34th International Conference on Digital Printing Technologies (NIP)

September 23-27, 2018 • Dresden, Germany

NIP/DIGITAL

Printing for DIGITAL Fabrication 2018

materials, applications, and processes

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Collocated event
2018 International Symposium on Technologies in Digital Photo Fulfillment

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The papers in this volume represent the program of
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held September 23-27, 2018, in Dresden, Germany.

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NIP/DIGITAL DIGITAL
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Welcome to Printing for Fabrication 2018

I am delighted to welcome you to Dresden, the capital of Saxony, Germany, host of the 2018 Printing for Fabrication Conference. This is the third time this event, formerly known as NIP and Digital Fabrication, is held in Europe—and the first time in Germany.

From the iron age to the high-tech era, Dresden and greater Saxony have had a long history in being at the forefront of science, technology, and manufacturing. From china to automobiles, areas of expertise have included photography, printing, microelectronics, and more. I hope you have the opportunity to explore this exciting and steadily developing city and the people living and working here.

Printing as an unbeatable, efficient technology to deposit materials of all kind in patterns that create new objects, structures, and functions on an industrial scale is the focus of this conference. It covers a broad range of topics, from decorative, ever green applications of surfaces such as textiles with color and ornamental structures to printing electronic devices and objects in two and three dimensions. The present worldwide, digital transition, also known as "Industry 4.0", is a strong enabler, but also a demand driver for new and emerging printing processes and applications. Digital printing is increasingly becoming mainstream, and small and cheap "smart objects" that help society realize the visionary "Internet of Things" can be manufactured only by printing techniques in the large numbers needed.

Printing is a extremely multidisciplinary field. We need experts in physics, chemistry, material science, mechanical and electrical engineering, computer science, and many more fields to collaborate. This conference is the place where such collaboration takes place, where you can meet colleagues from all over the world, exchange results, concepts, and ideas, and work toward future innovations and products. Please use the conference and its social events as a platform for your personal networking. And let us know if you'd like to get more involved in leading the event next year in San Francisco, September 29 to October 3, 2019.

Finally, I would like to express my gratitude to Special Outreach Chair Reinhard Baumann for providing considerable leadership and support in bringing this conference to Dresden, and to Executive Program Chair Ingo Reinhold who shared his knowledge, working power, time, and experience unsparingly in the preparation of the technical program. I'd also like to thank the conference committee members from across the globe and IS&T staff, who support all of our efforts. Finally, I express my appreciation to the sponsors and exhibitors who always support the conference and make it a better event.

—General Chair Wolfgang Schmidt, Felix Schoeller Group

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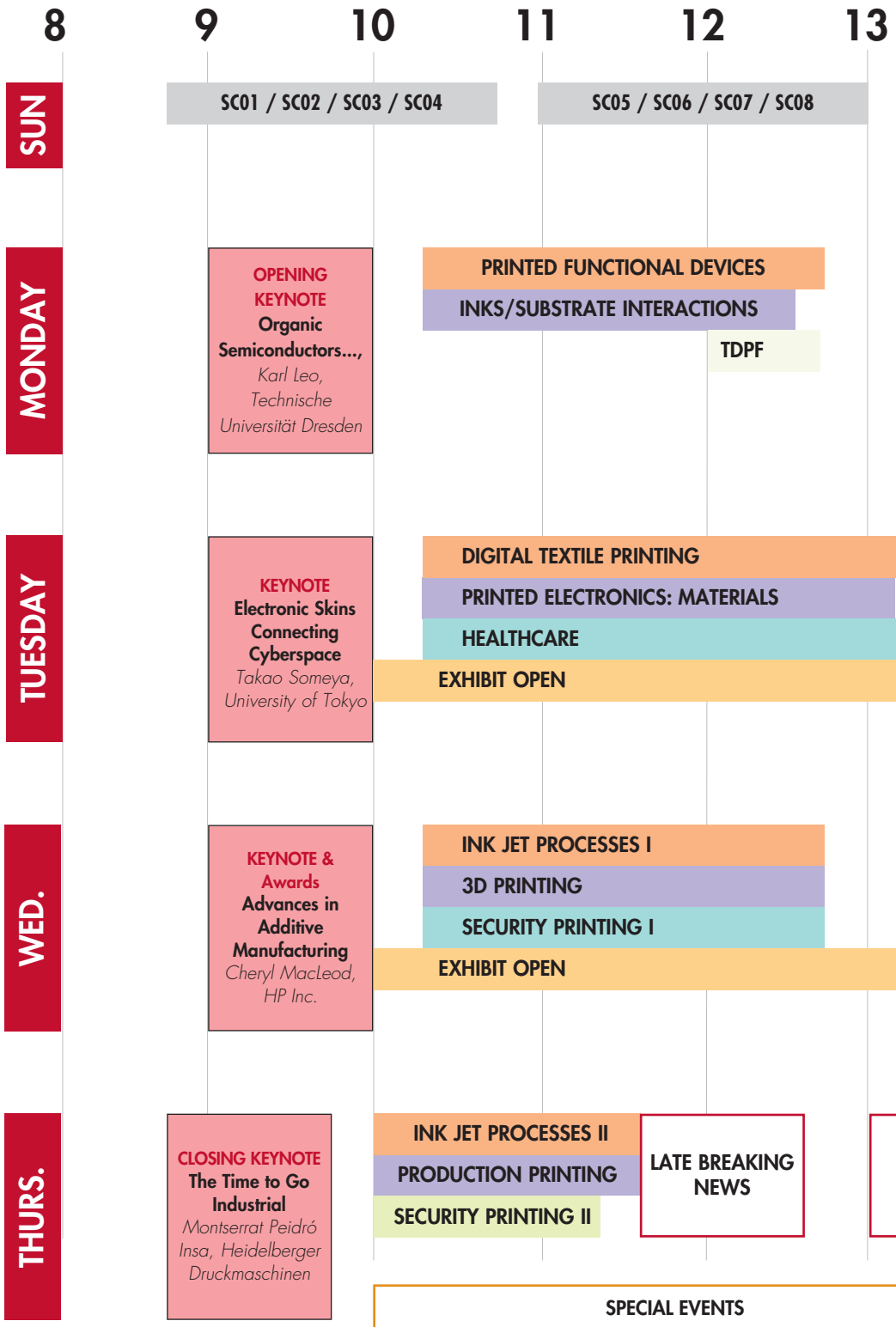
- Piano Bar Foyer
- Room noted on ticket

Please note: Lunch and coffee breaks are not shown. Refer to schedule for these times.



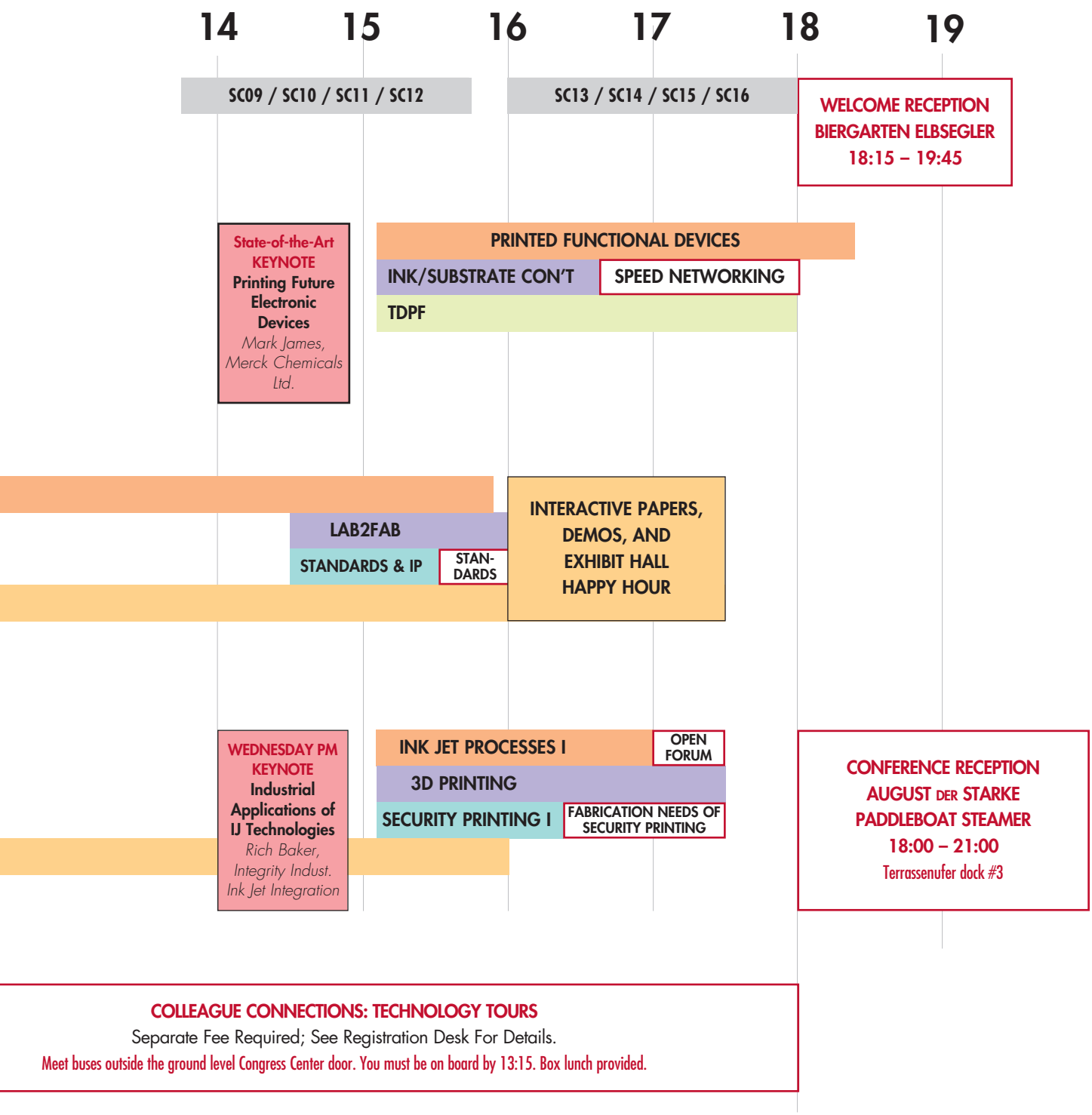
SPECIAL EVENTS

Welcome Reception
Sunday 18:15 – 19:45

Colleague Connections: Print4Fab Speed Networking
Monday 16:40 – 18:00

Colleague Connections: Students/Young Professionals Get Together
Monday 19:00; meet in hotel lobby

Annual Meeting of Members
Tuesday 8:15 – 8:30; Rossini



COLLEAGUE CONNECTIONS: TECHNOLOGY TOURS

Separate Fee Required; See Registration Desk For Details.

Meet buses outside the ground level Congress Center door. You must be on board by 13:15. Box lunch provided.

Conference Exhibit
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Colleague Connections:
International Standards Supporting Printing for Fabrication
Tuesday 15:30 – 16:00

Interactive Papers, Demonstration Session, and Exhibit Hall Happy Hour
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Colleague Connections: Ink Jet Open Discussion
Wednesday 17:00 – 17:30

Colleague Connections:
Connections for Innovation in Security Printing: The Fabrication Needs of Secured Print
Wednesday 16:20 – 17:30

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Wednesday 18:00 – 21:00

Colleague Connections: Late Breaking News
Thursday 11:40 – 12:40

Colleague Connections: Technology Tours
Thursday 13:00 – 18:00

Conference Committees

NIP/DIGITAL **Printing** for DIGITAL **Fabrication** 2018
materials, applications, and processes

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- demonstrate the JetXpert system for visualization and measurements of inkjet drops in flight including wave form optimization capabilities
- illustrate new features of the JetXpert Print Station, preview video at https://jetxpert.com/products/print-station/
- explain the latency option for measuring the initial behavior of ink after jetting has been idle.

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CONFERENCE EXHIBIT

Exhibit Hall Hours
Tues. 10:00 – 17:30 and Wed. 10:00 – 16:20

Interactive Papers Session, Demonstrations, and Exhibit Hall Happy Hour
Tuesday 16:00 – 17:30

Meet with interactive authors, authors demonstrating products, exhibitors, and other colleagues over a beer.

Piano Bar Foyer

Technical Papers Program: Schedule and Contents

SPECIAL EVENT

WELCOME RECEPTION

Sunday, 23 September
18:15 – 19:45
Biergarten Elbsegler
Westin Bellevue Hotel

Kick off the conference by joining colleagues on Sunday for a traditional Biergarten experience on the banks of the Elbe River

KEYNOTE TALKS ALL TRACKS / ALL DAYS

Congress Center Saal 1&2

MONDAY, 24 SEPTEMBER

Opening Keynote

Session Chair: Wolfgang Schmidt, Felix Schoeller Group (Germany)

9:00 - 10:00

9:00 **Organic Semiconductors: From Vacuum Deposition to Printing,** *Karl Leo, Technische Universität Dresden (Germany)*

Organic semiconductors consisting mostly of carbon are currently intensively investigated for electronic and optoelectronic applications. They offer key advantages, such as flexibility, easy recycling, low cost, and many more. In the first part of this talk, I will discuss some of the recent progress on devices such as highly efficient OLED, solar cells, transistors, and sensors and discuss the many novel applications these "soft" electronic devices" offer. In the second part, I will address manufacturing issues and discuss how the field of organic electronics will move from the current vacuum techniques to low-cost printing.*

State-of-the-Art Keynote

Session Chair: Ingo Reinhold, XaarJet Ltd. (Sweden)

14:00 - 14:50

14:00 **Printing Future Electronic Devices with Organic Semiconducting Materials,** *Mark James, Merck Chemicals Ltd. (UK)*

Merck has been actively researching organic electronic materials since before 2000, with the objectives to develop products that enable mass production of electronic devices with new functionality not readily obtainable using existing silicon technologies. Multi-disciplinary innovation is required to develop many interrelated materials and processes in parallel to realize these step-change technologies. This talk discusses this process as well as the developement of solution processable and printable, functional material sets, covering the technologies of OLED, OTFT, OPV, and OPD.

How the co-development of polymeric organic semiconductors, passive materials, and formulations with process optimisation enable the printing of high performance OTFT backplane arrays, with charge carrier mobility greater than 2 cm^2/Vs, suitable for the mass production of printed flexible displays and sensors is also presented.*

TUESDAY, 25 SEPTEMBER

Tuesday Keynote and Awards

Session Chair: Norio Nagayama, Ricoh Co., Ltd. (Japan)

9:00 - 10:00

9:00 **Electronic Skins Connecting Cyberspace and Human,** *Takao Someya, University of Tokyo (Japan)*

Wearable electronics are expected to open up a new class of applications ranging from health-monitoring, motion-capturing, human-machine interfaces, and new IT fashion. In order to expand emerging applications of wearable technologies, printed flexible biomedical sensors have attracted much attention recently. To minimize the discomfort of wearing sensors, it is highly desirable to use soft electronic materials particularly for devices that come directly into contact with the skin and/or biological tissues. In this regard, electronics manufactured on thin polymeric films, elastomeric and textile substrates by printing are very attractive. This keynote reviews recent progresses of wearables and artificial electronic skins (E-skins) from the contexts of high-precision and long-term vital signal monitoring. Furthermore, the issues and the future prospect of wearables and beyond wearables is addressed.*

* Abstract only; no extended abstract or proceedings paper.

WEDNESDAY, 26 SEPTEMBER

Wednesday Keynote and IS&T Awards

Session Chair: James Stasiak, HP Inc. (USA)

9:00 - 10:00

9:00 **Advances in Additive Manufacturing: The Evolution of HP Inc.'s Jet Fusion™ 3D Printing Technology,** *Cheryl MacLeod, HP Inc. (USA)*

Recent advances and innovations in 3D printing, digital fabrication, and additive manufacturing methods are disrupting the way we design, develop, manufacture, and commercialize new technologies and products. These disruptions are enabling improved efficiencies on the manufacturing floor and in making the vision of mass customization a reality. It is clear that the newest industrial revolution is already well underway. The next phase of the revolution will extend beyond fit, form, and finish and will involve designing and engineering the functionality of the finished part by controlling the fundamental physical properties of the materials digitally, in real time, and at molecular and atomic scales. In this next phase, designers and engineers will be able to select and tune the physical properties of individual voxels as easily as geometric attributes. Leveraging decades of research and expertise in precision mechanics, microfluidics and materials sciences, HP has developed a 3D printing technology that achieves this level of control and is already reinventing the digital fabrication and manufacturing paradigms. This presentation will provide an overview of the Jet Fusion™ technology, discuss how it has evolved since its introduction in 2016. The presentation will conclude with a vision of how voxel-scale engineering will help to define the future of 3D printing, additive manufacturing, and digital fabrication.*

Wednesday Afternoon Keynote

Session Chair: Wolfgang Schmidt, Felix Schoeller Group (Germany)

14:00 - 14:50

14:00 **Industrial Applications of Inkjet Technologies,** *Rich Baker, Integrity Industrial Ink Jet Integration LLC (USA)*

Inkjet is a versatile, precision deposition process, that is increasingly finding utilization in industrial manufacturing of products. These usages range from traditional graphics, labels and date-coding, to more novel applications, such as, deposition of functional fluids (biological, pharmaceutical, electronic, etc.), 3D item fabrication, and the deposition of adhesives and coatings. Using his perspective as president and founder of one of the largest independent inkjet systems integrators in the United States, Baker highlights a few of these novel applications of inkjet, plus explore the challenges and barriers to implementation of inkjet into main stream manufacturing.*

THURSDAY, 27 SEPTEMBER

Closing Keynote

Session Chairs: Reinhard Baumann,Fraunhofer Institute for Electronic Nano Systems ENAS and Technische Universität Chemnitz (Germany), and Ingo Reinhold, XaarJet Ltd. (Sweden)

8:45 - 9:30

8:45 **2018-2020 – The Time to Go Industrial with Digital Packaging Production,** *Montserrat Peidró Insa, Heidelberger Druckmaschinen (Germany)*

Due to the automated collection and analysis of user data, the customer approach has become more segment-orientated. As a result, go to the next supermarket and you will see how the variation of products is almost exploding, which has a strong impact on shorter runs and faster production cycles.

We live in a world where the question is not any longer if digital is the answer for packaging printing. Today the question is how to build a profitable business with it, which technology to select strategically and what to take into account to succeed.*

* Abstract only; no extended abstract or proceedings paper.

MONDAY 24 SEPTEMBER 2018

SPECIAL EVENT:
STUDENT/YOUNG PROFESSIONALS GET TOGETHER

Join other students and young professionals to explore Dresden's nightlife.

Monday, 24 September
Meet at 19:00 in the Hilton Dresden Lobby

Opening Keynote: Organic Semiconductors: From Vacuum Deposition to Printing
Karl Leo, Technische Universität Dresden (Germany)
9:00 – 10:00
see details page viii, Congress Center Saal 1&2

10:00 – 10:20 Break to Change Rooms + Mini Coffee Break — Congress Center Foyer

Monday Coffee Breaks sponsored by
IOP Institute of Physics
Printing and Graphics Science Group

TRACK 1

Printed Functional Devices

Session Chairs: Chunghui Kuo, Eastman Kodak Co. (USA); Shinichi Nishi, Japera (Japan); and Enrico Sowade, Zschimmer & Schwarz (Germany)

10:20 - 18:20
Congress Center Saal 1

10:20 **Printed Flexible Pressure Sensor for Robot Skin (Focal),** *Atsushi Nakajima[1,2], Toru Miyoshi[1], Kenji Kohiro[1,3], Motoshi Itagaki[1], Toshihide Kamata[1,4], and Tetsuo Urabe[1,4]; [1]Japan Advanced Printed Electronics Reseach Association (JAPERA), [2]Konica Minolta, Inc., [3]Sumitomo Chemical Co., Ltd., and [4]The National Institute of Advanced Industrial Science and Technology (AIST) (Japan)* 1

JAPERA (Japan Advanced Printed Electronics Technology Research Association) has developed a basic technology to create OTFT array with all printing. In accordance with the requirements of each component, various printing methods including inkjet are used selectively to realize a high-precision flexible pressure sensor array by full printing. A high resolution active matrix type pressure sensor was made on the film base material and the sensor surface was covered with a thin rubber sheet with the same thickness as the sensor pitch. In this research, we apply our printed flexible pressure sensor to robot skins and show examples of tactile judgment and two-way communication at high speed by using obtained pressure distribution.

10:50 **Fabrication and Characterization of Different Sensors on Paper as a Flexible Substrate,** *Goran Stojanovic and Tijana Kojic, University of Novi Sad (Serbia)* A-1

Printed electronics enables the fabrication of electronic components on flexible substrates such as plastic, paper, or textiles, using functional inks and usually additive manufacturing processes. Paper can be a good choice for mechanically flexible substrate in printed electronics, because it is widely available, inexpensive, and well-established in printing industry as well as it is biodegradable and lightweight. The paper-based electronic components can be easily trimmed and folded into different shapes and configurations. Different types of papers can be used as substrates for sensors fabrication intended for a wide range of possible applications.

The goal of this talk is to present fabrication of different sensors—humidity sensors and sensors for bacteria detection, manufactured on various types of papers as a flexible substrates. Sensors have been printed on commercial papers from Felix Schoeller Group, using ink-jet technological process (DMP-3000 Dimatix printer). Structural, electrical, mechanical and optical characterization of developed components will be presented in this talk.

11:10 - 11:45 Coffee Break — Congress Center Foyer

11:45 **A Study of the Potentiality of Inkjet-Printing Technique for the Fabrication of Metal-Insulator-Semiconductor Organic Rectifying Diodes,** *Silvia Conti, Carme Martinez-Domingo, Lluis Terés, and Eloi Ramon, Instituto de Microelectrónica de Barcelona (Spain)* 5

A route for the inkjet-printing of organic rectifying diodes based on Metal-Insulator-Semiconductor (MIS) structure is outlined. The proposed strategy is based on a layer stack of two silver electrodes between which a polyvinyl phenol (PVP) insulator layer and an amorphous organic semiconducting layer are sandwiched. Thanks to the energy barrier given by the presence of a leaky dielectric layer between the electrode and the semiconductor, the current versus voltage characteristics present a rectification ratio of up to $1.5*10^3$ at |10 V| and a current density up to approximately $0.1mAcm^{-2}$.

Finally, a first example of a gas sensor based on the MIS diode is presented as a proof-of-concept for the possible applications of these structures

12:05 **Development and Evaluation of Inkjet Printed TFTs based on Architecture, Materials, and Process Deposition for Better Suitability to Flexible Electronics (Presentation-only Paper; see Appendix for extended abstract),** *Kalyan Mitra[1], Sunil Kapadia[2], Maxim Polomoshnov[2], Reinhard Baumann[1,2], and Ralf Zichner[2]; [1]Fraunhofer Institute for Electronic Nano Systems and [2]Technische Universität Chemnitz (Germany)* A-3

The escalation of the required process development by industrializing the manufacturing of inkjet printed thin film transistors (TFTs) and their respective performance is of high focus. Besides this, the entire progress over the manufacturing of TFTs based on the conventional design architecture i.e. horizontal stack via inkjet technology is limited. Here, the limitation is mainly defined by the technological capabilities to produce lower channel lengths between the Source/Drain (S/D) electrodes. Alternatively, in contrast a TFT design architecture route i.e. based on vertical stack is exploited, where the device performance is improvised and not limited anymore by the channel length between S/D, despite of using similar functional ink materials. This has led to breaking of the technological bottle neck.

12:25 **Special Pattern Design based on Printed Electronics (Interactive Preview),** *Yingmei Zhou, Shanghai Publishing and Printing College and Zhongmin Jiang, University of Shanghai for Science and Technology (China)* 10

With the development of technologies in printed electronics, the products more personalized, irregular and customized application are more and more welcome. Nowadays, technologies have solved many technology problems such as circuit conductivity, functional inks, printing method, substrate, etc. In this paper, the aim is to achieve different LED display by same background circuits. We designed the common circus that suited personalized various appearance with low cost. Then we tried irregular circuit to achieve different effect. This study attempts to show the important ways on design and art, to help optimize ways to special pattern application.

12:30 **Preparation of Graphene/Cellulose Composite Conductive Films (Interactive Preview),** *Fuqiang Chu[1], Bo Cui[1], Xin Wang[1], Xintao Gao[2], and Zhiwei Zhang[1]; [1]Qilu University of Technology and [2]Shandong Hongfei Packaging Corporation (China)* 12

In this paper, carboxymethyl cellulose was used as matrix and graphene was used as conductive filler, compounding graphene with carboxymethyl cellulose. To prepare graphene/cellulose composite conductive film, the composite effect of it was discussed. Firstly, graphene was prepared by chemically reducing graphene oxide with ascorbic acid as reducing agent, and its conductivity was up to 110.2 S/cm. And then, graphene and carboxymethyl cellulose were composited by physical blending. When the mass ratio of graphene oxide to carboxymethyl cellulose was GO:CMC=1:6, the electrical conductivity of the composite film was 8.5×10-2 S/cm. Finally, graphene/cellulose composite conductive film was prepared by coating a graphene/cellulose composite system on a polytetrafluoroethylene substrate.

12:35 **Flexible Circuits Fabricated through Inkjet Printing (Interactive Preview/Presentation-only Paper; see Appendix for extended abstract),** *Xingye Zhang, Shuo Wang, Zhidan Li, Haiyan Wang, and Yanlin Song, Chinese Academy of Sciences (China)* A-5

Inkjet printing is an advanced digital functional material deposition method, and is replacing screen printing in many application fields. In this work, nano silver conductive ink was prepared and printability was test. Flexible circuits were fabricated through inkjet printing with epson4880 inkjet head. Furthermore, the printed circuits were cured by NIR light, which avoid high temperature baking for long time. The circuit graphic quality and electronic performance were comprehensively studied and the possibility for replacement of thick film conductive circuits fabricated through screen printing was evaluated.

12:40 – 14:00 Lunch Break (on own)

State-of-the-Art Keynote:

Printing Future Electronic Devices with Organic Semiconducting Materials,

Mark James, Merck Chemicals Ltd. (UK)

14:00 – 14:50

see details page viii, Congress Center Saal 1&2

14:50 – 15:10 Break to Change Rooms

Printed Functional Devices continues

Session Chairs: Oh Hyun Baek, Samsung Electronics, Inc. (South Korea); Scott Silence, Corning Inc. (USA); and Enrico Sowade, Zschimmer & Schwarz (Germany)

15:10 – 18:20

Congress Center Saal 1

15:10 **Inkjet Printing for MEMS Device (Presentation-only Paper),** *Matti Mäntysalo, Mika-Matti Laurila, and Behnam Khorramdel, Tampere University of Technology (Finland)**

Printed electronics is one of today's revolutionary approaches to fabricate electronics and electronic packages. Using inkjet printing offers the ability to apply controlled amount of functional (i.e. conductive, dielectric, and semiconductive) material with very high precision accuracy on many different substrates ranging from ceramics to low-cost plastics and even paper. The direct deposition of functional materials gives flexibility to production and inkjet printing technology is used, for instance, in RFIDs, intelligent packages, and microelectronic packages. Generally, the focus of printed electronics research has been more in organic devices rather than in fabrication steps of semiconductor technologies. This research, however, presents the use of inkjet printing in fabrication of high-density re-distribution layers (RDL) and through silicon vias (TSV).

Nowadays, TSV are used in 3D interconnections in highdensity microelectronics devices. TSVs are fabricated using chemical vapor deposition (CVD) or electroless deposition to fill the vias. Since these methods are time consuming, inkjet technology as an additive digital fabrication can be implemented to make the filling process much faster, more agile and more cost efficient. In this research, we investigate the use of inkjet printing as an alternative fabrication method for a high- density RDL and TSV of a MEMS device. In order to achieve the necessary wiring density, we used a super inkjet (SIJ) capable of femtoliter droplets enabling only few micron line widths.

15:30 **Fabrication of Large Area Inkjet-Printed OTFTs on Flexible Substrates: Manufacturing Challenges and Electronic Design Constraints (Presentation-only Paper; see Appendix for extended abstract),** *Eloi Ramon, Institute of Microelectronics of Barcelona IMB-CNM (CSIC) and Universitat Autònoma de Barcelona (UAB) (Spain)* A-6

Trends in electronics industry, such as demand for wearable devices and pervasive sensing, target the realization of low-cost, flexible and autonomous electronic systems for which foldable displays, large area sensors or smart labels require new fabrication methods. In this context, inkjet printing (IJP) technology has attracted a lot of interest as an advanced micro/nanofabrication technique due to its high pattern flexibility and processing simplicity. IJP is based in an efficient use of materials, which makes it a low cost approach as only a very small amount of materials is required in comparison to other solution-based deposition techniques. The low thermal budget and the high degree of mechanical flexibility of inkjet deposition open new opportunities to produce soft, lightweight, environmentally friendly and flexible electronic devices.

All-inkjet printed devices such as amperometric sensors, organic thin film transistors (OTFTs) and bioFETs have been demonstrated in the literature manufactured on low-cost and flexible substrates such as polymeric, paper or delicate substrates. Although alternative manufacturing processes for electronic devices such as inkjet printing suffer from lower accuracy and lower yield compared to traditional microelectronic manufacturing methods, their large surface area, the use of flexible substrates and biocompatible inks, and the rapid prototyping and low-cost of the fabricated devices, makes these manufacturing technologies highly promising for various sensing applications such as biosensors or disposable point-of-care devices among others.

All this makes the presented manufacturing methods promising towards a novel industrial manufacturing route for low-cost devices and circuits as alternative to traditional lithography-based manufacturing interesting for a wide range of applications such as flexible, disposable and highly portable personal diagnosis.

* Abstract only; no extended abstract or proceedings paper.

15:50 **Micro-Reactive Inkjet Printing of Polyaniline,** *Mei Ying Teo, Logan Stuart, Kean Aw, and Jonathan Stringer, University of Auckland (New Zealand)* 16

Inkjet printing, the digitally-controlled deposition of microdroplets onto a substrate, presents a number of potential advantages as a polymer additive manufacturing technique due to a relatively high spatial resolution and the ability to easily deposit multiple materials in one structure. It is, however, fundamentally limited by the low viscosity of the printed ink, which limits both the amount of solid phase present within the ink or necessitates the use of post-deposition curing of the ink to form the structure. Micro-reactive inkjet printing attempts to circumvent these limitations by exploiting the controlled in-air collision of two complementary reactive microdroplets, so as produce a microdroplet of the desired product before impact with the substrate. In this work, we explored the formation of polyaniline (PAni) on glass substrate through oxidative polymerisation of aniline in an acidic environment via a microreactive inkjet printing technique. We successfully printed different patterns of polyaniline onto glass substrates, as shown by microscopy and spectroscopy, and a conductivity of approximately 0.6 S cm-1 was achieved. We envision this printing technique to be particularly useful for a wide range of conducting polymer synthesis in the future.

16:10 – 16:40 Coffee Break — Congress Center Foyer

16:40 **PANI-Graphene Nanocomposite as an Active Material for Large-Scale Low-Cost Electrochemical Double Layer Capacitors (Presentation-only Paper; see Appendix for extended abstract),** *Rekha Singh[1], Thomas Weissbach[2], Tino Zillger[2], Anil Kumar[1], and Arved Hübler[2]; [1]Indian Institute of Technology Bombay (IITB) (India) and [2]Chemnitz University of Technology (Germany)* A-8

Electrochemical double layer capacitors (EDLC) are better known as "Supercapacitor" or "Ultracapacitor" and occupy a kind of intermediate position and bridge the power/performance gap between traditional dielectric capacitors (high power) and batteries (high energy). Key requirements for a successful application are a high energy density, a rapid, easy and scalable fabrication and low cost of the overall system.

High surface area, high double-layer/pseudocapacitance, and low resistivity are the ideal features for an active material to be used in EDLCs. Graphene, carbon nano tubes (CNT) and metal oxides have been used in the past. Because it is practically impossible to get all the desired and abovementioned properties in a single material, using composite (hybrid) materials is an excellent approach, leading to the enhance-

ment of the properties due to the synergistic effect of the two/more components. In the past, various substrate materials such as metal, textile, or carbon paper have been used. More recently, conventional paper was shown as substrate for EDLCs. Print processes such as flexographic and gravure printing are ideal for the preparation of stacks of layers on a large scale and therefore also the fabrication of EDLCs.

In this contribution, we selected graphene and polyaniline (PANI) as the two components of our active material because of their low-cost of synthesis and excellent in-situ properties. An electrochemical process and a mechanical process is utilized for producing graphene – faster than direct solution exfoliation methods. The highest specific capacitance obtained by us till now for PANI- graphene composite materials is 160 F/g (at 100 mA/g) in a symmetric parallel-plate capacitor assembly using a common gel electrolyte (H_3PO_4 / polyvinyl alcohol). In contrast, graphene gives a specific capacitance of ~ 60 F/g under similar conditions, which is considerably lower. We are working on the precise optimization of the polymerization conditions of PANI in order to increase the synergistic effect of the two components and to improve the composite nano-structure. Moreover, the effect of the material of the paper substrate is crucial on the preparation and stability of the EDLC device. The performance degradation of the EDLC is investigated on the basis of the internal resistance, the capacity and the energy density. Challenging are the stability of the current collector and the electrical connection as a high conductivity is crucial for high energy densities. Large-scale fabrication on paper substrates is demonstrated, thereby lowering fabrication cost and increasing the energy density of the overall system.

17:00 **Flexible High-Performance Metallic Interconnects Prepared by Innovative Diode Laser Array Treatment of Inkjet-Printed Layers (Presentation-only Paper),** *Mykola Vinnichenko[1], Marco Fritsch[1], Junchen Xiao[1], Denys Makarov[2], Tetiana Voitsekhivska[2], Viktar Sauchuk[1], and Mihails Kusnezoff[1]; [1]Fraunhofer Institute for Ceramic Technologies and Systems IKTS and [2]Helmholtz-Zentrum Dresden-Rossendorf (Germany)**

Inkjet printing is a digital technology, offering key advantages in terms of high speed (R2R compatible), low material consumption, and miniaturization of printed features. A thermal post-processing of inkjet-printed structures in furnace approximately for 30 min at temperatures at least 130 °C for silver or >300 °C in case of copper and gold is usually required to remove organic components, sinter the metallic particles, and enable electrical conduction. This is a critical technological step determining, on the one hand, the final morphology and properties of the printed materials, but on the other hand limiting the processing speed, narrowing the range of applications and materials, and increasing the costs of the printed structures.

The present work focuses on advanced approach based on high power diode laser array treatment of inkjet printed layers. In this case, the energy of incident light is absorbed selectively by the printed structures leading to their localised heating on a millisecond timescale without damaging the thermally sensitive substrate. The water-based proprietary IKTS metallic nano-ink formulations (silver, gold, and platinum) were used for printing metallic interconnects on various thin (PET, 120 µm, paper, 170 µm) and ultrathin (PET, <10 µm) substrates. All 22 to 30 mm long printed lines were electrically conducting already after drying. In case of printed silver, electrical resistivity values were by a factor of ~7 (paper) to ~14 (PET) higher than those of the bulk material. Subsequent millisecond laser processing enabled silver contacts with a low electrical resistivity (~3x of bulk) even on ultrathin 2.5 µm PET substrates. The interconnects on paper were bendable to a radius as small as 4 mm with the resistivity increase of 1%; a 100 cycle test of bending to a radius of 10 mm led to negligible changes of their resistivity values. The resulting porous morphology of the silver layers appears to be crucial to ensure their high flexibility. The developed interconnects were validated by realizing electrical contacts for large area (75 mm x 200 mm) flexible arrays of magnetic field sensors. In case of gold and platinum inks, this approach also yielded layers with low electrical resistivity, which was in case of gold structures by a factor ~10 higher compared to the values of the bulk material. The effect of laser processing parameters on the electrical properties of interconnects was related to their microstructure modification.

17:20 **Green Laser Sintering of Copper Oxide (CuO) Nanoparticle Ink (Presentation-only Paper; see Appendix for extended abstract),** *Kye Si Kwon[1], Zhao Lu[1], and Md. Khalilur Rahman[1,2]; [1]Soonchunhyang University (South Korea) and [2]Comilla University (Bangladesh).* A-10

In the recent years, the interest of printed electronics have extensively increased due to its advantages of fast, cheap and simple process. For this reason, there has been a growing interest in metal NP ink for functional printing of conductive track. Recently, Cu NP ink have been developed as a potential candidate alternative to Au and Ag as a low cost material. However, Cu NP is easily to be oxidized thus make thermal sintering impossible in ambient environment. So, inert environments have been used to sinter this particular ink, but it will again increase the processing costs. To mitigate this issue of Cu ink, several approaches are increasing the interest such as plasma sintering, IPL sintering and laser sintering. But plasma sintering are too slow and IPL sintering affects much larger areas at a time and hence for small area sintering, laser is most suited for better accuracy.

* Abstract only; no extended abstract or proceedings paper.

17:40 **JIST-FIRST Process Development of Large Area R2R Printing and Sintering of Conductive Patterns by Inkjet and Infra-Red Technologies Tailored for Printed Electronics,**
Kalyan Mitra[1], Sunil Kapadia[2], Melinda Hartwig[2], Enrico Sowade[2], Zhenxing Xu[3], Reinhard Baumann[1,2], Ralf Zichner[1]; [1]Fraunhofer Institute for Electronic Nanosystems ENAS, [2]Technische Universität Chemnitz, [3]Zschimmer & Schwarz, and [3]PadaLuma Ink-Jet-Solutions GmbH & Co. KG (Germany) 21

The technological advancement in the field of printed electronics over roll-to-roll (R2R) platform has become very attractive, because of the several advantages such as mass production, large area application, cost-saving and high-speed capabilities. The inkjet technology, on the other hand, among other printing technologies promotes individualization and contact-less deposition process qualities. In this article, the authors demonstrate the state of the art R2R setup for printing silver (Ag) conductive patterns on PEN substrate using inkjet and infra-red technologies. The deposition of the conductive patterns was accomplished using a nanoparticle-based Ag ink and industrial printheads from Fujifilm Dimatix. The novelty of the research work is realization of a print setup, consisting of an industry relevant flexible printhead assembly and drop evaluation station, which are mounted over a R2R printing system. The entire setup allows the user to first evaluate the ejection of the droplets and then stabilize the print parameters without involving the web substrate, followed by re-positioning of the inkjet assembly back to the R2R printing system. The capability of the print setup is exhibited by varying the printing resolution for the defined digital patterns. In addition, the post-treatment of the conductive patterns was tailored with the implementation of an infra-red based sintering module from Heraeus Noblelight GmbH. The power density of the filaments from the sintering module was varied to achieve the maximum conductivity and to ensure no physical damage to the patterns and substrate. The results indicate that such a print setup is very flexible and can offer several benefits to the printing process of conductive patterns, e.g., obtaining line width below 80 µm and sheet resistance of about 0.5Ω/□, with the advantage of sintering the patterns within 20 s.

18:00 **JIST-FIRST Inkjet Printing and Intense Pulsed Light Sintering of Multiwall Carbon Nanotubes for Sensor Applications,** *Dana Mitra, Tatiana Zubkova, Carina Gerlach, Olfa Kanoun, Dominique Miesel, Heinrich Lang, and Reinhard Baumann, Technische Universität Chemnitz (Germany)* . . . 33

Fully inkjet-printed multiwall carbon nanotube (MWCNT) layers and their feasibility towards the implementation as a low cost and flexible sensing element is reported. The focus is set on the resistive behavior of the carbon nanotubes (CNTs) and the adjustability towards a defined target range. To realize the sensors on a low cost and high flexible polyethylene terephthalate (PET) foil, the intense pulsed light (IPL) sintering is introduced to achieve the required performance for both the CNT dispersion as well as the silver electrodes. The very novel topic of the simultaneous photonic sintering of a two-material layer stack and the involved challenges are demonstrated. The MWCNT dispersion was successfully printed with the inkjet printing technology and functionalized by thermal and IPL sintering methods, achieving a resistance of 100 kΩ in the target area (1 kΩ to 1 MΩ) for the sensor. The dependence of the resistance on parameters like number of CNT overprints, the pattern layout as well as the post-treatment methodology is analyzed in detail. These results can be further employed for the development of CNT-based sensor elements and the change in their resistance caused by environmental conditions. In addition, such single sensors raise the opportunity of a combination to a sensor matrix to demonstrate the integration in applications such as a shoe sole (proof of concept) but primarily for medical applications e.g., in mattresses in hospitals for constant recording of bedfast or comatose patients.

CONCURRENT EVENT Colleague Connections: Print4Fab Speed Networking
16:40 – 18:00
see details page xvii, Congress Center Saal 2

TRACK II

Ink/Substrate Interaction

Session Chairs: Jiro Oi, HIT Research Corp. (USA); Shinri Sakai, Yamagata University (Japan); and Zhe Shu, Albert-Ludwigs-Universität Freiburg (Germany)

10:20 – 16:10

Congress Center Saal 2

Session sponsored by

RICOH

10:20 **Structure and Chemistry—Functional Paper for Sublimation Printing and Transfer (Focal/Presentation-only Paper; see Appendix for extended abstract),** *Michael Jocher, Emanuele Martorana, Sebastian Scholz, Georg Bieniek, Dirk Hörnschemeyer, and Knut Hornig; Felix Schoeller Holding GmbH & Co.KG, (Germany)* A-12

Functional paper for sublimation printing and transfer is increasingly used in textile industry, graphics and gift production. These papers are mainly printed by inkjet-printing technology with sublimation inks. The printed paper side is then brought into contact with polymeric substrate mainly polyester textiles or polymeric coated other substrates like cups or aluminum plates. By applying heat in a calender or transfer press the ink undergoes phase transition into gaseous state and sublimates onto the polymeric substrate for example the polyester fibres within the textile, where it is being fixed.

10:50 **Development of an Optimized Nonwoven Substrate for Digital Printed Wallpaper (Presentation-only Paper),** *Knut Hornig, Michael Avermann, Dieter Goeppert, and Dieter Kaumkoetter, Felix Schoeller Holding GmbH & Co.KG (Germany)**

Digitally printed wallpaper meets an increasing demand for personal home decoration as well as for professional decoration. Several printing technologies are used to produce wallpaper prints, ink jet printing using solvent or latex inks as well as electrophotography. We developed a range of dedicated digitally printable wallpaper substrates to meet the specific demands and needs regarding material properties, printability and workability/gluing.

The goal of our development is a range of specialized substrates for wallpaper, based on so-called nonwovens. The web consists mainly of virgin cellulosic fibres and is produced by a wet lay process like paper making, but contains some amount, typically 10 … 20 % of synthetic fibres to obtain a dimensional stable sheet also in the wet gluing process. Furthermore, stiffness/softness is significantly lower than that of a classical paper or nonwoven wallpaper substrate, to give an optimized workability in the gluing process, and a perfect look and feel of the web as well as the final wall surface.

For achieving a sufficient opacity to cover optical unevenness or specks of the wall background, white pigments with high light scattering power are incorporated into the nonwoven base sheet in the wet lay process on the paper machine.

Depending on the print technology and ink system used, further coating or surface processing can helpful for best image quality and surface robustness. Matting to lowering the gloss of the substrate can avoid unwanted effects like differential gloss. Different inks systems like solvent or latex inkjet inks or electrophotographic toner systems require different coatings and surface properties for the best print quality.

An overview regarding challenges of the different printing technologies and technical solution on substrate side will be provided.

11:10 – 11:45 Coffee Break — Congress Center Foyer

11:45 **Study on Printing Performance of Degradable Polylactic Acid Film Packaging Material,** *Hongge Guo, Gaiying Wei, Yingying Qin, and Maohai Lin, Qilu University of Technology (China)* 38

In this paper, the PLA resin of Ingeo 4032D from Nature Works(USA) is selected as the research object. Linear Low Density Polyethylene (LLDPE) or EPDM rubber grafted glycidyl methacrylate (EPDM-g-GMA) is selected for PLA blend modification. At first, the mixture was granulated in an extruder and then blown to obtain various films. The mechanical properties, optical transparency, barrier properties, contact angle and printability of the polymer film were measured. The results show that through the modification, without loss of transparency, the mechanical properties, barrier properties, polarity of the surface and the adhesion of the printing code of the PLA film are improved, which is beneficial to the solution of environmental pollution caused by the undegradable of current plastic film.

* Abstract only; no extended abstract or proceedings paper.

12:05 **Basic Study on Effects of Water Content on Printing Paper on Equivalent Thermal Conductivity,** *Takashi Fukue[1], Hirotoshi Terao[2], Koichi Hirose[3], Tomoko Wauke[2], Hisashi Hoshino[2], Koji Sato[3], and Mayu Endo[2]; [1]Kanazawa Institute of Technology, [2]Alps Electric Co., Ltd., and [3]Iwate University (Japan)* 41

This paper describes a relationship between a water content of printing paper and an equivalent thermal conductivity that affects to printing quality of printers using the heat such as laser printers and direct thermal printers. Our study targets to describe the relationship between the water content and the thermal conduction in the printing process. Especially in this report, we firstly investigated a relationship between the humidity around the paper and the change of the water content of the thermal paper. The dried thermal paper was mounted in the constant temperature and humidity chamber and the time history of the change of the paper weight was measured by using the precision balance. It is found that the water content of the thermal paper is dependent on the humidity. However, even if the humidity around the paper is changed, the water content of the paper is rapidly saturated according to the humidity. Therefore, from the viewpoint of the thermal design of the printing process, the transient change of the water content of the paper may not become important against the value of the humidity itself. In addition, the relationship between the water content of the paper and the thermal conductivity was investigated through a combination of the 1-dimensional thermal conduction experiment in the constant temperature and humidity chamber with the thermal network analysis.

12:25 **Tall Oil Rosin: A Substitute for Gum Rosin in Development of Offset Printing Ink (Interactive Preview),** *Mahuya Biswas and Srabana Kundu, DIC India Limited, and Shankhya Debnath, Regional Institute of Printing Technology (India)* 44

Gum rosin based resin is widely used in manufacturing of offset printing inks, because of its robust chemical and physical properties. However, another by-product obtained in the kraft pulping process, by distillation of crude tall oil is tall oil rosin. The rosin acid content in the tall oil rosin makes the resin made from it especially of interest to the ink maker. Moreover, tall oil resin offers some economic benefit over gum resin. This work involves exploring the viability of using inks made from tall oil rosin based resin and whether it can be used as a suitable substitute for gum rosin based resin, especially for being used in package printing purposes, which requires ink having good gloss and quick-drying properties at the same time. In this work a varnish was made from tall oil resin and was characterized. Finally complete process set of finished inks were made from both tall oil resin and gum resin and their properties were compared.

12:30 **New and Unique Hotend for 500°C Range 3D FDM/FFF Usage (Interactive Preview),** *Hideo Taniguchi and Nobuhisa Ishida, HIT Research Corporation (Japan), and Jiro Oi, HIT Research Corporation (USA)* 49

Three-dimensional (3D) printing is one of the fast-growing printer fields and the most popular & simplest method is known as Fused Deposition Modelling (FDM) or Fused Filament Fabrication (FFF). The process is to heat up a thermoplastic material to the melting point by a heating device and extrudes the melted material through a small hole. The extruded material is placed, layer by layer, to create a three-dimensional object. The heating device is referred to as a "hotend" in industry. We found our patented temperature-controllable heating devices to be an excellent match for this application.

There are many hotends on market today for the materials with lower (low to mid-200°C) temperature range. However, the market is in need for high temperature (400°C~500°C) hotend which is compatible with the materials with higher mechanical strength and durability. This type of material is known as super engineering plastic such as PEEK (Polyether Ether Ketone), TPI (Thermoplastic Polyimide) and so on.

We developed a unique heater which is the hotend key part for the high temperature application. Our heating element is integrated on a ceramic substrate and it doubles as the temperature sensor. The heating element has a high TCR (Temperature Coefficient of Resistance) – positive 3300 ppm/°C. The temperature change can be detected easily by monitoring the driving current of the element. Another part is that the hotend body is made of single low thermal conductive metal (Titaniumalloy) piece rather than multiple materials. Heating is done "as needed" base since the characteristics of the heater is "on-demand-heating-like" and the Titanium-alloy body acts as the heat-break so that the big cooling system is not required.

12:35 – 14:00 Lunch Break (on own)

State-of-the-Art Keynote:
Printing Future Electronic Devices with Organic Semiconducting Materials,
Mark James, Merck Chemicals Ltd. (UK)
14:00 – 14:50
see details page viii, Congress Center Saal 1&2

14:50 – 15:10 Break to Change Rooms

COLLEAGUE CONNECTIONS: PRINT4FAB SPEED NETWORKING

Monday, 16:40 – 18:00
Congress Center Saal 2

Moderator: Ingo Reinhold, XaarJet Ltd. (Sweden)

Join colleagues in a fast and fun session where you learn about the technical expertise and interests of others attending the conference. A great way to get to know fellow delegates, share knowledge, and enhance your network of digital printing professionals.

Ink/Substrate Interaction continues

Session Chairs:Mineo Kaneko, Canon Inc. (Japan); Steve Simske, Colorado State University (USA); and Zhe Shu, Albert-Ludwigs-Universität Freiburg (Germany)

Congress Center Saal 2

15:10 **Stability of Line Structures Produced by Inkjet Printing (Presentation-only Paper),** *Jinxin Yang and Brian Derby, University of Manchester (UK)**

Precise patterning is critical for inkjet printing, especially to achieve a wide range of printed electronic devices. Thus, an understanding of the formation of a stable parallel line structure is a starting point to achieve optimum patterning. Duineveld developed a dynamical model for the stability of a growing line with a zero receding contact angle as a function of the spacing and arrival rate of printed drops. The printed line structure may become unstable when the dynamic contact angle between the liquid line and the substrate is larger than the advancing contact angle. This results in a line morphology of a series of bulges connected by a uniform liquid bead. Stringer further developed Duineveld's model to predict the stability region of appropriate drop spacing and printing rate for arbitrary ink/substrate combinations.

15:30 **New White Pigment Ink: Correlation between Structure of Inorganic Hollow Particles and White Opacity,** *Tomohiro Hirade and Hiroshi Goto, Ricoh Co., Ltd. (Japan)* 53

We have developed a new white ink which features less sedimentation and high white opacity even upon non-permeable media. Titanium dioxide has been used in the white ink in order to obtain high opacity, but it has the problem of sedimentation. Hollow resin particles have also been used for white ink. Sedimentation is drastically reduced, however, white opacity is limited when heating and drying especially on non-permeable media. In order to solve these problems, we focused on characteristics of hollow silica particles with low density in addition to heat resistance and solvent resistance. We developed new white pigment of hollow silica particles which lead to less sedimentation and high white opacity by optimizing primary particle size and wall thickness size.

15:50 **Water-based Green Lithography,** *Haihua Zhou, Yunxia Liu, and Yanlin Song, Chinese Academy of Science and Beijing National Laboratory for Molecular Science (China)*. 57

Environmental friendly materials have aroused great attention. Lithography printing takes the most important position in traditional printing industry. So far, it is still a great challenge for lithography printing to use water based inks for mass production. Here we report the integration of green plate, green plate-making technology and water based ink to achieve water based lithography. The main problem is how to get a clear hydrophilic and hydrophobic area discrepancy on the printing plate. The key is to control the surface energy in micro-area on the printing plate. Nano materials have been developed to achieve this water based lithography.

16:10 – 16:40 Coffee Break — Congress Center Foyer

Colleague Connections: Print4Fab Speed Networking
16:40 – 18:00
see details xvii Congress Center Saal 2

* Abstract only; no extended abstract or proceedings paper.

TRACK TDPF

INTERNATIONAL SYMPOSIUM ON TECHNOLOGIES FOR DIGITAL PHOTO FULFILLMENT (TDPF) 2018

Session Chair: Joe LaBarca,
Pixel Preservation International (USA)
12:00 – 18:10
Salon St. Petersburg

12:00 **Welcome and Introductions**

12:10 **V-Paper Tower for In-House V-Paper Production,** *Brigitte Peleman-Vantieghem, Peleman Industries (USA)***

Last year we reviewed V-Paper, the new paper product for premium photo books that will lay flat when opened. The V-Paper is specially produced to easily allow production of premium lay-flat photo books. This paper will discuss the new V-Paper Tower, which is available for use in-house to produce moderate to high volumes of V-Paper for premium photo books produced in-house and on-site. Lay-flat photo books are a growing segment of the premium photo gifting market. This paper will also review the new PHOTOMORE photo gifting products available to produce in-store customized photo gifts.

12:40 – 14:00 Lunch Break (on own)

State-of-the-Art Keynote:
Printing Future Electronic Devices with Organic Semiconducting Materials,
Mark James, Merck Chemicals Ltd. (UK)
14:00 – 14:50
see details page viii, Congress Center Saal 1&2

14:50 – 15:10 Break to Change Rooms

15:10 **The Importance of Dark Keeping Factors in Determining Overall Image Permanence of Photographs,** *Patrick Webber, Kodak Alaris (USA)***

Traditional reporting of the image permanence of photographs has tended to primarily focus on light stability. The reality of how consumers use and store prints is that the vast majority of the print life is stored in the dark. The dark stability of traditional silver halide photographic paper was primarily driven by thermal affects. However many of the newer digital material used for photographic prints are susceptible to additional dark factors including humidity, and atmospheric pollutants can result in predicted life times being significantly shorter than reported by light stability data alone. This paper will discuss these additional dark factors and provide comparisons to traditional silver halide photographic paper.

15:40 **Image Permanence of Photographic Prints Under LED Lighting,** *Hiroshi Ishizuka, Fuji Photo Film Co., Ltd. (Japan)***

LED (Light Emitting Diode) lighting has been widely used as a major light source to illuminate photographic prints. Stipulating the spectrum of the LED lamp is essential to evaluate the light stability of photographic prints under LED lighting. Moreover, the uniformity and consistency of the light are also critical for the image permanence tests. These essential points have been discussed in this study. The fading behaviours of some photographic prints under LED lamps are shown in comparison with those under UV filtered Xe lamp, which simulates indirect sun light.

16:10 – 16:40 Coffee Break — Congress Center Foyer

***All papers from IS&T's International Symposium on Technologies for Digital Photo Fulfillment are available for free download on the IS&T Digital Library at http://ist.publisher.ingentaconnect.com/content/ist/tdpf.*

16:40 **Improvements in the Image Quality of Thermally Printed Security Cards,** *Mark Mizen, HID Global (USA)***

Thermal transfer printing has proven useful in the production of security cards using relatively low-cost desktop printers. Retransfer printers are particularly popular for the production of technology cards incorporating edge-to-edge graphics. Unlike standard thermal transfer printing, retransfer printing uses an intermediate transfer film to transfer the image to the security card. Most thermal printers operate at 300 dpi; however, there has recently been a move to higher resolution 600 dpi printers. These printers are able to more easily reproduce small text sizes and intricate graphics, including Asian fonts.

Thermal transfer is an asymmetric process in that the thermal printhead governs resolution in one dimension, while the ability to rapidly change temperature of individual elements in the thermal printhead governs resolution in the other dimension. To minimize the overall cost of the printer, the thermal printhead is generally aligned with the short edge of the plastic card.

High-resolution printheads improve image quality with resin transfer and dye sublimation printing. Resin transfer is generally used for black text and bar codes, while dye sublimation is optimized for colored text, graphics, and photos. For text and bar codes, higher resolution gives greater legibility to small text sizes and greater readability to bar codes. For color graphics and photos, higher resolution improves the printer's ability to reproduce fine details.

17:10 **An Overview of WIR Print Permanence Ratings for Color Print Materials Used in Consumer and Professional Markets,** *Henry G. Wilhelm, Wilhelm Imaging Research, Inc. (USA)***

This presentation gives an overview of the various factors affecting the display permanence and dark-storage stability of the many types of color prints commonly found in consumer and professional markets. The similarities and differences between Epson, Canon, and HP inkjet prints, made with dye-based inks, pigmented inks, traditional silver-halide (chromogenic) prints made with Kodak and Fuji color papers (including the new, improved-permanence Fujicolor Crystal Archive papers to be introduced by Fujifilm in late 2018), thermal-dye-transfer prints (often called "dye-sub" prints), ChromaLuxe dye-sublimation prints (often referred to as "metal prints"), and prints made with UV-curable pigment inkjet processes are discussed. WIR print permanence test methods are described for light stability, dark storage stability, ozone resistance, waterfastness, and humidity-fastness. The effects of ozone in polluted air is an especially important factor to consider in evaluating the permanence of dye-based inkjet prints made with "instant dry" microporous photo papers. In this study, both the Wilhelm Imaging Research "Display Permanence Ratings" and the WIR "Unprotected Ozone Resistance Ratings" were found to cover an extremely wide range – the most stable prints were rated to last more than 200 times longer than the least stable prints..

17:40 **Company Profiles**

Concurrent Event: Colleague Connections: Print4Fab Speed Networking
16:40 – 18:00
see details page xvii, Congress Center Saal 2

***All papers from IS&T's International Symposium on Technologies for Digital Photo Fulfillment are available for free download on the IS&T Digital Library at http://ist.publisher.ingentaconnect.com/content/ist/tdpf.*

TUESDAY 25 SEPTEMBER 2018

Tuesday Keynote and Awards
Keynote: Electronic Skins Connecting Cyberspace and Human,
Takao Someya, University of Tokyo (Japan)
9:00 – 10:00
see details page ix, Congress Center Saal 1&2

2018 Exhibit Open
10:00 – 17:30
see details page vii, Piano Bar Foyer

10:00 – 10:20 Break to Change Rooms + Mini Coffee Break — Piano Bar Foyer

SPECIAL EVENT

INTERACTIVE PAPERS SESSION, DEMONSTRATIONS, AND EXHIBIT HALL HAPPY HOUR

Tuesday, 16:00 – 17:30
Piano Bar Foyer

Meet with interactive authors, authors demonstrating products, exhibitors, and other colleagues over a beer.

TRACK I

Digital Textile Printing

Session Chairs: Rich Baker, Integrity Industrial Ink Jet Integration LLC (USA); Christian Maus, Evonik (Germany); and Atsushi Tomotake, Konika Minolta Inc.(Japan)
10:20 – 15:50
Congress Center Saal 1

10:20 **Digital Textile Printing: Current State and Transformation to Digital Textile Manufacturing (Focal/Presentation-only Paper),** *Ronald Askeland, Howard Doumaux, and Edward Davis, HP Inc. (USA)**

The primary colorant classes of textile printing inks are reactive dyes, acid dyes, disperse dyes and pigments. Reactive dyes are used with cellulosic fibers such as cotton, viscose, rayon and linen and can also be used on silk, wool and nylon. Acid dyes are used with polyamide fibers such as wool, silk and nylon. For both reactive and acid dyes, a steaming process is required for fixation, followed by washing to remove excess dye. Disperse dyes are used for polyester and polyester blends. At high temperatures (~200° C), disperse dyes go into the vapor phase and are absorbed into the fabric fibers. Pigment inks print on all textiles by utilizing a binder to bind the colorant to the fabric. Heat fixation is used to achieve fastness and washing is not required as part of the pigmented ink printing process.

The total worldwide textile market is ~450 billion square meters. Dyed fabrics accounted for ~418 billion square meters and ~32 billion square meters were printed with analog processes (primarily screen printing). Digital textile printing accounted for 1.8 billion square meters (approximately 5% of the total printed textile market). The most prevalent digital textile inks are reactive dyes and dye sublimation. Over 50% of analog printing uses pigmented inks, while only 3% of digital roll-to-roll printing use pigment. Direct to garment (tshirt printing) is the primary application for digital pigmented inks. Growth of digital textile printing (19% CAGR over the next 5 years) will continue to be driven by factors including fast fashion, inventory reduction, variable data, elimination of analog processes and improvements in digital textile inks. Most of the growth will be in dye sublimation and pigmented inks due to the environmental concerns with reactive and acid dyes.

Digital textile printing will evolve into digital textile manufacturing due to increases in ustomization, fabric functionality and performance features. This transformation will be driven by the confluence of democratization of the design process, supply chain efficiencies and integration with Industry 4.0.

10:50 **Inkjet Printing of Textiles – Inkjet Ink Formulations and Further Textile Auxiliaries (Presentation-only Paper; see Appendix for extended abstract),** *Enrico Sowade, Oliver Richter, Peter Oehme, Nora Wetzold, Julia Ahrens, and Andreas Schoenfeld, Zschimmer & Schwarz Mohsdorf GmbH & Co. KG (Germany)* A-13

During the last years, inkjet printing of textiles is attracting increasing interest and the market is growing rapidly. However, screen printing was and still is the major technology for the textile printing industry. But for some textile market segments, there is already a clear transition from the traditional screen printing technology to digital printing technologies. Due to the rising customization trend, smaller production batch sizes, requests for faster product availability and higher ecological requirements, digital textile printing is becoming more and more mainstream. The worldwide digital textile printing market in 2016 for apparel, flags and banners, home decors, industrial textiles for automotive and

* Abstract only; no extended abstract or proceedings paper.

aerospace and similar textile products was rated to about 1.3 billion USD with about 1 billion m² of digitally printed textiles. There is strong market growth of digital textile printing with about 17-25% each year. Especially inkjet dye sublimation printing on synthetic fabrics is already considered as a mature technology for textile applications with a market share in inkjet textile printing of approximately 60%. The market share of inkjetprinted pigment inks for textiles is in the range of 3% and thus very small compared to about 45% market share of screen-printed pigment inks.

11:10 **Synergistic Effect of Pre-Treatment Solution and Inkjet Ink to Control Coloring Characteristics on Fabric,** *Yoshitaka Miyajima, Nao Kozaka, Takuya Sonoyama, and Hiroshi Kiguchi, Seiko Epson Corporation (Japan)* 61

In textile field, digital textile printing has recently expanded its presence as a practical option for printing designs on fabrics, and many users of digital textile printer has actually attempted to widen their business. However, there are many factors that affect printing qualities on fabric. One of these factors is pre-treatment. Owing to proper pre-treatment depending on fabric types, various chemical reactions or chemical interactions between ink and fabric are strictly controlled in printing and steaming processes. Furthermore, adjusting the compositions of pre-treatment solution enables us to control coloring characteristics on fabric under user's printing environment. As a result, high printing quality is achieved by digital textile printing. Thus, in this paper, we focused on pre-treatment process and attempted to alter coloring characteristics on fabric by changing key material such as thickener in the pre-treatment solution.

Exhibit Hall Opens at 10:00

11:30 – 12:05 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

12:05 **The Effect of Surface Structure and Performance of Cotton Fabric on the Resolution of Ink-Jet Printing,** *Zhen Shi, Rui Dan, Longyun Hao, Weichao Chen, Ruyi Xie, and Kuanjun Fang, Qingdao University (China)* 65

Pure cotton knitted fabric is deeply loved by the people because of its good water absorption, breathability and comfort. Meanwhile, jet printing technology is a new printing method with broad development prospect. Therefore, in order to explore what kind of cotton knitted fabric can get good effect of inkjet printing, we measured the capillary effect hydrophilic, contact angle and glossiness of the 135 g/m2, 140 g/m2 and 160 g/m2 in three different specifications of cotton knitted fabric, with seven different colors of jet printing, after the comparison of color characteristic values.

The results showed that when the amount of ink is 100%, the printing effect of 160 g/m2 cotton knitted fabric is the best and when the amount of ink is 50%, the printing effect of 140g/m2 cotton knitted fabric is the best

12:25 **Influence of 3D Printing on Physical Properties of Textiles (Focal/Presentation-only Paper; see Appendix for extended abstract),** *Sarah Göbel, Saxon Textile Research Institute (Germany)* A-15

Versatile additive manufacturing processes are in focus of research and development for several decades. The advantages of these kind of manufacturing technologies are higher process control and more flexibility by digital data, freedom of design, no need of tools or stencils as well as the possibility to create customized products.

Also, in the field of textiles there are different developments to use the so-called 3D printing technique. On the one hand designers create completely new clothes for their fashion shows by various additive manufacturing processes like stereolithography, Selective Laser Sintering, Polyjet 3D printing or Fused Layer Modelling. The first completely 3D printed ready-to-wear bikini was created by Continuum Fashion. Researchers examine the possibilities of 3D printing textile like structures by Selective Laser Sintering and Fused Layer Modelling processes. On the other hand additive manufacturing processes are investigated to print directly onto textile substrates for surface modification and functionalization of textiles.

12:55 **Effects of Polyols Solvents on Rheological Properties of Reactive Dye Inks for Textile Digital Inkjet Printing (Interactive Preview),** *Ruyi Xie, Kuanjun Fang, Weichao Chen, Zhen Shi, and Longyun Hao, Qingdao University (China)* 69

Reactive dye inks are the basic consumables for textile digital inkjet printing and the definition of the printed patterns depends on their rheological property. In this research, the influence rules of polyols solvents on rheological behaviors of reactive dye inks were investigated in detail. The reactive dye inks were characterized in terms of dynamic surface tensions and viscosities. Results showed that the surface tensions of inks were affected greatly by the position of hydroxyl groups in polyols solvent molecules and their carbon chain length. The viscosities were influenced obviously by the Van der Waals forces and hydrogen bond forces among the ingredients of reactive dye inks.

13:00 **Improved Stability of Disperse Dyes/Polymer Composite Nanospheres for Aqueous Inkjet Inks (Interactive Preview/Presentation-only Paper; see Appendix for extended abstract),** *Yawei Song, Kuanjun Fang, and Weichao Chen, Qingdao University (China)* A-16

Using a commercial disperse dye, disperse dyes/P(St-BA-MAA) composite nanosphere dispersions was prepared by dyeing the P(St-BA-MAA) nanosphere dispersions synthesized through emulsifier-free emulsion polymerization and exhibited homogeneous spherical structure observed by TEM. Changes determined by DSC showed the interaction between disperse dye moleculars and macromolecular chains in P(St-BA-MAA) nanospheres. Centrifugal stability was measured by nephelometry method to evaluate the influence of pH values and sodium nitrilotriacetate (NTA) on the stability of the dispersions. The color polymer composite nanosphere dispersions turned to be stable when the pH of dispersions was from 8 to 9. Further improved stability of nanosphere dispersions could be obtained with NTA absorbed onto the surface of nanospheres. Different foaming ability between NTA and sodium dodecyl sulfate (SDBS) was also investigated by measuring the foam height of dispersions, and the dispersions with NTA exhibited low foaming ability which is essential to the preparation of inkjet ink

13:05 **A Novel Four-Color Dyes/P(St-BA-MAA) Nanosphere Dispersions with High Dye Absorption for Inkjet Inks (Interactive Preview/Presentation-only Paper; see Appendix for extended abstract),** *Kuanjun Fang, Yawei Song, Weichao Chen, Ruyi Xie, and Zhen Shi, Qingdao University (China)* A-18

Four kinds of disperse dyes with different colors were applied to dyeing P(St-BA-MAA) nanosphere dispersions prepared with emulsifier-free emulsion polymerization. The color polymer nanospheres showed uniform spherical structure determined by TEM images. The influence of nanospheres' glass transition temperature (Tg) and pH on the amount of fixed dyes into nanospheres were studied. The results exhibited that the amount of dyes fixed into nanospheres increased with the nanospheres' Tg decreasing. The four different dyes were incorporated to varying levels at same pH, corresponding to their different ability to diffuse into the polymer nanospheres. The four-color polymer nanospheres can be a promising colorants for inkjet inks with integrating good color performance from disperse dyes and self-dispersing ability from P(St-BA-MAA) nanospheres.

13:10 – 14:30 Lunch Break (on own)

Digital Textile Printing continues

Session Chairs: Ron Askeland, HP Inc. (USA); Christian Maus, Evonik (Germany); and Hirotosi Terao, ALPS Electric Co., Ltd. (Japan)

14:30 **Integrative Digital Manufacturing Approach for Processing Technical Textiles (Presentation-only Paper; see Appendix for extended abstract),** *Frank Siegel, Sarah Göbel, Dirk Wenzel, Falko Schubert, and Sten Döhler, Saxon Textile Research Institute (STFI), and Andreas Böhm, futureTEX Management GmbH (Germany)* A-20

The future of manufacturing textile products is closely related to digital manufacturing approaches. Direct digital printing methods such as Inkjet are becoming more and more relevant for the textile industry but in total printed square meters digital printing is still a niche of almost 3 % in 2016. But due to the advantages of this technology, recent developments in new textile compatible pigment inks and a more holistic view to the whole value-chain Smithers Pira Group is forecasting an growth for digital printing onto textiles of 17.5 % from 2016 to 2021. The textile market is not limited to fashion and home interior textiles. Especially high valued technical textiles are market drivers in the European Union and these kinds of textiles are still manufactured in the EU.

To increase the awareness of applying novel technologies for the manufacturing individual technical textile products it is necessary to show the possibilities of digital manufacturing strategies to decision-makers of small and medium-sized enterprises. This presentation gives an introduction to the futureTEX research and test field "textile factory of the future" which is under development to show the possibilities of an individual and flexible production combining digital manufacturing processes and conventional textile processes like weaving and hotmelt back coating.

14:50 **Functionalization of Textiles by Screen Printing – Realization of Protective Textiles Against Mechanical Risks (Presentation-only Paper; see Appendix for extended abstract),** *Maren Gültner and Romy Naumann, Saxon Textile Research Institute (Germany), and Dita Krácalová and Jirí Procházka, SINTEX a.s. (Czech Republic)* A-21

Current trends in research and development of advanced textile materials show an increased interest in novel materials, new functionalities, solutions and modifications to improve processing methods. Aim is to combine the positive comfort characteristics of products with high-performance technical parameters.

Technical textiles are able to protect the user against various mechanical risks (including mechanical hazards such us cutting, stabbing/puncture and abrasion). Nowadays, 2D fabrics arranged in several layers are used. The outstanding properties of such structures can be achieved by a combination of highstrength fibres (like e. g. Kevlar®, Dyneema®) as well as individual additive enhanced polymer coatings. These coatings can be applied by different coating technologies like spraying, roller coating, blanket coating or dipping. The resulting full-surface coated fabrics have the disadvantages of an extremely high rigidity and nonexisting dexterity/tactile sensitivity. In summary, materials with an increased protective function show an extreme decrease in wearing comfort, flexibility and thus the sense of touch.

15:10 **Printed Hybrid System on Technical Textiles: Battery, Communication Elements, Antennas, Conductive Paths (Presentation-only Paper; see Appendix for extended abstract),** *Carmen Meuser, Andreas Willert, and Ralf Zichner, Fraunhofer Institute for Electronic Nano Systems ENAS (Germany)* A-22

Nowadays various applications of functional devices becomes more and more precious. They have to be lightweight and flexible, so that the consumer could use them everywhere without disturbing his environment. All this applications need a tailored, reliable supply with electric energy. As an electrochemical system a battery is able to deliver electric energy for functional devices and smart applications. Due to the common usage several rigid types of batteries have been standardized. The full integration of a battery in flexible products which is adaptable in power, free in design of geometry and with a thickness less than 1 mm can be realized by printing technology. So far, usual polymeric films like PET (polyethylenetheraphtalate) or PEN (polyethylennaphthalat) have been successfully used as substrates and battery housing.

15:30 **Printed Conductive Patterns on Technical Textiles (Presentation-only Paper; see Appendix for extended abstract),** *Christian Zeiner[1], Tatiana Zubkova[1], and Reinhard R. Baumann[1,2]; [1]Technische Universität Chemnitz, Chemnitz and [2]Fraunhofer Institute for Electronic Nano Systems(Germany)* A-24

In the last years a growing market of wearable devices with smart conductive features, integrated into flexible materials, is observed. The integration of devices in clothing, daily used objects and medical items is of typical interest in industry. According to the application, a certain amount of flexibility and elasticity is a requirement. The demand of smart features on the technical textiles as e.g. sensors and antennas can be satisfied with different printing technologies as inkjet and gravure. With the digital based inkjet printing technology, a simple customization as well as a contactless application of the printed pattern can be realized. Compared to inkjet, gravure printing allows to deposit thicker ink layers at a higher speed.

Concurrent Event: Colleague Connections:
International Standards Supporting Printing for Fabrication
15:30 – 16:00
see details page xxx, Rossini

Interactive Paper Session/Demonstrations/Exhibits Happy Hour
16:00 – 17:30
Join colleagues to discuss the Interactive (Poster) Papers with their authors, view technology-based demonstrations, and speak with the exhibitors in a Happy Hour environment
Piano Bar Foyer

TRACK II

Printed Electronics: Materials

Session Chairs: Norio Nagayama, Ricoh Co., Ltd. (Japan); Travis Walker, South Dakota School of Mines (USA); and Andreas Willert, Fraunhofer Institute for Electronic Nano Systems ENAS (Germany)

10:20 – 13:10

Congress Center Saal 2

10:20 **[Solar Cell Interconnection Using a Liquid Metal] Room Temperature Interconnection of Silicon Solar Cells Using a Liquid Metal (Focal/ Presentation-only Paper; see Appendix for extended abstract),** *Dong-Youn Shin and Hae Wook Chung, Pukyong National University, and Hyung-Jun Song, Jeong In Lee, and Gi-Hwan Kang, Korea Institute of Energy Research (South Korea)* A-25

Crystalline silicon solar cells have prevailed in the photovoltaic market for the last decades due to their high photo conversion efficiency, low cost, and excellent reliability in the outdoor environment. To render them more economical, such attempts to consume less materials like silicon have been made by adopting a thinner silicon wafer, 180 μm as of now and 110 μm by the year 2027. However, a conventional soldering method, which generally requires a processing temperature as high as 190°C to melt a solder alloy, leads to a high thermomechanical stress while metal ribbons are bonded to the busbars of a solar cell. Albeit interconnection technologies with a less thermomechanical stress have been investigated, such as laser welding, ultrasonic welding, and conductive gluing, their residual thermomechanical stress might be still high enough to bend or break a thin solar cell.

10:50 **Direct Printing of Conductive Metal Lines from Molten Solder Jets via StarJet Technology on Thin, Flexible Polymer Substrates,** *Zhe Shu[1], Björn Gerdes[1], Michael Fechtig[1], Lutz Riegger[1], Roland Zengerle[1,2], and Peter Koltay[1,2]; [1]Albert-Ludwigs-Universität Freiburg and [2]Hahn-Schickard-Gesellschaft für angewandte Forschung e.V. (Germany)* 72

We present the direct printing of thin (linewidth of 70 μm) conductive lines from molten solder on thin, flexible substrates. The lines are generated via the so-called StarJet technology that enables the printing of micro jets from molten metal. In this work, metal lines are printed for the first time on flexible substrates, possibly enabling applications in the field of printed electronics. The printed lines are evaluated regarding their mechanical and electrical properties. To the knowledge of the authors, this is the first time that direct printing of a functional metallization, requiring no further treatment, on a flexible polymer substrate was demonstrated. The lines exhibit a low ohmic resistance and can endure shear forces of up to 3.5 N on polyethylene terephthalate (PET) substrates.

11:10 **JIST-FIRST Piezoelectric Inkjet-Printed Metallic Igniters,** *Allison Murray, Whitney Novotny, Nikhil Bajaj, I. Emre Gunduz, Steven Son, George Chiu, and Jeffrey Rhoads, Purdue University (USA)* 76

This work demonstrated printed metallic bridge wire and spark gap igniters suitable for use with energetic materials. These devices were fabricated from an aqueous dispersion of silver nanoparticles on a flexible, mesoporous substrate using a piezoelectric inkjet printer. This manufacturing process resulted in precise samples fabricated without the need for thermal curing. Geometric parameters were varied for the devices to determine the design criteria of importance and to quantify the electrical excitation needed for optimal performance. The work successfully demonstrated the integration of bridge wires and spark gaps with energetic material to produce fully printed igniters that are of practical use in applications ranging from munitions to vehicle airbags.

Exhibit Hall Opens at 10:00

11:30 – 12:05 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

12:05 **New Developments in Printed Electronics Using Offset Lithography on Paper Substrates,** *Rakel Herrero, Maite Aresti, María Lasheras, Itziar Landa, Juncal Estella, and Saioa Los Arcos, NAITEC (Spain)* 82

In the graphic industry, a clear business opportunity has been identified using conventional printing technologies for the manufacture of high-performance, low-cost electronic products. However, despite having identified the business opportunity, often the developments can not be carried out because the right materials are not found.

Offset Lithography appears as the most suitable technique for paper substrates but it is not used in Printed Electronicsdue to the lack of conductive materials appropriated for this printing technology.

In this work the goal is to obtain a conductive offset inkthat does not currently exist on the market. This achievement would mean a leap towards the manufacture of electronic products through offset on a more ecological substrate such as paper.

12:25 **Functional Integration in Fiber Reinforced Plastics (FRP) by use of Digital Printing (Focal/Presentation-only Paper; see Appendix for extended abstract),** *Volker Zöllmer[1], Katharina Haag[1], Jonas Deitschun[1], Manuel Kreienborg[1,2], Dirk Godlinski[1], and Katharina Koschek[1]; [1]Fraunhofer Institute for Manufacturing Technology and Advanced Materials and [2]University of Bremen (Germany)* A-27

Fiber Reinforced Plastics (FRP) are innovative materials for lightweight construction, especially in the aeronautics and automotive sector. Although these materials show a high potential based on their low weight to high stiffness ratio, in structural applications large safety factors are applied due to a possible fiber delamination and sudden failure. In contrast to metal structures, fiber delamination as a result of e.g. an impact cannot be observed externally by common analytics. For this reason, the integration of piezoelectric sensor structures used for a Structural Heath Monitoring (SHM) are of great interest. In the present paper we report on digital printing of piezoelectric sensor structures on textile glass fiber for an integration into Glass Fiber Reinforced Plastic (GFRP). Silver electrodes, conductive traces as well as piezoelectric layer structures are deposited directly on glass fabrics and cured at T=100°C for t=20 min. Such functionalized fabrics have been applied as reinforcing fabric in a vacuum infusion process to produce GFRP. By applying a DC-current of U=400V for t=30 min. at T=120°C, a post-polarization of the printed and cured piezoelectric structures could be performed. Mechanical loads and/or impacts can be detected, and localized by a sensor array due to runtime differences. In conclusion, FRP-components with integrated sensor structures and conducting tracks are available, enabling a predictive maintenance.

12:55 **Generalized Computational Halftone Image Formation (Interactive Preview),** *Chunghui Kuo, Eastman Kodak Company (USA)* 87

A basic premise of forming a halftone image pattern on a two-dimensional substrate receiver in a traditional printing process is that there exists an identical spatial mapping relationship between the original image and its reproduced counterpart. As the printing technology being adopted to become a manufacturing process on flexible substrates as well as three-dimensional objects, this inherent property is no longer valid. Furthermore, similar to all manufacturing processes with mass customization capabilities, the natural evolution for the existing digital printing technology is to become an autonomous process with minimal operator interference. Therefore, a new paradigm of a general halftoning algorithm is proposed where the final image formation is controlled by the local geometry, the intended exposure and instantaneous feedback compensation signals.

13:00 **Spectral Reconstruction of Chinese Painting based on Pseudo-Inverse Method in Graphic Communication (Interactive Preview),** *Maohai Lin[1,2], Meiqi Lin[1], Hui Chen[1], and Guangyuan Wu[1]; [1]Qilu University of Technology and [2]South China University of Technology (China)* . . . 91

In this paper, the multi-channel spectral reconstruction system was built by using the digital camera with filter, which could help the digital camera to get the CCD response value that could be conversed into spectral reflectance. As result, the relative color information of the Chinese painting could be acquired and the process of spectral reconstruction could be accomplished. About research process, firstly, the Chinese painting color cards were made by using the Mali Chinese painting pigment coated on xuan paper, and part of these card were chose as the training samples, and the other part was as for experimental samples. Secondly, the color information of Chinese painting card could be gotten by using the EOS 5D canon digital camera to take photos with these cards. At the same time the spectral reflectance of these card could be tested by spectrophotometer. Finally, the relative spectral reconstruction algorithm was used to reconstruct spectral reflectance for experimental samples. The result showed that based on Pseudo-inverse method to reconstruct spectral reflectance of Chinese painting card could have higher accuracy and the color information of the Chinese painting could be accurately reproduced.

13:05 **Research on Several Models of Computer Color Matching for Flexographic Printing based on Improved BP Neural Network (Interactive Preview),** *Xiaozhou Li[1,2], Jingqiang Jia[2], Mingming Cui[2], and Yu Liu[2]; [1]South China University of Technology and [2]Qilu University of Technology (China)* 95

The requirements on flexographic spot-color matching model is put forward due to the rapid development of flexography printing and the wide use of environmentally friendly aqueous ink and corrugated paper. In this paper, the flexographic spot-color matching model was designed using BP neural network algorithm for flexography printing where the aqueous ink and corrugated were used. The training and testing samples were obtained by using IGT, and the data was trained based on several mathematics models to find a suitable weighting factor. The matching models' performance and prediction error were analyzed, and the improved algorithm was put forward according to the BP neural network. It showed that the improved BP algorithm was better than the other algorithms in the area of convergence speed and training accuracy.

13:10 – 14:30 Lunch Break (on own)

Lab2Fab Challenges

Session Chairs: Katrina Donovan, Oregon State University (US); Liisa Hakola, VTT (Finland); and Nobuyuki Nakayama, Fuji Xerox Co., Ltd. (Japan)

14:30 – 16:00

Congress Center Saal 2

14:30 **A Novel Process of Automated Waveform Optimization,** *Kyle Pucci, ImageXpert Inc. (USA)* 99

In this research project, ImageXpert attempts to combine drop visualization with a methodology for waveform creation into an automated process for designing and optimizing waveforms. Waveforms are an essential, but often mysterious, aspect of inkjet printing that controls the performance of the system. It is important to understand how waveforms work in order to properly design them. In piezoelectric printheads, the waveform is an electrical signal that is applied to the piezoelectric materials, causing them to deform. This deformation, when done with proper rhythm, is the driving force behind the nozzles of the printhead filling and jetting ink. Getting the proper rhythm of ink in the nozzle to ensure consistent, stable jetting is the goal when optimizing a waveform.

The waveform optimization methodology that was used was optimization of the pulse width, then voltage, then pulse spacing while monitoring behavior over a range of frequencies. Using commercially-available systems along with custom scripting, a process for fully automating this optimization

was developed. It works by specifying a range for each parameter and automatically sweeping through that range, while capturing images and data at each value. Using this technique, a waveform can be developed or optimized using automation in a fraction of the time spent doing it manually.

14:50 **Planning and Integration of a Non-Standard Inkjet Print Process into an Industrial Manufacturing Line—View of an Integrator (Presentation-only Paper; see Appendix for extended abstract),** *Uwe Buerklin, Thieme GmbH & Co KG (Germany).* A-28

More and more companies in the manufacturing industries request for a solution to integrate a digital print process into their production lines. Either a complete new process should be integrated or an established print technology (e.g. screen print, pad printing, ...) should be replaced. The reasons for choosing a digital print process are various, however mostly the key arguments are: flexibility, individualisation and reducing of stock capacities. In comparison to presses in printeries, the print machines for the manufacturing industries are often requested to non-standard application: printing direct to product, integration of pre- and post-processes, adding functional layers or implementing a complex material handling. Such non-standard processes require high development effort whereas the lot size for machines is quite low. Additionally, often an existing ink has to be optimized or a completely new ink has to be formulated for specific requirements. In such a case the development may spend several months or years.

15:10 **Substrate Transport for Production at Variable Process Speeds,** *Thomas Oberle[1], Christoph Ziegler[1], Robert Thieme[1], and Martin Porschen[1,2]; [1]GT+W GmbH and [2]Technische Universität Darmstadt (Germany)* 103

Printing for fabrication of functionalities requires diverse materials and techniques. Unlike graphic products functional devices are produced in a large sequence of production steps that differ in techniques as well as in materials. Moreover, their process parameters can vary over magnitudes. Just for the reason of different manufacturing speeds, press layouts like 6 colour + lacquer will not be feasible.

How can different techniques and processes be integrated into one substrate transport concept? The present talk discusses this question focusing on technological and economic parameters. Especially drying, curing and sintering processes are significant for production of functional layers. They are time consuming to be completed. Gravure printing on the other hand requires high printing speeds to achieve high quality. Once implemented, a substrate transport system with variable speeds offers opportunities for the process definition and eliminates the need of wide-stretched assemblies.

Our approach to meet those conflicting objectives is a substrate transport concept named sheet-on-shuttle. We discuss the characteristics of our lab scale substrate transport system, the measures taken to design a system suitable for fabrication and current challenges.

15:30 **Advanced Laser-based Manufacturing for Digital Fabrication(Focal/Presentation-only Paper),** *Tino Petsch, 3D-Micromac AG (Germany)**

The presentation will give a brief overview of different production solutions where laser processing achieves new dimensions in terms of precision, quality and process efficiency. Technologies for ablative as well as additive laser manufacturing will be introduced.

Concurrent Event: Colleague Connections:
International Standards Supporting Printing for Fabrication
15:30 – 16:00
see details page xxx, Rossini

Interactive Paper Session/Demonstrations/Exhibits Happy Hour
16:00 – 17:30
Join colleagues to discuss the Interactive (Poster) Papers with their authors, view technology-based demonstrations, and speak with the exhibitors in a Happy Hour environment
Piano Bar Foyer

* Abstract only; no extended abstract or proceedings paper.

TRACK III

Healthcare

Session Chairs: Brian Derby, University of Manchester (UK); Makoto Omodani, Tokai University (Japan); and Min Zhao, Purdue University (USA)

10:20 – 13:15

Rossini

10:20 **Real World Smart Packaging for Pharmaceuticals (Focal/Presentation-only Paper),** *Michael Petersen, Information Mediary Corp. (Canada)**

Michael will walk you through his 18 years of experience combining printed and regular electronics into making scalable, robust and user friendly medication packages. A look into the future will explore challenges and opportunities and explain the relevance of real world adherence data for clinical AI and consumer focused healthcare models.

Michael will give a live demonstration of smart packaging using iPhone. The first time such technology has been shown to the public anywhere in the world.

Michael is COO and co-founder of smart packaging and printed electronics experts Information Mediary Corporation in Ottawa, Canada. Since 2001, IMC has commercially developed and sold millions of devices connected to the cloud via RFID, NFC and iOS NDEF.

10:50 **Industrial Inkjet Printing for On-Demand Manufacturing of Film-in-Capsule Dosage Forms (Presentation-only Paper; see Appendix for extended abstract),** *Wen-Kai Hsiao[1], Diogo Lopes[1], Laura Hauser[2], Thomas Wutscher[1], Amrit Paudel[1], Massimo Bresciani[1], Johannes Khinast[1], and Andreas Zimmer[2]; [1]Research Center Pharmaceutical Engineering and [2]University of Graz (Austria)* A-29

Pharmaceutical printing via inkjet technology promises to bring flexibility to the manufacturing of oral dosage forms. By leveraging the reliability and scalability of the industrial inkjet print heads and associated system, the approach can be applied to both personalized medicine and other drug treatment and development innovations. However, a holistic approach which involves advanced formulation aiming to balance both the biopharmaceutical and jetting/printing performance, a novel product concept, and a realistic roadmap to achieve production readiness, *i.e.* GMP-compliance, is needed to take advantage of this innovation. In this work, we exemplified our approach by using industrial inkjet printing technology (print heads and printing system) to flexibly produce a novel film-in-capsule dosage form. Specifically, a systematic formulation approach is adapted to overcome biopharmaceutics challenges such as poor aqueous drug solubility while maintaining the jetting/printing reliability and depositing appropriate drug loads. Carvedilol was selected as an example BCS class II drug compound, which has several effective dose strengths: 3.125, 6.25, 12.5 and 25 mg. The printed film-in-capsule dosage form concept was developed for immediate drug release in the GI tract via an amorphous solid dispersion formulation. A schematic of the printing approach/product concept, as well as steps followed in the development can be seen in Fig. 1.

11:10 **Digitally Printed Pharmaceuticals to Deliver Personalised Therapeutic Dosing (Presentation-only Paper),** *Hannah O'Brien and Alan Hudd, Alchemie Technology Ltd. (UK)**

A significant proportion of adverse reactions and clinical trial failures are due to inappropriate dosing of pharmaceutical products. To date, the pharmaceutical industry has only been able to deliver relatively limited control over dose level, particularly for oral dose medications. Digital printing of oral dose medications has the potential to deliver the capability to personalise dosing on a per patient basis, enabling significant reductions in adverse reactions and improvements in overall efficacy. In this presentation, we will review the current state-of-the-art in printed pharmaceuticals and explore the opportunities to develop personalised drug treatment approaches by combining digital printing with diagnostics.

Exhibit Hall Opens at 10:00

11:30 – 12:05 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

12:05 **Inkjet Printing Platforms for DNA-based Pathogen Detection,** *Min Zhao, Susana Diaz Amaya, Seon-ah Jin, Li-Kai Lin, Amanda J. Deering, Lia Stanciu, George T.-C. Chiu, and Jan P. Allebach, Purdue University (USA)* 107

Printing technologies recently have been applied to environmental pollution and food safety testing applications because there is more and more demand for inexpensive, portable and functional devices to be used for monitoring food and environment, such as enzyme-based biosensors. A system for printing nanoliter DNA based solution droplets on a lateral flow test strip with improved sensitivity

* Abstract only; no extended abstract or proceedings paper.

COLLEAGUE CONNECTIONS: INTERNATIONAL STANDARDS SUPPORTING PRINTING FOR FABRICATION

Tuesday, 15:30 – 16:00
Rossini
Moderator: Alan Hodgson, Alan Hodgson Consulting, Ltd.

Various committees are writing standards that impact the Printing for Fabrication community. Join us for a discussion on where we should concentrate our efforts in the future, with particular reference to Printed Electronics, Textiles, and 3D Printing.

for detection of Escherichia coli O157:H7 (E.coli O157:H7) is described in this article. We will present an overview of the results obtained with our printing process and the image analysis of the responses in the test strips. The printing process includes the precise control of droplet volume, the design of the print masks, and functional printing of the DNA-based solution. We create an image analysis system to read the responses of the test strips to the foodborne pathogens (Escherichia coli O157:H7) and determine the relationship between the responses and the concentration of the E.coli. Furthermore, we confirm that our printed test strips can successfully detect the presence of E.coli O157:H7 with a concentration as low as 10^2 CFU/ml.

12:25 **Bioink Development and Bioprinting Bio-based Matrices (Focal),** *Kirsten Borchers[1,2], Eva Hoch[3], Annika Wenz[3], Birgit Huber[3], Sandra Stier[4], Christiane Claaßen[2], Lisa Sewald[2], Petra Kluger[4], and Achim Weber[1,2]; [1]Fraunhofer-Institute for Interfacial Engineering and Biotechnology IGB, [2]University of Stuttgart, and [3]Formerly: University of Stuttgart, [4]Formerly:Fraunhofer-Institut for Interfacial Engineering and Biotechnology IGB (Germany)* 113

The future vision of medical care comprises the generation of biological implants. Thus, formulations based on biological or biocompatible matrices with or without cells are needed for automated generation of tissue engineered products. Such so called bioinks have to match the technical requirements of the deposition processes, and at the same time fulfill the biological needs of the cells and mimic the properties of native tissue.

We introduce gelatin-based biomaterials for the manufacturing of flexible structures by freeform fabrication methods: printable non-gelling precursor solutions and crosslinked hydrogels with tunable physico-chemical properties constitute biomimetic matrices with adjustable properties for engineering of specific tissue models such as cartilage or bone. Currently, computer-controlled 3D manufacturing techniques are being successfully adapted for tissue engineering (TE) applications in order to enable sophisticated manufacturing of artificial tissue substitutes. One approach called bioprinting particularly aims for the direct deposition of biological and biologically relevant materials, such as biomolecules and living cells, into spatial orientations and geometries.

12:55 **Personalising Medicines by Drug Printing (Presentation-only; see Appendix for extended abstract),** *Maren Katherina Preis, Abo Akademi University (Finland)*. A-31

Using printing technologies for the production of customized medicinal products is an emerging trend in the pharmaceutical industry. The potential for new products by transferring established technologies is promising to provide patients with tailored treatment solutions.

13:15 – 14:30 Lunch Break (on own)

Standards and IP

Session Chairs: Mark Mizen, HID Global (USA); Michael Willis, Pivotal Resources Ltd. (UK); and Hiroshi Yamazaki, Yamamoto Trading Co., Ltd. (Japan)

14:30 – 16:00
Rossini

14:30 **International Standards Enabling Printed Electronics for Wearables,** *Alan Hodgson, Alan Hodgson Consulting Ltd. and University of Manchester (UK)* 116

This paper serves as an introduction to the standardization effort taking place to support the industrialization of Wearable Electronic Devices and where Printing for Fabrication technologies will fit into these. It commences with a short overview of the market sectors for Wearable Electronic Devices and examine where Printed Electronics and other technologies will contribute. In this way it will show where the interest in Printing for Fabrication currently lies, concentrating in particular on textile electronics and sensor fabrication.

It explains the concept of e-textiles in this space and by describing the structure and organization of IEC TC 124 it charts the route whereby interested parties can participate. This way it shows some of the benefits that can be gained by participation and lists some of the groups that a participant would expect to meet. It finishes by listing at some of the challenges that need to be met by future standardization activities.

14:50 **Overview of Standardization Activities for Inkjet Additive Manufacturing (within IEC TC 119 Printed Electronics),** *Kei Hyodo[1,2] and Shinri Sakai[2]; [1]Yuasa System Co. Ltd. and [2]Yamagata University (Japan)*. 119

Until recently, Inkjet printing technologies are relatively isolated industry especially for conventional printing. Thus, there was no need to have any standardized evaluation methods for those technologies. However, rise of additive manufacturing and expansion of printed electronics are changing that.

Especially, rapid expansion of inkjet printing application in printed electronics requests industries to have standard evaluation methods of that printing. As an International Standardization Organization for Printed Electronics, IEC TC 119 answers that request.

15:10 **Basics of Standard Essential Patents and Licensing Them,** *Scott Slomowitz and Gary Greene, Caesar Rivise, PC (USA).* 123

Technology for various devices and for each component in these devices must work together, even when many different manufacturers produce similar technology. For example, in the field of smart phones, all manufacturers, such as Samsung, Apple, Oppo, LG, etc. all must operate on common cellular networks, Wi-Fi networks, and, typically, additionally operate using Bluetooth technology for peripherals such as ear buds and printers. To be marketable, these devices must comply with "standards" that allow these devices to communicate and/or interact with each other to obtain the desired functionality. The standards may involve many hundreds of patents or more that cover the individual technologies.

Colleague Connections: International Standards Supporting Printing for Fabrication
15:30 – 16:00
see details page xxx, Rossini

Interactive Paper Session/Demonstrations/Exhibits Happy Hour
16:00 – 17:30
Join colleagues to discuss the Interactive (Poster) Papers with their authors, view technology-based demonstrations, and speak with the exhibitors in a Happy Hour environment
Piano Bar Foyer

WEDNESDAY 26 SEPTEMBER 2018

SPECIAL EVENT

CONFERENCE RECEPTION

Wednesday, 18:00 – 21:00

August der Starke
Paddleboat Steamer
Terrassenufer Dock # 3

Dresden, Germany, is home to the largest paddleboat steamer fleet in the world. Join colleagues as for an evening meal and much commaradery as we journey on one of these iconic boats along the lovely Elbe River.

From the Hilton Hotel lobby exit, turn left, then left again on Münzgasse, which ends at the Elbe. Almost directly in front of you you'll find the August der Starke. Boarding starts at 18:00 and ends at 18:15. Please be in line to board no later than 18:15.

Wednesday Keynote and IS&T Awards:
Advances in Additive Manufacturing: The Evolution of HP Inc.'s Jet Fusion™ 3D Printing Technology,
Cheryl MacLeod, HP Inc. (USA)
9:00 – 10:00
see details page ix, Congress Center Saal 1&2

2018 Exhibit Open
10:00 – 16:20
see details page vii, Piano Bar Foyer

10:00 – 10:20 Break to Change Rooms + Mini Coffee Break — Piano Bar Foyer

TRACK I

Ink Jet Processes I

Session Chairs: Rich Baker, Integrity Industrial Ink Jet Integration LLC (USA); J. Frits Dijksman, University of Twente (the Netherlands); and Kye-Si Kwon, Soonchunhyang University (South Korea)

10:20 – 17:30
Congress Center Saal 1

Session sponsored by

XAAR®

10:20 **Newly Developed MEMS Printheads for Industrial Inkjet Applications,** *Kenji Mawatari, Akito Shimomura, Takashi Matsuo, Daisuke Ishibashi, and Hideyuki Kobayashi, Konica Minolta, Inc. (Japan)* 127

We have developed new print heads suitable for industrial inkjet applications by combining long experience in industrial inkjet business and novel MEMS technology. Print heads used in industrial inkjet applications are required high precision, high durability and compatibility to a wide range of ink.

To meet these requirements, we chose bulk PZT material for an actuator, and Si MEMS technology for processing of ink channels and nozzles. The bulk PZT material has high durability against thermal and mechanical stresses and enables to use an internal heater to raise ink temperature up to 60 degrees Celsius. Si based ink channels and nozzles have high mechanical precision and can achieve high jetting straightness and high uniformity of droplet velocity and droplet size.

We have also developed new ink channel dimensions and driving waveforms to achieve small binary droplet size of 3.5 pL and high pump ability of 20 pL at 24 kHz. Our new print heads have already tested in a wide range of applications from sign and display to printed electronics markets.

10:40 **Xaar 5601, a Thin Film PZT Si-MEMS Inkjet Printhead for Industrial Applications (Presentation-only; see Appendix for extended abstract),** *Ramon Borrell, Xaar plc (UK)* A-32

The critical performance factors for High End Commercial and Industrial presses are productivity, consistent print quality and total cost of operation. Developing a printhead that optimizes the three of them requires a systematic approach combining suitable pritnhead architecture and the use of the most adequate actuation technology. Xaar has used this approach for the development of the Xaar 5601 printhead using Thin Film PZT Drop on Demand jetting with integral Si-MEMS actuator structure combined with cost efficient, robust, ease of use and feature rich body and drive electronics which meet the requirements of the target applications.

Exhibit Hall Opens at 10:00
11:00 – 11:30 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

11:30 **Increased Ink Space with Existing Thermal Inkjet Silicon and Printhead Modules Using Micro Pumping (Focal),** *James Przybyla, Alex Govyadinov, and Nick McGuinness, HP Inc. (USA)* . 131

High solids aqueous ink chemistries are desirable to provide high optical density and durability after application to the media but these inks can have tradeoffs in jettability due to Pigment/Vehicle separation (PiVS) and increased solvent evaporation in idle nozzles and fluidic chambers (decap) which can reduce both jettability and observed image quality (IQ). Low volatility co-solvents are commonly used to reduce decap by slowing the rate of evaporation through uncapped nozzles but these solvents have tradeoffs at the system level because final removal of these agents after deposition on media by drying can be challenging. The increased density (2400 nozzles per inch per color) of the HDNA thermal inkjet (TIJ) silicon die has been used on recently introduced HP industrial packaging printing and signage presses in a 1200 nozzle per inch configuration to enable high solids, high volatility ink chemistries with existing printhead silicon circuit designs and printhead modules by utilizing the unused nozzle positions as in-situ ink pumps to mix and flush stagnant ink from ink chambers. This configuration enables good jettability and IQ with high solids ink chemistries without requiring external ink recirculation systems.

12:00 **What Determines the Performance Limits of Piezo Inkjet Heads? (Presentation-only; see Appendix for extended abstract),** *Shinri Sakai, Yamagata University (Japan)* A-34

A piezo type inkjet head applies high fluid pressure to ink in a small pressure chamber by using electromechanical deformation of a piezoelectric actuator and ejects ink droplets from a minute nozzle opening connected to a pressure chamber. Over the past thirty years, various ink jet heads based on piezoelectric actuator configurations such as Bend-Mode, Direct-Mode, Shear-Mode, etc. have been developed and put to practical use. In the development of these ink jet heads, pursuing the miniaturization of the droplets to be jetted, the improvement of the jetting frequency, and the high density of the nozzles have been conducted so as to be able to print with higher image quality and higher productivity. The amount of ink droplet was miniaturized from 1 nano-liter or more down to sub pico-liter and the nozzle density was able to line up 360 nozzles per inch. On the other hand, the ink that can be ejected is limited to several tens of milli Pa·s or less with respect to viscosity. These performance improvements are obtained by optimizing designs of various piezo ink jet systems. Today, development to high-speed production printing machines and applications such as printed electronics is proceeding. In the future, how high performance can be obtained by optimizing the head design? What gives performance limits? With this kind of discussion, it is important to clarify the future possibilities of ink jet technology.

12:20 **Visualization of Ink Fluidity in Inkjet Imaging Process Using Method of Optical Coherence Tomography,** *Yoshihiro Harada and Masataka Mohri, Ricoh Co., Ltd. (Japan)* 135

In order to enhance the performance of the inkjet printer, it is important to be able to appropriately control the ink fluidity in the imaging process. For examples, it is useful to know how the ink fluidity changes when inside the inkjet head or when adhering to the media. As a method that can be used for this judgment, it was attempted to use method of optical coherence tomography was attempted. It is clarified that the fluidity distribution and its time change inside the ink can be visualized by optical measurement and signal analysis. It will bring way to know if the control condition of ink fluidity is appropriate.

12:40 – 14:00 Lunch Break (on own)

Wednesday Afternoon Keynote:
Industrial Applications of Inkjet Technologies,
Rich Baker, Integrity Industrial Ink Jet Integration LLC (USA)
14:00 – 14:50
see details page ix, Congress Center Saal 1&2

14:50 – 15:10 Break to Change Rooms — Exhibits Open

Ink Jet Processes I continues

Session Chairs: J. Frits Dijksman, University of Twente (the Netherlands); Masahiko Fujii, Fuji Xerox Co., Ltd. (Japan); and Jim Przybyla, HP Inc. (USA)

Congress Center Saal 1

15:10 **JIST-FIRST On Plateau-Rayleigh Instability of a Cylinder of Viscous Liquid,** *Leonid Pekker, FUJIFILM Dimatix (USA)* 139

In 1892, in his classical work, L. Rayleigh considered the instability of a cylinder of viscous liquid under capillary force, the so-called Plateau–Rayleigh instability. In this work, in linear approximation, he obtained a dispersion equation describing the increment of this instability as a function of wavelength, the radius of cylinder, the mass density, surface tension, and viscosity of the liquid. Hundreds of authors referred to this work, but none of them used his dispersion equation in its complete form; they used only the asymptotic solutions of his equation for zero or infinitely large viscosities. A reason for this is, probably, that Rayleigh's writing is difficult and his dispersion equation is quite complex. Then, in 1961, S. Chandrasekhar, in his monograph, also considered the stability of a viscous cylindrical jet and obtained his dispersion equation which is also quite complex and differs from the one obtained by Rayleigh. As in the case of Rayleigh's dispersion equation, other works use only the asymptotic solution of Chandrasekhar's equation that corresponds to the case where the viscosity is very large in comparison to inertia. In this article, the author demonstrates that Chandrasekhar's dispersion equation is equivalent to Rayleigh's and then simplifies their dispersion equations to a form which can be easily solved numerically for arbitrary values of viscosity. He also presents a Mathematica code to calculate the maximum increment of the Plateau–Rayleigh instability for given parameters of the jet. To illustrate how the code works, he applies it to a cylindrical jet to estimate its breakup.

15:30 **Ultra Small Droplet Generation in Inkjet Printing by Higher Order Meniscus Oscillations,** *Paul C. Duineveld, Philips Personal Health, and J. Frits Dijksman, University of Twente (the Netherlands)* 147

Piezo inkjet printing is a widely known technology to generate small droplets for accurate patterning of functional materials. The droplet generation is a complex interaction of the internal pump dimensions, the piezo electric driving characteristics and the liquid properties. For low viscosity inks standard drop formation is executed by employing the keynote mode of the waveguide type of print head. In such a print head the pump chambers are long, in order to allow for a close staking of the nozzles to end up with a large native drop per inch (DPI) number. This keynote mode produces droplets with a diameter that is of the order of the nozzle diameter. As there is a need for patterns with finer and finer features, especially for non-graphical applications, while still maintaining a robust printing process, i.e. without clogging of the nozzle, it is very interesting to generate smaller sized droplets while using a standard print head. In this paper it is shown experimentally and theoretically that such droplets can be made via higher order oscillatory meniscus modes. In such a mode the fluid motion is confined to the very close environment of the meniscus. When the print head and pulse are designed such that an overtone of the waveguide coincides with a symmetric resonance mode of the meniscus, it is possible to make stable droplets that are more than an order of magnitude smaller than the standard droplet

15:50 – 16:20 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

16:20 **Meniscus Motion in Piezo-Drop on Demand Inkjet Printing,** *Stephen D. Hoath[1], Peter Boltryk[2], Claudio S. Ravasio[1], Ioannis Menicou[1], and Marko Dorrestijn[2]; [1]Wolfson College Cambridge and [2]Xaar plc (UK)* 151

In this paper we report our analyses of the fluid motions for jetting piezo-driven DoD (drop-on-demand) print-heads, having previously reported at NIP 32 our experimental data and preliminary analyses for MicroFab AB-type nozzles. Frits Dijksman introduced his non-linear analysis for piezo-DoD inkjet printing at the same conference, independently and unaware of our experimental work on MicroFab nozzles. We compare some of his predictions with our data. We have also numerically modelled the linear second-order system response and compared this with the observed MicroFab meniscus motion during and after the duration of the applied waveform. CFD modelling for these jetting experiments has also been applied to the MicroFab print-head geometry and representative properties to provide an insight into the implications for other piezo-DoD inkjet print-head geometries more relevant to industrial printing.t

16:40 **JIST-FIRST Particle Transport in Microchannels,** *Leonid Pekker, FUJIFILM Dimatix (USA)* . . . 156

In this article, the author describes a set of models of particle transport in microchannels that has been recently developed at FUJIFILM Dimatix for design and optimization inkjet print heads. The models are used to estimate the modes of particle transport in horizontal channels, the times for particles to settle at the bottom of a channel, and the fluidization flow velocity. The Rouse number is commonly used to estimate the mode of sediment transport in horizontal turbulent flow with large Reynolds number.

However, in microchannels such as in modern inkjet systems, the liquid flows are usually laminar. In this article, the author uses a modified Rouse number that is expanded to the case of weakly turbulent and laminar flows. To illustrate the applicability of the modified Rouse number, he applies it to the transport of pigment particles in a horizontal channel in the FUJIFILM inkjet print head and compares theoretical results with experimental observations. In the article, he also constructs a model to estimate two settling times in rectangular channels: the time of formation of a monolayer of particles at the bottom of a channel and the required time for all particles to settle at the channel bottom. In design and optimization of a print jet head, it is also important to know the critical fluidization flow velocity of the ink to prevent sedimentation of ink pigment particles in vertical channels. In this article, the author constructs a simple model to estimate the maximum fluidization flow velocity as well. The modified Rouse number constructed in this article, as well as presented models, can be used in other applications as well.

Colleague Connections: Inkjet Open Forum
17:00 – 17:30
Join colleagues for an open discussion about the inkjet papers presented on Wednesday.
Congress Center Saal 1

Concurrent Event: Colleague Connections:
Connections for Innovation in Security Printing—The Fabrication Needs of Secured Print
16:20 – 17:30
see details page xxx, Rossini

Conference Reception: August der Starke Paddleboat Steamer
18:00 – 21:00
see details, page xxxii

COLLEAGUE CONNECTIONS: INK JET OPEN FORUM

Wednesday, 17:00 – 17:30
Saal 1

Join colleagues for a discussion on inkjet printing.

TRACK II

3D Printing

Session Chairs: Masahiko Fujii, Fuji Xerox Co., Ltd. (Japan) ; Krzysztof Nauka, HP Inc. (USA); Alvaro Jose Rojas Arciniegas, Universidad Autonoma de Occidente (Columbia)
10:20 – 17:20
Congress Center Saal 2

10:20 **Transport of Engineered Nanomaterials in Polyamide Powders (Presentation-only; see Appendix for extended abstract),** *James Stasiak, HP Inc., and Katrina Donovan, Oregon State University (USA)* A-34

HP's Multi Jet Fusion (MJF) technology, is a hybrid 3D printing process which combines inkjet-based digital patterning with Powder Bed Fusion (PBF) build materials. The MJF process is similar to other PBF methods but uses a specialized fusing agent to pattern the build powder layer digitally. Chemical properties of the fusing agent sensitize the areas of patterned powder and make them highly efficient at absorbing energy delivered by a radiant source. These areas then fuse leaving the unpatterned areas unaffected. The process of digitally dispensing chemical agents into unfused powder can also be used to modify the physiochemical properties of individual voxels. For example, the effective dielectric constant of a voxel can be predictably determined by "doping" the unfused powder with a chemical agent containing a dispersion of dielectric nanoparticles. Assuming the nanoparticles remain homogeneously mixed within the powder, the effective dielectric constant of the fused voxel is a function of the nanoparticle to polymer powder ratio as predicted by the Effective Medium Theory (EMT). The design and engineering of a voxel's physical properties using this doping process promises to expand the functionality of future 3D printed materials. In this presentation, we will discuss the voxel doping process in detail. We present the results from an experimental study focused on identifying and quantifying the mechanisms influencing the transport, immobilization, and retention of molecules and engineered nanomaterials (ENMs) in porous media. The study was motivated by current research on voxel-scale materials synthesis using HP's Multi Jet Fusion 3D printing technology. In this study, we used and extended an experimental technique that was described in detail at the 2017 Printing for Fabrication Conference.

10:40 **Voxel-Level Materials Science: Selective Mechanical Property and Electronic Property Control within 3D Printed Parts Using Multi Jet Fusion (Presentation-only; see Appendix for extended abstract),** *Kristopher Erickson, Paul Olumbummo, Sterling Chaffins, Aja Hartman, Lihua Zhao, and Howard Tom, HP Inc. (USA)* A-35

Selectively controlling material properties within 3D printed parts is an area of increasing interest due to the potential to fabricate printed electronic devices and variable rigidity parts directly from the printer. Previous approaches have produced enticing research results, but suffer from limitations like speed and scale. HP's Multi Jet Fusion 3D printing technology is designed for high throughput and high performance polymer printing, and is capable of using numerous agents during printing. There are two research-level investigations at HP labs where we have developed Conductive and Mechanical Tailoring Agents (CAs and MTAs) which allow for voxel-level materials science, resulting in parts with selective regions with modified electronic or mechanical properties. For the CAs, details for creating a conductive strain gauge device and other devices are explained. For the MTAs, where certain portions of the printed part can be made more rigid or more ductile, printed parts which have been made with a range of mechanical properties within a single part are presented.

Exhibit Hall Opens at 10:00

11:00 – 11:30 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

11:30 **Real-Time X-Ray Visualization of Ink Penetration into Powder Bed for Binder Jetting Process (Focal),** *Shin Mizutani and Daichi Yamaguchi, Ricoh Co., Ltd., and Takeshi Fujiwara, Masato Yasumoto, and Ryunosuke Kuroda, National Institute of Advanced Industrial Science and Technology (Japan)* 162

We have developed an in-situ X-ray imaging system to visualize penetration dynamics of small ink droplets into powder bed in binder jetting process. The imaging system consists of a micro focus X-ray source, an ink depositing device by remote control and a high resolution flat panel detector. The whole process of the ink penetration, such as ink penetration through the powder bed and powder bed densification, was visualized in sequence applying this system. The results show that the difference of the amount of ink cause the change of the powder bed densification and the penetration distance in depth and plane direction. The real-time visualization of the ink penetration dynamics can be useful to clarify the mechanism of the defects in the fabricated objects, such as internal porosity and weak bonds between the layers.

12:00 **3D Printing of Cellulose by Solvent on Binder Jetting,** *Mathieu Soutrenon, Gabriel Billato, and Fritz Bircher, iPrint/HEIA-FR and Thomas Geiger, EMPA (Switzerland)* 166

This project aims to 3D print wood by products. The printed parts are only made of cellulosic derivatives. The proposed process is powder based. Parts are made of semi-crystalline cellulose mixed with ethylcellulose (50/50). Similarly to binder jetting, successive layers of this mixture are spread out. Using an industrial inkjet print head from Fujifilm-Dimatix, isopropanol is selectively deposited on each of the powder layers. Isopropanol dissolve the ethyl cellulose, binding the cellulose particles together. The produced parts are brittle and require a post-treatment. A dedicated printer was built for this project. Ongoing research is done on optimizing of the layer formation and drying to increase mechanical properties.

12:20 **3D Printing with Xenon Flash Lamp (Presentation-only; see Appendix for extended abstract),** *Krzysztof Nauka, Seongsik Chang, Aja Hartman, and Lihua Zhao, HP Inc. (USA)* A-37

A Xenon (Xe) strobe lamp has been used to selectively fuse polymer powders with the process of selectivity achieved using common aqueous color inks promoting light absorption. This solution can provide a large range of low cost fusing agents, faster printing cycle, and extension of the potential 3D printing process to materials with high melting temperatures.

12:40 – 14:00 Lunch Break (on own)

Wednesday Afternoon Keynote:
Industrial Applications of Inkjet Technologies,
Rich Baker, Integrity Industrial Ink Jet Integration LLC (USA)
14:00 – 14:50
see details page ix, Congress Center Saal 1&2

14:50 – 15:10 Break to Change Rooms — Exhibits Open

3D Printing continues

Session Chairs: Katrina Donovan, Oregon State University (USA); Krzysztof Nauka, HP Inc. (USA); and Shinri Sakai, Yamagata University (Japan);
Congress Center Saal 2

15:10 **Permanence Testing of 3D-Printed Objects Subjected to Fade Testing with Outdoor Sunlight and with High-Intensity Fluorescent Illumination and Evaluated with a Multispectral Camera and Image Analysis System,** *Richard M. Adams II[1], Henry G. Wilhelm[2], and Jeremy Littler[1]; [1]Ryerson University (Canada) and [2]Wilhelm Imaging Research, Inc.(US)* 170

In the past two decades, 3D printing using polylactic acid (PLA) and other plastics has become widely used for modeling, prototyping, and manufacturing, for both professional and amateur applications. Statistics website <www.statista.com> predicts that the global 3D printing market will grow from $12 billion in 2018 to $20 billion in 2021. Like 2D-printed signs, prints, and photos, 3D-printed objects, if placed outdoors or in windows, will be exposed to visible light and UV radiation that can cause colorant fading, surface chalking, crazing, and other degradation (including a loss of brightness in the case of fluorescing colors). Little recent work has been published concerning testing of 3D-printed materials for light fading, ozone resistance, and the long-term dark storage stability. To develop a protocol for permanence testing of 3D-printed objects, the authors first developed a 3D-printable test target inspired by the widely-used Macbeth ColorChecker. Fade-resistance testing of samples placed in the 3D color test target was conducted under accelerated fluorescent illumination and in outdoor sunlight.

15:30 **Development of a Closed-loop Control System for the Movements of the Extruder and Platform of a FDM 3D Printing System,** *Manuela Cerón Viveros and Alvaro Jose Rojas Arciniegas, Universidad Autonoma de Occidente (Colombia)* 176

Most 3D printing systems work with control systems that can be considered open-loop, having little or no feedback to ensure appropriate movements or material output. With openloop control, 3D printing systems (low-end printers more significantly) are susceptible to factors that cannot be measured or corrected and result in errors during the printing process. Failures in mechanical fittings, jams on the movement system, loss of steps in step motors and external perturbations are some common situations during the printing process and can cause displacement of layers, that ultimately means, producing defective pieces. To achieve closed-loop control in 3D printing systems, the work reported addresses closing the loop on the positioning of the nozzle and building platform. This is performed using an independent microcontroller to read the signals sent from the printer controller board (RAMPS 1.4), which correspond to the desired positions and compares it with the signals coming from three linear optical encoders located in the x, y and z axes of the 3D printer, providing the current relative position of the head and the printing platform. The comparison generates a control action to reduce the error, following the target trajectory. A continuous monitoring of the movements throughout the printing process, ensures a more accurate positioning against possible disturbances, which means a significant saving of time, material and money. This work is applied to an FDM 3D printer but can be extended to other printing techniques or CNC machines improving both the machines and the fabricated pieces.

15:50 – 16:20 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

16:20 **High-Resolution 3D Printing at the Tip of Optical Fibres (Presentation-only; see Appendix for extended abstract),** *Richard Caulfield, Saja Aabith, Richard Colchester, Sacha Noimark, Anna David, Ioannis Papakonstantinou, Adrien Desjardins, and Manish Tiwari, University College London (UK)* A-38

High-resolution microscale structures have many potential applications across a wide range of fields such as electronics, microfluidics and healthcare. In this project the focus is on applications in the medical field. By creating high-resolution microstructures on the tips of optical fibres miniaturised imaging and sensing probes can be fabricated.

16:40 **Additive Manufacturing of Optical Components,** *Erik Beckert, Falk Kemper, Sophie Sauva, and Maximilian Reif, Fraunhofer IOF (Germany)* 182

Inkjet printing of 3D optical elements by using the hybrid polymer ORMOCER is described. Focus is on a proper material formulation for providing suitable inkjet printing parameters, and on the processing of printing 3D structures layer by layer. Specific challenges for optics, like minimizing layer-to-layer interface effects for creating a close to bulk 3D structure as well as shape and roughness requirements are discussed.

17:00 **Towards 3D Digital Printing of Micro-Electromechanical Systems,** *Ofer Fogel[1,2], Zvi Kotler[2], and Zeev Zalevsky[1]; [1]Bar-Ilan University and [2]Orbotech Ltd.(Israel)* 186

Additive manufacturing offers several advantages over conventional methods of production, such as flexibility in design and reduction of required steps during fabrication, leading to faster production

times. One promising method for manufacturing complicated 3D devices is based on laser induced forward transfer (LIFT); LIFT is a printing method which allows solid bulk materials to be printed directly. The backside of the supplier material, which is a transparent substrate coated with a thin layer of material, is heated with a pulsed laser and jets a micro-droplet (6-8 μm) of the coated material. The ability to print almost any material and the high accuracy and resolution of the droplet deposition gives LIFT a strong potential to be used in printed functional devices. Moreover, in the field of 3D structures this method can contribute to designing novel structures such as multilateral structures and complicated geometries (e.g. hollow cubes). Such structures are very hard to create using conventional methods and can be used for various implementations such as MEMS and micro-batteries. In this paper, we present initial steps towards additive manufacturing of 3D functional devices, by showing 3D metallic microstructures printed using the LIFT method. In order to print complex 3D structures (e.g. bridges), a sacrificial layer technique was used. Sacrificial layers were printed for support of the desired design and are later removed using a selective etching process, leaving only the required 3D structure.

Concurrent Event: Colleague Connections: Inkjet Open Forum
17:00 – 17:30
Join colleagues for an open discussion about the inkjet papers presented on Wednesday.
Congress Center Saal 1

Concurrent Event: Colleague Connections:
Connections for Innovation in Security Printing—The Fabrication Needs of Secured Print
16:20 – 17:30
see details page xxxix, Rossini

Conference Reception: August der Starke Paddleboat Steamer
18:00 – 21:00
see details, page xxxii

TRACK III

Security Printing I

Session Chairs: Yumiko Kishi, Ricoh Co., Ltd. (Japan), and Robert Ulichney, HP Inc. (USA)
10:20 – 17:30
Rossini

Session sponsored by

RECONNAISSANCE DIGITAL DOCUMENT SECURITY™

10:20 **The Smartphone as a Security Print Inspection Tool,** *Alan Hodgson, Alan Hodgson Consulting Ltd. (UK), and Robert Ulichney, HP Labs, HP Inc. (USA)* 189

There is currently substantial interest from the Security Print and Authentication industries in the use of smartphones to authenticate and verify products from printed features. Past meetings of this conference have shown some of the printed features that have been produced with this in mind. However, with the rapid evolution of smartphone vision systems there are now opportunities for a new generation of print features to provide extra layers of security to documents and packaging.

This work will illustrate the opportunity for a combined approach between print and electronic imaging communities to bring forward a new generation of features. However, it will also show that the different rates of secure document and smartphone product development cycles bring tensions that have yet to be resolved. The work is illustrated with some practical examples of the imaging capabilities of current smartphones. It is shown that the close focus performance of today's mobile video frame capture enables considerable opportunity for print inspection and authentication.

10:40 **Extending the Reach of a Barcode-based Imaging System,** *Matthew Gaubatz and Marie Vans, HP Inc., and Steven Simske, Colorado State University (USA)* 192
An imaging ecosystem, such as a supply chain or manufacturing line requires imaging devices to interact with 2- and 3-D objects. In such a setting, different services are exposed to and/or provided by the objects via image capture and analysis: examples include track-and-trace, shopping assistance, recall administration, access to customer service and rights management. For ease-of-use and ease-of-adoption, the best solutions allow a wide range of objects to be interrogated by a range of devices. Progressive barcodes offer a convenient scheme to image a dynamic object throughout an ecosystem than can extend into the actual production of an object or part. This paper investigates a framework for extending the reach of an image ecosystem with three components: Object-centric functionalities invoked via bar-code scanning operations, hybridization of mobile imaging and desktop browsing environments, and a compact, evolving representation of data that can be rendered and interpreted on 3D surfaces.

Exhibit Hall Opens at 10:00
11:00 – 11:30 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

11:30 **Authentication of 3D Printed Parts Using 3D Physical Signatures (Focal),** *Stephen Pollard, Guy Adams, Faisal Azhar, and Fraser Dickin, HP Labs (UK)* 196
We present a flexible workflow for the authentication of 3D printed parts and a series of experiments to show that 3D physical signatures extracted from the surfaces of 3D printed parts are able to robustly and uniquely identify and differentiate otherwise identical printed examples. This forms a useful role within the contexts of track-and-trace, product authentication and anti-counterfeiting. It does not require the product itself to be marked in a specific fashion, thus it does not affect the aesthetics or structural integrity of the printed product.

12:00 **Information Embedding in 3D Printed Objects Using Metal-Infused PLA and Reading with Thermography,** *Piyarat Silapasuphakornwong[1], Chaiwuth Sithiwichankit[2], and Kazutake Uehira[1]; [1]Kanagawa Institute of Technology (Japan) and [2]Chulalongkorn University (Thailand)* 202
Digital fabrication has the potential to innovate manufacturing and logistics in the near future. An attempt to increase the value of real fabricated objects by embedding information and including copyright protection is often proposed. We present a new technique for embedding information using metal fused materials (Copper powder-infused PLA) to form a fine structure inside the 3D printed objects. Then, information can be detected nondestructively by thermography. Our experiment proved that a binary code array of metal-infused material can be successfully printed and embedded inside a sample of fabricated 3D based objects (ABS). In the thermal image, the implanted structure areas were clearly observed with temperature conditions different from the surroundings. We also studied the factors that influence the quality of readouts, such as how deeply infused-metal is embedded from the surface, the colors of the filament substances, and the clearance of the image binary code compared to previous methods. The best condition was embedding metal-infused material 1 mm deep from the surface. Moreover, the color of the printing filament had no effect on the quality of the read-out information. These results mean that we can increase the value added to various kinds of objects fabricated with 3D printers more conveniently.

12:20 **Improvements in the Image Quality of Thermally Printed Security Cards,** *Mark Mizen, HID Global (USA)* 208
Thermal transfer technology is generally considered to be a relatively mature technology; yet advancements continue to occur. Most recently, thermal technology has begun to transition from 300 dpi to 600 dpi. The increased resolution has resulted in a significant improvement in image quality that is apparent in photos, bar codes, text, and Kanji characters.

12:40 – 14:00 Lunch Break (on own)

Wednesday Afternoon Keynote:
Industrial Applications of Inkjet Technologies,
Rich Baker, Integrity Industrial Ink Jet Integration LLC (USA)
14:00 – 14:50
see details page ix, Congress Center Saal 1&2

14:50 – 15:10 Break to Change Rooms — Exhibits Open

COLLEAGUE CONNECTIONS: CONNECTIONS FOR INNOVATION IN SECURITY PRINTING— THE FABRICATION NEEDS OF SECURED PRINT

Wednesday, 16:20 – 17:30
Rossini
Moderators: Alan Hodgson, Alan Hodgson Consulting, Ltd., and Steve Simske, Colorado State University

The secured print industry needs a continuous supply of innovative features. Polymer printing, fluorescents, metallics, and smartphone readable features are all in vogue at present and applications in 3D print are emerging. Come and join in the discussion about how we package Printing for Fabrication technologies to create systems of value to the secured document industry. Join us to debate this question as we work to position print in the continuum of physical and digital documents.

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Security Printing continues

Session Chairs: Teruaki Mitsuya, Ricoh Co., Ltd. (Japan), and Robert Ulichney, HP Inc. (USA)

Rossini

15:10 **Stable Inks Containing Upconverting Nanoparticles based on an Oil-in-Water Nanoemulsion (Presentation-only; see Appendix for extended abstract),** *Jon J. Kellar[1], Jeevan Meruga[2], William M. Cross[1], Jacob B. Petersen[1], P. Stanley May[3], Aravind Baride[3], and Khadijah Cessac[4]; [1]South Dakota School of Mines and Technology; [2]Secure Marking Inc.; [3]University of South Dakota; [4]Southern University & Agricultural and Mechanical College (USA)* A-40

An oil-in-water nanoemulsion capable of dispersing upconverting nanoparticles (UCNPs) for 7 months was investigated. Negative staining transmission electron microscopy shows that the UCNPs reside in the oil phase of the nanoemulsion. Dynamic light scattering measurements indicate that the majority of the oil volume is contained in droplets less than 1 μm in diameter. The system studied could be used to inkjet print UCNPs at least 7 months after the ink was first formulated. Nanoemulsion stability was tested in the short term, over 11 days, using an ink stability test developed for this research. It was found that after an initial loss of UCNPs, the majority of the UCNPs remained well-dispersed in solution. The UCNP dispersion was stable for longer periods under storage at 333 K compared to storage at 277 K.

15:30 **Functional Ink Formulation for Individualized Smart Tags,** *Liisa Hakola and Kaisa Vehmas, VTT (Finland)* 211

Smart Tags are functional elements that combine 2D bar codes and environmental sensing into a cost effective tag that can be attached to e.g. product packages, where additional elements should not increase the product costs. Because the Smart Tags are sensitive to environmental conditions, they are dynamic thus enabling context aware services. The enabling technology behind these Smart Tags are functional inks, such as thermochromic and photochromic inks. Functional inks are available commercially for analog printing technologies, but availability to digital printing is limited. In this paper we have shown that it is possible to formulate functional inks also for inkjet printing.

15:50 – 16:20 Coffee Break — in the Exhibit Hall, Piano Bar Foyer

Colleague Connections:
Connections for Innovation in Security Printing—The Fabrication Needs of Secured Print
16:20 – 17:30
see details page xxxix, Rossini

Concurrent Event: Colleague Connections: Inkjet Open Forum
17:00 – 17:30
Join colleagues for an open discussion about the inkjet papers presented on Wednesday.
Congress Center Saal 1

Conference Reception: August der Starke Paddleboat Steamer
18:00 – 21:00
see details, page xxxii

THURSDAY 27 SEPTEMBER 2018

Closing Keynote:
2018-2020—The Time to Go Industrial with Digital Packaging Production,
Montserrat Peidró Insa, Heidelberger Druckmaschinen (Germany)
8:45 – 9:40
see details page x, Congress Center Saal 1&2

9:40 – 10:00 Break to Change Rooms + Mini Coffee Break — Congress Center Foyer

TRACK I

Ink Jet Processes II

Session Chairs: Ramon Borrell Xaar, plc (UK); Mineo Kaneko, Canon Inc. (Japan); and Leonid Pekker, FUJIFILM Dimatix (USA)

10:00 – 11:40

Congress Center Saal 1

10:00 **Inkjet Printing on Three-Dimensional Freeform Objects (Presentation-only; see Appendix for extended abstract),** *Olivier Bürgy, Raphael Rätz, and Fritz Bircher, iPrint/HEIA-FR (Switzerland)* A-41

This paper presents a new direct-to-shape printing platform enabling digital inkjet printing on three-dimensional freeform objects. Previous work in this field has focused mainly on geometrical shapes. This paper describes a new system that uses a Wavefront OBJ file containing a tessellated description of the object with his texture to generate the trajectory for the robot and the images for the print system. An articulated arm with an inkjet printhead mounted on the end effector follows the surface of the object to print the image. The algorithms used to generate the trajectories and images and the general printing platform will be described in this work.

10:20 **Direct-to-Shape: Increasing the Throw Distance,** *Renzo Trip[1], Nick Jackson[1], Felix Steinchen[2], Volker Till[2], and Werner Zapka[1]; [1]Xaar plc (Sweden) and [2]Till GmbH (Germany).* 215

Direct-to-shape printing demands a high drop placement accuracy, such that the drop placement is still acceptable at larger throw distances (> 1mm). In this study, the influence of the nozzle shape on the drop placement accuracy has been investigated. Experiments were conducted employing a series of prototype Xaar 126 printheads fitted with a silicon nozzle plate, with various nozzle taper angles. The results presented in this study show that a larger nozzle taper angle improves the drop placement accuracy; that is, when the printhead is operated at a drive voltage required to have a drop velocity of 6m=s. The required drive voltage is reduced due to the increased nozzle efficiency associated with a larger nozzle taper angle. A lower drive voltage is likely to be the underlying reason for a smaller drop-to-drop velocity variation, which in turn results in an improved drop placement accuracy. An even better drop placement accuracy is obtained when the drive voltage is increased to give a larger than typical drop velocity (of upto 10:3m/s), but this also causes the formation of satellite drops reducing the overal print quality.

10:40 – 11:00 Coffee Break, Congress Center Foyer

11:00 **The Importance of Software in Managing and Maintaining Image Quality and Enabling New Industrial Inkjet Applications (Presentation-only; see Appendix for extended abstract),** *Simon Edwards, Global Inkjet Systems Ltd. (UK)* A-43

As industrial print demands for inkjet print quality increase, there is only so much that can be achieved through machine design and printhead capability. Simon Edwards will present how software management of the datapath from artwork to print offers significant capability to achieve high image quality through intelligent image management and the application of compensation and correction strategies.

COLLEAGUE CONNECTIONS: LATE BREAKING NEWS

Thursday, 11:40 – 12:40
Congress Center Saal 1
Moderator: Werner Zapka, XaarJet Ltd. (Sweden)

Bring your knowledge of the latest technological announcements to this lively session that is a perennial favorite. See the moderator prior to the session if you'd like to present on a particular topic, or just come and listen to the latest from colleagues. A great way to end the week.

Session sponsored by

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11:20 **Printing of Dielectric and Conductive Patterns on Non-Planar Surfaces Using Dispensing and Inkjet (Presentation-only; see Appendix for extended abstract),** *Robert Thalheim[1], Maxim Polomoshnov[2], and Ralf Zichner[1]; [1]Fraunhofer ENAS and [2]Technische Universität Chemnitz (Germany)* A-44

Conventionally the aim of functional printing is the mass production of cost reduced electronical devices like printed antennas, batteries and sensorson flexible but necessarily planar substrates in a roll-to-roll mass production process.

Using digital printing technologies on non-planar surfaces offer the direct application of images to objects without limitations to the material and a new degree of freedom of applicable object geometries when it is combined with a robot or multiple axis system. So far just a few publications are available which are dealing with digital printing of functional layers on non-planar surfaces. For example a state of the art technology for the manufacturing of non-printed conductive paths on three dimensional objects is 3D-MID (Molded Interconnect Devices). Challenges of the 3DMID technology are the necessity of a master molding form and high material costs.

Colleague Connections: Late Breaking News
11:40 – 12:40
Congress Center Saal 1

Colleague Connections: Technology Tours
13:00 – 18:00
see details, page xliv

TRACK II

Production Printing

Session Chairs: Teruaki Mitsuya, Ricoh Co., Ltd. (Japan), and Travis Walker, South Dakota School of Mines (USA)
10:00 – 11:40
Congress Center Saal 2

10:00 **Modeling Printing System Relationships based on Weibull Distribution,** *Nikita Gurudath, Mikel Stanich, and Larry M. Ernst, Ricoh Americas Corporation (USA)* 221

Commercial inkjet printing is a complex system that poses advanced technical challenges. The relationship between the amount of ink deposited per unit area and light reflected due to the ink in the same unit area is important to understand various imaging characteristics associated with a printing system. The amount of ink deposited per unit area is referred to as mass deposition. Optical Density (OD) defines the light reflected by ink on paper. Well-known methods used to define mass deposition versus OD require extensive knowledge of the halftone. These techniques require detailed halftone information regarding the mass deposition precisely for each halftone pattern as well as for the halftone calibration. Often, halftone information is unavailable, and this causes barriers in characterization of printing systems. With the advent of industrial printing, it has become necessary to characterize printers with media other than paper and unconventional ink options. This must not be hindered due to lack of drop count information of the fluid/polymer based on the ink or the media. The model has been used over a wide range, from the microscopic level of printing lines and dots to the macroscopic scale of halftones. It describes printing systems having different halftone designs, resolutions, printer speeds, calibration, multipass and multidrop printing.

10:20 **Liquid Ink Development System for Production Printing Using Volatile Carrier Oil and Fine Toners,** *Nobuyuki Nakayama, Satoshi Tatsuura, Taichi Yamada, Toshihiko Suzuki, Takamaro Yamashita, and Osamu Ide, Fuji Xerox Company, Ltd. (Japan)* 225

A liquid ink development system for production printing was developed using liquid developer consisting of volatile carrier oil with a high boiling point and fine toner particles. To obtain applicability to a wide variety of production print applications, such as commercial printing, labels, cartons and soft packaging, the system was aimed to achieve high image quality, high productivity, wide media versatility, low running costs, and high post-process capability. For the purpose, in addition to newly designed developer and additives, an image formation process using a contact development process and tandem type electrostatic multi transfer process, back heat-type oil drying process, roller fixing process, and developer circulation and dispersion process were developed. High image quality comparable to analog prints, printability onto a wide variety of media and high post-process capabilities were achieved.

10:40 – 11:00 Coffee Break, Congress Center Foyer

11:00 **Permanent Charge Roller for Indigo Digital Presses (Presentation-only; see Appendix for extended abstract),** *Seongsik Chang, Tom Anthony, Michael Lee, Omer Gila, Anthony McLennan, and Henryk Birecki, HP Inc. (USA), and Eyal Lovton, Shmuel Borenstain, and Yonni Hartstein, HP Indigo (Israel)* A-46

Charge rollers for electrophotographic processes are usually made with conductive rubber and has a finite lifetime. We developed a charge roller that essentially has infinite lifetime and became a part of the Indigo press, not a consumable. Permanent charge roller is made of semiconductive ceramics and operates with a gap up to 80um from a photoconductor surface. No mechanical or chemical failure mechanisms are found. Permanent charge roller is implemented in hp7900 and is planned to be retrofitted to every series 3 HP presses.

11:20 **State-of-the-Art Printing Machine Technology (Presentation-only; see Appendix for extended abstract),** *Yoshinori Komori, Kormori Graphic Technology Center, and Takeshi Yoshikawa, Komori Corporation (Japan)* A-48

Komori is one of the leaders of printing machine manufacturers worldwide. Since its founding in 1923, it has been developing, manufacturing, selling and servicing printing presses for 95 years. Komori offer a wide range of services such as banknote / securities printing press, offset sheet-fed printing press, offset web-fed printing press, packaging web-fed printing press, Printed Electronics printing system, digital printing system as well as its peripheral equipment and related materials, etc.

More than 100 years have elapsed since the offset printing method was established, and offset printing covers most of the current printed products. Komori would like to explain the background of today's offset printing as mainstream in the printing market and some of the latest technologies in modern printing systems in this P4F

Colleague Connections: Late Breaking News
11:40 – 12:40
Congress Center Saal 1

Colleague Connections: Technology Tours
13:00 – 18:00
see details, page xliv

TRACK III

Security Printing II

Session Chairs: Guy Adams HP Labs (UK); Matthew Gaubatz, HP Inc. (USA); and Yumiko Kishi, Ricoh Co., Ltd. (Japan)
10:00 – 11:20
Salon St. Petersburg

Session sponsored by
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10:20 **Near-Infrared (NIR)-to-NIR Upconversion Nanocrystals for Security-Printing and Forensic Applications (Presentation-only; see Appendix for extended abstract),** *Stanley May[1], Jon Kellar[2], William Cross[2], Aravind Baride[1], and Jeevan Meruga[2]; [1]University of South Dakota and [2]South Dakota School of Mines and Technology (USA)* A-51

Upconversion (UC) phosphors have the interesting property of producing luminescence at wavelengths shorter than that of the excitation light.1 The most intently studied UC phosphors to date are those that convert near-infrared (NIR) radiation to visible luminescence. NIR excitation does not produce background emission, is less damaging to sensitive substrates, and penetrates more deeply into biological tissue compared to UV-Vis light. Over the past six years, our group has made significant advances in the use of upconversion nanocrystals (UCNC) as activators for inks in security printing applications.2-6 Early success includes covert printing using NIR-to-visible upconverting (UC) inks that produce both monochrome (green)5,6 and RGB4 luminescent images when excited with NIR light. Printed features (e.g. quick response codes) from these inks, activated by lanthanide-doped UCNCs, are invisible under ambient and UV lighting. However, they can be 'read' under NIR illumination because they exhibit visible UC luminescence. Across all fields of UC research, however, very little attention has been paid to phosphors that convert NIR excitation into shorter-wavelength NIR emission (NIR-to-NIR upconverters). Here we will summarize our recent work involving NIR-to-NIR UCNC and highlight the unique advantages these materials bring to security printing applications.t

10:40 **Printing Reflective Features for Security Printing (Presentation-only; see Appendix for extended abstract),** *Nikhil Pillai, Rudy Ghosh, Dave Pope, and Stan Farnsworth, NovaCentrix (USA), and Alan Hodgson, Alan Hodgson Consulting Ltd. (UK)* A-52

From the perspective of the wider print industry there are several drivers that have encouraged the

development of the capability to fabricate metallic appearance in print. The first of these is for a purely decorative effect aimed at brand enhancement for items such as packaging and labels. These features have also been developed for a number of printing techniques allowing them to be easier to integrate into existing production workflows.

With this brand enhancement comes some level of brand protection. This comes from the fact that illicit duplication of metallic effects requires more than traditional CMYK colour management and printing capability. Print systems that can produce sparkle and dichroic effects add to both enhancement and protection and have been deployed as such.

In this paper we will focus on the utilisation of printed electronics production capability to produce these metallic effects and how they can be considered as an option to formulate parts of optical security features, an area of growing interest to this community with a dedicated conference, Optical Document Security1. This is an evolving opportunity that could well prove lucrative for print engine and materials providers.

10:40 – 11:00 Coffee Break, Congress Center Foyer

11:00 **Intrinsic Signatures for Forensic Identification of SOHO Inkjet Printers,** *Zhi Li, Wanling Jiang, Daulet Kenzhebalin, Alexander Gokan, and Jan Allebach, Purdue University (USA)* 231

Counterfeiting of currency globally remains a significant problem. And according to the authorities, a large portion of the fake currency is produced by Small Office Home Office inkjet printers. Therefore, a new inkjet printer forensics technology would be useful to identify the model of the source printer given a print sample. In our paper, we study the print patterns from 15 low-cost inkjet printers that are being sold on the market and examine test targets at the microscopic level. We design 4 printer intrinsic features including Dot Size, Dot Density, Average Distance to Nearest Dot, and Nearest Dot-Sector Density Function to characterize the behavior of inkjet printers. Furthermore, we extend our research and develop a machine learning based Printer Identification System. Unlike handcrafted features that have intuitive meaning to human viewers, an alternative set of intrinsic features are extracted from the Residual Neural Network, and based on the Neural Network features, a Support Vector Ma-chine classifier is trained and is able to perform the printer model classification. Our evaluation shows that the proposed system produces robust and reliable results

Free Time for Discussions
11:20 – 11:40

Colleague Connections: Late Breaking News
11:40 – 12:40
Congress Center Saal 1

Colleague Connections: Technology Tours
13:00 – 18:00
see details, below

COLLEAGUE CONNECTIONS: TECHNOLOGY TOURS

From Pulp to Photo Cards—
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APPENDIX A

Extended abstracts were submitted by authors who choose the "presentation-only" talk option. They are not considered conference proceedings papers and are not available in electronic form on this USB, nor in the IS&T Digital Library. To view the extended abstracts, refer to the TECHNICAL PROGRAM, ABSTRACTS, AND USB PROCEEDINGS or TECHNICAL PROGRAM AND PROCEEDINGS hardcopy books.

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- Arabic number (1, 2, 3) indicates page on which full paper is found in the hardcopy version of the book and the usb stick.
- A-followed by an arabic number indicates the page on which the extended abstract of a presentation-only paper is found in this book, within the Appendix section.
- * indicates abstract only; there is no extended abstract nor proceedings paper associate with the talk.
- (tdpf) after the indicates this is a Technology in Digital Photo Fulfillment talk and if there is a paper associated with the talk, it will be open access at http://ist.publisher.ingentaconnect.com/content/ist/tdpf, otherwise it is just the abstract

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