33rd International Conference on Digital Printing Technologies (NIP)

NIP/DIGITAL

Printing for Fabrication 2017

DIGITAL

Materials, Applications, and Processes

November 5-9, 2017
Denver, Colorado, USA

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Collocated event
2017 International Symposium on Technologies in Digital Photo Fulfillment

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ABSTRACT BOOK AND USB PROCEEDINGS

The papers in this volume represent the program of
Printing for Fabrication 2017 (33rd International Conference on Digital Printing Technologies, NIP)
held November 5 – 9, 2017, in Denver, Colorado.

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Welcome to Printing for Fabrication 2017

I am delighted to welcome you to Denver, Colorado—The Mile High City—and host to the 2017 Printing for Fabrication Conference. Some of you may have attended the NIP22 and the second annual Digital Fabrication Conference which was also held in Denver in 2006. Returning to Denver more than a decade later provides an opportunity to reflect upon the continued evolution of graphics-based digital and non-impact printing technologies and also on the remarkable and surprising advances in print-based digital fabrication, additive manufacturing, and 3D printing that have taken place during the last eleven years.

For example, graphics-based digital and non-impact printing has made steady progress on many fronts including new digital image processing, pipelines, writing systems, and workflow that exploit the latest advances in computing hardware, artificial intelligence, and machine learning. Other important advances include the development of high-performance, ultra-reliable printheads that enable single-pass printing processes that produce high-quality output at astonishing print speeds. New developments in inks, toners, and media continue to capture markets that were once the domain of analog printing technologies. Moreover, the adoption of functional inks and toner are making it possible to print on a wider range of substrates and media—transforming static packaging into smart, responsive surfaces and user interfaces. In the package printing domain, it is clear that the boundaries that once defined traditional digital printing technologies and digital fabrication are no longer distinct and continue to blur.

With respect to the evolution of digital fabrication and additive manufacturing technologies, it would be impossible to describe the progress that has occurred in the last decade in this brief introduction. In 2005 and 2006, we referred to the use of digital printing processes and materials to "print things" as a new paradigm. Since then, the paradigm has become a mainstream technology that has irreversibly transformed analog fabrication and manufacturing. These developments have become the foundation for astonishing and unforeseen capabilities and applications. For example, the use of digital inkjet printing technology to deposit biological materials was the province of academic laboratories a decade ago. Today, there are a number of companies who have successfully commercialized cell-based printing, tissue engineering, and bioprinting that promise to revolutionize regenerative medicine, surgical processes, and therapies. In the next decade, it is conceivable that we will see the deployment of inkjet-based bioprinters into clinical environments and operating theatres.

The subject of "printable and functional materials" has been one of the conference cornerstones. In the last decade, the conference has included sessions focused on the incorporation of inorganic, organic, and biological materials as components of functional inks and toners. From the earliest demonstrations of electrically conductive inks composed of metal nanoparticles to the most complex biological additives, the conference has served as a rallying point for materials scientists and technologists who are developing new functional fluids that leverage the benefits of digital and drop-on-demand printing processes. Over the last decade, we have seen lab-scale advances in the synthesis and formulation of inks composed of nanoparticles, carbon nanotubes and fullerenes, quantum dots, graphene, and biological materials such as DNA, proteins, enzymes, peptides, and cells. In subsequent conferences, we have learned how these new functional agents are being used and are transforming a wide range of industries and markets.

Finally, 3D printing technologies and 3D manufacturing has been a featured subject since the beginning. It has been a conference mainstay because of its fundamental connections with traditional 2D printing technologies—including document security, materials, and processes used for printing and data workflow. Over the years, we have watched as 3D printers have moved from the desktop to the factory floor and now promise to be the foundation of the next industrial revolution. As in previous years, the conference program will continue to focus on the commercialization of new 3D printing technologies and the emergence of new applications and markets.

Outstanding technical breakthroughs are made not only by the continuous efforts of individuals and companies to master specialized technical areas, but also through contacts with different technical domains and colleagues. The development of new ideas that are catalyzed by the intersection of diverse technological domains has been the conference's raison d'être since its inaugural event. I am confident that the 2017 Print4Fab Conference will continue in the tradition of excellence we have come to expect from previous years. In addition to an outstanding technical papers program, this year's event is rounded out by a technical exhibition, short courses, roundtable discussions and the annual Late Breaking News/Success Stories final session.

In summary, I would like to express my gratitude to Executive Program Chair Wolfgang Schmidt who provided his knowledge and experience unsparingly in the preparation of this conference, and to the conference committee members and IS&T staff, who support all our efforts. I also express my appreciation to the sponsors and exhibitors who always support the conference and make it a better event.

—General Chair Jim Stasiak, HP Inc.

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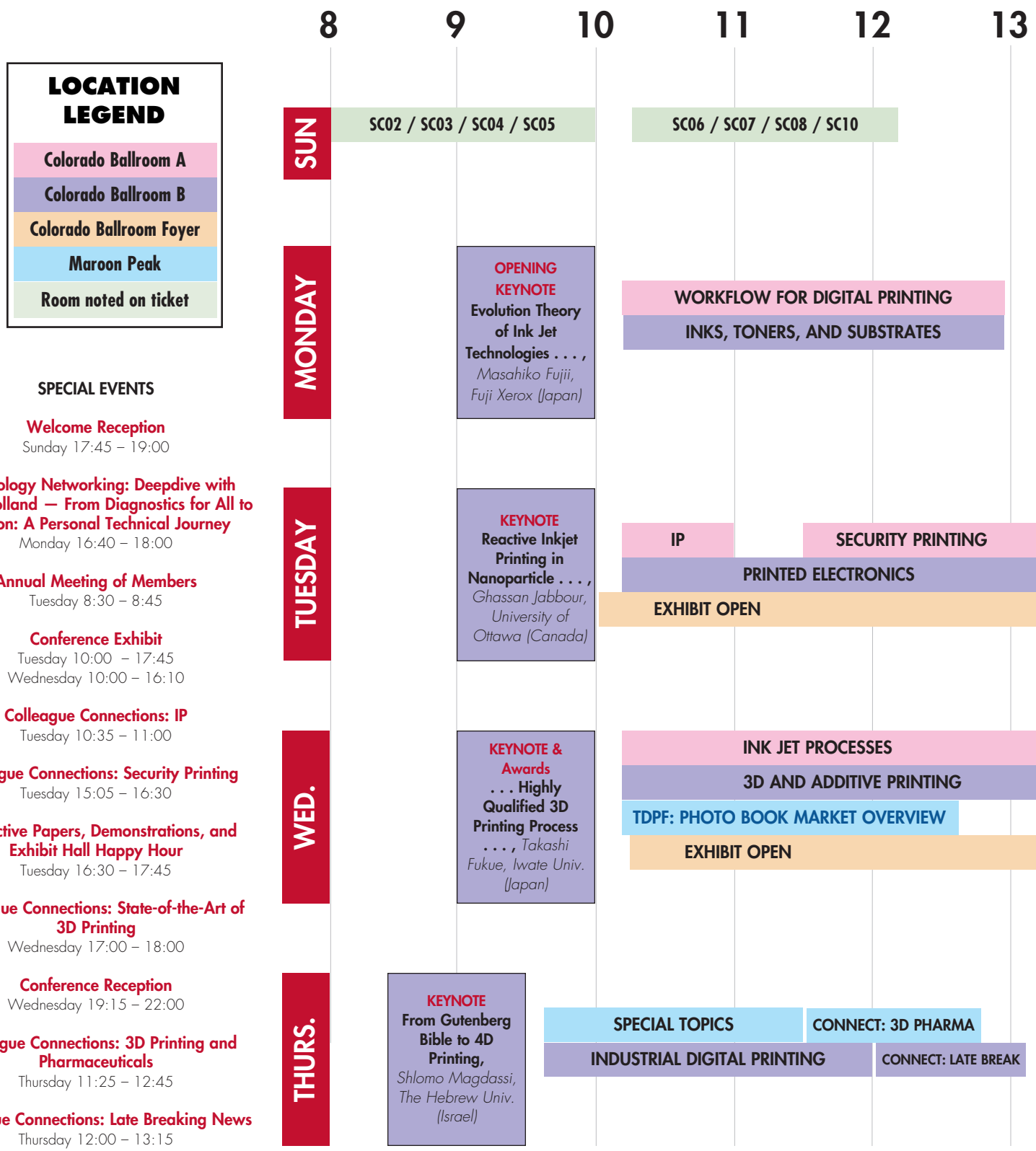


SPECIAL EVENTS

Welcome Reception
Sunday 17:45 – 19:00

Technology Networking: Deepdive with Jason Rolland — From Diagnostics for All to Carbon: A Personal Technical Journey
Monday 16:40 – 18:00

Annual Meeting of Members
Tuesday 8:30 – 8:45

Conference Exhibit
Tuesday 10:00 – 17:45
Wednesday 10:00 – 16:10

Colleague Connections: IP
Tuesday 10:35 – 11:00

Colleague Connections: Security Printing
Tuesday 15:05 – 16:30

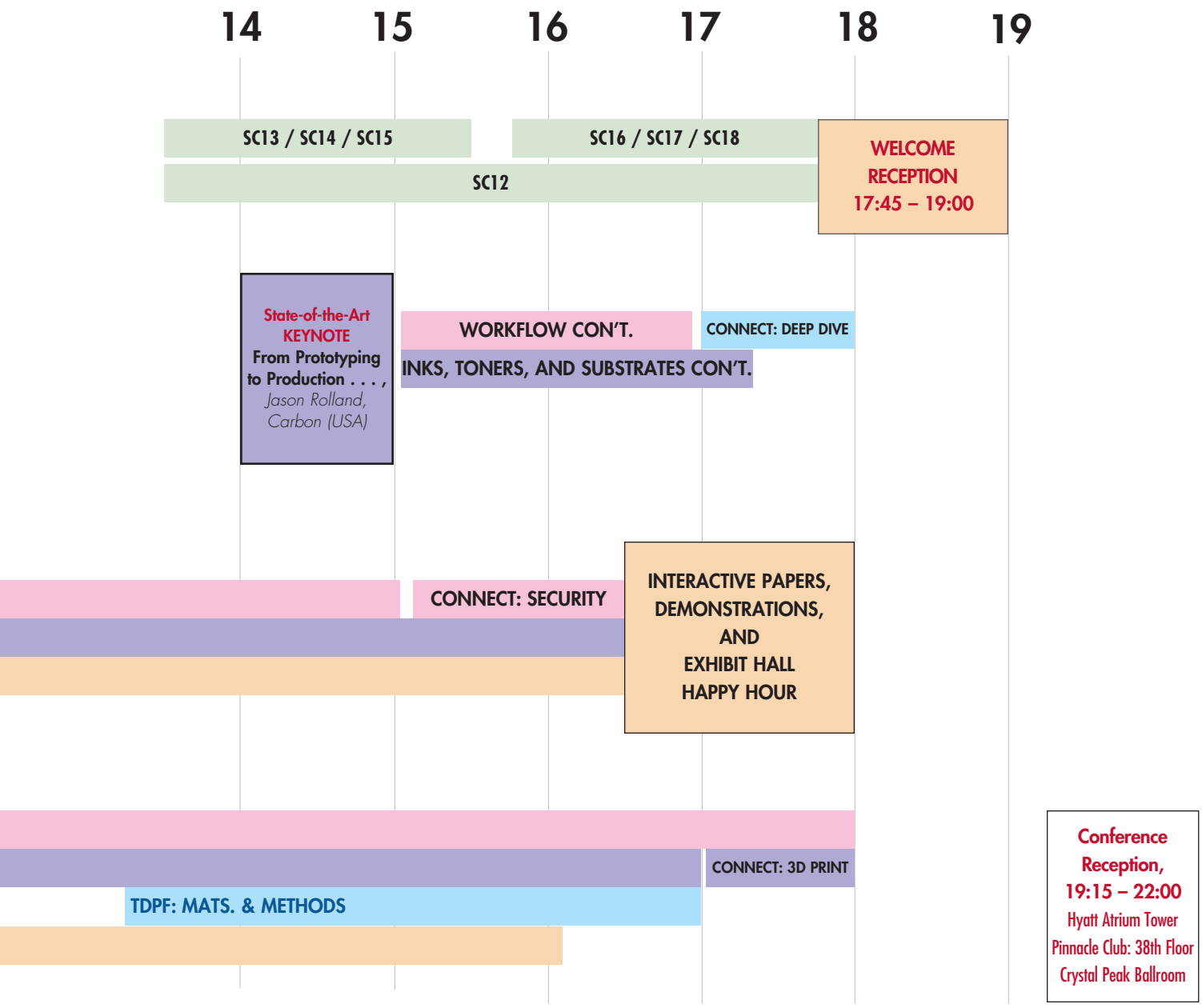
Interactive Papers, Demonstrations, and Exhibit Hall Happy Hour
Tuesday 16:30 – 17:45

Colleague Connections: State-of-the-Art of 3D Printing
Wednesday 17:00 – 18:00

Conference Reception
Wednesday 19:15 – 22:00

Colleague Connections: 3D Printing and Pharmaceuticals
Thursday 11:25 – 12:45

Colleague Connections: Late Breaking News
Thursday 12:00 – 13:15



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

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Exhibit Hall Hours
Tues. 10:00 – 17:45 and Wed. 10:00 – 16:10

Interactive Papers Session, Demonstrations, and Exhibit Hall Happy Hour
Tuesday 16:30 – 17:45
Meet with interactive authors, exhibitors, and other colleagues over a beer.

Colorado Ballroom Foyer

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Technical Papers Program: Schedule and Contents*

SPECIAL EVENT

WELCOME RECEPTION

Sunday, November 5th
17:45 – 19:00
Colorado Ballroom Foyer

Kick off the conference by joining colleagues on Sunday before heading to dinner

KEYNOTE TALKS

Colorado Ballroom B

MONDAY, NOVEMBER 6

Opening Keynote

Session Chairs: Kye-Si Kwon, Soonchunhyang University (South Korea); Teruaki Mitsuya, Ricoh (Japan); and James Stasiak, HP Inc. (USA)

9:00 - 10:00

9:00 **Evolution Theory of Ink Jet Technologies—Progress by Component or Architectural Knowledge (Presentation-only Paper),** *Masahiko Fujii, Fuji Xerox Co., Ltd. (Japan)*

Ink jet technology has extended its market by upgrading functions and improving performances of a few key components (printhead, ink, and media) under simple marking processes for years. However, this trend has saturated in the personal market and the activation of markets has dulled. In this situation, two directions for ink jet technology progress have become obvious. One is expansion of ink jet to various applications such as digital fabrications utilizing a simple process and the other means challenges (to commercial printing market) against performance limitations derived from imaging process achieved only by the interaction between ink and media.

Differences of technical approaches in each direction also exist. Progress of elemental technology (key components) has been noticeable in extending possibilities. Challenge against limitations has been dazzling in system integration or peripheral technologies progress. The former evolution (concentrating functions progress) can be called incremental innovation and needs component knowledge to improve component performances. The later (sharing functions progress) demands architectural knowledge to test the optimum combination of components (dominant design) maximizing systems performance and is called as architectural innovation.

Generically, venture companies or small start-ups play a role in pushing architectural innovation because they are free from resource allocation mechanism or organizational forms of incremental innovation. But in the current commercial printing market, many big names have introduced printers with different component combinations and the dominant design has not yet been fixed. The shift from incremental innovation to architectural innovation also has occurred in additive manufacturing.

State-of-the-Art Keynote

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

14:00 - 14:50

14:00 **From Prototyping to Production: Rethinking Materials for Additive Manufacturing (Presentation-only Paper),** *Jason Rolland, Carbon (USA)*

Additive manufacturing processes use time-consuming, stepwise layer-by-layer approaches for part fabrication. We demonstrate the continuous production of monolithic polymeric parts with feature resolution below 100 micrometers. Digital Light Synthesis (DLS) is achieved with an oxygen-permeable window below the ultraviolet image projection plane, which creates a "dead zone" (persistent liquid interface) where photopolymerization is inhibited between the window and the polymerizing part. We define critical control parameters and show that complex solid parts can be drawn out of the resin at rates 25-100X that of conventional technologies.

Additionally, we show that DLS enables a wide range of new and commercially relevant materials. These include: tough, resilient elastomers; rigid, impact-resistant plastics with excellent abrasion resistance; flexible materials capable of producing living hinges; high-temperature cyanate ester resins; and other novel polymer formulations. These materials open possibilities across a range of industries including automotive, footwear, medical, aerospace, wearables, and many others.

The combination of rapid, layerless printing with high-performance engineering polymers having a range of mechanical properties represents a major step toward fulfilling the promise of additive manufacturing.

TUESDAY, NOVEMBER 7

Tuesday Keynote

Session Chair: Wolfgang Schmidt, Schoeller Technocell GmbH & Co. KG (Germany)

9:00 - 10:00

9:00 **Reactive Inkjet Printing in Nanoparticle Manufacturing and Device Applications (Presentation-only Paper),** *Ghassan Jabbour, University of Ottawa (Canada)*

Reactive inkjet printing (RIJ) is becoming a versatile and promising technique in materials synthesis and device engineering. In this regard, Ghassan Jabbour will discuss the application of RIJ, for the first time, in modifying the sheet resistivity of conducting polymer layers, and in combinatorial mapping of such property. In addition, we will introduce our latest accomplishments in this field, including the self-assembly of nanomaterials, quantum dots, and conductive textile.

WEDNESDAY, NOVEMBER 8

Wednesday Keynote and IS&T Awards

Session Chairs: Norio Nagayama, Ricoh Company, Ltd. (Japan), and Shuichi Maeda, Tokai University (Japan)

9:00 - 10:00

9:00 **Attractive and Innovative Solutions for Highly Qualified 3D Printing Process Development in Next Generation (Presentation-only Paper),** *Takashi Fukue, Iwate University (Japan)*

The dawn of 3D printing technologies has ended and it is entering the development phase. Two years ago, due to the slowness of 3D printers, it was understood that much time would be needed to apply 3D printers to production facilities. Now, many types of 3D printers have already been prepared on designer's desk. Designers are now using 3D printers to make product prototypes. 3D printers are already a useful tool for small-lot and custom-made production, such as in the medical device industry. 3D printers have also established their status as a popular industrial technology.

Soon 3D printer use will be expanded beyond prototype development and customization to become a mass production tool in an assembly line. To effectively use 3D printers as part of this process, advanced printing process controls must be developed to inhibit the occurrence of variations. While in prototypes, individual differences are less important, producing something that is globally competitive requires decreased development and manufacturing costs and an improvement in the quality of 3D printing.

Against this background, this keynote proposes considerations that should be addressed in the next generation of 3D printing processes from the viewpoint of building new products using 3D printers in the assembly line. An important key factor in improving the quality of 3D printing is the effects of heat on the printing process. For example, in the case of fused deposition modeling, the printing quality of the first layer has a dominant effect on the printing accuracy of the whole product. However, due to the occurrence of a distribution of a contraction in a solidification process by temperature distribution, curling can happen. Similar thermal problems are also caused in selective later sintering printers and binder jetting printers. In this lecture, we investigate our understanding of "invisible" thermal problems in the 3D printing processes and how to obtain "next generation attractive quality".

THURSDAY, NOVEMBER 9

Closing Keynote

Session Chair: Wolfgang Schmidt, Schoeller Technocell GmbH & Co. KG (Germany)

8:30 - 9:30

8:30 **From Gutenberg Bible to 4D Printing (Presentation-only Paper),** *Shlomo Magdassi, The Hebrew University of Jerusalem (Israel)*

Functional printing brings additional performance of printed patterns, beyond graphic output. Our research is focused on synthesis and formulations of nanoparticles and inks, and their utilization in printed devices and responsive and 3D objects. The formation and application of inks composed of nanoparticles and polymerizable materials in smart windows and electrical circuits will be reported. These inks address major challenges in fabrication of flexible and 3D electronics devices, in which the printing should be performed at sufficiently low temperatures that will not damage the polymeric substrates. New approaches for formation of porous 3D objects and conductive electrodes will be also described, based on using new UV curable oil-in-water emulsion inks, and for rapid 3D and 4D printing in water by using new nanoparticles of photoinitiators. Utilization of 3D and 4D printing technologies for fabrication of objects composed of shape memory polymers, elastomers and hydrogels will be demonstrated, for applications such as soft robotics, delivery systems, responsive connectors, dynamic jewelry, and medical devices.

Please note: Page numbers listed after paper titles refer to the page on which a paper is located in the full proceedings book, found digitally on the USB stick that accompanies this book.

MONDAY NOVEMBER 6, 2017

Opening Keynote: Evolution Theory of Ink Jet Technologies—Progress by Component or Architectural Knowledge
Masahiko Fujii, Fuji Xerox Co., Ltd. (Japan)
9:00 – 10:00
see details page viii, Colorado Ballroom B

Workflow for Digital Printing

Session Chairs: Xiaorong Cai, Troy Security Solutions (USA) and Hiroshi Yamazaki, Yamamoto Trading Co., Ltd. (Japan)
10:10 – 16:55
Colorado Ballroom A

10:10 **Using IIO Structure to Enable Additional Workflows,** *Margaret Sturgill, Steven Simske, and Marie Vans, HP Inc. (USA)* 1
Serialization is an important VDP (variable data printing) application. Incremental Information Objects (IIOs) allow us to keep track of steps in a workflow by modifying their serialized information at each step. Usually the IIO progression is defined by specific rules that change the visual properties of the IIO. We herein propose an additional constraint that defines a specific structure to the underlying bit string defining the IIO. We can then use the structure to either identify the workflow stage without access to the main ID database; modify the current workflow stage due to additional factors (user authentication, location, etc.); or use the information in the IIO as additional security information.

10:35 **Photogrammetry-based 3D Digitization Method for Oil Paintings,** *Chen Chen, Xiaochum Wang and Guangxue Chen, South China University of Technology (China)* 5
This paper proposes a new oil painting digitization method using photogrammetry technology to compensate for the deficiencies of the existing methods. The color and the 3D geometric information of the oil painting are recovered better by acquiring several sets of orthophotomaps, and modeling accuracy is ensured with a control mesh or by flattening. The 3D reconstruction and digital representation of oil paintings mainly includes two aspects: 3D geometric information recovery of oil painting surface and color rendition of oil painting. Photogrammetry can acquire a digital 3D model of the surface geometrics of an oil painting, restore the color image and plane geometry of the painting in the form of orthophotomap, and implement the 3D digital representation of color in the painting.

11:00 – 11:30 Coffee Break — Colorado Ballroom Foyer

11:30 **From 8-bit to 4K: A Leading Computational Image Formation Architecture for Digital Printing Technology (Focal),** *Chunghui Kuo, Eastman Kodak Company (USA)* 9
As printing technology continues to evolve, the next technical challenges will most likely arise from fully automated digital print production and high-precision digital fabrication, where the printing press needs to detect faults in the printing process, automatically recover without human intervention, and construct images and/or three-dimensional objects beyond the capability of human perception. In this paper, we introduce a computational image formation algorithm of which tonal resolution at each pixel is elevated from the current technology standard of 8-bit to a class-leading 12-bit, *i.e.*, 4K tonal resolution. Combined with a 1200-dpi high spatial resolution adaptive LED printhead, we will demonstrate that the proposed image formation algorithm can effectively address technological challenges for the future of image formation and digital fabrication technologies.

12:05 **Embedding a Standard within a Standard Using Mobile Progressive Barcodes,** *Marie Vans, Matthew Gaubatz, and Steven Simske, HP Inc. (USA)* 13
Progressive barcodes have been proposed as a mechanism to employ Data Matrix barcodes on a package or label to enhance security services for products in a supply chain by layering additional data into color channels. While the standards-based component of the code remains readable by the same equipment, the extra (color) layer requires additional processing to extract relevant information, communicate with appropriate database modules, etc. This paper examines the problem of extending the scope of applications addressable by this technique to a wider range of designs intended for

mobile consumption. This challenge involves developing a scheme that can be naturally used by a greater number of mobile devices, as well as increasing the ease of adoption. The extension of progressive barcodes to the more ubiquitous QR code via embedding a compact Data Matrix code into the design is an approach for improving functionality of print and document workflows. The two barcodes can be used simultaneously for their most familiar purposes. Mobile processing allows us to leverage many more possible object-driven workflow touchpoints.

12:30 **HDR Image Reproduction based on ICAM06 and Bilateral Filtering (Interactive Paper Preview),** *Xiaozhou Li, Yang Zhao, and Jingqiang Jia, Qilu University of Technology (China)* 17

HDR Image could not be reproduced on LDR medium directly. A lot of tone information and detail information can't be perceived when we use the LDR medium, e.g., display and paper, which are the most often medium used. Although there are several progresses in traditional display medium technique including large gamut, adaptive lightness adjustment, etc., a lot of details are compressed in the reproduction of HDR image. In fact, HDR image is always correlated to the surround conditions when it is perceived through human eyes. When we perceive the scene with high dynamic range, e.g., sun rise or sun set, the responses captured by human and processed in our brain always show beautiful aspect. Theoretically, HDR image representation is highly correlated to color appearance. And the image appearance and dynamic range are always satisfied at the same time when we use our eyes as the receptor. To solve the problem that HDR image could not be reproduced in most LDR medium, a novel method based on iCAM06 and bilateral filtering was presented in this paper. Firstly, the HDR image was subjected to bilateral filtering based on the human visual characteristics. Then it was processed adaptively according to the light source information and the edge details retained. As a result, the noises in shadow portion could be reduced by the brightness adaptive function and the HDR image could be reproduced using the digital print output. It showed that the saturation of the image color was enhanced and the image contrast was improved. Additionally, the Halo phenomenon was eliminated more and the details information and edge sharpening were enriched.

12:40 **A CUPS-based Print Control and Management Solution for UNIX-Like Operating Systems (Interactive Paper Preview/Presentation-only Paper),** *Wenjing Song, Bo Wan, Weiwen Cai, and Min Pang, Xidian University (China)*

This paper presents a CUPS-base print control and management solution for UNIX-like operating systems using virtual print driver, print control subsystem, and print manage subsystem. This solution can control user to print with authorized printers only, records the information related with the print, such as user name, copies, and pages, etc. The print related information is printed on the paper in form of QR code image. This image can be used to trace the source of the hard copy. More important, the administrator can view the content of the print request in form of PDF file and agree or refuse the print request through web-based manage subsystem. Following a brief overview of the related research work, this paper explains our solution to control and management the user's print request in Unix-liked operating systems and gives the typical printing process under our solution. The proposed creative solution takes advantage of CUPS, the popular client-server architecture and the model-view-controller design pattern. The benefits enabled by the solution include enhanced the print control and management under UNIX-like operating systems, and reduced the cost of record and check print request manually.

12:50 – 14:00 Lunch Break

State-of-the-Art Keynote:
From Prototyping to Production: Rethinking Materials for Additive Manufacturing
Jason Rolland, Carbon (USA)
14:00 – 14:50
see details page viii, Colorado Ballroom B

COLLEAGUE CONNECTIONS: DEEPDIVE WITH JASON ROLLAND— FROM DIAGNOSTICS FOR ALL TO CARBON: A PERSONAL TECHNICAL JOURNEY

Monday, 16:40 – 18:00: Maroon Peak
Moderator: James Stasiak, HP Inc. (USA)

Dr. Jason Rolland serves as vice president of materials at Carbon3D, Inc. In this role, he is focused on creating the broadest possible range of materials for growing 3D objects with Carbon3D's CLIP technology. During this networking event, Dr. Rolland discusses his personal journey from the co-founding of Liquidia Technologies, Inc. to senior director of Diagnostics for All to Carbon3D. While this event will be of interest to anyone attending this year's conference, it will be of special interest to young professionals charting their futures in various technology domains. Please join us for a unique opportunity to hear from an industry leader who is shaping the future of digital fabrication, additive manufacturing, and 3D printing.

Workflow for Digital Printing continues

Session Chairs: Hiroshi Yamazaki, Yamamoto Trading Co., Ltd. (Japan) and Xiaorong Cai, Troy Security Solutions (USA)
Colorado Ballroom A

15:00 **3D Visualization of Out-of-Gamut in Graphic Communication,** *Maohai Lin[1,2], Meiqi Lin[1], Haiyan Cao[1], Hongge Guo[1], and Guichun Hu[1]; [1]Qilu University of Technology and [2]South China University of Technology (China)* 20

In order to achieve high-fidelity representation of colors, it needs to do some purposeful interference when colors are conversed, so the color gamut mapping which is the main technology to ensure visual matching would be used during this process. And the accurate visualization of out-of-gamut between images and devices plays an important role in color gamut mapping, so a method of the 3D visualization of out-of-gamut in graphic communication based on segment maxima algorithm was proposed in this paper. And this method mainly had two steps, the first step was that the device color gamut boundary points could be obtained when used the color conversed information in digital output device profile, so as to generate accurate device color gamut. The next step was that out-of-gamut points could be obtained through making comparison between device gamut and digital image gamut, as result that the area of out-of-gamut could be presented in digital images and image gamut according to the out-of-gamut cloud dots. The advantages of this method were that it can encourage us to predict whether the image gamut is beyond the output device gamut in advance, and then it can help us to select appropriate color gamut mapping algorithm according to the result of out-of-gamut judgment, so as to realize the accurate reproduction of colors.

15:25 – 16:00 Coffee Break — Colorado Ballroom Foyer

16:00 **Fatigue Life Prediction of SUS Sleeve in Laser-Printer Fuser (Interactive Paper Preview),** *Sun Ho Park and TaeHan Kim, S-Printing Solution Co., Ltd. (South Korea)* 25

One of the most frequent durability issues in laser printer system is the failure of thin metal sleeve in the fuser assembly. In order to ensure the reliability of the laser printer, it is important to predict the failure of the thin metal sleeve in the fuser assembly.

In this study, the method to predict fatigue life of fuser SUS sleeve with 3D dynamic simulation and fatigue simulation using ABAQUS and FEMFAT is introduced. Fatigue property of fuser SUS sleeve is correlated with MIT folding endurance test results and safety factor is calculated to endure the product life specification.

16:10 **Structure Design and Synthesis of Waterborne Resins and Their Application in Processless Computer-to-Plate (Interactive Paper Preview/Presentation-only Paper),** *Shuyun Zhou, Technical Institute of Physics and Chemistry (China)*

We designed the structure and synthesied waterborne resins which play a key role to achieve the new type water developable green photopolymerization plate.

16:20 **Study on Synthesis and Properties of Photo Acid Generator and Water-Solube Resin Used in Cationic Photo-Polymerization System (Interactive Paper Preview/Presentation-only Paper),** *Shizhuo Xiao, Technical Institute of Physics and Chemistry (China)*

A class of photo acid generators (PAGs) and hydrophilic-oligomer resins about cationic UV curable had been designed and synthesized. The acid generation efficiency and photo-polymerization

kinetics of these PAGs were investigated in detail. Through exposure experiment and pure water-development, the imaging performance of photosensitive composites fabricated by oximesulfonates type photo-acid generators and hydrophilic oligomer resin was investigated. A clear image could be obtained with an exposure energy of 150 mJ/cm2.

Colleague Connections: Deepdive with Jason Rolland—
From Diagnostics for All to Carbon: A Personal Technical Journey
16:40 – 18:00
see details page xiii, Maroon Peak

Session sponsored by

RICOH

Inks, Toners, and Substrates

Session Chairs: Jay Bhatt, HP Inc. (USA); Nobuyuki Nakayama, Fuji Xerox Co., Ltd. (Japan); Atsushi Tomotake, Konica Minolta Inc. (Japan); and Achim Weber, Fraunhofer IGB (Germany)

10:10 - 17:20

Colorado Ballroom B

Sponsored by Ricoh Company Ltd.

10:10 **The Influence of pH on the Stability of Inks of Two-Dimensional Materials for Digital Fabrication,** *Viviane Forsberg, Renyun Zhang, Magnus Hummelgård and Håkan Olin, Mid Sweden University (Sweden)* 29

We aim to achieve stable printable 2D inks with environmental friendly solvents using a surfactant as a stabilizer. This study focuses on the influence of the pH on the stability of the MoS_2 dispersions in acetic acid at concentrations ranging from pH 1 to 5. The effectiveness of liquid-based exfoliation using shear exfoliation was also evaluated though SEM images and resulted in very thin nanosheets. We observed that at pH concentrations higher than 2, the dispersions were more stable.

10:35 **Manufacturing of Micro-Scale Polyurethane Foams by Reactive Inkjet Printing,** *Fabian Schuster[1], Fabrice Ngako Ngamgoue[2], Thomas Hirth[3], and Achim Weber[1,2]; [1]University of Stuttgart, [2]Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, and [3]Karlsruhe Institute of Technology KIT (Germany)* 32

Reactive inkjet printing (RIJ) was used as an additive manufacturing (AM) tool. Combined with polyurethane (PU) chemistry, it is shown that RIJ can be used to build micro-scale foams. Waterblown polyurethane foams (PUF) based on polyethylene glycol 200 (PEG200), glycerol ethoxylate (Star-PEG) and 1,6-hexamethylene diisocyanate (HDI) were used to prepare the foams. The system was catalyzed using iron(III) chloride, dibutyltin dilaurate (DBTL), diazabicyclo octane (DABCO) and bis(2-dimethylaminoethyl) ether. The influence of iron(III) chloride and DBTL were investigated by means of temperature profile measurements. The stability of the catalyst system was tested for 32 hours within the ink formulation. The ink formulations were then printed with a Dimatix DMP3000 (Fujifilm, USA) printer using a 16 nozzle printhead with a nominal 10 pL drop volume. The reaction of the inks and the building of PUF after printing were investigated by light microscopy and SEM. It seems favorable to use high amounts of catalyst in order to obtain a more porous structure.

11:00 - 11:30 Coffee Break — Colorado Ballroom Foyer

11:30 **The Effect of Drying Behavior of Coatings Containing Pigment and $CaCl_2$ on Inkjet Print Quality (Focal),** *Katriina Mielonen[1,2], Sami-Seppo Ovaska[1], Johanna Lyytikäinen[1], Leena-Sisko Johansson[2], Monika Österberg[2], and Kaj Backfolk[1]; [1]Lappeenranta University of Technology and [2]Aalto University (Finland).* 37

The effect of drying behavior of coatings containing starch, synthetic silicate pigment and $CaCl_2$ on inkjet print quality was studied. It is known, that print quality is dependent on the ink-substrate interaction, absorption behavior of the substrate and colloidal stability behavior of the ink at the substrate interface. One efficient way of improving the fixation of anionic inkjet pigment colorants is by controlling the electrostatic interaction and colloidal stability by using e.g. divalent or multivalent metal salts. In this study, we have investigated the effect of end moisture content of coating containing hydroxypropylated-starch, synthetic silicate and divalent metal salt ($CaCl_2$) on inkjet print quality of pigment-based ink. It was seen that significant differences in print density could be obtained when using different drying

strategies. The obtained effects on substrate-ink interactions were ascribed to changes in coating structure and migration of $CaCl_2$ and better film forming caused by the more intense drying process.

12:05 **Ink Formulation and Printing of Superhydrophobic Paper,** *Michelle Jensen[1], Jacob Petersen[1], Chris Schultz[1], Jon Kellar[1,2], and William Cross[1,2]; [1]South Dakota School of Mines and Technology and [2]Center for Security Printing and Anti-Counterfeiting Technology (USA)* 42

Security printing has been performed for years to combat against counterfeit documents. In this research hydrophobic silica nanoparticles are suspended into an ink and printed on paper and glass substrates. It was shown that under certain conditions superhydrophobic substrates could be created. In addition, a superhydrophobic security-feature was printed using these methods.

12:30 **A Study on the Factors Affecting Ink-Substrate Interactions in Maplitho Papers (Interactive Paper Preview),** *Mahuya Biswas[1,2], Shankhya Debnath[1], Munmun Dey[1], Srabana Kundu[1], and Abhijit Bandyopadhyay[2]; [1]DIC India Limited and [2]Calcutta University (India)* 47

The nature of paper used plays a pivotal role in determining the quality of the final printed product. The quality of paper is defined by a number of parameters, which affect not just the quality of print, but also controls the physical aspects during print production in offset lithographic presses. Maplitho paper is almost always the substrate of choice for run-of-the-mill commercial jobs. This work deals with the study of the inter-dependability of the various substrate parameters with the print quality. The study was conducted on commercially available maplitho papers of different GSM from various manufacturers. This work presents a relationship that exists between physical factors of the substrate like rate of penetration of ink in paper, surface regularity with ink film drying time and gloss levels of printed substrate that defines ink-substrate interactions. A strong correlation was obtained between the datasets used for the experiment suggesting that, for the same ink film, its drying time and gloss levels on different maplitho papers is dependent on physical factors intrinsic to the paper.

12:40 **The Inkjet Dispensing and Control of Explosive Solutions on Surfaces (Interactive Paper Preview/Presentation-only Paper),** *Alexandra Charleson, Catherine Skidmore, Lauren Holley, Peter Glover, and Marie Shackleford, Dstl (UK)*

Micro-dispensing technologies can be used to produce explosive deposits on surfaces. One of the key benefits of using this approach is the ability to deposit a precise number of droplets with good spatial control in a highly reproducible manner, to control crystal morphologies. Key attributes to control include crystal size, shape, spatial distribution, composition, and phase depending on the context for the deposit. In this poster we will discuss three areas of study to achieve predictable deposits of explosives materials on surfaces. These include ink formulation, surface properties, and crystallisation- most notably polymorphic form. To achieve this Dstl has formulated explosives solutions in a binary solvent system to exploit Marangoni fluid dynamic effects for even crystal distribution on a substrate. In addition, we carried out surface treatments to ensure depositions have a high contact angle on wicking surfaces and investigated the effects of ink concentration and solvent antisolvent crystallisation on polymorphic forms.

12:50 – 14:00 Lunch Break

State-of-the-Art Keynote:
From Prototyping to Production: Rethinking Materials for Additive Manufacturing
Jason Rolland, Carbon (USA)
14:00 – 14:50
see details page viii, Colorado Ballroom B

Inks, Toners, and Substrates continues

Session Chairs: Jay Bhatt, HP Inc. (USA); Gustav Mårtensson, Mycronic AB (Sweden); Nobuyuki Nakayama, Fuji Xerox Co., Ltd. (Japan); and Atsushi Tomotake, Konica Minolta Inc. (Japan)

Colorado Ballroom B

Sponsored by Ricoh Company Ltd.

15:00 **Experimental Study of Filament Break-off of Dense Suspensions,** *Gustaf Mårtensson[1,2] and Fabian Carson[1]; [1]Mycronic AB and [2]Chalmers University of Technology (Sweden)* 54

Higher particle volume fractions lead to shorter break-off times in filament-stretching measurements, which correlates with higher satellite levels and poorer dot shape when jetted onto a substrate.

Suspensions within a certain break-off time range show optimal jetting results. This implies that filament stretching of dense suspensions can be connected to their jetting behaviour, potentially allowing for this technique to be used to predict jetting results. The purpose of this study is to establish a deeper understanding of the break-off process of filaments of dense suspension in order to enable a more repeatable volume deposition of electronic materials, such as conductive adhesives, solder pastes et cetera.

15:25 – 16:00 Coffee Break — Colorado Ballroom Foyer

16:00 **Tuning Inkjet Printability of Hydroxypropylated-Starch-based Coatings by Mineral Selection,**
Sami-Seppo Ovaska, Katriina Mielonen, Johanna Lyytikäinen, and Kaj Backfolk, Lappeenranta University of Technology (Finland) 58

Coatings based on hydroxypropylated starch (HPS) provide extraordinary print density with dye-based inkjet inks, but their suitability for pigment-based inks can be limited due to inadequate carrier medium (water) absorption and colorant fixation. In the present work, HPS-based coatings were tailored for both a pigment-based and a dye-based ink by adding silicate minerals or acid clay (both Lewis and Brönstedt acid sites present in the acid clay). Substrate-ink interaction and colorant distribution were investigated via uncoated gloss and print quality indicators such as print density, ink bleeding tendency and delta gloss after printing with desktop printers. Three-dimensional z-stack CLSM images taken from printed samples revealed substantial differences in ink holdout and penetration characteristics between the studied materials. Pigment-filled HPS coatings showed up to 60% increase in print density compared to uncoated reference substrate and an increase of up to 35% compared to plain HPS coating with dye-based inks. In case of pigment-based ink, the increase was 17% between plain HPS coating and acid-clay-filled HPS coating. In addition, a combination of HPS and silicate mineral decreased ink bleeding substantially, but lower print gloss compared to substrate initial gloss was observed with the majority of experimental coatings. It was found that the pigment type affects substantially the unprinted gloss, which is naturally high in the case of pure HPS coating, but also the observed drastic difference in substrate permeability may explain the differences in print quality. The findings suggest that coating morphology, together with chemical interactions between starch and mineral and coated substrate and ink, has a key role in achieving high gloss and good print quality.

16:25 **Visualization Analysis on Melting Deformation of Toner Particles in a Fusing Nip (Focal),** *Kenichi Hamada, Minoru Ohshima, Toru Ogawa, and Yoshihisa Kitano, Fuji Xerox Co., Ltd. (Japan)* 64

Image gloss in electrophotographic copiers and printers is closely related to the image structures, which are spatial structures of melted toner layers on media. Therefore, in order to design the image gloss when copiers and printers are developed, it is necessary to clarify relations between the image gloss and the image structures, and relations between the image structures and system parameters. We clarified the relations between the image gloss and the image structures by constructing a relation model between the image gloss and characteristic indices of two image structures that crucially affect the image gloss in our previous report. However, with respect to clarifying the relations between the image structures and the system parameters, analysis on the melting deformation behavior of toner particles is the most important problem to be solved.

In this report we newly developed a visualization measurement method for melting deformation of toner particles in a fusing nip. The method enables us to directly observe the behavior of toner particles in the fusing nip under the condition simulating time variation of temperature and pressure in the actual fusing system.

By using the method, dependences of the deformation behavior of the toners in the fusing nip on the system parameters were analyzed. As a result, it was found that the toner particles are deformed completely in the fusing nip. We also clarified the effect on the deformation of toner particles in the fusing nip caused by temperature of a heating unit and that of a pressurizing unit. Considering the results, it was found that the restoring deformation of the toner after the fusing nip caused by residual stress stored inside the toner particle significantly affects the image structures and image gloss after fusing.

17:00 **Water based Green Lithography (Interactive Paper Preview/Presentation-only Paper),** *Haihua Zhou and Yanlin Song, Chinese Academy of Sciences (China)*

Environmental protection has aroused attention in recent years. A primary pollution source of printing industry is the organic solvent of printing ink, *i.e.,* volatile organic compounds (VOC). Although water based ink has been used in gravure or flexography, the cost of plate making for gravure or flexography is much higher than lithography. So far, most high-volume books and magazines have been printed with offset lithography, which has become the most common form of printing technology since the 1960s. The common used printing ink in lithography is mainly solvent-based ink with high viscosity. Currently, the printing plate is made up of alumina coating with photosensitive materials, while the image-text areas are hydrophobic and the blank areas are hydrophilic, so the common used printing plate cannot be used to print with water based ink. Water based green lithography means lithography using water based ink. This new technique is of great significance but with great challenges. The key problems include the cooperation of water based ink with printing plate, and the printing machine is also needed change accordingly. The lithography printing machine has some rubber rollers to transfer printing ink, while for water based ink too many rollers will cause the ink adhere to the rollers.

17:10 **Growth and Characterization of Nd-Doped Niobate Laser Crystals (Interactive Paper Preview/Presentation-only Paper),** *Shoujun Ding[1,2], Qingli Zhang[1], Wenpeng Liu[1], Jianqiao Luo[1], and Dunlu Sun[1]; [1]Anhui Institute of Optics and Fine Mechanics, CAS and [2]University of Science and Technology of China (China)*

With the rapid development of high power laser diodes, much attention has been paid on the investigation of new Nd-doped materials that have good diode-pumped laser properties. Recently, a new series of Nd-doped niobate laser crystals have been grown successfully by Czochralski method. In this work, the growth and characterization of these Nd-doped niobate laser crystals have been reviewed, including Nd:$YNbO_4$, Nd:$GdNbO_4$, Nd:$GdYNbO_4$ and Nd:$GdLaNbO_4$. All the obtained results indicating that these crystals have great application prospect in low even moderate lasers. Moreover, the broad spectral bandwidth of Nd:$GdYNbO_4$ and Nd:$GdLaNbO_4$ mixed indicating that they are promising to generate short laser pulse.

CONCURRENT EVENT **Colleague Connections: Deepdive with Jason Rolland—From Diagnostics for All to Carbon: A Personal Technical Journey**
16:40 – 18:00
see details page xiii, Maroon Peak

TUESDAY NOVEMBER 7, 2017

SPECIAL EVENT

INTERACTIVE PAPERS SESSION, DEMONSTRATIONS, AND EXHIBIT HALL HAPPY HOUR

Tuesday, 16:30 – 17:45
Colorado Ballroom Foyer

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

Tuesday Keynote
Reactive Inkjet Printing in Nanoparticle Manufacturing and Device Applications
Ghassan Jabbour, University of Ottawa (Canada)
9:00 – 10:00
see details page ix, Colorado Ballroom B

2017 Exhibit Open
10:00 – 17:45
see details page vi, Colorado Ballroom Foyer

Intellectual Property

Session Chairs: Nobuyuki Nakayama, Fuji Xerox Co., Ltd. and Michael Willis, Pivotal Resources (UK)
10:10 – 11:00
Colorado Ballroom A

10:10 **Intellectual Property Rights of Inventors and Employers in the US,** *Scott Slomowitz and Gary A. Greene, Caesar Rivise, PC (USA)* 70

Intellectual Property (IP) rights for both inventors and employers can be a confusing quagmire for all involved. The traditional aspects of inventor IP rights, viz., patents, copyrights, and trade secrets as well as related to employer and employee rights will be compared in this paper. Issues discussed include ownership rights of IP from the perspective of both the employer and the employee. From the perspective of the employer, issues include the importance and content of employment agreements, timing of the agreement (*i.e.,* issues related to an agreement execution before and after commencement of employment), identification of what is and what isn't considered to be an invention owned by the company (e.g., inventions made prior to employment and inventions made outside the scope of employment may not be owned by the company), and agreements with respect to employees vs. agreements with respect to independent contractors. From the perspective of the employee, issues include inventions made outside of course of employment, the importance of carefully reading and understanding the employment agreement, both the inventor's rights and obligations and the employer's rights and obligations under the agreement (and complying with those terms), whether or not there is even an employer/employee relationship (e.g., are you an independent contractor or employee), and the importance of proper record keeping, particularly for inventions made that are outside the scope of employment. The terms of employment agreements with regard to IP can be stringent in some cases and inventors especially need to be aware, from the start, of these obligations such as identifying the existence of their inventions to the employer prior to beginning employment.

This paper will survey the IP rights of the inventor/employee and of the employer and guidelines for both.

Colleague Connections: Intellectual Property: A Moderated Discussion
10:35 – 11:00
see details below, Colorado Ballroom A

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

COLLEAGUE CONNECTIONS: INTELLECTUAL PROPERTY—A MODERATED DISCUSSION

Tuesday, 10:35 – 11:00: Colorado Ballroom A
Moderator: Michael Willis, Pivotal Resources Ltd. (UK)

Join Michael Willis (Pivotal Resources Ltd.), Scott Slomowitz and Gary Greene (Caesar Rivise), and other colleagues in an open, moderated discussion of issues related to intellectual property, including the rights of inventors and employers.

COLLEAGUE CONNECTIONS: STATE-OF-THE-ART SECURITY PRINTING AND PRINT-BASED ANTICOUNTERFEITING TECHNOLOGIES

Tuesday, 15:05 – 16:30: Colorado Ballroom A
Moderator: Jon Keller, South Dakota School of Mines and Technology (USA)

Please join us for a round table discussion focused on state-of-the-art security printing and print-based anti-counterfeiting technologies. A central topic will be the intersection of materials science, information-hiding, and new methods of print-based information encryption. The event will be moderated by Dr. Jon Kellar, the Douglas Fuerstenau Professor of Materials and Metallurgical Engineering at the South Dakota School of Mines and Technology. Professor Kellar also serves as the director of the NSF-funded Center for Security Printing and Anti-Counterfeiting (SPACT).

Security Printing

Session Chairs: Peter Brown, The Technology Partnership (UK); Makoto Omodani, Tokai University (Japan); Hirotosi Terao, ALPS Electric Co., Ltd. (Japan); and Bob Ulichney, HP Inc. (USA)

11:30 – 15:05
Colorado Ballroom A

11:30 **Visible-to-Infrared Converting $CaCuSi_4O_{10}$ Security Ink (Focal),** *Jacob Petersen[1,3], Jeevan Meruga[1,3], Aravind Baride[2,3], Chandler Bogart[3], William Cross[1,3], Stanley May[2,3] and Jon Kellar[1,3]; [1]South Dakota School of Mines and Technology, [2]University of South Dakota, and [3]Center for Security Printing and Anti-Counterfeiting Technology (USA)* 73
A blue silicate, cuprorivaite ($CaCuSi_4O_{10}$), with strong conversion of visible input to infrared emission at around 910 nm, was previously demonstrated for use as a micron scale powder for latent fingerprint imaging. In this research, we prepare a cuprorivaite powder and subject it to mechanochemical treatments that organically modify and exfoliate the material to produce a pigment ideal for ink formulation. The prepared ink was then used to print a security feature.

12:05 **Inkjet and 3D Security Printing (Presentation-only Paper),** *Vitaly Talyansky, Stardust Materials, LLC (USA)*
This presentation will give an overview of the security materials currently used as taggants in inkjet. It will discuss the role of luminescent ceramics and challenges needed to be overcome for their successful application in inkjet. Case studies describing inkjet printing of variable data for document security, textiles, and AM parts will be presented.

12:30 **The Expected Lifetime for Printed Security Cards,** *Mark Mizen, HID Global (USA)* 77
Printed security cards are among the most abused of all photographic prints. These cards are used as identification, shown to various officials, passed through multiple readers, and stored in a wallet without protection. Security cards are exposed either accidentally or intentionally to various chemicals. They are handled in cold climates and left in a hot car exposed to sunlight. Security cards must resist alterations, yet must remain readable throughout their expected lifetime. To meet these needs, the security industry has operated at the forefront of technology, adapting conventional and digital imaging technologies to specific industry requirements.

12:55 – 14:15 Lunch Break

14:15 **Development of a Mechano-Responsive Ink for Security Printing,** *Chandler Casey[1], Rohit Dulal[2], Delaney Clouse[3], Cassandra Degen[2], Jon Kellar[2]; [1]University of Notre Dame, [2]South Dakota School of Mines and Technology; and [3]The University of Southern Mississippi (USA)* 80
Security printing is an emerging field to prevent forgery, tampering, and counterfeiting of a wide variety of documents and consumer goods. In this work, mechanochromic ink for security printing is suggested as a viable option for a reversible, easily detectable way of determining the legitimacy of a document or product. Generally, mechanochromic polymers change color and exhibit fluorescence in response to a mechanical force due to the presence of mechanophore molecules covalently linked within the polymer structure. A well-known mechanophore, spiropyran (SP), is easily incorporated into poly(dimethylsiloxane) (PDMS), an elastomeric polymer. In this study, SP-PDMS ink for security printing applications is studied by tuning the initial viscosity with a solvent. Additionally, the printed film quality is determined through both optical and mechanical techniques. Printing conditions were deter-

mined for printing with a Nordson Engineered Fluid Dispensing (EFD) Printer. The responsiveness of the mechanochromic ink to mechanical loading is explored through visible color change..

14:40 **Development of Loaded Microspheres for Tamper-Activated Security Features,** *Forest Thompson[1], Abigail McBride[1], Linta Farooq[2], George Wicks[3], and Grant Crawford[1]; [1]South Dakota School of Mines and Technology, [2]New Jersey Institute of Technology and [3]Applied Research Center, Inc. (USA)* 86

The ongoing technological fight against counterfeiting demands the development of new anti-counterfeiting strategies based on novel material systems. In this work, we report on a unique material system, employing porous-wall hollow glass microspheres as versatile carriers for functional security materials. To evaluate the feasibility of using these glass microspheres in anti-counterfeiting applications, several deployment configurations and processing routes were developed, whereby microsphere cargo included either (1) precursor functional materials, (2) functional materials, or (3) reactive functional materials. Microspheres were loaded using a wet vacuum technique and subsequently characterized using scanning electron microscopy, energy dispersive x-ray spectroscopy, x-ray diffraction, and spectral imaging techniques.

Colleague Connections:
State-of-the-Art Security Printing and Print-based Anti-counterfeiting Technologies
15:05 – 16:30
see details page xix, Colorado Ballroom A

Interactive Paper Session/Demonstrations/Exhibits Happy Hour
16:30 – 17:45
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
Colorado Ballroom Foyer

Printed Electronics

Session Chairs: Oh Hyun Baek, Samsung Electronics, Inc. (Korea); Roger Bollstrom (morning), Omya International AG (Switzerland); Shinichi Nishi, JAPERA (Japan); Wolfgang Schmidt, Schoeller Technocell GmbH & Co. KG (Germany); and Ghassan Jabbour, University of Ottawa (Canada)

10:10 – 16:40
Colorado Ballroom B

10:10 **Conductivity and Microstructure of Inkjet Printed Nanoparticle Silver Layers Processed with Intense Pulsed Light (IPL) Sintering on Various Polymeric Substrates,** *Dana Mitra[1] and Reinhard Baumann[1,2]; [1]Technische Universität Chemnitz and [2]Fraunhofer Institute for Electronic Nano Systems ENAS (Germany)* 92

Novel manufacturing methods for flexible, light weight and cost-efficient electronics have gained high interests in the recent years, especially the additive printing technologies are of major relevance. Here, the digital inkjet printing technology is an attractive printing method due to its additive, high precision and up-scalable deposition process. One of the key components of a printed electronic device, such as capacitor, transistor and sensor, is the conducting track. A major requirement is the device dependent electrical performance induced by an appropriate post treatment process. Traditional thermal sintering via an oven or hotplate requires on one hand long sintering times (up to minutes and hours) and on the other hand high sintering temperatures (above 150°C - 300°C), which are unsuitable for flexible polymeric foils with low glass transition or melting temperature. However, the novel method of intense pulsed light (IPL) sintering has great potential when it comes to the fabrication of functional layers on thin, flexible and temperature instable polymeric foils. In our research, the IPL sintering methodology is used to convert printed liquid films into solid and conducting metallic layers on various flexible polymeric substrates, like Polyethylene terephthalate (PET), Polyethylene naphthalate (PEN) and Polyimide (PI). Based on their glass transition temperature as well as applied energy densities the defect formation in the micrometer rang was analyzed. Furthermore, the electrical performance was measured and the conductivity calculated. It was found, that the substrate material property in terms of glass transition temperature and melting point have a prominent influence on the defect rate and the electrical performance.

10:35 **Electrically Conductive Polymer Composite Dispensing Process for EMI Shielding Structure,**
Oh Hyun Baek, Keon Kuk, and Eun-Bong Han, Samsung Electronics Co., Ltd. (South Korea) . 97
Electro Magnetic Interference (EMI) shielding structure with low cost and high performance is proposed. Conductive polymer composite is formulated with metal based filler and silicone polymer and solvent. The liquid composite material can be easily dispensed through the low pressure injection nozzle and cured to the conformal structure with high aspect ratio. High electro conductive polymer composite dispensing process is developed to build a conformal structure for the EMI shielding of PBA(Printed Board Assembly). In order to increase electrical conductivity of composite material, Ag coated copper is adopted for conductive filler material and dendrite structure is applied to reduce content ratio of the conductive filler in the composite material. An EMI shielding structure is designed to cover the exposed surface of the chip package and modified for the shielding module containing chips and electrical elements on the PBA. The wall thickness of shielding layer is under 0.6 mm and aspect ratio is lower than 2.0. The conformal structure is fabricated by dispensing process with side slot nozzle and viscoelastic behavior of composite material maintains the vertical thin wall structure. EMI shielding performance is verified by measurement of chip level EMI shielding test procedure developed in this study.

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

11:40 **Rewritable Paper Sheets having Kapok Fibers Containing Chromic Materials,** *Shuichi Maeda, Shuichi Kiyama, Misako Katano, and Shinichi Yoshinari, Tokai University (Japan)* 102
The target of this present work is, using natural hollow fiber named Kapok fiber and functional materials, to obtain color changeable sheets which have potential to be used as rewritable and electronic paper in simple preparation and with low cost. We will introduce three types of kapok fibers containing chromic materials such as thermochromic, solvatochromic, and piezochromic materials.

12:05 **Development History and Current Achievements of Printed Primary Batteries,** *Andreas Willert[1] and Reinhard Baumann[1,2]; [1]Fraunhofer Institute for Electronic Nano Systems ENAS and [2]Chemnitz University of Technology (Germany)* 106
Since the end of the last century tremendous efforts have been spent to utilize various aspects of printed electronics' components. One aspect in driving electronics is to provide electrical energy for it. The most appropriate way is to employ printing approaches rather than assembly processes for the integration of battery technology. Doing so, the application basically can be fully printed—if all components are printable.

Looking for commercial applications, there are already some available on the market: e.g. temperature logger, RFID smart tagging cards, or cosmetic patches.

In this paper a review on printed primary batteries is presented and discussed. Since 2007 Fraunhofer ENAS and Chemnitz University of Technology are active in developing and manufacturing printed batteries and applications thereof. Besides the historical sketch also the current achievements are shown and discussed.

12:30 **Green Printing Technology for Manufacturing Functional Devices (Presentation-only Paper),**
Yanlin Song, Chinese Academy of Sciences (China)
Traditional printing process results heavy pollution, thus developing green printing and patterning technology is of great significance. The blooming of printed electronics is promoting fashion electronic manufacture to flexible, wearable, ultraintegrative, ultralight, transparent devices, and clean, efficient, mild productions. Among various materials demonstrated adoption in printability. Nanoparticles have aroused great attentions due to their board applications. The research and development of pigment nano-particles has greatly improved the performance of printing products. The critical scientific challenges of the printing process are wettability manipulation and dynamics of ink droplets. Based on the droplet drying process on the surfaces with different wettability, controllable nanoparticles assembling and patterning could be achieved, through controlling the movement of vapor-liquid-solid three phase contact lines.

12:55 – 14:15 Lunch Break

14:15 **Evaluation of Inkjet Printed Electronic Devices by Investigating the Manufacturing Yield and Performance Tolerance for the Application in Flexible Electronics (Presentation-only Paper),** *Kalyan Mitra[1], Christian Zeiner[1], Enrico Sowade[1], Eloi Ramon[2], Carme Martinez-Domingo[2], Henrique Gomes[3], Stefanie Kreissl[4], Christine Boeffel[4], and Reinhard Baumann[1,5]; [1]Chemnitz University of Technology (Germany); [2]Institut de Microelectronica de Barcelona (Spain); [3]Universidade do Algarve (Portugal); [4]Fraunhofer Institute for Applied Polymer Research (IAP) (Germany); and [5]Fraunhofer Institute for Electronic Nanosystems (ENAS) (Germany)*

In this present research work an attempt has been made to develop a manufacturing platform using inkjet technology, where several electronic devices e.g. conductive structures, capacitors, diodes, TFTs and OPVs etc. are manufactured in large quantities on flexible polymeric substrates (DIN A4 sized sheet). The quantity of the manufactured devices ranges to several thousands and the fabrication of such devices are accomplished using commercial inks, substrates, industrial printheads and other accessories. Hence, it proves its industrial relevant manufacturing process, followed by the novelty of evaluation using statistical analysis. The devices from the individual categories are manufactured by varying the size and deposition parameters. The devices are characterized topographically and then for electrical properties, manufacturing yield and the device performance regime from device-to-device and from sheet-to-sheet. The results show that the performance of the all inkjet printed devices are in par with those that are obtained in several publications e.g. (a) capacitance of > 100 pF/mm^2 for capacitors; (b) rectification ratio of > 200 and current density of 40 mA/cm^2 for diodes; (c) source-drain current of 1 µA, charge carrier mobility of 0.1 cm^2/V.s and On/Off ratio of > 1000 for TFTs; and (d) open circuit voltage of 0.45 V, power conversion efficiency of 0.15%, short circuit current of 0.3 mA/cm^2 and fill factor of 38% for OPVs. But in addition, the performance of these devices was found to strongly depend on the deposition process itself. The devices exhibit performance in high and low tolerance values for sheet-to-sheet and for device-to-device configurations. This high deviation in the tolerance appears from the device processing characteristics, which is related to the failures. Special focus has been put forward in knowing the reason for the failures and their origins. The deposition process of printing these electronic devices is very close to industrial relevance and this potential aid in achieving the manufacturing yield for the devices up to 90%. These manufactured devices with high yields are foremost desired and they definitely open the application field to produce electronic circuits and end user products.

14:40 **Novel Organic Multi-Color Electrochromic Device for E-Paper Application,** *Norihisa Kobayashi, Masahiro Yukikawa, Zhuang Liang, and Kazuki Nakamura, Chiba University (Japan)* 111

Electrochromism is reversible color change by electrochemical reaction. In this paper, we designed novel organic electrochromic device based on bispyridinepyrrole derivatives and phenothiazine molecule. The EC properties of the devices were analyzed and discussed for the possibility to multi-color representation

15:05 **Effect of the Nano-Cellulose on the Preparation and the Conductivity Properties of the Polyaniline,** *Fuqiang Chu and Zhiwei Zhang, Qilu University of Technology, and Xintao Gao, Shandong Hongfei Packaging Corporation (China)*. 115

Polyaniline is widely used as a kind of conductive polymer. The preparation of polyaniline has been studied mainly by the methods of chemical synthesis and electrochemical synthesis. In this paper,

polyaniline was synthesized by chemical oxidation under acidic conditions using ammonium persulfate as oxidant. And then, the polyaniline was doped with a certain concentration of protonic acid to make it conductive. Finally, Nano-cellulose and polyaniline were combined to obtain composite products. The optimum conditions were discussed in the experiment and the composite with good electrical conductivity was achieved. The results shown that the conductivity of the conductive polyaniline was 9.98 S/cm under the optimum experimental condition (reaction temperature was 0°C, the amount of material APS:AN was 1:1, HCL concentration was 2 mol/L). The best compound effect was that Nano-cellulose and polyaniline were mixed by in situ polymerization and ultrasonic treatment of the combined effect and the composite ratio was 3:2. This work provide a new method to prepare conductive polymer of polyaniline.

15:30 **Inkjet Printed Circuits Board based on Nano Conductive Inks and Solder Resist Inks (Presentation-only Paper),** *Xingye Zhang and Yanlin Song, Chinese Academy of Sciences (China)*

Printed electronics is an emerging area of research that promises large markets due to the ability to fabricate a variety of devices on flexible substrates using high-throughput printing approaches. Printed circuit board is a fundamental and vital component in electronic industry. Traditional etching process caused widespread liquid pollution and solid waste, and received great attention of environmental supervision. In this work, conductive circuits and solder resist layer were fabricated by additive inkjet deposition method. As conductive filler, nano silver powder with controllable particle diameter was produced in large scale and conductive inks customized for a variety of industrial inkjet head were developed. Film based flexible circuit board and Aluminum substrate based LED circuits board were fabricated by digital deposition conductive inks and solder resist inks with industrial inkjet printer.

15:55 **Dynamic Analysis of Organic Conductive Ink Jet Printing (Interactive Paper Preview/ Presentation-only Paper),** *Ting Chen[1], Wei Li[2], and Guangxue Chen[1]; [1]South China University of Technology and [2]Hunan University of Technology (China)*

In this work, we reported the printing dynamic analysis of organic conductive ink PEDOT: PSS by SE-128 AA jetting assembly. The droplet morphology, flight trajectory and velocity were observed and analyzed by high speed CCD imaging system. The effects of nozzle output voltage and waveform on flight state, ink viscosity, and surface tension on the morphology and flight state of ink droplets were studied respectively. The different momentum of the ink droplets in different states, and the effect on the morphologies after attachment on the substrates were investigated. Finally, the influence of the above parameters on the printing of conductive lines and pattern accuracy was summarized.

16:05 **Paper-based 3D Printing Industrialization for Customized Wine Package Applications (Interactive Paper Preview),** *Jiangping Yuan[1,2], Xingyan Yan[2], Xiaochun Wang[2], and Guangxue Chen[2]; [1]Yuncheng University and [2]South China University of Technology (China)* 118

To take advantages of 3D printing technology in personalized wine packaging production, taking the paper-based 3D printing process as an example, three keynote issues including model designing, manufacturing process and quality evaluation, were analyzed and characterized to explore feasible solutions and specific rules from given cases study. Based on one Chinese wine brand, four original customized wine packaging models with different remarkable features were designed and compared by quantitative tests between the Cutting-Bonding Framework and printing time for each specimen. Considering specific supply chain of printed customized wine packaging models, the principles for marketing quality evaluation were mainly focused on surface color consistence and fragility, and corresponding evaluation frameworks were developed for printed wine packaging models. According to test results of designed cases for paper-based 3D printing, three practical solutions including models design rules, process optimization strategy and printing quality evaluation workflow were offered respectively and illustrated to contribute promising industrialization of the paper-based 3D printing technology in customized wine packaging applications..

16:15 **New Digital Printing Process for Manufacturing of Conductive Patterns in Flexible Electronics (Presentation-only Paper),** *Yu Liu, Jiangnan University (China)*

Manufacturing a metallic film structure on a flexible substrate is attracting interests from the community researching on flexible devices, which owns significant advantages including lightweight, low cost, wearability, and in matching with sustainability required by the society and new—era technical R&D. In this field, liquid—ink based inkjet—printing method is highly desired due to its flexibility and controllability to provide a digital writing of a conductive structure on a flexible substrate. However, it is in a certain degree of trouble with strict precondition on frequent cleaning of inkjet system and designed modification on the substrate to fix the ink drop which is very hard to deal with because of

the wettability. Both of wet and dry improvements from our work will be presented for alleviating the existing issues.

First, we will introduce our efforts on design of direct patterning of ionic catalytic based ink as seed layer for continuous electroless deposition of conductive tracks, to prompt accomplishing an eco-friendly manufacturing process. It emphasized on tuning characteristics of silver ion ink in combination with its additives to modify the rheology and evaporation during inkjet printing. It helps achieving an inkjet printing process free of any heating with fast evaporation rate. Comprehensive characterization methodologies will be delivered for better understanding fundamentals. Based on it, we further developed a colour mapping strategy for one—pot direct fabrication of conductive patterns with utilizing colour registration. Both of processes provide high quality metallic electrodes and they together reduce process complex and related manufacturing costs.

Second work to be presented will be our first development, in this field, of a solvent-less fabricating system for manufacturing metallic film structure on a flexible substrate. Particularly, a solvent-less system is in construction which mainly consists of an electrophotographic subsystem to fabricate a seed layer pattern for metal deposition. It only relies on manipulation of dry toner powders and is free of the issues associated with inkjet printing. Toner particles have been designed for electrostatic pattering of conductive tracks on flexible substrates. And the whole preparation process for the toner particle has been carried on all-in-one wet environment, which is preferable for mass production. The printed conductive tracks with the as prepared functional toner particle followed by ELD of copper layer have good conductivity, which could be used for electrodes, antennas, and so on.

CONCURRENT EVENT — Colleague Connections:
State-of-the-Art Security Printing and Print-based Anti-counterfeiting Technologies
15:05 – 16:30
see details page xix, Colorado Ballroom A

Interactive Papers Session/Demonstrations/Exhibits Happy Hour
16:30 – 17:45
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
Colorado Ballroom Foyer

WEDNESDAY NOVEMBER 8, 2017

Wednesday Keynote and Awards:
Attractive and Innovative Solutions for Highly Qualified 3D Printing Process Development in Next Generation
Takashi Fukue, Iwate University (Japan)
9:00 – 10:00
see details page x, Colorado Ballroom B

2017 Exhibit Open
10:00 – 16:30
see details page vi, Colorado Ballroom Foyer

SPECIAL EVENT

CONFERENCE RECEPTION

Wednesday, 19:15 – 22:00

Hyatt Atrium Tower, Pinnacle Club—38th Floor, Crystal Peak Ballroom
Join colleagues for an evening of fun overlooking downtown Denver.

Ink Jet Processes

Session Chairs: Ron Askeland, HP Inc. (USA); Mineo Kaneko, Canon Inc. (Japan); Ingo Reinhold, XaarJet Ltd. Filial (Sweden); and Koei Suzuki, Ricoh Co., Ltd. (Japan)
10:10 – 17:25
Colorado Ballroom A
Sponsored by Xaar plc

Session sponsored by

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10:10 **Improved Water-Resistance Test Methods Utilizing a Multispectral Imaging System to Quantify Black and Color Ink Bleeding for Plain Paper Office and Legal Documents Printed with Pigment- and Dye-based Inkjet Inks,** *Henry Wilhelm[1], Richard Adams[2], Ken Boydston[3], and Charles Wilhelm[1]; [1]Wilhelm Imaging Research, Inc. (USA), [2]Ryerson University (Canada), and [3]MegaVision Inc. (USA)* 122

Current ISO standards that pertain to water-resistance testing with inkjet prints were developed for moisture-impermeable RC photo papers and do not take into account the kinds of ink diffusion behavior that can occur with inkjet printing on highly absorbent plain papers, especially with dye-based inks. Contact with water with plain paper documents can result in significant lateral ink bleeding, migration of inks through the paper to the backside of the sheet, transfer of ink from one sheet to adjacent sheets, and two-way transfer of inks with double-sided printed documents. Shipping labels and envelopes can become illegible should they become wet, and Barcodes and QR codes may be rendered completely unreadable. This study attempts to better understand the water-resistance behavior of plain paper documents printed with dye-based and pigment inkjet inks. The use of high-resolution multispectral imaging and colorimetric analysis systems to provide a quantitative assessment of ink bleeding, migration, and ink transfer to adjacent pages is explored as an alternative to the subjective, qualitative, water-resistance evaluation methods specified in current ISO standards.

10:35 **An Electrohydrodynamic (EHD) Jet Printing Method for Increasing Printing Speed,** *Thanh-Huy Phung, Soobin Oh, Jaeryul Yu, Seora Kim, and Kye-Si Kwon, Soonchunhyang University (South Korea)* 126

It is well known that drop-on-demand electrohydrodynamic (EHD) jet printing can make small dots and fine line patterns thereby. However, it is believed that drop-on-demand based EHD printing is only limited to very slow printing applications due to small dot size and limited jetting frequencies. In this study, we propose using the change of printed relic shape to enhance printing speed. For this purpose, high molecular polymer was mixed into the silver nanoparticles ink for printing. The proposed method could help to increase the printing speed and reduce the line-pattern width as well. The video of our recent development can be found from website: https://youtu.be/ak6Zl-9yE-c.

Exhibit Hall Opens at 10:00
11:00 – 11:40 Coffee Break — in the Exhibit Hall, Colorado Ballroom Foyer

11:40 **Study on Printing Quality Improvement for Continuous-Type Inkjet Printer Using Multi-Objective Genetic Algorithm and Ink Droplet Trajectory Simulation,** *Koma Sato[1], Eiji Ishii[1], Nobuhiro Harada[2], and Tsuneaki Takagishi[2]; [1]Hitachi, Ltd. and [2]Hitachi Industrial Equipment Systems Co., Ltd. (Japan)* 128

Continuous-type inkjet printers (CIJPs) can be used to print on surfaces with various shapes at high

speeds without contacting the printing target. Recently, the need for CIJPs with higher speeds and quality to speed up industrial production lines has been increasing. By increasing the exciting frequency of the piezo element, the ink droplet generation cycle can be shorter, thereby increasing the printing speed. However, as the distance between each charged ink droplet becomes shorter, forces such as air drag and Coulomb repulsion can greatly affect the trajectories of the droplets and may deteriorate the printing quality. To determine the optimal particle injection pattern, we developed an automatic design technique with a multi-objective genetic algorithm (MOGA) and ink droplet trajectory simulation and applied it to the character "7" in a 5 × 5 dot matrix. A MOGA with 20 populations and four generations was performed, and it was confirmed that the developed technique could automatically improve the printing quality of the character. Additionally, correlation analysis was applied to the data obtained from the optimization and some printing control rules to improve the quality were extracted. By applying the rules to the character "3" and "5," it was revealed that the printing qualities of those characters could be also improved.

12:05 **AcuDrp™ Technology—Implementation and Application of Per-Nozzle Trimming (Presentation-only Paper),** *Michael Hook and Stephen Jeapes, Xaar plc (UK)*

Traditionally piezo printheads have been driven in a 'hot-switch' manner, where the power to drive the piezo is generated on the printhead itself. Thermal management of 'hot-switch' printheads becomes increasingly challenging as print resolution and performance—hence power dissipation—increases. Conversely, using a 'cold-switch' architecture provides a small number of common drive waveforms to the printhead which are distributed to all nozzles. The power dissipation is now outside of the printhead providing several options for simplified thermal management of both actuator and ASICs. Many factors will cause individual jet velocity & volume variation, including but not limited to: fluidic

crosstalk, residual energy in chambers, and manufacturing variations. In order to achieve consistent optical density across a printhead, tight control of jet velocity and volume across a printhead is required. As applications push the boundaries of print resolution and media speed, achieving this consistency in dot diameter and dot placement becomes increasingly challenging. The use of a common drive waveform in the cold switch architecture restricts the ability to adjust individual jets as the common drive waveform is distributed to multiple actuator channels

12:30 **A New Standard for Thin Film Actuators with Sol-Gel PZT,** *Peter Mardilovich, Charalampos Fragkiadakis, Song Won Ko, and Mani Sivaramakrishnan, Xaar plc (UK)* 133

The actuator of the XAAR 5601 GS3 printhead is based on thin film PZT deposited by the sol-gel technique. To meet the required printhead performance, the PZT should be as good as or better than the best-known sputtered PNZT films. This objective was achieved through a systematic investigation of sol-gel PZT films including the effect on all critical PZT properties of pyrolysis and crystallization conditions, lead excess, the nature of dopants and their concentration and distribution. The outcome is presented in this paper.

12:55 – 14:15 Lunch Break

14:15 **Newly Developed UV-Curable Inkjet Technology for Forming High Quality Image with High Productivity (Focal),** *Toshiyuki Takabayashi, Hirotaka Iijima, Akio Maeda, Masashi Ikeda, Tadashi Hirano, and Toshiyuki Mizutani, Konica Minolta, Inc. (Japan)* 136

We have developed a new and unique UV-curable inkjet technology for a sheet-fed inkjet digital press AccurioJet KM-1, which achieves offset like high quality image with high productivity; 3,000 sheets per hour. A number of AccurioJet KM-1 have already run in the production lines of customers, and have gained reputation as "Real Digitalization Pioneer" for commercial printing industry.

The single-pass inkjet printing technology, one of the key technology for the high productivity, is still a big challenge for image processing. To avoid the dots coalescing, we developed a new ink formulation and curing process which can control the ink viscosity precisely in the print head and on the recording media. We also improved the technology which can control the gloss level of the image. Combining them, we succeeded to develop a printing system which achieves offset like high quality image with high productivity.

14:50 **Software Alignable Printheads,** *Jesus Garcia Maza, Jason Remnant, and Michael Hook, Xaar plc (UK)* 140

Alignment of nozzles within a printhead and between interlaced printheads is implemented with software. The z profile design of the printhead enables compact arrays. Actuators (Silicon MEMS die with drop ejectors) are positioned within a printhead so that an overlapping region with a vernier scale guarantees 2 nozzles will be aligned inside the overlapping region to within 1 µm. The rows of nozzles in each actuator have three different regions: the normal 1200 npi pitch region (21.166 µm nozzle spacing) in the center, the lower pitch region at one end, and the higher pitch region at the other end. Two consecutive actuators (either inside a printhead or in adjacent printheads) are placed such that the lower pitch region of one of them overlaps with the higher pitch region of the other. By jetting with appropriate nozzles in the overlap region, a smooth transition in the printed pixels is achieved and expensive, time-consuming mechanical alignment is eliminated.

15:15 **JIST-FIRST: Real-Time Jet Failure Detection of Inkjet Heads with 1024 Ejectors,** *Kye-Si Kwon, Jaeryul Yu, and Thanh Huy Phung, Soonchunhyang University (South Korea)* 145

Recently, inkjet-printing industry demands high-speed and single-pass printing that requires simultaneous jetting of a large number of ejectors. As a result, the jetting reliability has become an important issue in most industrial inkjet-printing applications. To ensure the jetting reliability, a real-time monitoring of the jetting status is needed. Since the monitoring process should not interrupt the printing process, the monitoring time for all of the nozzles should be less than 1 second. For this purpose, the authors developed two module prototypes to monitor the commercial inkjet heads with 1024 nozzles: (1) a head driver with an internal self-sensing capability; (2) an external monitoring module that can be used for third-party drivers. To deal with a large number of nozzles effectively, the authors are proposing a parallel sensing scheme that can be used to monitor multi-head jetting. Lastly, the authors verified our monitoring scheme by using a drop visualization system for a comparison of the monitoring results with the droplet jetting images.

15:40 – 16:10 Coffee Break — in the Exhibit Hall, Colorado Ballroom Foyer

16:10 **The Digital Revolution: Integrating Inkjet Technology into the Industrial Manufacturing Process (Presentation-only Paper),** *Tim Scully and Nancy Lewis, Engineered Printing Solutions (USA)*

A digital revolution is happening in the decorating and marking print industry. Integrating inkjet technology into industrial manufacturing is the smart, efficient business practice. It can increases production as well as your bottom line. How do you know digital inkjet printing is the intelligent solution for your business? Our goal is to explain what it is and how it can fit into your manufacturing production line. Some key industry drivers for every business are market demands, technology, human resources, scheduling, and challenging customers. Inkjet technology can support theses drivers while increasing yield and market share. The manufacturing process can be complicated. As consumer and client demands increase exponentially, the direct to shape custom printing technology is there to carry that load. Decorating and marking your product can be part of the manufacturing process. Decorating and marking products is part of a company's identity, function, and success and it needs to be skillfully managed. Digital inkjet technology is a solution that can streamline this part of the fabrication process. Is integrating digital inkjet printing the best for your assembly? You can find the answer during our presentation. Understanding the dynamics, design considerations, and logistics before entering into a new technology is an essential part of the process. Operation, resources, and environmental issues are identified. Robotics and transport decisions are addressed. Print process and ink management are explained. The presentation is an educational opportunity for companies considering utilizing direct to shape technology in their manufacturing lines. How does industrial printing process compliment manufacturing? Digital inkjet technology competes at the highest levels in manufacturing. Employing industrial printing can dynamically change the way you do business. The forces that move a business are global competition, world markets, logistics, timing, and ROI. How does digital inkjet favor these forces? It is efficient, high quality, and flexible. It allows the clever business person to confidently say to their demanding clients, "I can do that here because we have the technology.

16:35 **An Approach to Enhance Plain Paper Saturation of Secondary Colors When Using Pigmented Inks (Presentation-only Paper),** *Jay Bhatt and Sundar Vasudevan, HP Inc. (USA)*

Inkjet inks using pigments as colorants are preferred over dye-based inks because of their light/ozone/water fastness advantages. However, pigment based inks are not as bright and saturated on plain paper as dye-based inks. HP ColoLok technology certainly has helped the plain paper performance of pigment inks. However, this technology is still not ubiquitous in non-HP plain papers. Therefore, there is a need to improve pigment performance on plain papers. Even when the saturation of primary colors is improved by ink chemistry, secondary colors do not perform very well on papers that do not have ColoLok technology. A new approach has been developed that utilizes pigment inks stabilized by opposite charges so that when they are printed together the resultant secondary colors are very much saturated. A few different implementations of this approach will be presented along with the challenges.

Colleague Connections: Review of State-the-Art of 3D Printing
17:00 – 18:00
see details, page xxxi, Colorado Ballroom B

Conference Reception: Hyatt Atrium Tower, Pinnacle Club—38th Floor, Crystal Peak Ballroom
19:30 – 22:00
see details, page xxv

3D and Additive Printing

Session Chairs: Michael Hook (morning), Xaar plc (UK); Shinri Sakai, University of Tokyo (Japan); James Stasiak, HP Inc. (USA); and Michael Willis (afternoon) Pivotal Resources Ltd.(UK)

10:10 – 18:00

Colorado Ballroom B

10:10 **Inkjet Printing Strategies for High Laydown and Its Potential for 3D-Applications (Presentation-only Paper),** *Wolfgang Voit, XaarJet Ltd. Filial (Sweden)*

While many applications in the printing for fabrication field require smaller droplet volumes and higher printing resolution, there is also an increasing demand for printing thicker layers within a single pass and hence achieving high material laydown for e.g. tactile effects or 3D-printing applications. Xaar has recently developed a number of patented/patent pending 'Single-Cycle' printing modes for the Xaar 1003 and Xaar 2001 printheads, which allow all channels to be fired simultaneously and significantly increases the printing productivity as compared to the standard '3-Cycle' printing mode. In this way the laydown density can be increased by more than a factor of 5 as compared to the standard operation of Xaar 1003 printheads, and layer thicknesses in the order of 50 – 100 µm are achievable in single-pass. As the same printhead can be used for different printing modes, a combination of subsequent printed fine structures and thick layers is possible as well. Here we evaluate also the feasibility to print with certain single-cycle modes fluids with different viscosity ranges than usually found when printing in 3-cycle mode. Results for some selected cases will be presented, and advantages and limitations of these new printing modes will be discussed.

10:35 **Development of Polyester Composite as Water-Soluble Support Material for 3D Printer,** *Tomoya Tsuboi, Tadanori Yoshimura, Hiroki Sawada, George Hirai, Akihiro Onoue, Akira Takenaka, and Katsutoshi Aoki, Kao Corporation (Japan)* 156

The study was carried out to develop a 3D-printing support material which has water solubility, moisture resistance, high Tg, and high toughness. For this purpose, polyester resins having functional groups were prepared and their properties were determined. By controlling structure of the polymer, the polyester showed both solubility in neutral water at 70°C and high moisture resistance. Furthermore, the Tg of the polymer was above 100°C, which is higher than the chamber temperature of 3D printers using ABS, so the polymer is suitable as a support material in 3D pinting of ABS.

However, the polyester was too brittle for the production of tough, flexible filaments that are needed for 3D printing. Compounding the polyester with elastomer and compatibilizer was investigated to improve toughness of the polyester. Using a batch mixer / twin screw extruder, three components were mixed. The cross sections of the composites were observed by SEM. Submicron domains of dispersed elastomer were observed in the polymer matrix. The toughness of the composite was high enough to produce filaments with sufficient flexibility for 3D printing. Filaments of the composite were made by single screw extruder.

3D printing of model material (ABS) and the water-soluble support material was examined. The support material showed good solubility in neutral water at 70°C after printing and it was easy to remove from ABS.

Exhibit Hall Opens at 10:00

11:00 – 11:30 Coffee Break — in the Exhibit Hall, Colorado Ballroom Foyer

11:30 **Four-Dimensional (4D) Printing and Its Applications (Focal),** *Yu-Ju Wu, Appalachian State University (USA)* 160

Four-dimensional (4D) printing is one of the emerging technologies. The fourth dimension in 4D printing refers to the ability of 3D printed material objects to alter its geometric configuration from one to another in a fully controllable manner, thus providing additional functional capabilities and performance-driven applications. With the additional dimension, 4D printing is emerging as a novel technique to enable configuration switching in 3D printed items. The purpose of this paper is to briefly discuss the 4D printing and to review some applications to demonstrate the potential of 4D printing.

12:05 **High Temperature (500°C) Hotend for FDM 3D Printer,** *Hideo Taniguchi, Nobuhisa Ishida, and Jiro Oi, HIT Research Corporation (Japan and USA)* 165

Three dimensional (3D) printing is one of the fast growing printer fields and most widely used process among several processes is known as Fused Deposition Modelling (FDM). The process heats up a thermoplastic filament to the melting point by a heating device and then extrudes the melted material through a small hole. The extruded material is placed, layer by layer, to create a three dimensional object. The heating/extruding device is referred to as "hotend" in industry.

One of the current shortcomings of this process is an inability to use the materials which have a high temperature range (400°C ~ 500°C) such as PEEK (Polyether Ether Ketone) which is so called super engineering plastic. It is at the higher end of the temperature spectrum, generally with very high mechanical strength and thermal resistance. It is used in high temperature, high stress applications, in harsh environments, and low to medium volume production.

We decided to take up the momentous challenge of this high temperature hotend. There have been many problems to be solved to achieve the goal and we are sharing some of the issues we had to deal with.

12:30 **Inkjet Printing of Microlenses: A Study on Post-Processing Parameters,** *Sophie Sauva, Maximilian Reif, Erik Beckert, Ramona Eberhardt, and Andreas Tünnermann, Fraunhofer-Institute for Applied Optics and Precision Engineering (Germany)* 170

Microlenses printed by inkjet have been studied since at least two decades but are not yet implemented at the industrial scale. A lack of trust in the process accuracy is most probably the main break of microlens printing industrialization. However, inkjet process suits perfectly for microlens manufacturing. Low costs, easy implementation and versatility are the main advantages of the process. This paper tends to reduce the gap between research and industry as well as to grow the knowledge on microlens printing and functional ink for optical applications. A design of experiment as well as a model for microlens printing has been established. The study showed that it is possible to predict the exact height printed depending on drying time, drying temperature and UV curing.

12:55 – 14:25 Lunch Break

14:25 **Function of Fumed Metal Oxides for 3D Printing Materials (Presentation-only Paper),** *Yuki Amano, Evonik Corporation (USA)*

Fumed metal oxides (Silica, Titania, and Alumina) are widely used in electrophotography and inkjet applications because of their nano-structure and intrinsic ability for organic chemical surface modification—there is also a burgeoning interest for these materials in Additive Manufacture. The nature of this structure & surface chemistry are described and examples presented. Particular focus is placed on the potential these particles have for introducing unique and diverse function into the processing and performance of parts through Additive Manufacture.

Fumed metal oxides (FMO) play a key role in electrophotography as external additives to control the charge and to improve the free-flow of toner powders. In ink jet printing fumed metal oxides play an important role enabling microporous coatings for ink absorption and immobilization. In this presentation we show how fumed metal oxides can play an equally important role across multiple methods of 3D printing (additive manufacturing).

Selective laser sintering, which relies on sintering of plastic or metal powders, requires excellent flowability of the powders and absence of clumps due to caking; both characteristics are enabled and well controlled by the fumed metal oxides based on silica, alumina, or titania. In addition, FMO can be used to control the charge accumulation and dissipation in powders, preventing undesirable behavior.

The Binder Jetting method combines powder flow to form the powder bed and liquid rheology to control flow of the liquid binder. In addition to enhancement of powder flow, FMO can be used to assure stable rheology of the binder, including anti-settling, thixotropic and shear-thinning behavior to reduce pressure needed to dispense the binder and at the same time prevent binder run-off.

In stereolithography (SLA), FMO can be used to reinforce UV sensitive resins and silicone materials and impart thixotropic and shear-thinning behavior. Special surface treatments on the surfaces of FMO are required to provide compatibility with the resin systems and to avoid excessive thickening. In the formulations where fillers are used, e.g. as a color additive, FMO can function as anti-settling additives to prevent sedimentation and formation of hard-settling during long-term storage of the finished resins for printing. Furthermore, fumed metal oxides and precipitated oxides are often relied upon to adjust the surface roughness and thereby change visual appearance of the 3D printed structures from high gloss to matt ("dull") appearance, which is often a desirable feature in many applications. FMO based on titania can provide additional benefit of UV absorption to avoid surface hazing and cracking often associated with the SLA parts.

We will introduce FMO products and functions for 3D printing and application data in this presentation.

14:50 **2.5-Dimensional Inkjet Fabrication Using UV Curable Ink,** *Manabu Arita, Mie Yoshino, Shinichi Hatanaka, and Toshihito Kamei, Ricoh Company, Ltd. (Japan)* 175

In recent years, 2.5-dimentional (2.5D) fabrication for reproduction of oil paintings and decoration

COLLEAGUE CONNECTIONS—REVIEW OF STATE-THE-ART OF 3D PRINTING

Wednesday, 17:00 – 18:00: Colorado Ballroom B
Moderator: Sascha de Pena, HP Inc. (Spain)

Established additive manufacturing technologies evolve and new ones are appearing each day to extend the 3D printing toolkit, solving different problems, and providing profound daily benefits. Once thought of as simple prototyping technologies, some of them have graduated to become a way to manufacture end-use parts and push the breakeven limits with respect to traditional manufacturing techniques, enabling the clear emergence of two "killer apps" with significant market impact: manufacturing and medical and dental applications.

This "Colleague Connections" session is devised to review the State-of-the-Art of 3D Printing and to explore, from the process and materials perspective, trends and technology challenges that prevent broader adoption in "ready" markets and the trigger of new innovative solutions. It is intended as a forum for discussion, a meeting place for sharing ideas, and a source of information for those interested in creative possibilities of 3D printing technologies.

becomes known. UV curable ink is used for fabrication of 2.5D images because of its good stackability. However, the surface of the structures fabricated by UV curable inkjet printer is granular. Shape accuracy and surface smoothness had a trade-off relation. Therefore, we developed UV curable ink which can control wet-spreadability of the cured ink surface. Then we can switch between both stacking processes for accuracy and smoothness. The cured states and the wet-spreadability are controlled by UV irradiation energy for curing. This technology makes it possible to express the precise profile with shape accuracy and surface smoothness.

15:15 **Density Matrix Generation for 3D Printing,** *Robert Ulichney and Andrew Fitzhugh, HP Inc. (USA)* 181

A system for creating a rectangular-cuboid periodic matrix for rendering a variable density 3D print is described. This is important for applications where the interior of manufactured objects require less material or weight while still maintaining strength. The matrix elements are grown from a line-based skeleton lattice using a "Line Dilation Algorithm". The method is computationally efficient allowing the design of large matrices to match the resolution and aspect ratio of the 3D printer. A voxel-based halftone model uses the resulting threshold arrays, allowing continuously varying densities. While the method is quite general, the very strong tetrahedral-octahedral lattice is detailed; rendering this triangular structure is made possible by reducing it to a simple rectangular period. Also, rendering constraints preserve structural integrity for multiscale lattices by guaranteeing strut-to-strut connectivity.

15:40 – 16:10 Coffee Break — in the Exhibit Hall, Colorado Ballroom Foyer

16:10 **Advancements in Inkjet Technology for Materials Deposition in Processing and Manufacturing (Presentation-only Paper),** *Scott D. Liniger, Matthews OEM Solutions (USA)*

Inkjet technology continues to advance, providing greater opportunities for research, prototyping, and manufacturing. This presentation provides an overview of the capabilities today's ink jet technologies provide, as well as where this technology is headed. We will target multi-head systems and their uses for research, prototyping, and manufacturing. Today's printhead technology provides a robust and precise method of ejecting fluids and materials. Advancements in speed, height, and durability are ongoing. With these advancements, printheads are finding their way into all areas of use. Featuring piezo technology, today's inkjet printheads offer precise performance, ideal for all sorts of research, development, and manufacturing opportunities. Typical fluid characteristics are viscosities in the 2-30 centipoise range. Inkjet printhead components have advanced to where there is little or no impact or "contamination" to the jetted material, ensuring pure performance from the deposited fluid. Today's inkjet printhead technologies are compatible with most organic solvents and acrylate materials. Printheads provide drop size repeatability within ranges of 3.5%, and can be adjusted to provide in the area of 0.5% repeatability. Drop size and drop spacing are also widely ranging, and are getting smaller (and larger!) with advanced technology developments. While a single printhead provides great flexibility, multi-head inkjet systems provide tri-dimensional printhead positioning for accurate drop placement and materials deposition. Multi-head systems are ideally suited for configurable 3D materials deposition, as well as for printed electronics, biology, and other applications requiring a high degree of material placement accuracy. These systems feature multiple camera installations, to ensure precise printhead alignment and saber angle adjustment. These systems also provide tools for drop observation, so materials can be fine-tuned to optimize printhead performance and ensure consistent performance. With this droplet ejection analysis, these systems provide a qualitative measure of trajectory and velocity, enabling the refinement of the performance of inks and jettable materials.

16:35 **The Development of Novel 3D Printing Materials and Processes Using Combinatorial Materials Science Methods (Presentation-only Paper),** *Katrina Donovan,[1,2] James Stasiak,[1] and Skip Rochefort[2]; [1]HP Inc. and [2]Oregon State University (USA)*

The development and use of combinatorial experimental methods and informatics-based data analyses are new experimental approaches and practices that have dramatically reduced the time required to bring new drugs and therapies to market. In addition to large and multivariate combinatorial-based experimental designs and informatics-based data mining and management, the development and use of new automated liquid handling and dispensing technologies have played an essential role in reducing the time required to complete large-scale and complex experimental assays and studies. In this presentation, discussion of how combinatorial methods and a new high-throughput digital titration technology are being applied to the development, characterization and optimization of new 3D printing materials and processes will be described. Direct imaging of fluid infiltration and colloid transport in unsaturated porous media is enabled by these innovative measurement techniques. Visualization of the process involves the transmission of light through a transparent flow cell packed with porous media and recording the temporal and spatial evolution of a fluid as it infiltrates the media. Tracking the infiltration process is improved by adding UV-activated dyes, fluorescein, or solutes as additives to the fluid. Fluorescein is excited by ultraviolet (UV) light and emits visible light at discrete wavelengths. Using a method based on the Beer-Lambert law, the dye concentration can be estimated from the fluorescence intensity. Automated digital dispensing instrumentation improves the process of converting fluorescence intensity to solute concentration. The HP D300e Digital Dispenser uses thermal inkjet printing technology to dispense picoliter to microliter volumes of compounds into standard-format microtiter plates. A D300e Digital Dispenser generates "fluorescence-concentration" calibration panels that can be used to improve the accuracy of converting fluorescence intensity to solute concentration in porous powder bed. Calibration plots of fluorescence intensity versus fluorescent additive concentration were generated.

Colleague Connections: Review of State-the-Art of 3D Printing
17:00 – 18:00
see details, page xxxi, Colorado Ballroom B

Conference Reception: Hyatt Atrium Tower, Pinnacle Club—38th Floor, Crystal Peak Ballroom
19:30 – 22:00
see details, page xxv

INTERNATIONAL SYMPOSIUM ON TECHNOLOGIES FOR DIGITAL PHOTO FULFILLMENT (TDPF) 2017

Wednesday Keynote and Awards:
Attractive and Innovative Solutions for Highly Qualified 3D Printing Process Development in Next Generation
Takashi Fukue, Iwate University (Japan)
9:00 – 10:00
see details page x, Colorado Ballroom B

2017 Exhibit Open
10:00 – 16:30
see details page vi, Colorado Ballroom Foyer

TDPF: Photo Book Market Overview

Session Chair: Joseph LaBarca, Pixel Preservation International (USA) and Natsuko Minegishi, Konica Minolta Inc. (Japan)
10:10 – 12:40
Maroon Peak

10:10 **Expanding the Photo Print Market: The Shift from Analog to Digital (Keynote),*** *Don Franz, Photo Imaging News (USA)*
The authors will show how a variety of technical advances and social changes have created and will advance tailwinds that will continue to lift growth of photo printing. The authors will identify key technology innovation that are driving growth opportunities as well as adoption of new technologies and behaviors that are making photo printing more accessible and rewarding. The authors will provide examples about how the ongoing shift from traditional analog photo printing to digital printing continues to lift opportunities for consumers, professional photographers, members of the printing industry and retails across many channels.

The authors will support their conclusions with evidence from recent estimates of amateur and professional print volumes in the U.S. market.

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

11:30 **Expanding the Ever-Growing On-Site Photo Book Market,*** *Brigitte Peleman-Vantieghem, Peleman Industries, Inc. and Unibind (USA)*
As the worldwide photobook market continues to expand, the onsite portion is also expanding at the same rate. Premium photobooks are being produced in lay-flat format by both central print service providers and onsite by retailers. Unibind has developed a special Vpaper which can then be bound together with triple staples, perfect binding machines or Unibind binding systems. It has also developed the Vpaper Tower, which converts also any paper into lay-flat format at speeds up to 6,000 sheets/hr.

12:05 **High Variety of Photo Books as Result of a Wide Choice of Materials and Production Methods,*** *Matthias Hausmann, CEWE Stiftung & Co. KGaA (Germany)*
CEWE is the European market leader for the production of photobooks and sold 6.2 million CEWE PHOTOBOOKs in 2016. CEWE serves multiple customer demands by using a high variety of production methods and materials.

In this paper CEWE's research on the varying production methods and their influence on the

** 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.*

qualities and characteristics of the different CEWE PHOTOBOOKs is introduced. CEWE uses dry and liquid toner printing, silver halide printing, and inkjet printing. Subsequent coating or other treatment is chosen to further influence color appearance, surface structure and other physical properties of the photo book. Hardcover or softcover and different binding technologies result in further varieties as does the type of paper. All these increase the possibilities of the end consumers to individualize their personal photo book.

However, these parameters strongly influence the properties of the resulting CEWE PHOTOBOOK, such as the stability to temperature and humidity, light or dark fading, pressure sensitivity, or scratch and friction resistance. In consequence, standards of photo books or limits other than health, safety or environmental issues could lead to restriction of customer choice, industrial flexibility and innovation. Open communication on the company website reflects on advantages and disadvantages of the product of choice.

12:40 – 14:10 Lunch Break

TDPF: Materials and Methods for Long- lasting Hard Copy and Gifts

Session Chairs: Don Franz (before coffee break), Photo Imaging News (USA); Matthias Hausmann (after coffee break), CEWE Stiftung & Co. KGaA (Germany); Natsuko Minegishi (after coffee break), Konica Minolta Inc. (Japan); and Atsushi Tomotake (before coffee break), Konica Minolta Inc. (Japan)

14:10 – 17:15

14:10 **Image Permanence of Fujifilm Original Photopaper,*** *Evert Groen, FUJIFILM Europe BV (the Netherlands)*

In general it is known that over time, the density, colour balance, and whites of prints are gradually changing by degradation. The rate of deterioration is depending on the different technologies used for printing, paper quality, type of illumination, and the different types of protection (such as framed under glass, UV filtered glass, acrylic, polycarbonate or totally uncovered).

End-consumer don't know "how long will your photo prints last".

The indoor light display permanence test results including the test method will be explained of silver halide technology prints as original photopaper.

14:35 **KODAK PROFESSIONAL ENDURA Premier Paper: Technology for Long Lasting Photo Gifts,*** *Patrick Webber, Kodak Alaris (USA)*

The growing popularity of web and smart phone fulfillment for hard copy prints and photo gifting needs to consider the output media as an important component of photo gifting. Silver halide media in general and KODAK PROFESSIONAL ENDURA Premier paper in particular provide important benefits for image quality and long term preservation. Quality attributes include excellent image quality and long image permanence. Pleasing flesh tone and accurate color reproduction, sharpness, highlight and shadow detail, are all critical attributes for high quality photo gifts. In addition excellent image permanence ensures that the photo gifts will last for many generations without the worry of digital file obsolescence.

15:10 **Company Profiles**

15:30 – 16:00 Coffee Break — in the Exhibit Hall, Colorado Ballroom Foyer

16:00 **Photo Book Construction and Preservation,*** *Mark Mizen, All About Images (USA)*

Photo books have become the means to preserve photographs for future generations, replacing the scrapbooks of yesteryear. Photo books include photos along with related information creating a unique body of work often dedicated to a specific location, time period, or group of people. They provide a unique perspective on today's events. Unfortunately poorly constructed books with inferior bindings or unstable images will not survive the test of time. These books result when manufacturers use materials and manufacturing processes that they have not properly tested for long-term permanence. In some cases, manufacturers may not have the resources or expertise for testing; in other cases they may not consider it important. While it is impossible to address apathy, experts within the industry can provide general information that makes it easier to produce high-quality photo book.

16:35 **Materials of Construction Test: Insuring the Use of Safe Materials in Photo Books,*** *Joseph LaBarca, Pixel Preservation International, and Stuart Gordon, independent (USA)*

The photographic industry has had a long-standing concern over the use of materials containing poly vinyl chloride (PVC)-containing materials. This was warranted due to PVC materials and plasticizers causing

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damage to silver halide photographic materials in the 1970s and early 1980s, often in album covers and print storage sleeves, among others. Several international standards for safe storage of photographic materials specifically forbid the use of PVC-containing materials. However, as the photo book industry has grown, new imaging materials are now in use, such as pages produced with electrophotographic printing technologies. In addition the actual materials used in construction of the photo book itself have changed, including the use of modern PVC-containing materials. With the historical concerns around the use of PVC, an extensive test was designed to explore a range of modern PVC-containing materials in combination with the typical range of imaging media in use today. This includes silver halide, electrophotographic, inkjet, and thermal dye transfer imaging systems. This paper will review the design, implementation, and results of this test, as well as provide recommendations and test procedures that can be used to determine the compatibility of photo book construction materials with various imaging systems.

Conference Reception: Hyatt Atrium Tower, Pinnacle Club—38th Floor, Crystal Peak Ballroom
19:15 – 22:00
see details, page xxv

THURSDAY NOVEMBER 9, 2017

Closing Keynote: From Gutenberg Bible to 4D Printing
Shlomo Magdassi, The Hebrew University of Jerusalem (Israel)
8:30 – 9:30
see details page x, Colorado Ballroom B

Special Topics

Session Chairs: Frits Dijksman, University of Twente (the Netherlands); Makoto Omodani, Tokai University (Japan); and James Stasiak, HP Inc. (USA)
9:40 – 12:45
Maroon Peak

9:40 **Design and Application of a 3D Printing Digital Workflow (Presentation-only Paper),**
Hao Yin and Guangxue Chen, South China University of Technology (China)
3D printing is a new type of digital advanced manufacturing technology, it has broad application prospects in cultural industry. However, due to its material, equipment and accuracy and other factors, 3D printing methods meanly provide single color items, it is difficult to meet the needs of high-quality color art, which limits the emerging 3D high value-added cultural products potential market further development. This paper proposed a 3D Printing Digital Workflow specific for color-based layer by layer manufacturing with color graphics, the development of a low-cost color 3D printing technology for cultural products by creative inspiration. To the design and manufacture, and even the final graphic printing to provide integrated rapid way to achieve new cultural and creative products market by a viable way. The main results of this paper: (1) To study the characteristics of 3D modeling theory and related data structure, and to analyze and compare 3D modeling theory and method based on polygon mesh; (2) Surface polygon mosaics and 3D scene rendering technology, and proposes a hierarchical slicing method based on layer-by-layer digital printing to develop a special rendering data channel for paper-based 3D reinforcement technology. (3) learn from the existing Printing technology, color management processes and digital processes to explore the 3D printing manufacturing color management and digital process model, put forward a variety of compatible 3D printing technology and equipment prepress data processing technology; (4) designed to develop paper-based color 3D print content data (5) based on the output of the PDF, and non-content data processing software modules. the development of color 3D printing technology is significant, it created a new digital printing applications for rapid prototyping in theory and practice, it provides new way of thinking and methods.

10:05 **3D Fakes: Chemical Fingerprinting in Additive Manufacturing, from Pharmaceuticals to Engines,** *Sharon Flank, InfraTrac (USA)* 187
The rise of 3D printing brings with it manufacturing opportunity and new challenges in intellectual property protection. We address the use of chemical fingerprinting as a strategy to validate genuine product and protect against counterfeits.

COLLEAGUE CONNECTIONS—3D PRINTING AND PHARMACEUTICALS

Thursday, 11:25 – 12:45: Maroon Peak

Moderator: Maren Preis, Åbo Akademi University (Finland)

Please join us for an emerging technology round-table discussion focused on the intersection of pharmaceutical engineering and 3D printing. The event will be moderated by Dr. Maren Preis from Pharmaceutical Sciences Laboratory, Åbo Akademi University, Turku, Finland. Dr. Preis is a senior researcher in the PharmaFabLab and is a pioneer in the development of print-based pharmaceutical drug delivery and dosage technologies. The focus of the discussion will be the use of 2D and 3D printing techniques to accelerate drug design and development, new drug delivery technologies, and personalized drug treatments, dosage, and therapies.

10:30 – 11:00 Coffee Break — Colorado Ballroom Foyer

11:00 **Towards Printing of Medicine in 2D and 3D,** *Maren Preis, Åbo Akademi University (Finland)* 191

The pharmaceutical industry showed an increasing interest for printing technologies during the recent years. Besides diagnostic aspects, printing techniques are nowadays used for the fabrication of actual dosage forms or to enable the drug loading of pre-manufactured devices and dosage forms. The present work intends to give an overview of the opportunities given by inkjet printing and extrusion-based printing systems for the manufacturing of medicine.

Inkjet printers have been widely used in the pharmaceutical field for depositing small amounts of drug-loaded liquids onto suitable substrates, such as orally disintegrating polymer films. The precise printing process and a layer-by-layer printing approach enables flexibility in dosing. In particular with regard to special patient groups who need individualized doses and drug combinations, respectively, a fast and flexible printing process combining several active components can be considered a promising solution for on-demand patient supply.

Extrusion-based printing, for example using semi-solid materials, or more common using polymer melts in a fused-deposition modeling approach, can moreover be described as a three-dimensional printing technique. The required dosage form in terms of size, shape, surface area, and total weight, can be designed with computer-aided design softwares. The most challenging part of the 3D manufacturing process is, however, identifying the right polymers and excipients for the formulation to match with the requirements for drug release and overall disintegration of the dosage form once it has been administered to a patient.

The current developments show that more printers will enter the market, including hybrid systems combining inkjet and extrusion-based systems specifically for pharmaceutical purposes.

Colleague Connections: 3D Printing and Pharmaceuticals
11:25 – 12:45
see details above, Maroon Peak

Industrial Digital Printing

Session Chairs: Hirotosi Terao, ALPS Electric Co., Ltd. (Japan); Dinesh Tyagi, Lexmark International Inc. (USA); and Andreas Willert, Fraunhofer ENAS (Germany)

9:40 – 13:00
Colorado Ballroom B

9:40 **Prediction Technology of Paper Curl in Fusing System,** *Masato Ando, Tomoyuki Ito, and Takashi Ogino, Fuji Xerox Co., Ltd. (Japan)* 195

A high accuracy model to predict the amount of paper curl, which varies depending on the design parameters of fusing systems, is developed. To predict the curl, a visco-elasto-plasticity deformation model considering material properties under high temperature and moisture conditions in a fusing nip, and a dehumidification model considering the influence of decreasing drying were investigated. Proposed models were verified with two-roll fusing system and free belt nip fuser, and the models could predict the curl of different types of fusing systems under several conditions varying fusing temperature, moisture content of paper, paper type and amount of toner with high accuracy. This technology enables specification study of fusing and decurler systems without constructing many prototypes and, design man-hours needed for the development of a new system are reduced.

COLLEAGUE CONNECTIONS—LATE BREAKING NEWS

Thursday, 12:00 – 13:15: Colorado Ballroom B

Moderator: Werner Zapka, XaarJet Ltd. Filial (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.

10:05 **Development of a Method of Evaluating Uniformity based on the Human Vision Property (Focal),** *Hideyuki Kihara and Makoto Hino, Ricoh Company, Ltd. (Japan)* 202

Uniformity is an important quality factor of a hard-copy image and needs to be properly managed using a numerical index. We therefore developed a new method of evaluating quality. The evaluation method involves calculating the delta E profile using the color difference of the neighborhood to remove the effect of image noise. This calculation algorithm is based on a persons contrast detection mechanism. Furthermore, the maximum color difference is extracted by comparing profiles because a person evaluates the part having the worst uniformity part in multiple regions. Our method provides a numerical index that represents a subjective score of image uniformity. We expect to manage image quality using our method.

10:40 – 11:00 Coffee Break — Colorado Ballroom Foyer

11:00 **Where Next for Industrial Digital Printing? (Focal),** *Peter J. Brown, Matthias Ediger, Tristan Downing, Jianye Wang, and Rob Day, TTP plc (UK)* 206

At present, there are two dominant technologies for the digital deposition of liquids: inkjet and valve-jet. Both have very different ejection mechanisms and each has very different technical specifications. As a result, they are exploited in very different applications. Inkjet is used where high image resolution and small droplets are required, leading to its adoption in surface decoration, digital document presses and the like. The construction of inkjet printheads, and the fundamental physics of droplet formation, prevent its use with viscous or sedimenting inks. In comparison, valvejet is a far cruder technology as the droplets are much larger, the firing rate is lower and the nozzle density is low. Array versions of valve-jet were initially developed for carpet decoration and it is best suited to applications where the print resolution doesn't need to be high. Unlike inkjet, valvejet printheads are capable of processing viscous fluids.

There is thus a large capability-gap between inkjet and valvejet. As a result, in a wide range of applications where there is a demand for accurate digital deposition of viscous materials, no solution is readily available. In this paper, we show that TTP's Vista Inkjet technology is ideally suited to many of these applications, and provide an initial estimate of the market demand for such a solution.

11:35 **Enabling Mass Customization in Print and Direct Object Manufacturing with Pagewide Printhead Arrays (Presentation-only Paper),** *Thomas J. Roetker, Memjet (USA)*

Page wide printhead arrays provide increasingly better performance and low cost for creating mass customized and short run products. Inkjet printhead arrays offer high resolution and high throughput. This capability can be applied to the creation of personalized products for consumers. This customization can be in the form of printed decoration or in the form of an object itself. Inkjet printheads can an increasingly wide variety of fluids which can be applied to products directly for customers. Memjet offers such a printhead and offers access to inkjet technology to businesses seeking to develop products to serve a great variety of markets. This presentation will show how printhead technology can be applied in a variety of ways. The presentation will also illustrate an approach for simplifying the application of inkjet technology to a variety of product manufacturing technologies. Memjet's second generation printhead designs will be explained as an example of technology capability and an approach to addressing the need for small lot and mass customized products.

Colleague Connections: Late Breaking News
12:00 – 13:15
see details above, Colorado Ballroom B

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INDEX KEY

- Roman numeral (i, v, x, etc.) indicates page on which the talk and abstract may be found in this book
- Arabic number (1, 2, 3, etc.) indicates page on which full paper is found in the hardcopy version of the book and the usb stick
- "po" indicates that there is no paper associated with the talk; it is presentation-only
- "tdpf" 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

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