as good candidates for flexible electronics due to their excellent mechanical flexibility, printability in large-area as well as outstanding electrical performance. Here, we present a low-cost method to transfer and pattern single layer graphene on large-area flexible and transparent substrates, resulting in a co-planar interdigitated capacitive structure. In terms of the sensing performance, our sensors can detect minimum pressures down to 0.11 kPa with a uniform sensitivity of 4.3
Pa−1 along a broad pressure range. Thanks to the transparency of graphene, the integration of touch sensors atop a photovoltaic cell is possible, which paves a new way for energy-autonomous, flexible, and tactile e-skin (Figure 1(d)).

Using v-NWFET to realize hardware neural network is an interesting approach as by printing NWs on large area flexible substrates it will be possible to develop a flexible tactile e-skin with distributed neural elements (for local data processing, as in biological skin) in the backplane. Given the previously demonstrated metal-assisted chemical etching NW synthesis method and contact printing for large-area assembling of NWs, the v-NWFET presented here is promising for large-area and low-cost flexible electronics. Modeling, simulation and fabrication of v-NWFET shows that the overlapping areas between individual gates and the floating

gate determines the initial synaptic weights of the neural network. Further, proof-of-concept is shown by interfacing it with a transparent tactile e-skin prototype integrated on the palm of a 3D printed robotic hand and performing coding of touch gesture.

The research finds place in numerous futuristic applications such as prosthetics, robotics and electroceuticals, and this presentation will show the interesting progress made in this direction.

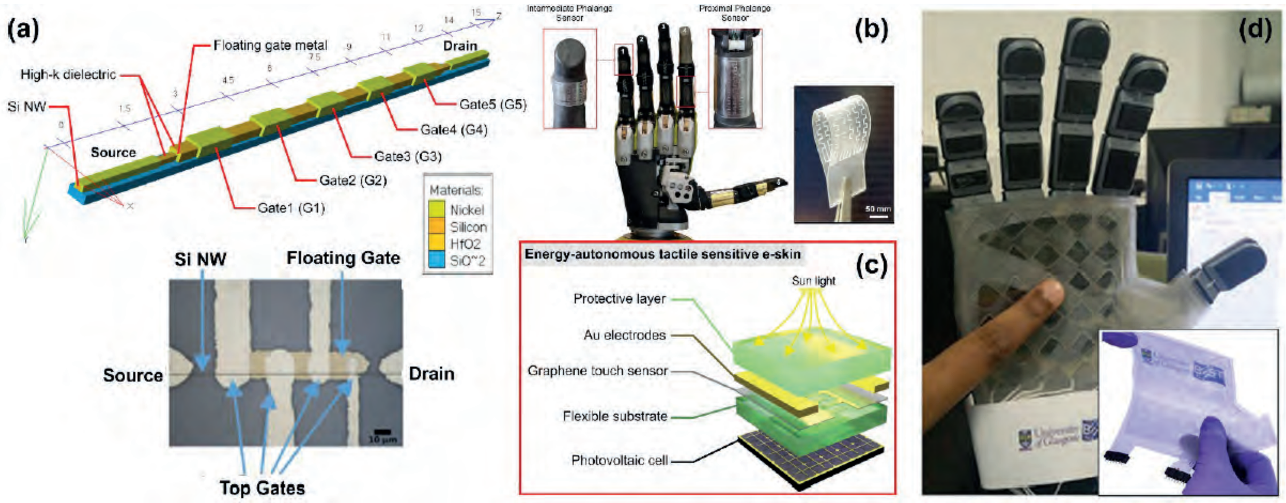


Figure 1. Tactile sensitive e-skin with energy autonomy and neural distributed data processing: (a) v-NWFET (b) Schema of energy-autonomous e-skin (c) Flexible transparent e-skin on 3D-printed prosthetic hand.

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[2] C. García Núñez, W. Taube, E. O. Polat, and R. Dahiya, "Energy-Autonomous, Flexible, and Transparent Tactile Skin," *Advanced Functional Materials*, vol. 27, pp. 1606287-n/a, 2017.
[3] W. Taube Navaraj, C. García Núñez, D. Shakthivel, V. Vinciguerra, F. Labeau, D. H. Gregory, *et al.*, "Nanowire FET Based Neural Element for Robotic Tactile Sensing Skin," *Frontiers in Neuroscience*, vol. 11, 2017-September-20 2017.

BIOGRAPHY

Ravinder Dahiya is Professor of Electronics and Nanoengineering and EPSRC Fellow. He is the leader of Bendable Electronics and Sensing Technologies (BEST) group, which conducts fundamental research on high-mobility materials based flexible electronics and electronic skin, and their application in robotics, prosthetics and wearable systems. He is also the Director of Electronics Systems and Design Centre (ESDC) in the School of Engineering at University of Glasgow.

Prof. Dahiya He has published more than 180 research articles, 4 book (3 at various publication stages), 9 patents (including 7 submitted) and given more than 90 invited talks. He has led many international projects including those funded by European Commission, EPSRC, The Royal Society, The Royal Academy of Engineering, and The Scottish Funding Council.

He is Distinguished Lecturer of IEEE Sensors Council and is on the Editorial Boards of Scientific Reports (Nature Group), IEEE Transactions on Robotics and IEEE Sensors Journal. He has been guest editor of 5 Special Journal Issues. He is the Technical Program Chair (TPC) for 2017 and 2018 IEEE Sensors Conferences. Prof. Dahiya holds EPSRC Fellowship and in past he received Marie Curie Fellowship and Japanese Monbusho Fellowship. He has received several awards and most recent among them are: 2016 IEEE Sensor Council Technical Achievement Award, the 2016 Microelectronic Engineering Young Investigator Award.

Dr Claudia Delgado Simao

EURECAT

Conformable electronics: materials, processes and integration towards robust hybrid printed devices on stretchable substrates

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ABSTRACT

Hybrid printed electronics technology have shown the potential to combine compact high-performance circuit integration on thin, flexible and elastic substrates with impact in Internet of Things, Health and Sports sectors. Reliability and robustness of hybrid printed electronics is a major challenge for the implementation of the technology in practical applications such as flexible displays, smart labels, photovoltaic devices, sensing devices, and radio frequency identification (RFID) tags. Two particular important open issues are the mechanical incompatibility between rigid components and the soft substrates and the reliability of conductive inks under stretch routines. Our recent work has focused on investigating the parameters that affect the underlying mechanisms to control these drawbacks, by emphasizing the study of materials elasticity role and their deposition process, both for inks, adhesives and encapsulants and integration with injection molding. This strategy settles the direction towards conformable devices, by promoting stretchability up to elasticity. In this talk, materials, including substrates, conductive inks, based on silver or carbon nanoparticles, processing with screen and inkjet printing in lab scale sheet to sheet up to pre-industrial roll to roll, photonic curing and integration with injection molding are discussed. In addition, recent developments in demonstrators involving in mold electronics for conformed electronics, conformable skin moisture sensors and LED hybrid elastic systems are presented, depicting processes and characterization involving electrical performance under mechanical strain and stability to controlled ambient conditions.

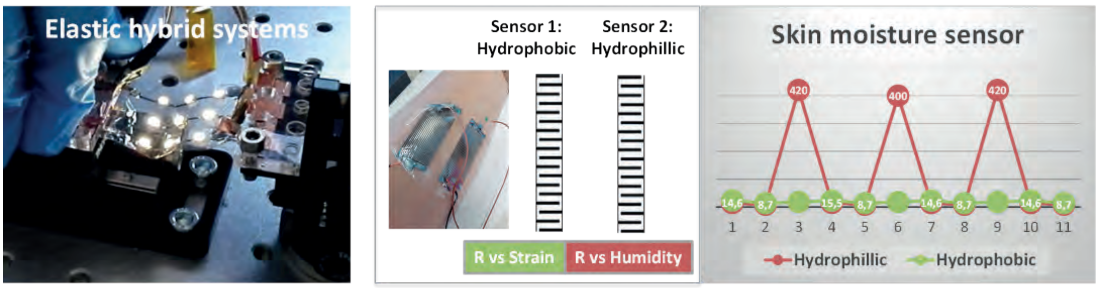

Figure 1. Examples of hybrid and conformable printed electronics systems

BIOGRAPHY

As a Marie Curie fellow, received her PhD (2011, UAB) working on smart surfaces with designed optical, magnetic and electrical properties. As a post-doctoral researcher (2011-2015) focused on surface nanopatterning. Currently, as Senior Scientist at Eurecat, is leading the Printed Electronics group and developing conformal, large area and cost effective innovative printed electronics solutions. Has participated and lead several national and European projects, authored multiple high impact publication and patent applications and received several awards for her research.

Professor Stephen Beeby

UNIVERSITY OF SOUTHAMPTON

Low temperature flexible materials for energy harvesting from textiles

ABSTRACT

The Department of Electronics and Computer Science (ECS) at the University of Southampton has been at the forefront of energy harvesting research for over 20 years and developments have been underpinned by our expertise in printing functional electronic materials which dates back to the 1980's. This talk will provide an overview of our research into the implementation of energy harvesting in textiles for wearable applications. The technologies covered include screen printed low temperature smart materials and an evaluation of the energy that can be harvested from textiles. In each case the fabrication processes, device design and applications will be discussed.

BIOGRAPHY

Stephen P. Beeby obtained a BEng (Honours) degree in Mechanical Engineering from the University of Portsmouth, UK, in 1992. He obtained his PhD from the University of Southampton, UK, in 1998 on the subject of micromechanical resonators. He has received two EPSRC Fellowships and was awarded a personal Chair in 2011. His research interests include energy harvesting, e-textiles, active printed materials development and sensor systems. He is Head of the Smart Electronic Materials and Systems research Group in the Department of Electronics and Computer Science and is currently PI on 2 EPSRC grants involving the develop of e-tetxiles technology and energy harvesting for wearable applications. He is a co-founder of Perpetuum Ltd, a University spin-out based upon vibration energy harvesting formed in 2004. He has over 260 publications, 8 patents and 5 books and an h-index of 42. Prof. Beeby is a Fellow of the Institution of Engineering and Technology and a senior member of the Institute of Electrical and Electronics Engineers.

Dr Wenzhuo Wu

PURDUE UNIVERSITY

Large-scale hybrid monolithic nanomanufacturing of liquid-solid heterojunction devices for self-powered smart skin

Wenzhuo Wu
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ABSTRACT

The seamless and adaptive interactions between functional devices and their environment (e.g. the human body) are critical for advancing emerging technologies, e.g. wearable devices, consumer electronics, and healthcare. The current scheme of operation not only requires a complex integration of heterogeneous components but also lacks a direct interface between the (opto)electronics and the working environment. Moreover, all existing technologies require a power source, which complicates the system design and limits operation schemes.

The state-of-the-art electronics/optoelectronics are based on planar and rigid structures, limiting their integration with three-dimensional soft biological systems. Mechanically deformable devices incorporating confined liquids present an ideal platform for enabling the conformal coverage of electronics on curved and soft surfaces in related applications. However, to date, liquid-based devices have been limited to merely incorporate liquid components as the passive electrodes given the difficulty in the fabrication of liquid-based heterojunctions. The heterogeneous interfaces between functional materials are the central constituents in the state-of-the-art electronics and optoelectronics. Moreover, there is a lack of the fundamental understanding and technological capability of monolithically integrating liquid structures (e.g. electrodes) with functional materials, in particular, the inorganic semiconductors that offer desired electronic and optoelectronic properties in the anticipated applications.

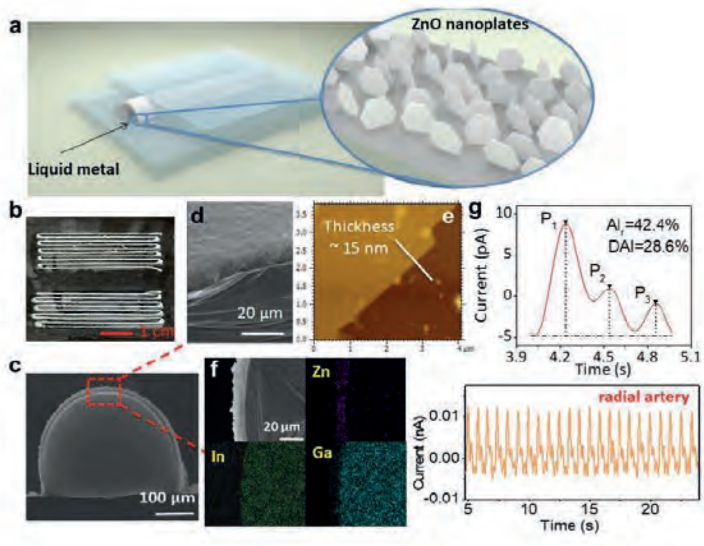

Figure 1. Hybrid liquid metal/2D semiconductor device for cardiovascular monitoring

Here, we demonstrate for the first time a versatile platform for the monolithic integration of liquid-solid heterojunction devices through the hybrid manufacturing of self-assembled two-dimensional (2D) inorganic semiconductor nanostructures on additively-manufactured liquid electrodes. This presents a significant advancement towards the realization of liquid-solid hybrid functional systems. The device architecture and fabrication scheme we present are generic for different "functional" liquids, enabling devices responsive to various kinds of stimuli. Moreover, owing to the thin structure, this new class of wearable devices are conformable to human skins and can sustainably perform non-invasive physiological functions, e.g. detection of pulses and vocal vibration, by harvesting the operation power from the human body. Our results show that such devices can generate a peak operation power density of ~ 10 nW/cm2 from the pulse activity. This research is expected to have a positive impact and immediate relevance to many societally pervasive areas, e.g. biomedical monitoring, consumer electronics, and human-machine interface.

BIOGRAPHY

Dr. Wenzhuo Wu is an Assistant Professor in School of Industrial Engineering at Purdue University. He was previously a postdoctoral fellow in School of Materials Science and Engineering at Georgia Institute of Technology. He received his B.S. in Electronic Information Science and Technology in 2005 from the University of Science and Technology of China (USTC), Hefei and his M.E. in Electrical and Computer Engineering from the National University of Singapore (NUS) in 2008. Dr. Wu received his Ph.D. from Georgia Institute of Technology in Materials Science and Engineering in 2013. Dr. Wu's research interests include synthesis, manufacturing and integration of nanomaterials/devices for applications in energy, electronics, optoelectronics, sensing, and self-powered micro/nano-systems.

Dr Miguel Carrasco

CDT

Progress in printable energy harvesting and storage devices

ABSTRACT

Many applications such as wearables and autonomous wireless sensors will require the development of a new generation of thin and flexible/conformable power sources. In addition to flexible energy storage, the use of energy harvesting will be required to circumvent the need for labour intensive battery replacement for autonomous systems. To address these needs, CDT is developing a number of energy harvesting and storage technologies, including printable thermoelectrics, battery/supercapacitor hybrids and organic photovoltaics.

In this talk, we will give an overview of the status of these technologies, with special focus on the recent progress in the area of thermoelectric generators. We will touch on how the power requirements of applications are impacting the energy harvesting system design, demonstrating the importance of application specific technology development in this very broad area.

BIOGRAPHY

Miguel holds an MSc (Hons) in Solid State Physics and Electronics from the University of Sevilla, Spain, and a PhD in Physics from the University of Hull, UK where he studied Polymer Networks for Photovoltaics applications.

At CDT Miguel is responsible for the R&D development in the area of lighting and energy harvesting and storage applications. Prior to that Miguel was responsible for a research group at NPL in London working on electrical metrology and novel applications with graphene. Previous positions include Merck Chemicals ltd and also Hewlett Packard Labs in the UK where Miguel occupied a variety of roles in development and commercialisation of OPV and OTFT technologies.

Indrachapa Bandara

UNIVERSITY OF SURREY

Low temperature meso-structured flexible perovskite single junction solar cells

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ABSTRACT

In the process of realising new, renewable and environmentally friendly energy sources to replace scarce fossil fuels, the field of photovoltaics (PV), has provided a viable solution. Currently, solution proccessible organic-inorganic hybrid semiconductor materials allow thin, flexible, low cost and light weight devices leading to easy fabrication of PV devices from semiconductor "inks".

The recently emerged "perovskite" materials have led to power conversion efficiencies of >21% for single junction solar cells.1 As means of fabricating PV devices with both high efficiency and improved stability, triple cation $Cs_aFA_bMA_{1-b}PbX_3$ (X = halogen, FA = formamidinium, MA = methyl ammonium) perovskites have been recently proven to be excellent candidates[2] where the bandgap can be tuned by the mixed halogen (X = mixture of I and Br) approach.[3] However the PV device fabrication process using these material systems require high temperature processing techniques to produce a suitable compact electron transport layer (ETL) using titanium oxide (TiO_x) solgel route. This prevents these perovskite systems to be used in roll to roll printed flexible solar cells. Here we report replacing the said ETL with a solution processed thin layer of tin oxide (SnO_2) with a thickness of ~10nm, which allows reduction of processing temperature from 450°C to 180°C with a reduction in processing time from 4h to 1h, while retaining high efficiencies of >14% and exhibiting an external quantum efficiency (EQE) of ~90%. Flexible PV devices based on the solution processed SnO_2 are also fabricated with the inclusion of a meso structured Aluminium oxide (Al_2O_3) interlayer yielding power conversion efficiencies of >5%. The Al_2O_3 interlayer results not only in the improvement of the quality of the active layer leading to higher fill factors, but also in increment in the open circuit voltage (V_{oc}).

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3. Eperon, G. E. et al. Perovskite-perovskite tandem photovoltaics with optimized band gaps. Science (80-.). 354, 861–865 (2016).

BIOGRAPHY

Indrachapa Bandara is currently a PhD candidate in the Advanced Technology Institute of the University of Surrey. Before coming to the UK she gained her BSc in Chemistry from the University of Cincinnati, USA and the Institute of Chemistry in Sri Lanka. Her research mainly focuses on photovoltaic energy generation via thin film solar cells using semiconducting organic polymers and organic-inorganic hybrid semiconductors such as perovskite materials. Her interests further expand into the fabrication of solution processed, large area, light weight and flexible solar cells that allows roll to roll printed devices for highly efficient solar energy harvesting. She can be contacted at: i.rajapakshe@surrey.uk.ac .

Mathieu Bellanger

LIGHTRICITY

Ultra-high efficient photovoltaic energy harvester for wearable devices

ABSTRACT

We will present Lightricity unique PV energy harvesting (EH) technology performance under realistic indoor lighting conditions. Lightricity Energy harvester can be fully customised: various shapes, sizes, thicknesses and output configuration can be achieved depending on the application requirements. Combined with low-power printed electronics, Lightricity EH technology will enable new IoT applications including self-powered wearable devices.

BIOGRAPHY

Mathieu Bellanger is Technical Director of Lightricity, a spin-out from Sharp Laboratories of Europe. Previously he was in in charge of developing the energy harvesting and IoT activity within Sharp Laboratories for the last 4 years. While working for Sharp between 2008 and 2017, Mathieu has also been involved in various projects covering a range of photovoltaic device technologies, for flat plate, CPV and space applications. Mathieu holds a physics and engineering degree from the French “Grande école” Institut National des Sciences Appliquées (INSA) of Toulouse together with a master’s degree in Nanophysics from University of Paul Sabatier (Toulouse) in France.

Professor Rodrigo Martins

NEW UNIVERSITY OF LISBON

Sustainable hybrid materials applied to flexible electronics

ABSTRACT

In this talk we will discuss the state of the art and potential future directions in paper-based electronics with special emphasis to the work developed at CENIMAT|i3N, covering electronic devices, smart displays, printed electronics, sensors and diagnostic tests.

We have been observing a rapid and growing interest concerning the utilization of biological materials for a wide range of applications. One of the most representative example is cellulose, not only in the form of raw material mainly for pulp and paper production, but also in the development of advanced materials/products with tailor-made properties, especially the ones based on nanostructures.

5 years ago paper electronics was pure science fiction, but today we have already several paper-based electronics like integrated circuits, supercapacitors, batteries, fuel cells, solar cells, transistors, microwave electronics, digital logic/computation, displays, force-sensing MEMS, user interfaces, transparent substrates, substrates with high strength, wearable devices, and new rapid diagnostic test sensors. These devices with their associated physics and processing will play an important and relevant to our society ongoing efforts to in environmental sustainability, safety, communication, health, and performance.

BIOGRAPHY

Rodrigo Martins is full professor in Materials Science Department of Faculty of Science and Technology of New University of Lisbon, a Fellow of the Portuguese Engineering Academy since 2009 and a member of the European Academy of science since 2016. He was decorated with the gold medal of merit and distinction by the Almada Municipality for his R&D achievements.

Currently he is the:

- Head of Materials Science Department of FCT-UNL;
- Director of the Centre of Excellence in Microelectronics and Optoelectronics Processes of the Institute of New Technologies, CEMOP/Uninova;
- Head of the group of Materials for Electronics, Optoelectronics and Nanotechnologies (MEON) of CENIMAT/I3N;
- Member of the Advisory Board of Horizon 2020 on DG Research and Innovation (Advanced Materials, Nanotechnology, Biotechnology and Manufacturing);
- Chair of The European Committee Affairs of European Materials Research Society, E-MRS;
- Chair of The Global Leadership and Service Award Committee of the International Union of Materials Research Societies, IUMRS;
- Vice-Chair of Energy, Materials Industry Research Initiative, EMIRI;

Rodrigo Martins has been involved in the pioneer European research on amorphous silicon semiconductors and pioneer with is group worldwide activity related to passive and active oxides, the so called transparent electronics and it is one of the inventors of the so-called paper electronics, where paper is exploit not only as a substrate but also as a functional component in active devices.

Martins published over 700 papers and during the last 10 years got more than 14 International and national prizes and distinctions for his work (e.g: Lisbon Energy Live Expo, Innovation prize, 2012 (Solar tiles); European Patent Office Innovation nomination 2016 (paper electronics); Exame Informática Innovation prize 2016 (paper solar cells)).

Chen Jiang

UNIVERSITY OF CAMBRIDGE

All-inkjet-printed low-voltage bias-stress stable organic thin-film transistors

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ABSTRACT

Rapid advances in electronic materials have stimulated the development of organic thin-film transistors (OTFTs) with low fabrication cost, high performance, and good mechanical flexibility. This rapid development of OTFTs has made them potential candidates for various applications, such as sensors, radio frequency identification tags, point-of-care diagnostic devices, and wearable systems. All-inkjet-printed (AIJP) OTFTs take the advantages of inkjet printing technology, including drop-on-demand direct patterning, reduced material wastage, and high compatibility to large area manufacturing. Therefore, AIJP-OTFTs are in high demand for future low-cost large-area electronics. However, to achieve their real-world applications, two issues commonly seen in OTFTs need to be addressed, i.e., high power consumption and instability during operation.

From the standpoint of power consumption, low operating voltage and current of the AIJP-OTFT is essential. To reduce operating voltage, a typical way is to use an ultrathin gate dielectric layer or a high-k dielectric material to achieve a large gate dielectric capacitance per unit area (C_i). These methods, though effective in reducing operating voltage, can induce adverse effects, such as large gate leakage current and bias-stress instability. These adversities can be even exacerbated in AIJP-OTFTs due to processing limits of inkjet-printing techniques. Here, we will demonstrate low-voltage AIJP-OTFTs with a low operating voltage of 3 V can be achieved through reducing the trap density at semiconductor/dielectric interface. The devices demonstrate a steep subthreshold slope (128 mV/decade) and a close-to-zero threshold voltage (−0.16 V). In terms of operating current, the devices are biased at near-threshold regime. With the reduced operating voltage and current, the power consumption of OTFTs can be lowered to nano-watt levels, which is ideal for ultralow-power wearable electronics.

The operational instability in AIJP-OTFTs is mainly attributed to the water molecule polarisation in the dielectric material. To suppress this effect, non-polar dielectric materials are commonly used in vacuum-processed or semi-solution-processed OTFTs. However, this method is not compatible with the fabrication processes for AIJP-OTFTs, due to the poor wettability of available solvents on non-polar materials. Here, we will demonstrate that Lewis-acid monopolar dielectric materials would be ideal for AIJP-OTFTs to achieve high bias-stress stability. This group of materials can prevent water molecules migrating or trapping in the dielectric layer, and meanwhile, they allow good wetting by organic solvents for further deposition of other functional layers. With a hydrophobic and lipophilic dielectric layer, the AIJP-OTFTs demonstrate high operation stability under both positive and negative bias stress without noticeable threshold voltage shift, i.e. $|V_{th}| < 0.13$ V even after 45-min stress. This level of operational stability in AIJP-OTFTs is comparable to the state-of-the-art vacuum-processed devices.

BIOGRAPHY

Chen Jiang is currently with Prof Arokia Nathan working on inkjet-printed electronics at the Department of Engineering, University of Cambridge.

Dr Daniel O'Connor

NATIONAL PHYSICAL LABORATORY

Metrology for large area electronics: a roadmap

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ABSTRACT

Accurate and traceable measurement lies at the heart of manufacturing, and is the key to increasing yield, optimising reliability and unlocking novel product ideas. Metrology (the science of measurement) is essential at all stages of production. For example, position referencing metrology is needed to control digital structuring processes such as holography, inkjet printing and laser patterning, as well as enabling accurate deposition, overlay and lamination processes [1]. Additionally, surface defect detection and critical dimension metrology is needed to ensure the functional performance of components before further value is added [2]. Furthermore, functional metrology is needed, not only to qualify completed devices after manufacture, but also for defect classification and the initial specification of any in-process dimensional metrology [3].

We present a roadmap of the metrology required to enable high precision control of advanced manufacturing techniques for large area electronics (LAE) and describe a number of metrology concepts we have developed for the characterisation of LAE components and the in-line control of their manufacture, see figure 1. Furthermore, we present the highlights of work we have done recently to support and develop test method standards for LAE.

Acknowledgements

The parent project 14IND09, MetHPM is delivered under the EMPIR initiative, which is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States. The authors gratefully acknowledge that the funding for part of this work came via the EPSRC Centre for Innovative Manufacturing in Ultra Precision (CIMUP).

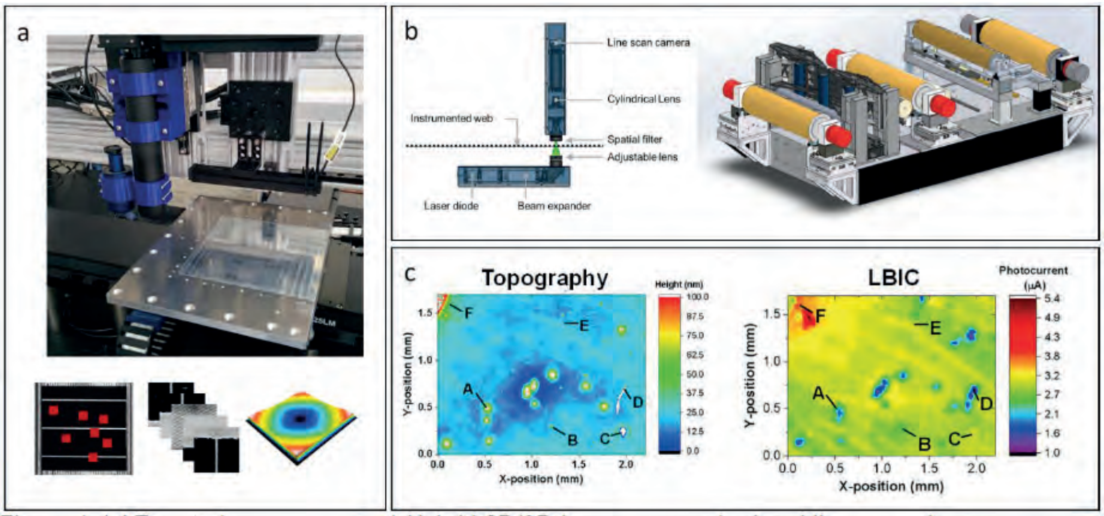

Figure 1. LAE metrology concepts a) Hybrid 2D/3D instrument and printed linear conductor test case. b) Position referencing metrology for a roll to roll system. c) Metrology for functional characterisation e.g. registered topography and light beam induced current mapping on photo voltaic cells.

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BIOGRAPHY

Dr Daniel O'Connor is the lead scientist of the Dimensional Surface Metrology team at the National Physical Laboratory (NPL) in Teddington, UK. His main expertise is in the design and experimental implementation of optical sensor systems for non-contact critical dimension metrology, areal surface topography measurement and defect detection. In 2010, he was admitted to the degree of Doctor of Philosophy in Physics at the Queen's University of Belfast, after which he held a postdoctoral position there and subsequently, at King's College London. In 2013, he became a visiting assistant Professor in the physics department of the University of North Florida before joining NPL in 2014.

Dr Bin Yang

UNIVERSITY OF CHESTER

Quality-control of UV offset lithographically printed electronic-ink by THz technology

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ABSTRACT

Inkjet-printed electronics are showing promising potential in practical applications, but methods for real-time, non-contact monitoring of printing quality are lacking. This work explores Terahertz (THz) sensing as an approach for such monitoring. It is demonstrated that alterations in the localised dielectric characteristics of inkjet-printed electronics can be qualitatively distinguished using quasi-optically-based, sub-THz reflection spectroscopy. Decreased reflection coefficients caused by the sintering process are observed and quantified. Using THz near-field scanning imaging, it is shown that sintering produces a more uniform spatial distribution of permittivity in the printed carbon patterns. Images generated using THz-TDS based imaging are presented in Fig.1, demonstrating the combination of high resolution imaging with quantification of complex permittivities [1]. This work, for the first time, demonstrates the feasibility of quality control in printed electronic-ink with THz sensing, and is of practical significance to the development of in-situ and non-contact commercial-quality characterisation methods for inkjet-printed electronics.

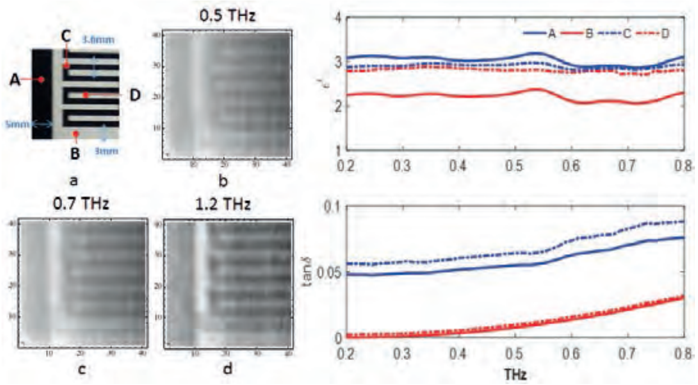

Figure 1: Transmission imaging measurement of a printed meander-line pattern by THz-TDS. Left: images at selected frequencies; Right: permittivities and loss tangents at selected points.

Reference

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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.

Professor Tim Claypole

SWANSEA UNIVERSITY

Advanced rheology and its application to large area printed electronics

Tim Claypole, Rhodri Williams, James Claypole, Dan Curtis, Alex Holder and David Gethin
Swansea University

ABSTRACT

The printing industry has relied on crude measures of rheology which frequently bore no correlation with the print quality. It is frequently assumed the printer will adjust the ink and the process by trial and error, in order to make a satisfactory print. Whilst this might be acceptable in graphics printing and crude functional printing, this will not lead to consistent, high quality results necessary for printing electronics. Adopting a holistic approach involving the whole supply chain is required to increase the yield and hence profitability of large area screen printed electronics.

The advanced rheological techniques, such as SAOS and CSPS, have been shown in the ARPLAE project to be related to the printability of model screen printing inks. The application of this work to process control during the formulation and application of commercial functional inks will be described. For example, how the phase angle produced for the different functional groups on GNP's correlates with their ability to disperse in the resin, which effects the printability and functionality. It can also be used to quantify the stability of formulations.

There is a real benefit in the FT-CSPS techniques being developed in the P²CAR-2 Flagship project, as it reduces the time taken to measure each sample. Thus, opening the possibility for in line real time measurement.

BIOGRAPHY

Prof. Tim C. Claypole MBE, Phd, BSc (Hons), C. Eng, F.I.Mech.E., M.I.E.T.

Prof. Tim. C. Claypole is the current "Haydale Chair of Advanced Manufacture by Printing" and a faculty member of the College of Engineering, Swansea University. His areas of research include colour control, manufacturing systems, quality, maintenance, reliability experimental design, fluid mechanics and process thermodynamics. He is a British Expert on ISO TC130 on standards for the graphic arts. Tim is director of the WCPC (Welsh Centre for Printing and Coating, Swansea University). This developed from his fundamental research into Printing and Coating as a manufacturing process. Tim was awarded an MBE New Years Honours for his services to research in graphic arts and industry. He is a Co-investigator on the EPSRC Centre for Innovative Manufacture of Large Area Electronics. Tim was the principle investigator on the DIPLE project which won the 2009 EU Regiostars for technology transfer into industry. Tim Claypole also founded icmPrint, a not for profit company, which promotes best practice, training and University collaboration. It also funds underpinning research for the benefit of the whole print industry.

Dr Guangbin Dou

IMPERIAL COLLEGE LONDON

Interconnection technologies for integration of active devices with printed plastic electronics

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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 hybrid plastic electronics with a combination of both printed electronics and conventional silicon electronics. At the present time reliable system integration for hybrid plastic electronics is mainly based on conventional Anisotropic Conductive Adhesive (ACA) packaging which is too slow and expensive to address the highest volume products envisioned for the plastic electronics market. In this research we investigated the use of low cost Non Conductive Adhesive (NCA) packaging as an alternative route for integrating active devices on low-temperature substrates. In addition to working on pure NCA packaging, we also explored the feasibility of using thermosonic (TS) bonding to form metal-metal micro-joints between the bumps and substrate pads. And based on the process development of NCA and TS bonding, a combined thermosonic-adhesive (TS-A) process has been developed for plastic electronics packaging in which a thermosonic (TS) bonding step is carried out during the NCA curing cycle as illustrated in Figure 1. The process comprises three steps: (a) place and align active device to plastic electronic substrate pre-bonded with NCA; (b) apply pressure, heat and ultrasound as required to form TS bonds and cure NCA; and (c) cool and withdraw pick-up tool. In the bonding trials, dummy Cu-bumped fine pitch Si chip was successfully packaged on PET substrate using NCA bonding with acceptable temperature and humidity (T60/TH90) reliability testing results. And dummy flexible Polyimide (PI) chip and PET substrate were used in the process development of NCA, TS and TS-A bonding for flex-on-flex packaging. The test samples were Ag printed with 480µm×480µm×8µm bonding pads and conductor tacks for 4W joint resistance measurement. The electrical test results showed the joint resistance of optimized NCA and TS bonding was lower than 10 mΩ, with no apparent thermal/mechanical damage found on the as-assembled samples. And the joint resistance of TS-A bonding developed from the optimized NCA and TS bonding was measured lower than 5 mΩ. Initial bending reliability tests indicated the TS-A assembled samples appeared to accommodate bending radii at 30 mm, 15 mm and 7.5 mm, but failed in the bending radii at 5mm testing. The package failure was resulted from the weak adhesion of NCA film on PET substrate; and the electrical failure was that the Ag-printed pad bonded with chip bump was lifted from the PET substrate. This suggested that the TS-A bonding was stronger than the NCA adhesion and pad bond on the PET substrate. Currently reliability testing (T60/TH90) on NCF, TS and TS-A bonding of flexible IC on PET substrate is ongoing; and the results will be presented in the innoLAE 2018 conference. Demonstrated novel bonding techniques for plastic electronics packaging, this research could lead to low-cost manufacturing of plastic electronics to address the trillions of products envisioned by the IoT market.

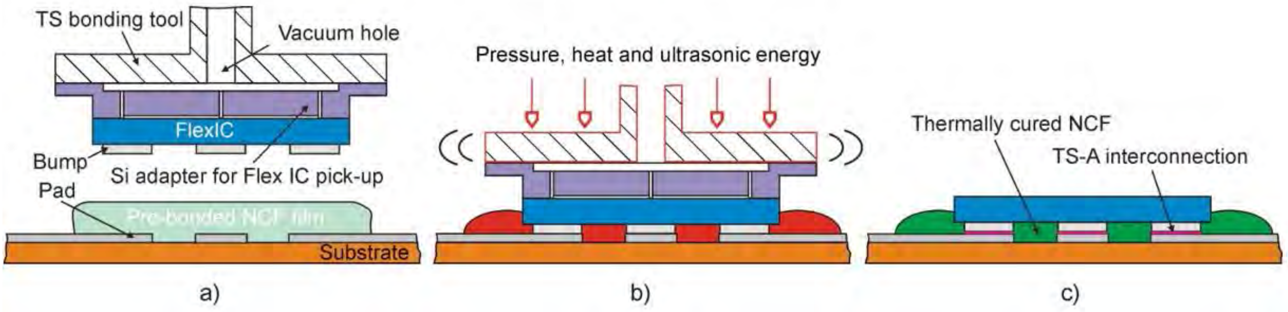

Figure 1. Thermosonic-adhesive packaging process combining NCA packaging and thermosonic bonding

BIOGRAPHY

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.

João Manuel Carvalho Gomes

CENTI

Development of interactive automotive interiors with integrated printed electronic solutions

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ABSTRACT

The development of interactive automotive interiors and of specific components and structures that are in direct contact with driver and passengers, has been a highlight for the integration of printed and hybrid electronics into and onto thermoplastic components. The flexibility and mechanical performance of printed and hybrid devices is enabling the integration of interactive properties, lighting and haptic feedback onto passive polymeric components designed for aesthetic purposes. Nowadays, it is possible to combine design and functionality, fully integrated onto a single polymeric component, providing design freedom, seamless integration of interactivity and “invisible electronics”. These new developments are being enabled by extensive research and technology applications, forming a new technological trend in the areas of plastic molding and component manufacturing for the automotive interior.

At CeNTI we have been working in the integration of smart functionalities in traditional materials to create functional automotive interior parts. The approach that is being followed is the integration of printed electronic devices in IML (in-mould labelling) and IMD (in-mould decoration) processes using traditional materials such as PP (with and without additives).

Some of the challenges are the integration of these new applications in the traditional process that are used by the companies, are the high temperatures and pressures that limit the materials and devices that can be incorporated in the processes. The combination of printed electronics with traditional electronics and how they are integrated in the thermoformed plastic components is another challenge that was address and required the use of digital fabrication technologies.

Due to the nature of the collaboration between CeNTI and industrial partners, the scalability of the processes that are used is one of the major focuses of the scientific and technological approaches. In the development of the printed electronic devices an integrated and multi-disciplinary approach has been taken comprising different steps, such as design optimization, deposition and characterization of the devices.

BIOGRAPHY

João Gomes holds a Master's degree in Materials Processing and Characterization from and a Degree in Physics from University of Minho. Previously worked as physical data and device analyst and as a junior meteorologist at the Portuguese National Meteorological Institute. From 2006 to 2007 worked as a researcher for the Electroactive Materials Group of the Department of Physics of the University of Minho. Since 2007 worked a researcher, and from 2013 to 2017 as R&D Manager of the Smart Materials & Embedded Systems Department at CeNTI, focusing on the areas of Printed and Integrated Electronics and Embedded Systems. Currently holds the position of Chief Operations Officer at CENTI with the responsibility of overseeing development of new technologies and products with printed and integrated electronics and smart functionalities for the automotive and aeronautic, home and wellness, and construction industrial sectors. He has many publications in this field in international journals including several patents.

Professor Yu Liu

JIANGNAN UNIVERSITY

Development of intelligent hybrid platform for direct printing of functional patterns at large-scale flexible substrate

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2. Changzhou Printed Electronics Industry Institute, Changzhou, China.
3. Department of Electrical and Computer Engineering, Western University, London, Canada.
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ABSTRACT

Direct printing of a functional structure on a flexible substrate is attracting interests from the additive manufacturing community researching on flexible devices, which owns significant advantages including lightweight, low cost, wearability, and in matching with sustainability required by the society and new – era technical R&D [1,2]. In this presentation, both of wet and dry improvements from our work on development of hybrid platform will be presented for alleviating the existing issues when scaling up the printing process. We will introduce our years' efforts on design of direct patterning of different thin layers for fabrication of functional electronics, based on electrostatic, jetting, deposition, and transferring techniques. These techniques may be further improved with intelligent capability for providing direct fabrication of largely stretchable meso- 3D parts, including conductor, foam, aerogel etc. Not only reporting these applications research updates, we will also point out our instrumentation and control during process development, esp. on industrial considerations from cost – down and process stability.

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[4]. X. Jin, Y.Q. Deng, W.R. Cai, W.M. Lau, D. Hui, H. Yan, J. Mei and Y. Liu, Composites Part B – Engineering, vol. 105, pp. 111 – 115, 2016.

BIOGRAPHY

Yu Liu is a full professor in School of Mechanical Engineering, Jiangnan University, Wuxi, China, and he is leading the Institute of Precision Intelligent System Engineering (iPISE). His research interests include additive manufacturing of functional materials, printed electronics, precision intelligence system design, composite material surface engineering and nanoscale characterizations. He obtained his bachelor degree in control science and engineering, and then his master and PhD degrees in mechanical engineering. Before he took his academic position in present school, he had worked in Bosch and Xerox. He has published for more than 50 journal papers and 70 patents. His both academic and industrial researches with different sectors from transport, energy, building, and environment, are leading his group for establishing optimal solutions to the emerging 3D mechatronics.

Dr Davide Deganello

SWANSEA UNIVERSITY

SIMLIFT optimisation of laser induced forward transfer resolution through both coating and laser parameters

Davide Deganello*[1], Ben Clifford[1], Riccardo Gerimia[2], David Beynon[1] and Dimitris Karnakis[2]
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2. Oxford Lasers Ltd, 8 Moorbrook Park, Didcot, Oxon, OX11 7HP, UK

ABSTRACT

The SIMLIFT project an EPSRC CIMLAE pathfinder project brought together the printing and coating expertise of WCPC with the laser processing knowledge of Oxford Lasers to advance the reliable resolution achieved in the Laser Induced Forward Transfer (LIFT) process. Keeping the industrial relevance through the direction of an industrial user group with representatives from NeuDrive, PragmatIC, NSG and MicroSemi the research of SIMLIFT (Single Micron Laser Induced Forward Transfer) focussed on the systematic investigation of resolution critical parameters.

Integral to the LIFT process is the coating of a donor substrate, from this donor layer a pulsed laser is used to cause a jet of material to transfer to an acceptor substrate. Therefore critical parameters for the formation of the donor layer have been investigated. The project assessed different thin film deposition methods (spin coating, blade coating, roll coating) analysing uniformity, associated ink rheology and optical transmission. Therefore the most suitable conditions of donor layer deposition could be determined in terms of quality, morphology and compatibility with large area electronics. The project then combined the donor deposition with a wide range parametric study of laser parameters at Oxford lasers, adopting a nanosecond DPSS laser assessing effect of gap, speed, power and donor thickness towards transfer of high resolution features.

The results of the project underlined the requirement for a thin, high viscosity liquid donor layer with a high level of uniformity for good transfer, instead of the traditional solid donor. Additionally, it was found that there is a direct correlation between laser power and donor layer thickness. It was observed that very tight control is required of the gaps between the focal lens and the donor layer as well as between the donor and acceptor layers. By optimising these settings high quality lines with widths between 40 and 100 micron were produced. Finally, by optimising the process parameters further the researchers produced fine lines with width of 12 microns (figure 1).

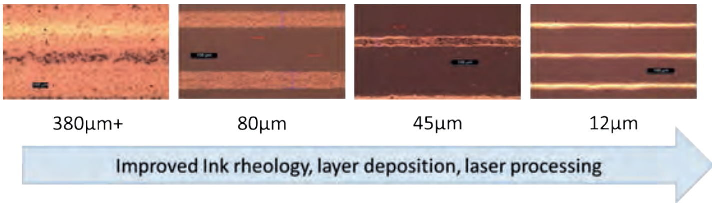

Figure 1. Progressive resolution improvement by optimising donor deposition and laser parameters.

BIOGRAPHY

Dr. Davide Deganello is an Associate Professor in the College of Engineering, Swansea University. He has a Ph.D. in Mechanical Engineering (Swansea University, 2008). His research interests comprise functional printing and additive processing for energy storage, electronic and biomedical applications, combined with study of underlying complex fluids rheology.

Dr Simon Tuohy

OXFORD LASERS

High-speed selective laser sintering of Ag nanoparticle inks on flexible substrates

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ABSTRACT

Laser sintering of printed metallic inks is a technique growing in interest within the industrial community. Laser sintering offers a number of advantages over more traditional methods such as oven or UV lamp sintering, primarily due to its superior spatial selectivity and finely controlled heat input. Namely, the imparting of laser-induced heat solely on the area of interest over the printed lines avoids excessive heating and potential damage of all unprinted substrate regions. As many inks require a sintering temperature above that of the degradation point of plastic or other sensitive substrates, such selectivity can be vital, as without it, the high temperature load would lead to melting or even decomposition and undesirable distortions in the underlying substrate. Much of the interest in plastic/flexible electronics is driven by the market demand for lower cost electronics, thus to be industrially competitive, laser sintering has to also offer a high processing speed atop other advantages. An obvious method to achieve this is by increasing the incident laser power and laser scanning speed over the sample, but an upper limit applies for both. An alternative to bypass such limitations, but still increase the effective sintering speed, is to parallel process with multiple beams. We therefore investigated the use of Spatial Light Modulators (SLM) to split a single incoming high power laser beam to several lower power beamlets on target. Such digital devices when inserted in an optical beampath can additionally provide spatial laser beam intensity control by reshaping a nominal Gaussian laser beam profile to a more homogenised tophat output for uniform laser heating on target.

In this presentation, we will show recent progress towards the twin goals of sintering (i) on plastic substrates without any damage and (ii) at high throughput with industrially relevant speeds using short pulsed DPSS lasers at kHz rate and liquid crystal on silicon SLMs. To benchmark our selective laser sintering capabilities, we utilise two different silver inks with viscosities ranging between 3000-86,000cP and very shallow LIFT (Laser-induced Forward Transfer) printed line feature heights (0.5μm and 3.3μm).

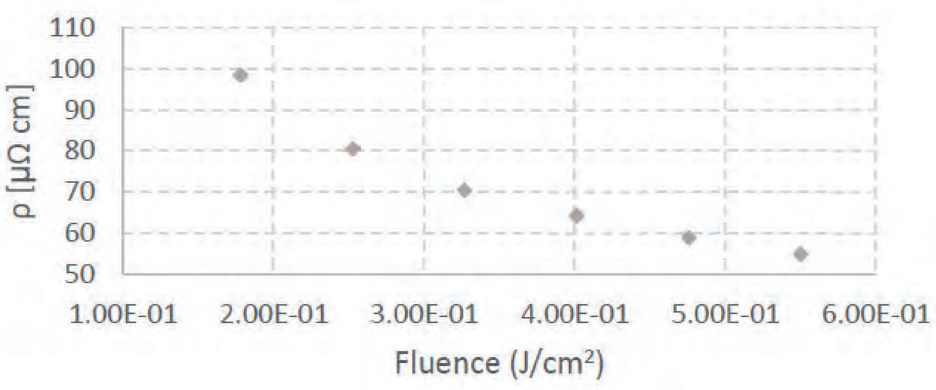

Fig.1 Laser sintered Ag ink measured resistivity (in μΩ cm) vs laser fluence (J/cm2)

Preliminary results shown in Figure 1, show Ag ink sintered conductivities of less than 60 uΩ cm^{-1} and we still work to reduce that further. A parametric study on pulsed laser sintering with varying average power, laser frequency and scan speed will be displayed along with a discussion on the merits of process parallelisation.

This work has been part funded by EU H2020 project Hiperlam (723879), www.hiperlam.eu. All metallic ink materials provided by project partner PV Nanocell Ltd (Israel). All Ag lines were LIFT printed by partners Orbotech(Israel) and TNO (Holland).

BIOGRAPHY

Simon Tuohy obtained his Bachelor in 2004 from NUI, Galway (Ireland) in Experimental Physics and his Master in 2005 from Queens University of Belfast (UK) in Optoelectronics and Optical Information Processing. Simon obtained his PhD in Physics in 2011 from the University of Kent at Canterbury (UK) where the focus of his research was on combining optical coherence tomography with Adaptive Optics. Later he worked as post-doctoral research fellow at Oxford University (UK) for 6 six years primarily in researching a variety of microscopy techniques, this was also combined with research undertaken in Neuroscience. In September 2015 Simon joined Oxford Lasers Ltd (UK) as Laser Applications and Development Engineer working mainly on R&D projects.

Professor George Malliaras

UNIVERSITY OF CAMBRIDGE

Implantable electrophoretic devices for localized drug delivery

George Malliaras
Department of Engineering, University of Cambridge, UK

ABSTRACT

Neurological disorders represent a major health concern worldwide. The most common treatment is oral or intravenous administration of pharmaceutically active compounds. These methods, however, require repeated administration and allow the drug to interact with tissues indiscriminately. Moreover, drug delivery in the brain is often precluded by a variety of physiological and metabolic obstacles such as the blood–brain barrier (BBB). These issues provide strong motivation for the development of alternative drug delivery approaches. I will discuss a novel class of devices that are implanted past the BBB and deliver the drug where and when is needed. They use electrophoresis, as opposed to convection, to deliver the drug without the solvent. In vitro characterisation shows low-voltage operation, high drug-delivery capacity, and high ON/OFF ratio. In vivo validation in a rodent model of epilepsy shows that these devices can stop, or even prevent seizures. These results represent a significant step forward toward the development of implantable drug-delivery systems for neurological disorders.

BIOGRAPHY

Professor George Malliaras received a PhD from the University of Groningen (1995) and did a postdoc at the IBM Almaden Research Center. Before joining the University of Cambridge, he was a faculty member at Ecole des Mines de St. Etienne (2009-2017) and at Cornell University (1999-2009), and served as the Director of the Cornell NanoScale Facility (2006-2009). His research has been recognized with awards from the New York Academy of Sciences, the US National Science Foundation, and DuPont. He is a member of the Hellenic National Council for Research and Technology, a Fellow of the Materials Research Society and of the Royal Society of Chemistry.

Professor Xian Huang

TIANJIN UNIVERSITY

Printed flexible sensors integrated with metal organic frameworks

ABSTRACT

Flexible sensors that effectively detect various biological chemicals generated by human body offer attractive solutions for highly accurate fitness tracking and disease diagnosis. Combination of novel materials with flexible electronic technology opens up new concepts of flexible electronic devices that offer unique properties adopted from the materials, while mechanically compatible to the soft, curvilinear organic tissues. We recently developed flexible sensors integrated with conductive metal-organic frameworks (MOFs), which are notable for their tunable properties according to their composition materials. The flexible sensors that are obtained through highly effective screen printing approaches can be surface modified by various MOFs such as copper-MOFs (Cu-MOFs) and cobalt-MOFs (Co-MOFs) to yield highly specific and sensitive electrochemical detection. The sensors modified with Cu-MOFs can detect various trace amounts of chemical/biological compounds such as hydrogen peroxide (H_2O_2), glycine, ascorbic acid (AA) and L-tryptophan (L-Trp), and the sensing resolution of AA and L-Trp can reach 25 μM and 15 μM, respectively. In contrast, the sensors integrated with Co-MOFs can be used to detected glucose. These flexible sensors minimize the use of biological active chemicals, while offering sensing capability even under highly deformed geometry and complex surrounding environment. The sensors can be continuously used for 15 days to satisfy the requirement of many implantable applications. Experiments using living cells and animals demonstrated that the MOF-modified sensors are biological safe to living cells, and can detect L-Trp in blood and interstitial fluid. This is the first example of flexible sensors integrated with MOFs, suggesting the potential use of MOFs in flexible electronics to enhance device performance.

BIOGRAPHY

Xian Huang is a Professor in Biomedical Engineering in the School of Precision Instrument and Opto-electric Engineering and Director of biological microfluidic and flexible electronics laboratory in Tianjin University. He was an Assistant Professor in the Mechanical Engineering department in Missouri University of Science and Technology from 2014-2016. He got his PhD degree in Mechanical Engineering from Columbia University in Oct. 2011, and worked as a postdoctoral researcher in Materials Research Laboratory in the University of Illinois at Urbana-Champaign from Aug. 2011 to June 2014.

His research interests lie in the field of flexible electronics and biosensors. He developed implantable glucose affinity sensors based on viscosity and dielectric detection, and received a gold award from Diabetes Technology Society due to his work in implantable miniaturized glucose sensors. He has developed flexible and stretchable skin sensors that can be conformably attached to skin and measure biophysiological signal from skin. In addition, he developed bioresorbable electronics devices that can dissolve in water for implantable healthcare, environmental protection, and security. He is currently supported by "1000 Talent Plan" in China and "First class universities and first class discipline" plan in Tianjin University to conduct research in flexible electronics. He is working on extending the capability of flexible and stretchable electronics, allowing the devices to monitor tumors and analysis molecule concentrations in biofluids. He is also developing novel manufacturing techniques for bioresorbable electronics based on nanoparticle inks and low temperature photonic sintering.

Dr John Hardy

LANCASTER UNIVERSITY

Multiphoton fabrication of bioelectronic biomaterials for neuromodulation (MFBBN)

John Hardy[1] and Frances Edwards[2]
1) Lancaster University. 2) University College London
Industrial Partners: Galvani Bioelectronics, 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 focus of this project was 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 an update on our progress on this project facilitated by a Pathfinder Award.

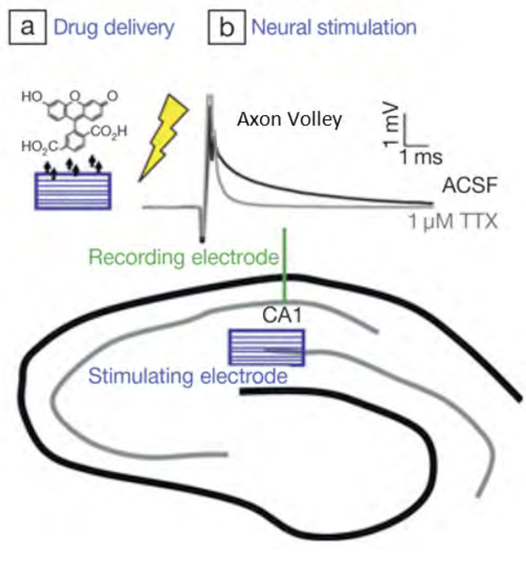

Figure 1: Conducting polymer-based electrode prepared by multiphoton fabrication for application as a neural electrode.
Collaboration with Frances Edwards at UCL Neuroscience.
Hardy & Edwards, J. Mater. Chem. B. ***2015****, 3, 5001.*

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.

Frances Edwards is a Reader in Neurophysiology in the Department of Neuroscience, Physiology & Pharmacology at University College London. She obtained her first degree from the University of Sydney, and her PhD from the Australian National University and the Max Planck Institute for Biophysical Chemistry working with Professor Bert Sakmann in Germany where she continued as a postdoctoral fellow for 2 years. She obtained a Wellcome European Fellowship to undertake research in David Colquhoun's group in at the Department of Pharmacology at UCL, returned to Australia for 2 years as a senior research officer and 4 years as a Queen Elizabeth II Research Fellow at the University of Sydney. She began her independent career at UCL in 1996 where she runs a research group that uses electrophysiology, immunohistochemisty and molecular biology to study fundamental neuroscience.

Professor Luisa Torsi

UNIVERSITÀ DEGLI STUDI DI BARI "ALDO MORO"

Organic bioelectronics for bio-chemical detections at ultra-low detection limits

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[2] Università degli Studi di Bari – "Aldo Moro" - Dipartimento di Fisica "M. Merlin" - Bari (I)
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ABSTRACT

Counting the molecules present in a solution instead of assaying its concentration is the ultimate and visionary goal in chemical analysis. Its actuation however, necessarily requires reliable technologies that can "count" the molecules one by one. Such an approach would enable not only fundamental understanding of subtle effects in an affinity interaction likely hidden in ensemble measurements, but also it would pave the way to striking applications. Indeed, proteins and biomolecules detection at the physical limit are foreseen to generate ground-breaking technological fallouts such as for instance, label-free biosensors endowed with high selectivity as well as sub-femtomolar (10^{-15} M, fM) sensitivity for non-invasive label-free quantitative analysis of pathogens or diseases' markers in bio-fluids such as saliva or tears.

The present lecture thus aims at presenting an overview on the challenges and on the exciting perspectives, that are associated with the quantification of ultra-low concentrations of proteins. An outlook on the extremely high performance level of millimetre-size organic bioelectronic sensors integrating a trillion of capturing molecules, will be provided showing that sub-fM detection limits can be reliably reached.[1] As cases of studies, the selective and ultra-sensitive assay of immunoglobulins and C-reactive protein in saliva will be discussed. The organic bioelectronic transistors used are mm-size, low-cost and are operated at physiologically relevant conditions as well as in human saliva setting the ground for a revolution in immunoassay for early bio-markers detection[2-3].

References:
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2. M.Y. Mulla *et al.*, "Capacitance-modulated transistor detects odorant binding protein chiral interactions," Nature Communication., vol. 6, pp. 6010, 2015.
3. E. Macchia *et al.*, "Organic bioelectronics probing conformational changes in surface confined proteins," Scientific Reports (Nature), vol. 6, pp. 28085, 2016.

BIOGRAPHY

Luisa Torsi is professor at the University of Bari (I) and immediate past-president of the European Material Research Society. She received her laurea in Physics in 1989 and the PhD in Chemical Sciences in 1993. She was post-doctoral fellow at Bell Labs from 1994 to 1996. In 2010 she has been awarded with the Heinrich Emanuel Merck prize. She is also the recipient of the Global-WIIN main overall platinum prize for 2015. She has also served as Chair of the E-MRS 2012 (Strasbourg) and of the MRS 2015 Fall Meeting (Boston). This year she has been elected Fellow of the MRS for pioneering work in the field of organic (bio) electronic sensors and their use for point-of-care testing. Torsi has authored more than 180 scientific contributions, including papers published in Science, Nature Materials, Nature Communications, PNAS and is co-inventor of several awarded international patents. Her works gathered almost 9300 citations resulting in an h-index of 47 (Google scholar). She has given more than 150 invited lectures, including plenary and key notes to international conferences. Awarded research funding comprises several European contracts as well as national and regional projects.

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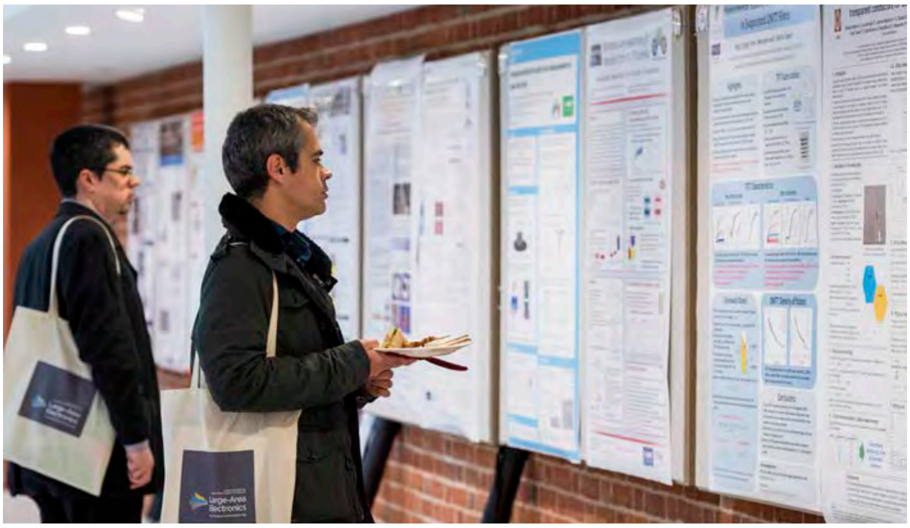

POSTER PRESENTATIONS

Posters will be displayed in the exhibition space.

A drinks reception will be held in this same area on Tuesday 23rd January from 16:30 - 19:00, prior to the gala dinner.

The Programme Committee will award a prize to the best poster. The prize is generously supported by our gold sponsor.

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The runners-up will receive vouchers from Cambridge University Press who are supporting this event.

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Poster presenters are requested to make sure that their poster is displayed on the appropriate board before lunch on Tuesday 23rd January, and removed at the conclusion of the lunch break on Wednesday 24th January

	Authors	Title	Institution
1	Pelumi W. Oluwasanya, Luigi G. Occhipinti	*Pervasive PM_{25} detection and monitoring: capacitive method*	University of Cambridge
2	Arfan Ghani	*Low power sensing and integrated healthcare system within smart cities*	Coventry University
3	Kai Zhang	*Roll-to-Roll manufacture of OTFT sensors based on PVDF*	University of Oxford
4	Emre Ozer	*PlasticArmPit: Accelerating the development of flexible integrated smart systems*	ARM
5	Julianna Panidi, Alexandra F. Paterson, Dongyoon Khim, Zhuping Fei, Yang Han, Leonidas Tsetseris, George Vourlias, Panos A. Patsalas, Martin Heeney, and Thomas D. Anthopoulos	*High Mobility Organic Semiconductors for Transistors*	Imperial College London, National Technical University of Athens, Aristotle University of Thessaloniki, King Abdullah University of Science and Technology (KAUST)
6	Xiang Cheng, Yoann Courant, Mohammed Firas, Arokia Nathan	*Modelling of TFT s-parameters and extraction of cut-off frequency*	University of Cambridge
7	Hanleem Lee, Felice Torrisi	*Molecular Engineering For Developing MoS2 Thin Film Field Effect Transistor*	University of Cambridge, Sungkyunkwan University
8	Shiv Bhudia, Ana Beaumont, Xiang Chen, Pedro Barquinha, Arokia Nathan	*Static and dynamic modelling of oxide TFTs with high-κ multilayer dielectrics*	CENIMAT/I3N Universidade Nova de Lisboa
9	Joe Troughton	*Advances in Low Temperature IGZO TFT preparation for large area flexible electronics*	Durham University
10	Bowen Zhang, Judith Driscoll	*Preparation transfer and characterization of very high quality freestanding oxide thin films*	University of Cambridge
11	Ahmed Y. Ismail, Thomas D. Anthopoulos, Martyn A. McLachlan	*Thermally evaporated nickel oxide as charge transport layer for photovoltaics*	Imperial College London, Zagazig University
12	Lana Lee, Dr Robert Hoye, Boadan Zhao, Dawei Di, Mari Napari, Judith Driscoll	*Atmospheric pressure chemical vapour deposition of p-type NiO_x* for perovskite solar cells	University of Cambridge
13	Donal O'Sullivan	*New approaches to the development and manufacture of power harvesting and flexible electronics devices*	Sherkin Technologies
14	Canlin Ou, Abhijeet Sangle, Anuja Datta, Sohini Kar-Narayan	*Turning up the heat on energy harvesting: flexible printed thermoelectric nanogenerators*	University of Cambridge
15	Constantinos Tsangarides, Arokia Nathan Yoann Courantb Mohammed Firasb	*Modelling of size-effect on thermoelectric parameters of PEDOT:PSS thin films*	University of Cambridge
16	Zakaria Saadi, Simon G. King, Vlad Stolojan, Jose V. Anguita, and S. Ravi P. Silva	*Thermoelectric devices based on carbon nanotubes*	University of Surrey
17	R.D.I.G. Dharmasena, K.D.G.I. Jayawardena, C.A. Mills, R.A. Dorey, S.R.P. Silva	*Triboelectric Nanogenerators – A theoretical framework for the expansion towards large area electronic applications*	University of Surrey
18	C. Banjongprasert, W. Pongsaksawad, A Jak-ra	*Development of Al-Zn Alloy Anodes for Al-Air Battery by Severe Plastic Deformation*	Chiang Mai University
19	Youmna Mouhamad, Eifion Jewell, Justin Searle, Geraint Williams and Trystan Watson	*Charge collection from hybrid metal / metal oxide transparent conductors*	Swansea University

	Authors	Title	Institution
20	M. I. Caupers, J. Leppäniemi, M. Vilkman, L. Pereira, E. Fortunato, R. Martins, M. Smolander	*Optimization of Printed Inverted Organic Solar Cells*	CENIMAT/I3N Universidade Nova de Lisboa, and VTT
21	J.T Carvalho, M. Franco, V. Dubceac, A. Kiazadeh, M. Gall, A. Clausner, A. Garitagoitia Cid, E. Zschech, Elvira Fortunato, R. Martins, L. Pereira	*Printed ZnO nanoparticles for applications in transistors and memory devices*	CENIMAT/I3N Universidade Nova de Lisboa, and Fraunhofer ICTS
22	J. Almeida, J. Leppäniemi, L. Pereira, E. Fortunato, R. Martins, A. Aastalo, M. Smolander	*Fabrication and Functionalization of printed In_2O_3 Thin Film Transistors for Biosensing Applications*	CENIMAT/I3N Universidade Nova de Lisboa, and VTT
23	I.B.Dimov, H. Sirringhaus, K. Franze	*Mechanically compliant devices for long-term peripheral neural Interfaces*	University of Cambridge
24	Stuart Higgins, Alessandra Lo Fiego, Michele Becce, Hyejeong Seong, Christopher Spicer, Molly Stevens	*Combining organic bioelectronics and nanostructures for cell Interfacing*	Imperial College London
25	Robyn Worsley, Daryl McManus, Freddie Withers, Veronica Sanchez-Romaguera, and Cinzia Casiraghi	*Inkjet Printing of Water-based and Biocompatible 2D Crystal Inks on Different Substrates*	University of Manchester
26	Yeonsik Choi	*Advanced printing technique for polymer nanocomposites*	University of Cambridge
27	Jincheng Tong, Amadou Doumbia, Adriana Alieva, Michael Turner, Cinzia Casiragh	*Gas Blow Coating to Control the Crystal Morphology in Thin Films of Organic Semiconductors for use in Large Area Electronic Devices*	University of Manchester
28	Ben Clifford, David Beynon, Chris Phillips, Davide Deganello	*Optimisation of aerosol jet deposition for the development of novel printed electronics devices*	Swansea University
29	Shengyang Chen, Paul Stavrinou, Natalie Stingelin, Ioan Botiz	*Convective self-assembly a versatile tool for assembling and ordering organic/inorganic nanoparticles into hierarchical structures on large areas*	Imperial College London
30	Bahaa Abbas, John Lau, Youmna Mohammad, Eifion Jewell, Justin Searle & Tim Claypole	*A study of the potential for photonic processing of nano copper*	Swansea University
31	Dr Thomas D.A. Jones, Ms Assel Ryspayeva, Dr Jose Marques-Hueso and Professor Marc P.Y. Desmulliez Dr Mohammadreza N. Esfahani, Professor Russel Harris, Professor Robert W. Kay	*Direct metallisation method onto 3-D printed polyetherimide Substrates*	Heriot-Watt University
32	Wenyu Andy Wang, Xia Li, Yan Yan Shery Huang	*Core-shell electrospinning of micro/nano flexible silver fibre*	University of Cambridge
33	B. Notebaert, M. Gaceur, F. Mammeri, N. Battaglini, S. Ammar	*Engineering soft chemistry materials to large area QD-ACTFEL electroluminescence devices*	ITODYS Laboratory
34	C P Watson, E M Lopes, R F de Oliveira, N Alves, J A Giacometti and D M Taylor	*From photo-capacitance to optical sensors and imaging arrays*	Bangor University
35	Parikshit Sahatiya and Sushmee Badhulika	*Flexible MoS_2 (n)-CuO (p) based piezotronic diode for active analog frequency modulator and broadband photodetector*	Indian Institute of Technology Hyderabad
36	H. M. Thirimanne, K. D. G. I. Jayawardena, C. A. Mills, S. R. P. Silva	*Inorganic-organic hybrid X-ray detectors as wearable real-time Dosimeters*	University of Surrey
37	Wenbo Zhu, Jing Wang, Zhaoxia Zhou, Changqing Liu	*Self-propagating bonding process to enable large area electronics assembly*	Loughborough University

1: Pervasive $PM_{2.5}$ detection and monitoring: capacitive method

Pelumi W. Oluwasanya*, Luigi G. Occhipinti

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ABSTRACT

Bad air quality has been linked to various cardiovascular conditions by several epidemiological studies. Particulate Matter (PM) has been found by some of these studies to be more correlated to the health problems than other classes of pollutants. $PM_{2.5}$ (fine particles), is particularly more dangerous as it can penetrate deep into the human body. Regulatory efforts to mitigate personal exposure must rely on a knowledge of spatio-temporal variability of air pollution to evolve efficient tailor-made solutions for different environments. Further, user compliance and acceptance for mobile devices requires that eligible techniques be non-intrusive. This requirement has been difficult for most current methods to satisfy as their readouts are usually desktop equipment due understandably, to the very low signals presented by fine particles.

We present a capacitive method for continuous $PM_{2.5}$ monitoring. Particles of different sizes fed into a controlled inlet are first discriminated into size classes by thermophoresis. Particle flow trajectory is then intercepted by sensors corresponding to their size class. Simulation results show an unmistakable signal with interdigitated electrodes with five comb fingers. Sensor fabrication is done by conventional photolithography processes. Prototype device (out of scale) is shown in Figure 1(a). The electrode surface can be adapted for particle capture and release. Further, we show by a proof of concept experiment that the signal is large enough to be measured by a simple multi-meter (Figure 1(b)). The device is cost effective and miniaturized. Further work is currently being done to develop and optimise the electrodes fabrication and miniaturized frontend readout electronics using a capacitive Application Specific Integrated Circuit (ASIC).

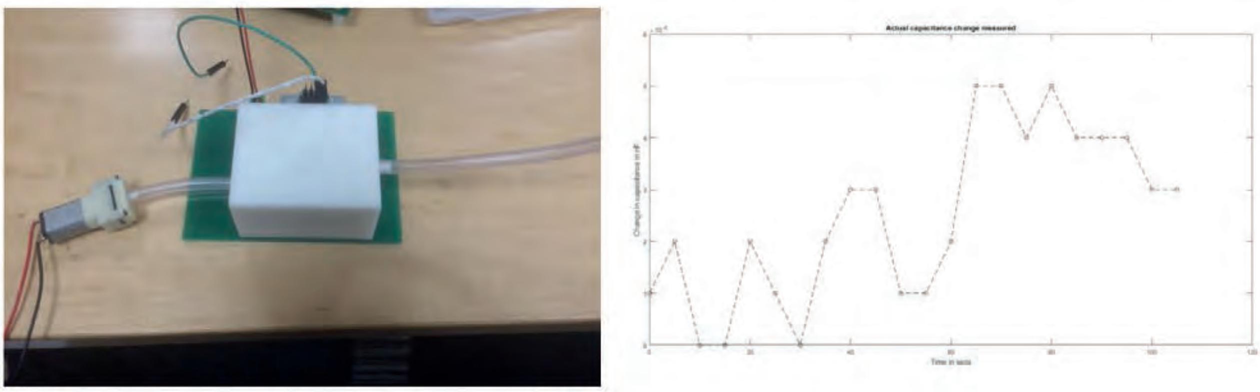

Figure 1 – (a) Prototype sensor and housing with lid closed. (b) Measured capacitance changes due to particles.

BIOGRAPHY

Pelumi is a PhD student at the University of Cambridge. He is supervised by Dr Luigi Occhipinti, with Dr Tawfique Hassan and Prof. Rod Jones as co-supervisors. His current research interests include air quality monitoring, and sensor design and development. He has a BSc(Hons.) degree in Engineering from Olabisi Onabanjo University, an MSc in Signal Processing from The University of Edinburgh and has recently completed a Master of Research(MRes) degree in Sensor technologies as part of the Sensors Centre for Doctoral Training(CDT) programme at the University of Cambridge.

2: Low power sensing and integrated healthcare system within smart cities

Arfan Ghani
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ABSTRACT

My research interests lie at the intersection of smart environments and cyber-physical systems, in particular building hardware and software architectures to support large-scale analytics on pervasive sensing devices, in context to healthy living within smart cities. Modern cities are alive with sensors, including but not limited to infrastructure cameras, vehicles, smartphones, and wearable devices. Realizing our grand plans for smart cities of the future necessitates a radical transformation in the way these devices perceive and interact with the environment. My expertise lies in leveraging city-wide neuromorphic sensing devices, towards developing a multimodal data integration and interpretation framework. Such a synergy has the potential to change the way our cities function; from optimizing transportation to provisioning city services, and further to pervasive healthcare and monitoring. My research enables ubiquitous devices to expand their role and innovate new services, ranging from large-scale neuromorphic models, and artificial vision to pervasive sensing. The hardware/software I have developed provide a generic neural fabric whereas the long term objective of my research is to facilitate the transition from the current lab-based experimental system to a useable wireless “plug and play” devices for particular applications such as IoT based low power sensor nodes, pervasive healthcare monitoring, and big data analysis. In this presentation/poster I will talk about my previous research projects and current activities as stated in Fig. 1.

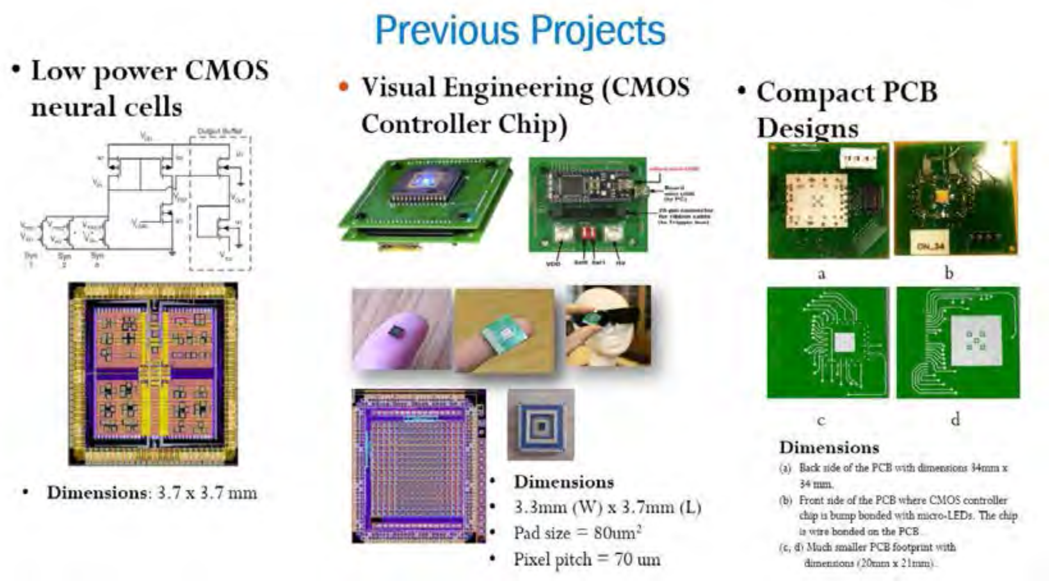


Fig. 1

BIOGRAPHY

Dr. Arfan Ghani is currently employed as Senior Lecturer within School of computing, Electronics and Maths at Coventry University. His background is in microelectronics and research focus is the creation of neuro inspired intelligent systems/technologies for healthcare. His work experience involves working with Danish Technical University, Newcastle University, University of Ulster, Intel Research Cambridge and Vitesse Semiconductors, Denmark. He has developed several low power microelectronic chips for neural rehabilitation and retinal prosthesis in the past and has been exploring the design of neuro-inspired devices on number of research projects funded by UK/EU research councils (EPSRC, EU-FP7, KTP and German Aerospace Centre). Dr. Ghani is a Chartered Engineer, SMIEEE and Fellow HEA.

3: Roll-to-Roll manufacture of OTFT sensors based on PVDF

ABSTRACT

The high flexibility and relatively low cost of organic electronics are gradually providing more possibility for their application. Compared with conventional silicon based electronics, organic electronics have relatively low lifetime and processor speed, but they are more promising in the market of wearable and flexible devices, for example, wearable health care device, simple memory devices and flexible displays. In recent years, there are some flexible and wearable sensors developed, e.g. skin-touching sensors embedded in a sports suit can detect the change of heart rate, blood pressure, ion concentration of perspiration, and infrared radiation from human body.

In most OTFT based sensors made to date the semiconductors are employed directly to detect analytes: (1) Lifetime of this design is short due to the low stability of organic semiconductors; (2) Any modification for selectivity needs to be compatible with the semiconductor.

In this project, a novel design of extended floating gate is applied to separate the sensory area from the semiconductor, allowing the organic semiconductor to be covered by a protective layer to avoid degradation. Transistors are manufactured in Oxford Webcoater capable of a Roll-to-Roll process. The principle can be demonstrated for a simple strain sensor, ferroelectric PVDF is spin-coated on the extended floating gate directly to directly act as sensory materials. To evaluate the sensor performance, a diagram of strain current against time is plotted as the strain is changed, stepwise, by bending.

BIOGRAPHY

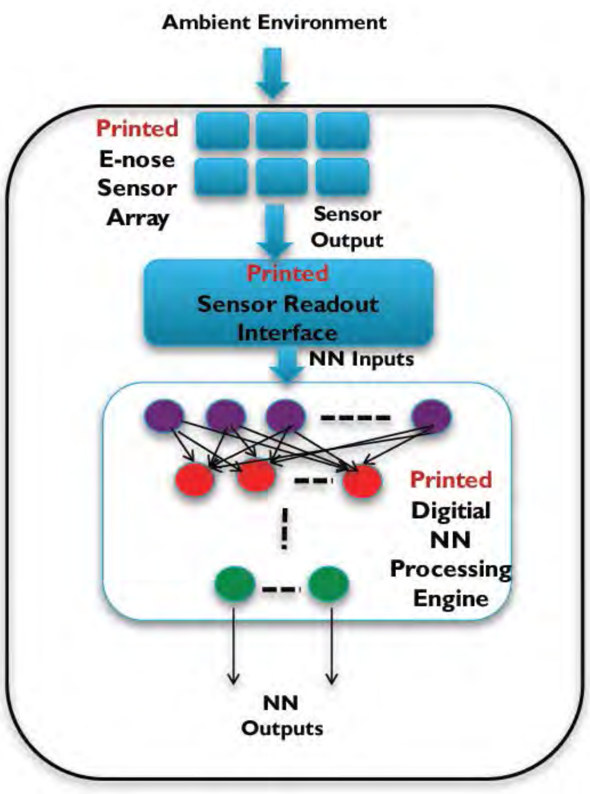
I'm Kai Zhang, 2nd Year DPhil student supervised by Prof Hazel Assender in Department of Materials, University of Oxford. My DPhil project is to use Roll-to-Roll process to develop Organic Thin Film Transistor (OTFT) based sensor for flexible applications. In this group, a well-performed OTFT has been manufactured by large scale Roll-to-Roll process . However, OTFT sensor with organic semiconductor (OSC) are not very stable due to degradation of OSC . The objective of my project is to give a solution to protect OSC without affecting the sensory response, and we have designed an extended floating gate architecture for OTFT to facilitate protective encapsulation in my first year. Currently, devices made with this idea have been made and tested, and it is very possible to create a very stable OTFT sensor in future.

4: PlasticArmPit: Accelerating the development of flexible integrated smart systems

ABSTRACT

Future flexible electronic devices will be highly integrated, diversified, and interact with the ambient environment by performing intelligent activities such as fingerprint, vein and odour recognition. These devices will require a flexible high-performance, energy-efficient processor to meet the computational demands of future smart applications. Hence, there is an immediate need for a flexible high-performance energy-efficient processing engine to deliver these devices.

PlasticArmPit proposes plastic Neural Networks (NNs) as the digital processing engine to accelerate the development of flexible integrated smart systems (ISS). The NNs are customised for a specific application, capable of operating in extremely parallel fashion to achieve high performance, and consume low power. The project is the first proposal to pioneer digital hardware NNs as de-facto processing engine of the printed electronics world. It will demonstrate this disruptive concept with a prototype consisting of flexible e-nose sensor array coupled with a plastic NN that can be worn under the armpit.



PlasticArmPit Proof-of-Concept flexible ISS prototyp

PlasticArmPit is a 2.5-year collaborative R&D project funded by InnovateUK Emerging & Enabling Technologies programme, and started in October 2017. The project partners are Arm (lead), PragmatIC, Unilever and University of Manchester. The project will develop a disruptive processing engine in the form of digital NN in plastic that will be the key to realising the predicted flexible ISS as well as addressing the main technological challenge in unlocking the flexible intelligent IoT market. The focus of the project will be the development of a plastic NN, a flexible ISS prototype and its demonstration in a challenging human malodour perception environment, addressing an important problem in deodorant industry.

BIOGRAPHY

Emre Ozer is a Principal Research Engineer and works in Arm since 2005. He received his PhD from North Carolina State University in 2001. His research interests are energy-efficient architectures, flexible electronics/ICs, fault tolerance, neural networks and biocomputing. He has published over 50 international conference/journal articles, and holds over 20 US patents. He is the technical coordinator of the PlasticArmPit project.

5: High mobility organic semiconductors for transistors

Julianna Panidi[1], Alexandra F. Paterson[1], Dongyoon Khim[1], Zhuping Fei[2], Yang Han[2], Leonidas Tsetseris[3], George Vourlias[4], Panos A. Patsalas[4], Martin Heeney[2], and Thomas D. Anthopoulos,[1,5]
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[2] Department of Chemistry & Centre for Plastic Electronics, Imperial College London, United Kingdom
[3] Department of Physics, National Technical University of Athens, Greece
[4] Department of Physics, Laboratory of Applied Physics, Aristotle University of Thessaloniki, Greece
[5] Division of Physical Sciences and Engineering, King Abdullah University of Science and Technology (KAUST), Saudi Arabia

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ABSTRACT

The tremendous demand for organic thin film transistors (OTFT) with improved performance has been the driving force in the development of new semiconductor materials with enhanced charge transport properties. A generic approach for improving OTFT characteristics, such as charge carrier mobility, stability, contact resistance and operating frequency, is through the use of molecular dopants[1]. Lewis acid materials, such as the tris(pentafluorophenyl)borane [$B(C_6F_5)_3$], have been shown to result in effective doping via the formation of Lewis acid-base adduct formation. Herein, we show that admixing of $B(C_6F_5)_3$ into several organic small-molecules, polymers and semiconducting blend systems has a remarkable impact on the hole transport of all systems, with the small-molecule:polymer blends exhibiting the most remarkable performance enhancement, as shown in Fig. 1[2]. In particular, for blends comprised of diF-TESADT:PTAA, C_8-BTBT:C_{16}IDT-BT and TIPS-pentacene:PTAA, maximum hole mobility values of 8, 11, 3.7 cm^2/Vs, respectively, are obtained highlighting the generic nature of the proposed doping approach. Detailed analysis of the effects of doping reveals that addition of $B(C_6F_5)_3$ improves the blend layer crystallinity with evidence of molecular terracing similar to those reported in single crystals of the small molecule system. The present work highlights a simple and generic approach towards OTFT performance enhancement.

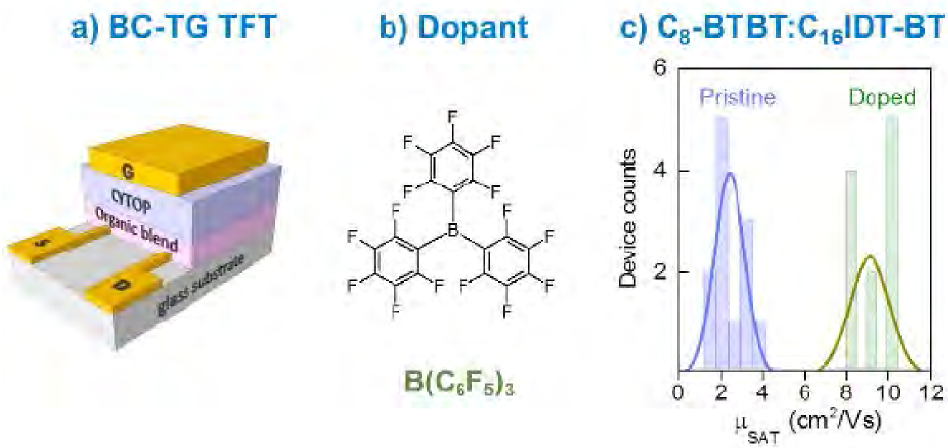

Fig. 1. a) Bottom-contact, top gate (BC-TG) transistor architecture, b) chemical structure of the dopant $B(C_6F_5)_3$, and c) hole mobility of pristine vs doped OTFTs for the C_8-BTBT:C_{16}-IDTBT blend.

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[2] J. Panidi, A. F. Paterson, D. Khim, Z. Fei, Y. Han, L. Tsetseris, G. Vourlias, P. A. Patsalas, M. Heeney, T. D. Anthopoulos, Advanced Science 2017, 1700290.

BIOGRAPHY

Julianna Panidi is a Postgraduate student in the Experimental Solid State Physics group at the Blackett Laboratory of Imperial College London and a member of Plastic Electronics CDT. She is working under the co-supervision of Prof Thomas Anthopoulos and Prof Martin Heeney on the doping of organic semiconductor materials for transistor applications.

Julianna received her Master's Degree in Nanomaterials and Nanotechnology from the Pierre and Marie Curie University in France and a Master of Research in Plastic Electronics from Imperial College London. She holds also a Bachelor's Degree in Material Science from the University of Patras, Greece.

6: Modelling of TFT s-parameters and extraction of cut-off frequency

Xiang Cheng[a], Yoann Courant[b], Mohammed Firas[b], Prof. Arokia Nathan[a]
[a] University of Cambridge, Cambridge, UK
[b] Infiniscale, Grenoble, France

ABSTRACT

One of the important parameters that limits TFT analogue performance is the unity-gain frequency (f_T), as it has a direct bearing on the gain-bandwidth product of amplifiers or filters which in turn limits the range of applications of the technology. The general way of extracting a transistor's f_T through a network analyzer cannot normally provide enough accuracy. This is due to the inaccuracies both in modeling the TFT small signal parameters and their measurements.

Here, based on our previous results on a more accurate small signal model for TFTs, we've further examined the analytical expression of relevant s-parameters and f_T extraction procedure and derived simpler expressions for parameter fitting and extraction that reduce errors from measurements. A simplified current gain expression based specifically on TFT parameters is derived and the prevailing s-parameters, namely S_{11} and S_{21}, are modeled with dominant zeros and poles for parameter fitting. Better and cleaner overall current gain curve is achieved which overcomes the difficulty of modelling small signal performance at low frequencies and in the case of high impedance devices.

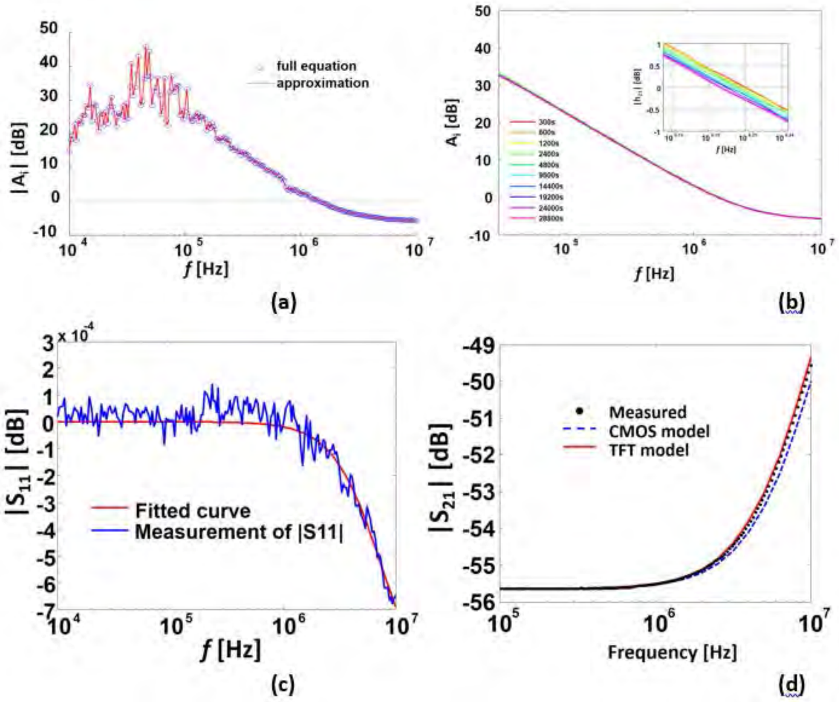

Figure 1 (a) Comparison of extracted current gain using simplified and full expressions (b) current gain after parameter fitting in a bias stress test (c) fitting of $_{11}$ (d) fitting of $_{21}$

BIOGRAPHY

Xiang Cheng received his bachelor degree in electronic engineering from Shanghai Jiao Tong University in 2013. During the degree, he did his final year project for AMOLED pixel circuit design and simulation. He's currently a Ph.D student under supervision of Prof Arokia Nathan at University of Cambridge, working on TFT simulation models, frequency responses and analogue circuit designs.

7: Molecular engineering for developing MoS_2 thin film field effect transistor

Hanleem Lee[1,2], Felice Torrisi[1]*
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2 Department of Energy Science, Sungkyunkwan University, 2066 Seoburo, Jangan-gu, Suwon, Gyeonggi-do, 440-746, Republic of Korea.

ABSTRACT

Two dimensional transition metal dichalocoganizes (TMD) have attracted increasing interest in several different fields due to its outstanding optical and electronic properties. Especially, solution process exfoliation of TMD have been intensively explored to demand low cost/large area flexible electronics with high end technology. Despite recent achievements in the production of TMD, the quantitative exfoliation of TMD into pristine single layer TMD has remained one of the main challenges in developing practical devices. The biggest problem of exfoliation is phase changes and harsh condition create amorphous region. Here, we exfoliate TMD using organic molecule without any metal component include organometalic compound. We choose diazomium salt because of mild reactivity. Diazonium salt selectively attached on edge side due to strain induced higher reactivity. Nevertheless diazonium doesn't change the configuration of MoS_2 in center, leading to reduce fraction of IT phase and amorphous area, its functional group enable to exfoliate MoS_2 by intermolecular force modulation. Finally, we fabricate thin film FET with edge functionalized MoS_2 and it shows high mobility and good on/off ratio even without post annealing. We believe that polarity of COOH functional group facilitate not only exfoliation by increased electrostatic repulsion force between MoS_2 sheet, but also fast electron transport in MoS_2 based thin film FET by strong H bonding between nanosheets.

BIOGRAPHY

Dr Hanleem Lee is an Academic Visitor to the Cambridge Graphene Centre and the Engineering Department of Cambridge University.She is in the Nanomaterials and Spectroscopy Group in the Electrical Engineering Division. She is from Sungkyunkwan University, Suwon ,Korea.

8: Static and dynamic modelling of oxide TFTs with high-κ multilayer dielectrics

Shiv Bhudia[1], Ana Beaumont[1], Xiang Chen[2], Pedro Barquinha[1], Arokia Nathan[2]
[1]I3N|CENIMAT, Department of Materials Science, Faculty of Science and Technology, Universidade NOVA de Lisboa and CEMOP/UNINOVA, Campus de Caparica, 2829-516 Caparica, Portugal
[2]Engineering Department, University of Cambridge, Cambridge, CB3 0FA, United Kingdom

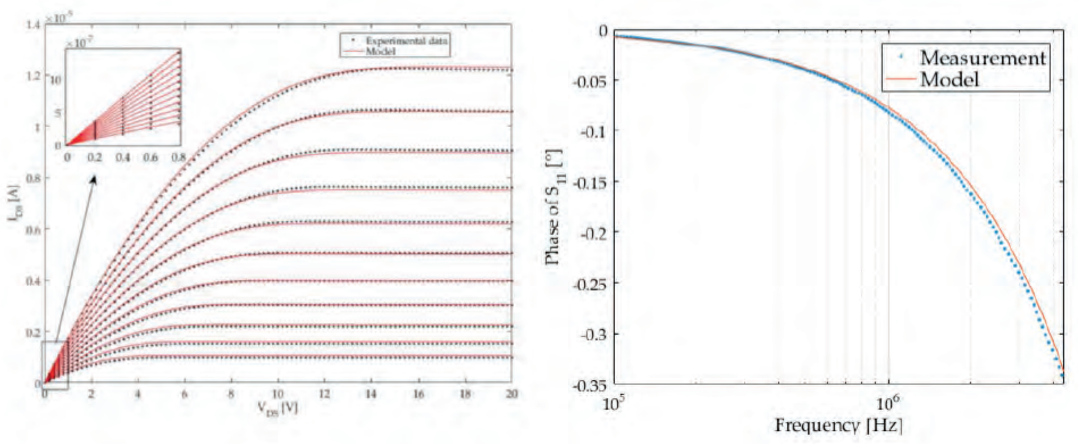
ABSTRACT

Transistor models are of utmost importance for device behaviour prediction and circuit design. Physical modelling has the advantage of being based on parameters directly related with device physics. This allows to gain insight on the underlying mechanisms during the analysis and parameter extraction phase. However, the extraction methods may not consider possible non-idealities of the devices, which can lead to modelling issues when working with new materials, novel thin-film transistor (TFTs) structures or low-temperature processed devices.

In this work a compact model was developed and applied to indium-gallium-zinc oxide (IGZO) and zinc-tin oxide (ZTO) TFTs using a multilayer high-κ dielectric based on Ta_2O_5 and SiO_2, with annealing temperature of only 180 °C. Devices were fabricated at I3N|CENIMAT (Portugal) and characterization/modelling was carried out at Electrical Engineering Division of University of Cambridge, within the BET-EU project (GA 692373).

Two DC models were developed, the main difference being the contact resistance extraction using the classic transmission-line method or a more effective procedure based on MOSFETs with non-ideal behaviour that considers the possible bias dependency of the parameter.

A dynamic small signal model was also developed, based on conventional FET models and its validity was studied with the help of S-Parameters and capacitance-voltage characteristics (C-V) characteristics.



(a) (b)

Figure 1 – Experimental and simulated characteristics of IGZO TFTs using static and dynamic compact models: a) output characteristics; b) phase of S_{11} parameter.

The great advantage of the developed models, in both static and dynamic aspects, is the low number of parameters required to be extracted physically with good fitting results. The compact models developed here can be extended to a broad range of other device families and can empower users to carry out not only analysis of device behaviour but also expedient design of circuits for system realization.

BIOGRAPHY

Pedro Barquinha, Ph.D. in Nanotechnologies and Nanosciences (2010) and Assistant Professor at FCT-UNINOVA since 2012. His work in transparent electronics spans many areas, from the design, deposition and characterization of multicomponent oxides, fabrication and characterization of oxide TFTs, to their integration in analog/digital circuits on flexible substrates. He is co-author of more than 130 peer-reviewed papers (h-index=34, as October 2017), books and book chapters on this area. In 2016 he got an ERC Starting Grant (TREND) to advance oxide electronics towards the nanoscale area.

9: Advances in low temperature IGZO TFT preparation for large area flexible electronics

ABSTRACT

Indium Gallium Zinc Oxide (IGZO) is one of the leading metal oxide semiconductor in the world of large area electronics. A great deal of work has been put into optimisation of IGZO for use as driving and switching electronics in back planes, leading to commercially available display technologies leveraging IGZO's large area uniformity and relatively high mobilities. However, this work has focused on applications with a high thermal budget, particularly processing on glass, seeing temperatures over 500°C. This ignores a very large sector of the large area electronics market – flexibles.

Flexible electronics require quite different processing conditions due to the much lower thermal budget of the plastic substrates, which are only just starting to be explored. When processing IGZO devices on flexible substrates, with maximum temperatures often not in excess of 200-300°C, treatments developed for the optimisation of display applications, such as high temperature spike annealing, cannot be applied. Instead, more gentle treatments, such as medium/low temperature anneals for extended times, are needed to approach the same performance as is achieved with high temperature processing. These treatments are needed primarily to reduce the density of defects, both within the bulk and at the interfaces of the materials.

Here we present the latest findings in our work, looking at the technical challenges surrounding low temperature IGZO processing. This builds on the work published in Appl. Phys. Lett. 110, 011903 (2017), in which significant improvements in TFT KPIs where achieved with a low temperature anneal, due to densification of the IGZO layer. The latest work expands on this by considering the interaction of the IGZO semiconducting layer with the surrounding materials, both at the interface between these materials and the bulk of each layer. This includes the application of novel experimental techniques to add more fundamental understanding of device performance, and performance results of commercially produced devices to show the true effect of treatments on device performance.

BIOGRAPHY

Joe Troughton is a 3rd year PhD student in the Department of Physics, Durham University, supervised by Prof. Del Atkinson. He studied physics in Durham, gradating in 2013 with an MPhys. As part of the PhD process Joe spent two years working on a Knowledge Transfer Partnership with PragmatIC Printing Ltd., who now sponsor his ongoing work.

10: Preparation, transfer and characterization of very high quality, freestanding oxide thin films

Bowen Zhang*, Professor Judith L. MacManus-Driscoll
* Department of Materials Science and Metallurgy, University of Cambridge, CB3 0FS

ABSTRACT

Oxides have a very wide range of physical properties, from insulating dielectrics to semiconductors to superconductors. Their quality is often not optimum if grown at temperatures which are compatible with flexible substrates. A way to overcome this problem is to grow oxide films at high temperatures (500-700°C) on single crystal oxide substrates and then to transfer the films to more practical substrates.

In this work, we applied a new approach to transfer very high quality epitaxial oxide thin films to arbitrary substrates. CeO_2 thin films were grown epitaxially on the water-soluble $Sr_3Al_2O_6$ buffer layer on single crystal $SrTiO_3$. By etching the $Sr_3Al_2O_6$ buffer layer in water, the thin films could be removed and then transferred to a polymer membrane and then onto Si wafer. This approach preserved the integrity and composition of the film very well.

BIOGRAPHY

Bowen is a 2nd year PhD student in Professor Judith Driscoll's research group since 2016. Previously he got his BSc in materials chemistry at Peking University (China) and MSc in chemistry at New York University (USA). He is currently working on ionic conducting oxide thin film via pulsed laser deposition, and he is also interested in investigating the structural insight of ionic conduction at the interface.

11: Thermally evaporated nickel oxide as charge transport layer for photovoltaics

Ahmed Y. Ismail,[1,2] Thomas D. Anthopoulos,[3,4] Martyn A. McLachlan[1]
[1]Department of Materials, Imperial College London, UK
[2]Department of Physics, Zagazig University, Egypt
[3]Department of Physics, Imperial College London, UK
[4]Division of Physical Sciences and Engineering, KAUST, Saudi Arabia

ABSTRACT

Interfacial layers including transition metal oxides (TMOs), organic materials, and inorganic-organic hybrids have significantly contributed to the improved performance and stability of organic and perovskite photovoltaics. TMOs have been engaged as charge transport layers, due to the formation of Ohmic contact with electrodes, enhancement of charge selectivity, and device stability [1]. Remarkably, nickel oxide (NiO) has drawn great attention as charge transport layer (CTL) for optoelectronic applications due to its high optical transparency, low cost, and environmental stability. Significant research effort has been made toward the development of solution-processed NiO [2]. However, the inhomogeneity of surface morphology limits the suitability of solution-processing method for large-area applications. Thermal evaporation is capable of depositing highly uniform layers with precise thickness control, allowing this interesting material to be studied in devices [3].

Here, we report on a novel deposition route for NiO, which highlights its potential as a CTL for large-area optoelectronic applications. Key structural, optical, and morphological properties of evaporated NiO films are investigated using complementary characterization techniques including; X-ray photoelectron spectroscopy, UV-Vis spectroscopy, and atomic force microscopy. We demonstrate evaporated NiO of varying thickness incorporated into bulk heterojunction OPV devices comparing performance characteristics with other oxide species and organic material (PEDOT: PSS). Through careful optimization of the film thickness and deposition conditions we investigate the role of this CTL with a variety of organic active layer composition and extend the work to perovskite solar cells.

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[3] Vishal, S., Gang, L., Yan, Y., Chih-Wei, C., Yang, Y. Transition metal oxides as the buffer layer for polymer photovoltaic cells. Applied Physics Letters, 2006, 88, 073508.

BIOGRAPHY

Ahmed is a PhD student at department of Materials, Imperial College London. He received his BSc in Physics & chemistry and MSc in physics from Zagazig University, Egypt. He is awarded the Egyptian Government PhD Scholarship.

12: Atmospheric pressure chemical vapour deposition of p-type NiO_x grown at 350ºC for perovskite solar cells

Lana Lee*, Dr Robert Hoye*‡, Baodan Zhao‡, Dr Dawei Di‡, Dr Mari Napari*, Prof Judith MacManus-Driscoll*
Department of Materials Science*, Department of Physics‡, University of Cambridge

ABSTRACT

Nickel oxide (NiO_x) is a wide band-gap p-type semiconductor that has recently attracted attention as a stable hole-transport/electron blocking layer in inverted lead-halide perovskite solar cells, demonstrating power conversion efficiencies of over 17%. However, the highest-performing NiO_x hole transport layers have been synthesized using batch processes. Atmospheric pressure chemical vapour deposition (AP-CVD) is a method that can synthesise high-quality oxide films with high throughput on an industrial scale, essential to achieve commercialisation. We report the growth of NiO_x by AP-CVD. NiO_x growth rates of 0.025 nm/s and a growth per cycle (GPC) as high as 2 nm/cycle are achieved, an order of magnitude higher than vacuum based atomic layer deposition. NiOx films grown at 350ºC are phase pure and crystalline, with a grain size of 30 nm and < 1 nm roughness on silica substrates measured by atomic force microscopy. In lead-halide perovskite solar cell devices we demonstrate a champion efficiency of 15.9% without hysteresis, exceeding the performance of control devices on PEDOT:PSS and highly competitive with the best literature devices. To understand the properties of the films giving rise to the excellent performance in devices we characterise the NiO_x surface chemistry using X-ray photoemission spectroscopy and study the defect chemistry of the films using photoluminescence spectroscopy. Furthermore, through electrochemical impedance spectroscopy, X-ray diffraction and atomic force microscopy, we will demonstrate the effect of annealing under air, inert gas and vacuum on the electrical and structural properties of the films. We provide understanding about how and why the device performance is excellent.

BIOGRAPHY

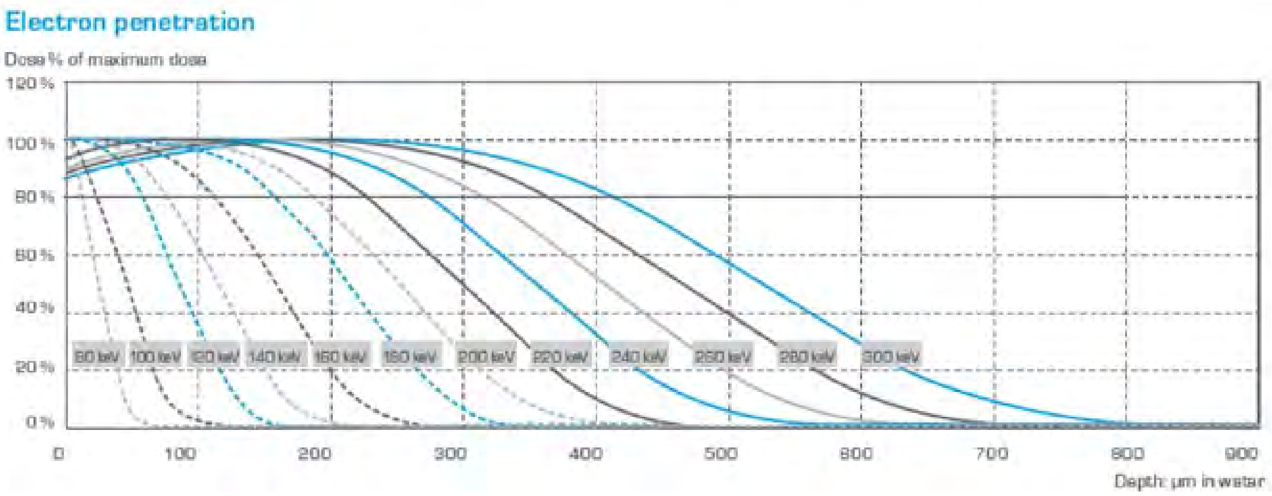
I studied for my undergraduate degree at Imperial College London, where I gained an MSci in Chemistry in 2014. I completed my Master's thesis on the 'spectroscopic and optoelectronic properties of semiconductor sensitised solar cells' supervised by Dr Saif Haque. I am now studying for a PhD in Materials Science as part of the EPSRC Centre for Doctoral Training in New and Sustainable Photovoltaics, where I research p-type oxides as hole transport layers in solar cells and the development of new bismuth-based non-toxic absorber materials for solar cells.

13: New approaches to the development and manufacture of power harvesting and flexible electronics devices

ABSTRACT

Key manufacturing processes involved in the manufacture of flexible packaging and labels for the fast-moving consumer goods sector are surface treatment, printing (conventional and digital presses), converting and finishing. Enabling technologies for these processes include atmospheric plasma and low energy electron beam. Atmospheric plasma is applied in the pre-treatment of substrates such as paper and polymer films, to adjust the surface energy/chemistry leading to the improvement in the adhesion of inks, coatings and adhesives to the substrate. Electron beam (EB) curing enables the rapid curing of inks and coatings, which can also be formulated for food safe packaging applications.

Recent advances in EB curables have enabled the investigation of new approaches to the assembly and manufacture of flexible circuits. We will present case studies which demonstrate the efficacy of these approaches, along with results from the evaluation of the performance of these samples.



BIOGRAPHY

Donal O'Sullivan is an electronic engineer who has worked in the research, development, and commercialization of embedded mechatronic systems, complex sensors, and scientific instrumentation for over 20 years. In this time, he has delivered solutions for applications in the automotive, semiconductor, and solar sectors. Currently Managing Director of Sherkin Technologies, his role includes the investigation of applications for atmospheric plasma and electron beam technologies in the development of cost-competitive and reliable flexible electronics devices.

14: Turning Up the Heat on Energy Harvesting: Flexible Printed Thermoelectric Nanogenerators

Canlin Ou, Abhijeet Sangle, Anuja Datta, Sohini Kar-Narayan
Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge CB3 0FS, UK.

ABSTRACT

Compared with traditional energy sources, harvesting waste heat from the environment into usable electricity by means of the thermoelectric generator is predicted as one of the most promising renewable energy solutions in the future. Thermoelectric generator can also be easily scaled down to charge 'small power' applications such as wireless electronics and wearable devices.

In this work, a flexible and robust thermoelectric nanogenerator (ThENG) based on a novel hybrid organic-inorganic nanocomposite structure for thermoelectric energy harvesting applications has been successfully fabricated via a cost-effective, scalable and low-temperature aerosol jet printing (AJP) technique with the combination of our in-house nanocrystal fabrication methods. The flexible thermoelectric nanocomposite and nanogenerator fabrication processes developed in this project include the nanocrystal synthesis, nano-ink processing, AJP of thermoelectric nanocomposite, and final thermoelectric nanogenerator fabrication.

Nanostructured and micro-sized Bi_2Te_3 and Sb_2Te_3 were firstly prepared by various fabrication methods e.g. hand grinding, ball milling, and solvothermal synthesis. Then, these thermoelectric nanocrystals were dispersed into different water or organic-based solvents to prepare printable inks for the subsequent AJP process. By integrating high Seebeck coefficient and high electrical conductivity Bi_2Te_3 and Sb_2Te_3 with low thermal conductivity organic polymers, the resulting figure of merit could be optimised. Different loading weight percentage of Bi_2Te_3 and Sb_2Te_3 in polymer matrix and different thicknesses of thermoelectric nanocomposites were printed onto a flexible polyimide sheet via AJP method. Their morphological, microstructural, and thermoelectric properties were investigated in order to optimise their ink formulation and printing conditions, thereby maximising their final thermoelectric performance.

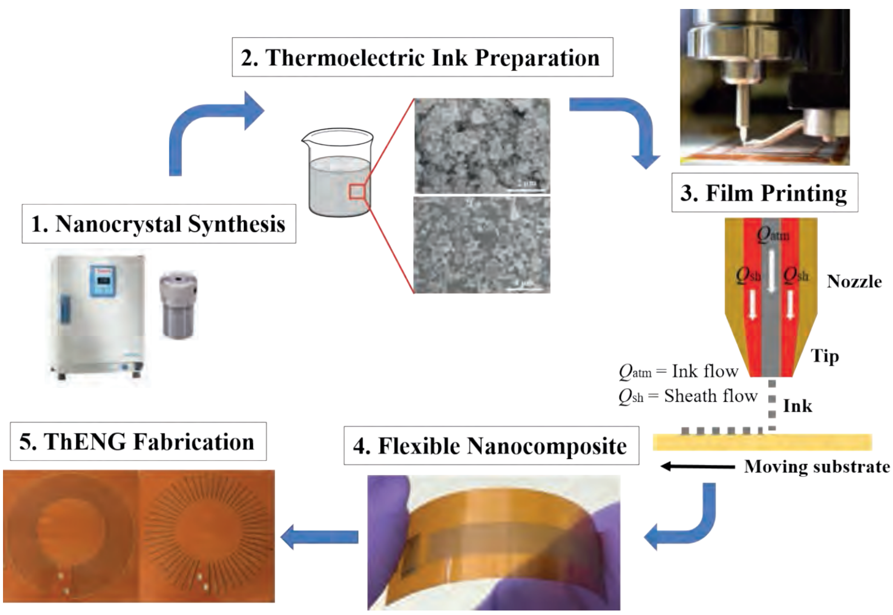


Figure 1. Schematic illustration of the fabrication processes for flexible printed thermoelectric nanocomposites and thermoelectric nanogenerators (ThENGs).

The as-printed organic-inorganic thermoelectric nanocomposites on a flexible substrate can be directly integrated into a ThENG with minimal post-possessing treatment, and the resulting ThENG can be particularly flexible and robust with stable energy harvesting performance. Thermoelectric properties measurements are on-going to determine their thermoelectric performance. The improvement of flexibility also enables potential applications in wearable electronic devices.

BIOGRAPHY

Canlin Ou, is currently a second-year Ph.D. student at the Device Materials Group, Department of Materials Science, University of Cambridge. He is a college member of King's College, and is fully funded by a prestigious China Scholarship Council and Cambridge Trust Scholarship. Prior to taking up his Ph.D. research, he received his MPhil. Degree in Materials Science from University of Cambridge (2016), following his B.Eng. Degree (First Class with Honours) in Materials Science from University of Birmingham (2014) and Central South University in China (2012). His PhD research focuses on "Flexible Printed Thermoelectric Nanogenerators Based on Hybrid Materials". He has been working extensively on the development of a new class of flexible and robust hybrid organic-based nanocomposites for thermoelectric and piezoelectric energy harvesting applications, making them as clean, efficient and competitive energy technologies in the future.

15: Modelling of size-effect on thermoelectric parameters of PEDOT:PSS thin films

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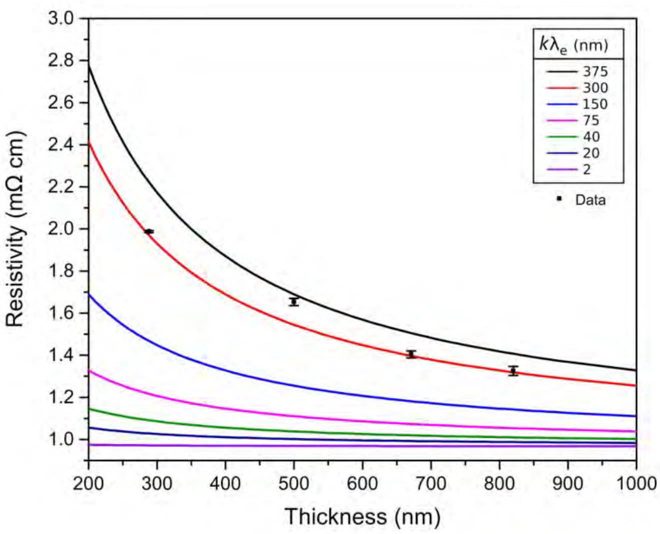
ABSTRACT

PEDOT:PSS thin films have been of great interest in thermoelectrics due to their low-cost processing as well as their promising properties that can be tuned in accordance via different doping mechanisms. Many studies have been contacted on how to enhance its electrical conductivity while not compromising its Seebeck coefficient.[1,2] Nonetheless, no isolated investigation has been contacted on how such properties could change by its thickness. In this study, thin films of PEDOT:PSS are fabricated with the help of an inkjet-printer, forming configurations of four different thicknesses. Both their electrical conductivity and Seebeck coefficient values have been obtained, with which a model was built. Based on this model, it is shown how such inherent properties can change through thickness variation, aiming to find the optimum configuration. The model is inspired by the size-effect theory that was initially developed for metals and then adapted for polycrystalline semiconductors.[3,4]



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BIOGRAPHY

Dr. Constantinos Tsangarides holds a BSc(Hons-2012) degree in Physics from the University of Leeds. Then, he followed further studies in the University of Cambridge where he obtained an MRes(2013) degree in Photonics System Development while being a member of the CDT-IPES (Integrated Photonic and Electronic Systems). Continuing his studies in Cambridge by being granted the EPSRC research scholarship, he recently received his Ph.D degree under the supervision of Prof. Arokia Nathan. Currently, he is a research associate in the HGL group working on flexible/stretchable electronics as well as energy harvesting for hand-held applications.

16: Thermoelectric devices based on carbon nanotubes

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ABSTRACT

Thermoelectric (TE) materials are devices that are capable of converting heat energy directly into electrical energy. An electrical potential across the device is established when a temperature gradient exists across the two ends of the material. The wide application range of TE materials for scavenging waste heat energy includes the sectors of automotive, wearable electronics and power stations. However, current TE devices are composed of semiconductor materials which tend to be toxic, inorganic and expensive to manufacture such as Bismuth Telluride, thus making low-cost production of these devices challenging. In this project, carbon nanotubes (CNTs) are presented as a possible alternative material for TE devices, with additional properties that include mechanical flexibility, low manufacturing cost and non-toxicity when encapsulated. The process of functionalizing and fabricating CNT films and doping them to n-type and p-type semiconductors is investigated. An efficient TE device should feature a high figure of merit (ZT) which requires a high power factor and a low thermal conductivity. Here we investigate two surfactants, Sodium dodecylbenzenesulfonates (SDBS) and Sodium dodecyl sulfate (SDS) to make TE devices. We observe that samples exposed to ambient oxygen show p-type behavior, while the inclusion of Polyethylenimine (PEI) results in n-type behavior [1]. PEI is a polymer known to cause electron scattering in low dimensional structures that can result in low electrical conductivity and low thermal conductivity due to its large, electrically-insulating molecules [2]. The highest output power from our TE devices made of a single pair of p and n-type elements was 71 nW for a 36K temperature gradient.

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Acknowledgements

We would like to thank Dr Christos Melios for electrical conductivity measurements

BIOGRAPHY

Zakaria Saadi, born in Algeria in 1991. He received his Bachelor of Science in Electronics from the University of Surrey in 2014, where he is currently doing a PhD in thermoelectric materials made of Carbon Nanotubes supervised by Prof Ravi Silva and Dr Vlad Stolojan.

17: Triboelectric Nanogenerators – A theoretical framework for the expansion towards large area electronic applications

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ABSTRACT

Triboelectric Nanogenerators (TENGs) are a rapidly expanding energy harvesting technology, exhibiting the potential to generate high power outputs at high efficiency and low cost. The maximum power density for TENGs is reported to be as high as 500 W/m2.[1] These devices are being extensively researched for various large area electronic applications, including energy scavengers and self-powered sensors, demonstrating the potential to become a key component in the internet of things (IoT).[1] However, the lack of knowledge in the working principle of TENGs has impeded the progress in this area, especially in large area applications.[2]

Reaching beyond conventional circuit element based models, this study develops a model to fully describe the working principles of contact mode TENGs, based on Maxwell's equations.[2] The spatial field variations of finitely large charged sheets are used to derive the electric field equations that describe the behavior of current, charge, voltage and power output of TENGs. The experimental TENGs show an excellent agreement with the theoretical predictions, verifying the high accuracy of the model. More importantly, the new model is not limited to planar devices as the previous models, and capable of predicting the outputs of non-planar complex geometries which are commonly found in real life applications. For the first time, a range of device parameters and motion parameters are studied, confirming their effect on the power output. In conclusion, this work provides critical guidance for the design and construction of optimized TENGs for large area applications.

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BIOGRAPHY

Ishara Dharmasena is a PhD student at the Advanced Technology Institute (ATI), University of Surrey, working in Prof. Ravi Silva's research group. He is the recipient of the prestigious MAS award, Hirdaramani award, and the Textile Institute gold medal for academic and research excellence in Sri Lanka. Ishara worked as a Scientist at the Sri Lanka Institute of Nanotechnology (SLINTEC) prior to joining the ATI. His research interests include energy harvesting, triboelectric nanogenerators and wearable electronics.

18: Development of Al-Zn Alloy Anodes for Al-Air Battery by Severe Plastic Deformation

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ABSTRACT

This research aims to study the effects of Severe Plastic Deformation (SPD) on microstructure and properties of an Al-5Zn-0.02In (in wt%). The Al-5Zn-0.02In with a diameter of 20 mm and 100 mm long was pressed in an ECAP die (press angle $\varphi = 90^{\circ}$, $\psi = 20^{\circ}$) using route Bc with 1, 2, 3, and 4 passes. The microstructural evolution was observed using optical microscopy (OM) and scanning electron microscopy (SEM). The SEM images also indicated the fragmentation of AlFeSi intermetallics due to an intensive shear strain from ECAP. Electrochemical impedance spectroscopy (EIS), polarization test, and immersion tests were carried out in a 3.5wt% NaCl solution, and performance test in galvanic system was carried out in an artificial seawater pH 8.83 for 336 hour. It was found that corrosion occurred around AlFeSi interfaces. ECAP led to an intensive refinement of AlFeSi precipitate and resulted in a high performance in aluminium anode, current capacity and %efficiency 2,652.98 Ah/kg and 90.41% in non-solutionize set, 2,971.66 and 99.69% in solutionize set (450ºC for 1 hour). The uniform corrosion of the anode tended to occur as the passivation was reduced with an increase in number of ECAP passes. The high current capacity and %efficiency indicate a high potential for use as an anode for Al-air battery in the future.

BIOGRAPHY

Dr. Chaiyasit Banjongprasert is an Assistant Professor in Materials Science at Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Thailand. In 2015, he received the Thailand Nanotechnology Innovation Award (1st prize), awarded under Her Royal Highness Princess Sirindhorn Debaratanasuda. He is also a member of Materials Research Society (MRS) Thailand.

19: Charge collection from hybrid metal / metal oxide transparent conductors

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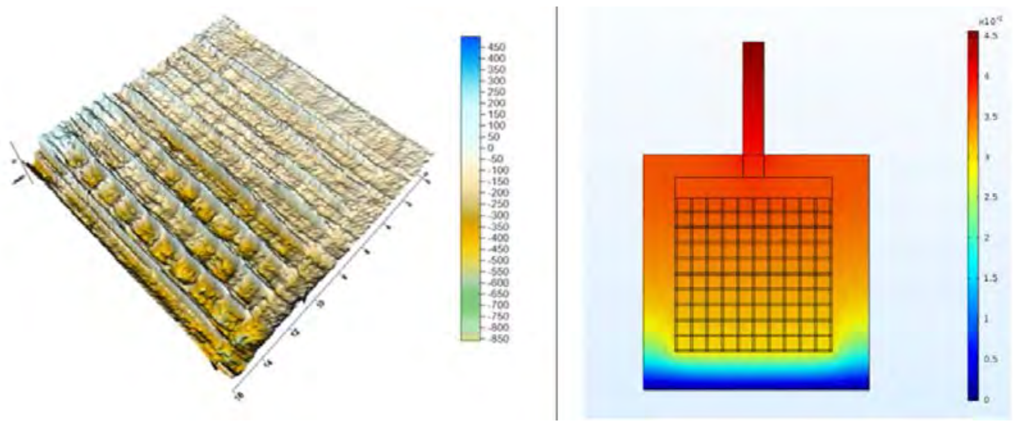
ABSTRACT

The printing of conductive microstructures in order to produce pseudo transparent layers or for conductivity enhancement of transparent layers is well established. The technology has applications in many electro-optic devices such as displays, lighting, smart windows and PV. The success of technology is dependent on the production of conductive patterned micro metal structures which are imperceptible (or at least just perceptible) to human eye which offer high conductivity combined with an underlying transparent conductor. The effectiveness of the metallic network is dependent on the geometric and dimensional characteristics of the structures. Modelling provides an ideal tool for investigating and defining design guidelines for the optimization of the structures such that conductivity is enhanced with minimum impact on the optical transparency. Geometric features and structures can readily be altered in software and their impact evaluated without the need for multiple iterations of design (particularly when an image carrier is required, screen printing screens) and testing. In order for confidence to be created in the models, validation is required at a number of discrete points within the design space. Without such validation, the value of the models in relation to real world scenarios will remain a point of discussion.

Modelling was carried out using COMSOL Finite Element package using an unstructured grid. Boundary conditions and material properties were taken in accordance with the experimental setup of the validation samples. Validation of the models was carried out using area large scanning Kelvin probe (SKP) which allows accurate measurement of surface potential under conditions under a variety of current flow conditions. Screen printed line structures of nano silver on FTO coated glass were used for validation. The experimental measurements and modelling showed good agreement in the overall distribution, Figure 1, of surface potential on the substrate, although absolute numerical agreement was not obtained.

The validation has allowed the the modelling technique to be used effectively and its limitations identified. The study also shows that there is also scope for the development of the SKP technique for examining charge distribution on other larger (50 x 50 mm) scale devices.



(a) Measured potential distribution *(b) Predicted potential profil*

Figure 1 : Measured and predicted surface potential distribution over a x mm x x mm area of the substrate

BIOGRAPHY

Dr Youmna Mouhamad has a Bachelors degree in Chemistry /Physics from Marseille Aix University, an Mphys in Physics from Leeds University and a PhD in polymer physics from Sheffield University. After graduating she joined Swansea University as a research scientist working on the formulation of carbon based inks for various applications including, a piezoresistive ink for large area pressure sensor and a flexible ink for heated garments. Two patents were filed for these innovative technologies. As part of haRFest, a project co-funded by Innovate UK she contributed to the development of a screen printed antenna and tunable capacitor for an energy harvesting device powered by near-field communication. She is currently a Technology Transfer Fellow working on HI-PROSPECT which aims to deliver a high resolution electrostatic ink jet technology for metallization of solar cell.

20: Optimization of printed inverted organic solar cells

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ABSTRACT

The major challenge today for photovoltaic technologies is providing reasonably performing devices at low cost. The goal is to provide access to renewable energy to almost everyone, almost everywhere. Organic Photovoltaic (OPV) devices can typically provide energy for low power applications and can be produced in large quantity with a Roll-to-Roll industrial printing setting in a small-time frame. The main objective of this work is to increase device performance while maintaining process scalability. With that in mind, several variations were introduced (in separate samples), starting from a typical inverted configuration OPV device.

Argon plasma surface treatment proved not to improve device performance. Generally, the longer the plasma treatment is applied, worse is the device performance. Adding a graphene film on top of the electron transport layer showed complete performance deterioration, suggesting that this material is compromising the device behaviour. The aluminium-zinc-oxide and silver coating is functional as cathode and tin oxide works well as an electron transport layer without the need for a plasma treatment, both with indium tin oxide and with the aluminium-zinc-oxide and silver coating (working better with the latter). On the other hand PEDOT:PSS and graphene oxide mix used as hole transport layer compromised device performance, mostly due to film non-uniformity.

To conclude, tin oxide has high potential as an electron transport layer material, changing nothing in the production processes except the material itself. The aluminium-zinc-oxide and silver coating proved to be a good substitute for indium-tin-oxide, working well with both zinc oxide and tin oxide. This material also changes nothing in terms of Roll-to-Roll processing besides the material itself.

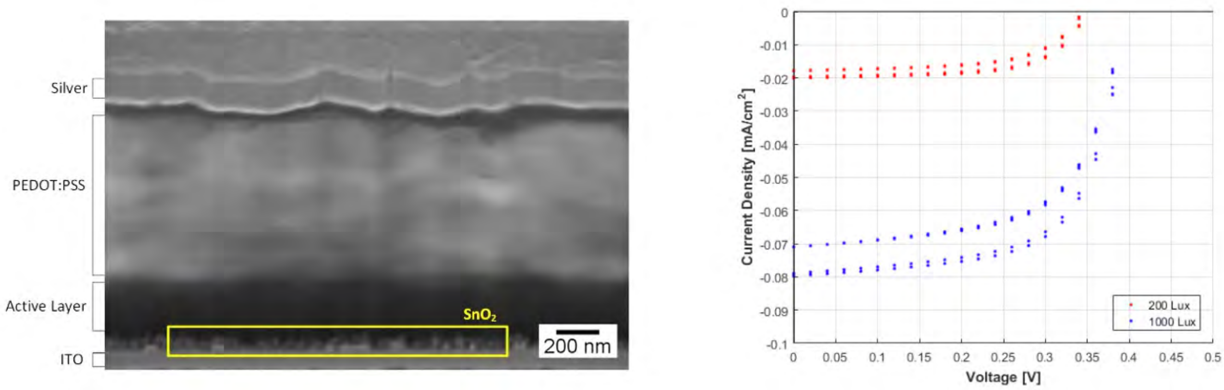

Figure 1: SEM image of optimized solar cell with SnO2 cross section and I-V curve under different irradiation conditions

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21: Printed ZnO nanoparticles for applications in transistors and memory devices

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ABSTRACT

This work reports the application of ZnO layers based on nanoparticles to electronic devices such as electrolyte gated transistors (EGTs) and resistive random access memories (RRAMs). The ZnO ink itself consists of a dispersion of the nanoparticles into a matrix based on different cellulose derivates. Proper optimization of the nanoparticles content in the ink allowed for the formation of a semiconductor layer suitable to be used in EGTs, at a maximum annealing temperature of 150 ºC, compatible with paper substrates. Fully printed devices on paper, using a composite solid polymer electrolyte to gate the devices, show low operation voltages, with a subthreshold slope of 0.21 $Vdec^{-1}$, turn on voltage close to 0V and saturation mobility above 1 $cm^2V^{-1}s^{-1}$.

Concerning the printed resistive memory devices, they can be programed in unipolar regime for up to 100 cycles. The retention time for both states is reached up to 100 ks. Also, these memories have fast switching times. Thus, it is suggested that the resistive switching is due to growth of filaments during cycles related to the presence of the cellulose derivative itself.

Finally, the ZnO nanoparticles printed layers were submitted to different bending cycles in order to assess for crack formation. Mechanical characterization was also performed using nanoindentation. This characterization method allowed to discover that bending caused the film to have lower values of Young's modulus which can be translated to unpacking of the NPs. This unpacking effect will increase the film's electric resistance.

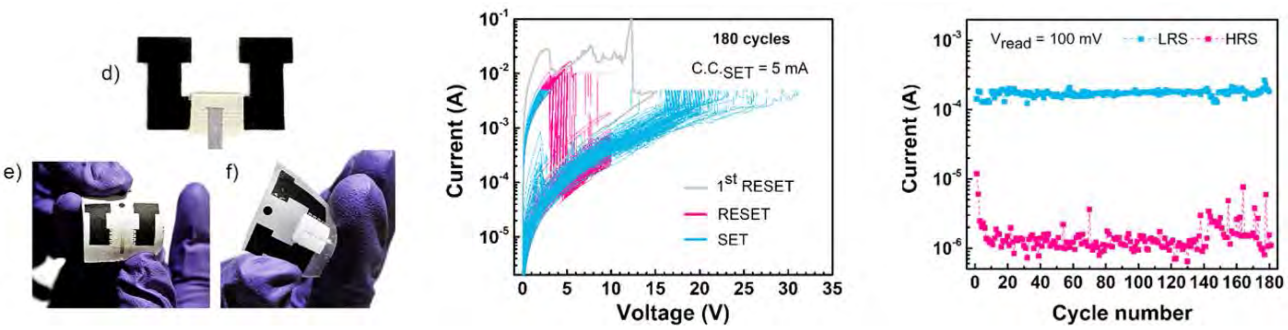

Figure 1: Printed EGTs on paper; RRAM I-V sweeps made over 180 cycles in unipolar programing, and read measurements at 100 mV after switching the device for 180 cycles.

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22: Fabrication and functionalization of printed In_2O_3 thin film transistors for biosensing applications

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ABSTRACT

Due to unprecedented interest in the development of new ways of detection, quantification and monitoring of different molecules and compounds, the biosensor arises as the most promising approach to fulfil such requirements [1]. The biosensor is a device which can detect and quantify the presence of certain chemical compounds or biological reactions by the use of electrical, thermal or optical signals. Combining this with the advantages of microelectronic technologies, such as well developed miniaturization and ability to amplify and control an input, biosensors based on TFTs are currently the most studied devices for this kind of applications [2].

The goal was to fabricate In_2O_3-based TFTs functionalized with 3- aminopropyltriethoxysilane (APTES) to work as pH sensors. For that several concepts were used: using Al electrodes and an insulator layer, SU-8; and using Cr/Au electrodes with two different designs, planar and interdigitated. The devices with best performance were the ones with Cr/Au electrodes and planar configuration. The functionalization and liquid-gating of these devices are successfully demonstrated in this work. Nevertheless, a cleaning method had to be established in order to measure the same sample several times. The APTES film showed poor stability to the cleaning method performed. This poor stability can be due to siloxane bond hydrolysis catalyzed by the amine group which could also cause uncontrolled polymerization/ oglimerization of the amine groups [3]. Both will lead to a decrease in the device's performance. The measurement procedure and/or the cleaning method of the sample will have to be optimized in the future.

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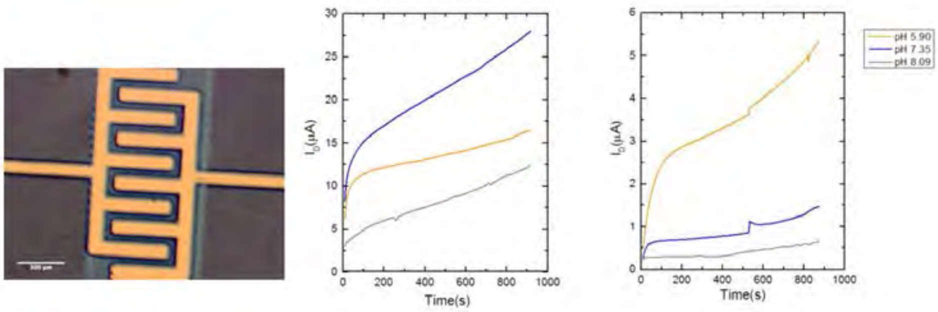

Figure 1: Optical microscope image of interdigitated configuration; representative response of TFT to different P solutions with different pH levels, using a DIW rinsing of the sample and DIW sonication for 30 min at 60ºC betwee measurements.

BIOGRAPHY

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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 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 163 publications in peer-reviewed journals and proceedings of the ISI with more than 4500 citations and has a H factor of 33.

He is currently Associate Professor at DCM-FCT/UNL and researcher at CENIMAT/I3N where coordinates and participates in R&D projects. He has been granted in 2015 with a Starting Grant of the European Research Council (ERC) 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.

23: Mechanically compliant devices for long-term peripheral neural interfaces

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ABSTRACT

Interfacing neural tissue to external electrical devices has the potential to revolutionize prosthetics by restoring lost functionality to deficient organs and systems. As such, reliable neural interfaces are a longstanding goal of basic and applied neuroscientific research. Devices that chronically stimulate brain or nerve tissue have existed for several decades in the form of various electrical stimulators – for example, in technologies like deep brain stimulation or cochlear implants. However, devices, capable of long-term recording of neural signals, are very far from routine even in a research environment.

A significant technical challenge that prevents the long-term stability of implanted neural interfaces, is the formation of a so-called glial scar. Glial cells are support cell populations in the brain and neural tissue, which perform various functions, among which are recognizing and encapsulating foreign bodies in scar tissue. Recently, it has been identified that the severity of this process can be strongly attenuated, by using implants which match the stiffness of the surrounding brain tissue (G'~1 kPa)[1].

We are currently developing a microchannel PDMS-based implant that matches the G' of neural tissue. Electrical interfacing would use organic electrochemical transistors, patterned using a combination of photolithography and femtoliter printing. The use of a microchannel to insulate the nerve from its surroundings[2], an active transistor at the recording site[3] have each been shown to increase signal-to-noise ratio in recording. A soft implant body has promoted biontegration in animal models[4] We speculate that a combination of those features would further improve quality and longevity of recordings.

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BIOGRAPHY

Ivan Dimov is a NanoDTC PhD student, working in the labs of Dr. Kristian Franze in Physiology, Development and Neuroscience, and of Prof. Henning Sirringhaus in Optoelectronics. His current project is on fabricating a stretchable implant for chronic recording and stimulation from peripheral nerves. Previously, he obtained an MChem in Chemistry from Oxford, having done his final research year in the lab of Prof. Hagan Bayley, working on printed networks of droplet interface bilayers.

24: Combining organic bioelectronics and nanostructures for cell interfacing

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ABSTRACT

Understanding how cells react to nanostructured environments can give us insight into the fundamental biochemical pathways that control different cell behaviours, such as endocytosis and differentiation.[1,2] Engineering high-aspect ratio structures, such as nanoneedles – silicon needles with <100 nm sharpened tips,[3] allows the response of a cell to be studied when the cell membrane and nucleus are placed under extreme curvature. Different cell types respond differently, and in a manner that depends on the geometry of the nanostructures.[4] Topography, material properties, and surface chemistry all play important roles - with the challenge understanding the impact of each.[5]

Here I will present the engineering side of this platform, plus the potential opportunities of combining these nanostructured surfaces with organic electronic materials to produce organic bioelectronics devices; devices that take advantage not only of the inherent bio-compatibility of many organic semiconductors,[6] but also of the impact of physical geometry.

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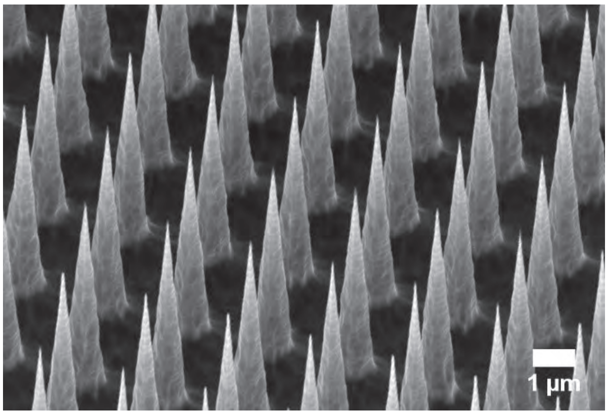

Figure: Array of silicon nanoneedles for cell-interfacing. Imaged by Michele Becce.

BIOGRAPHY

Dr Stuart Higgins is a Research Associate in the Departmental of Materials at Imperial College London. Stuart works within the group of Professor Molly Stevens, focusing on the microfabrication of innovative materials for biomedical applications. His current research interests include the microfabrication of novel interfaces for interacting with cells, bio-sensing and organic bioelectronics.

25: Inkjet printing of water-based and biocompatible 2D crystal inks on different substrates

Robyn Worsley[1], Daryl McManus[1], Freddie Withers[1], Veronica Sanchez-Romaguera[1], and Cinzia Casiraghi[1]
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ABSTRACT

Inkjet printing is a very attractive fabrication technique as it allows the large-area production of low-cost, flexible and transparent electronics on a wide range of substrates. [1], [2]

The advent of 2-dimensional (2D) materials, with their ground breaking properties, shows promise in this regard: graphene inks can be easily produced by liquid-phase exfoliation in organic solvents such as N-methyl-pyrrolidone (NMP). [3] Due to the physical-chemical properties of NMP, such inks are directly suitable for inkjet printing and have been already used to fabricate in-plane devices. [4], [5] Water is a very attractive solvent as it is cheap, abundant, bio-compatible and has a relatively low boiling point. However, unlike NMP, water does not have the physical properties required for either liquid-phase exfoliation or inkjet printing. Hence, water-based formulations need to be carefully engineered.

Here we show a simple method to produce highly concentrated, stable and inkjet printable 2D dispersions in water. [6] The inks are suitable for fabrication of vertically-stacked devices, such as photodetectors [6] and they can be inkjet printed on a wide range of substrates (e.g. glass, plastic, paper, silicon, etc.).

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BIOGRAPHY

Robyn Worsley obtained her MEng Chemical Engineering with Industrial Experience degree from the University of Manchester in 2015. This included a 12-month placement year working as a process/project engineer in a Cadbury factory with the confectionery company Mondelēz International. As part of the multidisciplinary Graphene NOWNANO Centre for Doctoral Training, Robyn began her PhD in 2D-Material Printed Electronics in the Casiraghi group in April 2016, following a 6-month training period in the basics of nanoscience, graphene and related 2D materials.

26: Advanced printing technique for polymer nanocomposites

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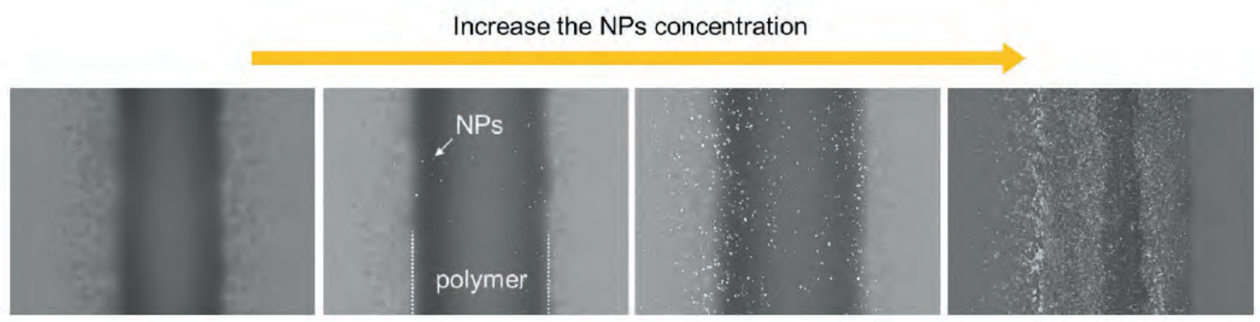
ABSTRACT

Polymer-based composites were heralded in the 1960s as a new paradigm for materials. By dispersing strong, durable, multifunctional nanomaterials in a polymer matrix, high-performance lightweight polymer nanocomposites could be developed and tailored to individual applications. However, the cost of nanomaterials and the challenges that remain to achieve good dispersion and distribution pose significant obstacles to these goals. Here, we introduce a novel and new method to reveal highly uniform nanocomposite. Using an advanced printing technique, an unprecedented dispersion and distribution of the nanoparticles (NPs) are realized for polymer based nanocomposite with significantly low concentration of NPs, allowing for precise control of various physical properties of interest. Perfectly dispersion of NPs in the solvent can be preserved in the polymer matrix as well due to the dual atomizing and printing technique. Besides, uniformity can be finely controlled up to micro-meter scale, which is the resolution of the printer.



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 commercialization of the carbon nanotube based nanocomposite. 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 energy applications.

27: Gas blow coating to control the crystal morphology in thin films of organic semiconductors for use in large area electronic devices

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ABSTRACT

Great efforts have been devoted to develop techniques, such as spin coating, dip coating, zone casting, solution shearing, to control the crystal growth of organic films with the final goal to maximize the device performance. However, control of the nucleation and growth of crystals in thin films remains challenging. [1, 2]

Herein, we introduce a novel gas blow coating method for the deposition of organic thin films over a large area. Different parameters, including speed, gas supply pressure, height and angle, are investigated and correlated to the growth of crystals in the thin films. Thin-films of aligned single crystals of TIPS-Pentacene and C8-BTBT have been achieved and tested in Field Effect Transistors, showing mobilities of 0.2 and 1.4 $cm^2V^{-1}S^{-1}$ respectively, with low threshold voltage and high On/off ratio, comparable to those obtained by spray coating[3]. Films based on P3HT and DPPTTT have also been fabricated, showing the possibility to use gas blow for deposition of a wide range of organic films.

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BIOGRAPHY

Mr. Jincheng Tong received his bachelor's degree (2014) and master's degree (2016) from School of Materials Science and Engineering, Zhengzhou University, China. He is currently a Ph. D. candidate in Prof. Cinzia Casiraghi's group at School of Chemistry, University of Manchester, UK. His research interests focus on 2D materials, organic crystal growth, organic devices and catalysis.

28: Optimisation of aerosol jet deposition for the development of novel printed electronics devices

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ABSTRACT

Aerosol jet deposition is a comparably new direct-write technique capable of producing high resolution and highly customisable electronic and biological functional devices on both two and three dimensional substrates. This technology creates important market opportunities in the production of consumer electronics, semiconductor packaging, display technology, aerospace and defence, automotive and life sciences.

This presentation will discuss the identification and optimisation of a number of key process parameters which has resulted in the development of a highly customisable sensing platform that integrates elements of silicon and printed electronics. To demonstrate the capabilities of aerosol jet deposition, thin film humidity sensors have been fabricated over a pre-packaged integrated circuit showing the vertical integration of two technologies [1]. The resistive based sensor consists of an aerosol jet deposited interdigitated electrode structure of nano-particle silver overlaid with a thin film of Nafion® acting as a humidity sensitive layer. The interdigitated features show a high resolution and maintain continuity over the complex 3-dimensional surface resulting in a responsive sensor with low hysteresis.

The successful fabrication of the sensors over the surface and pins of a packaged integrated circuit demonstrates a new kind of integration between printed and silicon based electronics − leading to Printed-Sensor-on-Chip devices. While demonstrated for humidity, the proposed concept is envisaged as a platform for a wide range of applications, such as bio-sensing, temperature or gas monitoring.

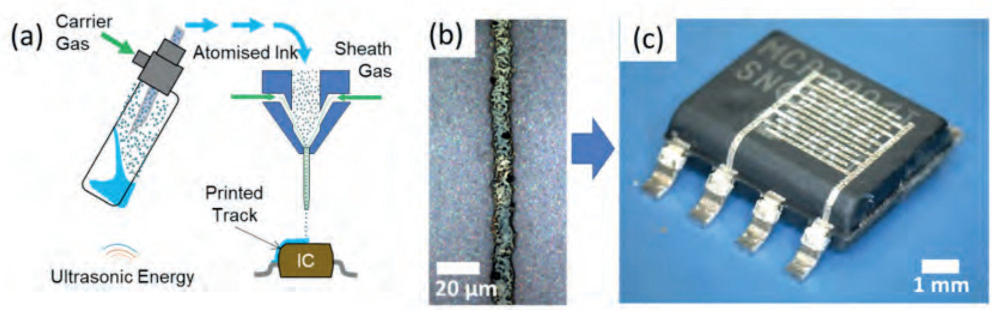

Figure: Schematic of AJD process (a), optimised nanosilver tracks down to 10um (b), interdigitated sensing electrodes printed over non conformal surface of chip (c) [1]

[1] Ben Clifford et al., Sensors and Actuators B: Chemical, 2017, in press, https://doi.org/10.1016/j.snb.2017.08.086.

BIOGRAPHY

Ben Clifford is a researcher at the Welsh Centre for Printing and Coating in the College of Engineering, Swansea University. He recently submitted his Ph.D thesis in Aerosol Jet Deposition for the Development of Printed Electronics (Swansea University, 2016), under the supervision of Dr. D. Deganello. His research is primarily focused on applications of aerosol jet deposition but also includes other direct-write fabrication technologies, such as LIFT, materials development and process optimisation

29: Convective self-assembly, a versatile tool for assembling and ordering organic/inorganic nanoparticles into hierarchical structures on large areas

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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. To understand how to immobilise colloidal spheres into predefined locations is significant in terms of the fabrication of complicated 2D/3D hierarchical structures. Here we show that depending on the geometrical relationship between the colloidal nanoparticles and the grating structures (Figure 1), spherical particles can be programmed into specific sites with either ordered or disordered, close-packed or non-close-packed, single layer or multilayer architectures. We scrutinise our hypothesis using grating structures into which different sizes of polystyrene nanoparticles are deposited.

To further verify the geometrical relationship rule and suggest potential applications of hierarchical structures, nanospheres of a green conjugated polymer emitter, polyfluorene-co-divinylbenzene (PF-co-DVB) and superparamagnetic fluorescent carboxyl-functionalized polystyrene nanospheres are deposited into the surface relief structures. Since both of their diameter values are very close to the optimum value (calculated by grating geometries), ordered and closed-packed structures form (Figure 2). This relationship rule can serve as a design platform in terms of the fabrication of complicated 2D/3D hierarchical structures for the use in solar energy applications.

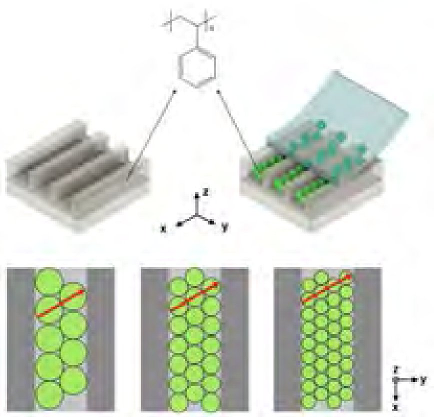

Figure 1. Deposition of colloidal spherical nanoparticles into a grating in a controlled manner seems to rely on the geometry of both the particles and grating. Top: Molecular structure of the grating and particle material: polystyrene (PS). Centre: Convective and shear-induced self-assembly of nanospheres into grating. Bottom: Close-packed ordered structures form when the number of spheres along the close-packed direction (as indicated by red arrows) is 2, 3 and 4, respectively.

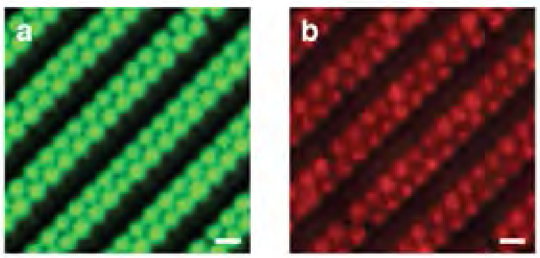

Figure 2. Fluorescence microscopy allows to identify emissive nanospheres inside gratings. Hierarchical structures with (a) PF-co-DVB and (b) superparamagnetic fluorescent carboxyl-functionalized polystyrene nanospheres are measured and the excitation wavelengths are 380 nm and 594 nm, respectively. Scale bars: 2 μm.

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).

30: A study of the potential for photonic processing of nano copper

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ABSTRACT

Copper is the material of choice for circuit boards manufactured using subtractive processes due to its conductivity and low cost. For circuitry manufactured using additive technology, silver is the material of choice as a dispersion of metallic particles a readily be manufactured while copper particles are easily oxidized to their non conducting oxide. Nano copper materials are commercially available but these usually incur extended drying times (30 – 90 minutes) in a reducing atmosphere which necessitates batch manufacturing. In order to explore whether nano copper could be continuously processed a study was undertaken using high power broad area pulsed visible light photonic emission[1,2] which potentially offers near instantaneous sintering, without the register required by laser sintering [3].

A commercially available nano copper material was screen printed to FTO coated glass at two film thickness and seven line widths. Reference samples were sintered using a conventional reducing thermal sintering procedure (30 minutes at 150^{o}C). The remaining samples were photonically sintered using a pulseforge 1200 laboratory photonic sintering unit where the number of pulses, pulse power, pulse frequency and intra pulse gap could be varied. An initial optimization study identified an operational range of photonic energy profile where sintering could be obtained without destructive delamination of the printed sample. Under these optimum conditions, the best possible line conductivity obtained was around a factor of 2 greater than that obtained by conventional thermal sintering, Figure 1. This relative conductivity of photonically sintered features further deviated from conventionally sintered features as the film thickness increased and as the line width reduced. The reduction in conductivity was attributed to the partial sintering sintering of the nano copper whereby the upper layer of ink which is exposed directly to the photonic energy is sintered, while the region nearer the substrate remains largely un-sintered. Some delamination of the photonically sintered samples was also evident which was attributed to interfacial stresses associated with differential heating, Figure 2. Finer structures were adversely affected by exposure to the photonic energy with areas exhibiting substrate delamination and physical damage.

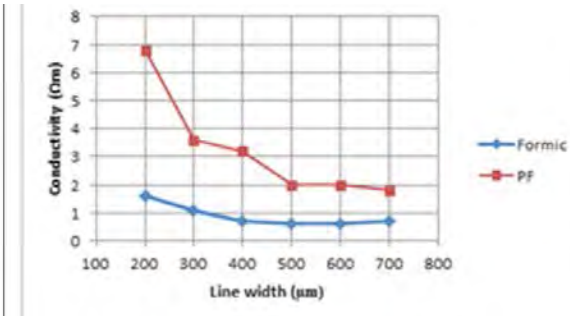

Figure 1 : Relative performance of nano copper sintered with pulseforge (PF) and formic acid.

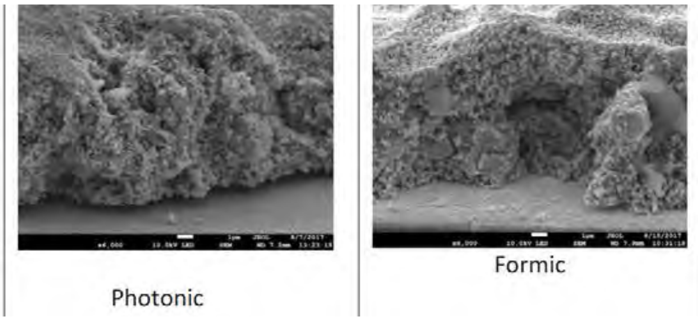

Figure 2 : SEM cross section

The study has shown that it is possible to photonically sinter nano- copper screen printed features, but that this comes at the expense of conductivity with the best conductivity being approximately ½ that obtained by conventional curing. The relationship between the ideal photonic profile and the material and print characteristics is complex. The ideal photonic exposure conditions are linked to the feature size and film thickness and this imposes a critical interaction between the processing and design stages. Further work is recommended on establishing design rules which relate print and material characteristics to the emission profile required.

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3 D. Lopez-Espiricueta, E. Fearon, S. Edwardson, and G. Dearden, Phys. Procedia 83, 194 (2016).

BIOGRAPHY

Eifion was a founder of the Welsh Centre for Printing and Coating (WCPC), Swansea University. His focus is now on scalable manufacturing technologies at SPECIFIC IKC (Sustainable Product Engineering Centre for Innovative Functional Industrial Coatings). SPECIFIC's mission is to develop scalable manufacturing solutions for energy harvesting, storage and generation for the build environment. An author of over 70 academic research papers he has also been responsible for technology transfer from the science base to industry through training, tool development, material optimization and production design.

31: Direct metallisation method onto 3-D printed polyetherimide substrates

Dr Thomas D.A. Jones[1], Ms Assel Ryspayeva[1], Dr Mohammadreza N. Esfahani[2], Professor Russel Harris[2], Dr. Robert W. Kay[2] , Dr Jose Marques-Hueso[1] and Professor Marc P.Y. Desmulliez[1]
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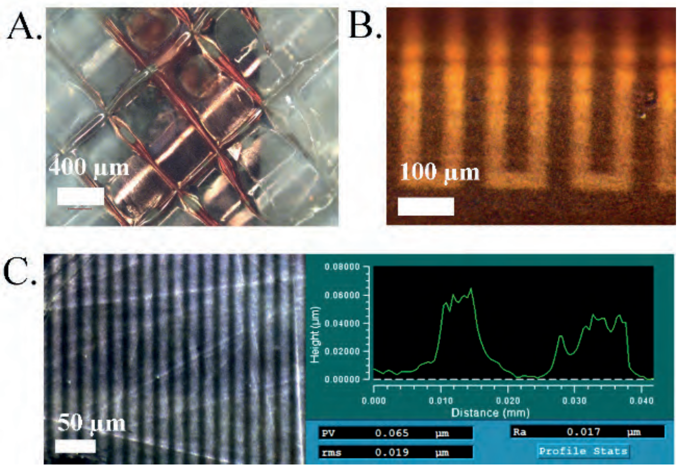
ABSTRACT

Direct metallisation (DM) of tracks for electrical devices offers cost savings over traditional techniques due to the reduction of necessary lithographic manufacturing steps [1]. Additive manufacturing (AM), on its own, provides reduction in waste material and the formation of innovative 3-D shapes [2]. These two processes combined together for microelectronics manufacture, enable further economic benefits over existing manufacturing techniques. Polyetherimide (PEI) is a polymer used in AM whose properties enable its use for low error, high frequency electrical signal transmission and extreme environmental applications, such as space and aerospace [3]. Evidence has been provided in [4] for the enhanced optical sensitisation of PEI, enabling direct patterning for fast copper (Cu) track formation. Different PEI material shapes have been processed with enhanced sensitisation, to evaluate variability of the DM process for flexible and rigid electronics applications.

Highlighted in the figure are images of optically patterned PEI surfaces after electroless copper plating. The material surfaces include A) 3-D printed substrate, B) 1.75 mm diameter wire and C) 70 μm thick flexible substrate. The minimum feature size obtained was influenced by the roughness of the substrate and its flatness. The 3-D printed substrate show metal deposits of thickness 0.5 μm. The wire surface displayed a high uniformity enabling definition of 30 μm wide Cu features, although the curved surface limited the area patterned. The flexible substrate provided the highest feature resolution with 10 μm wide Cu features of thickness approximately 70 nm, as indicated in the track cross-section insert. After electroless Cu plating, the 3–D printed substrate and the wire showed conductivities approximately half of the value for bulk copper [5].

Direct metallisation of AM material PEI was successful using enhanced sensitisation chemistry, for a variety of material forms, where feature size and quality of tracks are limited by the substrate topography.



Ultem 9085 Polyetherimide patterned with electroless copper for structures A) 3-D printed substrate, B) 1.75 mm diameter wire and C) 70 μm thick flex with cross-section profil

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BIOGRAPHY

Dr Thomas Jones is a Research Associate at Heriot-Watt University, whose research interests include Direct Metallisation techniques on Additive Manufactured substrates.

32: Core-shell electrospinning of micro/nano flexible silver fibre

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ABSTRACT

Fibre-based electronics, including fibre-based electrode, light emitting fibre, energy generating and storage fibres and fibre-based sensors, refer to a new generation of electronics. With integrating electronic functional materials into micro to nano fibres, fibre-based electronics possess unique properties, which are unachievable from traditional planer and rigid electronics, such as flexibility, transparency, breathability and deformability. Fibre-based electronics can be assembled into electronic textiles and wearable device, changing the way people interact with electronic device currently.

This project presents an efficient one-step deposition process to produce micro/nano conductive silver fibres. A self-developed Core-Shell Low-Voltage Electrospinning [1] (Co-LEP) is set up to fabricate silver fibre based on a reactive silver ink [2], and this is a one-step process under mild temperature (<90□), without needing any post processing like annealing. Characterization shows the silver fibre has a core-shell structure with continuous silver phase being wrapped by a polymer shell, as shown in Figure 1b. The continuous silver core provides the fibre with a higher conductivity than fibres with dispersed metallic particles inside. Mechanical testing shows that the fibre's Young's Modular and ultimate strength are similar with human skin, which makes it perfect for wearable electronics. Besides, the fibre acquired in this project has a desirable bending stability, and experiments show repeated bending does not compromise conductivity, which is another essential feature for making electronic textile.

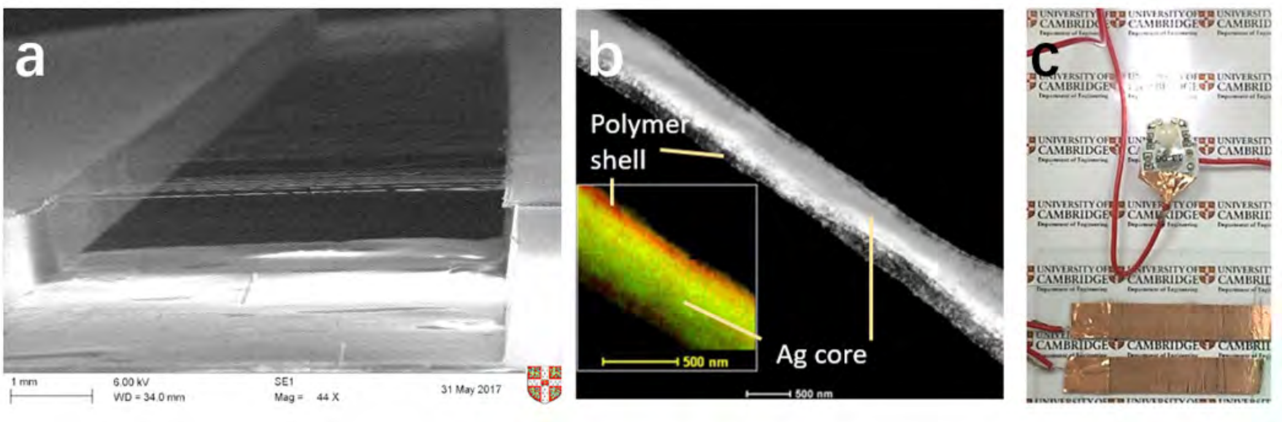

Figure 1: a) Suspended silver fibres under SEM. b) TEM image of single silver fibre with EDX mapping. c) Demonstratio of the conductivity of silver fibres

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BIOGRAPHY

I acquired my Bachelor's degree of mechanical engineering from Tsinghua University (Beijing) in 2016, and then I started Ph.D. study at the University of Cambridge, focusing on biofabrication. My supervisor is Dr. Shery Huang.My current research focuses on improving the functionality of additive manufacturing methods to enlarge the applications of the final products, like soft electronics and biocompatible device.

The first research project I participated in was to improve the accuracy of processing method of turbine blades. I was responsible for reconstructing the turbine blade numerically on computer and predict the processing error, and I co-authored two articles under this project. Then I joined biomanufacturing center at Tsinghua University and soft material lab at UCSD to research stereolithography technology. I constructed a multi-material stereolithographic 3D printer by my own as my forth year undergraduate project.

33: Engineering soft chemistry materials to large area QD-ACTFEL electroluminescence devices

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ABSTRACT

Quantum Dot based Light-Emitting Diode devices (QD-LED) are promising candidates for next-generation displays to respond low-cost, low-consumption, high color purity and high stability electroluminescence devices[1]. Current developments are focused on electronic band structure engineering to develop commercial lighting products with QD incorporation[2]. To achieve high external quantum efficiency (EQE), efforts are made to optimize carrier injection process through the addition of specific transporting layers and avoid nonradiative effects[3] (Auger effect, surface traps, field-induced quenching) in the QD emissive layer.

An alternative option is to use QD layer in Alternating Current Thin Film Electroluminescent devices[4] (AC-TFEL). In QD-ACTFEL devices, electroluminescence is induced by an ionizing electric field applied to the QD film sandwiched by two dielectric layers. This design permits the generation of radiative recombination without any external carrier injection[4]. QD-ACTFEL structures are often deposited by physical vapor deposition techniques[5,6] (PVD) mostly not suited for large area electronics. So, we propose to develop QD-ACTFEL structures by soft chemistry processes and solution based device assembly techniques (polyol-based QD synthesis, sol-gel film precursors, spin-coating, ink-jet printing). This full-development of QD-ACTFEL enables low-cost fabrication of large area printable QD-ACTFEL displays.

In this work, the layer by layer fabrication of QD-ACTFEL is presented and the fluorescence and electroluminescence properties of the built ITO/SiO_2/CdSe@ZnS/SiO_2/Ag stacking (Fig. 1) are discussed.

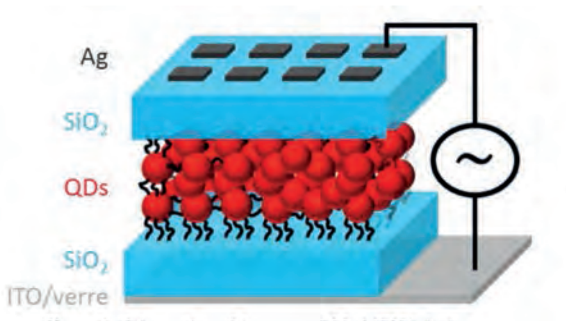

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Figure 1 : Schematic architecture of QD-ACTFEL device

BIOGRAPHY

Baptiste Notebaert is a PhD student working for ACTINOVA, a french company supplying in QD-based light emitted devices, in collaboration with Paris Diderot University (ITODYS Laboratory). He obtained his Engineer’s degree in Materials and Nanotechnologies from Engineering Department of University Paris Diderot (France) in 2015 and received the same year a Master’s degree in Quantum Devices from the same University. His research is currently focused on printing electroluminescence nanomaterials integrated in lighting displays.

34: From photo-capacitance to optical sensors and imaging arrays

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ABSTRACT

Organic phototransistors have received considerable interest both as optical sensors and for applications in imaging arrays [1]. In such devices, two modes of operation are possible, namely the photocurrent and photovoltaic modes which are often difficult to disentangle. By concentrating on the core structure, i.e. the metal-insulator-semiconductor (MIS) capacitor, the photovoltaic mode is readily identified as a shift in the flatband voltage caused by the trapping of photo-induced electrons in interface or bulk insulator states. In this presentation, we show two different approaches, namely capacitance-voltage (CV) plots and dynamic response measurements, for investigating the effect and a third approach that could provide the basis for an optical sensor/imaging array.

Fig.1 shows C-V plots obtained from a MIS capacitor based on p-type poly(3-hexylthiophene) (P3HT) and SU8 as the insulator. Plots obtained in the dark both before and after illumination show no hysteresis, albeit that in the latter case a shift occurs along the voltage axis owing to electron trapping in deep interface or insulator states. Under illumination, marked hysteresis occurs accompanied by an increase in the minimum capacitance attained during the voltage sweep. The extent of these effects depends on factors such as wavelength, illumination intensity, voltage sweep rate, and on the concentration and energy of trapping states [2].

Dynamic response was investigated by adjusting the applied voltage to maintain a fixed capacitance both during and after illumination. The resulting response was composed of a fast component (time constant ~5 s limited by the feedback circuit) arising from a photoconductive shunting effect in the P3HT depletion layer, and a slower component (time constants ranging from ~50 s to ~350 s depending on illumination wavelength) reflecting the dynamics of interface charge trapping and release.

In Fig. 2, we show how the photo-capacitance effect can be used for optical imaging. The capacitances of individual capacitors in a 3 x 3 array are measured, initially in the dark then during illumination through a shadow mask. The latent image of the mask is seen as an increase in the capacitances of the illuminated pixels, which persists for many hours afterwards, also allowing off-line measurements to be made.

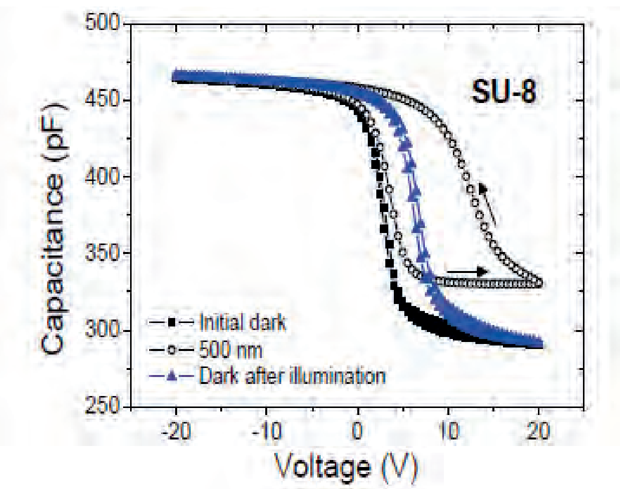

Fig.1 Capacitance-voltage plots of a P3HT/SU8 MIS capacitor obtained before, during and after illumination.

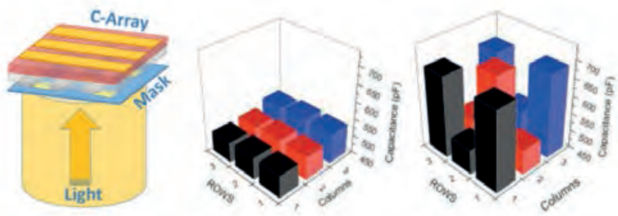

Fig.2 Demonstration of an imaging array based on the photo-capacitance effect

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BIOGRAPHY

Dr Colin Watson obtained his BSc and PhD from the School of Electronic Engineering at Bangor University. After periods as a KTP Associate with SmartKem Ltd he later joined the company to lead its transistor and circuit development effort. He has maintained links with the University through the award of a Senior Visiting Research Fellow. In a recent paper, jointly with the University, he reported the shortest stage-delay time for a ring oscillator based on a solution-processed p-type semiconductor.

35: Flexible MoS_2 (n)-CuO (p) based piezotronic diode for active analog frequency modulator and broadband photodetector

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ABSTRACT

In this work, we demonstrate solution processed MoS_2 (n)-CuO (p) piezotronic diode on flexible paper substrate for enhanced broadband photodetector and active analog frequency modulator by application of external mechanical strain. Till date, there are no reports on solution processed large area fabrication of MoS_2 based heterojunctions wherein the external mechanical strain modulates the transport properties at the device level which can be further utilized at circuit level for frequency modulation. When external strain is applied, because of the non-centrosymmetric structure of MoS_2, the piezopotential induced adjusts the band structure at the junction and broadens the depletion region which decreases the depletion capacitance of the diode. The widening of the depletion region improves the separation of photo-generated carriers and enhances the performance of diode under both visible and NIR illumination. The fabricated piezotronic diode exhibited higher responsivity towards visible light illumination when compared to NIR illumination. The Responsivity of the fabricated piezotronic diode increased by 69.7% under 2% strain. Such a versatile technique for fabrication of diode and its utilization at both device and circuit levels is a major step ahead in flexible and wearable electronics with applications ranging from digital, analog and optoelectronics.

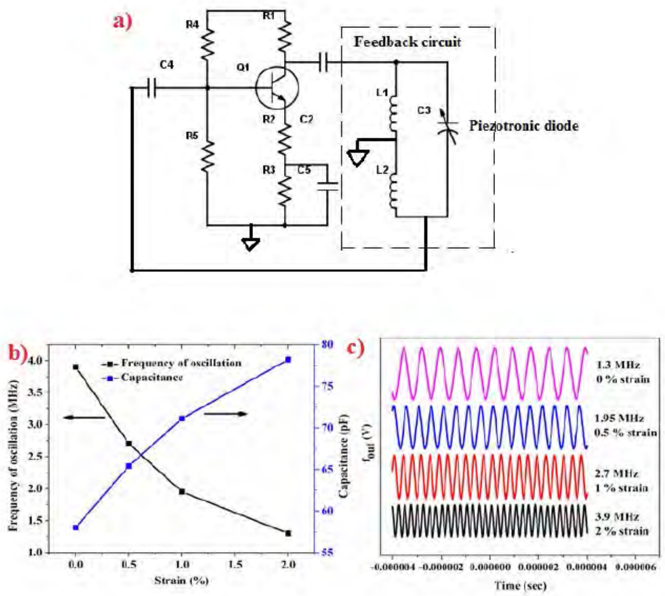

Figure 1: a) Circuit diagram for the oscillator with LC resonant feedback circuit b) Graph of frequency of oscillation and capacitance variation with strain c) Graph showing different frequency of oscillation under varying external mechanical strain. As applied strain increases frequency of oscillation increases

BIOGRAPHY

Parikshit Sahatiya is currently a graduate Student in the Department of Electrical Engineering at Indian Institute of Technology Hyderabad, India. With a background in nanoscience and engineering, his research interests include fabrication of large area, flexible and wearable nanoelectronics for applications in broadband photodetectors, FETs and sensors and exploring the use of emerging 2D nanomaterials in sensing applications.

Dr. Sushmee Badhulika obtained her M.S and Ph.D from the Department of Electrical Engineering, University of California, Riverside, USA. She is currently an Assistant Professor in the Dept. of Electrical Engineering at IIT, Hyderabad. Her research interests include Flexible and wearable nanoelectronics, paper electronics and nanomaterials based electrochemical sensors. She is the recipient of several national and international level awards and scholarships and has published over 45 journal publications, book chapters, monographs and conference proceedings. She is the Associate Editor of IOP Flexible and Printed Electronics.

36: Inorganic-organic hybrid X-ray detectors as wearable real-time dosimeters

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ABSTRACT

Organic semiconductor based diodes are emerging as a class of highly sensitive X-ray detectors with potential applications in the field of real time dosimetry. Other than their high sensitivity, they present many more added advantages including their solution processable nature, which allows the fabrication of such detectors on flexible substrates over any required area using printing techniques at low cost.

Thermoluminescent (TLD) badges which are currently the most widely used dosimeters, are very well known to suffer from a major disadvantage of not offering a real-time response. For example, CsI crystals used in such TLD badges are worn usually for three months and require to be sent for special laboratories to examine the cumulative X-ray dose a particular individual has been exposed to. The inability to record the radiation exposure in real time places significant risk to those work in radiation environments.

In this work, we have developed a wearable real-time dosimeter as an alternative for current TLD badges (Figure a). A semiconductor diode has been optimized with a thick bulk heterojunction (BHJ) (20 μm) layer consisting of an interpenetrating network of an electron donor and electron acceptor. In order to improve the X-ray sensitivity of the organic semiconductor system, high atomic number nanoparticles (NP) have been included into the BHJ active material (Figure b). The NP loading in the active layer is controlled by varying the nanoparticle concentration (10 – 33 wt %) in the semiconducting ink used for device fabrication. Under a 50 kV X-ray source, the detector exhibits a linear response to dose with sensitivities as high as 105 μC mGy-1 cm-3 (Figure c). The detector operation under different voltages (Figure d) demonstrates its capability to operate by just coin cell batteries (<10 V).

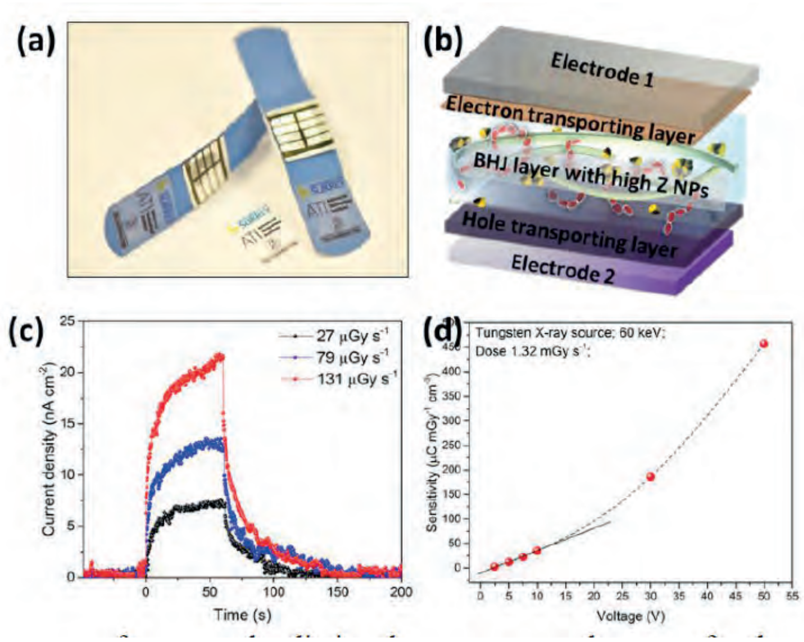

Figure. (a) A prototype of a personal radiation detector mounted on top of a plaster, to be used as a finger radiation dosimeter. (b) Device architecture. (c) Device response under different doses of 50 kV W X-ray source. (d) Voltage dependence of the X-ray detector.

The proposed organic-inorganic hybrid direct detector technology is low cost, operates under low voltages, and displays a high sensitivity making an ideal candidate as real-time radiation dosimeters.

BIOGRAPHY

Hashini Thirimanne is a third year PhD student studying at Advanced Technology Institute, University of Surrey. She is working on inorganic-organic hybrid radiation detectors and photovoltaics with a strong emphasis towards developing real-world related solutions. Her main interests are working around renewable energy, next generation radiation detectors and photovoltaics. Hashini has also won the Surrey 3 minute thesis award, and along with her project team they've managed to file a patent and have won two separate awards for their radiation detector invention. She can be contacted at: h.thirimanne@surrey.ac.uk

37: Self-propagating bonding process to enable large area electronics assembly

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ABSTRACT

Reactive nano-foils containing hundreds of alternated nano-layers of Al-Ni, Al-Ti and Al-Si elements can provide intensive and instantaneous heating confined to a localised area through self-propagating exothermic reactions (SPER) [1]. Once initiated with a small burst of energy, SPER exhibits a large negative enthalpy (e.g. 1381 J/g for Ni-Al) and proceeds self-sustainingly at fast propagation velocities (~10 m/s) (Fig. 1). With extremely narrow heat affect zone (HAZ) thus minimal effect on adjacent temperature sensitive components, this offers a unique bonding process for electronics integrations of a wide range of substrate materials [2]. The process can be controlled and optimised to suit the demands of the local heat for bonding. The potential benefits include: i) Negligible thermal load imposed on the parts being bonded due to the highly localised nature of the heating; ii) Compatible with a variety of both rigid and flexible substrates; iii) Rapid with bonding times typically being tens of ms; iv) Fluxless suitable for large area bonding.

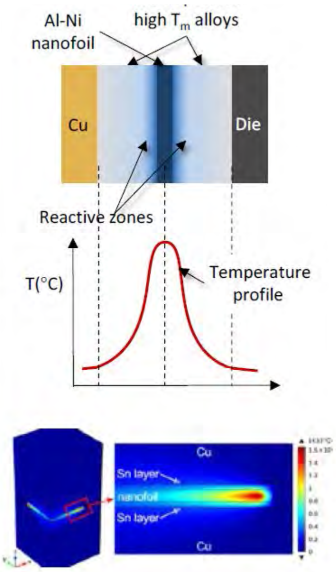

Fig.1. SPER bonding schematics

The solder interconnects via SPER have been achieved using electroplated Sn, $Sn_{63}Pb_{37}$, $Sn_{96.5}Ag_{3.0}Cu_{0.5}$, $Au_{80}Sn_{20}$, and $ZnAl_5$ solders as the intermediate layers to bond Cu and Si using multilayer Al-Ni nano-foil™ (Indium Co-operation). Finite element analysis (FEA) was implemented to aid and optimise the processing parameters to ensure optimal bonding temperature profile. The quality and microstructure of bonding were subsequently examined, and it is affirmed that the shear strength of bonding has exceeded 30 MPa owing to the strong interface interaction and elemental diffusion as evidenced by the nanoscale intermetallic compound (IMC) formation (Fig. 2). The bonds were typically featured with short-term ordered nano-sized IMCs such as AgSn/AgSn2 and $CuSn_3$ phases, formation and precipitation of metastable interfacial IMCs in columnar dendritic solder grains primarily due to the nature of rapid heating and cooling, as a non-equilibrium process.

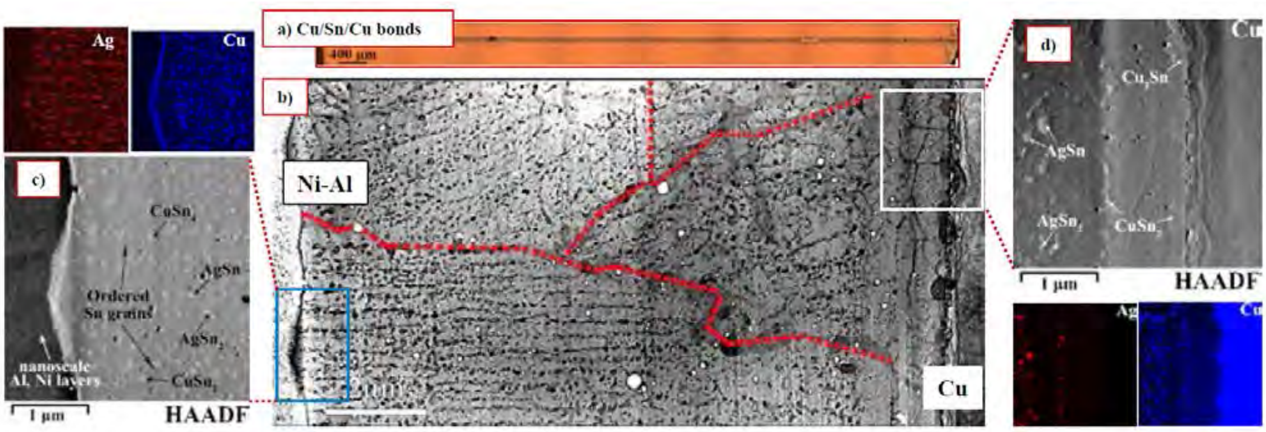

Fig. 2. Cu-Sn-Cu bonds: a) Overall optical bond structure; b) HRTEM of the cross section; c) HAADF details of Ni-Al/Sn interface; d) HAADF details of Sn/Cu interface

Some potential defects such as microvoids and nanovoids as expected are inevitable, plus the gaps among remaining NanoFoil fragments after bonding which may potentially become a source of failure subject to the extrenal thermo-mechanical conditions. It has been found that the shear strength increases with ambient temperature and pressure applied during the bonding process and the thickness of intermetaite solder layer up to a critical value. It is envisaged that the the bonding may be applied directly with the large area flexible substrates such as plastics through processing optimisation where the localised heat are less demanding.

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BIOGRAPHY

Changqing Liu: BEng of Nanjing University of Science and Technology (NUST, 1985); MSc of the Institute of Metals Research of Chinese Academy of Science (IMR-CAS, 1988). After 5 years assistant professorship at IMR-CAS, he was awarded an Overseas Research Scholarship (ORS) in 1993 and moved to UK and read his PhD at Hull University, followed by 3 years of postdoctoral research at Birmingham University (UK). From 2000 he joined the Wolfson School of Mechanical, Electrical and Manufacturing Engineering at Loughborough University, where he became Professor of Electronics Manufacture since 2011 following his appointment as Lecturer (2005), Senior Lecturer (2007). Dr Liu's research is centred on advanced materials and manufacturing to enable 3D multi-material heterogeneous embodiment, integration and miniaturisation of future multifunctional devices. He has published over 243 peer-reviewed research outputs including 120 academic journal articles yielding a citation h-index 44 (Google Scholar), and 25 (Scopus). He is a senior IEEE member served various technical committees of EPS society of IEEE.

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