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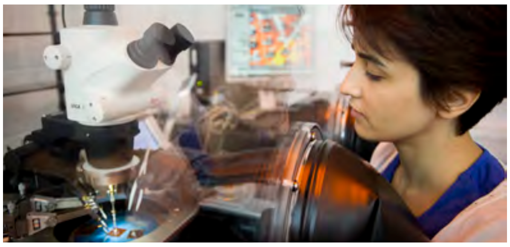

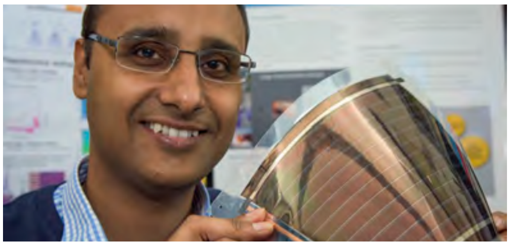

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ABOUT THE ORGANISERS

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Day 1

innoLAE
2019

08:30 - 09:00 Registration, tea/coffee on arrival

09:00 - 10:10
Session 1: Welcome — F.C.A
Keynote address: **Karl Leo***, *IAPP, TU Dresden.*
Novel high-performance organic transistor structures

10:10 - 10:40 Break

10:40 - 12:45
.1) 10:40 - 11:05
.2) 11:05 - 11:30
.3) 11:30 - 11:55
.4) 11:55 - 12:20
.5) 12:20 - 12:45

Session 2: Applications of LAE — F.C.A
2.1 **Ashutosh Tomar***, *Jaguar LandRover.* Applications of flexible and hybrid electronics in the car

2.2 **Ravinder Dahiya**, *University of Glasgow.* Biodegradable cloth with printed electrodes for sensors and energy storage devices

2.3 **Simon Johnson & Tim Moor**, *Centre for Process Innovation-HP1 Technologies.* Large area pressure sensor system for critical injury diagnosis

2.4 **Pascal Cachelin**, *Cambridge Display Technology Ltd.* Low power gas sensors for distributed monitoring for post-harvest applications

2.5 **Suman Nandy,** *Universidade NOVA de Lisboa*. Smart Power Emerging Energy Device (SPEED)

Session 3: Manufacturing for printed electronics — R.F.P
3.1 **Vivek Subramanian*** *Ecole Polytechnique Federale de Lausanne (EPFL).* Tools and processes for printed electronic systems

3.2 **Grigorias Rigas,** *M-Solv*. Additive and subtractive manufacturing for large area printed electronics

3.3 **Maxime Harnois**, *IETR -CNRS.* Water transfer printing technology for large area 3D conformable electronics

3.4 **Yin Cheung Lau**, *Swansea University*. Pushing the limits of screen printing: consistent and mass-producible 25 micron conductive tracks

3.5 **Dan Curtis***, *Swansea University.* Printed process control through advanced rheometry

12:45 - 14:00 Lunch, posters and exhibition

14:00 - 14:45
Session 4: Keynote address: Marco Meloni*, *Ellen MacArthur Foundation.* — F.C.A
The circular economy opportunity

14:45 - 15:10 Break

15:10 - 17:15
.1) 15:10 - 15:35
.2) 15:35 - 16:00
.3) 16:00 - 16:25
.4) 16:25 - 16: 50
.5) 16:50 - 17:15

[Please note that workshop timings differ!]

Session 5: LAE devices and circuits (1) — F.C.A
5.1 **Juan Pablo Prieto-Ruiz***, *Saule Technologies*. Flexible perovskite solar cells

5.2 **Derek Peden**, *DesignLED Products.* OLED alternative with inorganic LED based technology for diffuse lighting products

5.3 **Tanyaradzwa Mangoma,** *University of Cambridge*. Additive manufacturing of neuromorphic devices

5.4 **Sanjiv Sambandan,** *Indian Institute of Science/University of Cambridge.* Stretchable self-healing interconnects

5.5 **Henning Sirringhaus & Krishna Persaud*** *University of Cambridge-University of Manchester*. Integrated, solar-powered gas cards based on hybrid analogue amplifiers integrated with organic transistor sensors

Session 6: High performance materials for LAE — R.F.P
6.1 **Stephen Hodge***, *Versarien.* Graphene enhanced products

6.2 **Francisco Rodriguez,** *Cambridge Display Technology.* Solution processed organic photodetectors for the near infrared

6.3 **Mehmet Tas,** *University of Surrey.* Highly conductive, compressible, vertically-aligned-CNT-PDMS-metal composite films as strain sensors

6.4 **Hanleem Lee,** *University of Cambridge.* Material engineering of 2D materials for realizing the electronics from TFT to electrochemical devices

6.5 **Cinzia Casiraghi***, *University of Manchester.* Water-based, biocompatible and inkjet printable 2D-inks

Session 7: Workshop — J.W.P
Science, technology and commercialisation of electronic textiles
(15:10) 7.1 **Theodore Hughes-Riley***, *Nottingham Trent University.* Microchips in yarns -a revolutionary new approach to manufacturing intelligent garments

(15:30) 7.2 **Kay Ullrich***, *TiTV.* Working with smart textiles – about materials, processes, products and their testing

(15:50) 7.3 **Francesc Mañosa Moncunill***, *Eurecat.* Integration of fibre-based electronic devices into textile structures

(16:10) 7.4 **Felice Torrisi***, *University of Cambridge.* Washable and wearable electronic textiles enabled by two-dimensional materials

(16:30) 7.5 **James Hayward,** *IDTechEx.* The integration of flexible electronics within wearable electronic devices

(16:50) 7.6 **Panel Discussion**

17:15 - 19:00 Poster session & poster prize award ceremony

19:00 - 19:30 Transport to Queen's College for conference dinner at 19:30

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08:30 - 09:00	Tea/coffee on arrival	
09:00 - 10:10	**Session 8: Welcome** F.C.A Keynote address: **Janos Veres***, *Palo Alto Research Center (PARC)* Printing the IOT Plenary address: **Simon Johnson***, *Centre for Process Innovation (CPI)* Large area and printable electronics comes of age	
10:10 - 10:40	Break	
10:40 - 12:45 .1) 10:40 - 11:05 .2) 11:05 - 11:30 .3) 11:30 - 11:55 .4) 11:55 - 12:20 .5) 12:20 - 12:45	**Session 9: Manufacturing LAE systems** F.C.A 9.1 **Richard Price***, *PragmatIC*. Transforming manufacturing to deliver trillions of smart objects 9.2 **Mike Clausen,** *Centre for Process Innovation.* Smart hybrid electronics: Addressing the scale up challenge 9.3 **Andrew Holmes***, *Imperial College London.* Integration technologies for flexible hybrid electronics 9.4 **Jeff Kettle,** *Bangor University*. High performing AgNWs transparent conducting electrodes with 2.5Ω/Sq based upon roll-to-roll compatible post processing technique 9.5 **Antti Keranen***, *TactoTek*. Designing and Making parts using injection molded structural electronics (IMSE™)	**Session 10: Bioelectronics** R.F.P 10.1 **Magnus Berggren***, *Linköping University.* Large Scale Integrated Organic Bioelectronics – Nature Connected 10.2 **Henrique Gomes,** *Universidade do Algarve*. Conducting polymer based electrodes: A new tool to explore bioelectrical signals inaccessible using conventional electrophysiological methods 10.3 **Jean Manca,** *Universiteit Hasselt*. Living electrical nanowires: a new paradigm for bio- and organic electronics? 10.4 **Christopher Proctor,** *University of Cambridge*. Microfluidic ion pumps for seizure control 10.5 **Jamie Marland,** *The University of Edinburgh.* Implantable Microsystems for Personalised Anti-Cancer Therapy
12:45 - 13:45	Lunch and exhibition	
13:45 - 15:50 .1) 13:45 - 14:10 .2) 14:10 - 14:35 .3) 14:35 - 15:00 .4) 15:00 - 15:25 .5) 15:25 - 15:50 *[Please note that workshop timings differ!]*	**Session 11:** F.C.A **LAE devices and circuits (2)** 11.1 **Junichi Takeya***, *Tokyo University.* Organic single-crystal transistors and integrated circuits 11.2 **Moon Hyo Kang,** *University of Cambridge*. Air-stable hybrid CMOS operational amplifier on flexible substrates 11.3 **Chuck Milligan***, *FlexEnable.* Industrialization of game-changing OTFT based flexible displays and sensors 11.4 **Pedro Barquinha,** *Universidade NOVA de Lisboa.* Flexible oxide electronics: from TFT models to circuit integration 11.5 **Gwen Wyatt-Moon***, *University of Cambridge.* Schottky diodes with >1 GHz cut-off frequency fabricated from a-IGZO using adhesion lithography	**Session 12: Workshop** R.F.P **LAE and the Circular Economy** *(13:45)* 12.1 **Chris Rider,** *CIMLAE.* Introduction to the workshop *(14:00)* 12.2 **Clement Gaubert***, *Veolia.* Waste management and compliance considerations for LAEs *(14:20)* 12.3 **Sophie Verstraelen***, *Organic and Printed Electronics Association.* OE-A's initiative on sustainability *(14:35)* 12.4 **Gillian Ewers***, *PragmatIC*. A smart approach to reduce waste *(14:50)* 12.5 **Danick Briand,** *Ecole Polytechnique Federale de Lausanne (EPFL)*. Towards greener electronics: biodegradability and biomining *(15:15)* 12.6 **Panel Discussion**
15:50	Close and refreshments	

* Invited Speaker
F.C.A: Francis Crick Auditorium - The auditorium in the centre of the venue
R.F.P - Rosalind Franklin Pavilion - A large room located off the main exhibition space
J.W.P - James Watson Pavillion - A large room located off the main exhibition space

Novel high-performance organic transistor structures

Karl Leo

Dresden Integrated Center for Applied Physics and Photonics (IAPP), Technische Universität Dresden, 01062 Dresden, Germany

Organic field effect transistors (OFET) have so far not achieved major commercial impact, despite their many attractive properties such as low-cost, low-temperature processing, and flexibility. In this talk, I will discuss recent work which addresses some of the shortcomings of the OFET. One key approach is to introduce controlled electrical doping into OFET structures, allowing better injection and novel operation principles such as inversion operation. Furthermore, I will discuss vertical transistor structures which have very short channel length without micropatterning. These structures allow much higher current densities than the lateral OFET despite rather simple processing technology. These devices are e.g. well suited to drive organic light emitting diodes (OLED), allowing all-organic flexible OLED displays. Recently, we have achieved current densities as high as kA/cm^2 /1/ and record frequencies above 40MHz /2/.

References

[1] M. P. Klinger et al., Sci. Rep. 7, 4471 (2017)
[2] B. Boroujeni et al., Sci. Rep. 8, 7643 (2018)

Biography

Karl Leo obtained the Diplomphysiker degree from the University of Freiburg in 1985, working with Adolf Goetzberger at the Fraunhofer-Institut für Solare Energiesysteme. In 1988, he obtained the PhD degree from the University of Stuttgart for a PhD thesis performed at the Max-Planck-Institut für Festkörperforschung in Stuttgart under supervision of Hans Queisser. From 1989 to 1991, he was postdoc at AT&T Bell Laboratories in Holmdel, NJ, U.S.A. From 1991 to 1993, he was with the Rheinisch-Westfälische Technische Hochschule (RWTH) in Aachen, Germany. Since 1993, he is full professor of optoelectronics at the Technische Universität Dresden. His main interests are novel semiconductor systems like semiconducting organic thin films; with special emphasis to understand basics device principles and the optical response. His work was recognized by a number of awards, including: Otto-Hahn-Medaille (1989), Bennigsen-Förder-Preis (1991), Leibniz-Award (2002), award of the Berlin-Brandenburg Academy (2002), Manfred-von-Ardenne-Preis (2006), Zukunftspreis of the German president (2011), Rudolf-Jäckel-Prize (2012), and a Dr. techn. h.c. of the University of Southern Denmark (2013). He is cofounder of several companies, including Novaled GmbH and Heliatek GmbH.

Nach dem Physikstudium an der Universität Freiburg promovierte Karl Leo 1988 an der Universität Stuttgart mit einer am Max-Planck-Institut für Festkörperforschung bei Hans Queisser ausgeführten Arbeit zur Ultrakurzzeit-Spektroskopie in Halbleitern. Von 1989 bis 1991 war er Postdoc bei den Bell Laboratories in Holmdel, NJ, U.S.A. und ab 1991 Oberassistent an der RWTH Aachen. Seit 1993 leitet er das Institut für Angewandte Photophysik der Technischen Universität Dresden. Sein aktuelles Arbeitsgebiet sind Organische Halbleiter, von den Grundlagen bis hin zu Anwendungen, z.B. als Organische Leuchtdioden (OLED) und Organische Solarzellen. Seine Arbeiten wurden mehrfach ausgezeichnet, u.a. mit dem Leibniz-Preis der Deutschen Forschungsgemeinschaft und dem Zukunftspreis des Deutschen Bundespräsidenten. Er ist Mitbegründer einiger Firmen, u.a. Novaled GmbH und Heliatek GmbH.

Applications of flexible and hybrid electronics in the car

Ashutosh Tomar

Engineering Research, Jaguar Land Rover

Cars have moved on from being just a vehicle that is driven, to an extension of person's digital life today. Future of adding more feature content leads to more electronics in car, this leads to, shrinking space, added weight and excessive energy utilization. Not counting infotainment and connected features, in premium cars today we have 175 + features. This drives 94.7 KG of wiring and 100+ computer systems connected to 100+ sensors.

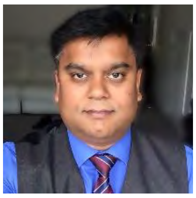
Jaguar Land Rover research has found a way to use flexible and hybrid electronics in a way to create light weight electronics that does not demand it's own space, and mitigate the finite headroom problem for electronics, networks and sensor packaging.

After three years of research into state of the art conductive and dielectric inks and using Printing processes to create printed and structural electronics components, Jaguar Land Rover research has proven that it is possible to print lightweight electronics that can change the future of electronics in the car.

This research area investigated a challenge of ever growing electrical architecture in the car, and issues generated due to its growing size, weight and complexity, and proved that, in order to preserve customer's usable space in the car, the nature of the underlying electronics needs to change.

Main objective of using printable and organic electronics is now, to help make the electronics ubiquitous in the car. Structural and printable electronics offers a way of reducing the space taken by electrical componentry, by making it the additive part of the surface itself. This can lead to the creation of a whole new range of products such as: flexible interaction surfaces (A-surface), flexible display areas, large-area energy efficient lighting, printed logic and controls, printed sensors, flexible batteries, low cost printed solar cells integration and entirely new form factors for functional electronic devices.

Biography



Ashutosh Tomar has been working with various industries in research and development since 1999. His previous experience varies from developing embedded systems for telecommunications, to defense systems, to internet security, to automotive electronics. As a keen researcher and inventor for last eleven years he has been part of a Jaguar Land Rover research team working as Principal Engineer and Technical Manager in Jaguar Land Rover research. With several patents under his belt, his innovations and experience in automotive have been centered around electrical research. He has developed innovations around various aspects of cars like connected multimedia, Social infotainment, Flat and Planar speakers, laser-based heaters, light weight printed and structural electronics etc. His key recent achievement is to create automotive qualified structural electronics. This is weight and space saving, automotive qualified package using IMSE (In mold structural Electronics) and ILSE (In Laminate Structural Electronics) by employing various printed electronics techniques. He believes this will change the way electronics is packaged in the car in near future.

Biodegradable cloth with printed electrodes for sensors and energy storage devices

Libu Manjakkal, Wenting Dang, Ravinder Dahiya*
Bendable Electronics and Sensing Technology Group, Electronics and Nanoscale Engineering, University of Glasgow, G128QQ, UK. Email: Ravinder.Dahiya@glasgow.ac.uk

Electronics waste, which contain hazardous and toxic substances, is a major global concern today threatening the environmental sustainability and social life. The current technology for the development of flexible sensors, electronics system, energy system often relies on use of non-degradable polymers-based substrates, which could have negative environmental impact. Among several solutions that are being explored to address these concerns the most important are related to finding alternative to the textile-based electronics called 'e-textile'. Recently flexible devices like solar cells, sensors, batteries etc [1-3]. were successfully integrated into textiles and attracted significant application in healthcare, defence, and fashion. Advancing these initiatives towards green electronics, in this work we present the cloth-based electrodes for sensors and supercapacitor applications. CNT-PEDOT:PSS ink and graphite paste were investigated as an conductive matrix in the cloth. The cost-effective thick film potentiometric pH sensors for wearable sweat monitoring applications on textile substrate were developed by using graphite (sensitive electrode (SE)) and Ag/AgCl film (reference electrode (RE)) on cellulose-polyester blend cloth (Figure 1a). Potentiometric, cyclic voltammetry (100 mV/s) and electrochemical impedance spectroscopic (EIS) (1 mH to 100 kHz) analysis were employed to investigate the sensing performance of the textile pH sensor. The fabricated sensor exhibits a sensitivity of 4 mV/pH with fast a response time of 5 s in the range of pH 6-9. For proper working of functional components and sensors in wearable systems required miniaturized energy storage devices. The current alternative such as lithium-ion batteries will be unable to meet these targets due to toxicity and lack of flexibility. By developing natural fibre based flexible supercapacitor (SC) in textile we have attained the environmentally friendly energy storage in wearable system. Conductive CNT-PEDOT:PSS ink coated on fabric were used for the fabrication of SC. The cellulose cloth was converted into a conductive fabric by reacting with PEDOT:PSS. A SEM image in Figure 1b shows the formation of the material on cloth. The conductivity and surface area of the proposed fibre can be utilized as a current collector and active electrode in SC. The electrochemical performance of the conductive cloth were analysed by cyclic voltammetry and EIS analysis. The obtained capacitance of the fabricated cloth with different frequency range is shown in Figure 1b. The proposed electrodes of SC shows a power sources for sensors.

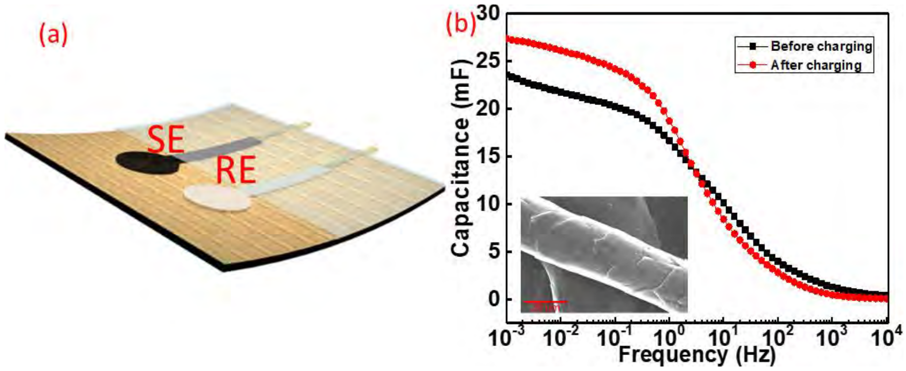


Figure 1. (a) schematic of textile pH sensor (b) Frequency Vs Capacitance of SC with inset SEM image.

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[1] Zamora, M. L. et al. Potentiometric textile-based pH sensor. Sensor. Actuat. B: Chem. 260, (2018) 601.
[2] Pu, X. et al. Wearable Self-Charging Power Textile Based on Flexible Yarn Supercapacitors and Fabric Nanogenerators. Adv. Mater. 28, (2015).
[3] Manjakkal, L., et al, Potentiometric Textile Based Electrochemical Sensor for Wearable Application (review)
Acknowledgement :- This work was supported by the Frontiers of Engineering for Development Seed Funding (FoESFT5/100025/304218-01) by Royal Academy of Engineering as a part of circular economy programme.

Biography

Ravinder Dahiya is Professor of Electronics and Nanoscale Engineering in University of Glasgow. He has published more than 200 articles and has given more than 90 invited talks. He has more than 12 years of experience in the field of flexible electronics and has won several awards including the 2016 IEEE Sensor Council Technical Achievement Award. He is leading the Bendable Electronics and Sensing Technologies (BEST) research group with more than 20 researchers (including 7 post-docs, 12 Ph.Ds).

Large area pressure sensor system for critical injury diagnosis

Simon Johnson[1], Tim Moor[2]

[1] *Centre for Process Innovation, Netpark, Thomas Wright Way, Sedgefield, TS21 3FG, UK*

[2] *HP1 Technologies Ltd., Harrogate, HG3 1PA, UK*

Utilising printed sensors on a flexible substrate, a novel pressure sensor system has been created by HP1 Technologies (HP1T), a UK business which is working in collaboration with CPI.

HP1T's patented technology was originally designed to meet an identified need for data related to traumatic brain injuries caused by cycling accidents, inspired by its inventor's cycling accident.

The aim was to develop a versatile, low cost device that could capture accurate data about the time, location, force and direction of an impact to a helmet in the event of an accident. The is to provide data which could be valuable to clinicians when assessing a head injury to insurers when dealing with the outcome of an accident and to helmet manufacturers when considering improvements to helmet safety and design.

The goal was to create a low cost device (sensor arrays, electronics and software) that can be integrated into helmets to improve the medical and social outcomes for the victims of traumatic brain injury and to reduce the costs of such incidents.

Figure 1: On the left model is the one-piece sensor array as it is formed around the head. On the right model is a production prototype of the covered sensor array that can be worn comfortably beneath a helmet.

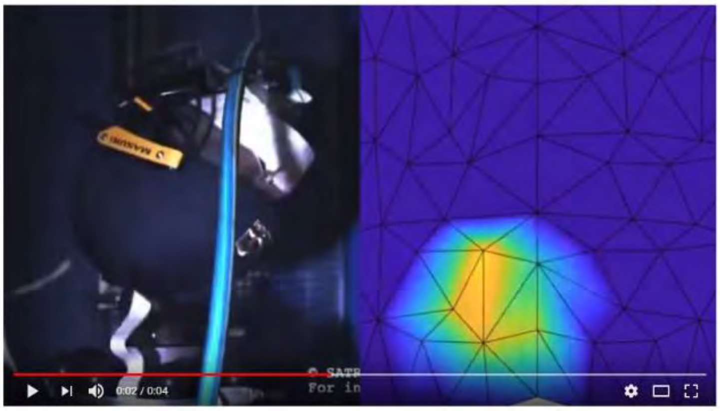

Figure 2: Drop testing a cricket helmet (with the sensor on the inside between the head and the helmet), generating a visual output of the actual split second impact and pressure distribution that occurred.

CPI has worked with HP1 to create arrays of printed pressure sensors based on a design that can be cut to conform to the head within a helmet. The arrays contain 64 sensors which cover the critical areas of the head. The sensor has been designed to minimise power consumption through a novel sensor architecture and this has been found to be effective.

The sensors have been screen printed using a Dek Horizon printer and inks selected for the performance and pressure range anticipated for this application. The sensor ink requires thin layer printing for the sensitivity required at 3.5 micron thickness. Layer thickness measurements using a Tallysurf CCI interferometer system have shown reasonable layer quality for the ink.

The sensors have been characterised to understand their tolerance, manufacturing spread and temperature variability. Figure 3 shows the variation of resistance with pressure for 32 sensors on a single panel for a pressure range of 10 to 3000 N/cm^2 using 1cm diameter circular bearing face placed directly over the pressure sensor.

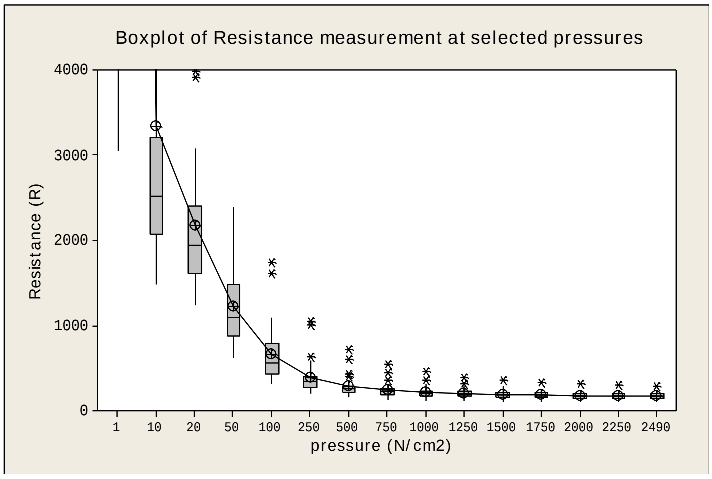

Figure 3. Variation of resistance with pressure for a 32 sensor array

A range of further data will be presented which show that while the sensors show variability due to manufacturing tolerance and surface quality, they can be used in the proposed system.

The system demonstrates the feasibility of creating multi-sensor arrays which can be used to provide diagnostic data for potential injury in a wide range of applications.

Biography

Simon Johnson studied Physics at undergraduate level, a Master of Engineering in IC Design at Durham and a PhD in IC Failure Mechanisms. He has worked as an IC Design Engineer and spent over 20 years as an academic at Durham University researching various aspects of IC design (including test and reliability, neural-electronic interfacing, self-reconfiguring processors) while teaching electronic devices and circuits. He setup and ran a technology start-up for 7 years which developed and sold an educational audio system for young children, and has worked in electronics instrumentation for radiation detection in industry before joining the Centre for Process Innovation in the UK. He runs an experienced team of electronics and software engineers who work on application for printable electronics at CPI.

Tim Moor studied product design at Northumbria University prior to working for the UK Government, researching and designing new high performance gas respirators for the military. All of Tim's inventions are either in production or clinical trial stage and span across fields from consumer goods to medical devices. He has over 70 patents to his name and received 8 national and international awards for his designs. Including the HP1 printed flexible sensor technology (http://www.hp1t.com), he is experienced in the concept creation and development of new product through a design led innovation process.

Low power gas sensors for distributed monitoring for Post-Harvest Applications

Dr Pascal Cachelin
CDT

Abstract
CDT's printable electronics portfolio addresses a large range of application sectors including biosensors, image detectors, gas sensors and energy generation & storage systems. In this presentation we shall provide an overview of CDT's gas sensor technology with particular focus on opportunities for gas monitoring in the post-harvest industry.

The field of printable electronics is an area that utilises a large range of printed and conventional electronic components that can be used for novel applications where flexibility in the design, functionality, form factor and the scaling of electronics systems are required. This lends itself to the fabrication of low cost, distributable gas sensors which is a technology that may provide opportunities within the post-harvest industry to inform decisions regarding identification of early on-set of disease in crop-storage facilities or the quality of crops in transport.

Data will be presented showing that such sensors can respond to the presence of ethylene gas and provide a quantified reading of concentration. CDT are also working as part of an Innovate UK funded collaboration to develop the potential of these sensors for detecting the onset of rot in apples during storage.

Biography
Pascal holds an MChem in Chemistry from the University of Sussex, an MRes from Imperial College London as part of the Centre for Doctoral Training in Plastic Electronics and a PhD from Queen Mary University of London where he studied thin film chiral nematic liquid crystalline sensors.

At CDT Pascal is a scientist in the Sensor Systems group, developing gas sensors to monitor apple crops for early signs of rot during storage within the post-harvest agricultural sector.

Cambridge Display Technology Limited, UK (Company Number 02672530)

Smart Power Emerging Energy Device (SPEED)

Suman Nandy, Sumita Goswami, Andreia dos Santos, Rodrigo Martins, Elvira Fortunato

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

Email: s.nandy@fct.unl.pt (SN), rm@uninova.pt (RM) emf@fct.unl.pt (EF)

In this ultra-modern era, everyone is looking for speed for betterment of their future. But, for keeping our speed, we require energy. Why not we get energy from this speed? Therefore, the specific vision of our “SPEED” is to build an effective cooperation between science and society, to materialize new smart technology for science and to pair scientific nobility with social awareness and responsibility. Our proposed research approach and manufacturing product concept will address both technical performance and cost-effectiveness of energy harvesting wearable applications[1,2], targeting accumulation of energy dissipated by the daily body movement into the sustainable electrical energy through high performance flexible wearable systems that could be integrated safely into everyday objects for an improved quality of life. The technology commonly referred to as Smart Power Emerging Energy Device (SPEED) aims to promote higher quality of life with built-in power generator that can harvest spontaneous electrical energy, that can instantly provide electrical power to the daily used smart electrical products.

Here, we newly developed polymeric functionalized human-motion interactive textile energy generator (HiTEG) which is working under mechano-responsive charge transfer mechanism. Each functionalized textile fiber has been used to produce current by simple patting, bending, or even soft touching, using different mechanism other than conventional piezoelectric or triboelectric platform[3]. We have designed prototype device HiTEG, integrated with free-standing functionalized fibers which is working under human-motion interaction, produces a peak power density of ~0.6 W m^{-2} with output current density of ~22 mA m^{-2}. Very cheap, easy synthesis and durability are the key factors behind this application. As a very first initial report, we have succeeded to glow at least 10 white LEDs of 2.5 watt and charge a commercial 10 μF capacitor to 3 V in 80 seconds. Our prototype energy harvester device HiTEG responds stably over 100 thousand times of patting, bending for six months without any degradation. Considering the existing huge garments market[4], overall objective of SPEED is to contribute an emerging platform of wearable e-cloth technology as relatively new industry that will serve as a means of increasing social welfare and they might lead to important savings on welfare budget.

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[3] Forecasted value of the global wearable devices market from 2012 to 2018. https://www.statista.com/statistics/302482/wearable-device-market-value/

Acknowledgement

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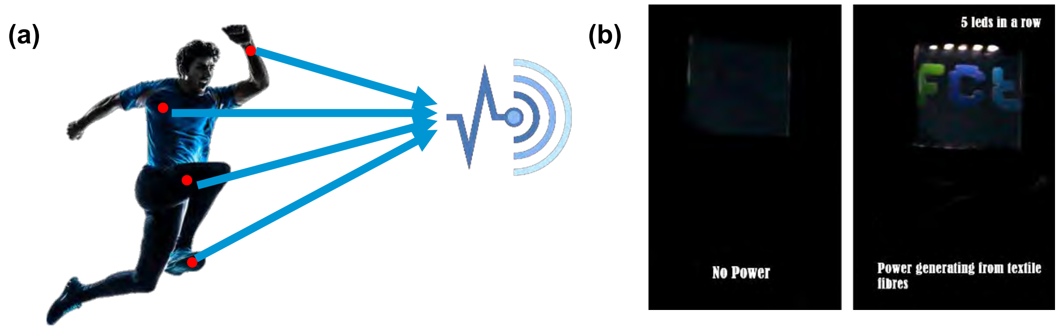

Figure: (a) Speed used in SPEED. (b) Snap-shot of powered 5 white LEDs from HiTEG.

Biography

Dr. Suman Nandy has 13+ years of admirable experience in the field of Materials Science and Engineering from his Ph.D. Currently he is working on developing new polymeric platform for wearable energy harvesting device in CENIMAT-i3N research center. He is also working on mechano-electrical study and its application in self-powered writable-readable organic data sheet of conjugated polymeric films fabricated on different types of substrate. His research at CENIMAT has opened a new door towards the study of localized current transport dynamics for different nanostructure materials and device interface by AFM using different kind of electrical mode. He is one of the responsible to this characterization. He is a person who believes on “out of the box” thinking and always try to cultivate new area of research in materials engineering. It reflects, when he started a new work on bio-waste derived carbons materials towards the concept of sustainable developments. He is part of a project under horizon 2020 (1D-Neon, GA: 685758).

Tools and Processes for Printed Electronic Systems

Vivek Subramanian[1,2]
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In recent years, there has been significant interest in the applications of printed electronics in the realization of a range of low-cost, large area, flexible electronic systems such as displays, distributed sensors, and low-cost disposable tags. To make printed electronics a viable technology, however, there is a need for significant innovations across all aspects of these systems, including realization of advanced printable materials, improvements in printing technology, and design and realization of devices and systems that exploit the capabilities of this emerging technology.

In this talk, I will review our progress in advancing the state of the art in printed electronics. I will begin by discussing the physical underpinnings of printing and will discuss how understanding and control of printing-related phenomena allows for substantial advancement in the capabilities of the same. I will additionally discuss advances in printable material systems that enable the realization of high-performance printed structures. In particular, I will discuss the importance of proper material design for use as printable precursors. Finally, I will show how the combination of advanced printed techniques with appropriate materials and proper device design may be used to realize printed devices with unprecedented performance levels, thus helping to usher in the era of printed electronics.

Biography

Vivek Subramanian received his PhD in electrical engineering from Stanford University in 1998. Since 2000, he has been at the University of California, Berkeley, where he is currently a Professor of Electrical engineering and Computer Sciences. In 2018, Prof. Subramanian moved to École polytechnique fédérale de Lausanne, where he is a Professor of Microengineering.

Dr. Subramanian is a member of the Institute of Electrical and Electronic Engineers (IEEE). In 2002, he was nominated to Technology Review's list of top 100 young innovators (the TR100), and his work at Matrix Semiconductor was nominated to the Scientific American SA50 list for visionary technology. Awards he has received include the Paul Rappaport Award for the best paper in an IEEE EDS journal, the IEEE Device Research Conference and the IMAPS best paper awards, the 2015 IEEE Kiyo Tomiyasu Award, and the outstanding teaching award from the EECS Department at the University of California, Berkeley.

Additive and subtractive manufacturing for large area printed electronics

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Additive and subtractive manufacturing (A&SM) is currently reinventing the way we fabricate our electronic devices. Inkjet materials deposition and laser processing by, for example: ablation, modification, sintering or material transfer are rather complementary techniques as they are implemented on very similar machine platforms and are compatible with high-speed sheet to sheet or roll-to-roll processing, if necessary in controlled environments (clean, low H_2O, low O_2). By combining these processes, new concepts can be realised at a less wasteful and, more cost-effective way than ever before.

From the plethora of applications that can benefit from A&SM, bioelectronics hold most of the promise to act as a disruptive force in our everyday life. More specifically, microfluidic Micro-Electro-Mechanical Systems (MEMS) are increasingly recognized as a unique technology field for the development of biomedical devices (BioMEMS), due to their functional performance on the microscale, at the dimensions of which most physiological processes are operative. Applications near micro- and nanoscale are promising in the field of intelligent biosensors, where it enables the monolithic integration of sensing devices with intelligent functions like molecular detection, signal analysis, electrical stimulation, data transmission, etc., in a single microchip.

In this talk, our contribution towards realising the aforementioned concept, through our involvement in the H2020 M3DLoC project, will be presented. Examples from our current portfolio of activities will also be discussed, including applications such as touch panel displays, thin film photovoltaic interconnects and biomedical devices.

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Biography

Dr. Adam Brunton is the director the M-Solv's Business Development group. He has a wide experience of technology development and implementation in challenging industries. Before joining M-Solv, Adam developed prototype exposure tools and optics for extreme-ultraviolet (EUV) lithography of semiconductor devices at Exitech and Media Lario Technologies. This was a change from his early career as a university lecturer researching X-ray optics for astronomy and planetary science applications. After receiving an MA in Physics from Oxford University he studied for a PhD on X-ray optics from Leicester University. Adam also worked on calibration of NASA's Chandra X-ray observatory and has published over 40 papers.

Dr. Grigorios (Greg) Rigas is currently leading the Advanced Manufacturing group at M-Solv Ltd, which focuses on the development of novel processing techniques for large area printed electronics (PE). After graduating in the top 1% of his class as an Electronic Engineer in Greece, Greg moved to Surrey to pursue an MSc in Nanotechnology and Nanoelectronics, where he received a distinction for his work on PE. In 2013 he was awarded a 4-year scholarship from the National Physical Laboratory (NPL) to pursue a PhD at the University of Surrey (UoS).
His research project, titled "Advanced processing and characterisation of printable single crystal electronics", aimed to tackle the key challenges associated with introducing PE into large-scale manufacture. Greg is the recipient of a series of academic awards including the 2017 Award for an Outstanding Researcher from the Institution of Engineering and Technology (IET). His current research interests are within the field of printable biomedical devices and energy harvesting-storage configurations.

Water transfer printing technology for large area 3D conformable electronics

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ABSTRACT

3D conformable electronics rely on the fabrication of devices on flexible or stretchable substrate. Its ultrathin thickness offers bendability and the stretchable design enables conformability. Recently, flexible and stretchable electronics have been demonstrated many applications ranging from health monitoring to optoelectronics.[1, 2] However, it still remains a challenge that wrinkles and folds will occur when a 2D planar sheet wraps a complex 3D object such as a sharp corner or a torus surface (figure 1a).

Water Transfer Printing (WTP), which has been widely applied in graphic arts, has been recently adapted to the field of large-area conformable electronics. [3] The functional electronics fabricated on a hydrosoluble substrate are placed on the water surface. After the substrate dissolves, the floating device can be easily transferred to a 3D object by dipping process. The Van der Waals force provides the adhesion between the electronics and the 3D object. Our previous works have demonstrated the capability of the WTP technology to fabricate conformable electronics on variety of object shapes and roughness (figure 1b and 1c).[3,]

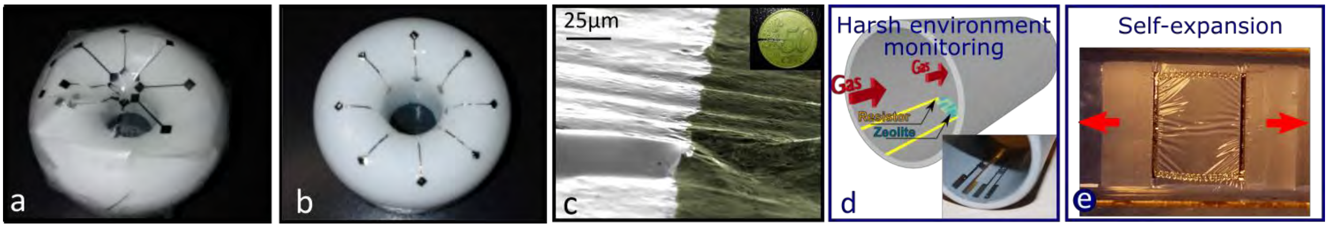

Figure 1. *a) Metallic ribbons fabricated on 50µm-thick polyethylene naphthalate (PEN) substrate which is fixed on the outer surface of a torus. The inner surface of the torus cannot be fully wrapped. From b to e), WTP technology capabilities for large-area 3D electronics applications. b) Conformal wrapping to the torus using WTP technology. c) SEM images showing excellent conformability of the metal film (silver) transferred onto a coin (dark). d) 3D Sketch of a zeolite-based gas sensor directly transferred to a pipe. The inset shows an experimental picture. e) Self-expansion of interconnects during the dissolution of the hydrosoluble substrate.*

Here, we present a zeolites-based gas sensor mounted inside a pipe by WTP technology (figure 1d). The result shows that WTP technology holds the potentials to transfer conformable electronics to some extreme locations. We also elaborate how to control the self-expansion of the floating device driven by the surface tension, allowing the fabrication of 3D large-area electronics from a conventional small-sized electronics.

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BIOGRAPHY

Maxime HARNOIS received his PhD. degree in 2008 from the University of Rennes (IETR Microelectronics & Microsensors group). He has joined CNRS in 2009 in BioMEMS group of the university of Lille (IEMN BioMEMS group). He is currently working at CNRS in Microelectronic & Microsensors group (IETR RENNES). His research interests include all the aspects of materials science and engineering. He has especially worked on: i) biosensor devices, ii) materials and interfaces engineering for omniphobic coating, iii) materials and methods for flexible, stretchable and conformable electronics and iv) additive manufacturing. Recently, he specializes in additive manufacturing. He is focusing on inkjet printing technology and has developed new additive manufacturing concepts such as Water Transfer Printing.

Pushing the limits of screen printing: Consistent and mass-producible 25 micron conductive tracks

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As the leading technology in printed electronics, screen printing is a crucial industrial process but remains limited in terms of resolution. Printing a network of sub 30 micron, highly conductive fine tracks onto flexible substrates in large format is technologically challenging. This work presents the new potential of screen printing for high resolution thanks to new mesh technology combined with tuning of ink rheology to correspond with screen mesh characteristics.

Mesh size limitations and rheological characteristics of the inks currently limit repeatable fine line production. The fundamental barriers to flow for achieving high resolution features in high yield contact printing processes are addressed in the study by exploring the interactions between ink rheology, mesh, screen emulsion and printing conditions. The study compared a range of high resolution metallic meshes from 430 to 900 threads per inch, together with micro and nano-particle conductive inks with modified rheology.

Consistent printed tracks of sub 25 micron width were achieved with a rigorous basis for better prediction, control and consistency in screen printing. Lines with a resistance of sub 40 ohms across a 3 cm long, sub 30 micron wide track and 60 ohms across a 3cm long, sub 25 micron wide track on the 900 mesh has been achieved.

This work was funded by EPSRC and Nippon Sheet Glass and with the kind support of Asada Mesh and Sun Chemical.

Acknowledgement - The author would like to thank Dr Erika Rebrosova and Mr Frank Eirmbter of SunChemical for providing the inks. Additionally, the author would like to thank Mr Hideaki Asada and Mr Koji Honda of Asada Mesh Co Ltd for providing the high resolution meshes. Dr Joe Boote of NSG Pilkington and Dr Chris Phillips of WCPC for their support.

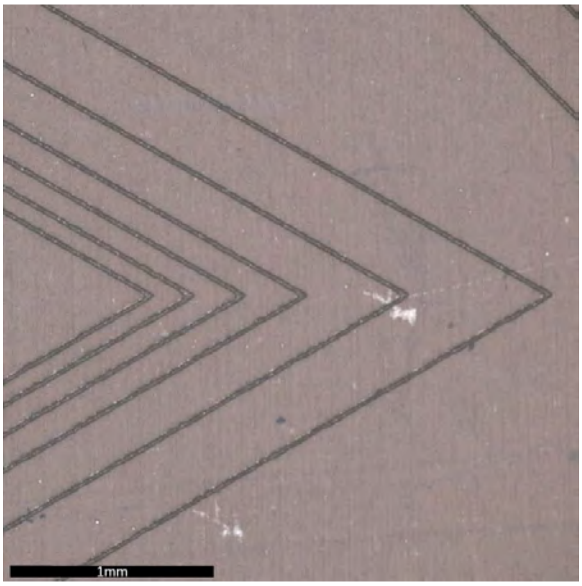

Figure 1. Complex pattern of sub 30 micron tracks printed

Biography

Yin Cheng Lau (John) is currently a research assistant in Welsh Center of Printing and Coating (WCPC). He has received the MEng degree in Chemical Engineering from Swansea University in 2013. John previously interned with Bayer MaterialScience and Haemair Ltd. He is currently pursuing the EngD degree in Materials Engineering at Swansea University sponsored by NSG Group. During his EngD, he has successfully generated generate some intellectual property which resulted in a patent being filed. His current research interest is the fabrication of conductive patterns on flexible substrates.

Novel approaches to print process control based on advanced rheometry

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Manufacturability, process control and, ultimately, product performance of structured products manufactured by flow-based processes are critically dependent on the rheological behaviour of complex fluids. Advances in formulation to achieve successful manufacture in such processes demands appropriate levels of rheological information but such advances are presently constrained by a lack of appropriate rheological characterization. We report how limitations associated with rheological characterization using traditional small amplitude oscillator shear (SAOS) can be overcome using a novel exploitation of parallel superposition rheometry to probe viscoelastic changes linked to the response of material microstructure to unidirectional shear flows. Further, we demonstrate the utility of performing Fourier transform controlled stress parallel superposition (FT-CSPS) measurements to inform formulation in a study of functional ink performance to rapidly characterise these fluids over a range of relaxation timescales. The FT-CSPS rheometric technique is shown to be superior to traditional rheometric techniques currently used by industry to inform formulation. The data presented herein demonstrates the utility of CSPS in providing a new basis for establishing process control in flow based manufacturing.

Biography

Dr Dan Curtis is a Senior Lecturer within the Complex Fluids Research Group of the College of Engineering, Swansea University. His research interests involve the development of advanced rheometric techniques for the study of Complex Fluids. His work on advanced manufacturing and healthcare applications involves techniques for studying fluid microstructural responses to flows under conditions of manufacturing process and clinical relevance.

His rheometric, imaging and molecular dynamics simulation studies of biopolymers have involved combined viscoelastic and spectral analysis of gel network development and have contributed to improved understanding of blood clot evolution. He is also developing NMR and microrheometric methods for studying flow within soft solids and complex fluids.

The circular economy opportunity

Marco Meloni
Ellen MacArthur Foundation

We are increasingly surrounded by ever more complex products, from smartphones and computers to wearable devices. Although these devices have become an essential part of life, most are still treated as if they are disposable.

If we want to enjoy the benefits of technological innovation and access to the services that electronic devices bring, we need to create an electronics system that works.

This presentation will offer an overview of how the principles of a circular economy can be applied to the electronics industry, relevant case studies, and will explore the opportunity that circular economy represents for large area electronics.

Biography

Marco is a Research Analyst in the Insights and Analysis team of the Ellen MacArthur Foundation, working to provide evidence of the economic, environmental and societal benefits that a circular economy transition could deliver. He has worked on a wide range of topics since joining the Foundation, ranging from applying the circular economy concept to the food system, to exploring design strategies and a vision for consumer electronics.

Marco has a background in Industrial Ecology and has worked in the field of Life Cycle Assessment before joining the Foundation. Outside of work, he is enjoying the water sport activities the Isle of Wight offers.

MSc. Industrial Ecology, TU Delft and Leiden University

Flexible perovskite solar cells

Juan P. Prieto-Ruiz[1], Olga Malinkiewicz[1], Anni Määttänen[1], Barbara Wilk[1]
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Metal halide perovskites constitute a very attractive class of materials for optoelectronic applications, such as solar cells, light emitting diodes, lasers and photodetectors[1]. Most notably, solid-state photovoltaic devices based on these materials have reached power conversion efficiencies (PCEs) of 23.7% after just five years of academic research[2], paring their performance with the inorganic thin-film technologies.

In this context, it is easy to understand the great commercial potential of perovskite solar cells. However, there still remain few challenges which need to be resolved to prove the viability of this technology. Particularly, a cost-effective, reliable fabrication process capable of delivering highly efficient, large-area perovskite modules is yet to be demonstrated. In order to address these challenges, inkjet printing offers multiple advantages[3]. Precise control of deposited volume of functional inks with minimal material wastage, high productivity, scalable print quality and limitless printed pattern design possibilities are some of the most remarkable features of this fabrication technique.

In this talk, we will describe the work performed at Saule Technologies on the design and development of a fully scalable inkjet printing process for the production of perovskite photovoltaic modules on flexible substrates, carried out in ambient atmosphere. Moreover, we present printable mini-modules of areas up to A4 size together with a robust encapsulation methodology. The utilization of inkjet printing technique enables us to design arbitrary-shape modules, which combined with the use of light weight, flexible substrates opens many new avenues for PV applications. These new market perspectives, as well as different aspects related to the scaling up of the technology from laboratory to industrial manufacturing will be also discussed from a perspective of an early-stage, fast growing tech company.

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Biography

Dr. Juan Pablo Prieto-Ruiz carried out his studies in Physics at the University of Valencia (Spain). In 2015, he obtained his PhD in Nanoscience and Nanotechnology at the group of Prof. Eugenio Coronado ,a pioneer in the field of molecular magnetism and multifunctional materials. During this time he developed a new generation of organic light emitting spintronic devices, the so-called spin-OLEDs. In October 2015, he joined Saule Technologies team as a Printing Process Engineer, where he is working in the fabrication of perovskite solar cells by inkjet printing, focusing in the scale up of the process from laboratory to production line.

OLED alternative with inorganic LED based technology for diffuse lighting products

Presenting D. Peden, J. Lai, L. Zhu, N. Kerr and J. Gourlay

Design LED Products Ltd, Alba Innovation Centre, Alba Campus, Livingston, West Lothian, EH54 7GA, UK

A platform for the manufacture of thin, mechanically flexible and diffuse lighting panels, based on conventional inorganic LEDs, have been developed as an alternative to unstable organic materials. A distribution of emitters are embedded in a printed light-guide structure. Homogeneous surface illumination (**Error! Reference source not found.**.) is achieved through a combination of source obscuration through a multi-layered material stack, and a complex distribution of surface optics across the light-guide surface. Fine pitch printed circuits and surface mount technology enables the deployment of smaller LEDs. Optimisation of integrated reflector and diffuser integration gives good optical efficiency. Homogeneous luminance exceeding 20,000 Cd/m^2 has been demonstrated on 170 x 170 mm format. A 1D scalable extended format of 340 x 170 mm is under development, with a view to the creation of very large area surface lighting format over multiple metre lengths.

DesignLED are exploring further extensions of the technology platform for the creation of 2D scalable formats. This disruptive and commercially viable platform exceeds the luminous output and efficiency of fragile organic materials and is manufacturable using conventional, additive printed electronics.

Figure 1. Homogeneous light-tile platform.

Biography

Dr Derek Peden is Innovation Manager at Design LED Products Ltd. Derek's responsible for defining and implementing the company's Innovation strategy and leading Innovation projects. He oversees the application for UKRI and European funding in support of the company's Research & Innovation activities, project execution and delivery. He is engaged in managing customer led joint development projects, and manages the protection and development of DesignLED's IP platform. Derek joined DesignLED in 2009 and was Product Development Manager prior to his role as Innovation lead. Derek has a PhD in Applied Physics, and BSc in Laser Physics and Optoelectronics, both from The University of Strathclyde.

In addition, Derek is an Innovation Champion at the Construction Scotland Innovation Centre, an industry led and demand driven Innovation Centre, with input to the work of the CSIC.

Additive manufacturing of neuromorphic devices

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Traditional computing has relied on von Neumann architectures, which separate the memory from the processor. The limiting factor of these architectures is the speed at which a command from the processor can reach the memory and vice versa. Current industrial trends are focused on reducing the distance between the memory and processor. However, despite best efforts; the most advanced of von Neumann architectures cannot process information as efficiently as the brain. While traditional computers consume tens of thousands of Watts, the brain only requires 20 Watts to operate [1]. The brain is furthermore capable of real-time processing and learning [2,3]. This enhanced operation of the brain can be attributed to the nature of the brain's base unit. the synapse, its use of ionic fluxes for communication and the complex 3D connectome structure of the brain [4].

The field of neuromorphic computing examines how to mimic the synaptic nature of the brain. Current neuromorphic architectures being developed are fabricated on rigid silicon substrates using traditional lithography techniques, which only allow planer device fabrication. As a result, mechanical or architectural design flexibility is extremely challenging. This limits the ability to develop complex 3D connectome-like structures, a key feature necessary in enabling the enhanced functionality of neuromorphics.

In this research, we propose and illustrate the use of digitally-enabled additive techniques that allow for mechanical and architectural design flexibility. Fused deposition modelling and inkjet printing additive manufacturing techniques were used to fabricate globally gated 4×4 crossbar neuromorphic architectures. The devices were based on commercially available organic materials such as semiconducting PEDOT:PSS and conductive polylactic acid/carbon black composite, to form bioelectronic devices.

Neuromorphic and logic current-voltage characteristics were obtained when the device junction was submerged in a phosphate buffered saline (PBS) solution. Results show that simple, available and scalable additive manufacturing techniques can be used to fabricate organic electrochemical neuromorphic logic devices with mechanical and architectural design flexibility.

It is hoped that the findings from this research will firstly pave the way to the realisation of additive manufacturing as a fabrication technique for bioelectronics devices and neuromorphic computing; and secondly that fused deposition modelling specifically can be tuned to deliver effective neural network architectures.

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Acknowledgement–

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Biography

Tanya is a first year PhD student at the Institute of Manufacturing, Department of Engineering, University of Cambridge. Her PhD mainly focuses on "Additive Manufacturing of 3D Integrated Neuromorphic Devices and Neural Networks" and is supervised by Dr R. Daly and Professor G. Malliaras.

She received her MEng degree in Material Science and Engineering from the University Manchester in 2017 before joining the Centre for Doctoral Training in Ultra Precision Engineering. As part of her MRes for her doctoral training, Tanya undertook a 5 month project on neuromorphics which she continued with for her PhD project.

Stretchable self-healing interconnects

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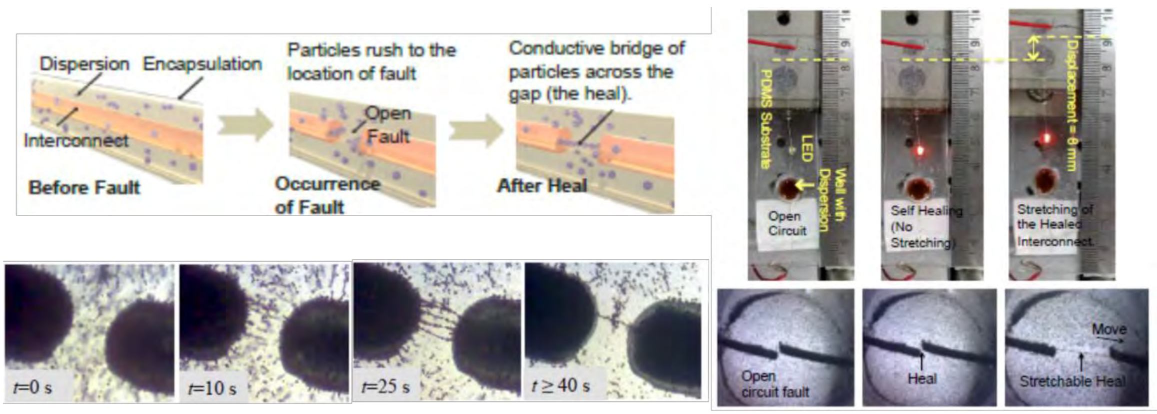
Large area flexible electronics offers advantages such as rapid manufacturing via roll to roll processing, conformable electronics and wearable electronics systems. These advantages come at the cost of poor operational reliability. Interconnects on flex commonly experience open faults during operation due to mechanical and thermal stress, electrostatic discharge and environment related degradation. Passive approaches based on using meandered geometries and stretchable conductive material improve tolerance to mechanical stress but do not provide a means to repair the interconnect if an open fault were to occur. Active approaches (self-healing) perform real time repair of an open fault. Self-healing interconnects have been demonstrated using liquid metals, hydrophobicity driven Janus particles, and conductive polymers. While effective, these approaches either use relatively rare materials, change conventional interconnect fabrication processes, only address mechanical stress related faults or do not permit flexible interconnects.

We demonstrate stretchable self-healing interconnects that overcome these drawbacks. Self-healing is achieved using a dispersion of conductive particles in an insulating fluid packaged over the interconnect as shown in Fig. 1a. Upon the occurrence of an open circuit fault in a current carrying interconnect – irrespective of the mechanism that causes it - an electric field appears in the gap. This polarizes the conductive particles of the dispersion allowing them to chain up into linear clusters due to dipole-dipole attraction. These clusters form a bridge across the gap and re-establish the current. For certain materials (e.g. copper), the joule heating due to this current enables the sintering of the particles thereby forming a low resistance heal across the open gap.

This mechanism also permits highly stretchable heals (Fig. 1b). Upon stretching the interconnect, the heal momentarily breaks and re-establishes the field. This field polarizes and encourages locally available particles to fill the gap to re-establish connectivity. The heal therefore stretches by increasing the number of particles constituting the chain. Using 80 mg/ml dispersions of copper microspheres (radius 5 um) in silicone oil (viscosity 300cSt), stretchable heals with a conductivity of $5x10^5$ S/m permitting a strain of 12.5 to 60.25 (depending on the strain rate) were achieved.

In summary, this work demonstrates self-healing and stretchable interconnects with the heal effectively composed of ‘stretchable copper’. This promises improved interconnect reliability to open faults.

Acknowledgement - We acknowledge EPSRC Grant No. RG92121 and DST IMPRINT Grant No. 7969 for funding.



(a) (b)

Figure 1. (a) Mechanism of self-healing, (b) Stretchable heals for flexible electronics.

Biography

Sanjiv Sambandan is a lecturer at the Department of Engineering, University of Cambridge, Cambridge, UK. He holds a joint academic position at the Indian Institute of Science, Bangalore, India. Prior to academic appointments, he was with the Electronic Materials and Device Lab, Xerox Palo Alto Research Centre, CA, USA.

Integrated, solar-powered gas cards based on hybrid analogue amplifiers integrated with organic transistor sensors

Daniel Tate[1], Vanessa Tischler[1], Sheida Faraji[1], Suresh Garlapati[1], Aiman Rahmanudin Hamdan[1], Krishna Persaud[1], Mike Turner[1], Iyad Nasrallah[2], Moon Hyo Kang[2], Henning Sirringhaus[2]
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In this presentation we will present the outcomes of the IPESS project, one of the flagship technology projects of the EPSRC Centre for Innovative Manufacturing in Large Area Electronics (CIMLAE). This has been a joint project between the University of Manchester, that has developed a novel approach to highly sensitive gas sensors based on low-voltage organic field-effect transistor arrays, and the University of Cambridge, that has developed low-voltage analogue amplifiers combining solution processed n-type oxide transistors with p-type conjugated polymer transistors. We have combined these two technologies to realize an integrated gas sensor card with sufficiently low power consumption that it can be powered by a solar cell.

Biography

Prof. Krishna Persaud is Professor of Chemoreception at the School of Chemical Engineering and Analytical Science, University of Manchester. He has been involved in research in chemoreception, crossing disciplines from biological aspects of olfaction to sensor arrays, electronics, signal processing and pattern recognition, and commercial development of artificial olfaction technologies. He developed gas sensor arrays for sensing odours based on conducting polymers that became commercialised by Aromascan plc and is currently a director of Multisensor Systems Ltd.

Prof. Henning Sirringhaus, FRS, is the Hitachi Professor of Electron Device Physics at the Cavendish Laboratory, University of Cambridge, and works on the charge transport, photo and device physics and the thermoelectric properties of conjugated polymers, molecular semiconductors and other advanced energy materials. He is co-founder of the spin-off companies, Plastic Logic/FlexEnable and Eight-19 Ltd, commercializing organic transistor and organic solar cell technology, respectively.

Graphene enhanced products

Stephen Hodge
Versarien

Biography

Dr Stephen Hodge was a Postdoctoral Research Associate in the Cambridge Graphene Centre at the University of Cambridge, Teaching Fellow in the EPSRC Centre for Doctoral Training in Graphene Technology and is currently a bye-fellow at Murray Edwards College. He was recently appointed Versarien plc's Head of Research, primarily responsible for overseeing all the company's graphene and other 2d materials research and development activities, including the company's participation in the recently announced Graphene Engineering Innovation Centre at the University of Manchester. He is based as an industrial visitor at the Cambridge Graphene Centre, to foster the training of students in Graphene Technology and develop joint projects.

Solution processed organic photodetectors for the near infrared

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Organic photodetectors (OPDs) have important advantages over conventional inorganic photodetectors that make them preferable in many applications. Solution processing allows large area detection as well as unique form factors on different substrates. The flexibility of organic synthesis allows tailoring the performance and cost to specific applications. Moreover, OPDs allows easy integration with other printed electronic components (OTFTs, OLEDs, passive components). Cambridge Display Technology Limited (CDT) is developing OPDs for various applications including Transducers for Biosensors, X-ray digital imagers, Wearables, Biometric sensors and Near IR image sensors. To that end we use materials produced by Sumitomo Chemical.

OPDs based on donor-acceptor blends take advantage of the intensive research done recently for organic solar cells and apply it to the field of photodetection. Although many of the features of solar cells and photodetectors are similar, there are some significant differences that can require different device architecture or materials. As an example, in order to reach high sensitivity, it is necessary to keep the dark current low. We will present the different approaches that we follow in order to reduce the dark current in our devices.

Another critical parameter is the spectral responsivity, related to the external quantum efficiency (EQE). For many applications it is desirable to have good responsivity in the near infrared. We have developed devices performing well in the spectral region extending to about 1 μm wavelength (Figure 1) and will present its performances.

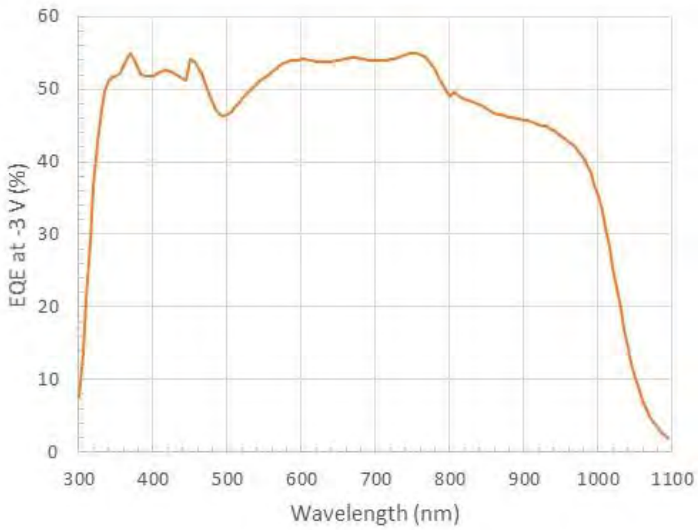

Figure 1. External Quantum Efficiency of one of the photodetectors

Biography
Francisco Rodriguez is a scientist at Cambridge Display Technology Limited (CDT), part of Sumitomo Chemical Co. He obtained his PhD in Physics at the University of Zaragoza. He has worked as a researcher in Tampere University of Technology, ICFO and the University of Manchester in fields such as photo-addressable polymers, second harmonic generation and other nonlinear optical parametric processes, polymer solar cells or graphene optical modulators and photodetectors. He joined CDT in January 2018 where he works mainly in the development of organic photodiodes and in their integration together with OLEDs in prototypes for multiple applications.

Cambridge Display Technology Limited (Company Number 02672530)

Highly conductive, compressible, vertically-aligned-CNT-PDMS-metal composite films as strain sensors

M.O. Tas[1], M. A. Baker[2], J. Bentz[3], K. Boxshall[4], V. Stolojan[1]
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[4]*Smiths Group plc, 11-12 St James's Square, London, SW1Y 4LB, UK*

Flexible and highly-conductive vertically-aligned multi-wall carbon nanotube-(VA-MWCNT) Polydimethylsiloxane (PDMS) composite films can be exploited as shock-absorbent electrical contacts, as highly-sensitive strain sensors, or as flexible energy-storage components. Here, we present a simple, cost-effective, high-yield method to transfer VACNTs with PDMS as uniform, well-aligned composite films. Samples of different VA-MWCNT lengths (densified and non-densified) are transferred on to PDMS before metallisation (Au, Al-Au, Al-Cu) and tested for their electrical and mechanical response. Firstly, we report that a contact resistance as low as 0.019 Ω/mm^2 under strain is achieved for a metallised VA-CNT-PDMS film, demonstrating good power handling capabilities. Further, we report gauge factors (GF) as high as 378.6 at 52% compressive strain, with full elastic recovery, indicating a very high sensitivity for applications such as human motion detection and electronic skin. It is observed that some metallised CNT-PDMS films suffer from peeling of the metal coating under large-strain (>50%) cyclic compression stresses. This is overcome by plasma treatment and the use of an Al adhesion layer. Electromechanical durability and structural robustness of the films are tested through a cyclic test (> 10,000 cycles) at strain rates of up to ~75 % which shows that these composite films are very good candidates as conductive shock-absorbers for MEMS components or as wide-range, sensitive motion detectors.

Keywords: *Carbon nanotubes, conductive nanocomposite, nanosensors, electrical resistivity, compressibility*

Acknowledgement: We are grateful for financial support provided by Smiths Interconnect.

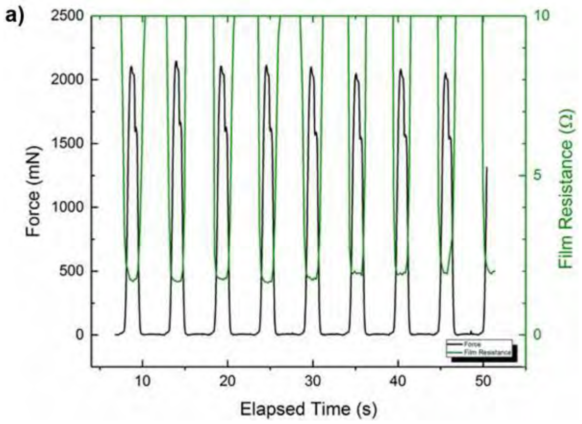

Figure 1. (a) Electromechanical response (Cyclic loading) of a 100 nm Au-metallised VA-CNT-PDSM film under 20% strain. (Contact area diameter ~250 µm)

Biography

Mehmet Tas is a PhD student at the Advanced Technology Institute (ATI), University of Surrey working under the supervision of Dr Vlad Stolojan and Dr Mark Baker. He studied materials engineering as his bachelor's degree (with honours) at METU in Ankara, Turkey. He then studied a MASc study sponsored by General Motors working on carbon based-low friction coatings (diamond-like carbon) for cylinder bore applications at the University of Windsor in Ontario, Canada prior to joining the ATI. He has interest in semiconductor testing, flexible electronics and sensor devices.

Material engineering of 2D materials for realizing the electronics from TFT to electrochemical devices

Hanleem Lee[1], Felice Torrisi[1]

[1] Cambridge Graphene Centre, Department of Engineering, University of Cambridge, Cambridge CB3 0FA, UK.

Chemistry on 2D materials and of 2D material has not studied much although chemistry of 2D material has been proposed as a candidate for modulating intrinsic properties of materials such as surface tension, electrical, optical, mechanical, and thermal properties. In some cases, even though conductivity losses occur, functionalization of 2D materials can be used to improve solubility, processability, and other specific properties to facilitate the practical utilization. However, chemical reaction with TMD has been less studied than that with graphene because the chemical reactivity of TMD is lower than that of the semi-metallic graphene.

Here, we investigate several chemical reactions of 2D material and hybrid composite with 2D material (e.g., Diazonium salt reaction, thiolation, organometallic reaction, C-C Coupling via cross-linking reaction) to understand how the chemical reaction or chemical environment affects to the materials' intrinsic properties. As a result, we are able to manage defect and edge state of 2D materials and use them to change their intrinsic chemical/physical properties: 1. Exfoliation behavior[1], 2. Electrical behaviour[1] related to mobility, type of carrier, and on/off, 3. Catalytic behavior[2], 4. Printability and coat-ability of materials.

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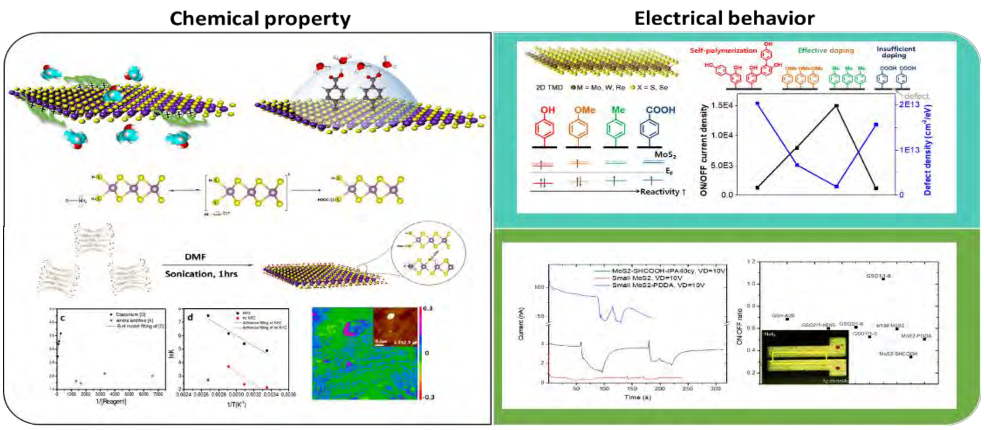

Figure 1. Summary of chemical engineering for 2D materials

Biography

Dr. Hanleem Lee studied at the Pohang University of Science and Technology (POSTECH) in Korea where she obtained her bachelor's degree in chemistry in 2010. She went to the Department of Energy science at the Sungkyunkwan University (SKKU) for her Master and Ph.D. working on investigating the chemical reaction of nanomaterials, synthesis of the flexible composite, and fabricating the electronic devices. She joined Center for Integrated Nanostructure Physics (CINAP) of Institute for Basic Science in Korea during her Ph.D. (from 2015) for multidisciplinary research on 2D material-based electronics. Now, she is a Research Associate at the Department of Engineering of Cambridge University. She is in the Nanomaterials and Spectroscopy Group in the Electrical Engineering Division and working on printed electronics and fibre electronics.

Water-based, biocompatible and inkjet printable 2D-inks

Cinzia Casiraghi
School of Chemistry, University of Manchester, UK

The isolation of various two-dimensional (2D) materials allows to combine them into heterostructures. Such a concept can be used to make functional devices such as tunnel diodes [1], tunneling transistors [2,3], photodetectors [4] and light emitters [5]. Solution processing of 2D materials [6] allows simple and low-cost techniques such as inkjet printing [7, 8] to be used for fabrication of heterostructure of arbitrary complexity. However, the success of this technology is determined by the nature and quality of the inks used. Furthermore, these formulations must be suitable for all-inkjet printed heterostructure fabrication - the remixing of different 2D crystal gives rise to uncontrolled interfaces, resulting in poor performance and lack of reproducibility of the devices.

In this work we show a general formulation engineering approach to achieve highly concentrated, and inkjet printable water-based 2D crystal formulations, which also provide optimal film formation for multi-stack fabrication [9]. Examples of all-inkjet printed heterostructures, such as arrays of photosensors [9], logic memory devices [9], strain sensors [10] and capacitors [11] will be discussed.

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Biography

Prof Cinzia Casiraghi graduated in Nuclear Engineering from Politecnico di Milano (Italy) and received her PhD in Electrical Engineering from the University of Cambridge (UK) in 2006. She was awarded with the Humboldt Fellowship and the prestigious Kovalevskaja Award (1.6M Euro) in 2008, which allowed her to establish an independent research group at the Physics Department of the Free University Berlin (Germany). In 2010 she joined the School of Chemistry, at the University of Manchester (UK), where she holds a Chair in nanoscience. She is recipient of the Leverhulme Award in Engineering (2016) and the Marlow Award (2014), given by the Royal Society of Chemistry in recognition of her meritorious contributions in the development of Raman spectroscopy for characterisation of carbon nanostructures. She authored and co-authored more than 70 peer reviewed articles, collecting more than 22k citations. Her current research work focuses on the development of 2D inks and their use in printed photodetectors, memories, thermoelectrics, sensors and biological applications.

http://casiraghi.weebly.com

Microchips in yarns - a revolutionary new approach to manufacturing intelligent garments

Tilak Dias, presented by Theodore Hughes-Riley
Advanced Textiles Research Group, Nottingham Trent University

Textile clothing has always been multifunctional. A shirt might provide warmth, demonstrate one's status or be somewhere to keep one's pen. Over the centuries technologies have developed to enhance functionality of textiles. Major developments have been the introduction of synthetic fibres, advances in breathable waterproof fabrics and easy care properties together with specific functions such as impact protection or flame resistance. Presently there is a growing interest in integrating electronics with textiles, and the current approaches include inserting pre-packaged electronics into pockets, stitching or printing circuits to the fabric surface or integrating functionality using conductive threads. However, the ultimate goal should be to integrate electronic functionality into textiles without compromising the required textile characteristics of softness, flexibility and conformability. In addition, to minimise costs, it is essential that electronic textiles can be produced on conventional textile equipment. A novel approach is to encapsulate semi-conductor chips within the fibres of yarns. As a textile conforms to a shape some regions bend and some go into shear deformation. Both factors are important for drape and conformability. Knitted and woven textiles are able to conform to a shape as they bend and shear. For example, thin polymer films can bend but, as it cannot shear, it buckles and crumples rather than conform to a shape.

This presentation will focus on a novel approach that is being pioneered at UK's Nottingham Trent University in which semi-conductor chips are soldered to fine copper wires and then incorporated within the fibres of a yarn. The chips are protected by polymer micro-pods (Figure1). Free fibres between micro-pods help retain the desired textile characteristics. The electronically functional yarns are then woven or knitted using conventional textile equipment.

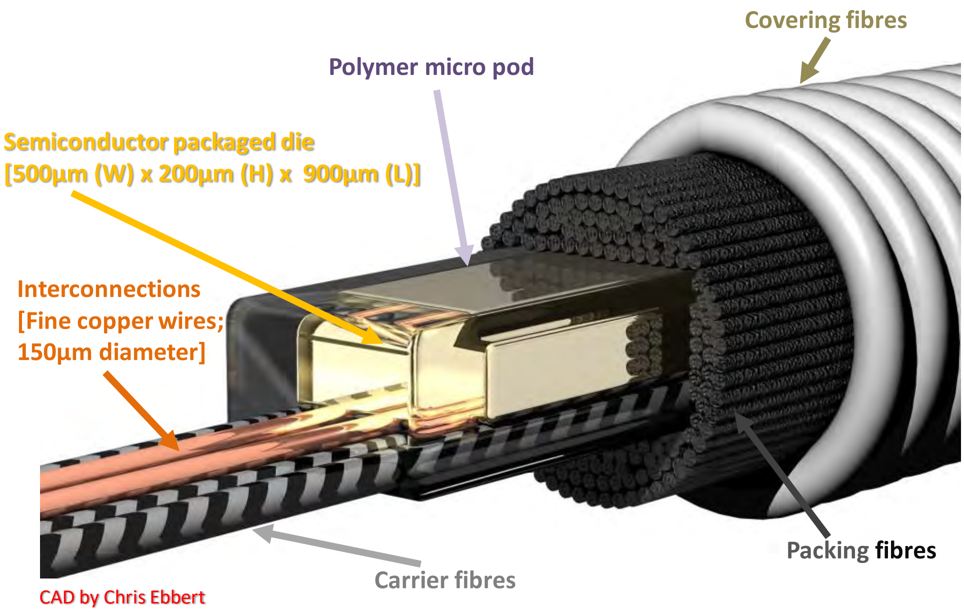

Figure 1: Conceptual design of micro-electronic yarn

Biography

Professor Tilak Dias directs the activities of the Advanced Textiles Research Group and brings a unique background in electronics, textiles and electronic textiles to the School of Art & Design at Nottingham Trent University (NTU). He leads the development of research in the fields of advanced textiles, flexural composite materials and electronic textiles, to enhance NTU's capacity to undertake internationally excellent research. Developments to date include wearable technologies for medical applications that include a vest for vital signs monitoring, engineered compression garments for the treatment of venous disease and lymphoedema, heated knitted textiles, and gloves and socks embedded with sensors for use in stroke rehabilitation. He has developed three novel core technology platforms, which have resulted in the formation of three spin out companies in the UK for their commercial exploitation, and has published over 150 scientific papers in leading journals and conferences and is named as the lead inventor in 74 patents. Of all his achievements, however, Tilak is most proud of becoming the first Professor of Knitting at NTU.

Dr Theodore Hughes-Riley is embedded within the Advanced Textiles Research Group in the School of Art and Design at Nottingham Trent University. His main area of responsibility is to apply his physics expertise towards the development of electronic textiles. His research focus is on the development and characterisation of novel textile-based sensors to create health monitoring devices. He has a growing reputation in fields of wearable devices, electronic textile, and sensor technologies and has authored over 40 publications.

Working with smart textiles – about materials, processes, products and their testing

Kay Ullrich
TITV Greiz, Germany

During the last ten to fifteen years we observed an increasing interest in metallized textiles for applications in smart textiles or wearables as well as for micro system technology. The development is driven by the market and by increasing miniaturization of electronic devices to focus not only on the size of the components but also on their flexibility.

Different technologies are suitable for the manufacturing of smart textiles. As the possibilities for the mass production of smart textiles are limited, the imbut GmbH focused together with researchers at the TITV Greiz on the development of new technologies for the continuous manufacturing. In particular, we discuss the construction of special fabrics for lighting and heating applications and solutions for the automatic manufacturing of embroidered electronic circuits. Amongst other topics we will discuss the FSD™-technology for automatically embroidered shining textiles and the new eWeb for easy interconnecting of conductive fabrics.

In the second part of the presentation we will focus on the reliability of Smart Textiles by using new test methods with the combination of textile stresses with electronic functionality tests on materials, fabrics and the final products.

Biography

Mr Kay Ullrich received his diploma in the study of physical technologies from the University of Applied Science in Zwickau, Germany. Since then he has worked at TITV Greiz – initially as a scientific assistant, progressing to deputy group leader of “Smart Textiles”, and now as deputy head of Research and Development.

His field of work within TITV Greiz encompasses:

- integration of electronic functionalities in textiles
- automation of developed manufacturing and processing technologies
- textile and electronic testing of Smart Textiles / Wearable Electronics

Integration of fibre-based electronic devices into textile structures (Eurecat contribution to the 1D-NEON vision)

Francesc Mañosa, Petar Jovancic
Functional Textiles Unit of EURECAT, Spain

The general vision of 1D-NEON is to develop fibre-based electronic devices based on smart materials and to validate different strategies to integrate them into advanced textile structures- wearable devices as a base for manufacturing of new products with multi-sectorial applications in consumer electronics, energy, healthcare and fitness, smart buildings, sensors and e-skin for soft robotics.

The textile integration of 1D-NEON developed fibre-based electronic devices (fibre stretchable electrodes, F-SE; fibre transistors, F-FET; fibre light emitting diode, F-LED; and fibre super-capacitors, F-SC) is still very challenging with many issues that have to be addressed because the properties of conventional textile structures are completely different comparing to the 1D-NEON fibre-based electronic devices. Therefore, this talk is an attempt to summarize the main obstacles occurring during the textile integration of fibre-based electronic devices and to propose some alternative approaches. Basically, the Eurecat emphasis is on the adaptation of existing weaving technology to meet the particular requirements for proper integration of 1D-NEON fibre-based electronic devices while preserving their functionality.

Biography

Francesc Mañosa Moncunill, Senior Technician in Technical Design in Textiles and Leather and Technician in Commerce and Marketing. 30 years' experience in the textile sector, in design and product development departments in several national and multinational companies of the textile industrial sector and in different subsectors; fabrics for clothing, decoration, automotive and industrial fabrics. Simultaneously he has developed teaching activity on textile technology in fashion design centers of University level. Author of the book Tecnologia i disseny de Teixits (Fabric Technology and design) (Edicions UPC, 2007) and of several translations and articles in specialized magazines. He is currently a researcher in the functional fabrics unit of the Eurecat technology center.

Washable and wearable electronic textiles enabled by two-dimensional materials

Felice Torrisi
Cambridge Graphene Centre, Electrical Engineering Division, University of Cambridge, UK

Graphene and related 2D materials (GRMs) hold a great potential for electronics and photonics thanks to their novel electrical and optical properties, suitable for future wearable and textile electronics [1]. I will give a brief overview on the development of GRM-based solutions and inks for printable and flexible (opto)electronic devices. [2]. Then I will demonstrate how the combination of electrical and chemical properties of graphene [3] are ideal to enable graphene-cotton smart fabrics, textile electrodes and sensors [3]. Finally, I will show how these new textile electronic components pave the way to flexible GRM-based devices on textiles for sensing and energy applications, such as integrated textile-based circuits [4] and textile-based solid-state capacitors [5].

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Biography

Felice Torrisi is a University Lecturer in graphene technology in the University of Cambridge and Fellow of Trinity College.

He graduated at the University of Catania in Italy, followed by a research period at the Institute of Microelectronics and Microsystems of the Italian National Research Council, where he worked on di-block copolymers for phase-change memories.

He joined the Department of Engineering at Cambridge in October 2008 as PhD student, then as a Schlumberger Research Fellow and finally as a Lecturer in 2014. He received the “Parmee Prize for Entrepreneurship” from Pembroke College and the “Science of Printing” Prize from the Institute of Physics. His research interests cover printed and flexible electronics with graphene and 2D materials with applications on wearable and textile electronics.

The integration of flexible electronics within wearable electronic devices

James Hayward

IDTechEx, 20 Station Road, Cambridge, UK

Wearable devices saw a significant wave of commercial attention, activity and investment starting in late 2013. Five years later, the hype surrounding the sector has all but faded, but the knock-on effects from the interest and investment continue to show. A highlight of this innovation is in device form factor, where the introduction of increasingly flexible and stretchable components has been an ongoing target for some time.

The bulk of wearable technology devices today remain direct derivatives from technology commercialised and commoditised via the smartphone. Deployment of low power displays, wearable sensors, efficient processors and effective communication methods such as Bluetooth Low Energy has enabled products such as smartwatches and fitness trackers to generate around $10bn annually (2018 forecast). AR, VR & MR devices (~$8bn in 2018) have also seen strong growth based on similar technology, but with huge investment and development in sector-specific technology needs in areas such as optics, microdisplays and sensing.

However, these smartphone derivatives just scratch the surface of what is possible with wearable technology. It has been a common narrative that wearable electronic products need an evolution in form factor, moving away from bulky rigid devices towards products that are stretchable, conformal and comfortable for the user to wear. However, observing device types such as electronic skin patches and electronic textiles reveals the over-simplification of this vision. Extra comfort derived from a flexible product needs to be balanced with factors such as ease of use, device performance and price, viewed within the competitive landscape which each product faces.

For example, the market for electronic skin patches was already more than $4bn in 2017, with medical devices such as continuous glucose monitors (CGM) and mobile cardiac telemetry (MCT) making up most of this revenue. However, the structure of these devices is still largely rigid and bulky, despite the long-term aim to progress towards better form factors.

In electronic textiles, a wide range of technology options has been developed, enabling technology to be increasingly seamlessly integrated into apparel. However, here the issue lies in realising an appropriate product. Early focus was around sports and fitness, with early players releasing e-textile compression garments aimed everyone from professional athletes to “weekend warriors”. Increasingly, it seems to have been slightly too early for this option to be feasible, with surviving companies shifting focus to the healthcare space, with similar products being trialled for use in areas such as inpatient monitoring or clinical trial assessments.

In this presentation, IDTechEx will present the latest trends and case studies on the integration of flexible and stretchable electronics into wearable devices. It will focus on product types such as electronic skin patches and electronic textiles, where the discussion and efforts are most prominent. It will also highlight some of the latest case studies around development achievements and technology trends occurring throughout the value chain, helping to enable the next generation of wearable products.

Biography

James leads IDTechEx’s research around markets and enabling technologies for wearable electronics. This includes authorship of leading market research and technology scouting reports focusing on several technology and application areas including wearable technology, wearable sensors, electronic textiles (e-textiles), augmented, virtual & mixed reality (AR, VR, MR), stretchable and conformal electronics, haptics and user interfaces. James works with clients around the world, from small startups and research groups to Fortune 100 companies, assisting with strategy, technology scouting and new business development. This includes supporting IDTechEx's subscription and event customers, as well as bespoke projects. James is a regular speaker, both at IDTechEx events and other events around the world.

Printing the IOT

Janos Veres

PARC

Electronics is entering a new era in which we need to go beyond mass production and begin to address unique, customized devices that are made on-demand. Wearables, automotive and a vast range of IOT applications cannot be served by traditional “electronics in a box” solutions. A key enabler for this transition is flexible and conformal electronics. For the last couple of decades printed and flexible electronics was viewed as a low cost manufacturing option for mass products such as displays and RFID. The challenge of delivering cost and performance in competition with well-established products has been significant. More recently, we see new opportunities for flexible, printed and hybrid electronics to deliver unique, often niche products. Unique form factors and tight integration of electronics will benefit from a digital, additive manufacturing infrastructure. Printing is an enabler for mass customization of electronics, for an IOT with smart things that fuse form and function in new ways.

Biography

Janos Veres leads PARC's Novel and Printed Electronics Program exploring the Future of Electronics. He is passionate about the future of manufacturing and the new ecosystems enabled by digital technologies. His main interest is exploring 2D and 3D printing and large area processes for electronic devices to merge form and function and to “free electronics from the box”. By combining novel materials, device designs and unique deposition processes, it becomes possible to print flexible circuits, sensors, memory and hybrid electronic systems. Janos creates projects that combine experts in technology, design, user experience and systematic innovation. Janos has held R&D, manufacturing and management positions in material, printing and electronics companies including PolyPhotonix, Kodak, Merck, Avecia, Zeneca and Gestetner, where he developed printed circuits, specialty functional materials, OLEDs, displays, and medical devices as well as printing/coating technologies. Janos holds a Ph.D. in Solid State Electronics from Imperial College, London.

Large area and printable electronics comes of age

Simon Johnson
Centre for Process Innovation, Netpark, Thomas Wright Way, Sedgefield, TS21 3FG, UK

Technologies for Large Area and Printable Electronics are well established and are steadily moving along the Technology Readiness Level scale. It is apparent that most electronic systems which make use of these technologies will be hybrids of conventional solid state components and a range of the newer technologies. The next stages for the evolution of printable and LAE include its integration as part of the electronic and system engineers toolbox. In this talk, we will briefly review what CPI sees as the key challenges of Printable and LAE roll out and integration.

Biography

Simon Johnson studied Physics at undergraduate level, a Master of Engineering in IC Design at Durham and a PhD in IC Failure Mechanisms. He has worked as an IC Design Engineer and spent over 20 years as an academic at Durham University researching various aspects of IC design (including test and reliability, neural-electronic interfacing, self-reconfiguring processors) while teaching electronic devices and circuits. He setup and ran a technology start-up for 7 years which developed and sold an educational audio system for young children, and has worked in electronics instrumentation for radiation detection in industry before joining the Centre for Process Innovation in the UK. He runs an experienced team of electronics and software engineers who work on application for printable electronics at CPI.

Transforming manufacturing to deliver trillions of smart objects

Richard Price

PragmatIC, Cambridge Science Park, Cambridge, United Kingdom

Traditional silicon integrated circuit (IC) production requires huge capital investment and takes years to install and commission. These multi-billion dollar giant factories are affordable by only a handful of the largest IC manufacturers, who must continuously pack more and more transistors into each IC to deliver the performance improvement the market expects. Whilst this is fine for the complex ICs used in high-end electronic products, it doesn't extend well to applications where relatively simple functionality is required, e.g. smart packaging for fast-moving consumer goods. PragmatIC conceived its revolutionary FlexLogIC™ fab-in-a-box manufacturing system with a completely different goal in mind: to enable a distributed and scalable production model for trillions of flexible ICs (FlexICs) that can deliver electronic intelligence at a cost point orders of magnitude lower than a silicon fab. In this session we will describe our journey to the first billion FlexICs and how this is set to revolutionise how we interact with everyday objects.

Biography

Dr Richard Price. CTO, *PragmatIC*

Richard has over 20 years' experience in technology commercialisation, focusing on printed electronics and materials chemistry. As a Venture Manager at the University of Manchester Intellectual Property Ltd, he led the creation of spin-out companies, including CableSense, Arvia Technology and Nano ePrint. Previously he was a Senior Chemist at Elam-T, discovering 100 novel materials. He is co-inventor of 7 patent families.

Smart hybrid electronics: addressing the scale up challenge

Mike Clausen[1], Attila Szabados[2], Neil Parker[3], Andrew Hamilton[4] Dan Kolb[5]

[1,2,,4,5] Centre for Process Innovation, The Neville Hamlin Building, Thomas Wright Way, NETPark, Sedgefield, County Durham, United Kingdom, TS21 3FG

The National Printable Electronics Centre located at the Centre for Process Innovation (CPI) is the UK national prototyping facility for the development and commercialisation of printable electronics.

The wide availability of Near Field Communication (NFC) with smartphones is driving new applications such as electronic payments and can now be further extended to enable direct interaction between printed media (labels, posters, documents, and packaging) with integrated electronics and the smartphone. These new application concepts address the needs of marketing, games and anti-counterfeit, and also provide a platform to provide more complex thin-film electronics within smart packaging (e.g. food, medical) and supply-chain logistics (e.g. retail).

This talk will focus on introducing CPIs newly built facility for delivering applications within this emerging space. Opened in summer 2018, CPI have installed and commissioned state of the art capability in roll to roll printing, integration and converting capability for the production of functional inlays and labels. The printing toolset is a standard graphics printing press configured with a range of printing techniques, gravure, screen, and flexographic for characterising functional inks. The integration toolset is configured with a number of modules including jetting capability of conductive adhesives, bare die flip chip attach, reel fed direct attach for surface mount components (LEDs, capacitors, resistors etc.) thermode curing and oven curing, glob top encapsulation, and inspection capability. The converting toolset is configured with a number of modules to allow the conversion of functional inlays into wet / dry labels for a range of packaging solutions. In addition to the larger scale equipment, an electronics design suite and batch prototyping equipment allows concepts and early prototypes to be conceived, designed and tested at batch scale prior to scaling up to higher volumes. The talk will also review CPIs involvement in both UK and EU funded projects currently active with the IOT space. These projects address a major barrier to the commercialisation of printable electronics, namely the establishment of large-scale manufacturing and technology transfer to multiple application sectors.

Figure 1. Muhlbauer R2R Integration Tool

Figure 2. Muhlbauer R2R Converting Tool

Biography

Mike is the Head of Technology within the CPI Printable Electronics platform. He is responsible for providing technical leadership, developing technologies so that they can be translated to innovative products capable of commercialization in the future. Mike has 25 years' experience within the electronics field working within research and development, mass production and customer service environments. He has worked for medium size British companies and major international blue chip organisations such as Fujitsu Microelectronics, NXP, Filtronic Compound Semiconductors and RFMD. His knowledge base spans Operations management, process engineering and integration, technology development, yield enhancement and project management.

Twitter handle: @uk-cpi.com

Integration Technologies for Flexible Hybrid Electronics

Andrew Holmes
Imperial College London

This presentation will review the ITAPPE and SIPEM projects which have formed part of the System Integration theme of the CIMLAE portfolio. Within ITAPPE we explored the use of non-conductive adhesive and thermosonic bonding for attaching active devices, in the form of either bare silicon dies or flexible integrated circuits, to low-temperature plastic substrates. These approaches potentially offer advantages in terms of throughput, cost and reliability over the more conventional methods based on conductive adhesives. In the SIPEM project we have been developing methods for manufacturing multi-layer flexible circuits by stacking metallised low-temperature polymer layers. Such multi-layer circuits will be important in future applications of flexible electronics requiring higher density. The talk will review the results from both projects and discuss potential future directions.

Biography

Prof Andrew Holmes is co-investigator of the Interconnection Technologies for integration of Active devices with Printed Plastic Electronics (ITAPPE) project, which explores the use of Non Conductive Adhesive (NCA) packaging as an alternative route for integrating active devices on low-temperature substrates.

Andrew Holmes received the BA degree in natural sciences from Cambridge University in 1987, and the PhD degree in electrical engineering from Imperial College London in 1992. He was a Research Associate in the Department of Electrical and Electronic Engineering, Imperial College London from 1991 to 1993, after which he took up a joint Research Fellowship in Microengineering with Imperial and the Rutherford Appleton Laboratory. In 1995 he was appointed to a Lectureship at Imperial College London, where he is currently Professor of Micro-Electro-Mechanical Systems (MEMS), Director of Postgraduate Studies, and Deputy Head of the Optical & Semiconductor Devices Group. Dr Holmes has worked on a range of topics in optical signal processing, integrated optics and MEMS, and has published around 150 journal and conference papers in these areas. His current research interests include micro-power generation by energy harvesting, power conditioning for energy harvesters, tribology of micro-scale mechanical systems, novel micro-assembly techniques, and laser processing for MEMS and electronics manufacture. He is 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.

High performing AgNWs transparent conducting electrodes with 2.5Ω/Sq based upon roll-to-roll compatible post processing technique

D. Kumar[1], Jeff Kettle[1]*
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This presentation reports a method for producing high performing, stable and planar silver nanowire (AgNW) transparent electrodes, which have been prepared onto polymeric substrates using a combination of ultrasonic spray coating and post-processing. An innovative process is presented that relies on three sequential steps; thermal embossing, infrared sintering and plasma treatment (see figure 1). This process leads to the demonstration of a film with a sheet resistance of 2.5Ω/sq and 85% transmittance, thus demonstrating the highest reported figure-of-merit in AgNWs transparent electrodes to date (FoM = 933). This is approximately 2x higher than previous reports in the literature and significantly better than the incumbent technology, ITO. A further benefit of the post process is that the surface roughness is substantially reduced. This has previously been one of the main issues for AgNW electrodes that has limited their commercial appeal. The surface roughness achieved in is comparable to that the levels measured for ITO deposited on plastic substrates. (see figure 2). Demonstration devices of OLEDs and OPVs will be reported.

Finally, consideration of the long-term stability is given; Quantitative Accelerated Life Testing (QALT) has been used to assess the stability of the AgNWs at elevated current and temperature. A bespoke life test model has been developed that estimates life of the electrodes at typical OLED/OPV operating conditions (see figure 3). This estimates that a ~1500-times improvement in stability is achieved, which can be further enhanced by modifying the interlayer applied over the AgNWs (i.e. ZnO, TiO_2, PEDOT:PSS) - see figure 4. Finally, X-ray photoelectron spectroscopy (XPS) has been used to understand the root cause of the improvement in long-term stability and changes in carbon, sulphur and silver content is studied as a function of time to show the material changes within the AgNWs as they are post-processed and aged.

Acknowledgements

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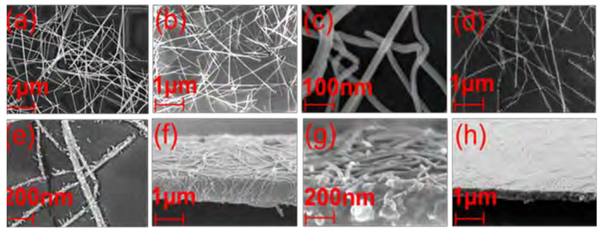

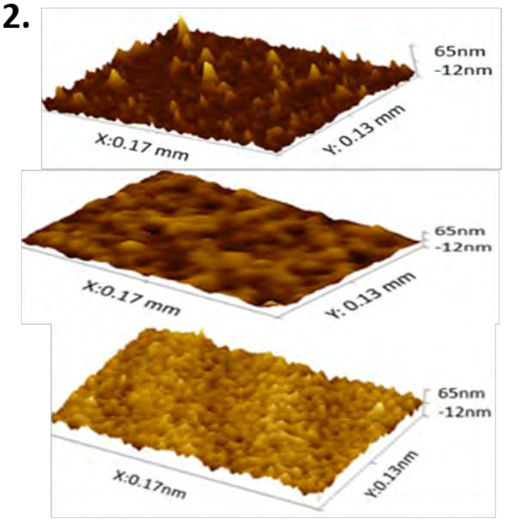

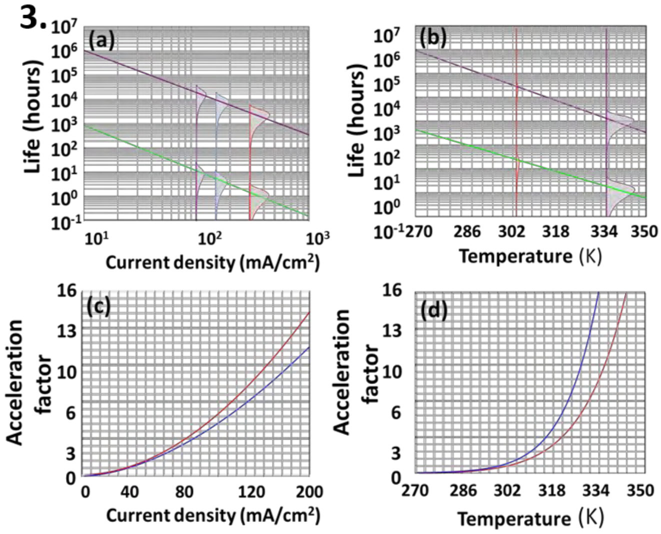

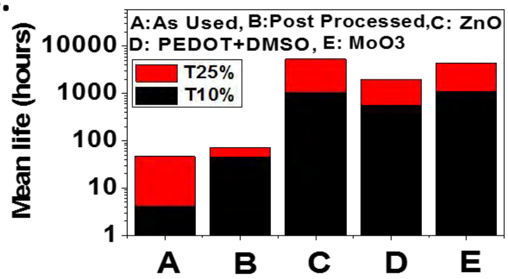

Figure 1. SEM images of a) AgNWs before and b) after embossing, c) after embossing at higher resolution, d) after embossing and sintered, e) after embossing/sintering at higher resolution. Cross sections show f) before embossing, g) before embossing at higher resolution and h) sample that has been embossed and sintered.

Figure 2. Surface topography images using white light interferometry (WLI), (a) the control sample, (b) post-processed sample and (c) post-processed with ZnO overcoating.

Figure 3. Regression line fitting for post-processed and 'as-used' AgNW films of the expected time to reach T10% as a function of (a) current density (mA/cm^2) and (b) temperature (K). The Acceleration Factor (AF) as a function of current density and temperature are shown in (c) and (d).

Figure 4: Bar chart showing mean time to reach T10% (black) and T25% (red) for AgNW films including 'as used), post processed, and post processed with ZnO, PEDOT:PSS+DMSO and MoO_3 transport layers.

Biography

Jeff Kettle has been based in the School of Electronics since 2011. During this time, he has acquired £2m of grant funding through Royal Society, Royal Academy of Engineering, Interreg, Welsh Government and EC projects. His expertise lies in semiconductor device fabrication, characterization and modelling and has worked at one spin-out companies and a large multinational (Alcatel SEL).He also works closely with organic and inorganic chemists to produce functional devices such as OPVs, TFTs, LECs and sensors with new materials A number of his research projects and engagement with industries are focused on reliability engineering including root cause analysis (RCA), predictive ageing, reliability modelling and Design of Experiments (DoE).

Designing and making parts using injection molded structural electronics (IMSE™)

Antti Keranen
TactoTek

TactoTek Injection Molded Structural Electronics (IMSE™) is a solution that combines in-mold labeling and surface decoration, printed electronics (circuitry, sensors, and antennas) and discrete electronic components (LEDs, ICs, etc.) inside of 3D plastic structures, thus changing the 100 years old picture of electronics as "components in a box" into thin, light and durable 3D smart plastic surfaces.

Together with multiple representative use-cases in different fields, we provide details on the mechanical, electrical, and optical design techniques and considerations for a specific use case: a seamless and elegant IMSE™ automotive overhead control panel (OHCP).

Biography

Dr. Antti Keränen is the technology mastermind behind TactoTek structural electronics. His main responsibilities are developing and maintaining the IP portfolio, directing R&D innovation activities, and communicating the company technology vision and practical applications to the community. Antti has been a major contributor to the technology of in-mold electronics since 2005, when he joined the VTT printed electronics team. He is an Adjunct Professor of theoretical physics at the University of Oulu where he earned his PhD in 2002.

Large Scale Integrated Organic Bioelectronics – Nature Connected

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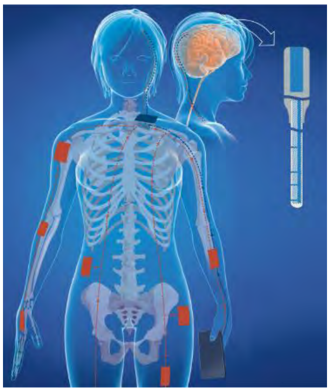
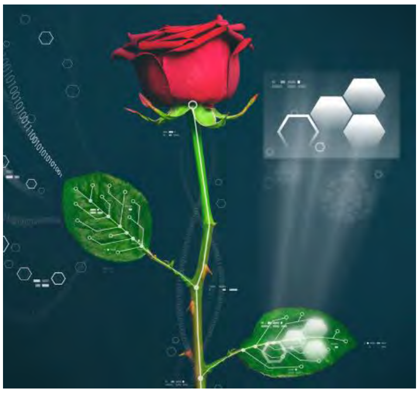
Organic electronic materials exhibit an array of desired characteristics making them excellent as the signal translator across the gap between biology and technology. These biocompatible materials, often complexed with polyelectrolytes and other functional materials, can be included in device structures, which are flexible, stretchable and even gelled, and can also process electronic, ionic and charged biomolecules in combination. This makes the organic electronic materials unique in several respects to record and regulate functions and physiology of biological systems.

Here, a short review of some of the recent progresses from the Laboratory of Organic Electronics is given. In the BioComLab effort, a body area network is used to “connect” electronic skin patches with drug delivery components. This system provides a feedback system, also connected to the cloud for future healthcare. Sensors, converting biochemical signals into electric ones, are typically built up from organic electrochemical transistors (OECT) and selectivity is provided from receptor mediation and by using oxidase approaches. Conversely, the organic electronic ion pump, converts an electronic addressing signal into the delivery of specific biomolecules, such as a neurotransmitter, to actuate and control functions of for instance the neuronal system. With the BioComLab technology the wide array of neuronal disorders and diseases are targeted, such as epilepsy, Parkinson’s disease and chronical pain. The same integrated bioelectronic approach is explored in regulating functions and physiology of plants, in an effort termed e-Plants. Some recent results and achievement from the e-Plant research will be presented, such as sensing and actuation of phytohormones and controlling growth rates.

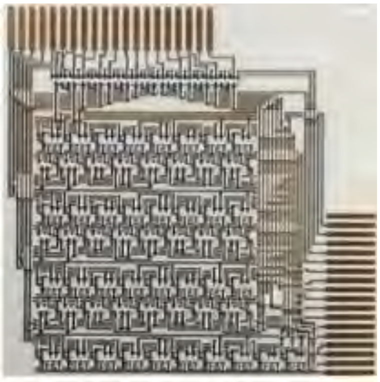
One common challenge in organic bioelectronics, regardless which application approach that is chosen, relates to building large area and large scale integrated organic circuits. Here, large scale integration of OECTs are presented, targeting to lower the number of contact pads between silicon chips and peripheral bioelectronic devices. Decoders and shift registers, including more than 100 OECTs have been realized and serve as the signaling bridge between silicon and organic bioelectronic and interface devices.



BioComLab



Electronic Plants



All-printed OECT circuits

Biography

Magnus Berggren received his MSc in Physics in 1991 and graduated as PhD (Thesis: Organic Light Emitting Diodes) in Applied Physics in 1996, both degrees from Linköping University. He then joined Bell Laboratories in Murray Hill, NJ in the USA, for a one-year post doc period focusing on the development of organic lasers and novel optical resonator structures. In 1997 he teamed up with Opticom ASA, from Norway, and former colleagues of Linköping University to establish the company Thin Film Electronics AB. From 1997 to 1999 he served Thin Film as its founding managing director and initiated the development of printed electronic memories based on ferroelectric polymers. After this, he returned to Linköping University and also to a part time manager at Acreo Swedish ICT. In 1999, he initiated the research and development of paper electronics, in part supported by several paper- and packaging companies. Since 2002, he is the professor in Organic Electronics at Linköping University and today he serve as the director of the Laboratory of Organic Electronics, today including more than 90 people. Magnus Berggren is one of the pioneers of the Paper Electronics, Organic Bioelectronics and Electronic Plants research areas. In 2012 Magnus Berggren was elected member of the Royal Swedish Academy of Sciences, in 2014 he received the Marcus Wallenberg Price and in 2016 he received the IVA Gold Medal. He is the co-founder of 8 companies, such as Consensum Production, Invisense (printed sensors), DP Patterning (manufacturing technology) and Ligna Energy (paper batteries).

His research interests cover utilizing organic electronics in novel applications such as in printed paper electronics and in biology applications.

Conducting polymer based electrodes: A new tool to explore bioelectrical signals inaccessible using conventional electrophysiological methods

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Conducting polymers are widely accepted has ideal materials to develop the next generation of electrophysiological sensing devices. Polymer exhibit desired mechanical compliance with soft matter and elicit signals with a better signal-to-noise ratio than conventional metallic electrodes [1], [2]. Here we demonstrate that polymer based electrodes offer a disruptive advantage to record electrical activity that remained inaccessible using conventional electrophysiological electrodes.
With the goal to understand how the brain works, action potentials have been under intense research for many years. However, the same channels that support electrogenesis in nerve cells, muscle cells, and cardiac myocytes are expressed and play major functional roles in cell types that have been traditionally considered to be nonexcitable or non-electrogenic cells. However, there is abundant evidence demonstrating that a number of ion channels including sodium channels participate in or regulate multiple effector functions in these nonexcitable cells. These cells produce low frequency oscillations from the segregation of charges by molecular machines like pumps, transporters and ion channels. Ions can also pass from cell to cell by gap junctions and by this a traveling electrical gradient is produced. These signals serve functional roles that control cell proliferation, differentiation and migration. Thusly, understanding these mechanisms is of high priority to developmental biology, regenerative medicine and cancer research. This bioelectrical activity has been observed using image fluorescence methods, but it had remained inaccessible using extra-cellular electrophysiological methods. This because in contrast with action potentials, these faint signals do not show as spikes but smooth and weak (μV range) oscillations that change over periods of several seconds and minutes. Typically these oscillations are one thousand slower and weaker than an action potential. To detect them is necessary to develop ultra-low noise electrodes. Polymer/electrolyte interfaces have a ultra-low intrinsic thermal noise and provide access to this bioelectrical signal mechanism.

In this contribution we develop flexible and biocompatible electronic transducers based on an inkjet-printed conducting polymer, the poly (3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS). These electrodes are printed on soft and porous bacterial cellulose substrates that provide a nanostructured-sensing surface. The ultra-high sensitivity was evaluated by recording electrophysiological signals from non-electrogenic or brain tumour cells *in vitro*. In a bandwidth of 12.5 Hz a noise level of 0.1-0.2 μV *r.m.s* is achieved. When signals are measured in current, the noise level can be as low as 1 pico-ampere *r.m.s*. This ultra-low noise level allows the detection of faint biological oscillations and signal patterns, which had remained inaccessible using conventional extracellular microelectrodes. The ultra-low detection limit is discussed in terms of an equivalent circuit model for the cell/electrolyte interface that also takes into account the intrinsic noise of the sensing interface.

As an example of application of these novel electrodes, we present a prototype device that can monitor in real time the establishment of cell-cell connections and the migration speed of cancer cells.

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Biography

Henrique L. Gomes is currently an Associate Professor with the Electronics Engineering Department, University of the Algarve, Faro, Portugal. He heads the organic electronics research group. His research interests have been directed towards the electrical characterisation of electronic devices such as field effect transistors, diodes and capacitor structures. He has a recognized experience in small signal impedance measurements techniques. In the field of organic electronics his major contributions were on the study of reliability and operational stability of organic based field effect devices. Since 2000, his research activities have expanded to encompass the interaction between electronic devices and living cells to develop biosensors and biomedical devices. In the bioelectronics research field his recent contributions have been focused on optimizing devices to detect ultra-weak signal generated by non-excitable cell cells.

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Living electrical nanowires: a new paradigm for bio- and organic electronics?

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In nature, fibre-like organisms such as Geobacter sulfurreducens [1], Shewenalla oneidensis [2] and the recently discovered Cable Bacteria [3] demonstrate surprising electrical transport properties and could be considered as ‘living electrical (nano)wires’. Since the emergence of novel organic and inorganic (nano-)materials with particular (semi)conducting properties have often opened the road towards novel disruptive electro-optical applications (e.g. OLEDs, perovskite solar cells,..), it is worthwhile to further investigate these remarkable electrogenic organisms also from a materials science point of view. Of particular interest is the comparison with nanofibres based on conjugated polymers, which have various similarities with the given organisms.

Introductory experiments have assessed electrical conductivities for these organisms in the order of S/cm. Next to the conductive properties, semiconducting behaviour has been reported for Shewanella oneidensis, used in a Field Effect Transistor FET configuration [4]. Due to their exceptional electrical properties these organisms are sometimes advertised within the biological research community as ‘biological graphene’. To investigate these claims and the potential of these organisms as a new paradigm for bio- and organic electronics, this world of living nanowires deserves further cross-disciplinary exploration.

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Biography

Prof. Dr. Jean Manca is full professor experimental Physics at Universiteit Hasselt (Belgium). From 2001 to 2014 he was group leader of the research group ONE2 (‘Organic and Nanostructured Electronics & Energy Conversion’) at the Institute of Materials Research (IMO-IMOMEC) of Universiteit Hasselt and IMEC (Belgium). Jean Manca was a co-founder of the spin-off company LUMOZA on large area printed electroluminescent displays. In 2015 he founded the cross-disciplinary research group “X-LAB” and started with the yearly X-FESTIVAL (www.x-festival.be). Activities of X-LAB involve the cross-disciplinary investigation of photosynthesis, bio-electricity, bio-photovoltaics and the exploration of novel (bio-inspired) concepts/ materials for energy conversion, sensing and next generation electro-optical applications towards a creative and sustainable future on earth and in space.

Microfluidic ion pumps for seizure control

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Despite tremendous research efforts, treatment options for many neurological disorders are inadequate. Systemic drug treatments suffer from side effects and long-term habituation; electrical stimulation is unspecific; and the fluidic injection of drugs often displaces the very cells that are being targeted due to the local pressure increase. Thus, there exists a pressing need to develop novel treatment strategies that overcome these limitations. One such technology is the recently introduced drug delivery platform known as the microfluidic ion pump (µFIP) [1]. The µFIP is an implantable device that electrophoretically pumps ions (eg. neurotransmitters, drugs, etc) to the target tissue. In addition to spatial and temporal control, a distinctive feature of the µFIP is that it delivers just the ion and not the solvent and thus does not increase pressure at the outlet. This “dry” delivery is of paramount importance for neural interfacing as it enables an intimate interface between the drug delivery outlet and the target cells. Here we report recent advances in incorporating µFIPs into implantable devices for treating neurological disorders including both depth probes and cortical arrays with recording capabilities. The efficacy of the µFIP platform is demonstrated by stopping epileptic seizures in vivo. This is the first in vivo demonstration of an ion pump for treating a neurological disorder and offers a glimpse of what can be achieved by tailored engineering of the µFIP platform. We anticipate this work to be the starting point for new stimulation, recording and drug delivery paradigms in chronic neural implantation.

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Biography

Chris received a B.Sc. in Interdisciplinary Physics from the University of Michigan in 2008. Following two years as a general scientist at the U.S. Nuclear Regulatory Commission, he earned a Ph.D. in Materials from the University of California, Santa Barbara where he investigated loss mechanisms in organic photovoltaics (2015).

Subsequently, Chris was awarded a postdoctoral fellowship from Whitaker International to develop implantable bioelectronic devices for treating neurological disorders at the Ecole des Mines de St Etienne. He is now continuing this work as a Research Associate and Borysiewicz Biomedical Sciences Fellow at the University of Cambridge.

Implantable microsystems for personalised anti-cancer therapy

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The interdisciplinary IMPACT (Implantable Microsystems for Personalised Anti-Cancer Therapy) project is a five-year EPSRC funded research programme at the University of Edinburgh [1, 2]. We are developing miniaturised implantable sensors for real-time monitoring of hypoxia (low oxygen) and pH within the tumour microenvironment. Data from these sensors will be used to personalise radiotherapy treatment and maximise its effectiveness (Figure 1). The project has produced microfabricated sensors including an electrochemical oxygen sensor, and an ISFET pH sensor with integrated instrumentation electronics. To make these sensors clinically useful, we have also developed an implantable packaging architecture, in which the sensor dies are wire bonded to a flexible PCB and encapsulated using photo-patterned epoxy (Figure 2). Biocompatibility of the sensor and packaging materials was tested in murine tumour xenografts, and showed that none of the materials caused a significant change in tumour pathology [3]. Robustness of the sensors and packaging was also proved following sterilisation, irradiation, and needle implantation. Sensor function *in vivo* was successfully demonstrated using a large animal model of lung cancer, providing proof-of-principle in a realistic clinical environment. This work lays a foundation for future integration of our sensor technologies with wireless power and communications, to create a miniaturised "smart sensor" for tumour monitoring.

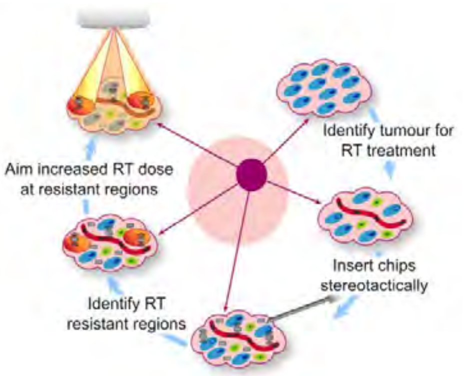

Figure 1. Personalised radiotherapy (RT) using implantable sensors to detect treatment resistant hypoxic or acidic regions

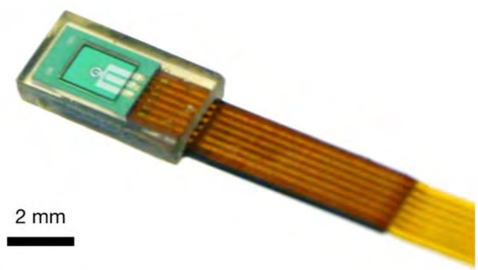

Figure 2. Implantable biocompatible packaging for an electrochemical oxygen sensor die

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Biography:

Dr Jamie Marland is a post-doctoral research associate at the University of Edinburgh, based at the Institute for Integrated Micro and Nano Systems. His research focuses on sensor development and integration for the EPSRC-funded "Implantable Microsystems for Personalised Anti-Cancer Therapy" (IMPACT) programme. Prior to this, he received his BA in Natural Sciences and a PhD from the University of Cambridge in 2011. His recent research at the University of Edinburgh on the miniaturisation and integration of implantable biomedical sensors was recognised by Worshipful Company of Scientific Instrument Makers, with the award of the Beloe Fellowship in October 2018.

Organic single-crystal transistors and integrated circuits

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Development of functional materials and scientific studies on their microscopic operating mechanisms mutually benefit. It has been indeed essential to understand the charge transport mechanism based on recently proposed band transport for development of organic semiconductor circuits to be implemented in flexible and printed electronics devices. The presentation begins with a brief overview on the establishment of charge coherence and the band dispersion in high-mobility solution-crystalized organic transistors. Minimized effect of inter molecular phonons is responsible to achieve high mobility exceeding 10 cm2/Vs in such systems. Key technologies will be also shown for printed integrated circuits to provide low-cost platforms for RFID tags, AD converters, programed processor units, and sensing circuitries. With excellent chemical and thermal stability in recently developed new materials of both p-type and n-type organic semiconductor crystals, such integrated CMOS devices are demonstrated in practical usage.

Biography

Jun Takeya is a professor in Department of Advanced Materials Science, Graduate School of Frontier Sciences, University of Tokyo from 2013 and is jointly appointed for a honored visiting researcher in National Institute for Material Science from 2017. He is also CTO of Pi-Crystal Inc. from 2013 and Organo-Circuit Inc. from 2016 which are start-ups founded on his scientific achievement in organic electronics. He received the B.S. degree in 1989, the M.S. degree in 1991, and Ph.D. degree in 2001 from the University of Tokyo, Tokyo, Japan, all in physics. He was a research scientist in Central Research Institute of Electric Power Industry, from 1991 to 2006, a visiting researcher in ETH, Zurich, Switzerland, from 2001 to 2002, a visiting researcher in RIKEN, Japan, from 2005 to 2006, a visiting associate professor in IMR, Tohoku University, Japan, from 2005 to 2006, and an associate professor in Graduate School of Science, Osaka University, Osaka, Japan, from 2006 to 2010. He was a professor in the Institute of Scientific and Industrial Research, Osaka University, Osaka, Japan, from 2010 to 2013.

Air-stable hybrid CMOS operational amplifier on flexible substrates

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Flexible electronics using field-effect transistor (FET) technology has been researched for a couple of decades using both inorganic materials and organic materials. P-type organic semiconductor materials have been well developed and recent researches show promising results, whilst a superior n-type characteristics is shown in inorganic metal-oxide semiconductors. For this reason, a hybrid structure of p-type organic and n-type metal-oxide transistors has been considered as a desirable way to go for yielding flexible CMOS circuits. However, there have been many issues in both the manufacturability and the device stability in bringing the hybrid technology to the real world. We developed a key technology to realize hybrid CMOS flexible operational amplifiers, with superior electrical performance and stability. A 2-stage operational amplifier was integrated on a polymer substrate using solution-based processes of organic and metal-oxide materials with the developed technology.

This talk will present the improvement in electrical characteristics of our flexible operational amplifier and experimental results on the stability of the circuit.

Biography

Dr. Kang is a researcher at the EPSRC Centre for Innovative Manufacturing in Large area electronics and a postdoctoral research associate in Optoelectronics group of the Cavendish Laboratory. He received Ph.D from Department of Engineering, University of Cambridge and currently works on flexible circuit integrated using organic FETs and oxide FETs within iPESS project. He has developed new graphene transfer methods to improve mechanical stability of graphene on flexible substrates and investigated spatial and temporal stability and electrical transport mechanism of chemically doped graphene. He also worked on highly efficient OLED and FET for AMOLED display with experimental works and circuit simulation and has extensive experience of array design and sensor development. He had carried out array design and development of image sensors, gas sensor, biosensor and fingerprint sensors and X-ray sensors for Silicon Display. Co. Ltd.

Mass production of flexible electronics for Organic LCD and other applications

Chuck Milligan
FlexEnable

Flexible electronics will play a pivotal role for enabling flexible displays and sensors that will break form factor constraints and unlock new product use cases. In particular, OTFT technology opens a new avenue for flexible displays and sensors on commodity plastics – it enables glass-free, thin, light and conformable devices, combined with a low manufacturing cost that is driven directly by the uniquely low temperature process (sub 100^{o}C) afforded by OTFT. 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.

FlexEnable is now industrialising its ground-breaking OTFT technology for the mass production of flexible Organic LCD (OLCD) and other applications, and working with OEMs to bring the next generation of products to the market.

Biography

Chuck Milligan is CEO of FlexEnable, the leader in the development and industrialisation of organic electronics for flexible displays and sensors. Chuck has over 25 years' commercial and general management experience across the globe in the semiconductor, consumer electronics, communications, industrial and aerospace markets.

Prior to FlexEnable, Chuck was CEO of EM Test, a Swiss EMC test equipment company which was acquired by AMETEK. Before EM Test, he was CEO of Heptagon, a Swiss/Finnish micro-optics company, which he grew from 16 to 300 employees and for whom he established a volume production wafer facility in Singapore and outsourced module assembly in China to provide millions of optical components per month to Nokia and Apple. He has also served as VP of Industrial/Aerospace at Bookham, Commercial Director for JDS Uniphase/Nortel's GaAs telecom pump laser diode business and Director of Sales for Harris Corporation, for whom he established a Europe/Africa Sales Office in Switzerland. Chuck also served overseas as an officer in the US Army.

Flexible oxide electronics: from TFT models to circuit integration

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As the market of flexible electronics continues to grow it is imperative to find a transistor technology enabling good electrical performance and mechanical reliability, without neglecting low cost, low temperature, large area fabrication. Organic thin-film transistors (TFTs) exhibit great flexibility but low field-effect mobility (μ_{FE}), hindering high speed electronics, while low-temperature polysilicon (LTPS) requires costly laser crystallization processes to exhibit μ_{FE}>100 cm^2/Vs uniformly throughout the entire substrate area. Oxide TFTs, particularly using amorphous oxide semiconductors (AOS) as indium-gallium-zinc oxide (IGZO), can offer a good compromise between speed and low-temperature/large area processability, given the amorphous nature of AOS with their peculiar charge transport mechanism, primarily derived from overlapping s-orbitals of the cationic species. Furthermore, AOS are wide band gap materials (E_g>3 eV), turning them suitable for transparent electronics operating at kHz-MHz range. Since the initial publication by Nomura *et al.* on IGZO TFTs in 2004, these devices had a tremendous development and are now implemented in Gen10 display fabs for the production of low power consumption, high refresh rate and high resolution displays.

In this presentation we show how oxide TFT potential goes far beyond display backplane applications. Instead, we present it embedded in a complete platform enabling a wide range of flexible digital, analog and mixed-signal circuits on foil. We start by showing how oxide TFTs are perfectly adaptable to different static and dynamic modelling strategies, going from empirical artificial neural networks (ANN), with development times of only a few minutes, excellent accuracy and generalization [1], to compact models based on modified level 1 MOSFET equations, taking into account physical non-idealities, such as contact resistance and free/trapped charges. We then show how these models integrate in a custom designed process design kit (PDK) including different verification decks to expedite accurate circuit design, simulation and layout extraction. The main part of the work is then devoted to demonstrate how simple circuit topologies can bring high-gain, robust and rail-to-rail operation to a variety of digital and analog blocks, without increasing processing complexity. These include rail-to-rail logic gates with level shifting capability, cascode current mirrors tolerant to bias stress and temperature, transimpedance amplifiers, multipliers and NFC compliant rectifiers [2-4]. Two final applications for these blocks are demonstrated, namely an addressing and readout system for an health dosimeter sensor array and a system for fill-level and temperature sensing readout integrated in a smart bottle.

References

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Acknowledgement - This work is funded by FEDER funds through the COMPETE 2020 Programme and National Funds through FCT - Portuguese Foundation for Science and Technology under the projects POCI-01-0145-FEDER-007688, UID/CTM/50025 and PEST-OE/EEI/UI0066/2013. This work also received funding from the European Community H2020 program under grant agreement No. 716510 (ERC-2016-STG TREND), and No. 692373 (BET-EU). This work is also supported by early career research grant with project ref. ECR/2017/000931. Authors would like to thank Prof. Vitor Tavares for the PDK files.

Biography

Pedro Barquinha, Ph.D. from Universidade Nova de Lisboa in 2010, in Nanotechnologies and Nanosciences. He is currently an Associate Professor at the Materials Science Department of FCT-NOVA. He has been working in oxide electronics since 2004, going from the design, deposition and characterization of multicomponent oxides, fabrication and characterization of oxide TFTs, to their integration in analog and digital circuits on flexible substrates. He is co-author of more than 130 peer-reviewed papers (h-index=37, as September 2018), 3 books and 4 book chapters in this area. His current research focus is to take transparent electronics to performance and integration levels suitable for future multifunctional concepts. This involves pursuing reproducible and low temperature synthesis routes of high-quality oxide nanostructures and integrating them in nanodevices and circuits using direct growth and transfer routes, always complemented by device modeling/simulation. In 2016 he got an ERC Starting Grant (TREND) to advance this research topic.

Pydi Ganga Bahubalindruni is currently working an Assistant Professor in school of electrical sciences, IIT Goa. Prior to that she worked as an Assistant Professor for two and half years in ECE Department, IIIT Delhi. She worked as a Post-Doctoral Researcher with CENIMAT, FCT- UNL for almost one year and she received Ph.D. degree from the Department of Electrical and Computer Engineering, FEUP/INESC, in 2014. Her research interests include large-area flexible and transparent electronics, analog/mixed signal design with emerging and sub-micron standard CMOS technologies, and device modeling and devices.

Schottky diodes with >1 GHz cut-off frequency fabricated from a-IGZO using adhesion lithography

Professor Andrew Flewitt[1] and Dr Gwenhivir Wyatt-Moon[1]
[1] *Electrical Engineering Division, University of Cambridge, Cambridge, CB3 0FA, UK*

The drive towards to high degrees of automation and the internet of things is dependent on the effective communication between different devices. A key element in this area is the radio frequency identification tag (RFID tag), with passive tags especially of interest due to their low cost and low power consumption. These tags are comprised of three distinct components: the rectifier, the antenna and the logic circuit. The rectifier is important for converting the AC signal captured by the antenna into a DC signal which is then used to power the logic circuit. The current dominant technology is high frequency tags operating at 13.56 MHz. These tags however have a short read range limiting their applications. Most technology within the flexible sensor and IoT fields desire RFID tags operating at significantly higher frequencies of 900 MHz and beyond.

Typical Schottky diodes with a sandwich architecture are unable to reach such high frequencies due to parasitic overlap capacitances. This capacitance can be reduced with planar devices though these can be difficult to fabricate using different work function metals for each electrode [1]. In this work, high speed planar diodes that have cut-off frequencies in the GHz regime have been fabricated using a low-cost adhesion lithography technique that allows for large area patterning of nanogap electrodes [2]. The electrodes can be made out of dissimilar metals allowing for the creation of Schottky diodes via the deposition of a semiconductor material on top of the two asymmetric electrodes. Amorphous indium gallium zinc oxide (a-IGZO), which has been commercialised as the channel material in thin film transistors for active matrix displays, has been used. The diodes show a high cut-off frequency >1 GHz, and exhibit air stability even without encapsulation.

Acknowledgement - The authors would like to thank the EPSRC for support of this project under grant no. EP/K03099X/1.

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[1] J. Semple, D. G. Georgiadou, and G. Wyatt-moon, “Flexible Diodes for Radio Frequency (RF) Electronics : A Materials Perspective,” *Semicond. Sci. Technol.* vol 32 (2017).
[2] D. J. Beesley *et al.*, “Sub-15-nm patterning of asymmetric metal electrodes and devices by adhesion lithography.,” *Nat. Commun.*, vol. 5, no. May, p. 3933, Jan. 2014.

Biography

Professor Andrew Flewitt received his Ph.D. from the University of Cambridge in 1998 investigating the growth of hydrogenated amorphous silicon thin films using scanning tunnelling microscopy. Andrew stayed in the Engineering Department following the Ph.D. as a Research Associate sponsored by Philips Research Laboratories working on the low temperature fabrication of thin film transistors for liquid crystal displays. Andrew was first appointed to a Lectureship in August 2002, and was made Professor of Electronic Engineering in 2015. He is a Member of the Institution of Engineering and Technology and is a Chartered Engineer.

Dr Gwen Wyatt-Moon is Postdoctoral researcher in the Electrical Engineering Division at the University of Cambridge under the supervision of Professor Andrew Flewitt. She is working on the EPRSC Centre for Innovative Manufacturing in Large-Area Electronics ‘Planalith4Manufacture’ project focusing on optimising device stability, efficiency and processing for radio frequency identification (RFID) applications. Gwen received her PhD from Imperial College London working on the adhesion lithography technique for optoelectronic applications. Previous to this she worked for a medical device company focusing on novel gas sensors and flow rheometry systems and gained her BEng in electrical and electronic engineering from Swansea University. Her current research interests include the use and development of innovative fabrication techniques, materials, and devices for flexible, large-area electronics.

Twitter handle: @gwenhivir

Waste management and compliance considerations for LAEs

Clement Gaubert
Veolia

The presentation will consider the ongoing and future challenges and opportunities involved with the final disposal of LAEs. We will look at examples of consumer electronics, internet of things and product smart label in packaging

The presentation will also look at the opportunities smart label on packaging (tagged products) could bring to the waste management sector.

Biography

I have managed the Veolia WEEE Producer Compliance Scheme since 2012. I oversee all aspects of WEEE Compliance, including the collection and treatment of electrical waste the Scheme is responsible for as well as the relationship with our Producers (which includes Argos, Apple, Boots). I also represent the Scheme with the Regulators (Environment Agency and Defra).

I was involved in the development and commissioning of Veolia's own WEEE treatment facility dedicated to the recycling of flat screen televisions. The facility is based in Bridgnorth, Shropshire and opened in October 2016. It processed 3,000 tonnes of flat screens in 2018.

OE-A's initiative on sustainability

Sophie Isabel Verstraelen

OE-A; Lyoner Str. 18, D-60528 Frankfurt, Germany; www.oe-a.org; sophie.verstraelen@oe-a.org

OE-A (Organic and Printed Electronics Association) is the leading international industry association for the emerging technology of organic and printed electronics. Representing the entire value chain, OE-A provides a unique platform for local and international cooperation between companies and research institutes.

In order to build a stronger organic and printed electronics industry, OE-A covers several important and current topics and issues. Through a set of working groups, OE-A enables and fosters collaboration by all members. One of those working groups deals with the topic sustainability.

As the organic and printed electronics industry moves into commercialization, the OE-A believes that sustainability is an increasingly important topic. The OE-A Working Group Sustainability aims to identify and understand the sustainability benefits of organic and printed electronics technology, emphasizing its contribution to a sustainable future in an open dialogue with key stake holders, markets, regulators, and wider society.

It is critical that we examine our products and processes to identify how efficiently they are produced, how well we use the materials with which they are constructed, and how well they use power and other consumables when in operation. Moreover, OE-A would like to provide the organic and printed electronics community with information, guidelines and methodologies that will allow members to understand the sustainability of their own products and processes. OE-A will present what the aims and activities of the OE-A Sustainability Working Group are, including the realization of a regulatory framework and the development of a quantitative model for the impact of printed electronics in waste streams resulting from common applications.

Biography

Sophie Isabel Verstraelen has worked for VDMA as project manager at OE-A (Organic and Printed Electronics Association) since 2015. Besides that she is responsible for public relations and press activities, she is in charge of the OE- A Working Groups Sustainability and Demonstrator.

Prior to OE-A, she worked for an international non-governmental organization in Bonn, Germany, where she was part of the global communications department, and later co-managed the EcoMobility World Festival – a unique pilot project in South Korea promoting a sustainable transport culture. She studied in the Netherlands as well as Australia and received a Bachelor of Commerce in 'International Business and Languages'. She also holds a Master of Science in 'Public Policy and Human Development', with a specialization in 'Sustainable Development'.

Twitter handle: @OEAonline

A smart approach to reduce waste

Gillian Ewers
PragmatIC

There are some staggering facts that highlight the challenge the world is facing in terms of the waste we produce. The World Bank estimates that, on average, we generated 1.2kg of waste per day, that's six times our body weight in waste per year. Of that waste, we are only recycling 18%, with almost half going to landfill. Gillian Ewers, VP Marketing at PragmatIC, will explore how smart packaging could help with recycling.

Biography

Gillian Ewers is an experienced marketing professional with a track record of launching new products to market in high tech businesses. She brings a wealth of knowledge of delivering strategic roadmaps, marketing materials and product life cycle management across multiple sectors including semiconductors and digital inkjet printing, at companies including Texas Instruments, Dialog, CSR and Xaar.

Towards greener electronics: Biodegradability and biomining

Danick Briand

Ecole Polytechnique Fédérale de Lausanne (EPFL), Soft Transducers Laboratory, Neuchâtel, Switzerland

Biodegradable materials are gaining attention, within the scientific community and the society, for problems related to food quality, climate change and the generation of electronic waste. Meanwhile, sensors are playing an increasing role in our lives, offering improvements for everyday health and security. Sensors today are either cheap and disposable, therefore generating waste, or they contain materials that can be harmful for the environment. Biodegradable sensors offer minimal environmental impact and a degradation behaviour that can be tuned for applications within zero-waste environmental sensing, food quality monitoring or personalized health. However, developing fully biodegradable sensing systems remain challenging because of the nature of the substrates involved and the need for silicon electronics in most cases.

In this contribution, we will first briefly review the progress made on biodegradable and transient electronics. We will expose some of the challenges towards solution processed green electronics and fully biodegradable systems. Our developments of printed electronics on paper and biopolymers will be presented, with research on TFTs, sensors and piezoelectric microsystems. Finally, besides biodegradability, recycling is another potential approach our group is considering for printed electronics. When products reaching their end of life, models need to be developed to environmental friendly dispose them. By applying biomining, microorganisms can be used to recuperate notably metals, such as silver and copper, patterned on printed electronic substrates.

So far, biodegradable electronics has referred mainly to thin film electronics fabricated on biodegradable substrates. Mainly biodegradable devices were reported involving clean room processes and systems have been so far rarely demonstrated. Some very interesting progresses have been made recently to develop devices using solution processing and targeting their full biodegradability. Biodegradable semiconducting polymer and metal-oxides have been implemented in TFTs. Biodegradable metallic inks are also under investigation using photonic processes for their sintering. However, a lot remains to be done to develop solution processed and printable biodegradable (opto)electronic materials.

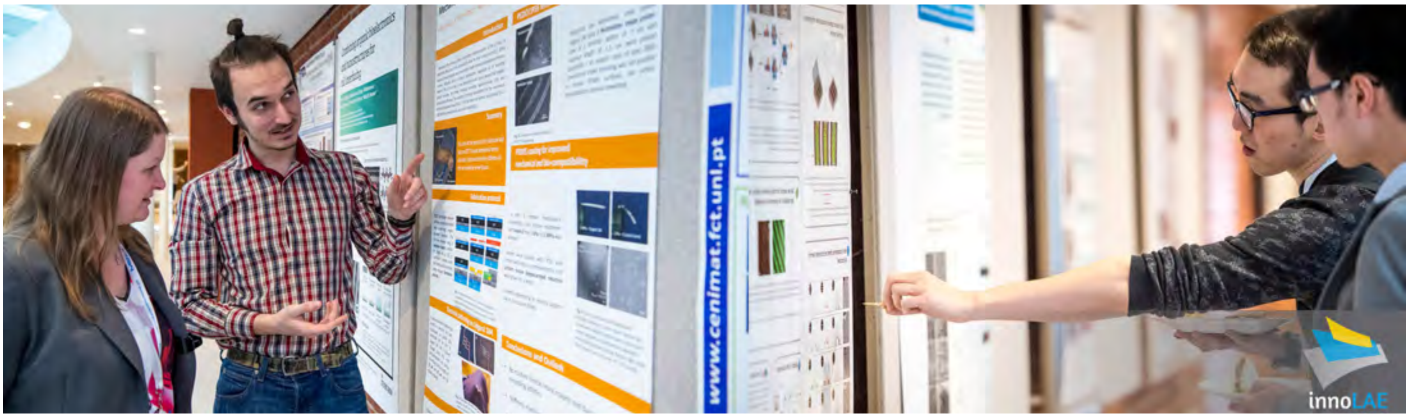
In our presentation, we will propose some approaches to realize fully biodegradable smart systems, highlighting where research is required, targeting chip less approach for their operation. We have worked on functional printing on paper and temperature sensitive biopolymers notably by flash photonic sintering of metallic conductive inks. Food grade resistors used as temperature sensors and interdigitated electrodes used as capacitive humidity sensors were demonstrated for smart packaging applications. Biocompatible organic electrochemical transistors (OECTs), uses as chemical and biosensors, have been fully printed on biodegradable polymers, and we are working on solution processed metal-oxide TFTs on paper and biopolymers. We have also initiated work on solution processed biodegradable piezoelectric films that can be patterned on various substrates, such as paper, and applied in a variety of sensors and actuators. Finally, biomining is being explored to recuperate metals deposited on paper and bio-polymers. We will share our first results on the degradation of paper and biopolymer electronics by micro-organisms.

In conclusion, according to the state of the art and the recent progress made in the field, we will provide some perspectives on the field of green electronics, targeting their environmental friendly disposability.

Biography

Danick Briand received his B.Eng. degree and M.A.Sc. degree in engineering physics from Ėcole Polytechnique in Montréal, Canada, in collaboration with the Institut National Polytechnique de Grenoble (INPG), France, in 1995 and 1997, respectively. He obtained his Ph.D. degree in the field of micro-chemical sensing systems from the Institute of Microtechnology (IMT), University of Neuchâtel, Switzerland in 2001. He is currently the team leader of the EnviroMEMS, Energy and Enviromental MEMS group at EPFL IMT LMTS. He has been awarded the Eurosensors Fellowship in 2010. He has been author or co-author on more than 200 papers published in scientific journals and conference proceedings. He is working on the development of environmentally-conscious

Microsystems, green microtechnologies and microfabrication, and microsystems for environmental and energy applications. His research interests include polymeric MEMS, Power MEMS and energy harvesting, autonomous smart sensing systems, and printed and flexible microsystems technologies.



Posters will be displayed in the exhibition space.

The conference will focus attention on the poster presentations during tea breaks, lunch and at the poster drinks reception on Tuesday 22nd January from 17:15, prior to the gala dinner.

The Programme Committee will award prizes to the best posters based on presentation quality, scientific excellence and the impact of the work for academia or industry.

The poster prizes are generously supported by our Gold Sponsors:

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Poster presenters are requested to make sure that their poster is displayed on the appropriate board before lunch on Tuesday 22nd January, and removed at the conclusion of the lunch break on Wednesday 23rd January.

POSTER PRESENTATIONS

Poster number	Authors	Abstract title	Institution/company
1	Arunakumari Mavuri, Andrew Mayes and Matthew S. Alexander	High-Resolution Inkjet Printing of Room Temperature Sintered Silver Nanoparticle Inks for Flexible Electronics	University of East Anglia
2	Felix Hermerschmidt, David Burmeister, Giovanni Ligorio, Sergey M. Pozov, Richard Ward, Stelios A. Choulis, Emil J. W. List-Kratochvil	Low temperature reductive sintering of printed copper nanoparticle ink for highly conductive thin films	Humboldt-Universität zu Berlin
3	Giovanni A. della Rossa	Grapholymer: Extrusion, coating, lamination for industrial production with graphene in polymers	Luigi Bandera spa
4	Varindra Kumar, Luigi Occhipinti	Graphene metamaterial absorber in GHz range	University of Cambridge
5	Richard Krumpolec, Tomáš Homola, Jakub Kelar, Zlata Tučeková, Miroslav Zemánek, Dušan Kováčik, Mirko Černák	Large-area atmospheric plasma for roll-to-roll processing of flexible materials	Masaryk University
6	Gwenhivir Wyatt-Moon, Andrew Flewitt	Adhesion lithography for large-area patterning of asymmetric nanogap electrodes	University of Cambridge
7	Miles Morgan, Dan Curtis , Davide Deganello	Dynamic control of conductivity and morphology of R2R printed organic layers for large area electronics through ink elasticity	Swansea University
8	Sarah-Jane Potts, Chris Phillips, Tim Claypole	High speed imaging of ink separation in screen-printing	Welsh Centre for Printing and Coating, Swansea University
9	Chung Hwan Kim, Cheol Kim	Development of apparatus capable of applying various mechanical deformations for reliability test of flexible electronic devices	Chungnam National University
10	Fengyuan Liu, William Taube, Dhayalan Shakthivel, Ravinder Dahiya	Contact Printing of Semiconducting Nanowires for High-Performance Large Area Flexible Electronics	University of Glasgow
11	Guohua Xie	Heat Induced Film Transfer for Vacuum-Free Multi-layered Film Deposition on Arbitrary Substrates and the Related Applications	Wuhan University
12	Ankur Singh , Adil Malik , Xenofon Nikolaou , Mathijis Van Kooten	Technology and Physics of smOLED displays	Helius Solar and Energy Efficient system
13	Michal R. Maciejczyk, Shuyu Zhang, Gordon J. Hedley, Neil Robertson, Ifor D. W. Samuel, Marek Pietraszkiewicz	"A highly efficient deep and sky-blue fluorescent solutionprocessed organic light-emitting diodes based on monothiatruxene-containing emitting materials"	University of Edinburgh
14	Xiwen Gong, Edward H. Sargent	Solution-processed 2D perovskite single crystals as efficient blue light emitters	University of Toronto
15	Paolo Melgari, (Sam) Yun Fu Chan, Elizabeth Bone, James Johnstone, Rasmus Havelund & Ian Gilmore	Beyond state-of-the-art 3D secondary ion mass spectrometry imaging for OLEDs directly encapsulated via atomic layer deposition aluminium oxide	Centre for Proces Innovation Ltd
16	Andrew Cook, Martyn Rush, Paolo Melgari, Richard Hardy, Christoph Sele	Direct Encapsulation of Low Light OPV modules by Atomic Layer Deposition - DIRECT	Centre for Process Innovation Ltd
17	Neil Graddage, Salima Alem, Jianping Lu, Terho Kololuoma, Raluca Movileanu, Ye Tao	Improving uniformity of printed organic polymers for organic photovoltaics	National Research Council Canada
18	Ioannis Ierides, Giulia Lucarelli, Thomas M. Brown, Franco Cacialli	Revealing the function of an MgO interlayer in 3rd generation photovoltaics	University College London
19	Sinclair Ratnasingham, Martyn McLachlan, Joe Briscoe, Russell Binions	AACVD of Methylammonium Lead Triiodide for Photovoltaic Applications	Imperial College London
20	David Poussin, Bob Xu, Natalie Stingelin, Martyn McLachlan	Three-dimensional ordered porous fluorine tin-oxide transparent electrodes for improved photovoltaics	Imperial College London

Poster number	Authors	Abstract title	Institution/company
21	Khashayar Jeshvaghani (withdrawn)	Elastic properties and band gap tunning of cubic provskite $SrHfO_3$: First-principles calculations for solar energy	Institute of Materials Science and Nanotechnology, Bilkent University
22	Youmna Mouhamad, Simone Meroni, Francesca De Rossi, Katherine Hooper, Jenny Baker, Justin R. Searle, Eifion Jewell, Trystan Watson	Optimization of large area printed Perovskite PV module design	Swansea University
23	Nazia Nasr, Muhammad Hassan Sayyad	Enhanced electric properties of TiO_2 photoelectrode using Laser ablated Ag nanoparticles	Ghulam Ishaq Khan Institute of Science and Technology
24	Pavlos Giannakou, Maxim Shkunov	Printed and Flexible NiO Supercapacitors for Energy Harvesting	Advanced Technology Institute, University of Surrey
25	Achala Satharasinghe, Theodore Hughes-Riley, Tilak Dias	Solar energy harvesting fabric for wearable, mobile, and off-grid applications	Nottingham Trent University
26	Donald Lupo, Jari Keskinen, Jari Taavela, Hannes Sirén, Juha Virtanen, Matti Mäntysalo	Flexible Temperature Logger Powered by Solar Cell and Supercapacitor	Tampere University of Technology
27	Dave Barwick, Chris Hunt, Simon Rutter	Developing Conductive Textiles for Antennas	Centre for Process Innovation Ltd
28	Brice Le Borgne, Bo-Yan Chung, Simon G. King, Inkyu Kwon, Radu A. Sporea	Low-cost printed RC filter using materials from daily-life	University of Surrey
29	Radu A. Sporea, Brice H. Le Borgne, Samuli Yrjänä, Sirpa Nordman, Peter Bagge, Haiyue Yuan, Emily Corrigan-Kavanagh Anu Seisto, George Revill, Miroslav Z. Bober, Alan Brown, Caroline E. Scarles, David M. Frohlich	Next-generation paper: an augmented travel guide demonstrator	University of Surrey
30	Silvia Conti, Carme Martinez-Domingo, Fabiola Vilaseca, Lluís Terés, Eloi Ramon	Inkjet-printed rectifying diodes on paper substrates	IMB-CNM (CSIC)
31	Miquel Moras, Alba Nuñez, Cristian Herrojo, Ferran Paredes, Ferran Martín, Eloi Ramon	Organic chipless-RFID tags inkjet printed on paper substrates	IMB-CNM (CSIC)
32	David Johnson, Hannah Askew, Nicola Broughton, Anna-Marie Stobo, Aimee Wyatt, Colin Graves, Dave Barwick	NECOMADA: low cost printed devices for the Internet of Things	Centre for Process Innovation Ltd
33	Mash-Hud Iqbal, Esther Ford (withdrawn)	LAE for IoT applications - a perspective from IP protection	Marks & Clerk LLP
34	David Lussey, Josephine Charnley	Quantum Technology Supersensors - environmentally friendly 'smart' pressure sensing inks	Quantum Technology Supersensors
35	Abdullah Alzahrani, Luigi Occhipinti	A flexible wearable sensor for remote physiological monitoring during daily activities	University of Cambridge
36	Nhlakanipho Mkhize, Krishnan Murugappan, Martin Castell, Harish Bhaskaran	Electrohydrodynamic jet printed polyaniline for highly sensitive chemiresitors	University of Oxford
37	Stuart G. Higgins, Julia Sero, Hyejeong Seong, Michele Becce, Molly M. Stevens	Developing nanostructured biomaterials for enhanced cell interfacing	Imperial College London
38	Ana Carolina Marques, João Ferrão, André F.R. Rodrigues, Tomás Pinheiro, Rodrigo Martins and N. Correia, Elvira Fortunato	Enzyme-free colorimetric paper-based platform for point-of-care testing off glucose sensing in the physiological range	FCT NOVA
39	Usman Khan, Glenn Sunley-Saez, Michael Turner (withdrawn)	Developing low-cost label-free bioelectronic sensors for detecting breast cancer biomarkers in serum	University of Manchester

Poster number	Authors	Abstract title	Institution/company
40	Alessandra Lo Fiego, Adam Creamer, Stuart G. Higgins, Martin Heeneyand Molly M. Stevens	Using fluorine-substituted organic semiconducting polymers in organic field-effect transistors with applications in bioelectronic interfacing	Imperial College London
41	Aiman Rahmanudin, Daniel Tate, Suresh Garlapati, Sheida Faraji, Krishna C. Persaud, Michael L. Turner	Printed Organic Field-Effect-Transistor multi-sensor array platform for vapour sensing applications	University of Manchester
42	Panagiotis Mougkogiannis, Michael Turner, Krishna Persaud	Ammonia Detection Using Solution Processed Organic-Field Effect Transistors	University of Manchester
43	Suresh K. Garlapati, Sheida Faraji, Daniel J. Tate, Aiman Rahmanudin, Palani Valliappan, Krishna C. Persaud, Michael L. Turner	High Performance, Solution Processed Organic Field-effect Transistors to Detect Volatile Organic Compounds	University of Manchester
44	Navid Mohammadian, Sheida Faraji, Daniel J. Tate, Michael L. Turner, Leszek A. Majewski	Ultra-low voltage organic field-effect transistors (OFETs)	University of Manchester
45	Julianna Panidi, Martin Heeney, Thomas D. Anthopoulos	Improving organic thin-film transistors with molecular additives	Imperial College London
46	Ke Zhang, Tomasz Marszalek, Philipp Wucher, Zuyuan Wang, Lothar Veith, Hao Lu, Hans-Joachim Räder, Pierre M. Beaujuge, Paul W. M. Blom, Wojciech Pisula	Crystallization control of organic semiconductors during meniscus-guided large area coating by blending with polymer binder	Max Planck Institute for Polymer Research
47	Jaspreet Kainth, Martyn McLachlan, Martin Heeney	Hybrid thin films prepared by solution processing and ALD for ambipolar thin film transistor devices	Imperial College London
48	Niels van Fraassen, Andrew J. Flewitt	High performance Indium Silicon Oxide TFTs for Large Area Electronics	University of Cambridge
49	Daisy Gomersall, Andrew J. Flewitt	Chemical vapour deposition of p-type inorganic thin film semiconductors	University of Cambridge
50	Mari Napari, Daisy Gomersall, Jerome Innocent, Robert Hoye, Timo Sajavaara, Andrew Johnson, Andrew J. Flewitt, Judith L. MacManus-Driscollari	Control of the electrical properties of non-stoichiometric nickel oxide thin films grown by chemical vapour deposition methods	University of Cambridge
51	Tianwei Zhang, Kham M. Niang, Andrew Flewitt	Small-signal measurement of the threshold voltage shift in thin film transistors under positive gate bias	University of Cambridge
52	Inês Martins, Cristina F. Fernandes, Joana Vaz Pinto, Pedro Barquinha, Rodrigo Martins, Elvira Fortunato	Conformable electronics based on Parylene-C polymer	FCT NOVA
53	Joana Vaz Pinto, Cristina F. Fernandes, Inês Martins, Ana Rovisco, Jorge Martins, Asal Kiazadeh, Pedro Barquinha, Rodrigo Martins, Elvira Fortunato	Low power electronics based on Parylene-C hybrid devices: top gate vs bottom gate TFTs	FCT NOVA
54	Emanuel Carlos, Spilios Dellis, Nikolaos Kalfagiannis, Loukas Koutsokeras, Demosthenes C. Koutsogeorgis, Rita Branquinho, Rodrigo Martins and Elvira Fortunato	Ultrafast photonic curing of solution-based aluminium oxide for thin film transistors	FCT NOVA
55	Loukas Michalas, Kham M. Niang, Ali Khiat, Spyros Stathopoulos, Andrew J. Flewitt and Themis Prodromakis	Two-terminal Metal-IGZO-Metal devices	University of Southampton
56	Yin Jou Khong, Khan M. Niang, Nigel J. Coburn, Sanggil Han, Andrew J. Flewitt	Bipolar metal oxide thin film diodes	University of Cambridge
57	Dinesh Kumar, Jeff Kettle	Control over voltage threshold shift in IGZO TFTs with enhanced electrical characteristics using novel passivation	Bangor University

1.High-resolution inkjet printing of room temperature sintered silver nanoparticle inks for flexible electronics

Arunakumari Mavuri, Andrew Mayes and Matthew S. Alexander
Engineering, Faculty of Science, University of East Anglia, Norwich Research Park, Norwich, United Kingdom.

Abstract:

Printed Electronics (PE) is a promising technology for the realisation of low-cost and flexible electronic devices. It uses processing techniques which has advantages such as reduce material waste, roll-to-roll production and provides the way to cut harmful chemicals that are not environmental friendly. In this technology the ability to produce highly conductive and high-resolution patterns using low-cost and roll-to-roll processes, such as inkjet printing, is crucial for the fabrication of printed electronic devices and circuits. Most conductive materials based on metal nanoparticle inks require to be sintered at elevated temperature in order to drive off stabilizing agents and to obtain suitable conductivity. Such sintering processes limit the application of these materials for the printing of conductive tracks on flexible substrates such as paper and plastic. Therefore, achieving a combination of a low temperature sintering process with high-resolution inkjet printing of the conductive tracks is crucial for future development of printed electronics technology.

In this study, we report our work in the development of stable Poly(acrylic acid) (PAA) capped silver nanoparticle suspensions for inkjet printing. We have optimised the formulation properties and printing performance to demonstrate the high resolution patterning of sub 100 micron silver tracks on flexible substrates such as plastic and paper as shown in figure 1. These nanoparticles material can then undergo chemically triggered room-temperature sintering to produce interconnects with a resulting conductivity approaching that of bulk silver. These results demonstrate the high-performance achievable from inkjet printing of room temperature sintered conductive interconnects that will enable advancement in PE and Large Area Electronics (LAE) devices in the future.

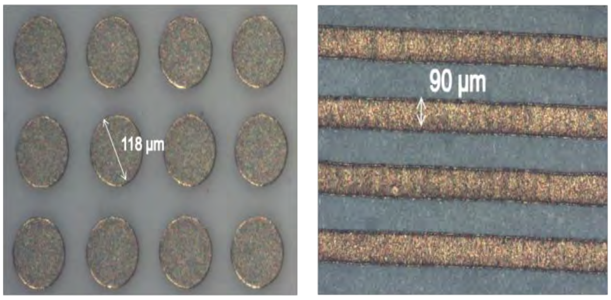

Figure 1. Optical images of the printed drops and tracks of silver nanoparticles ink on paper.

Biography

Arunakumari Mavuri graduated from JNTU Kakinada, India from department of Electrical and Electronics Engineering. I have done my masters in the field of Nanotechnology at JNTU Kakinada, India. Currently, I am a Ph.D. student at University of East Anglia, Norwich. My research interest is on printable and flexible electronics. I have worked on making of conductive inks for inkjet and screen printable inks for various applications and now focussed towards the printing of conductive inks with high resolution inkjet printer.

2. Low temperature reductive sintering of printed copper nanoparticle ink for highly conductive thin films

Felix Hermerschmidt[1], David Burmeister[1], Giovanni Ligorio[1], Sergey M. Pozov[2], Richard Ward[3], Stelios A. Choulis[2], Emil J. W. List-Kratochvil[1,4]

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[2] *Cyprus University of Technology, Department of Mechanical Engineering and Materials Science and Engineering, 45 Kitiou Kyprianou Street, 3041 Limassol, Cyprus*

[3] *Intrinsiq Materials Ltd., Cody Technology Park, Ively Road, Farnborough, Hampshire GU14 0LX, United Kingdom (now part of NovaCentrix)*

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Inkjet-printed electrodes have been utilised in a wide variety of (opto)electronic devices [1,2]. Inkjet-printing is an additive, direct write technique that requires no masks or lithographic pre-patterning of substrates, with droplets only deposited where required on the substrate, therefore minimizing material loss. Moreover, inkjet-printing can be transferred to a roll-to-roll process, able to access high productivity but also small feature sizes. This paves the way to fully solution-processed devices, with all layers including the electrodes being deposited from an ink.

Many approaches to printable conductive metal electrodes have focused on silver [3], due to its high oxidation resistance and good electrical conduction even in its oxidized states. The required sintering step to form uniform films of merged nanoparticles is therefore less demanding, i.e. simple thermal processes can be applied. However, the high cost of silver and its susceptibility to electromigration demand a shift of focus towards alternatives, for example copper. However, due to its susceptibility to oxidation, the usual post-deposition treatment methods include expensive and instrumentally elaborate flash lamp and laser sintering approaches.

This contribution introduces a truly low temperature (130 °C), easy to scale process using formic acid to sinter structures that have been inkjet-printed using an industrial scale copper nanoparticle (CuNP) ink. Electrical conductivity of up to 16% bulk Cu is reached after sintering at 130 °C and more than 25% bulk Cu conductivity is achieved above 150 °C. Four-point measurements and photoemission spectroscopy detail the formation of a conducting Cu film, while adhesion and bending tests confirm the stability of the printed structures. The developed sintering process is compatible with flexible low cost and “low temperature” substrates such as PET and underline the suitability of the inkjet process for upscalable and large area Cu electrode production in electronic devices [4].

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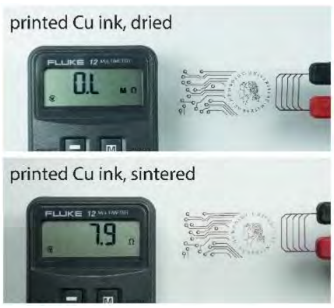

Figure 1. Whereas the just-dried structures do not show conductivity, the structures are conductive after the low temperature sintering process is applied.

Biography

Felix Hermerschmidt received his PhD in materials science and engineering from Cyprus University of Technology, focusing on inkjet-printed active layers and electrodes in organic solar cells and OLEDs under the supervision of Prof. Stelios A. Choulis. Before that, having obtained his BSc in chemistry at Freie Universität Berlin, he completed an MRes in green chemistry at Imperial College London, focusing on morphology control in solution-processed solar cell active layers under the supervision of Profs. Natalie Stingelin and James R. Durrant. He is currently post-doctoral researcher in Prof. Emil J. W. List-Kratochvil's Hybrid Devices group at Humboldt-Universität zu Berlin with expertise in the formulation, processing and characterisation of functional materials in hybrid optoelectronic devices as well as in printed electronics.

3. Grapholymer®

Extrusion, coating, lamination for industrial production with graphene in polymers

Giovanni A. della Rossa
Innovation & IP, Extrusion Academy, Costr. Mecc. Luigi Bandera spa, Busto Arsizio (Va), Italy
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A worldwide leader in Plastics Extrusion Machinery, Bandera has recently developed a laboratory EA-Extrusion Academy® with the goal of liaising between research and industrial production of the many products obtainable via the extrusion process, also associated to lamination, coating, foaming, converting and printing technologies.

Bandera, industrial sponsor of CGC Cambridge Graphene Centre, and partner with IIT Istituto Italiano Tecnologia for 2Dmaterials in extrusion, is an associate member of Graphene Flagship the Future Emerging Technology program by the European Commission.

Grapholymer® is the extrusion process to integrate graphene and 2D materials in many extrudable polymers.

The House of Extrusion® 5,000 sq.m facility of production lines allows the scale up of prototype results to industrial output of +3,000 kg/h

Laboratory Twin Screw Extruder for 2D Material compounding 2C15

Biography

Studied Gamma-Ray Bursts at Milan University Physics, R&D Management Master at Bocconi University Milan.

Holds several patents in Quantum Entangled Lithography with JPL - NASA and in plastic PV panels extrusion.

Science & Technology communication via podcast.

Serial entrepreneurial ventures, now holds the position of Innovation & IP Manager at Costruzioni Meccaniche Luigi Bandera spa where he supervises innovation and academia and research liaisons in the field of nano composites in/on plastics via the extrusion process and future plastic applications.

4. Graphene metamaterial absorber in GHz range

V. Kumar[1], L. Occhipinti[1]

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The paper talks about the design of graphene-based metamaterial for its application as a wide bandwidth microwave absorber and a comparison with copper-based metamaterial has been obtained. The structure consists of concentric rings and is connected through thin arms while it is laid over a thin layer polyimide substrate and a thin metallic strip at its bottom layer. The permittivity and permeability along with reflection and absorption behaviour has been plotted using MATLAB script. The structure shows its microwave absorption of about 70% within the frequency range from 19 GHz to 21.5 GHz, thus a bandwidth of 2.5 GHz has been obtained. In addition, the structure shows polarisation independence behaviour for its absorption due to its symmetry. The conductivity of a graphene material has been obtained at 0.1 V DC bias for its plot comparison with copper-based structure. Using its S – parameter, an equivalent circuit has also been obtained for the representation of microwave absorber within its frequency range. The tunability of graphene with its bias voltage provides its microwave absorption tuning through an electrical mechanism, hence the effect of DC bias over its frequency band has also been obtained and plotted. The bending effect of the designed metamaterial has been obtained and studied. The advantage of the proposed absorber lies in its wideband microwave absorption with the small size of structure (5 mm x 5 mm) and 1 mm thickness for its application.

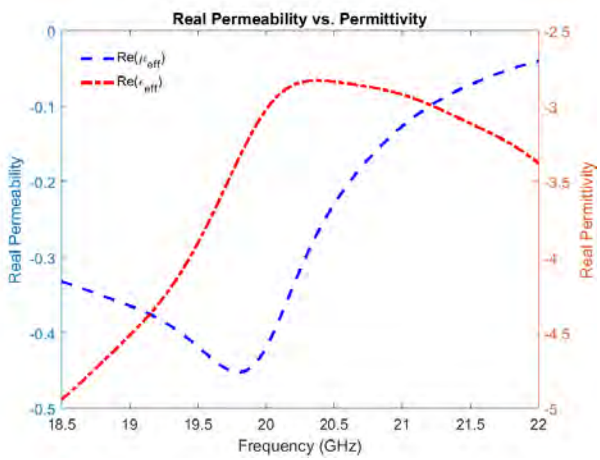

Figure 1. Real Permittivity and Permeability plot for Graphene

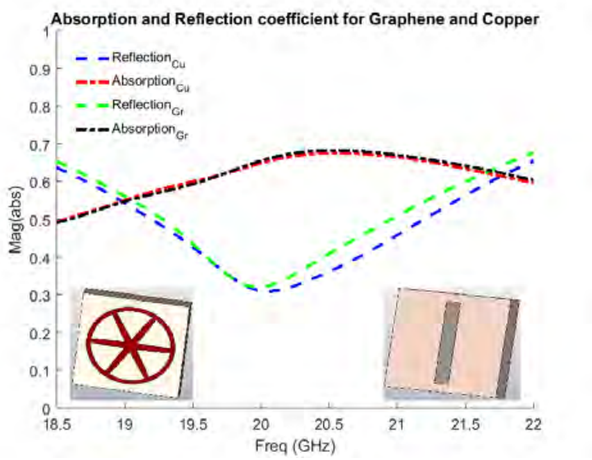

Figure 2. Absorption vs. Reflection plot for Copper and Graphene

$$\sigma(\omega,\mu_c,\tau,T) = \frac{je^2/\pi\hbar^2}{\omega - j(2/\tau)} \times \int_0^\infty \varepsilon \left[\frac{\partial f_d(\varepsilon)}{\partial \varepsilon} - \frac{\partial f_d(-\varepsilon)}{\partial \varepsilon} \right] d\varepsilon$$

$$+ je^2/\pi\hbar^2(\omega - j(2/\tau) \times \int_0^\infty \frac{f_d(\varepsilon) - f_d(-\varepsilon)}{(\omega - j(2/\tau))^2 - 4(\varepsilon/\hbar)^2} d\varepsilon.$$

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Biography

Dr Varindra Kumar has obtained his Bachelors in Electronics Engineering from National Institute of Technology Rourkela and Master of Technology in Electronics and Communication Engineering from Indian Institute of Technology Varanasi. Subsequently after working across various companies in electronics design, he joined PhD at the University of Nottingham in EMC Macromodeling. After finishing his PhD, he is working as Postdoc in gas sensing design and manufacturing at the department of Engineering, University of Cambridge. He is the editor and reviewer of some electronics and its related journals and conferences and has published a total of 22 journal and conference papers.

5. Large-area atmospheric plasma for roll-to-roll processing of flexible materials

Richard Krumpolec, Tomáš Homola, Jakub Kelar, Zlata Tučeková, Miroslav Zemánek, Dušan Kováčik and Mirko Černák

R&D Centre for Low-Cost Plasma and Nanotechnology Surface Modifications (CEPLANT), Department of Physical Electronics, Faculty of Science, Masaryk University, Kotlářská 267/2, 611 37 Brno, Czech Republic

In this contribution, we present atmospheric pressure cold (70 ºC) plasma technology generating high power density plasma (up to 25 kW/m^2) for surface modification of materials and coatings and related applications in flexible and printed electronics. The surface plasma generated by proprietary, easily scalable, Diffuse Coplanar Surface Barrier Discharge (DCSBD) is macroscopically homogeneous and diffuse in ambient air and other standard technical gases as nitrogen, oxygen, argon, hydrogen, CO_2, water vapour and others. The use of various gases leads to different plasma-chemical reactions on the surfaces of treated materials. The use of Argon and Hydrogen led to reducing processes induced by plasma treatment. The low-temperature DCSBD plasma is suitable for processing of thermally sensitive materials, e.g. polymers and paper.

The contribution presents a low-temperature method for dry hydrogen plasma reduction of inkjet-printed flexible graphene oxide (GO) electrodes, an approach compatible with processes envisaged for the manufacture of flexible electronics. The processing of GO to reduced graphene oxide (rGO) was performed in 1–64 seconds and sp^2/sp^2+sp^3 carbon concentration increased from approx. 20% to 90%. Since the plasma reduction was also associated with an etching effect, the optimal reduction time occurred between 8 and 16 seconds. The surface showed good mechanical stability when deposited on PET flexible foils and significantly lower sheet resistance after plasma reduction. The observed moderate etching process was found strongly selective and influenced mainly polymeric structures rather than metallic ones. This can be utilised in selective etching of flexible transparent conductive metallic/polymer mesh composite and for tailoring the metallic contacts on the polymeric surfaces. Pure hydrogen plasma treatment resulted in no damage to the metallic electrodes, and therefore, such composites can be used directly as electrode systems in various flexible electronics applications. As will be shown, extended exposures of polymer surfaces to reducing plasma led to the surface etching, which can be utilized for nanostructuring of polymer substrates.

Integration of stable and diffuse plasma in fast roll-to-roll line is crucial for high-speed and low-cost manufacture of materials in flexible and printed electronics. The method of cold hydrogen plasma reduction and selective etching using DCSBD could constitute an important and major step forward in the large-scale manufacture of photonic devices, among many other applications.

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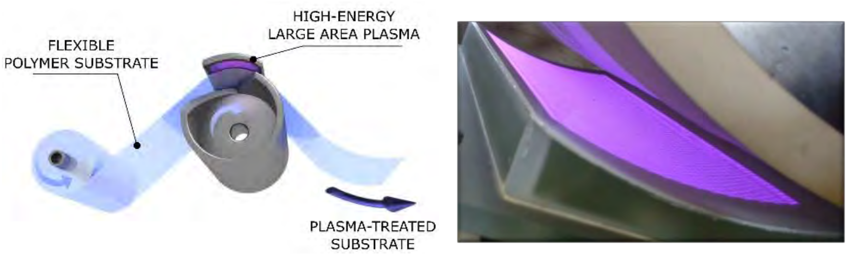

Figure 1. R2R DCSBD plasma for large-area modification of flexible polymer substrates.

Biography

Richard Krumpolec received his Ph.D. in plasma physics from Comenius University in Bratislava, Slovakia, in 2015. He is experienced from research stays in Finland and Germany. He is currently a Post-Doctoral Researcher with the R&D Centre CEPLANT, Masaryk University, Brno, Czech Republic, where he is focusing on the research of dielectric barrier discharges and plasma surface modification by reducing atmospheric plasma. He is also focused on the plasma-assisted deposition of thin films and atomic layer deposition, e.g. for optoelectronic applications.

6. Adhesion lithography for large-area patterning of asymmetric nanogap electrodes

Gwenhivir Wyatt-Moon[1] and Andrew Flewitt[1]
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As the resolution of devices in the electronics industry has hit the nanoscale, device fabrication costs have rapidly increased. Whilst commercial technologies such as electron-beam lithography are able to produce nanoscale feature size, they are costly and unsuitable for large area electronics. Research is now focusing on fabrication techniques that can reproduce this small size on flexible substrates without incurring such high costs, such as adhesion lithography (a-Lith). A-Lith is a large scale fabrication technique for producing planar asymmetric nanogap electrodes [1]. Devices have be created with gap width:length aspect ratios >100000. The technique can be carried out in air and at low temperature making it ideal for the field of plastic electronics [2].

A-Lith has already shown improved device performance across many areas of device electronics; electrodes have been utilised in device applications including high responsivity photodiodes [3], nano organic light emitting diodes [4] and high speed diodes [5]. However, to open up this technology to a greater number of device applications further process optimisation is needed. The a-Lith technique relies on a self-assembled monolayer (SAM) molecule attaching on a prepatterned metal (M1) which then changes the adhesion forces. A second metal (M2) is then deposited on the substrate and can be specifically patterned when peeled using an adhesive due to the reduced adhesion on M1. Therefore, M2 only remains in the areas where there is no M1 , remaining only in the areas where it directly contacts the substrate. Where M2 fractures at the edge of M1, a nanogap is formed between the two metals [1]. This was previously only successfully carried out with Al, Au and Ti as M1, and Al and Au as M2, with the Al and Au (with an Al adhesion layer) thermally evaporated. Hear we present successful execution of the technique with a variety of materials sputtered including Cu, Ni, Ti, Mo, Cr and Al as M1. M2 is shown to be successful with Al, Ni, Cu and Cr. This optimisation of the technique allows for specific tailoring of the electrodes for semiconducting materials and allows for better interfacing of the electrodes to emerging 2D materials such as graphene.

Acknowledgement - The authors would like to thank the EPSRC for support of this project under grant no. EP/K03099X/1.

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Biography

Gwen Wyatt-Moon is Postdoctoral researcher in the Electrical Engineering Division at the University of Cambridge under the supervision of Professor Andrew Flewitt. She is working on the EPRSC Centre for Innovative Manufacturing in Large-Area Electronics ‘Planalith4Manufacture’ project focusing on optimising device stability, efficiency and processing for radio frequency identification (RFID) applications. Gwen received her PhD from Imperial College London working on the adhesion lithography technique for optoelectronic applications. Previous to this she worked for a medical device company focusing on novel gas sensors and flow rheometry systems and gained her BEng in electrical and electronic engineering from Swansea University. Her current research interests include the use and development of innovative fabrication techniques, materials, and devices for flexible, large-area electronics.

Twitter handle: @gwenhivir

7. Dynamic control of conductivity and morphology of R2R printed organic layers for large area electronics through ink elasticity

M. Morgan[1], D. Curtis[1] , D.Deganello[1*],

[1] *College of Engineering, Swansea University, SA1 8EN, Swansea,UK*

Surface instabilities present in roll-to-roll printing are a salient cause of non-uniformity which is particularly critical in functional printing for large area electronics. Interfacial phenomena such as viscous fingering, extensional filamentation and misting can occur, resulting in uneven printed layers, often detrimental to device performance. This work explores how ink rheology - specifically elasticity - influences these instabilities and can be adapted to control the texturing and functionality of deposited layers. Organic conductive inks were specifically formulated to exhibit a wide range of extensional relaxation times. These organic inks were printed through a R2R flexographic printing process with the ink splitting process observed through high speed imaging. The uniformity of obtained printed layers was measured by identifying a characteristic directional morphological wavenumber as a parameter of texture. Extensive trials demonstrated a strong correlation of printing speed and extensional elasticity with the achievable morphological wavenumbers; and of morphological wavenumbers with electrical conductivity of the printed layers. Through control of elasticity and speed we could move from a quasi-isotropic conductive layer (similar conductivity in all directions) to a highly anisotropic conductive layer; this was linked to different modes of ink retraction observed through high speed imaging.

This work therefore demonstrates a new approach to control the functionality of large area printed layers in R2R processing, with envisaged implications and opportunities for multilayer devices.

Acknowledgement - The authors would like to acknowledge financial support from EPSRC (EP/M008827/1)

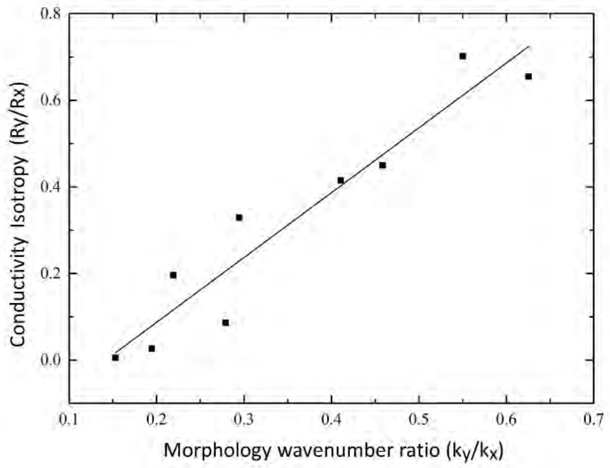

Figure 1. Effect of texture morphology on conductivity isotropy

Biography

Dr. Davide Deganello is an associate professor in the College of Engineering, Swansea University. He is deputy director at the Welsh Centre for Printing and Coating (WCPC). His research interests comprise functional printing and additive processing for energy storage, electronic and biomedical applications, combined with study of underlying complex fluids rheology. As PI, Davide has developed a sustained program of research, inclusive of Research Council, collaborative & industrial projects; these are inclusive of a EPSRC award for large-scale energy storage (EP/N013727/1), EPSRC first grant on extensional rheology and surface instabilities in roll-to-roll printing (EP/M008827/1) and an EPSRC CimLAE funded Pathfinder project on rheology and process parameter effects on laser induced forward transfer (SIMLIFT, 2017). Davide has a Ph.D. in Mechanical Engineering (Swansea University, 2008) and he is a chartered engineer for the Italian Engineering Association.

Miles Morgan is finalising his PhD with the Welsh Centre for Printing and Coating (WCPC) in the College of Engineering at Swansea University which concerns the use of ink rheology to improve printed electronics, specifically regarding extensional flows. Concurrently he is working as a researcher within the Complex Flow Lab, also at the college, studying the rheology of granular flows.

8. High speed imaging of ink separation in screen-printing

Sarah-Jane Potts, Chris Phillips, Tim Claypole
Welsh Centre for Printing and Coating, College of Engineering, Swansea University, Bay Campus, Crymlyn Burrows, Swansea SA1 8EN, UK

Screen-printing is the preferred process for producing a range of printed electronics including point of care, bio-sensors, energy storage and pressure sensors. However, there is a limited understanding of the fundamental science involved in the deposition of the ink onto the substrate and the separation of the ink from the mesh during the screen-printing process. High speed imaging has been identified as a way of assessing the ink deposition during screen-printing by Xu and Willenbacher (1), to visualise the ink flow in front of the squeegee, the contact region and the slumping of the ink. However, as these analyses were only conducted below the substrate, the results did not identify the extension and flow profiles occurring during the process, as well as the point of separation. To provide a more thorough understanding, a bespoke screen printer was constructed which enabled high speed imaging to be conducted from the side of the mesh, visualising the displacement of the mesh onto the substrate with the flow of the ink onto the substrate ahead of the squeegee, along with the separation mechanisms occurring behind it. These experiments were conducted on a commercial carbon-based ink at a range of line widths. To numerically assess the images produced, topography and microscopy analyses were conducted on the screen mesh and the printed lines. This enabled comparisons to be made between the location of the gaps in the mesh and the stages of printing identified by Riemer (2) and Messerschmit (3), as well as with the shear and extensional rheological profiles of the ink. The results found that there were correlations between the theories suggested and the images produced, shown in Fig. 1. Overall, these results have provided a new insight into the ink flow mechanisms occurring within screen-printing, enabling evaluation of previous hypothesis and a clear comparison with the fundamental physics, which will enable the development of new predictive models.

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Acknowledgement - The authors acknowledge the assistance from Ben Clifford and Yin Cheung Lau in developing the test rig and the financial support of the European Social Fund, the EPSRC (grant reference: EP/L015099/1) and icmPrint.

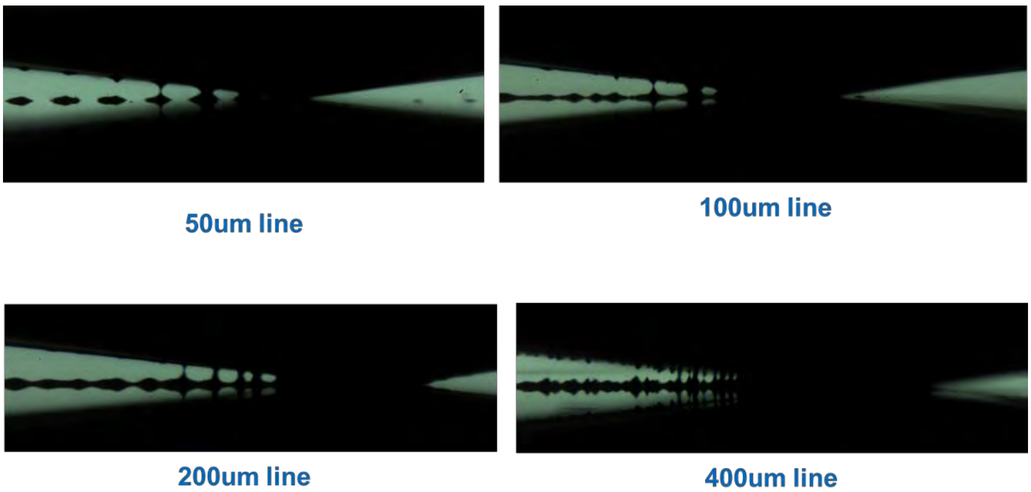

Figure 1. Visualisation of the deposition of a commercial carbon ink with screen printing

Biography

Sarah-Jane is currently studying for an EngD in Materials Engineering at the Welsh Centre of Printing and Coating (WCPC) at Swansea University with her industrial sponsor, icmPrint. She has a Master's Degree (MEng) in Product Design Engineering from Swansea University which she completed in 2015. Currently, Sarah-Jane's work focuses on investigating the fundamental science of screen-printing. She has conducted a range of experiments so far, these include printing parameter setting studies on carbon-based inks, assessing the effect of post processing on enhancing the surface profile and electrical performance of screen-printed inks, as well as visualising the deposition and separation mechanisms that occur during screen-printing with her bespoke screen printer. She is currently using her custom screen printer to assess how the printing mechanisms observed vary with the existing theories, as well as how the deposition and separation profiles relate to the rheological profiles of the inks and the print quality.

9. Development of apparatus capable of applying various mechanical deformations for reliability test of flexible electronic devices

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[2] *Department of Mechanical Engineering, Chungnam National University, 99 Daehak-ro, Daejeon 34134, Korea*

One of the requirements of flexible electronic devices is that they should maintain their electrical performance during and after repetitive mechanical deformation, which requires a proper reliability test apparatus. Current testing apparatus are typically only capable of applying a single type of deformation, and the methods of application often have drawbacks such as undesirable stress concentrations. This study describes the design and implementation of a new apparatus for the reliability test of flexible electronic devices under multiple and simultaneous deformations [1]. The developed apparatus applies the various mechanical deformations such as bending, twisting, shearing, sliding, and stretching as well as complex modes where two deformations can be implemented at the same time. It also equips with an in-situ resistance measurement unit as well as a load cell to measure tension of specimen. In addition to the conventional bending test methods, the novel one, where the specimen deforms in arc shape with perpendicular ends to clamps so that it undergoes uniform bending stress in whole part of it, was proposed based on mathematical model and control method. The proposed bending method can give two-side (inner-outer) bending mode where the specimen undergoes alternating compressive and tensile forces. As an application example, the changes in the resistances of printed RFID tag antennas were measured by applying repetitive inner bending, outer bending, and alternating inner-outer bending. After 5000 cycles, the increases in resistance that were due to inner only and outer only bending were 12% and 29%, respectively, while those that were due to alternating inner-outer bending were as high as 135%. The test using fine-line electrodes under these bending deformation showed the similar result. These results imply that the reliability test of flexible electronic devices should be performed at two-side bending mode for guaranteeing more reliable quality in commercialization as wearable and flexible electronic products. It is necessary to test the reliability of flexible electronic devices at various types of mechanical deformations they can undergo in actual field for the commercialization. The test apparatus such as developed one can be used to predict the fatigue-life and failure mode of flexible electronic devices assuming the situations where they undergo various kinds of mechanical deformations when used in the actual field. We can also analyze the effects of these various deformations on devices. By gathering data from reliability tests for various mechanical deformations, one can design the shapes and structures of devices to endure or reduce the effects of the fatal types of mechanical deformations. Therefore, the developed apparatus can contribute to enhance the reliability and accelerate the commercialization of flexible electronics.

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Biography

Chung Hwan Kim received Ph.D. in Mechanical Engineering from KAIST, Korea in 2003. He worked for Samsung Electronics and Korea Institute of Machinery and Materials. Since 2010, he has been working at Chungnam National University. Meanwhile he is working as the Convener of Working Group (Printability) of international standardization for Printed Electronics, IEC TC119. His main research interests are design and control of the printing machines, the measurement of the parameters in printing process, and the improvement of printability in the printing process for printed electronics.

10. Contact printing of semiconducting nanowires for high-performance large area flexible electronics

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Semiconducting 1D nanowires (NWs) with high aspect ratio are considered important building blocks for high-performance large-area electronics (LAE). Due to their outstanding properties such as excellent material flexibility, high charge carrier mobility and large on/off current ratio, NWs are considered to be promising candidates for applications in electronics, optoelectronics, photovoltaics, sensors and wearable devices [1]. In this regard, controllable NW synthesis and transfer over large-area are two main barriers towards high performance flexible large-area device applications. Here, we have demonstrated a home-made contact printing setup [2] with a close-loop control configuration (Fig.1 (a&b)). Two types of NWs have been printed to prove the versatility of the printing system. (1) ZnO NWs grown by bottom up vapour-liquid-solid (VLS) method (Fig.1c). (2) Si NWs synthesised by top-down metal assisted chemical etching (MACE) method (Fig. 1d). This setup enables a precise control of the contact printing parameters such as contact force/pressure and sliding speed during the entire NWs transfer process, both on rigid and flexible substrates. Combined with the pre-treatment of the receiver substrate, the system is able to reproducibly print electronic layers (NWs) with high density (~7 NWs/μm) and good alignment over large-area (Fig. 1 (e&f)). Furthermore, by using this setup, ZnO and Si NWs based ultraviolet (UV) photodetectors (PDs) in a Wheatstone Bridge (WB) configuration have been successfully demonstrated on flexible substrates. The printed devices show a reproducible photodetector performance and reduced thermal variations as a result of average effect from large-area aligned NWs and the inherent self-compensation of WB arrangement, respectively.

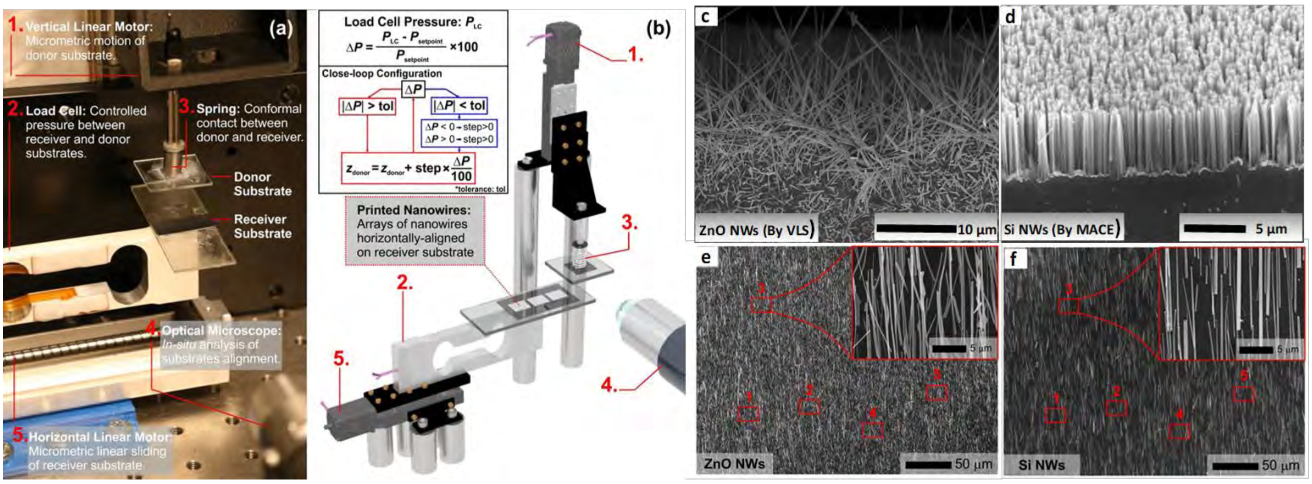

Fig. 1. *NWs Contact printing system (a) Photograph of the system (b) 3D schematic illustration of the contact-printing system. (b1) A linear stage motor allows a micrometric movement control of the donor substrate's vertical position with respect to the receiver substrate. (b2) The force exerted by the donor substrate on the receiver substrate is measured by a load cell placed underneath. (b3) The spring attached to the donor substrate ensures its conformal contact with receiver substrate. (b4) The donar-receiver alignment is ensured by in-situ analysis by optical microscopy. (b5) The system allows controlling the sliding speed/stroke of the contact-printing by using a second linear stage motor. (c & d) SEM images of the synthesized NWs. (c) as-grown ZnO NWs by VLS method (bottom up), (d) Si NWs by MACE method (top down) and (e & f) contact printed NWs on flexible substrates, respectively.*

Acknowledgement:

This work was supported by EPSRC Engineering Fellowship for Growth – PRINTSKIN (EP/M002527/1)

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Biography

Prof. Dahiya is an internationally recognized academic working in the area of tactile sensing and flexible electronics. He has published more than 200 articles in high impact journals, books, patents and has presented more than 90 invited talks. He has more than 12 years of research experience in the field of touch sensing and won several awards including the 2016 IEEE Sensor Council Technical Achievement Award. He is leading the research group (Bendable Electronics and Sensing Technologies (BEST)) with more than 20 researchers (including 7 post-docs, 12 Ph.D students). His leadership capabilities have earned several research projects from EU, EPSRC and the Royal Society (UK). His is a distinguished lecturer of IEEE Sensors Council and Senior Member of IEEE. He is serving in the Editorial Boards of Scientific Reports, IEEE Transactions on Robotics and IEEE Sensors Journal. Currently, He holds prestigious EPSRC Fellowship for engineering.

11. Heat induced film transfer for vacuum-free multi-layered film deposition on arbitrary substrates and the related applications

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A brand new method to deposit and pattern small molecular films with neither a vacuum system nor any kind of lithography approaches was developed for the first time. By controlling the molecular weight and temperature field, the film fabricated either with spin-coating, blade-coating, or printing can be easily transferred to any other substrate. Very fine patterns (down to tens of micrometers) can be realized by simply inserting a fine metal mask between the donating and the accepting substrates.

The heat induced film transfer technique proposed here can solve the problem of fabricating multi-layered thin films without incorporating orthogonal solvents. In the ambient atmosphere, the films can be consecutively transferred, deposited, and patterned on rough and living objects without dimensional limitation, which makes it feasible to design bio-compatible photonic and electronic devices.

This technique can be applied to the large area thin-film based devices with small molecular compounds, such as organic/hybrid LEDs, photovoltaics, photodiodes, and field effect transistors with desired arrays. A proof-of-concept multi-layered white organic light-emitting device with the external quantum efficiency over 10% was also demonstrated with three layers of organic films fabricated at ambient air.

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Acknowledgement

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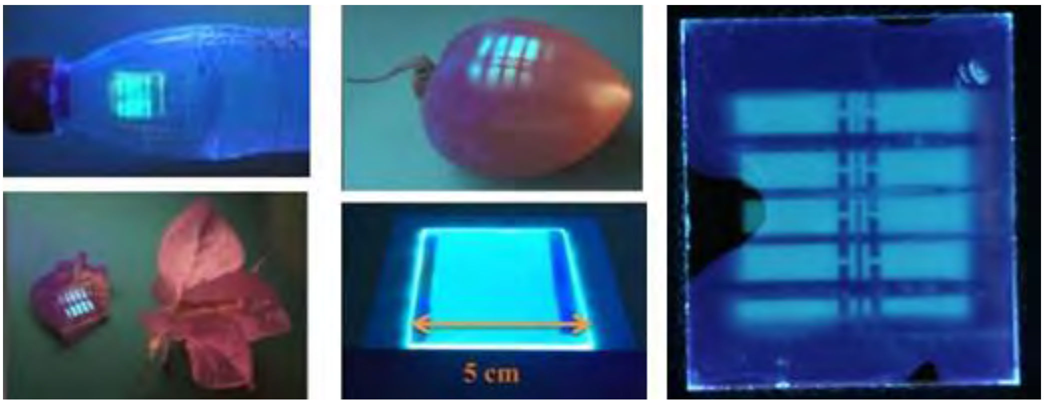

Figure 1. Examples of vacuum-free deposition and patterning of the films on arbitrary substrates

Biography

Dr. Xie received his doctoral degree of microelectronics and solid-state electronics from Jilin University (China) in 2011. From August 2011, Dr. Xie worked at TU Dresden and Franuhofer COMEDD (Germany), sponsored by Alexander von Humboldt Foundation. From January 2013 to January 2015, Dr. Xie worked for an interdisciplinary project funded by EPSRC (UK) at the Organic Semiconductor Center of the University of St Andrews. Since January 2015, he joined the College of Chemistry and Molecular Sciences of Wuhan University (China) as an associate professor. He has published more than 110 papers in reputed journals and has been serving as an advisory panel member of Nanotechnology (IOP). His current research interests are related to organic optoelectronic materials and devices.

12. Technology and physics of smOLED displays

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The most exciting development in display industry in last fifteen years has been discovery and development of OLED . OLED Technology is very energy efficient and ultra thin display can be manufactured through this technology which operates at lower voltages . On both anode and cathode sides of smOLED device (ITO/NPB/Alq3/LiF/Al) , research on improvement of work function at ITO coated surface and literature survey of best electron injection layer is investigated respectively , so that electron and hole pair recombination takes place in active region of the device . In this work , at anode side , improvement of work function of O_2 plasma treated ITO coated substrates has been done via surface potential measurements using AFM (Atomic Force Microscopy). The performance of work function of bare ITO and O_2 plasma treated ITO are compared and life time measurements of O_2 plasma treated ITO coated substrates are performed and tested .At cathode side , the best electron injection layer (LiF) has been surveyed . The smOLED device with best electron injection layer LiF had lowest driven voltage (~5V) among other three fabricated smOLED devices measured via Lab view software and Keithley source meter at optimized conditions of 1000 cd/m^2 and current density of 30mA/cm^2 .

Keywords: LiF(Lithium Fluoride) , smOLED (small molecule Organic Light emitting diode) , ITO(Indium Tin Oxide).

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I, Ankur Singh would like to thank to the team of OLED Technologies and Solutions B.V., Heerlen, Netherlands for providing clean room facilities for experimental work .

Biography

I, Ankur Singh , engineering graduate in bachelor of technology in electronics and communication engineering from BBDNIIT affiliated to Uttar Pradesh technical University, India. I have completed summer research internship in National Physical laboratory , India and OLED Technologies and Solutions B.V., Netherlands on organic photovoltaics and smOLED display devices respectively. I have six years of work experience in LED and Photovoltaic systems in startup companies in India.

13. A highly efficient deep and sky-blue fluorescent solution-processed organic light-emitting diodes based on monothiatruxene-containing emitting materials

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The development of blue materials with good efficiency, even at high brightness, with excellent color purity, simple processing and high thermal stability assuring adequate device lifetime is an important remaining challenge for organic light-emitting didoes (OLEDs) in displays and lightning applications. Furthermore, these various features are typically mutually exclusive in practice. Herein, four novel blue light emitting materials based on a monothiatruxene core are reported together with their photophysical and thermal properties, and performance in solution-processed OLEDs. The materials showed excellent thermal properties with high glass transition temperatures ranging from 171 °C to 336 °C and decomposition temperatures from 352 °C to 442 °C. Typically, in the literature the deep blue emission is defined as having a CIE coordinates $y < 0.15$ and $x + y < 0.30$.[1] In the review from 2017[2] "the bluest" Thermally Activated Delayed Fluorescence emitter with CIE coordinates (0.15, 0.07) obtained efficiency of 9.9 % but at 0.1 cd/m^2, very low impractical luminance. At higher brightness of 300 cd/m^2 the EQE dropped below 1%.[3] These are much lower values then obtained for other types of OLED emitters, like sky-blue or green, highlighting difficulty in designing efficient material that will maintain high efficiency in a range 360 to 409 cd/m^2 (a minimum luminance of OLED display under 0 to 5000 lux conditions in order to reproduce high-image-quality).[4] This is a typical behaviour of deep blue emitters as it is difficult to design material that will simultaneously inject electrons and holes into such wide band-gap organic semiconductor as the deep colour of emission is obtained by restricting the π-conjugation length, therefore inhibiting carrier injection and transport.[5] In this work, high external quantum efficiency of 3.7 % for a deep blue emitter with C.I.E. colour co-ordinates (0.16, 0.09) and 7% for sky blue emitter with colour co-ordinates (0.22, 0.40) was achieved at 100 cd/m^2. The efficiency observed was exceptionally high for fluorescent materials with a photoluminescence quantum yield of 24 % and 62%, respectively. The performance at higher brightness was very good with only 38% and 17% efficiency roll-off at 1000 cd/m^2. The results indicate that utilization of this unique molecular design is promising for efficient deep blue highly stable and soluble light-emitting materials.

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Acknowledgement (optional) - The authors would like to thank Mazowieckie voivodeship, co-financed with the European Union funds by the European Social Fund and European Union's Horizon 2020 Research and Innovation Programme H2020-MSCA-IF-2014-659237, Royal Society Wolfson Research Merit Award and from the Engineering and Physical Sciences Research Council (grant EP/J009016/1) for financial support.

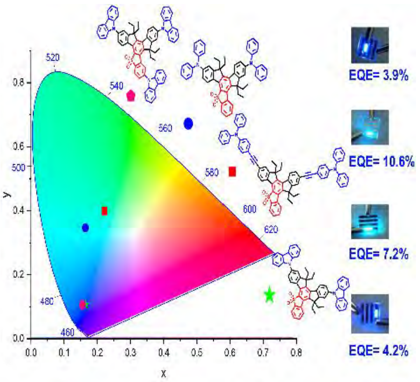

Figure 1. Chromaticity diagram and OLED performance for studied materials.

Biography

Dr Michal Maciejczyk is a Postdoctoral Research Associate at the University of Edinburgh under the supervision of Prof. Neil Robertson and Prof. Ian Underwood working on characterization and ink-jet printing of luminescent material within the project entitled ‘Manipulating light for enhanced PV generation’.

Michal completed his PhD at the Institute of Physical Chemistry, Polish Academy of Sciences, working under the supervision of Prof. Marek Pietraszkiewicz. During his PhD studies he was seconded five times abroad to work on light-emitting and charge-transporting materials for optoelectronic applications.

In 2014 he joined Prof. Neil Robertson group as a Postdoctoral Research Associate to work on hole-transporting materials for perovskite solar cells. In 2016 he was awarded Marie Sklodowska-Curie Individual Fellowship to be held in the same school. His research interests include design, synthesis, automated and continuous flow synthesis and solution-processed organic optoelectronics: organic light emitting diodes, organic photovoltaics and perovskite solar cells.

14. Solution-processed 2D perovskite single crystals as efficient blue light emitters

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Solution-processible organic-inorganic hybrid perovskites have been discovered with complementary features including excellent carrier transport properties, and bright emission with narrow line-width. Therefore, perovskites have been considered as promising candidates for applications in flexible electronics.

Two-dimensional perovskites have—in view of their high radiative recombination rates—shown great promise in achieving high luminescence brightness and color saturation. Here we investigate the effect of electron–phonon interactions on the luminescence of single crystals of two-dimensional perovskites, showing that reducing these interactions can lead to bright blue emission in two-dimensional perovskites.

Resonance Raman spectra and deformation potential analysis show that strong electron–phonon interactions result in fast non-radiative decay, and that this lowers the photoluminescence quantum yield (PLQY). Neutron scattering, solid-state NMR measurements of spin–lattice relaxation, density functional theory simulations and experimental atomic displacement measurements reveal that molecular motion is slowest, and rigidity greatest, in the brightest emitter. By varying the molecular configuration of the ligands, we show that a PLQY up to 79% and linewidth of 20 nm can be reached by controlling crystal rigidity and electron–phonon interactions. Designing crystal structures with electron–phonon interactions in mind offers a previously underexplored avenue to improve optoelectronic materials' performance.

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Biography

Xiwen Gong is currently a post-doctoral fellow work in the Prof. Zhenan Bao's research group at Chemical Engineering, Stanford. She is an inaugural Schmidt Science Fellow. In Nov 2018, Xiwen completed her PhD degree under the supervision of Prof. Edward Sargent in the Dept. of Electrical and Computer Engineering at University of Toronto. In 2014, Xiwen earned her bachelor degree in Material Physics, from Fudan University in Shanghai, China.

During her PhD, Xiwen has focused her research topics on solution-processed semiconductors, including nanocrystals, and emerging hybrid organic-inorganic materials for solar energy harvesting, light emitting, and sensing. Her work has been published in top-tier journals including Nature, Nature Materials, Nature Photonics, Nature Communications, Physical Review B, Nano Letters, and Advanced Materials. Xiwen was selected as one of the "Rising Stars in EECS 2017" (Stanford University). She was one of the ten recipients of the Extraordinary Potential Prize awarded by Chinese Government in 2017.

Twitter handle: @XiwenGong

15. Beyond state-of-the-art 3D secondary ion mass spectrometry imaging for OLEDs directly encapsulated via atomic layer deposition aluminium oxide

Paolo Melgari[1], (Sam) Yun Fu Chan[1], Elizabeth Bone[1], James Johnstone[1], Rasmus Havelund[2] & Ian Gilmore[2]

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[2] *National Physical Laboratory (NPL), Hampton Road, Teddington, Middlesex, TW11 0LW - UK*

The development of organic light emitting diodes (OLEDs) pose a number of scientific and technological challenges related to their lifetime, efficiency, and large scale manufacture. OLEDs are typically composed of multiple 10-100 nm layers of polymer or small molecules. Molecular degradation, diffusion of components across interfaces, and thermally induced segregation are potential mechanisms that lead to decaying efficiency and eventually device failure in OLEDs. A key cause is the presence of moisture and oxygen which can react with the components of the device. Hence, efficient encapsulation is required and this may be achieved using Atomic Layer Deposition (ALD).

Metrology that permits accurate and quantitative measurements of the chemistry at the nanoscale is essential for addressing the above challenges. The excellent depth resolution of 5-10 nm [1] and high sensitivity make secondary ion mass spectrometry (SIMS) depth profiling with gas cluster ion beam sputtering a powerful capability for analysing organic electronic devices. This capability has been further strengthened with the 3D OrbiSIMS which incorporates an Orbitrap™ mass analyser for high mass resolving power and high mass accuracy analysis [2].

In this paper, we summarise the analysis of two green phosphorescent OLED devices supplied using the 3D OrbiSIMS to characterise the layer structure. Both OLEDs were manufactured via thermal evaporation using an optimised OLED device structure developed by CPI. They consist of the same thin film composition, where one was provided directly encapsulated with ALD of an aluminium oxide (AlOx) thin film and one without.

Traces of AlOx ions were unambiguously recorded in the encapsulated device. Importantly, the change in the depth profiles for the AlOx ions and Al^+ ion shows a sharp transition between the direct encapsulation layer and the OLED cathode.

Characteristic peaks from the materials in the layer stack have been identified. The two materials in the mixed host:dopant emissive layer have nearly the same molecular weight which leads to their molecular ion patterns partly overlapping if using a time-of-flight mass analyser. Here, we utilise the high mass resolving power of the 3D OrbiSIMS to obtain depth profiles for the individual material and show that the mixed layer is homogeneous with no sign of vertical of either of the components to the interfaces.

The optimal encapsulation method developed at CPI is of importance for ALD direct encapsulation as an enabler for larger area electronic device applications. The work indicates that it is possible to optimise higher performing thin film devices by altering processing parameters and then analysing the resultant films by direct observation of chemical species.

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Acknowledgement- The authors would like to thank EMPIR project 14IND01 “Advanced 3D Chemical Metrology for Innovative Technologies” and High Value Manufacturing Catapult (HVMC) fund.

Biography

Mr Paolo Melgari Senior Scientist- Thin Films Applications at the Centre for Process Innovation Ltd (CPI), he has over ten (10x) years of industrial experience in Thin Films Technologies including CVD, ALD and PVD process development and implementation at various scale for Optoelectronics devices. PhD carried out on Pilkington NSG – Oxford University – Johnson Matthey collaboration project developing CVD for in-line glass coating processing. Previously Material Scientist at TATA Photovoltaics from 2009 to 2013. He is author of 5 patents, he has attended 5 conferences and author of 6 conference papers. Since joining CPI in mid 2013, he has being developing and implementing barrier coatings for optoelectronic devices encapsulation.

16. Direct encapsulation of low light OPV modules by atomic layer deposition - DIRECT

Andrew Cook[1], Martyn Rush[2], Paolo Melgari[1], Richard Hardy[2], Christoph Sele[2]
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Keywords

Roll–to–Roll (R2R), Atomic Layer Deposition (ALD), Barrier, Organic Photovoltaic (OPV).

Abstract

DIRECT (DIRect EnCapsualtion Technology) is a collaborative research and development project funded by Innovate UK that aims to reduce the cost of high performance barrier materials for use with organic photovoltaic modules.

The main aim of this Materials & Manufacturing Round 3 project was to bring together two organisations with complementary expertise and equipment. The objective being to applying CPI's low temperature 0.5 m wide roll to roll atomic layer deposition (ALD) barrier technology to increase the lifetime and competitiveness of Eight19's patented R2R-fabricated organic photovoltaic (OPV) modules. With the ultimate goal being to develop a module architecture combining both front- and back-side ALD barriers, for maximum cost and lifetime gains.

The poster will present details of the progress made within the project to date and details of the effects of CPI's technology on Eight19's OPV module performance. Including, details of batch tool setup and a direct encapsulation of a 30 metre continuous length of Eight19 cells, which demonstrates the methods employed to move from the batch scale to full roll to roll production.

Biography

Andrew Cook – As a Senior Process Scientist at CPI my main responsibly involves the development and scale up of roll to roll and vacuum based technologies such as ALD and sputtering. Prior to joining CPI, I worked at Oxford University in the Materials Department as part of the vacuum processing team. With the main focus of the work undertaken being the production of high energy density capacitors by roll to roll vacuum processing. I gained a PhD in Chemistry from Aberdeen University, where I synthesised and characterised liquid crystal molecules. I continued working on liquid crystal materials at Halle University (Germany), primarily focused on dendritic systems as part of an EU funded multi-partner collaboration.

Martyn Rush – My current role as Material Development Manager at Eight19 Ltd is to incorporate new materials, technologies and techniques into the manufacture of OPV with the aim to improve lifetime, performance and cost of manufacture. I started at Eight19 as a process technician after a change of direction from chemical detection (explosives and chemical weapons) using ion mobility methods with a Cambridge based startup Owlstone Ltd where I helped developed their silicon based FAIMS (Field Asymmetric Ion Mobility Spectrometer) sensor. Prior to this I was at DSTL, Fort Halstead in the EDG (Explosive Detection Group). I gained my BSc in chemistry from the University of Leeds, UK, in 2001.

17. Improving uniformity of printed organic polymers for organic photovoltaics

Neil Graddage[1], Salima Alem[1], Jianping Lu[1], Terho Kololuoma[2], Raluca Movileanu[1], Ye Tao[1]

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[2] *VTT Technical Research Centre of Finland, Oulu, Finland*

The development of roll-to-roll printing techniques for manufacturing of photovoltaics is essential in order to reduce cost and embedded energy. In addition, such techniques could enable greater freedom in substrate choice, including the potential for large area flexible devices. Many third generation photovoltaic technologies, such as organic photovoltaics (OPV), show potential for solution processing and hence roll-to-roll manufacturing, however obtaining high performance devices has been challenging. For OPV devices this is often due to the difficulty of obtaining a large-area, uniform and pinhole-free film of a prescribed thickness for the bulk hetrojunction layer.

This work presents the development of printing techniques to improve the quality of printed bulk hetrojunction layers in OPV devices. In particular, we demonstrate the use of flexography for depositing poly(N-9′-heptadecanyl-2,7-carbazole-alt-5,5-(4′,7′-di-2-thienyl-2′,1′,3′-benzothiadiazole:[6,6]-Phenyl C_{71} butyric acid methyl ester (PCDTBT:PCBM) [1]. This was achieved by a factorial study on the effects of pattern, solvent, print speed and drying process. The degree of improvement in film uniformity is demonstrated in Figure 1.

In particular the incorporation of halftone patterning, a common technique in the graphics industry, enabled significant improvements in film uniformity. By reducing the halftone density (ink transfer area) to as little as 30% of the total area, the ink is able to spread on the substrate and form a more uniform film. The solvent selection (1,2-dichlorobenzene, 1,2,4-trichlorobenzene, or ratios thereof) was seen to have an impact on the film formation by affecting the surface tension of the ink and drying time. The printing speed had a major impact on the film quality due to changes in the ink transfer, with a narrow process window of optimal speeds observed. Finally, slower drying processes were seen to reduce the number of pinholes in the printed film and hence improve device reliability.

The functionality of the flexo printed active layers was assessed by fabrication of photovoltaic cells. Efficiencies of up to 3.5% were obtained, which is comparable to alternative deposition processes. This work has demonstrated the feasibility of flexography as a roll-to-roll capable fabrication method for OPV.

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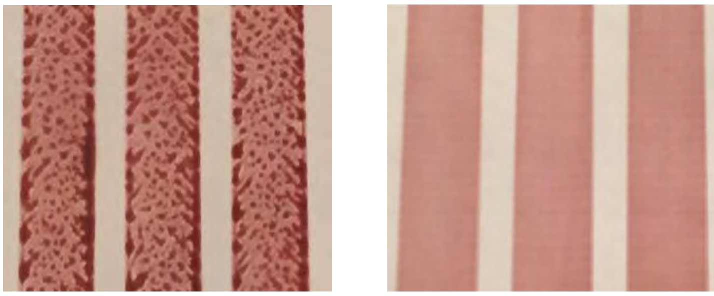

Before **After**

Figure 1. Improvement in film uniformity obtained after optimisation of plate patterning, solvent, print speed and drying process.

Biography

Neil Graddage received a M.Phys. degree in physics from the University of Exeter, U.K., in 2008, and a Ph.D. degree from Swansea University, U.K., in 2013. He was a Researcher with the Welsh Centre for Printing and

Coating, Swansea University, from 2012 to 2013. Since 2013, he has been a Research Officer with the Organic Materials and Devices group as part of the Advanced Electronics and Photonics Research Centre at the National Research Council Canada. His current research interests include printed electronics and carbon nanostructures, with a particular emphasis on upscaling and manufacturability.

18. Revealing the function of an MgO interlayer in 3rd generation photovoltaics

Ioannis Ierides[1], Giulia Lucarelli[2], Thomas M. Brown[2] and Franco Cacialli[1]
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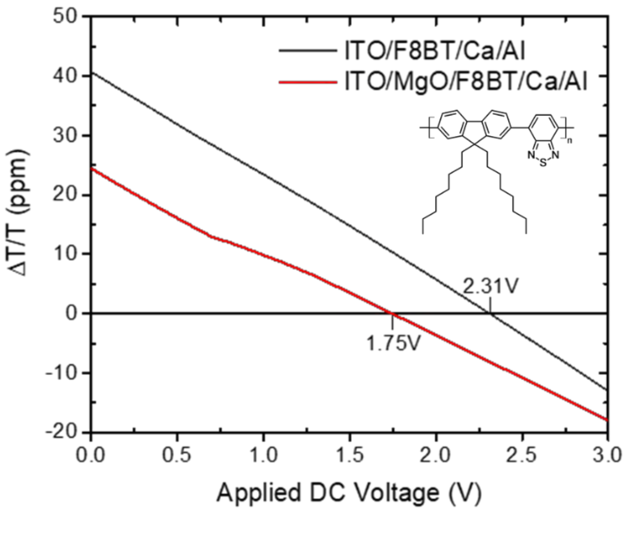
The great potential of 3rd generation photovoltaics in niche applications such as indoor energy generation has been recently demonstrated with the achievement of record high efficiencies for solar cells operating under standard indoor illumination conditions.[1]

This outstanding result was achieved by the introduction of an ultrathin MgO layer in the multilayer stack of photovoltaic devices. The insertion of this layer significantly enhances the performance and stability of both solid-state and liquid electrolyte solar cells.[2] Open circuit voltage decay and electrochemical impedance spectroscopy measurements revealed that electrons can effectively tunnel through MgO while holes are successfully blocked. This leads to reduced interfacial carrier recombination.[1,3] In addition atomic force microscopy showed that more uniform electron transport layers are yielded when MgO is deposited on top of SnO_2 or TiO_2. However, the complete description of the function of MgO is still lacking as its precise effect on the band alignment of devices has yet to be determined.

In the current work, we attempt to elucidate how MgO layers alter the work functions or conduction band levels of electrodes and electron transport layers. We employ electroabsorption spectroscopy to calculate the difference in the built-in voltage of devices after the addition of MgO. We utilise conjugated polymers as the active materials to allow for the analysis of electroabsorption spectra in terms of the quadratic Stark effect that necessitates the photogenerated charge pair to be Coulombically bound. Our results are accompanied with Kelvin probe measurements and we demonstrate that addition of MgO leads to energy level shifts towards the vacuum level, partly explaining the open circuit voltage increase observed in solar cells that employ MgO.



Error! Reference source not found.*: Variation of the electroabsorption signal with applied DC voltage. The point of intersection with the x-axis is the device's built-in voltage. The reduction of the built-in voltage is a result of the shift of the work function of the ITO electrode towards the vacuum level upon addition of an MgO layer.*

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Biography

Ioannis is a PhD student in the organic semiconductors and nanostructures group at UCL supervised by Franco Cacialli. He is very interested in renewable energy and more specifically the development of 3rd generation solution processed solar cells. He is experienced in electroabsorption spectroscopy and the photophysical characterisation of photovoltaic materials. He is keen to expand his knowledge and passion in advanced characterisation techniques by undertaking training as a member of the Centre for Doctoral Training in the Advanced Characterisation of Materials funded by the EPSRC. Prior to his PhD studies, Ioannis completed a BSc in Physics and the MRes in Nanomaterials at Imperial College London where he researched solution processed photovoltaics based upon inorganic nanocrystals.

19. AACVD of methylammonium lead triiodide for photovoltaic applications

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Organo-metal halide perovskites research has progressed rapidly, with photovoltaic devices reaching over 20% efficiency1. However, scalable production of these devices is an ongoing challenge. In this study we demonstrate the growth of methylammonium lead triiodide (MAPI) films via aerosol assisted chemical vapour deposition (AACVD). This is a scalable deposition process, requiring less complex equipment than conventional CVD.2

The films were deposited by sequentially passing aerosolized precursor solvent solutions into a reactor containing a heated substrate. This process was then repeated to form film of appropriate thicknesses. XRD measurements confirm the composition as MAPI. UV/vis absorbance measurements further validated the film composition, with Tauc plots giving an optical bandgap value of ~ 1.54 eV. SEM imaging revealed a film with large grains (2-10 µm), with film thicknesses ranging from 500-1500nm. These films were then used to fabricate working photovoltaic devices in the n-i-p structure, a first for films made via AACVD.

In conclusion, we have demonstrated successful synthesis of MAPI using AACVD. We have also shown that the sequential deposition method can create films of high quality. Moving forward, we intend to improve the solar cell efficiency by improving the morphology of the films.

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Biography

Sinclair graduated from Queen Mary University of London in 2015 with a MEng in Materials Science and Engineering. Following this, he joined the Centre of Plastic Electronics at Imperial College and is currently in his final year of PhD. The primary focus of his research is on AACVD of halide perovskites and related materials.

20. Three-dimensional ordered porous fluorine tin-oxide transparent electrodes for improved photovoltaics

David Poussin[1], Bob Xu[1], Natalie Stingelin[1,2], Martyn McLachlan[1]

[1]*Material department, Royal School of Mines, Imperial College London, United-Kingdom*
[2]*School of Material Science and Engineering, Georgia Tech, USA*

In the emerging field of solution processed solar cell, perovskites materials are one of the current major topics, due to their low-cost and high reported efficiency. A common structure for perovskite solar cell uses fluorine doped tin-oxide as a transparent conductive electrode, and titanium dioxide as an electron transport layer. In the research of a higher efficiency, the charge collection and the transport of the carriers to the electrodes are fundamental, and many studies are focused on improving these parameters, by tuning the materials used and also the structure of the solar cell itself.

In this work, we present a three-dimensional ordered structure, known as inverse opal, made of fluorine tin oxide, as an electrode, instead of a conventional planar one. An organised structure has multiple advantages compared to a randomly organized one, including a quicker transport to the electrodes, and a reduction of spatial traps for electron and holes. For the electron transport layer, a thin layer of titanium dioxide is coated on the structure by atomic layer deposition (ALD), because of the good conformity given by that technique. The coated inverse opal is then infiltrated with methylammonium lead iodide perovskite (MaPI) as an active layer, with a special spin coating deposition, to have a uniform infiltration. The perovskite layer being flat on top, the rest of the solar cell is similar to a classical one, with a thin layer of hole-transporting material, and an evaporated electrode on top of it.

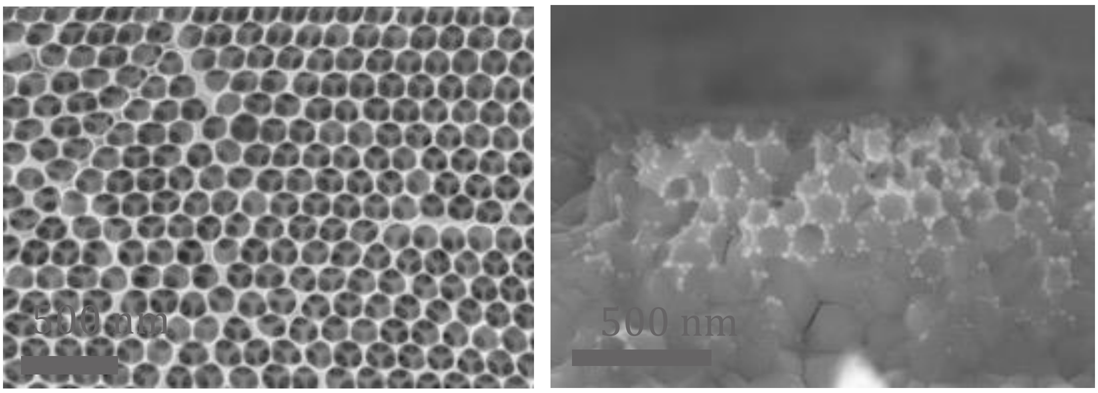

Figure 1: (left) SEM top-view of a FTO inverse opal, with pores of 100nm. (right) SEM cross-section of a FTO inverse opal, infiltrated with MaPI.

Biography

David Poussin is a PhD student at Imperial College London, Materials Department. His work focuses on the fabrication and characterisation of three-dimensional optical structures, and their implementation in optoelectronic devices for improved performances.

21. Elastic properties and band gap tuning of cubic perovskite $SrHfO_3$: First-principles calculations for solar energy

Khashayar Jeshvaghani [1]

[1] *UNAM-Institute of Materials Science and Nanotechnology, Bilkent University, Ankara 06800, Turkey*

Perovskite-type oxides due to their electrochemical properties, have received great interests for their applications in semiconducting devices like MOSFET. Among them $SrHfO_3$ with its 3.75 eV band gap and unique dielectric properties is of the most interesting perovskites. Density functional theory based first-principles calculations were used to study the mechanical, thermodynamic and electronic properties of cubic $SrHfO_3$ using projector-augmented wave pseudopotential with PBEsol approximation. We have obtained bulk and shear modulus using Voigt-Reuss-Hill approach, mechanical properties using anisotropy calculations, Debye temperature using Debye-Gruneisen model. Utilizing recently revised method we compared our results with other theoretical values showed 40 GPa rectification in computing Bulk module, which is the benefit of the method. Finally, we show the relationship between temperature, strain and band gaps with each other through different deformations. Results revealed that in room temperature, $SrHfO_3$ is under 20% strained condition rather than its stable ground state. Investigating electronic properties shows that band gap variation trend is reduced to 2.4 eV in room temperature.

Biography

Khashayar was an undergraduate student at the University of Bilkent, in the city of Ankara, Turkey. He is now graduated and working, and is continuing his research activities alongside his work. He is also keen on attending the relevant conference and intends to continue studying in the accredited universities. Participation in this conference can be very important for his scientific achievements.

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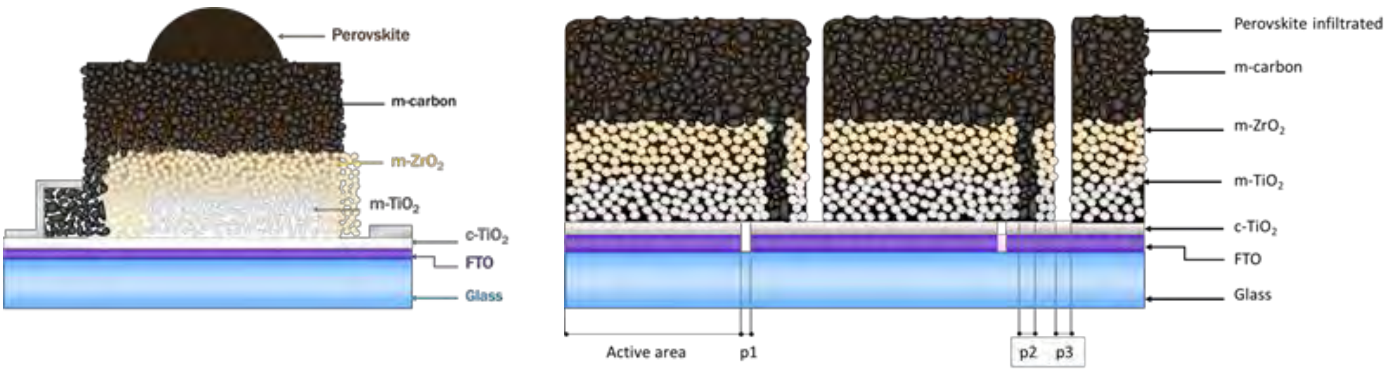
22. Optimization of large area printed Perovskite PV module design

Y.Mouhamad, S.Meroni, F. De Rossi, E. K. Hooper, J. Baker, S. Searle, E. Jewell, T.Watson

SPECIFIC, College of Engineering, Swansea University, Swansea, Wales, UK

There has been considerable interest over the last 5 years in Perovskite PV technology as it can achieve efficiencies above those reported for OPV and DSC while offering a fully solution based deposition route. In 2014, Mei *et al* reported a hole conductor free Perovskite PV cell which uses carbon as the top electrode [1]. Figure 1(a), typically the transparent electrode is coated with a compact blocking layer, followed by a mesoporous blocking layer, a mesoporous insulating layer and a porous carbon layer. The perovskite is infiltrated through a porous carbon layer which acts as an electrode. The stability, low material cost and all printable nature of this cell architecture means that this architecture promises a truly realizable and scalable 3rd generation PV. The scaling up of this cell in a serially connected module will depends on the active area of the sub-cell and the interconnection P2 which connect two subsequent sub-cells. Smaller interconnection would increase the geometrical fill factor; however this could result in significant resistive losses due to the resistivity of the ink and the contact resistance between the FTO substrate and the carbon.



(a) Carbon cell structure *(b) Module architecture*

Figure 1: Carbon perovskite PV at cell, module and real world scale

Wider active area will results in higher charge generation, however the resistive losses with limit the charge collection. Using a modelling approach a parametric study has been carried out on the impact of the of the width of the active area and that of the interconnection on the power output from a module using a characteristic IV response and known geometric limits for the critical dimensions (p1 and p3). The contact resistance between the FTO and the carbon was also accounted.

The findings have impact for next generation of module design and these have already been used to develop the next pilot manufacturing equipment set and Perovskite PV module demonstration programme at SPECIFIC

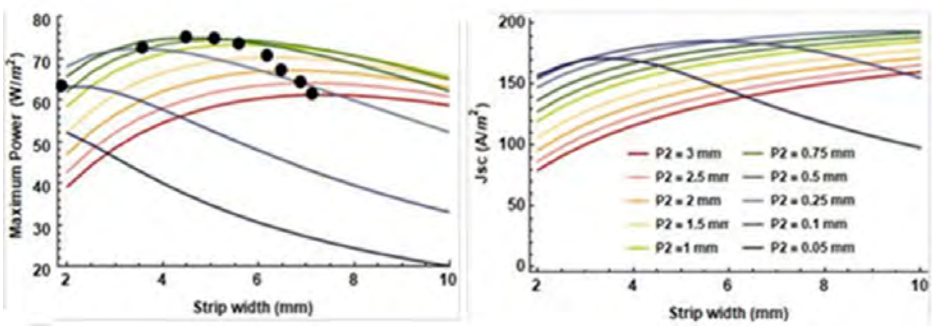


Figure 2 : Model results predicting the impact of geometry on output.

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Acknowledgement - The authors would like to thank EPSRC, Innovate and Welsh Government

Biography

Dr Youmna Mouhamad is currently a technology transfer fellow at SPECIFIC in Swansea University. She is working on Hi-Prospects a project funded by innovate UK which aims to improve the conductivity of transparent conductive oxide films by printing copper grids.

Youmna has a PhD in polymer physics from Sheffield University. Shortly after obtaining her PhD she joined the Welsh Centre for Printing and Coating as a research scientist. She worked on the formulation of carbon based inks for various applications including, a piezoresistive ink for large area pressure sensor and the development of a flexible ink for heated garnements. Two patents were files for these innovative. She then took on the printing of an antenna and tunable capacitor system for an energy harvesting module as part of the haRFest project co-funded by innovate UK.

23. Enhanced electric properties of TiO_2 electrode using laser ablated Ag nanoparticles

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Advanced Photovoltaics Research Labs, GIK Institute of Engineering Sciences and Technology Topi, Khyber Pakhtunkhwa, 23640, Pakistan
Email: nazi_9719@yahoo.com

In this paper the effects of silver nanoparticles on the performance of dye-sensitized solar cell (DSSC) has been investigated. The TiO_2 photoelectrode was treated with colloidal silver nanoparticles produced in deionized water via pulsed laser ablation. The DSSCs were fabricated using N719 dye with Ag treated photoelectrode and without Ag. Electrical parameters like J-V, impedence spectroscopy and absorbance spectra were carried out, showing 46.3% enhancement in efficiency due to the Ag treated TiO_2 photoelectrode.

Keywords: *electrical properties, laser ablation, dye-sensitized solar cell, silver doped photo electrode.*

Biography

Ms. Nazia Nasr did her MS in nanotechnology in 2013 from Islamic International University Islamabad. Currently, she is a PhD fellow under the PAK-US Science & Technology Cooperation Program, at the Faculty of Engineering Sciences, GIK Institute of Engineering Sciences & Technology, Pakistan.

She has been in South Dakota State University, USA, as a Visiting Research Scholar in Department of Electrical Engineering, Center for Advanced Photovoltaics from where she got training in solar cell fabrication and characterization under the Co supervision of Prof. Dr. Qiquan Qiao.

https://www.sdstate.edu/directory/qiquan-quinn-qiao

Currently, she is working on the optimization of 3rd generation solar cells under her PhD supervisor Prof. Dr. Muhammad Hassan Sayyad in Advance Photovoltaic Research Labs at the Faculty of Engineering Sciences, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology.

https://www.giki.edu.pk/Faculty/Prof-Dr-M-Hassan-Sayyad

24. Printed and flexible NiO supercapacitors for energy harvesting applications

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Abstract

Harvesting energy from various ambient energy sources including electromagnetic/RF, thermal, mechanical, solar opens opportunities for the development of self-powered wireless sensors, internet-of-things devices and autonomous wearable electronics. Energy harvesters tend to deliver 'packets' of energy with lots of power fluctuations, and supercapacitors represent an ideal energy storage solution as devices capable of handling high power densities, sustaining millions of charge/discharge cycles at fast rates.

In this work we have developed a fully inkjet-printed and flexible nickel (II) oxide (NiO) co-planar supercapacitor to support the energy storage demands of next generation wearable electronics. The supercapacitor is prepared by ink-jet printing the current collector of the device in a co-planar configuration (Fig. 1a, b) followed by deposition of the active electrode layers using a NiO nanoparticle ink (<50 nm particle size). Finally, a quasi-solid neutral electrolyte is inkjet printed on top to assemble the full device. Cyclic voltammetry analysis showed a maximum capacitance of 77 F·cm^{-3} and 3.1 mF·cm^{-2} for a wide range of scan rates from 10 mV·s^{-1} to 250 mV·s^{-1}. The devices showed excellent capacitive response even at as high as 1500 mV·s^{-1} of scan rate. The power density of the device was evaluated to be 3.81 W·cm^{-3}. The nanoparticle-defined NiO electrodes form a well-structured mesoporous layers that facilitate high ionic transport during charge/discharge cycles while also enabling high electrode conductivity. These results show the potential of nanostructured NiO for high performance, thin film and flexible supercapacitors that can be realised via roll-to-roll fabrication techniques compatible with printed electronics.

Acknowledgement

This research is supported by the European Regional Development Fund, Interreg France (Channel) England under the project SURFAS.

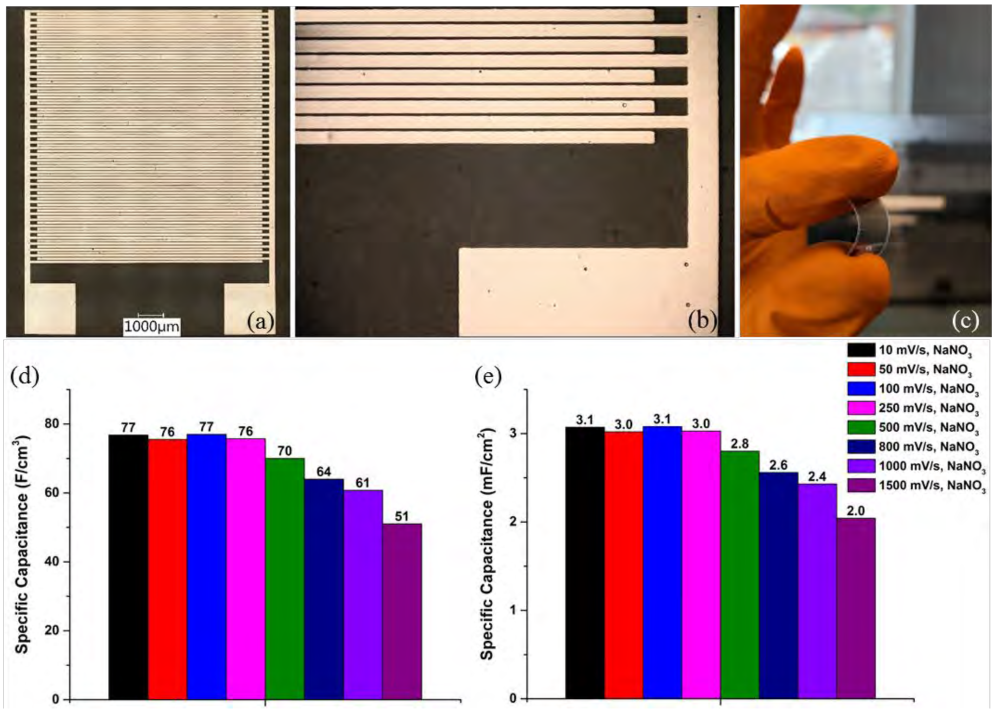

Figure 1. (a, b) High resolution inkjet-printed silver current collector in a co-planar supercapacitor pattern. (c) Full device. (d, e) Volumetric and areal capacitances at various scan rates from 10 mV·s^{-1} to 1500 mV·s^{-1}.

Biography

Pavlos Giannakou is a second year PhD student studying at Advanced Technology Institute, University of Surrey. His work is mainly focused on printed and flexible transition metal oxide supercapacitors with strong emphasis towards developing real-world related solutions. His main interests are working around renewable energy, energy harvesting and next generation flexible electronics including energy storage. Pavlos can be contacted at: p.giannakou@surrey.ac.uk

25. Solar energy harvesting fabric for wearable, mobile, and off-grid applications

Achala Satharasinghe, Theodore Hughes-Riley and Tilak Dias
Advanced Textiles Research Group, School of Art and Design, Nottingham Trent University

Wearable and mobile electronic devices play a dominant role in our modern lives, however robust and sustainable energy solutions for powering them is still an unmet need. Textile fabrics are large area structures that can be worn by a user, hence are a suitable platform for a wearable/mobile solar energy solution. In this work a novel solar energy harvesting fabric is presented. The fabric is constructed by weaving miniature solar cell embedded textile yarns (solar yarns) fabricated using the E-Yarn technology [1]. The fabric has textile like haptic (soft, conformable and breathable) and aesthetic properties and is also machine washable and mechanically robust making it superior to other textile energy solutions reported in literature [2], [3] for wearable and reusable applications. The fabric can be rolled and is lightweight, making it desirable for mobile and off-the-grid energy needs.

The solar energy harvesting fabric demonstrated here was woven using 20 solar cell embedded textile yarns creating a solar cell footprint of 50 mm × 45 mm. The solar yarns were fabricated by soldering ten miniature crystalline silicon solar cells (3 mm × 1.5 mm), in parallel, onto two fine multi-strand copper wires before encapsulating them individually inside of clear resin micro-pods. The encapsulated cell strand was then covered by a textile fibrous sheath comprising packing fibres and a tubular knitted structure. The resultant fabric generated a short-circuit current, an open circuit voltage, and a maximum power output of ~14.5 mA, ~5.1 V and 45 mW respectively, with a ~2mW/cm^2 power density under one sun (1000 W/m^2) solar illumination. The solar energy harvesting fabric can fully charge a 110 mF (3.2V) textile-form super capacitor bank within one minute and is suitable for charging a smart watch or a basic mobile phone. Additionally, by impregnating the photoactive side of solar yarns with a clear polymer resin, a ~60% increase in power output can be realized.

The solar yarns (in fabric form) survived a minimum of 15 machine wash and line dry cycles and 6000 abrasion cycles without deterioration in performance, confirming their utility for washable and reusable products.

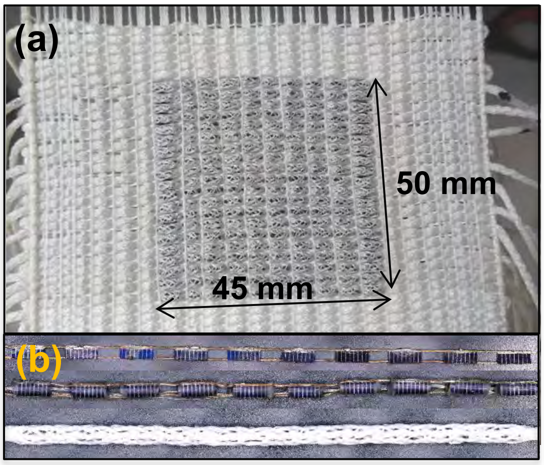

***Figure 1** – (**a**) Image of the solar cell embedded fabric. (**b**) Images of solar cell yarns after soldering (**top**), after encapsulation (**middle**) and after covering with fibrous sheath (**bottom**)*

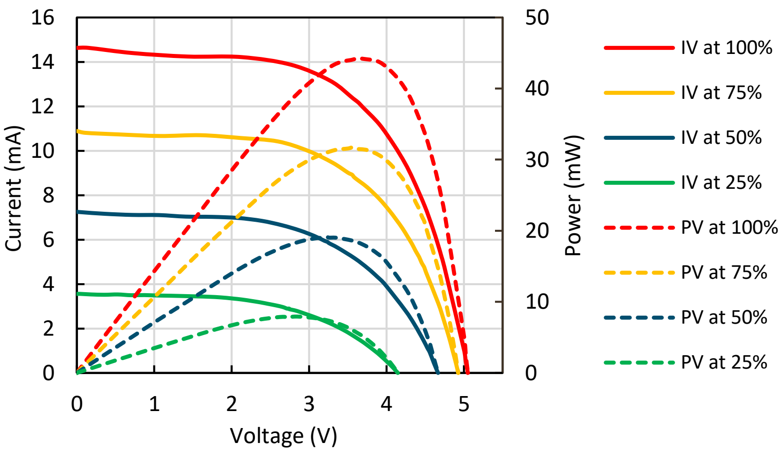

***Figure 2** – Characteristic curves (current/voltage-IV) and power/voltage -PV) for the solar cell embedded fabric under different irradiance intensities (one sun=100%).*

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Biography
Mr. Achala Satharasinghe is a postgraduate researcher currently in his 3rd year of study for his PhD in energy harvesting textiles at the Advanced Textile Research Group in Nottingham Trent University. He received his bachelor's degree in Textile Process Engineering and holds an MSc in Nanoscience and Nanotechnology. He has been working on research and development of E-textiles and wearable electronics for sports, lifestyle and healthcare applications for past 5 years. He also has 7+ years industry experience in developing innovative textile and apparel solutions for world-renowned brands and emerging start-ups in a project based environment.

26. Flexible temperature logger powered by solar cell and supercapacitor

Donald Lupo[1], Jari Keskinen[1], Jari Taavela[2], Hannes Sirén[2], Juha Virtanen[2], Matti Mäntysalo[1]

[1] *Tampere University of Technology, Korkeakoulunkatu 3, Tampere, Finland*

[2] *Confidex Ltd, Lumpeenkatu 6, Tampere, Finland*

Inexpensive power sources are needed e.g. in RFID and wireless sensor network applications. By applying printing techniques the manufacturing costs can be minimized. It is also possible to introduce materials that are environmentally friendly, can be disposed of with normal household waste and are incinerable. We have developed supercapacitors that can be combined with energy harvesting components such as printed photovoltaic or RF energy harvesting circuits. [1] In this presentation we demonstrate the use of printed supercapacitor and commercially available organic photovoltaic cell (OPV) to power a flexible temperature logger.

The temperature logger consists of three main components, a coil antenna, an IC, and a power source to the IC. The integrated RFID (HF) microchip with built-in temperature sensor was a commercial product from AMS (AS39513). The external communication with the IC is performed over the NFC interface with an NFC enabled smart phone. The HF antenna was specially designed and matched for this IC, ensuring optimal performance.

The microchip does not only enable fully passive on-demand temperature measurements but enables also autonomous data logging. To enable recording of temperatures as a function of time the IC requires an external 3 V power source to be connected. As this temperature logger is planned to work in a semi-active mode to enable autonomous data logging, there was a need for a connected external power. Temperature logger under discussion could also be powered e.g. with standard CR2016 coin cell batteries, but then the flexibility of the product would be at least partially compromised. Flexible batteries are also available in the market, but their power capacity or recharging capabilities are limited or require extra recharging circuits. Supercapacitor with a photovoltaic cell provides a simple structure for the product´s external power source.

The materials for the supercapacitors were chosen to be compatible with printing methods, e.g. the activated carbon powder in the electrodes is bound with the biopolymer chitosan. Since we preferred aqueous electrolytes due to environmental and safety reasons, the voltage of our single supercapacitor cell is limited to about 1.2 V. This requires the use of three series connected cells to reach the preferred 3 V. Supercapacitors of various configurations were prepared. The length and width of the series connected supercapacitors was defined by the free area inside the antenna loop. Antenna transmit power measurements showed that 50 mm x 25 mm can be put inside the loop without severely disturbing the transmission properties. The structure and manufacturing method of the supercapacitors allow up-scaling, so that the properties can be tailored according to the application.

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Acknowledgement - The authors would like to thank Business Finland including decision 40146/14.

Figure 1. Temperature-logger with battery and supercapacitor and OPV replacing the battery

Biography

Prof. Dr. Donald Lupo joined the Department of Electronics at Tampere University of Technology as professor in August 2010. He received his Ph.D. in physical chemistry from Indiana University on energy transfer in liquids in 1984 and has been an internationally recognized researcher in functional materials for photonics and electronics since 1987, with publications in leading journals in the fields of nonlinear optics, organic LEDs, organic photovoltaics, paper-like displays and printed electronics. He is responsible within the Laboratory for Future Electronics at Tampere University of Technology. He was speaker of the Education working group at the Organic Electronics Association (OE-A) from 2010-2015, has been on the core editorial team of the OE-A roadmap since 2009 and recently co-edited a textbook on the fundamentals of organic and printed electronics.

27. Developing conductive textiles for antennas

Dave Barwick[1], Chris Hunt[2], Simon Rutter[1]

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[2] *Pireta Ltd, c/o NPL, Hampton Rd, Teddington, TW11 0LW, UK*

Abstract

There is a requirement to develop improved processes for manufacturing conducting textiles. Textiles have properties which give them many advantages for clothing, medical devices and shelters but to make them "smart" by i) connecting them to the internet or a satellite; ii) powering them up iii) or hiding them to certain frequencies; current fabrication approaches compromise these properties.

The Texann project focuses on Pireta's proprietary process for making thin, controllable and highly durable conducting layers or tracks on a wide range of textiles. The coating retains the feel and mechanical properties of the original textile (unlike textiles made by incorporating wires), works on a wide range of surfaces and is resistant to washing (unlike printed coatings). The key objectives of our project are to optimise and scale up this process utilising assets within CPI's printable electronics facility to yield consistent, highly conductive textiles at medium volume (tens of m^2 per day) at a price which makes them applicable to a wide range of uses.

We will report on progress to date since the project commenced in May 2018. Current advancements include significantly enhancing achievable resolutions using scalable industrial printers as well as substituting reagents with more stable alternatives.

Biographies

Dr Dave Barwick is a Technology Manager within the device and component technology group of CPI, heading up a team of 8 scientists. He has worked at CPI since 2009 and has led projects focusing on the development of energy harvesting technology, internet of things applications, sensors and solid state lighting. Prior to joining CPI, Dave worked in the pharmaceutical industry where he focused on assessing materials properties of new drug candidates. Dave is a chartered scientist and a Fellow of the Royal Society of Chemistry with a PhD in surface science. He has particular expertise in coating technologies, ink formulation and characterisation.

Dr Chris Hunt is the Founder and Chief Technology Officer for Pireta, a start-up to develop a conductive textile technology. He is a co-inventor, named on the patent, of this technology which is an additive metallisation of individual fibres within the textile. He previously worked at the National Physical Laboratory for over 30 years, where he built a team that developed metrology methods for electronics interconnection, which covered a wide range of functional parameters. He has written 44 peer reviewed papers and 139 NPL reports. He was active in the standards arena and collaborated on many industrial projects, and supported UK trade organisations. He has been chair of IEC TC91 committee, Electronic Assembly Technology, and chair of BSI EPL501 committee, Electronic Assembly Technology, and he is chair of IMAPS UK committee.

Dr Simon Rutter is a Senior Scientist in the device and component technology group of CPI. He completed his PhD at the University of Durham studying prototypical molecular wires and has worked at CPI since 2010, initially focussing in the area of Organic Thin Film Transistors but more recently broadening into areas such as sensors and other printed devices.

28. Low-cost printed RC filter using materials from daily-life

Brice Le Borgne[1], Bo-Yan Chung[1], Simon G. King[1], Inkyu Kwon[1], Radu A. Sporea[1]

[1]*University of Surrey, Guildford, GU2 7XH, United Kingdom*

The growing number of SMEs, education organisms and makers' communities demand better support for very low-cost prototyping tools for large-area and flexible electronic devices. Such tools must be made available for non-specialists and provide low-temperature, risk-free and easy-to-use technologies with reasonable levels of performance.

Recently, different groups have developed electronics using daily-life materials such as albumin (egg white), fish gelatine or flowers as insulators [1], mixers [2], or even microfluidic channels [3] respectively. These works present the double-interest of dealing with cheap and almost non-transformed materials that could open new kinds of businesses for large public home users. Commercial bio-sourced materials suitable for inkjet printing are, however, much more complicated to find. Consequently, new additive manufacturing techniques and materials have to be developed.

Here, we demonstrate how to fabricate a simple electronic circuit - an RC filter (Figure 1.a) - using daily-life products and a cheap desktop inkjet printer. The RC filter has been chosen to illustrate the capabilities of the technique, i.e. allowing the printing of passive devices.

A carbon black ink has been prepared and its rheological parameters were carefully tuned in order to enable its jettability in the printer. This water-based carbon ink, once printed, exhibited a resistivity of 9.8×10^{-2} ohm.cm with no annealing or sintering step required. The ink dried in about 10 min at room temperature. The capacitor was fabricated using printed resistive electrodes based on carbon black and drop-casted egg white as dielectric (Figure 1.b). Considering the resistivity of the carbon black ink and the egg white dielectric constant, the resistor and capacitor's geometrical parameter where adapted to obtain a theoretical cut-off frequency of 190 kHz. The demonstration filter displayed a cut-off frequency of about 200 kHz, which represents an acceptable 5% error (Figure 1.c).

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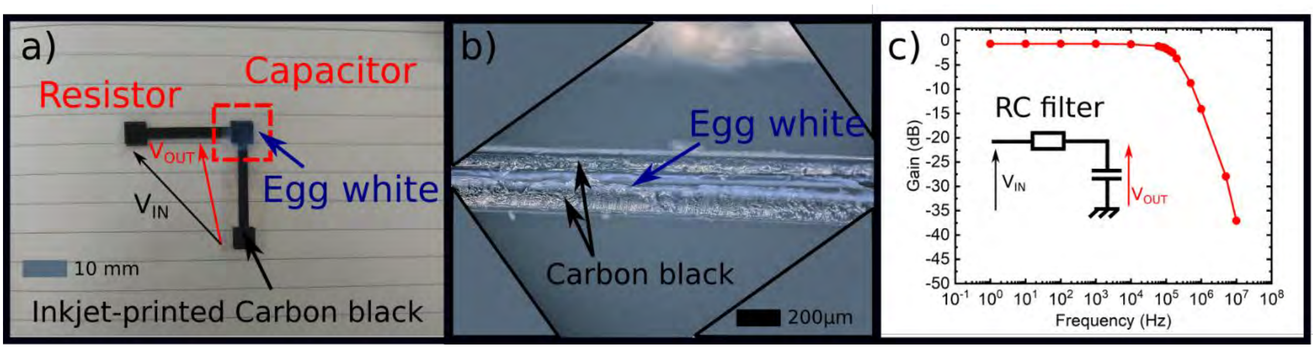

Figure 1. a) Optical image of an example of a printed 1st order RC filter composed of a carbon black-based resistor and a capacitor using egg white as dielectric. b) Obtained Bode diagram (gain) showing a cut-off frequency of about 200 kHz. c) Cross-section view of the capacitor showing the carbon black electrodes and the egg white.

BIOGRAPHY

Dr. Brice Le Borgne received his PhD. degree in 2016 from the University of Rennes 1 (IETR Microelectronics & Microsensors group). He is currently working at the University of Surrey as a Reasearch Assistant. His research, conducted at the Advanced Technology Institutes, is dedicated to all the aspects of soft materials science and engineering. He has especially worked on: i) chemical sensors, iii) materials and methods for flexible, stretchable and conformable electronics and iv) additive manufacturing. Recently, he dedicated his work to paper electronics, mainly using inkjet-printed organic and inorganic materials.

29. Next-generation paper: an augmented travel guide demonstrator

Radu A. Sporea[1], Brice H. Le Borgne[1], Samuli Yrjänä[2], Sirpa Nordman[2], Peter Bagge[3], Haiyue Yuan[1], Emily Corrigan-Kavanagh[1] Anu Seisto[2], George Revill[4], Miroslav Z. Bober[1], Alan Brown[1], Caroline E. Scarles[1], David M. Frohlich[1]

[1]University of Surrey, Guildford, GU2 7XH, United Kingdom
[2]VTT Technical Research Centre of Finland, Finland
[3]Otava, Uudenmaankatu 10, 00120, Helsinki, Finland
[4]The Open University, Milton Keynes, MK7 6AA, United Kingdom

We present an augmented book platform which links physical and virtual content in a system which comprises authoring tools, instrumented paper books and digital assets in a new type of interaction. Here, we focus on the first of two planned demonstrators, an augmented travel guide which responds to user interaction by presenting relevant digital content on an adjunct multimedia device (e.g. smart TV, smart phone, etc.).

The system is envisaged to add a new layer of dynamic, contextual digital information to otherwise seamless interactions with paper books with a conventional look and feel, and contributes to the recent wave of prototypes and technologies related to electronic systems which are paper-based or have the form factor of a book [1-4].

Figure 1 presents the general system, the structure of an instrumented sheet in the book, and the electronics embedded in the cover. At the time of content creation, digital assets are linked to physical elements of each page. As the user reads the book, organic photovoltaic (OPV) modules made at VTT [5] and embedded in the pages send signals to a microcontroller in the hard cover, thus uniquely identifying the open page. The system also contains touch areas for content type selection, power management including wireless charging, and a Bluetooth LE module for instructing the adjunct smart devices on the digital content to be presented in relation to the open page.

Several decisions have been taken specifically to serve as research questions during the user trials, and design aspects will be refined based on this learning in future prototypes.

The platform should enable a new generation of connected devices and user experience.

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Acknowledgement (optional) - The authors acknowledge EPSRC support through grant no. EP/P02579X/1.

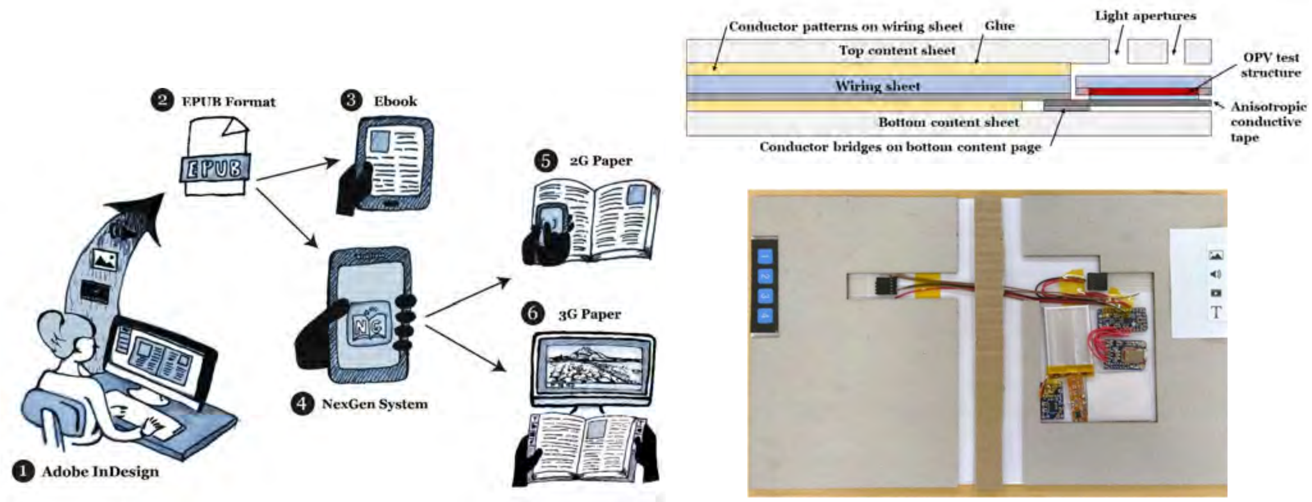

Figure 1. Augmented book platform: left – content authoring and consumption environment; top right – cross section of an instrumented sheet; bottom right – off-the shelf communication, power management and decision electronics housed in the book's hard cover.

Dr Radu Sporea is a Lecturer in Semiconductor Devices at the Advanced Technology Institute, University of Surrey, UK. His current research focuses on three main topics:

1. Advanced semiconductor device design, including transistors with increased tolerance to fabrication variability, improved energy efficiency and high gain. Research spans novel fabrication ultra-low-cost fabrication techniques, advanced materials, manufacturability and robustness of electronic devices and circuits (e.g. EP/R028559/1) and is supported by numerical simulations.

2. Large area sensors and sensor arrays for smart environments, focusing on multi-modal sensing of presence, gesture, gait, etc. and tailored to low-cost integration in commercial manufacturing platforms and mass-market products.

3. Paper-based electronics and physical-digital interaction, as part of EPSRC project, "Next Generation Paper", EP/P02579X/1, where he leads the design of low-cost multi-modal sensors for user interaction, flexible interconnect, energy management, decision and communication systems, and system integration for an electronically-augmented book.

30. Inkjet-printed rectifying diodes on paper substrates

Silvia Conti[1], Carme Martinez-Domingo[1], Fabiola Vilaseca[2], Lluís Terés[1], Eloi Ramon[1]
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[2] *Department of Chemical Engineering, Agricultural and Food Technology, Universitat de Girona, Maria Aurèlia Capmany 61, 17003, Girona, Spain.*

Over the past 20 years, the interest in organic and printed electronics has increased exponentially. Low-cost printed electronics seek to minimize the area limitations and number of steps associated with conventional silicon processing for applications that do not require high performances [1]. By using printing technologies, the process becomes all-additive without the need of expensive lithography or vacuum processes, resulting in a reduction of production costs. Furthermore, the development of novel multi-functional nanocomposites materials has gained tremendous research interest on using low-cost and renewable raw materials, to produce sustainable, biodegradable, and eco-friendly biomaterials to be used in electronic applications [2].

In this work, organic rectifying diodes fabricated by means of inkjet printing on nanopaper environmentally friendly substrates are presented. Figure 1a shows the scheme of the proposed structure: following a work recently published by our group [3], plastic substrates and bottom metal electrodes were substituted by the conductive nanopapers for the fabrication of organic rectifying diodes. Nanocellulose changes its electrical properties from being an insulator to a semiconductor and, eventually, becoming a conductor by the addition of conductive fillers [4]. Conductive nanopapers were obtained from two different cellulose pulps (high-purity softwood cellulose pulp CNF5 and eucalyptus pulp CNF15) adding conductive polymers (polythiophene (PT2, PH500) and polypyrrole (PPy) or Multi-Walled Carbon NanoTubes (MWCNTs). Poly-4vinylphenol (PVP), an epoxy insulator (SU8), and high permittivity (HK) Epoxy/Nanosilica insulator (UTDots) were investigated as the polymeric insulator layer. A commercial amorphous polymer (Merck Lisicon® SP400) was employed as the p-type semiconductor. The top electrodes were patterned using a commercial silver conductive paint (SCP03B).

The quality of the printed film was highly affected by the roughness of the nanopapers. In some cases, a non-homogenous insulator layer results in a short-circuit through the structure. Figure 1b shows the best results obtained employing CNF5 as the substrate. Rectification Ratio (RR) is defined as the ratio of the maximum forward current to the maximum reverse current registered at the same voltage. The electrical performances of the diodes seem to be more dependent on the choice of the insulator than on the nanopaper formulations. The ternary formulation with the combination of PH500 mixed with PPy as substrate and UTDots as the insulator showed a maximum forward current of 2μA and a maximum reverse current of 1nA (Figure 1c). As a result, extremely high RR value was obtained (2000).

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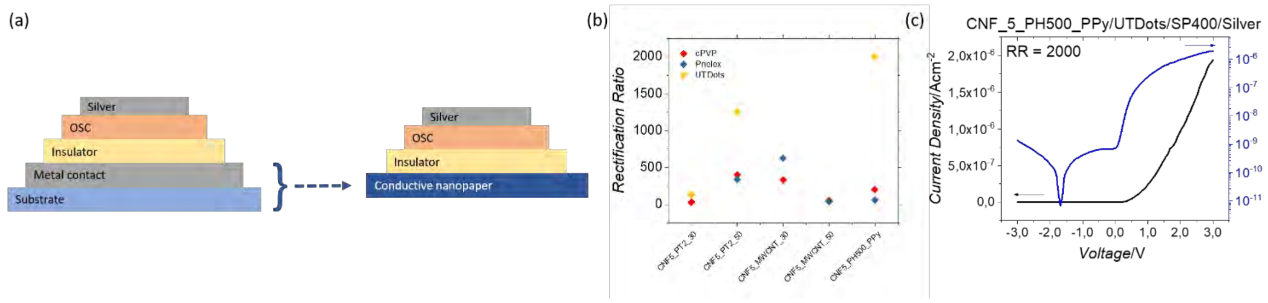

Figure 1. Scheme of the organic rectifying diode (a). Rectification Ratios for different diodes (b). Current Densisty-Voltage characteristics of CNF_5_PH500_PPy/UTDots/SP400/Silver structure in linear plot (left) and semi-logarithmic plot (right) (c).

Biography

Silvia Conti received her M.Sc. in Industrial Chemistry from the University of Bologna in 2013 (Unibo, 2010-2013). In January 2014, she joined the DEALAB group at the Department of Electric and Electronic Engineering of the University of Cagliari. In 2017, she defended her Doctoral Thesis "Fully printed Organic Thin Film Transistors for Biosensing Applications" under the supervision of Professor Annalisa Bonfiglio. She is currently enrolled in the Integrated Circuit & System (ICAS) group of the Institute of Microelectronics of Barcelona (IMB-CNM, CSIC) as a Post-Doctoral Researcher. Her research activity is focused on the fabrication of organic semiconductor devices by using inkjet-printing technique.

Presented by Dr Eloi Ramon

31. Organic chipless-RFID tags inkjet printed on paper substrates

Miquel Moras[1], Alba Nuñez[1], Cristian Herrojo[2], Ferran Paredes [2], Ferran Martín[2] and Eloi Ramon[1]

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[2] GEMMA/CIMITEC, Departament d'Enginyeria Electrònica, Campus Universitat Autònoma de Barcelona, *08193 Cerdanyola del Vallès, Spain*

In this work, an organic inkjet-printed chipless Radio-Frequency Identification (Chipless RFID) tag [1] is presented. The tag consists of a set of identical inkjet printed resonant elements that forms a sequence. Depending on its orientation, each element will provide a logic state ('1' or '0'), determined by the resonance of the induced radiation (resonator tuning/detuning). All the tags have been printed on ordinary A4 paper sheets using a commercial Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS) based ink (Poly-Ink HC).

In order to read the organic near-field coupling resonator chain, a reader has been developed. Auxiliary electronic circuits was used to generate the tone signal and an envelope detector allows the acquisition of the data. An important part of the reader is the mechanical system that permits to displace the tag over the reader transmission line in close proximity to it.

To demonstrate the organic ink properties (PEDOT:PSS) in the electrical response of the tag (envelope signal; Vout), different resonator chains have been printed using one, two or three layers to give '1111111111' codes. All the tags have been scanned in the top and down face using the reader presented above. The results have been compared with the ones obtained when a commercial silver ink (Ag DuPont PE410) is used, as it is shown in Figure 1. When PEDOT:PSS is employed, the best envelope signals are obtained for two or three printed layers. A clear response is visible for each face (all of the 10 bits are easily identified). Printing one layer makes it impossible to distinguish the amplitude of each resonator of the chain. On the contrary, when the silver ink is used, the best results are obtained for one and two printed layers, showing good signal amplitudes for both sides of the tag. As a consequence of the paper porosity, the amplitude of the signal in the down face is not clear due the ink accumulation on the bottom face for three silver layer tag.

Good amplitude response Chipless RFID tags printed on ordinary A4 paper sheets using an organic ink have been presented. The validity of using organic ink tags has been demonstrated and its behaviour is comparable with the ones obtained printing silver.

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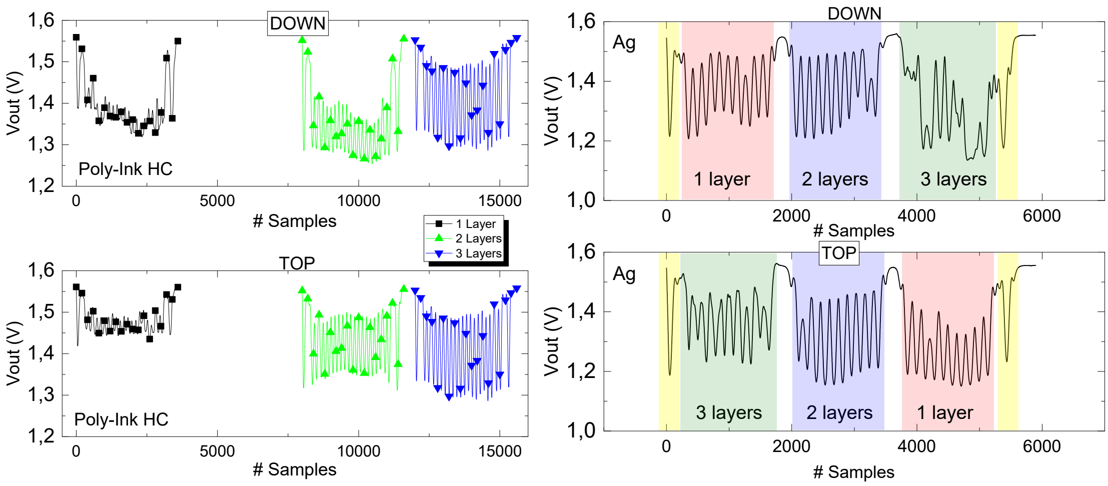

Figure 1. Resonator envelope signal level obtained for the tags printed using 1,2, or 3 layers of an organic (left) and silver (right) ink.

Biography

Miquel Moras received his M.Sc. in Micro and Nanoelectronics Engineering from the University of Barcelona in 2012. In the same year, he joined the REDEC group at the Electronics Engineering Department of the University of Barcelona. In 2017, he defended his Doctoral Thesis "Caracterización de la variabilidad dependiente del tiempo de MOSFETs ultraescalados para su modelado compacto" under the supervision of Professors Montserrat Nafria Maqueda and Javier Martin Martínez. He is currently enrolled in the Integrated Circuit & System (ICAS) group of the Institute of Microelectronics of Barcelona (IMB-CNM, CSIC). His research activity is focused on the fabrication of systems that involve inkjet-printing electronics systems.

32. NECOMADA: low cost printed devices for the Internet of Things

Presenting David Johnson[1], Hannah Askew[1], Nicola Broughton[2], Anna-Marie Stobo[1], Aimee Wyatt[2], Colin Graves[1], Dave Barwick[2]

[1] *Centre for Process Innovation, National Formulation Centre, Sedgefield, UK*

[2] *Centre for Process Innovation, Printable Electronics, Sedgefield, UK*

The NECOMADA* project is a collaboration of organizations across Europe addressing the key material challenges for Internet of Things (IoT). Specifically, it involves the integrated development of conducting materials, inks, adhesives and pilot line facilities to achieve a substantial reduction in printed electronic device costs. This is demonstrated through the pilot production of Near Field Communication devices for packaging, healthcare and home appliance applications.

The project will ultimately deliver a supply chain for future commercialization which incorporates: supporting RTOs for nanomaterials production and formulation, material suppliers for inks and adhesives, high fidelity print manufacturers, electronic device manufacturers, new open access pilot line facilities, and potential end users for the IoT (figure 1).

Here we report on the development of new conducting inks and adhesives which meet stringent cost and performance requirements. In addition, we provide an update on the capability of the newly established roll to roll print and pick and place lines at the Centre for Process Innovation.

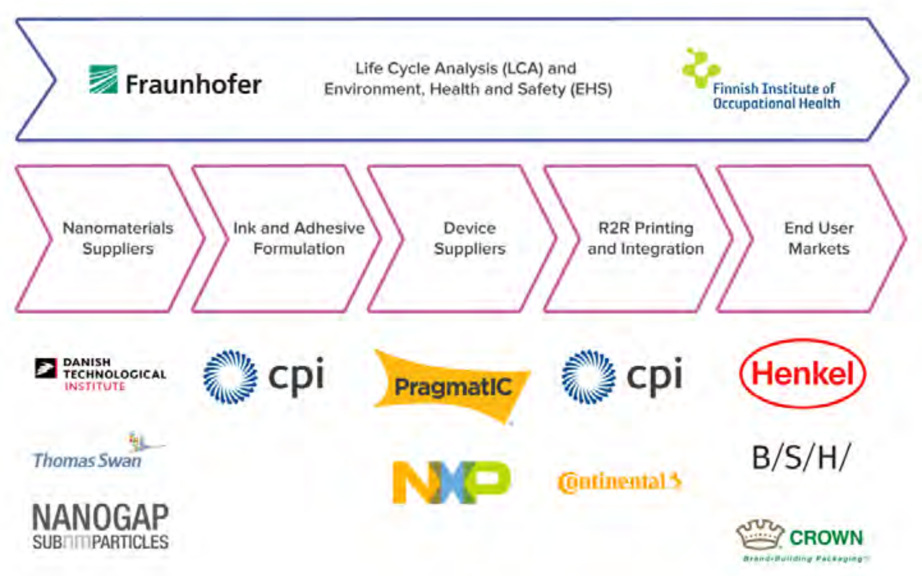

Figure 1: NECOMADA project pipeline

*NECOMADA: Nano-enabled conducting materials accelerating device applicability

Acknowledgement - The authors would like to thank the European Union's Horizon 2020 research and innovation programme Contract No 720897.

Biography

Dr David Johnson is a Senior Research Scientist at the Centre for Process Innovation's National Formulation Centre. His expertise is in polymer chemistry and nanomaterials which, as part of the CPI, he has used to help develop new conducting inks and adhesives for printable electronics.

33. LAE for IoT applications – a perspective from IP protection

Mash-Hud Iqbal, Esther Ford
Marks & Clerk LLP, 62-68 Hills Road, Cambridge, CB2 1LA, UK

The term 'IoT' is commonly applied with reference to consumer devices such as lighting, smoke detectors and kitchen appliances, but IoT also encompasses technologies including autonomous vehicles, industrial control systems and logistics management. LAE is expected to gain commercial traction in all of these areas. With predictions of 20, 50 or even 200 billion, IoT devices in use by 2020, data security, privacy and control are major concerns for IoT providers and consumers – just as they are for traditional computing devices. With expected improvements in data-transfer speed, latency and power consumption in 5G cellular networks, an imminent step-change in IoT usage only increases these concerns.

LAE inventions for IoT may cover smart products (inc. sensors, software and connectivity). Patents for physical products in this area may effectively protect a service, and thus the associated revenue stream enabled by the product. IoT players should also consider protecting all aspects of a system, e.g. IoT devices (sensors, actuators, flexible displays and other LAE device/systems), distributed systems and algorithms for data processing, production facilities and processes. Additionally, patent applications for inventions in the field of data security have high commercial potential.

All of these aspects further demand careful consideration of territories for IP protection. Patent claims, if drafted skilfully, can enable enforcement in one jurisdiction against infringements crossing borders. National jurisprudence is, after all, catching up with technological developments.

IP ownership is also important. We will consider how to manage partners and third party suppliers in a LAE and IoT ecosystem. Of particular interest, we will address whether licences can be crafted to avoid 'diluting' IP ownership, thus allowing an IP portfolio to be aligned with current/future business models.

We will also discuss patenting trends in LAE for IoT in different commercial applications, and which regions in the world are dominating IoT patent filings. In this context, we will further discuss IP strategies to protect an IoT-based business model that is, by nature, scalable and geographically borderless. The IP implications of Brexit, and the Unitary Patent Court (UPC) will also be addressed in relation to global IoT business models. Against this background, we will discuss case studies of how start-ups and international corporations may use LAE, and how they are protecting their IoT business models.

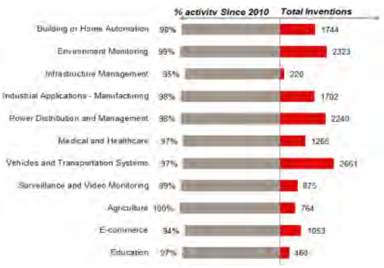

Figure 1. Application area trends,

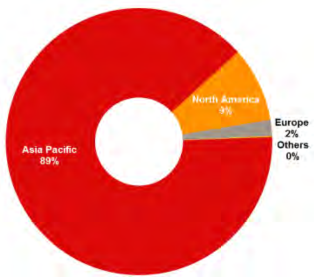

Figure 2. Patent activity by Source Region/Country

Figures produced from the data provided by Clarivate

Biography

Mash-Hud Iqbal has a keen interest in sensor systems and IoT related inventions. He has experience in drafting patent applications directed to smart medical devices, particularly using machine learning. Mash-Hud completed his PhD from the Engineering Department of Cambridge University, and he has been recognised as a rising star by Managing Intellectual Property, IP Stars, 2017 & 2018.

Esther Ford has worked extensively, as both a research engineer and IP specialist, in the fields of semiconductor devices, telecommunications and IoT. She has an MEng in Electronic Engineering and a PhD in Microelectronics from the University of Cambridge. She joined the patent profession in 2004 and has extensive experience in managing patent portfolios of growing SMEs and international corporations.

34. Quantum Technology Supersensors™ – Environmentally friendly 'smart' pressure sensing inks.

David Lussey and Josephine Charnley
Quantum Technology Supersensors
www.quantumtechnologysupersensors.com

Quantum Technology Supersensor™ environmentally friendly 'smart' pressure sensing inks enable a new way of making electronics for more sustainable product innovation at a reduced cost whilst advancing the circular economy. They change from insulator to conductor under pressure in proportion to the amount of force applied exhibiting resistance change over many orders of magnitude of over a billion ohms. These '**smart**' QTSS™ inks know 'where' and 'how hard' they are being pressed and can add 3D Force-Touch pressure sensing functionality to most surfaces including recyclable paper, card and textiles. They harness nature's Quantum Technology effects for environmental impact and energy reduction. Flexible and durable they are suitable for use in high growth markets such as healthcare, robotics, stretchable & conformable electronics, consumer goods, automotive, the Internet of Things, smart cities, packaging and wearables where they can be used to create single touch or multi-touch pressure sensors and can be printed or in-mould. They are Arduino & open-source software compatible. QTSS™ 'smart' pressure sensing inks have already been recognised by multiple awards including IDTechEX Toxicant Replacement Hero Award, Printed Electronics Show Berlin 2018, Business Green Technology 'Breakthrough of the Year' Award Dec 2017 and an OE-A Award at LOPEC, Germany 2018.

Biography

Quantum Technology Supersensors is an sme specialist smart materials development company founded by David Lussey and Josephine Charnley. Its novel Quantum Technology Supersensor™ environmentally friendly 'smart' pressure sensing inks harness nature's Quantum Technology effects to enable a new way of making electronics for environmental impact and energy reduction whilst reducing costs.

David Lussey has over 20 years experience of designing innovative smart electronic materials and novel sensors. His inventions have been internationally recognised by a Saatchi & Saatchi Award, a Millennium Products Award, a Tomorrow's World Industry Award, numerous British Engineering Excellence and Printed Electronics Awards and a Queens Award for Innovation.

35. A flexible wearable sensor for remote physiological monitoring during daily activities

Abdullah Alzahrani[1], Luigi Occhipinti[1]
[1] *University of Cambridge, Electrical Engineering, Cambridge Graphene Centre, Engineering Department, 9, JJ Thomson Avenue, Cambridge, CB3 0FA*

Healthy people and patients with cardiovascular disease (CVD), which consider as the main causes of disability and death [1], need a health-care monitor that would observe their health conditions continuously in order to prevent their status from deteriorating. Telemedicine technology in the means of non-invasive and optical approach is being well developed and is becoming a valuable means to reducing the costs of treatment, increasing service quality in the health care system and save time.

Photoplethysmography (PPG) is a non-invasive optical technique that is used to measure blood volume change in the micro-vascular bed of tissue. This study presents a non-invasive and wearable optical technique to monitor physiological signs by means of photoplethysmography (PPG). The project aims to research into an effective way to capture human critical physiological parameters, i.e. heart rate (HR) and oxygen saturation (SpO_2) through a flexible wearable patch sensor (FWPS) together with a real-time, cost effective and secure wireless communication functionalities. The patch sensor is designed and tested against stander and conventional methods e.g. pulse oximetry. The results promising and show high correlations with no significant difference between HR measured from our patch sensor and commercial device ($r = 0.96$, $p < 0.001$). The preliminary results from the bench tests and the laboratory setup demonstrate that the goal of the high performance wearable PPG is viable and feasible.

Transmission based upon the PPG principle is one of the most widely used groups of health assessment devices at hospital such as pulse oximetry. However, transmission sensor is still has some limitations such as restriction of our movement, discomfort and designed for specific area i.e. finger, ear-lop and toe. This project designed a reflection patch sensor that can be placed in different area onto the body. Figure 1 shows a transmission and reflectance sensor. A simple block diagram as shown in Figure 2 illustrates the system design of the reflectance patch sensor. Figure 3 and 4 show GUI and statistical correlation analysis respectively.

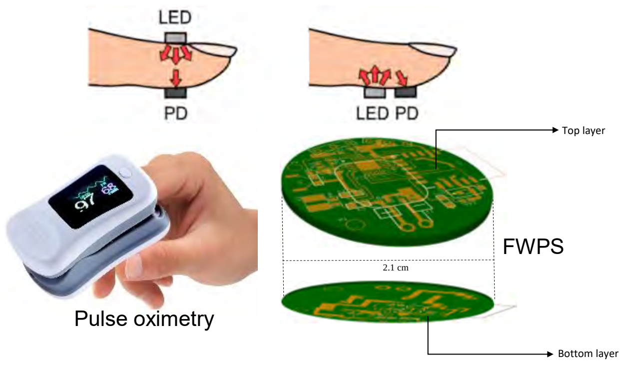

Fig. 1 Transmission and reflectance sensors

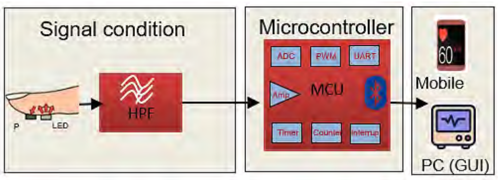

Fig. 2 System design of the reflectance patch sensor; (1) Signal condition end. (2) Microcontroller and digital processing. (3) Mobile/PC Unit.

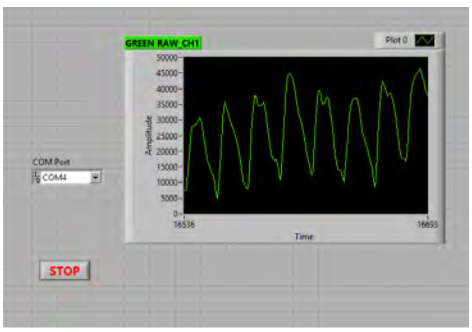

Fig. 3 Graphical User Interface GUI

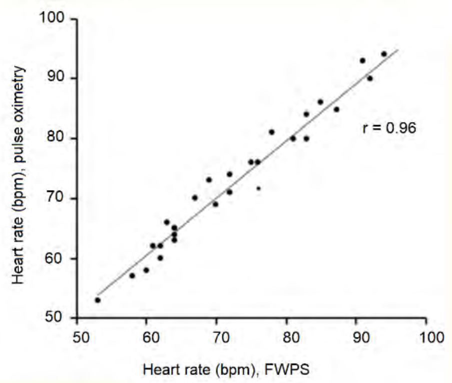

Fig. 4 Correlation analysis between commercial device (pulse oximetry) and FWPS

Dr. Abdul Alzahrani, is a post-doctoral research associate employed by the University of Cambridge, Department of Engineering, who is currently working in Dr. Occhipinti's team. The main area that he works with and focuses on are integrated smart sensors, wearable physiological-sensors, environmental sensors, embedded system and electronic design. Previously, he worked at start-up companies (Cerebrum Matter LTD and ASAS LTD). Alzahrani is a member of SPIE, IEEE as well as a reviewer board member of Advanced Research in Electrical, Electronics and Instrumentation Journal. Also venture member at Haydn Green Institute for Innovation and Entrepreneurship, the University of Nottingham. Alzahrani has several peer-review conference papers as well as a few journals publications.

Dr. Luigi Occhipinti, is a Principal Investigator of the Engineering Department, with more than 20 years industrial experience in microelectronics, post-silicon and innovative sensors' technology development and commercialisation. His team is composed by 3 Postdoctoral researchers, 3 PhD students and 3 visiting international students. He is acting as Deputy Director and COO of the Cambridge Graphene Centre at the University of Cambridge, a centre employing more than 120 research staff and students.

36. Electrohydrodynamic jet printed polyaniline for highly sensitive chemiresitors

Nhlakanipho Mkhize, Krishnan Murugappan, Martin Castell, Harish Bhaskaran

[1] *Department of Materials, University of Oxford, 16 Parks Road, Oxford, United Kingdom*

Gas sensors are a crucial element in ensuring the safety of people in environments where gas is routinely used or naturally abundant, such as factories, laboratories, mines etc. The early detection of gas leaks, even at low concentrations, is thus an important pursuit. Conductometric gas sensors also known as chemiresistors are a cheap and efficient way of monitoring gases in an environment. There is a great need to integrate chemiresistors into personal protective clothing, meaning that they need to be flexible. The most common type of sensing layer used in chemiresistors is based on metal oxides, however they require operating temperature exceeding 200 °C, which makes them unsuitable for flexible substrates as they will cause melting of the substrates. Conducting polymers are an attractive alternative sensing material as they operate at room temperature. In this work, we demonstrate the use of the conducting polymer polyaniline (PANI) printed onto plastic as a viable flexible chemiresistor for the detection of ammonia gas. Ammonia gas is an industrially important compound, used in the production of fertilizers and in other chemical processes. As with many compounds, excessive exposure for humans may lead to detrimental health conditions, mainly asphyxiation or severe breathing problems. The deposition of conducting polymers can be performed in many ways including spin-coating, drop-casting and thermal evaporation onto electrodes. Each of these have certain advantages such as ease of application, scalability and uniformity of polymer assembly. However, they all share the disadvantage of resulting in large area coverage. Whilst this can be seen to be advantageous, we propose in this work enhanced detection of ammonia gas by printing discrete regions of polyaniline onto a flexible substrate with pre-fabricated interdigitated electrodes. The printing is achieved by using electrohydrodynamic (EHD) jet printing, an additive manufacturing process which allows for high resolution deposition of a variety of materials. [1, 2] By reducing the area of coverage, we effectively move away from the less sensitive thin film region to the highly sensitive percolation region [3] where there are limited conducting pathways between the electrodes. It will be shown that much higher sensitivities and better response times are obtained for the chemiresistors fabricated via EHD printing than for drop-cast films for ammonia gas detection.

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Acknowledgement- The authors would like to thank EPSRC Manufacturing Fellowship EP/J018694/1 and the WAFT collaboration (EP/M015173/1) for funding.

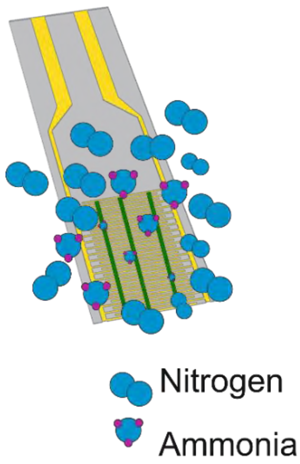

Figure 1. Schematic of the interaction of ammonia with the printed polyaniline on flexible electrodes

Biography

Nhlakanipho Mkhize received his BSc degree in 2012 and subsequent MSc degree in Chemistry from Rhodes University, South Africa in 2015. Following this, he briefly worked as a science communicator for Scifest Africa, a not-for profit organization making science accessible to the general public in South Africa. Since October 2015, he has been carrying out his doctoral studies at the University of Oxford, as a Rhodes Scholar in the Department of Materials. His present work is in the use of electrohydrodynamic jet printing as a viable additive manufacturing technique for functional device development, including work on flexible sensors.

Twitter handle: @Mr_Colin_Mkhize

37. Developing nanostructured biomaterials for enhanced cell interfacing

Stuart G. Higgins[1,2], Julia Sero[1,2], Hyejeong Seong[1,2], Michele Becce[1,2], Molly M. Stevens[1,2,3]
[1] *Department of Materials, Imperial College London, London, SW7 2AZ, UK*
[2] *Department of Bioengineering, Imperial College London, London, SW7 2AZ, UK*
[3] *Institute of Biomedical Engineering, Imperial College London, London, SW7 2AZ, UK*

Organic bioelectronics has shown the versatility of using organic electronic materials for biological applications [1]. Material interactions within living systems are complex, in particular cells are strongly influenced by micro- and nanoscale topographies.

We have worked extensively with nanostructured surfaces, including sub-50 nm sharp nanoneedles [2]. The nanoscopic dimensions are important, as the impact on cell response appears to be size-dependent in the sub-micron regime. Studying this helps us understand both cellular and nuclear mechanotransduction [3], processes such as endocytosis [4], and how we can use materials for intracellular delivery and sensing [5]–[7]. While our platform provides a clear topographical cue, we are also exploring how to integrate both chemical and electrical cues into the same system, to provide multiplexed control over cell behaviour and development.

Here I will present how we use inorganic nanoneedles to control and influence human mesenchymal stem cell topography. I'll discuss our recent results and how this can be useful in the design and application of these materials to a range of applications.

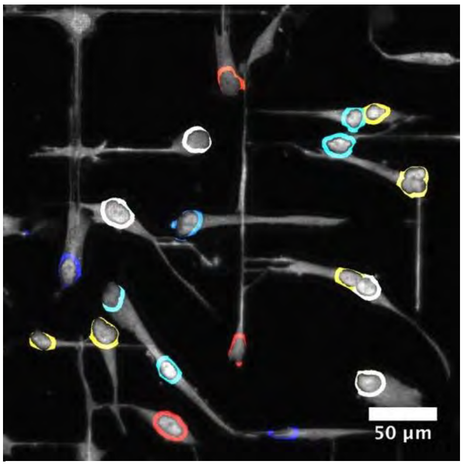

Figure 1. An optical micrograph of fluorescently-stained human mesenchymal stem cells, showing guided cell morphology.

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Biography

Dr Stuart Higgins' research focuses on the development of new organic and inorganic biointerfacing and biosensing platforms. He is a Research Associate at Imperial College London in the group of Professor Molly Stevens. Stuart has a background in organic electronics, having previously developing organic diodes for energy-harvesting circuits with Professor Henning Sirringhaus at the University of Cambridge, and before that working on printed organic complementary circuits for his PhD with Professor Alasdair Campbell, Imperial College London.

Twitter handle: @StuartGHiggins

38. Enzyme-free colorimetric paper-based platform for point-of-care testing off glucose sensing in the physiological range

Ana Carolina Marques[1], João Ferrão[1], André F.R. Rodrigues[2], Tomás Pinheiro[1], Rodrigo Martins[1] and N. Correia2, Elvira Fortunato[1]

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Diabetes mellitus is currently one of the most serious and prevalent diseases in the world, affecting million people worldwide and the rate of new cases is expected to continue increasing. Therefore, the development of cheap and simple methodologies for point-of-care glucose sensing is of paramount relevance for an effective diagnosis and management of patients, mostly in underdeveloped and developing countries where the access to medical infrastructures is limited and cost-effect and simplicity are of major concerns. Due to its properties, paper represents an alternative in the performance of point-of-care tests for colorimetric determination of glucose levels, providing simple, rapid and inexpensive means of diagnosis. In this work, we report the development of a novel, rapid, disposable, inexpensive, enzyme-free and colorimetric paper-based platform for point-of-care glucose detection. This method is based on the synthesis of gold nanoparticles (AuNPs) by reducing of a gold salt precursor in which glucose is the reducing agent. Different concentrations of glucose present during the reduction process result in the formation of AuNPs of different size, to which colour changes of the sensor are associated. The developed platform was tested and calibrated using different physiological concentrations of glucose from 1.25 to 50 mM and the obtained results were visually examined and digitally analysed through an image analysis software. It was also compared the colorimetric results obtained with a commercial scanner and with a smartphone camera, concluding that both methods are viable alternatives in the digital analysis of the sensor. The colorimetric sensor revealed sensitivity to determination of glucose levels in samples, in a simple, rapid, inexpensive and eco-friendly way.

An Android application was developed in order to perform colorimetric analysis of said biosensor through Image Processing techniques and two Machine Learning models for performing a colorimetric analysis: one for a fasting state analysis and another for 2 hours after meals. This is in order to facilitate the process of reading diabetes values, through the sensor's color captured by the mobile device's camera. Results from testing determined that the application is capable of correctly detecting the biossensor, as well as perform a highly efficient colorimetric analysis, in combination with an image color calibration step based on color reference zones located on the biosensor. Although testing also found the need to increase the number of color reference zones, as well as the need to improve the colorimetric output of the biossensor, in order to better distinguish different glucose concentrations and improve the application's diagnostic.

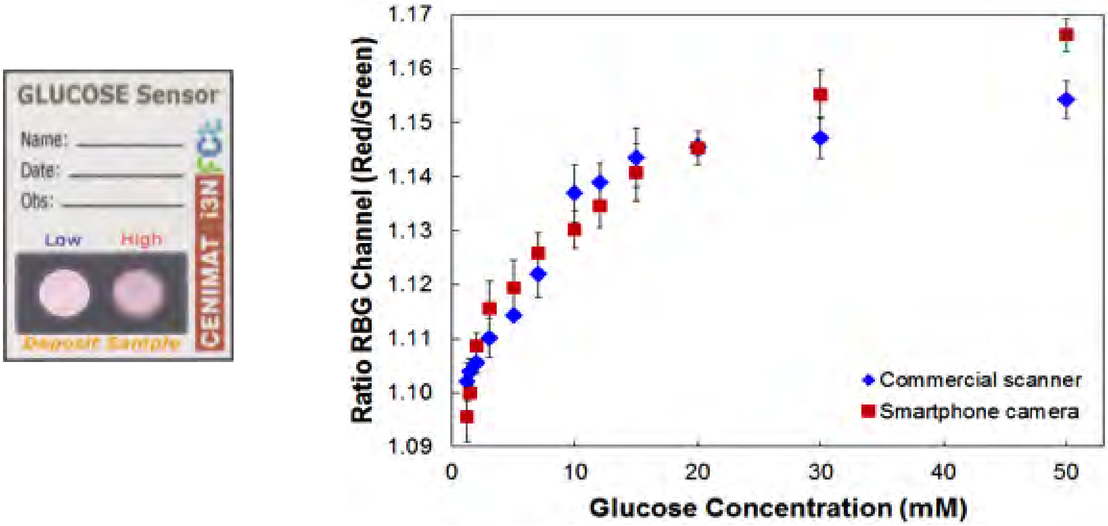

Figure 1. Photograph of the developed paper-based sensor, tested with a hypoglycemic (1.25 mM) (left well) and a hyperglycemic (50 mM) (right well) concentration of glucose. The real dimensions of the sensor are also shown in the image; (B) Graphical comparison between the colorimetric results acquired with a commercial scanner and a smartphone camera, concluding that both methods are viable alternatives in the digital analysis of the sensor.

Biography

Ana C. Marques received her MsC degree in Biochemistry in 2014 and she is currently taking her Ph.D in Nanotechnologies and Nanoscience at CENIMAT/I3N, New University of Lisbon, Caparica, Portugal. Her current research interest includes the development and optimization of low cost polymeric-based sensors for optical and electrochemical detection: application to biosensors.

39. Developing low-cost label-free bioelectronic sensors for detecting breast cancer biomarkers in serum

Usman Khan[1], Glenn Sunley-Saez[1], Michael Turner[1]
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Breast cancer is the most common diagnosis of cancer in women and the second most frequent cause of cancer-related death[1]. However, the majority of deaths are due to metastasis rather than the primary tumour[2]. It has been proposed that early and precise detection of the metastatic breast cancer could ultimately lower mortality rates[3]. However, current tests such as high-resolution imaging (e.g. mammography and MRI) are poor at detecting metastasis in its earliest stage, when the cancer cells are yet to form a tumour. Furthermore, high-resolution imaging techniques lack information regarding the patient's breast cancer subtype. Given that breast cancer is a heterogeneous disease and the subtype of the breast cancer determines the likelihood of metastasis, it is of paramount importance for the detection technique to be able to distinguish between the subtypes to determine suitable therapy required for effective treatment. ImmunoHistoChemistry (IHC) and fluorescence in-situ hybridisation (FISH) are methods that are effective at detecting biomarkers of specific breast cancer subtypes, but they are limited to a small group of biomarkers, require appropriate laboratory setting with trained personnel, biopsy samples and use expensive reagents.

Electrolyte-gated organic field-effect transistor (EGOFET) have the potential to offer a cheap, label-free and easy to miniaturise alternative for the detection of biomarkers of disease, with the capability of being applied at the point-of-care (POC)[4]. This paper will demonstrate how an EGOFET can be developed to have the sensitivity and selectivity required to detect breast cancer biomarkers in blood serum. This presentation will discuss the design of an EGOFET equipped with a flow cell to demonstrate feasibility of in-situ functionalization and sensing for biomarkers of herceptin positive breast cancers.

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Biography

Usman Khan is a PhD student at the Organic Material Innovation Centre (OMIC) at the University of Manchester, UK.

40. Using fluorine-substituted organic semiconducting polymers in organic field-effect transistors with applications in bioelectronic interfacing

Alessandra Lo Fiego,[1,2] Adam Creamer,[1,2] Stuart G. Higgins,[1,2] Martin Heeney,[4] and Molly M. Stevens[1,2,3]

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Organic electronics is a natural choice for bioelectronic applications thanks to mechanical compliance with biological tissues, ability to sense ionic currents, and flexibility of solution-based fabrication approaches.[1] A key advantage of organic semiconductors is the possibility to use organic chemistry to readily tailor both material and electrical properties. This is ideal for applications such as cell sensing and stimulating interfaces (which rely upon intimate contact), and in biosensing applications such as point-of-care diagnostics, which rely upon the ready tailoring of biorecognition elements.

We recently demonstrated a novel method for the direct functionalisation of organic conjugated polymers, post-polymerisation, in the context of polymer nanoparticles.[2] Modification is achieved via a quantitative nucleophilic aromatic substitution reaction on the fluorinated electron-deficient units of the aromatic backbone. The method enables the introduction of multiple different functional groups onto the polymer backbone in a quick and controlled manner, within a batch of consistent molecular weight and dispersity.

Here we explore how the same polymer systems can be used in the active-layer of an organic field-effect transistor, and present a viable and versatile material platform for bioelectronics. Our work is based on a fluorine-substituted version of the high field-effect mobility conjugated polymer indacenodithiophene-co-benzothiadiazole (IDT-FBT). We will explore how these new materials will aid the development of new neural-interfacing technologies, paving the way for more effective electroceuticals.

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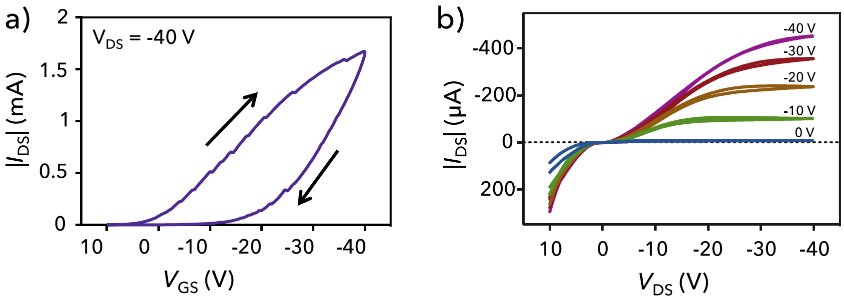

Fig 1. *a) Transfer and b) output characteristics of an IDT-FBT based OFET with 10 μm channel length.*

Biography

Alessandra Lo Fiego is a PhD student in Professor Molly Stevens' group and part of the Centre for Doctoral Training in Neurotechnology at Imperial College London. Her research focuses on the development of new material-based nanotechnologies for neural interfacing, with a particular interest for implantable bioelectronic devices. She holds an MRes in Neurotechnology from Imperial College London, with a thesis entitled "A new material platform for neuronal interfacing systems". Previously, Alessandra worked in Professor Fabio Biscarini's Laboratory of Organic Electronic on her MSc degree project "Multifunctional Bioelectronic Devices for in vivo treatment of Central Nervous System disorders; fabrication, characterization and implant", at the University of Modena and Reggio Emilia (Italy).

41. Printed organic field-effect-transistor multi-sensor array platform for vapour sensing applications

Aiman Rahmanudin[1],Daniel Tate[1], Suresh Garlapati[2], Sheida Faraji[3], Krishna C. Persaud[2], Michael L. Turner[1]
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Organic semiconductors (OSCs) have been extensively studied as active materials in organic field-effect transistor (OFET) sensors[1]. This is due to its unique ability to respond to stimulation caused by environmental conditions that can readily change charge-carrier density and mobility in the semiconducting channel of the device. Previously, we have demonstrated the development of a fully solution processed low voltage (≤3V) operation OFET sensor platform for ammonia sensing based on a diketopyrrolopyrrole (DPP) based OSC polymer as single active sensing component[2]. Herein, we report a multi-sensor OFET array platform that is selective to the detection of a variety of vapour analytes. Specific sensory additives were formulated into a matrix with the parent OSC component to induce selectivity to respective analytes. The various ink formulations were printed into an OFET array with multiple active sensing matrixes onto a single platform. Furthermore, the OFET array exhibited reasonable field effect mobility with low operational voltages utilizing a novel all-polymer dielectric bilayer architecture. This initial demonstration of a multi-sensor OFET array suggests a promising strategy towards improving selectivity and advancing sensory functionalities into OFET sensor devices for practical large are electronic applications.

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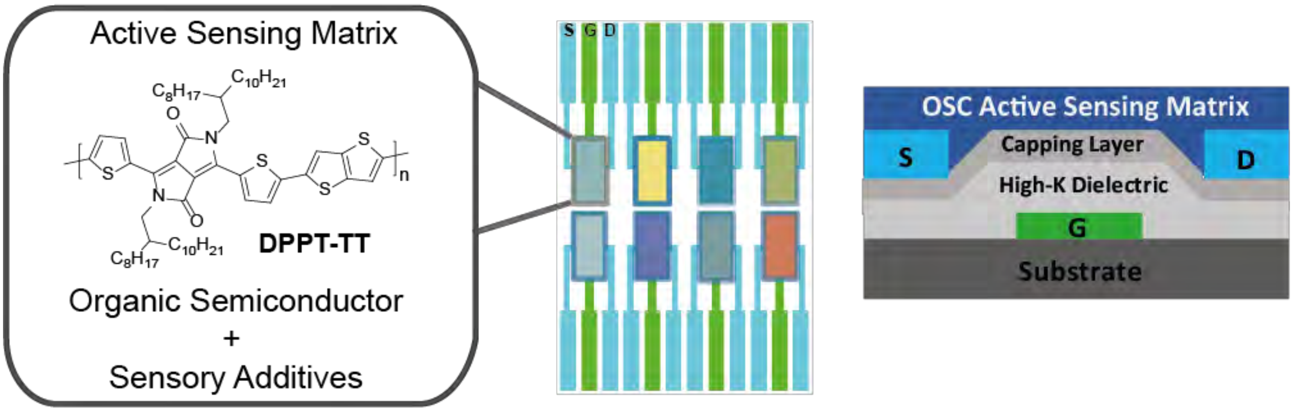

Figure 1.Schematic of the OFET Multi-sensor arrayplat form and the device architecture of a single FET sensor.

Biography

Dr Aiman Rahmanudin is a Research Associate at the Organic Materials Innovation Centre (OMIC) in the University of Manchester, UK.

His research interests are in the design, synthesis and processing of π-conjugated semiconducting materials for the fabrication of novel electronic devices. He focuses on using various thin-film processing techniques such as ink-jet printing and melt processing of organic semiconducting materials to understand the structure-property relationship between the self-assembly of organic semiconductors and its electronic performance.

Aiman completed his PhD at the École Polytechnique Fédérale de Lausanne in Switzerland developing a molecular engineering approach towards the morphology control and processability of organic semiconductors for optoelectronic applications. Prior to this, Aiman received his MChem in Chemistry with Business Management from the University of Manchester.

Currently, his research focuses on printing of organic semiconductors for the fabrication and characterization of field-effect-transistor arrays for sensing applications in support of the work of the EPRSC Centre for Innovative Manufacturing in Large Area Electronics at OMIC.

42. Ammonia detection using solution processed organic-field effect transistors.

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[2] *School of Chemistry, University of Manchester, Manchester, UK*

Organic field effect transistors (OFETs) manufactured using printable electronics techniques have been demonstrated to be promising volatile chemical sensors with good sensitivity and selectivity at room temperature. For detection of low concentrations of ammonia in environmental or medical applications, potential interferences need to be eliminated or compensated for. For example, the response of OFET gas sensors to analytes is affected by humidity and temperature. Here we investigate the responses of OFET devices to ammonia in the presence and in the absence of humidity with 5 min exposure of ammonia and 20 min recovery time between sequences.

Air stable OFET devices that can operate at low voltages ($V_{DS} \leq 3V$) were fabricated using the solution processable. semiconductor poly(3,6-di(2-thien-5-yl)-2,5-di(2-octyldodecyl)-pyrrolo[3,4-c]pyrrole-1,4-dione)thieno[3,2-b]thiophene) (DPPTTT) and these were operated at a drain-source voltage of -3V and a gate voltage of -3V. Ammonia gas cylinder (1000 ppm) was used to generate standard concentration of test analytes that were diluted to required concentrations using mass flow controllers.

Furthermore, we extracted the sensitivity values from the linear fits of sensors response vs. concentration of analytes. Fitting results also show that the sensitivity of the OFET sensor towards gas ammonia (20-80 ppm) in the presence of humidity (20%, 40%, and 60%) is 8.0 ± 0.0, 17 ± 1, 16 ± 1 % ppm^{-1} (4 replicates). However, this sensitivity increases dramatically (46 ± 4 % ppm^{-1}) at relative humidity 80% due to the complex of ammonia and water.

Finally, we have investigated electrical and surface properties of thin film transistors based on the extraction of output and transfer characteristics and by studying the surface morphology of the deposited films with the atomic force microscope. Herein, we report that the value of threshold voltage is -0.70±0.05 Volts, the ratio between the highest and lowest drain current is 2.1×10^3, the charge carrier mobility extracted from the saturation region of the transfer curve is $(1.5\pm0.2)\times10^{-2}$ $cm^2/(V\ s)$, the density of charge carriers before the gas sensing experiments is 2.33×10^{12} $eV^{-1}cm^{-2}$ and finally the subthreshold swing value is 501±14 mV/decade. By using non-contact AFM, we estimated the mean roughness square parameter, RMS = 0.7 nm and a statistical analysis of grains / grain boundaries (main grain size = 40 nm, total grain boundary length = 443 nm) presented at the semiconductor/dielectric interface.

Future work will concentrate on enhancing the quality of dielectrics for improving the isolation between gate and ‘’active’’ layer and the accumulation of charge carriers between semiconductors and insulator films.

Acknowledgement - The authors would like to thank CIMLAE - EPSRC Centre for Innovative Manufacturing in Large-Area Electronics for funding this work.

Biography

Panagiotis Mougkogiannis is a Doctoral candidate at the University of Manchester. He is supervised by Prof. Dr Krishna Persaud, with Prof. Dr Michael Turner as a co-supervisor. His current research interests focus on low voltage organic field effect transistors for gas sensing of volatile organic chemicals, and inkjet printing of functional materials. He has a BSc degree in Chemistry and a MSc in advanced technology materials from the University of Patras in Greece.

Quick links: https://www.research.manchester.ac.uk/portal/panagiotis.mougkogiannis.html

43. High performance, solution processed organic field-effect transistors to detect volatile organic compounds

S. K. Garlapati[1,2], S. Faraji[1,2], D. J. Tate[1], A. Rahmanudin[1], P. Valliappan[2], K. C. Persaud[2], M. L. Turner[1]

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Volatile organic compounds (VOCs) emitted from the human body can be used as biomarkers of diseases. The sensors that can detect these VOCs can reduce healthcare costs and also diagnosis time. Metal oxide sensors for the detection of VOCs are well-established but selective detection using this technology is challenging due to non-selective nature of metal oxides. By contrast sensors based on organic semiconductors are less established but potentially are sensitive, selective and can be processed at low temperatures. Herein, we report organic field-effect transistor (OFETs) based sensors that have been prepared by solution processes on flexible polyethylene naphthalate (PEN) substrates. In these OFETs, a polymer semiconductor acts as both channel and sensing layers, and a novel high-k/low-k dielectric combination has been used to enable low operating voltages (≤3 V). The OFETs have shown high mobility of 0.2-0.5 cm^2/Vs and on/off ratio of $\approx 10^3$. Interestingly the sensing experiments reveal that the OFETs are sensitive to VOCs such as alcohols, ketones, esters and carboxylic acids and the responses depend on the polarity of the analyte molecules. The selectivity of OFETs towards VOCs has been improved by incorporating additives into the semiconductor during fabrication.

Biography

Suresh Kumar Garlapati received his Master's degree from Indian Institute of Technology Madras, India and pursued his PhD in Materials science in Technical University of Darmstadt, Germany. Currently he is working as a postdoctoral researcher in the University of Manchester. His areas of interests include printed electronics, oxides, organic semiconductors and sensors.

44. Ultra-low voltage organic field-effect transistors (OFETs)

N. Mohammadian[1], S. Faraji[1,2], D. J. Tate[2], M. L. Turner[2], L. A. Majewski[1]
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Organic field-effect transistors (OFETs) are key components of low-cost, flexible and large area electronics. Extensive research has focused on the development of solution-processed, high mobility organic semiconductors for these devices, but recently attention has been being directed towards the development of high-k gate insulators to enable low voltage operation.

In this contribution, ultra-low voltage OFETs using two different high-k dielectrics; aluminum oxide (Al_2O_3, ε ~ 11) and tantalum oxide (Ta_2O_5, ε ~ 27), are demonstrated. The ultra thin oxide layers (d > 10 nm) were grown by anodisation – a low-cost, room temperature solution-based process suitable for large area electronics. OFETs were fabricated using solution-processed semiconductor, poly(3,6-di(2-thien-5-yl)-2,5-di(2-octyldodecyl)-pyrrolo[3,4-c]pyrrole-1,4-dione)thieno[3,2-b]thiophene) (PDPPTT) and its blends with poly (α-methylstyrene) (PAMS) and poly(methyl methacrylate) (PMMA). The optimised OFET devices (Fig. 1) operate at 1 V in high yields (>95%), with minimal hysteresis, low subthreshold slope (<150 mV/dec) and hole mobilities around 1 cm^2/Vs at 1 V. These materials are promising candidates for fabrication of OFETs as suitable platforms for use in aqueous based biosensors and low power electronics.

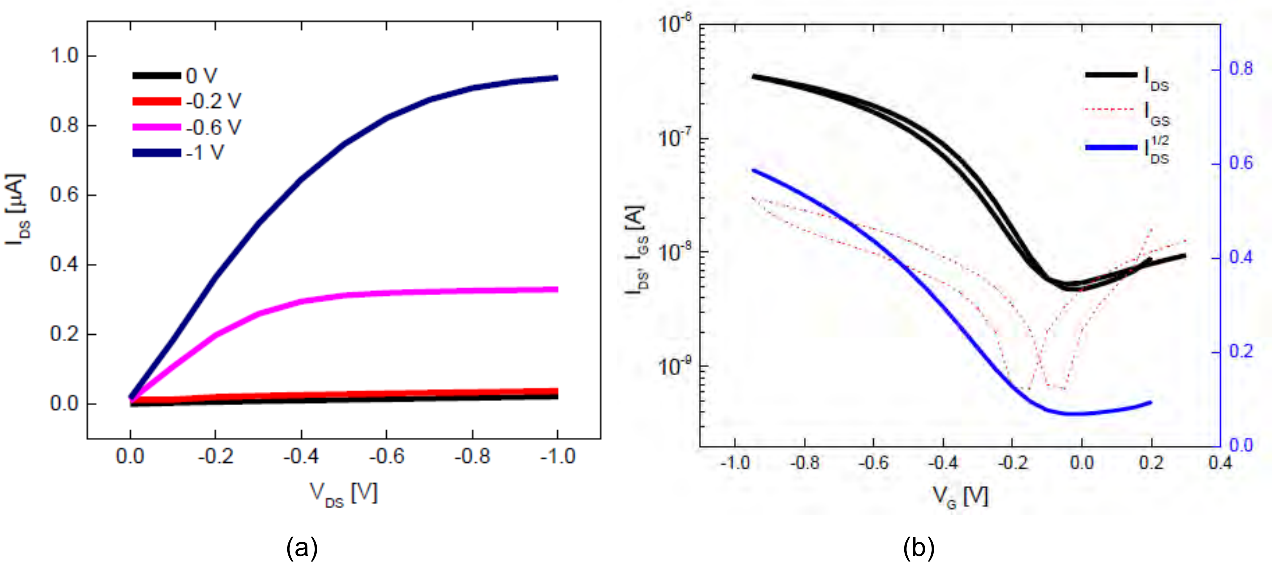

Fig. 1. (a) Output and (b) transfer characteristics of a representative ultra-low voltage OFET using 3nm thick, anodised Al_2O_3 dielectric and PDPPTT:PAMS (8:1) blend as the active layer.

Biography
I was born in Ahvaz, Iran, 1988. I graduated B.Sc. and M.Sc. in Electrical and Electronic Engineering at IA University in Iran 2011 and 2015 respectively. I'm currently doing my PhD at the University of Manchester and my research interests include solution-based TFT, oxide semiconductors and solution-based dielectrics.

45. Improving organic thin-film transistors with molecular additives

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Successful commercialization of organic electronics demands continuous improvements in device performance. New materials combined with improved synthetic strategies have so far lead the way to the development of state-of-the-art organic electronic devices and their application in a range of emerging forms of electronics. An alternative and less exploited approach towards high performing organic semiconductors (OSCs) is the use of molecular additives as a mean for tuning their physical properties and hence overall device characteristics. One such method is molecular doping which in the case of organic thin-film transistors (OTFTs) has resulted to improved charge carrier mobility and reduced contact resistance and threshold voltage. The positive effects were attributed to the filling of trap states be the excess free carriers introduced by the dopants. To this end, different theories have been put forward to account for the observed doping, including the ground state integer charge transfer where the key requirement is the existence of a minimum energy offset between the energy levels of the organic semiconductor and the dopant.

Although numerous studies have been reported on p-type doping of organic semiconductors, work on n-dopants remains surprisingly limited. The main reason for this is the difficulty of identifying n-type dopants that are stable and efficient. Here, we report the use of a new molecular dopant that is able to n-dope a number of organic semiconductors, which are then used as the channel materials in OTFTs. We show that key device parameters such as charge carrier mobility, contact resistance and threshold voltage improve dramatically upon addition of the dopant. The impact of the dopant on the morphology of the OSCs as well as the bias-stress stability of the resulting OTFTs will be also discussed and contrasted with pristine (non-doped) devices.

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 area of molecular doping of organic semiconductors 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.

46. Crystallization control of organic semiconductors during meniscus-guided large area coating by blending with polymer binder

Ke Zhang[1], Tomasz Marszalek[1,2], Philipp Wucher[3], Zuyuan Wang[1], Lothar Veith[1], Hao Lu[1], Hans-Joachim Räder[1], Pierre M. Beaujuge[3], Paul W. M. Blom[1], Wojciech Pisula[1,2]

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[3] *Physical Sciences and Engineering Division, Solar & Photovoltaic Engineering Research Center, King Abdullah University of Science and Technology, Thuwal 23955-6900, Saudi Arabia*

Small molecule organic semiconductors (OSCs) suffer from their uncontrolled nucleation and growth during solution processing limiting their functionality in electronic devices. In this work, we present a new method based on dip-coating a blend consisting of OSC and insulating polymer to control the crystallization of the active film for organic field-effect transistors. A small fraction of amorphous poly(methyl methacrylate) (PMMA) efficiently improves the crystallization of dip-coated small molecule OSCs, α,ω-dihexylquaterthiophene (DH4T) and diketopyrrolopyrrole-sexithiophene (DPP6T). The maximum charge carrier mobilities of dip-coated OSC:PMMA films are significantly higher than drop-cast blend ones and comparable with OSC single crystals. The high charge carrier mobility originates from a continuous alignment of the crystalline films and stratified OSC and PMMA layers. The improved crystallization is attributed to two mechanisms: firstly, the polymer binder leads to a viscosity gradient at the meniscus during dip-coating, facilitating the draw of solute and thus mass transport. Secondly, the polymer binder solidifies at the bottom layer, reducing the nucleation barrier height of small molecule OSC. Our findings demonstrate that a small fraction of a polymer binder during dip-coating efficiently balances the mass transport during solution processing and improves the crystallization as well as the electronic properties of small molecule OSC films.

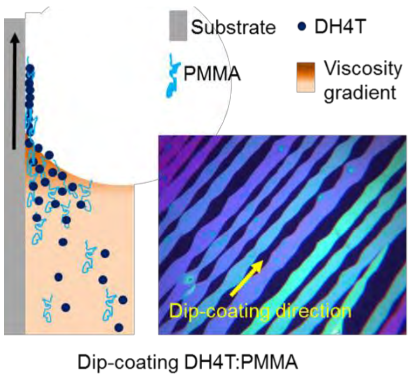

Figure 1. Diagram of dip-coating OSC:polymer blends and the dip-coated aligned crystalline film

Biography

Ke Zhang studied material science at the Shandong University and at Shanghai Jiao Tong University, China, where he gained his Bachelor and Master. In 2015, he joined the group of Professor Paul W. M. Blom as a Ph.D. student at the Max Planck Institute for Polymer Research until now. He focused on the control of self-organization of organic semiconductor by solution processing in their application in electronic devices.

47. Hybrid thin films prepared by solution processing and ALD for ambipolar thin film transistor devices

Jaspreet Kainth[1], Martyn McLachlan[1], Martin Heeney[2]
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[2] *Department of Chemistry and Centre for Plastic Electronics, Imperial College London, London, United Kingdom*

Hybrid active layers comprising of both inorganic and organic semiconducting materials are becoming more promising due to the ability to produce inexpensive, versatile and tailored electronic devices such as thin film transistors (TFT) or photovoltaic (PV) devices. By combining the advantages of the single components, it becomes possible to produce devices with the high stability of inorganic and the mechanical flexibility of organic materials.

TFTs generally exhibit unipolar behaviour where the dominant charge carrier in the channel is either electrons or holes. However, recent work has demonstrated the use of a hybrid layer consisting of poly(3-hexylthiophene-2,5-diyl) (P3HT) on top of ZnO in TFTs which exhibits ambipolar behaviour.[1] These solution processed devices exhibit lower saturated mobilities compared to their single component counterparts, however well-balanced electron and hole mobilities are achieved in their hybrid devices. There is scope for further optimisation of these devices, including reversing the active layer order and exploring alternative deposition techniques.

Atomic layer deposition (ALD) is a thin film deposition technique which produces extremely thin, conformal films due to the precise control over the thickness and composition of films on the atomic scale. The ability to grow ZnO films with such precision and at low temperatures results in ALD having good compatibility with organic materials. The growth of ZnO relies heavily on the surface chemistry therefore varies with the type of substrate. As a result, the nucleation and growth of ZnO on different polymers result in variations in morphology and electrical properties. Previous studies have explored the growth mechanism of ZnO onto P3HT via ALD, showing that the precursors are able to vapour diffuse into amorphous regions of the polymer thin film resulting in incorporation of ZnO within the polymer nanostructure.[2] Such hybrid structures have also been successfully incorporated into PV devices.[2][3]

In this contribution we investigate the well-studied P3HT/ZnO systems to develop the growth of oxide layers directly onto polymer thin films in TFT devices, comparing their performance with their single component counterparts. Our methodology is simple, first depositing P3HT from solution and subsequently ZnO by ALD. We demonstrate an ambipolar charge transport for these hybrid TFTS. Following this, the growth behaviour of ZnO onto alternative p-type semiconducting polymers are explored. The observed effects of polymer variation is investigated by examining the crystallographic and morphological characteristics, and their potential ambipolar properties are studied by investigating their electronic properties.

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Biography

Jaspreet Kainth is a third year PhD student in the Department of Materials of Imperial College London and a member of the Plastic Electronics CDT. She is working under the supervision of Dr Martin McLachlan and Prof Martin Heeney on atomic layer deposition of metal oxides for hybrid transistor applications.

Jaspreet received her integrated Master's degree in Pure and Applied Chemistry from the University of Strathclyde, Glasgow in 2015 and a Master of Research in Plastic Electronics from Imperial College London in 2016.

48. High performance Indium Silicon Oxide TFTs for large area electronics

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High performance, high stability and low cost thin film transistors (TFTs) offer enormous potential for many novel applications such as transparent and flexible sensors, tags and smartphones. Amorphous oxide semiconductors are a promising TFT channel material as their advantages include high mobility, compatibility with existing process technology, low temperature fabrication and optical transparency. Very promising amorphous indium gallium zinc oxide (a-IGZO) TFTs have been reported in recent years. The direct overlap of isotropic s orbitals of the In atoms and the ZnO crystal structure give a-IGZO a high mobility and the addition of Ga helps to suppress oxygen vacancies thereby reducing the instability in devices. There are however disadvantages associated with using Ga as an oxygen vacancy suppressor in a-IGZO. As this is a quaternary oxide it is difficult to achieve excellent stoichiometry required to guarantee reproducibility during the manufacturing process. Moreover, a-IGZO contains acid soluble Ga_2O_3 and ZnO which are very sensitive to wet etching processes and the channel can therefore be damaged while etching source and drain electrodes [1]. It is therefore worth investigating other n-type materials to improve stability and reduce costs. Instead of Ga other elements can be used to suppress oxygen vacancies and in 2013 Aikawa et al. showed that Si is a promising candidate to improve the stability of In_2O_3 [2].

For this work high performance indium silicon oxide (10wt% Si) TFTs have been fabricated with the following parameters: field effect mobility = 8 cm^2/Vs, subthreshold swing= 0.37 V/decade, V_T = 0 V and On/Off ratio = 10^8. These parameters are comparable with other high performance AOS TFTs and this level of performance should be sufficient for circuit design. Moreover, the thin film ISO layer have been characterized using XRD, UV-VIS and XPS & UPS to obtain information about the composition of the material and the band structure. Current work involves integrating the indium silicon oxide TFT with a cuprous TFT to form a metal oxide CMOS inverter.

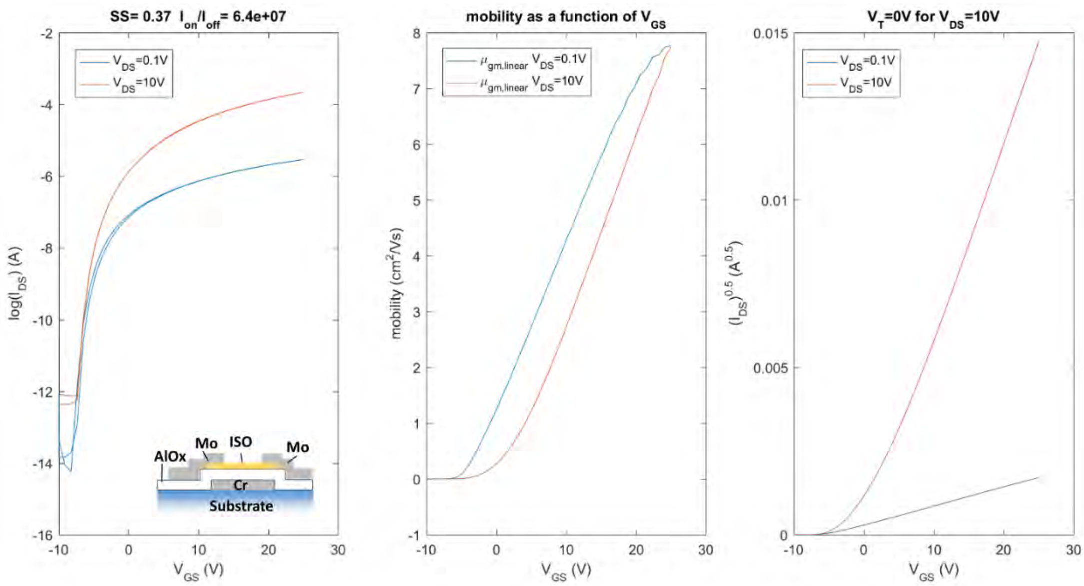

Figure 1. From left to right: Drain-source-voltage transfer curve, mobility plot, and $I_{DS}^{1/2}$-V_{GS} plot for ISO TFT. Inset: structure of ISO TFT.

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Biography

Niels van Fraassen was born and raised in the Netherlands. He was at Peterhouse in Cambridge for his undergraduate degree in Engineering and graduated in 2016 with an MEng in Electrical and Electronic Engineering (Hons Distinction). His fourth year project was on zinc oxynitride thin film transistors under the supervision of Prof Arokia Nathan. Currently he is part of the Centre of Doctoral Training in Integrated Photonic and Electronic Systems between UCL and Cambridge. After having finished the MRes year at UCL, he is now a member of Jesus College and pursuing a PhD within Prof Flewitt’s group. His current research is focused on metal oxide TFTs for CMOS applications.

49. Chemical vapour deposition of p-type inorganic thin film semiconductors

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Current large-area electronics is still dominated by silicon-based technologies, but the advance and development of both display and solar cell technologies, in particular, are limited by the relatively poor performance or high temperature processing conditions of amorphous silicon or polycrystalline silicon devices. Metal oxide semiconductors offer a promising alternative, but although devices based on n-type materials (for example amorphous indium gallium zinc oxide devices) have successfully been brought to market, there is still an absence of good p-type metal oxide materials, which limits the development of both metal oxide p-n junctions and CMOS devices, required by the solar cell and display industries respectively.

Cuprous oxide (Cu2O) is a non-toxic, low cost metal oxide that exists naturally as a p-type semiconductor due to intrinsic copper vacancies [1]. Reported Hall mobilities of ~10^2 $cm^2V^{-1}s^{-1}$ suggest potential [2], however with reported Cu_2O thin-film transistor (TFT) mobilities of ~10^{-1} $cm^2V^{-1}s^{-1}$ and a high off-state current [3], further research is required to optimise the deposition and fabrication process.

Existing literature has primarily focussed on sputtered Cu_2O films, however within this work, Cu_2O films have been deposited using plasma enhanced metal-organic chemical vapour deposition (PE-MOCVD), similar to that used for large-area amorphous silicon growth. The system includes substrate heating, RF plasma generation and a Kemstream Vapbox liquid precursor delivery system.

Optimum deposition parameters have been identified by exploring the impact of the substrate temperature, precursor and reactant gas flow rates, RF plasma power and chamber pressure on the material and electrical properties of Cu_2O films. X-ray diffraction, UV spectrometry and scanning electron microscopy have provided information about the material crystallinity and optical band-gap, and resistivity, capacitance and Hall measurements provide electrical characterisation.

This poster will discuss the motivation to develop metal oxides and the inherent material properties that have led to the focus on Cu_2O; briefly outline the method and experimental design; and summarise the main findings of the optimisation matrix.

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Acknowledgement - The authors would like to thank EPSRC for providing the funding for this work.

Biography

Current PhD student in the Integrated Photonics and Electronic Systems CDT, supervised by Professor Andrew Flewitt in the Electronic Devices and Materials Group, at Cambridge University.

50. Control of the electrical properties of non-stoichiometric nickel oxide thin films grown by chemical vapour deposition methods

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NiO_x has gained interest as an attractive thin material for a variety of applications and devices, such as thin film transistors (TFTs). While stoichiometric NiO is an electrical insulator, nickel oxide is known to become semiconducting when Ni vacancies are created either by doping or by introducing an excess of oxygen atoms. For charge compensation, these vacancies can further ionize to produce holes and Ni^{3+} ions, which makes the material behave like a p-type semiconductor.

In this work NiO_x films were grown at temperatures of 200 - 300 ^oC using plasma-enhanced atomic layer deposition (PEALD) and atmospheric pressure chemical vapour deposition (AP-CVD). In the PEALD approach, films were grown using $Ni(acac)_2$ precursor and oxygen plasma, while in the AP-CVD a highly volatile NiCpAllyl precursor was used together with O_2. All films were deposited at temperatures of 200 - 300 ^oC.

ToF-ERDA showed that all the as-deposited films had O/Ni ratio > 1, and according to Hall measurements, the films possessed p-type conductivity. The deposition method was observed to have an effect on the crystallinity and impurity contents of the films, which correlate with variations in film resistivities between 10^1-10^3 Ohm cm. By post-deposition annealing (PDA) in a reducing atmosphere the O/Ni ratio and, subsequently, the Ni^{3+}/Ni^{2+} ratio could be decreased. This leads to an increase in the resistivity, and a decreased hole concentrations and increased Hall mobilities. Hence, this study shows that the deposition parameters and PDA conditions can be used to tune the properties of the NiO_x films, and how this can be exploited in the fabrication of p-channel TFTs.

Acknowledgements – This work has been supported by EPSRC project "Precision manufacturing of flexible CMOS" (ref no. EP/P0270321/1) and PragmatIC.

Biography

Dr Mari Napari works as a postdoctoral researcher in Department of Materials Science and Metallurgy in University of Cambridge. She received her PhD in physics in 2017 at University of Jyväskylä, Finland, for work on thermal and plasma-enhanced atomic layer deposition of metal oxide thin films on plastic substrates at low deposition temperatures. Currently she is working in Prof. Judith MacManus-Driscoll's group on ALD and CVD of p-type semiconducting oxides for electronic device applications.

Twitter handle: @NapariMari

51. Small-signal measurement of the threshold voltage shift in thin film transistors under positive gate bias

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Thin film transistors (TFTs) are widely used in active matrix displays and are finding applications in emerging areas of large-area electronics, such as logic. A key limitation on the practical applications of TFTs is their inherent stability under bias stress. The two leading TFT materials for displays, hydrogenated amorphous silicon (a-Si:H) and amorphous indium gallium zinc oxide (a-IGZO) both suffer from a positive threshold voltage shift under application of a positive gate bias, a feature commonly called positive bias stress (PBS) [1], [2].

The most common method for quantifying PBS is a DC stability measurement which witnesses the threshold voltage shift by performing periodic gate transfer measurements whilst applying a gate bias for extended periods, and multiple parameters including threshold voltage can be extracted accordingly as a function of stressing time. However, the need to periodically remove the stressing gate bias voltage in order to conduct a gate transfer measurement introduces a systematic error which increases with measurement time.

To eliminate this problem, a novel small-signal measurement is proposed and demonstrated in this poster. The essential improvement is that a small-signal is superposed on the constant DC stress gate voltage which result in an AC element in the drain-source current. In this work, the drawback of DC measurement is analysed using a-IGZO TFTs under positive bias. A small-signal AC model of TFTs is reviewed where all the components have specific physical meanings. Simulation results are used to illustrate the expected voltage and current waveforms for different small-signal operating points are presented. The block diagram of the whole measurement system is then presented. Several difficulties with performing small-signal measurements are discussed, and solutions are described and tested experimentally. The small signal measurement is then validated experimentally with a-IGZO TFTs and compared with DC results, illustrating the small-signal test's advantages.

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Acknowledgement - The support of this project by the Engineering and Physical Sciences Research Council through grant no. EP/M013650/1 is gratefully acknowledged.

Biography

Tianwei Zhang received the B.Eng degree in Electronic and Electrical Engineering from the University of Birmingham, Birmingham, U.K., in 2016 and the MRes degree in CDT in Integrated Photonic and Electronic Systems from University College London, London, U.K., in 2017. Following this, he is now studying for the Ph.D. in Engineering degree in the University of Cambridge, Cambridge, U.K. supervised by Prof. Andrew Flewitt.

52. Conformable electronics based on Parylene-C polymer

I. Martins[1], C. Figueiredo[1], J.V. Pinto[1], P. Barquinha[1], R. Martins[1], E. Fortunato[1]
[1] *Department of Materials Science, Faculty of Science and Technology, Universidade NOVA de Lisboa and CEMOP/UNINOVA, Campus de Caparica, 2829-516 Caparica, Portugal*

Flexible electronics relies on the ability to produce high performance devices on flexible substrates, and usually requires the use of lower processing temperatures when compared to standard Si based electronics. The flexibility demands not just good mechanical properties of the substrate, but also devices that can withstand high bending radius without losing performance. There is a huge demand for materials that combine good mechanical properties, high environmental stability, compatibility with standard fabrication techniques and chemical processing reagents. Parylene-C is a polymer that polymerises at room temperature and presents all the aforementioned properties being therefore a promising candidate for flexible electronics applications. In this work we demonstrate the implementation of thin-film transistors (TFTs) fully conformal and flexible, combining all the qualities of parylene-C. For that, parylene-C was used as a flexible substrate and as the dielectric and encapsulation layers of the devices.

We present hybrid TFT devices using high mobility sputtered IGZO films processed at room temperature, and parylene-C gate dielectrics. The TFT layers were patterned using shadow masks and the devices were produced on parylene-C membranes of different thickness, grown on Si and glass carriers. The influence of the annealing temperature, the dielectric thickness and the encapsulation thickness on the mechanical and electrical properties of the devices will be discussed.

For parylene as TFT dielectric layer it was concluded that the optimum thickness was between 200 and 300 nm, reaching TFT mobilities between 10 and 15 $cm^2V^{-1}s^{-1}$, ON/OFF ratio higher than 10^6 and leakage currents smaller than 10^{-10} A. The use of parylene as an encapsulation and passivation layer improves the operational stability of the devices and by tuning the thickness of both substrate and encapsulation parylene layers, optimized mechanical properties can be obtained after peel-off from the carriers.

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Biography

Martins completed a Master degree in Micro and Nanotechnologies Engineering from Universidade Nova de Lisboa (FCT-UNL) in 2017 with the dissertation intitled “Parylene C as substrate, dielectric and encapsulation for flexible electronics applications”. In January 2018, I. Martins joined CENIMAT with a research fellow grant and since then has been working on PROXIMA project, developing low temperature oxide TFTs.

Presented by Joana Vaz Pinto

J.V. Pinto completed a PhD degree in Applied Physics from Universidade Nova de Lisboa (FCT-UNL) in 2008 and during her PhD she achieved a deep knowledge on semiconductor and insulating metal oxides and nanoparticles characterization, using Ion Beam techniques, XRD, SQUID and I-V characteristics. In October 2008, J.V. Pinto joined CENIMAT with a Postdoctoral research grant, and since then the main topics of her research was focused on the development of Field Effect Devices for flexible and biosensing applications. Since 2015 she is an Assistant Professor at the Materials Science Department. Her current interests include the use of parylene polymer for flexible and e-skin applications.

I.

53. Low power electronics based on Parylene-C hybrid devices: top gate *vs* bottom gate TFTs

J.V. Pinto[1], C.F. Fernandes[1], I. Martins[1], A. Rovisco[1], J. Martins[1], A. Kiazadeh[1], P. Barquinha[1], R. Martins[1], E. Fortunato[1]

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The implementation of electronic devices in flexible substrates has shown remarkable breakthroughs enabling application such as conformal sensors, electronic skin, flexible solar cells and batteries among others [1]. The combination of organic layers with inorganic amorphous oxides that can be produced at low temperatures allows the development of devices with simultaneously high motilities and flexible properties, suitable for conformal devices and sensors. Parylene-C is a promising material due to the excellent thermal, mechanical, chemical and electrical insulating properties and is used in a broad range of areas, including electronics, medical, aerospace, and industrial applications.

We present a set of hybrid devices comprising an inorganic oxide layer as the semiconductor and Parylene-C as the gate dielectric. The active layer is composed of high mobility sputtered IGZO processed at room temperature and both bottom-gate (BG) and top-gate (TG) configurations are discussed in terms of its stability and performance. The devices were fabricated in flexible polyamide substrates using shadow masks and its electric response is also evaluated under mechanical stress.

The CVD deposition of Parylene requires the use of an adhesion promotor and the role of this layer in the interface with the underneath layer, either metal contact or inorganic semiconductor will be presented considering the electrical performance of MIS capacitors and TFTs in bottom-gate and top-gate configurations. Devices with low leakage currents around 10^{-11} A, high On/Off ratios of 10^7, V_T near 0 V and high stability were produced on flexible substrates and its mechanical stability was also evaluated under compressive and tensile bending cycles. The passivation obtained in top gate structures presents an additional advantage due to excellent moisture barrier properties of Parylene, protecting the semiconductor layer from the environment. These results clearly show that these hybrid devices can be excellent candidates for large area electronics, where high mobilities are insured by the inorganic active layers and the conformability, flexibility and electric isolation is insured by the organic dielectric.

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Biography

J.V. Pinto completed a PhD degree in Applied Physics from Universidade Nova de Lisboa (FCT-UNL) in 2008 and during her PhD she achieved a deep knowledge on semiconductor and insulating metal oxides and nanoparticles characterization, using Ion Beam techniques, XRD, SQUID and I-V characteristics. In October 2008, J.V. Pinto joined CENIMAT with a Postdoctoral research grant, and since then the main topics of her research was focused on the development of Field Effect Devices for flexible and biosensing applications. Since 2015 she is an Assistant Professor at the Materials Science Department. Her current interests include the use of parylene polymer for flexible and e-skin applications.

54. Ultrafast photonic curing of solution-based aluminium oxide for thin film transistors

Emanuel Carlos[1], Spilios Dellis[2], Nikolaos Kalfagiannis[2], Loukas Koutsokeras[3], Demosthenes C. Koutsogeorgis[2*], Rita Branquinho[1*], Rodrigo Martins[1] and Elvira Fortunato[1*]

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[2] School of Science and Technology, Nottingham Trent University, Nottingham, NG11 8NS, UK.
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Solution processing of amorphous metal oxides using excimer laser annealing (ELA) has been lately used as a viable option to implement large-area electronics, offering high quality materials at a reduced associated cost and process time.[1,2] However, the research has been focused on semiconductor and transparent conductive oxide (TCO) layers rather than on the insulator layer. This work aims to evaluate amorphous aluminum oxide (AlO_x) thin films produced at low temperature (≤150 °C) combining combustion synthesis and photonic curing for oxide thin film transistors (TFTs) suitable for the manufacturing of flexible electronics.

The study showed that combining ELA and combustion synthesis leads to an improvement in the film densification, from 1.6 to 2.4 g/cm^3. Optimized dielectric layers were obtained combining 15 or 1 min thermal annealing at 150 °C with ELA treatment at a fluence ≥ 150 mJ/cm^2 or ≥ 225 mJ/cm^2, respectively. High breakdown voltage (4 MV·cm^{-1}) and optimal dielectric constant (9) was attained for the dielectrics. TFTs with dielectrics annealed for only 1 min followed by ELA, presented high performance at low operation voltage (< 2 V), with good saturation mobility (22.4 cm^2·V^{-1}·s^{-1}), small subthreshold slope (0.12 V·dec^{-1}) and current ratio of 10^5. ELA is shown to provide excellent quality solution-based high-κ dielectrics. The results achieved by combining both methods are promising and are expected to be of high value to the printed electronic industry due to ultra-fast film densification and surface selective nature of ELA.

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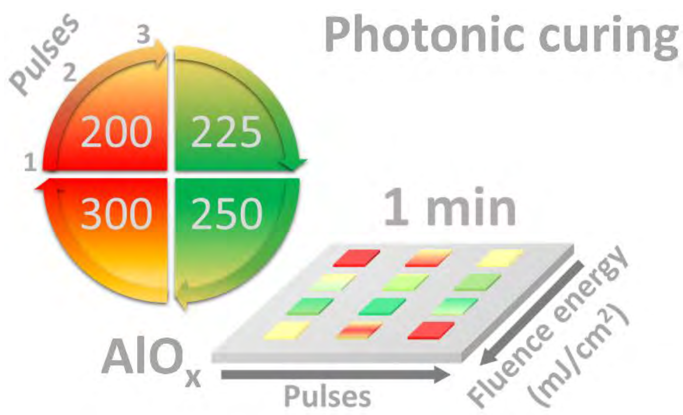

Figure 1. Ultrafast photonic curing of aluminium oxide after 1 min of thermal annealing at 150 °C.

Biography

Emanuel Carlos

M.Sc. in Micro and Nanotechnology at Faculty of Science and Technology (FCT) – New University of Lisbon (UNL) with a thesis about oxide transistors produced by solution to study the influence of annealing parameters on properties of the insulator (December 2015). Before start the doctoral program at FCT–UNL, he worked as a research fellow at the i3N/CENIMAT in a partnership with Merck (September 2015 to February 2017). Currently is doing the PhD in FCT–UNL about multifunctional and transparent low-cost metal oxide electronics. Recently, he did an internship in Nottingham Trent University on laser curing of solution-based oxides (May–July 2018).

Prof. Elvira Fortunato

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).

55. Two-terminal metal-IGZO-metal devices

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Oxides materials combine a unique ensemble of properties presenting great potential to meet the diverse requirements for developing modern electronic technologies. These properties are the driving force for oxide films nowadays being employed in transparent and flexible Thin Film Transistors (TFTs), with amorphous In-Ga-Zn-Oxide (a-IGZO) being of the most celebrated. Yet, despite the significant research activity, there is only limited information available on two-terminal devices for large area electronics. High quality Schottky diodes based on oxide semiconductors would offer additional functionalities such as high frequency applications and development of structures like Metal Semiconductor Field Effect Transistors (MESFETS). Moreover two-terminal metal-oxide devices are currently under scrutiny for exhibiting the memristive effect, i.e. the ability to store a multitude of non-volatile resistive states[1]. These Resistive Random-Access Memories (RRAMs) have brought new exciting prospects via novel applications in neuromorphic and reconfigurable systems, yet haven't found a clear role in large area electronics. RRAM cells typically require Schottky contacts and an electroforming process for exhibiting resistive switching. Thus two terminal semiconductor devices and RRAMs should be studied in parallel.

This work presents an experimental proof of concept study highlighting that by using appropriate electrode materials, room temperature deposited IGZO thin-films could be used for supporting such functionalities. To this end, 30 nm thick IGZO films were deposited by a HiTUS[2] system on top of 10 nm thick Pt bottom electrodes. Four different combination of stacks were fabricated by depositing 20 nm thick TiN, Pt, Au and 4 nm AlO_x and Pt at the top interface. TiN and AlO_x were sputtered while Pt and Au were deposited via e-beam evaporation. Electrical characterization was performed in the temperature range of 300K to 350K with a bespoke memristor characterization platform, Arc ONE™, revealing excellent stability and high reproducibly for all devices. The prototypes comprising a Pt/TiN combination resulted in clear Schottky contact formation, while all other combinations resembled the behaviour of back-to-back Schottky stacks[3] that support bipolar switching.

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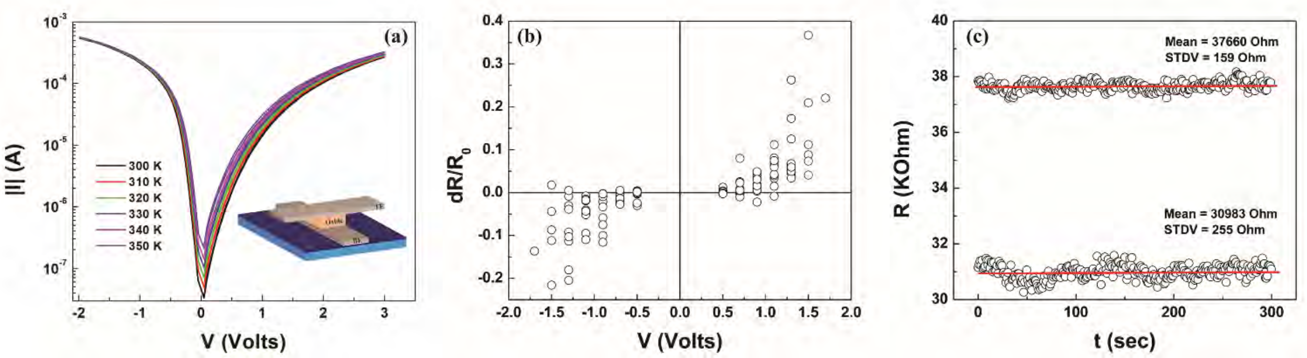

Figure 1. Depending upon the employed electrodes, two-terminals IGZO devices can operate as Schottky diodes (Pt/TiN) (a) or exhibit bipolar resistive switching (b), between discrete stable resistive levels (c) (Pt/Pt)

Biography

Loukas Michalas is a Senior Research Fellow within the Zepler Institute for Photonics and Nanoelectronics at the University of Southampton, working on the development and characterization of metal-oxide based technologies. Previously he was a "Marie Curie" Research Fellow with the IMM-CNR, Rome, Italy and a Research Associate at the University of Athens, Greece. He holds a PhD in solid state electronics.

56. Bipolar metal oxide thin film diodes

Yin Jou Khong[1], Khan M. Niang[1], Nigel J. Coburn[1], Sanggil Han[1], Andrew J. Flewitt[1]
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Lately, there has been an increasing demand of transparent and conformable electronics due to the growth of the Internet of Things (IoT), so different materials that conform to these requirements must be developed. The current semiconductor technologies employed to support the growth of electronics include amorphous and polycrystalline silicon and various organic semiconductors. Metal oxides are also viable candidates as they exhibit high uniformity across a large area and display better electronic characteristics than the alternative materials such as amorphous silicon. Metal oxides can also be fabricated at much lower temperatures compared to polycrystalline silicon and yet still achieve better if not similar performance, hence enabling them to be easily deposited on a wide range of substrates like plastics. Compared to organic materials, metal oxides show better stability under typical operating conditions for consumer electronics, which require less stringent encapsulation, reducing the manufacturing cost and complexities. Diodes are crucial components in a circuit because it is one of the most basic component of current flow control, acting as a one-way valve for electric currents. It is the one of the most fundamental type of switch in any electronic circuit and its design has paved way for invention of active switches such as the transistors, the key component in modern day processors and chips.

Metal oxides generally with their larger band gaps are hard to be doped both n- and p-type, so heterojunctions are the feasible way to construct diodes. Literature review indicated that most researches were focused on nickel oxide and oxides of copper for p-type materials, and variants of zinc oxide for n-type materials. Among these materials, it was found that cuprous oxide (Cu_2O) and amorphous zinc-tin oxide (a-ZTO) are materials with potential to form good p-n heterojunctions. Therefore, thin film p-n heterojunction diodes utilising these materials were fabricated and characterised. The interface between each of the metal contacts and the semiconductor layers were verified and confirmed to be ohmic. The results from the current-voltage (I-V) measurements of the diodes showed that they were rectifying with a rectification ratio of about 20. The capacitance-voltage (C-V) measurements of the diodes proved that the existence of a dominant p-n junction as evidenced by the $V^{-1/2}$ dependence of diode capacitance in reverse bias.

Acknowledgement - The authors would like to thank the EPSRC for support of this project under grant no. EP/M013650/1 and the Cambridge Trust for supporting the research. Yin Jou is a Commonwealth scholar, funded by the UK government.

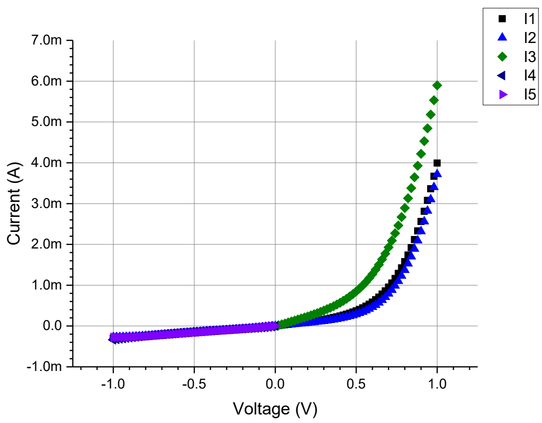

Figure 1. Current-voltage characteristics

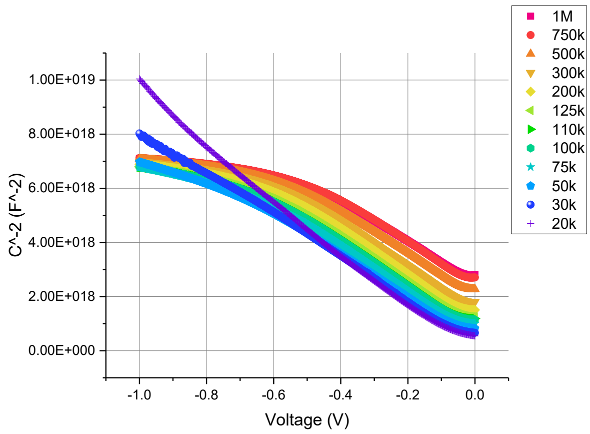

Figure 2. Capacitance-voltage characteristics

Biography

Yin Jou is currently a PhD candidate in electrical engineering division, the University of Cambridge investigating bipolar conduction-based devices using metal oxides as the active material. He is also a student member of the IET. He obtained his MEng (Hons) in electrical and electronic engineering in the University of Nottingham in 2015.

57. Control over voltage threshold shift in IGZO TFTs with enhanced electrical characteristics using novel passivation

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This presentation reports a method for controlling voltage threshold shift in metal oxide based thin film transistors (TFTs) fabricated using sputter coating on silicon dioxide substrates. The indium gallium zinc oxide (IGZO) that produce remarkable electrical performance using passivation layer of CYTOP, control over threshold voltage shift less than 1V is given. This research presents an innovative process that relies on passivation treatment over active layer. The effects of positive bias stress are investigated in inorganic thin film transistors based on indium gallium zinc oxide (IGZO) as the semiconductor and silicon dioxide as the gate insulator, with measurements carried out over a range of positive bias stress conditions. We fabricated amorphous indium gallium zinc-oxide thin-film transistors (TFTs) employing a novel organic-passivation layer (CYTOP) and results are compared with un-passivated TFTs. The TFT with the CYTOP passivation layer effectively exhibited a relatively good electrical characteristic (μ_{sat} = 27 $cm^2/V \cdot s$) compared with that (μ_{sat} =17$cm^2/V \cdot s$) of the unpassivated TFT. The CYTOP-passivated device exhibited relatively good stability (ΔVth: 1V) under positive bias-temperature stress while the unpassivated TFTs showed a 7.4V ΔVth shift, respectively. The CYTOP passivation was performed at low annealing temperature (160 ◦C), and therefore, it is a good candidate for advanced flexible displays.

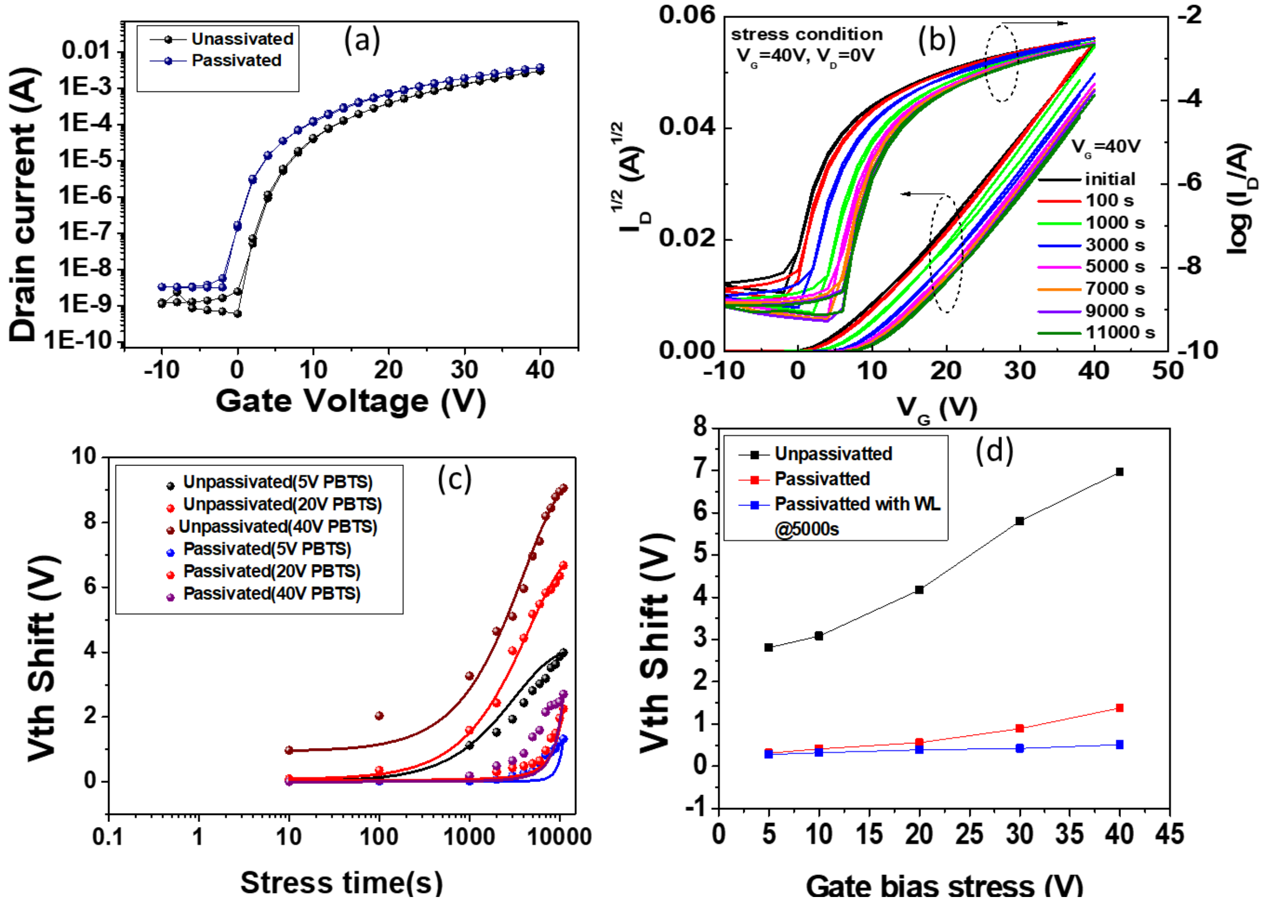

Figure 1. Transfer IV characteristics of a) passivated (with CYTOP) and un-passivated, b) Transfer characteristics showing the time-dependence of the bias stress resulting from applying a zero drain voltage, VD = 0 V and gate voltages, VG of 40 V, c) threshold voltage shift vs stress time curves for 5v,20v,40v PBTS on un-passivated as well as passivated IGZO TFTs, d) Bias stress condition at fixed stress time of 5000s showing Vth shift less than 1V.

Biography

Dinesh Kumar born Oct. 04, 1981,in Himachal Pradesh, India. He was awarded first class bachelor of technology degree in Electronics and Communication Engineering from National Institute of Technology (NIT) Hamirpur, India in 2005. After his graduation he worked in Secure meters limited company as Production Engineer, where he worked on SMT technology. Because of his interest in research, he did his Masters of technology in VLSI Design Automation & Techniques, from National Institute of Technology (NIT) Hamirpur, India in 2011. He is having eight years of industry and teaching experience. He was awarded National overseas scholarship from Indian Govt. for doing PhD abroad and presently he is at final stage of his PhD in school of electronic engineering at Bangor university.

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