

## 2018FLEX Europe - Be Flexible



M. Hack  
VP of Business Development  
Universal Display Corporation, Ewing, United States



### Biography

Dr. Michael Hack, is Vice-President of Business Development at Universal Display Corporation. He is responsible for developing and commercializing advanced high efficiency next generation OLED products, with a special focus on flexible display applications and solid-state lighting. Prior to joining UDC in 1999, he was associated with dpiX, a Xerox Company, where he was responsible for manufacturing flat panel displays and digital medical imaging products based on amorphous silicon TFT technology. Dr. Hack received his Ph. D. degree from Cambridge University, England in 1981 and in 2007 Dr. Hack was elected a Fellow of the Society for Information Display. In 2014 Dr. Hack was nominated to serve on the board of the U.S. OLED Lighting Coalition to promote the advancement and commercialization of OLED lighting.

### Moore for Medical



R. Dekker  
Research  
Philips Research, Microsystems, Eindhoven,  
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### Abstract

Gradually electronic devices are finding their way towards the human body. Body patches are being designed that provide continuous monitoring. Intelligent catheters assist during minimal invasive surgery, and tiny implants stimulate nerves with the aim to replace traditional medicines. Despite their apparent potential progress is however slow, certainly compared to the non-medical electronic industry. One of the reasons is the lack of scalable open technology platforms. In this presentation a selection of promising emerging in- and on-body electronic will be reviewed. Large European consortia supported by ECSEL and PENTA, are developing and implementing not only the essential open technology platforms, but also the necessary manufacturing infrastructure. The recently established Health.E lighthouse will further promote the open technology platform concept for medical devices to realize the "Moore for Medical" vision.

**Biography**

Ronald Dekker received his MSc in Electrical Engineering from the Technical University of Eindhoven and his PhD from the Technical University of Delft. He joined Philips Research in 1988 where he worked on the development of RF technologies for mobile communication. Since 2000 his focus shifted to the integration of complex electronic sensor functionality on the tip of the smallest minimal invasive instruments such as catheters and guide-wires. In 2007 he was appointed part time professor at the Technical University of Delft with a focus on minimally invasive devices and Organ-on-Chip. He published in leading Journals and conferences and holds in excess of 60 patents.

## Multicomponent Assembly on Flexible Material in Reel-to-Reel Process



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### Abstract

Mühlbauer introduces a complete solution for the Reel-to-Reel production of multicomponent products on flexible substrate in the area of LED, active RFID, sensor labels etc. The solution consists of systems that are capable of high-volume manufacturing processes. The upstream production process comprises the production of a flexible circuit, whereas the subsequent process attaches different components to the substrate which is the electronic portion of the final product. The flexible substrate production technology is a completely new development. Starting with the attachment of LEDs, the process was continuously extended to a multicomponent process.

Further progress was achieved in the component attach and curing technologies according to different end applications and the substrate material selection between aluminum and copper for flexible substrate production in relation to their respective areas of use. For example, with Mühlbauer's Reel-to-Reel RFID Antenna Production machine ACS 20000, the low cost materials PET and aluminum can easily be transformed into aluminum antennas on PET.

After the launch of the flexible LED production line TAL 15000\_LED in 2015, Mühlbauer further developed the assembly process towards a universal system: the Multicomponent Line. Besides the standard jetting of adhesives, the dispensing of ICPs and solder paste is now also possible. As a result, new curing requirements like the integration of an inline reflow oven, were developed. Furthermore, the component attachment has been simplified and enlarged so that now, a high variety of components can be attached: SMD, sensors, capacitors or even Flip Chips and other electrical components, which meet any future trend in flexible electronics.

### Biography

Christian Stöhr is working as Head of Business Development for Semiconductor Related Products at Mühlbauer GmbH & Co. KG. Christian has been with the company for more than twelve years and has been deeply involved in the development & implementation of Flexible Electronics and LED-based production solutions. With his international experience & engineering background, he built a worldwide network of industry related companies, and trained local staff in the Asian region for leading sales positions in the Mühlbauer Group.

## Towards R2R Manufacture of Flexible Hybrid Electronics – Technology Roadmap at Fraunhofer EMFT



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### Abstract

Sensors and electronics need the functionality of micro-controller ICs for data collection, data processing, digitization and data transfer to a host system. Therefore, any flexible electronic system will require a technical solution for embedding and interconnection of ultra-thin microprocessors in a bendable film based package.

The presentation will first explain the technological requirements for integration of thin IC on or in flexible film substrates. Key elements here are the manufacture of robust thin semiconductor devices, the preparation of very fine line metal patterns and adequate chip bonding and interconnection techniques. Latter topics can be realized in two different ways for chip orientation: face-down (flip chip) or face-up die bonding. In the second case, interconnects must be aligned with respect to I/O contact pads of ICs. As the distance between two contact pads may be in the range of just 20  $\mu\text{m}$  to 40  $\mu\text{m}$  the resulting alignment accuracy of dies with respect to the interconnect lines has to be less than 5  $\mu\text{m}$ . When using flexible film substrates as integration platform and roll-to-roll (R2R) equipment for manufacture this requirement represents a challenging task due to possible shrinkage or expansion of the film roll.

Thin chip foil packages with embedded microcontroller ICs were demonstrated successfully by Fraunhofer EMFT using single sheet film substrates. In order to achieve the next major step towards R2R manufacture we are currently setting-up a laser direct imaging (LDI) system for R2R lithographic patterning of interconnects and wiring schemes. Key advantage of such laser imaging system is its capability to correct the UV exposure process locally and, if necessary, individually at any chip position. Such "adaptive lithographic patterning" is supposed to bridge the gap between alignment requirements and geometric distortions in the web substrate. First results will be shown at the conference for the first time.

### Biography

Christof Landesberger received the diploma degree in physics from Ludwig Maximilian University in Munich. He joined Fraunhofer Institute in Munich in 1990 and is now heading the research group "Thin Silicon" within the department "Flexible Systems" at Fraunhofer EMFT. He has been working in the field of ultra-thin silicon since more than 15 years and prepared more than 20 patent applications in the field of handling and processing techniques for ultra-thin semiconductors. His current research topics are focusing on packaging technologies for ultra-thin semiconductor devices, including self-assembly and flexible chip foil packages.

## Light-assisted integration of electronic components



F. Chiappini  
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### Abstract

Following a current consumer trend, the demand for high-performance and highly-integrated multifunctional flexible systems has significantly increased in recent years. This has generated the need to develop hybrid systems in which printed circuitry is combined with silicon-based integrated circuits or surface mounted device (SMD) components. Flip-chip (FC) assembly of (opto)electronic components is a key technology in system packaging and integration because of the advantages it offers over the most commonly used wire bonding technique. With decreasing chip size, the density of interconnects increases, which demands advanced high-resolution interconnection technologies. Furthermore, with large-area flexible electronics on low cost polymer foils gaining significant attention lately, the compatibility of the interconnection technology with the carrier substrate has become more significant than ever.

At Holst Centre, we have developed two complementary technologies that enable fast and high-resolution integration of FC assembly components onto flexible foils using light.

The interconnect material (lead-free solder pastes as well as electrically conductive adhesives) is deposited onto flexible printed circuitries at unprecedented high speed using a laser-assisted digital deposition technology. In this talk, we will present the deposition of an array of 10 000 dots of conductive adhesive (< 100  $\mu\text{m}$  in diameter) within less than a second.

The interconnect process is then completed by soldering the components to the substrate using a novel roll-to-roll compatible soldering technology (photonic soldering), which exploits intense pulsed light generated by conventional flash lamps. In contrast to convection reflow soldering (the industry standard technology), photonic soldering is fully compatible with the integration of components on low-cost flexible substrates such as PET, while reducing the soldering processing time down to few seconds.

### Biography

Francesca Chiappini has obtained her PhD from the Radboud University (Nijmegen, The Netherlands) doing research on the electronic properties of graphene.

She then joined TNO (Delft, The Netherlands) working in several projects addressing some of the challenges faced by the semiconductor manufactory industry. In particular, she worked on the topics of contamination control and subsurface AFM imaging.

Currently, she works as scientist at Holst Centre (Eindhoven, The Netherlands) in the hybrid printed electronics domain. She focusses her research activities on novel interconnect technologies for flexible systems.

## Laser-Direct-Structuring of Flexible Textile Circuits



C. Linti  
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DEUTSCHE INSTITUTE FÜR  
TEXTIL+FASERFORSCHUNG

### Abstract

Textile conductive substrates are drapeable, highly flexible, and more insensitive to reversed bending fatigue compared to conventional rigid or flexible printed circuit boards. Despite this the surface mounting of microelectronic devices is not solved retaining the textile properties. Textile Circuits using conductive yarns are limited by textile patterning, printing of conductive inks often does not meet mechanical properties. Using LPKF-Laser Direct Structuring Process (LPKF-LDS) user defined circuits can be structured on the surface of special polymers, usually on injection Moulded Interconnect Devices (MID). Here textile fabrics made from LDS-polymers, the following metallization with the LDS-process, and the mounting of SMD was studied. Integrated Circuits on textile sheets preserving textile properties have been manufactured with LDS technology. For this purpose multifilament yarns have been produced by melt spinning of LDS modified polymers. These yarns have been processed to woven textile bands. These could be surface activated by laser. The activated areas could be copper plated chemically. These conductive circuits can be mounted with e.g. with SMD by soldering. In this study we could show that LDS-yarns can be produced with a special spinning process which can be processed with textile technologies. The LPKF-LDS-process can be applied to the fabric forming conductive circuit structures. The solderability and functionality of electronic parts on LDS-textiles was shown. The textile properties could be retained. The application as flexible circuit especially for the design of interfaces between hard and soft substrates shall be explored in future. Financial support (Laserstrukturierte textile Schaltungsträger) from the BMBF, grant number 16SV5064, is gratefully acknowledged.

### Biography

Degree in Mechanical Engineering with focus on precision engineering and biomedical engineering at the University of Stuttgart.

Since 1994 research assistant and project manager at DITF in the research group for biomedical engineering with focus on textile implants, micro-injection moulding of bioresorbable polymers.

Since 2000 additional in "Smart Textiles", textile and textile-integrated sensors for the monitoring of physiological parameters e.g. in Sensory Baby Vests, Ambient Assisted Living and Sensory Protective Clothing.



R. Ishihara  
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### Biography

Dr. Ryoichi Ishihara is associate Professor in the quantum and computer engineering department and a principal investigator in QuTech and a member of Kavli Institute of Nanoscience in Delft University of Technology in the Netherlands. After receiving PhD degree at Tokyo Institute of Technology and moving to TU Delft in 1996, he has established a new activity of large area electronics using thin-film transistors (TFTs). He has done and continues research on single-grain and printed silicon TFTs for flexible display, 3D integration and biodegradable/flexible electronics. He has significant experience in high-mobility Si TFTs, being the leading scientist in the world in this field.

## Unmet Material Needs in New Applications for Printed Electronics



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# Heraeus

### **Abstract**

Interesting new markets like Smart Textiles and In-Mold Electronics appear at the horizon for flexible printed electronics.

These new applications pose new challenges to both manufacturing and material performance needs. In this talk we address unmet needs in each application and suggest possible material solutions to overcome these obstacles.

### **Biography**

Christian Neumann heads the Heraeus activities in Digital Printed Electronics.

With a strong technological background he was responsible for the implementation of Corporate Technology Scouting and Corporate Venturing activities for Heraeus. He joined Heraeus in 2007 being responsible for development of basic materials for fused silica before starting a group devoted to the development of new porous carbon material system.

He studied physics at Justus-Liebig-University in Giessen and the University of Washington in Seattle before earning his PhD with the synthesis of novel optoelectronic materials by epitaxy.



## Polyester Film Substrates for Flexible and Formable Electronics



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### Abstract

Developments in flexible electronics technologies in application areas such as OLED displays, OPV modules, In-Mould-Structural-Electronics, HMI (Human Machine Interface) and sensors, have presented challenges to device manufacturers relating to the properties of flexible substrates. To improve yield and efficiency there is a need for materials that exhibit excellent dimensional stability and clean defect-free surfaces, and in some applications a requirement for additional functionality such as UV stability and Flame Retardancy.

Proposed solutions to these issues include the use of novel co-extrusion techniques, optical modification of surfaces, and the incorporation of non-halogen flame retardant materials into a polymer matrix.

Increasing interest and activity in flexible hybrid systems, foldable displays, and wearable devices, will require further modifications to substrate properties, and drive the development of flexible materials with new diverse properties and specifications.

This presentation will review the latest developments in polyester film processes and technology, including an update on substrates designed for ultra-high barrier use in Displays and OPV applications, and thermoformable films for use in In-Mould-Structural-Electronics.

### Biography

Thane is a Business Development Manager in DuPont Teijin Films. He has worked in the polyester films market for nearly 40 years, in a range of roles including R&D, Technical Support, and New Product Development in Packaging Films. He is now responsible for the development of polyester substrates that meet the needs of emerging applications in printed and flexible electronics.

## Wireless Embedded Circuits for Intelligent Composites



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Centre for Process Innovation, Sedgefield, United  
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### Abstract

In this paper we present the results of a study into the successful development of wireless flexible sensor circuits for embedding into carbon fibre composite materials.

There is significant interest in many industrial sectors in the use of ultra-thin and flexible sensor circuits for structural health monitoring as well as process and environmental monitoring. The challenges of this requirement include (inter alia) the provision of power to the embedded circuits, the accessing of sensor measurements and the impact of the sensors on the structural integrity of the composite.

Development work at the Centre for Process Innovation and the National Composites Centre in the UK has created a number of hybrid flexible circuits which utilise a printed strain gauge and COTS solid state components to monitor strain within a carbon fibre composite. The circuits developed use inductive power transfer combined with RF communications to provide measurement of strain and this could be extended to include other structural parameters such as pressure and temperature. Demonstrator circuits have been assembled into carbon fibre composites and power and data transfer functionality have been successfully demonstrated. The results of the testing of these assemblies will be presented.

Mechanical stress testing of the assembled circuits has been performed and the results show that the effect of the embedded circuit is measurable but this can be mitigated by careful selection of the approach to integration.

This work has shown that the embedding of wireless sensor circuits within carbon fibre composites is possible providing embedded sensor capability for a wide range of applications.

### Biography

Simon 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.

## Printing high aspect ratio narrow silver lines using nanoparticles



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### Abstract

In printable electronic device, narrow metal lines with low electrical resistance are essential. Commercial gravure, flexography or inkjet systems on the market can produce 30-100  $\mu\text{m}$  wide lines by properly choosing the ink and substrate, this feature size is still about one order of magnitude larger than what is required in many electronic device applications. Other R&D printing technologies like high throughput gravure, reverse-offset printing, and electrohydrodynamic jet printing can achieve a linewidth of 1-5  $\mu\text{m}$  at the expense of line thickness, which is normally characterized by a very low thickness-to-width aspect ratio, often far less than 0.05. Currently, it is very challenging to print narrow metal lines with high thickness-to-width aspect ratio and thus low resistance. In this work, we report a method of obtaining 4.6  $\mu\text{m}$  wide printed silver lines with an elliptical cross-section and an aspect ratio of 0.7. The silver lines were obtained by jetting a silver nanoparticle-based ink onto an SU-8-coated PET substrate to form well-defined silver lines, and then heating the lines to transform them into high aspect ratio narrow lines through ink dewetting and receding. The simultaneous dissolution and redistribution of SU-8 by the ink results in a concave structure, which prevents the lines from bulging and allows the lines to sink into the SU-8 film. The sheet resistance of the obtained 4.6  $\mu\text{m}$  lines was measured to be 0.05  $\text{ohm}/\square$ , and using special pattern designs, the method can also be used to get 0.5  $\mu\text{m}$  wide silver lines, with an aspect ratio of 1.0. The obtained wires are suitable for printing high-performance electrical devices.

### Biography

Dr. Zhiyi Frank Zhang received his Ph.D. in polymer chemistry from Zhongshan University. He worked with universities and companies before joining National Research Council Canada. His previous research included polymers and polymer composites, sol-gel, polymer-gas systems, photonic components and packaging, biomicrofluidics, sensors. In recent 6 years, he is working on printable electronics with a focus on materials, process, sensors and electronic devices.

## Flexo printing and selective sintering of metal based inks on paper – Optimization of RFID-HF loops for mass production



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### Abstract

This work examines the potential of paper for the production of printed NFC tags. Paper characterization demonstrates high temperature tolerance and very low roughness enabling the electrical performance of conductive inks to be fully developed.

Flexo process was considered for the printing of low-cost electronic devices. Moreover, the electrical performances of silver based inks are studied according to the size of their particles. Indeed, the use of metal nanoparticles can facilitate the activation of atomic diffusion mechanisms. In parallel, microparticles are cheaper. In any case, the coalescence of the metal particles after printing cannot be initiated without a thermal sintering treatment.

Sintering is usually carried out in an oven, temperature must therefore remain below the tolerance of the substrate. This leads to limited electrical performances for long duration. To fit with industrial constraints of large-scale production and to achieve the best electrical performance in a short time, deployment of emerging near-infrared (NIR) and intense pulsed light (IPL) photonic technologies is considered. These latter are based on the absorption of light energy by the ink thus causing rapid heating. The important absorption differential between the inks and the substrate allows high heating selectivity which makes it possible to limit the degradation of the substrate while the ink temperatures may be greater than 300 ° C. For each sintering process, the influence of the various parameters on the final electrical performance has been studied by using an in-situ resistance monitoring, allowing sampling frequency up to 250 kHz.

Finally, RFID-HF loops were printed, sintered and characterized while an estimate of the production costs was carried out. The obtained results demonstrate the potential of paper, coupled with flexographic roll-to-roll process and NIR technology, enabling the large-scale production of RFID-HF tags at a material cost of the order of 5 euros cents.

### Biography

Victor THENOT was born in Paris, France, in 1989. He graduated from PAGORA, the International School of Paper, Print Media and Biomaterials (Grenoble-INP) in 2013. He joined the Arjowiggins group (leading producer of specialty papers in Europe) in 2011 as an engineering apprentice during which time he worked on the development of PowerCoat® paper, a specially designed substrate for the printed electronics market. He received the Ph.D. degree in 2017, for his work on printed RFID tags on papers carried out in partnership with two laboratories: the French Laboratory of Pulp and Paper Science and Graphic Arts (LGP2) based in Grenoble, and the Microelectronics Center of Provence (CMP), part of the Ecole Nationale Supérieure des Mines de Saint-Etienne. His current research is in the area of printed electronics on flexible substrates with a particular focus on printing, sintering and RFID tags design and manufacturing on paper substrate.



A. Zimmermann  
Executive Board Member  
Hahn-Schickard, Stuttgart, Germany



### **Biography**

André Zimmermann was born in Schweinfurt, Germany, in 1971. He studied chemistry and crystallography at Julius-Maximilians-Universität Würzburg as well as materials science with specialization in mechanical engineering at Technische Universität Darmstadt. After several stays in the USA at NIST and University of Washington he received his PhD in 1999 at Technische Universität Darmstadt. He held positions as group manager at the Max-Planck-Institute for Metals Research, Stuttgart, and as senior manager for electronic packaging within the corporate research and development of Robert Bosch GmbH in Waiblingen.

Since January 2015, he is professor for micro technology at the Institute for Micro Integration (IFM) of the University of Stuttgart. Simultaneously, he is the head of the Institute for Micro Assembly Technology at Hahn-Schickard in Stuttgart.

## Flexible semiconductor products and how they will be manufactured



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### Abstract

The largest driver for thin-film semiconductors are active-matrix flat panel displays. Flexible displays are becoming a reality, and with them, the technologies to make high performance thin film transistors and OLEDs on large flexible plastic sheet. Similar in construction to OLEDs are organic photodetectors. We will discuss this flexible semiconductor technology platform that will lead to products as flexible displays, nail-to-nail fingerprint scanners, electronic patches and flexible IoT tags.

### Biography

Paul Heremans received the Ph. D. degree in Electrical Engineering from the University of Leuven, Belgium, in 1990.

He then joined the opto-electronics group of imec, to work on optical inter-chip interconnects, and on high-efficiency III-V thin-film surface-textured light-emitting diodes.

In 1998, he started the organic electronics activities at imec.

Paul became Fellow at imec in 2007. Since January 2018, Paul is director of the Energy and Large Area Electronics unit, heading the research activities on displays, large area imagers, flexible IoT, solid-state batteries and photovoltaics. Paul is also Professor at the University of Leuven in the EE department (ESAT).

## Flexible electronics: From lab to fab to the next generation of products



J. Socratous  
research engineer  
Flexenable Ltd, CAMBRIDGE, United Kingdom



### Abstract

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. The transistor is the fundamental building block for electronic devices, so a flexible transistor is the first step to turning this vision into a reality. Organic-based transistors (OTFT) have always been seen as the most flexible transistor option, and this talk will explain how the performance of OTFT has now exceeded amorphous silicon ensuring that product designers no longer need to compromise performance to achieve flexibility. For example, in terms of mobility, manufacturable OTFTs are now at least three times better than amorphous silicon, whilst having leakage currents nearly 1000X lower – both of which bring direct performance benefits to the device electro-optical performance alongside the benefits of flexibility.

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°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 working across the supply chain to establish the infrastructure necessary to bring the next generation of products to the market.

### Biography

Josephine Socratous holds a B.A. and M.Sci degree in experimental and theoretical physics from the University of Cambridge. She did here Ph.D. in the Optoelectronics Group, Cavendish Laboratory, University of Cambridge where her thesis focused on amorphous metal oxide semiconductors for thin-film transistor applications.

She has been with Flexenable Ltd since 2015 and is currently Senior Research Engineer. Her focus is on improving the performance and reliability of organic thin-film transistors together with managing grant-funded and customer projects.

## SmartEEs – Accelerating the uptake of Flexible Electronics



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### Abstract

The market for organic & printed electronic products is growing at a high level (BUS\$ 23-24 in 2014) with predicted annual growth rates of 20 % in all fields. Although the use of OLAE in products is still limited and only have been commercialized by large corporates, the number and type of products has grown significantly. These emerging markets are a huge opportunity for the EU industry. But EU small & mid-size companies have had only a limited access to technologies and often lack the capabilities needed to benefit from OLAE. These include the ability to fully understand the technological implications and the related business implications. They need support in the translation of the OLAE technologies into innovative products, assessing potential markets, finding investors, developing new business models and creating the right partnerships to optimally benefit from OLAE opportunities. SMARTEES will be the Digital Innovation Hub dedicated to OLAE, an organized European innovation network that provides both access to competencies and business support for innovation adoption. SMARTEES will help the European industry to create a competitive advantage within the global economy by providing access to disruptive OLAE technologies and innovation support in a pragmatic, operative and efficient pan-European manner. A 1-Stop-Shop will be set to establish a collaborative environment and to provide wider access to the technology at the same time as coordinating the bespoke services and efficiently and effectively linking them together. 20 Application Experiments will be conducted to explore the technology transfer into business, organization of cooperation, access to finance, services to be provided and act as showcases to raise awareness and activate potential users. The established eco-system will be harnessed by the consortium to propel the continuity of the initiative beyond SMARTEES. This will include the formulation of a comprehensive business plan as a strategic outcome.

### Biography

André Philipp, born 1983 in Dresden, studied Electrical Engineering at the Dresden University of Technology and specialized in the field of microelectronics. Since 2010 he is working as a researcher at Fraunhofer in the field of organic electronics. His specialty is the process and technology development especially for organic light emitting diodes (OLED). The main focus of his activity is the development of patterning and singulation technologies. In addition to his work at Fraunhofer FEP he is working on his PhD.



## Paper electronics with printed Poly-Si TFTs



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### Abstract

Paper electronics has emerged as a game-changing platform for future applications in display, healthcare, and environmental monitoring devices. The low-cost of paper combined with scalable manufacturability of printing technologies of electronic devices will allow production of a trillion of systems for IoT. Due to its biodegradable and fully-recyclable properties, the paper system paves a way for low carbon footprint and less environmental damages.

The technical challenge in the paper electronics lies in the printing of electronic devices. Organic and metal-oxide semiconductors can be printed at low-temperature and hence on a paper substrate. However, carrier mobility and reliability of thin-film transistors (TFTs) using those materials are still much inferior than those for silicon. Silicon as the base material, on the other hand, has advantages in terms of high-mobilities for the both of electron and holes, chemical and electrical stability, and low-power consumption by CMOS circuit configuration. The biocompatibility of silicon makes a good match with paper for the substrate.

Silicon can be printed using liquid silicon ink, which is a mixture of polymerized cyclopentasilane (CPS) and a solvent]. Thermal annealing higher than 350oC of this material, however, was necessary, to convert it to solid silicon, which prevented its usage on inexpensive substrates with a limited thermal budget.

In this presentation, we review a novel method that we developed for forming polycrystalline silicon (poly-Si) patterns directly on paper using the same liquid silicon with doctor-blade coating and local irradiation of excimer-laser with room temperature process. We review also the process and electrical properties of poly-Si TFTs fabricated on the paper. This technique will break-through the printed electronics by enabling applications such as fast printed electronics that are inexpensive, fully-recyclable, biodegradable and even edible.

### Biography

Ryoichi Ishihara is an associate Professor and head of the Quantum Integration Technology in the Quantum and Computer Engineering department in Delft University of Technology (TUDelft). He is currently a principal investigator in QuTech and a member of Kavli Institute of Nanoscience. He is also a visiting professor of Japan Advanced Institute of Science and Technology and a specially appointed associate Professor in Tokyo Institute of Technology.

He received the PhD in Physical Electronics from Tokyo Institute of Technology (1996). After moving to TU Delft in the same year, he has established new activity of large area electronics using thin-film transistors (TFTs). He has done and continues research on single-grain and printed silicon TFTs for 3D integration and biodegradable/flexible electronics. His current research in QuTech is growth and integration of diamond nitrogen center qubit for scalable quantum internet and computer applications.

He is a co-author of more than 85 journal papers and 120 international conference papers and a co-inventor of 13 granted patent families.

I. Denes  
Senior Expert  
Robert Bosch GmbH, CR/APP, Renningen,



Germany



### **Biography**

Dr. Istvan Denes (Ph.D.) is a senior expert of the Robert Bosch Company, responsible for the team: CT3 Connectivity - Functional Integration of Sensors.

In 2010 – 2015 he coordinated various corporate activities as well as publicly funded projects on electroactive polymers. His research field concerns the technological and economic aspects of polymer based electro-mechanical systems.

Istvan Denes got his M.Sc. in mechanical engineering and holding a Ph.D. in power electronics being supervised by the IEEE Fellow Prof. Istvan Nagy. In 2012 he was completing his studies at the Steinbeis Business Academy receiving the MBA title.

He is a member of the IEEE Dielectric and Insulation Society and the European Scientific Network for Artificial Muscles (ESNAM). He is a referee for project proposals of the funding announcement “Innovative Elektrochemie” of the German Ministry of Science (2016).

## Future Directions for Phosphorescent OLED Displays



M. Hack  
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States



### Abstract

OLED displays are now in commercial production for a range of products from cell phones, tablets, UHD TV's, and newly emerging applications such as AR/VR headsets and wearable devices. OLEDs offer excellent visual performance, and through the use of phosphorescent OLED (PHOLED) technology, lower power consumption than AMLCDs. OLEDs possess novel features such as transparency and flexibility, which will further increase their market potential over the next few years, and provide a much greater differentiation from current technologies. UDC is a pioneer in the development and supply of phosphorescent OLED technology and materials for both display and lighting applications. In this talk we will review the current status of OLED technology and discuss its potential for exciting new products over the next few years.

In addition we would like to report on our recent work to develop a solvent-less, mask-less printing technology for depositing patterned small molecule organic materials to manufacture large area side by side R-G-B OLED displays. Commercial manufacture of large area (TV), side-by-side RGB OLED displays is currently challenged by lack of a suitable methodology for the patterned OLED deposition. Fine metal masks used for mobile OLED displays have not been proven to scale to greater than Gen 8, and scanning smaller shadow masks across a large area has not provided acceptable yield. Inkjet technology has been in development for many years and has yet to provide sufficient performance for volume manufacturing. Organic Vapor Jet Printing (OVJP) has been developed to print patterned OLED layers for large area displays, while avoiding issues arising from the use of fine metal masks and use of solvents.

In this presentation we outline how we are ensuring that our PHOLED technology meets the ever more demanding performance requirements of future products, and we will outline how our technology can further improve their performance and lower cost.

### Biography

Dr. Michael Hack, is Vice-President of Business Development at Universal Display Corporation. He is responsible for developing and commercializing advanced high efficiency next generation OLED products, with a special focus on flexible display applications and solid-state lighting. Prior to joining UDC in 1999, he was associated with dpiX, a Xerox Company, where he was responsible for manufacturing flat panel displays and digital medical imaging products based on amorphous silicon TFT technology. Dr. Hack received his Ph. D. degree from Cambridge University, England in 1981 and in 2007 Dr. Hack was elected a Fellow of the Society for Information Display. In 2014 Dr. Hack was nominated to serve on the board of the U.S. OLED Lighting Coalition to promote the advancement and commercialization of OLED lighting.

## Stretchable Electronics for Electro-Mechanical Transducers



G. Kovacs  
CEO  
CTsystems, Dübendorf, Switzerland



### Abstract

In the past decades the development of compliant dielectric materials, capable of storing high electric energy density, is the object of considerable research efforts for commercial applications. Compared to the widely used soft dielectrics as compliant insulators, only a small variety of commercially available actuators based on dielectric polymers are available on the market up to date. The most challenging obstacle to be faced lies in the production technology of a stacked multilayer system consisting of thin (<25µm) silicon dielectrics and each one coated with even thinner (<100nm) mechanically compliant electrodes. This conclusion represents one of the most critical issues to be solved for manufacturing highly reliable and robust low-cost devices, which strictly require highly efficient production methods and facilities to become competitive and attractive on the market. The present talk gives an overview of different technological design approaches and will provide promising options for opening the door of industrial production of polymer transducers.

### Biography

Gabor Kovacs was a senior scientist at the Swiss Federal Laboratories for Materials Testing and Research (EMPA), specializing in EAP based actuators. After his PhD in mechanical engineering he has been working at the institute of lightweight structures and ropeway technology of the ETH Zurich. From 1996 to 2001 he was the head of competence centre "aerial cableway technology" at EMPA in Dübendorf (Zurich). Between 2001 and 2003 he was group leader of electroactive polymers (EAP) actuator technology for adaptive material systems. Between January 2003 and end of 2005, he was head of the laboratory for "Materials and Engineering" at EMPA. Since 2006 he was deputy head of the laboratory for mechanical systems engineering and group leader for novel actuator and manufacturing technologies in the field of artificial muscles based on EAP, dielectric elastomer actuator respectively. In March 2005 he received the certificate of appreciation for the EAP powered arm-wrestling robot. As staff member of the coordinator team of the European Scientific Network for Artificial Muscles - ESNAM ([www.esnam.eu](http://www.esnam.eu)) he represents the main inventor for the contractive stack actuator technology as best candidate for high power artificial muscle. Additionally, he is responsible for most relevant research and development activities in regard to new dielectric elastomer materials and multilayer thin film processing for artificial muscle actuators at Empa. Since 2011 he is co-owner and CEO of the Empa spin-off company Compliant Transducer Systems (CTsystems) GmbH in Dübendorf.

## Highly customizable process for fast manufacturing of thin flexible polyimide based circuit carriers and its application for a flow sensor using low-cost passive components



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Visions to Products

### Abstract

Commercially available flexible printed circuit boards are manufactured by using adhesives for bonding thick copper foil on polyimide in a lamination process. For realization of thin foil systems without adhesives we present a highly customizable, additive process using polyimide foils, PVD technology and a maskless direct imaging process to manufacture flexible polyimide based circuit carriers in short time and small lot sizes. First, polyimide foil is used as substrate for sputtering a thin Cr/Cu metal layer. Then photoresist is applied on the metalized foil by conformal coating. Structuring of the resist is carried out by direct imaging and subsequent developing of the resist. After applying of copper electroplating for enhancing the opened tracks, the mask is stripped off and the metal layer is etched until the base PVD metallization is completely removed. Finally a suitable metal finish for assembly processes is applied on the copper tracks by electroless plating of nickel and gold. With these base substrates a thermal direction sensitive mass flow sensor element was realized using low-cost passive SMD components such as a resistor as a heater and NTCs as temperature sensors on both sides of the resistor. The development of the read-out circuit as well as the characterization of the low cost flow sensors are in progress. The presented process chain combines the advantage of maskless lithography with its short preparation time on one side and batch processing for an industrial approach on the other side. The process offers thin, flexible and individualized sensor elements with easily scalable size and configurable layout without additional adhesives.

### Biography

Florian Janek received his Master degree in Microsystems- and Nanotechnology from the University of Applied Sciences Kaiserslautern, Germany, in 2015. His interest is in the field of functionalized and sensorized flexible systems made of foil and textiles. After his studies he began working for Hahn-Schickard and joined the group of Prof. Dr. Zimmermann as a PhD candidate in the laboratory for systems-in foil applications at the University of Stuttgart, Germany, in 2016. His research is focused on embedding ultra-thin chips into flexible packages forming system-in-foil applications.

## Ultra-Thin, solid-state rechargeable battery with vertically integrated solar cell



B. Berland  
Chief Science Officer  
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### Abstract

ITN Energy Systems and ENrG Inc. have developed and demonstrated a promising new thin, flexible solid state lithium rechargeable battery (SSLB) for flexible electronics, smart wearables, and medical devices. Combining ITN's SSLB technology with ENrG's ultra-thin flexible ceramic solves the capacity and packaging issues that have thus far limited the thin film battery technology to limited niche markets. With a capacity greater than 20 mAh in a thickness less than 250 microns, including hermetic packaging, the new SSLB enables energy density greater than 1,000 Wh/l while maintaining the long recognized benefits of enhanced safety and durability provided by the all solid state chemistry. Results are also presented for a new Flexible Integrated Power Pack (FIPP) that add in-field solar recharging by combing the SSLB with Lucintech's high efficiency CdTe solar cells. The new SSLB and FIPP products support operation across a wide range of duty cycles including high current pulses required for many wireless, display, and medical device applications. Results are presented for the battery and FIPP performance, including environmental and safety compliance testing.

### Biography

Dr. Brian Berland, Chief Science Officer— Dr. Berland serves as the Chief Science Officer for ITN Energy Systems. In this role, he directs both technology and business development activities with a focus on moving technologies from the lab to commercialization. Over the last twenty years, he has led research and development activities in flexible electrochromic and low-e window films, flexible lithium solid state batteries, redox flow batteries, alternate energy generation and storage materials, environmental barrier coatings, as well as gas and liquid separation membranes.

In his time at ITN, he has been an integral member of a team to successfully bid and execute over \$30M in R&D programs with corporate and government partners, including leading teams commercializing ITN's SSLB with leading worldwide corporate partners. He has been active in all aspects of product development for these technologies including cost-modeling, development of strategic partnerships, and definition of product performance requirements/market identification to support successful commercial transition and scale-up. Prior to joining ITN Energy Systems, Dr. Berland was a postdoctoral research associate at the University of Colorado in the labs of Professor Steven George, a world leader in ALD chemistry. He holds a BS in Chemistry from Carleton College and a Ph.D. in Chemistry from the University of Colorado.

## Development, Upscaling and Production of Printed Supercapacitors



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### Abstract

There is an ever-growing interest in sustainable and renewable energy sources such as solar, wind and water power. The rapid development in this field will require new ways of storing and balancing this energy. The power output from solar cells not only varies with the 24-hour rhythm of the sun, but also on shorter timescales with the passage of clouds. The intensity of wind also varies on different timescales, and this leads to large power fluctuations in the grid.

To balance the power grid, intermediate energy storage on massive scales is necessary. This energy storage must not only have high enough power density to smoothen the power spikes, but it should also be environmentally friendly and sustainable, just as the renewable energy sources.

We have developed a scalable paper-supercapacitor system based on the conductive polymer PEDOT:PSS and cellulose. The cellulose forms a large surface area for the conductive polymer to self-organize onto, as well as a porous network which facilitates high ionic conductivity. We have also shown how the charge storage capacity can be further enhanced by organic forest-based redox-molecules. Furthermore, we have developed new methods of producing the active material, as well as the other device components, in a large area and high throughput manufacturing processes capable of satisfying the future demand for green energy storage.

### Biography

Jesper Edberg received his Ph.D. in applied physics at the Laboratory of Organic Electronics at Linköping University, with the thesis title 'Flexible and Cellulose-based Organic Electronics'. He started working at RISE Acreo in 2017 at the department of Printed and Organic Electronics where he is working on cellulose-based electronics and energy storage devices.