Wednesday Afternoon, November 11, 2009

Inkjet Technology: Printing, Materials Processing, and Microfluidics Fundamentals Topical Conference
Room: B3 - Session IJ+MN+TF-WeA

Inkjet Printing Technology: Advances and Challenges
Moderator: D.P. Trauernicht, Eastman Kodak Company

2:00pm **IJ+MN+TF-WeA1 Scaling Inkjet Printing to Nano Dimensions**, ***J. Bokor***, University of California, Berkeley **INVITED**

For many applications of inkjet printing, scaling the droplet size, and hence the resolution of printed features to micro and even nanoscale dimensions would be of great benefit. I will describe work on scaling a thermal printhead technology to droplet diameter in the range of one micron (0.5 femtoliter). Prospects for further scaling to nanodimensions will also be discussed.

2:40pm **IJ+MN+TF-WeA3 The Technology and Capabilities of Thermal Inkjet Printing**, ***E.G. Hanson***, Hewlett-Packard Laboratories **INVITED**

Thermal ink jet (TIJ) technology has a wide range of capabilities in the non-contact dispensing and printing of materials. TIJ is best known as an extremely effective and successful method for printing of documents and images on paper, using colored inks, but its applications extend far beyond ink-on-paper.

A TIJ printhead is a MEMS (Micro Electro Mechanical System) device, incorporating electronic devices and micro-machined geometrical features which are fabricated on a silicon wafer. TIJ excels in scalability and nozzle packing density. Over the past 20 years, its performance in terms of ejected ink drops per second per printhead has doubled every 18 months.

TIJ technology is extremely precise, offering volumetric control as low as 1% coefficient of variation for volumes > 0.1 microliter, and placement accuracy as low as 3 micrometers standard deviation. A wide range of materials can be ejected very effectively, including nanoparticle suspensions, pharmaceutical compounds, bioactive molecules, polymers, and adhesives. In addition to aqueous solutions, TIJ can efficiently jet numerous non-aqueous solvents.

TIJ is a drop-on-demand ink jet technique, meaning that ink drops are only ejected from nozzles when needed. In contrast, continuous ink jet technology generates a steady-state stream of ink drops, using additional components downstream of the nozzles to deflect and recirculate those drops which are not needed. Aside from TIJ, there is one other common type of drop-on-demand ink jet: piezoelectric (piezo) ink jet. In both TIJ and piezo devices, ink is ejected from nozzles when needed by applying pressure pulses to fluid-filled chambers upstream of those nozzles. These two ink jet techniques use different pressure pulse generation methods – formation of a vapor bubble inside the chamber in the case of TIJ, and mechanical deflection of a diaphragm in the case of piezo. TIJ uses much smaller chambers and generates much higher peak pressures than piezo, giving advantages in nozzle packing density, low printhead cost, and high tolerance to trapped bubbles. Piezo printheads are larger, higher cost, and more sensitive to trapped bubbles, but they do also offer longer printhead life and a wider fluid space than TIJ.

A large variety of materials deposition and dispensing applications are benefiting from the high precision and versatility of TIJ technology. The base technology of TIJ was primarily developed originally for the large market of printed ink on paper, but now these materials applications are leveraging and extending that technology base.

4:00pm **IJ+MN+TF-WeA7 Recent Advancements in Continuous Inkjet Technology**, *J. Chwalek, E. Furlani, J. Gao, K. Vaeth,* Eastman Kodak Company*, G. Hawkins,* Eastman Kodak Company (retired)*,* ***J.M. Grace***, Eastman Kodak Company **INVITED**

Recent advancements at Eastman Kodak Company in the ability to precisely control the instabilities in thermally stimulated microjets, coupled with advancements in MEMS technology, computer modeling of complex microfluidic systems, nanopigment ink technology, and ink-substrate interactions, enabled the development and subsequent commercialization of a new continuous inkjet technology. This technology offers extremely high productivity with high image quality and excellent reliability on a wide variety of substrates while maintaining a low total ownership cost. This technology, referred to as KODAK Stream Inkjet Technology (or "Stream"), forms the basis of a technology platform that is highly extensible, allowing participation in markets that rely up on high-speed digital print production. The fundamental physics of droplet generation and control and nanopigment ink chemistry create inherent advantages in areas such as productivity, image quality, and ink latitude. In this presentation, we will describe the principles of operation of Stream 's printhead. These principles include the physics of droplet formation, a discussion of fluid properties relative to jet modulation, wavelength dependencies, thermal modulation schemes, satellite drop formation, and drop control effects.

4:40pm **IJ+MN+TF-WeA9 Innovative Strobe-Based System for Analysis of Drops-in-Flight**, *K. Johnson, Y. Kipman,* ***G. Bartos***, ImageXpert Inc.

Imaging and measurement of drops-in-flight often relies on the measurement system's ability to drive the print head directly in order to synchronize the strobe for repeatable image capture. In addition, many systems do not have the necessary combination of precise strobe control, camera triggering, and powerful image analysis for full drop-in-flight evaluation.

This paper includes a discussion of a fully integrated machine-vision based system for visualization and measurement of drops-in-flight that can be used with any frequency-based jetting system. The strobe is linked to the firing frequency of the print head, so while it is synchronized, it is independent of the specific print head being used.

The imaging system resolves droplets down to 3 picoliters in volume at the highest zoom level. And an open architecture software package allows for image collection and archiving as well as powerful and flexible image analysis.

This paper will give an overview of the details of this system as well as show some of the system capabilities through several examples of drop-in-flight analysis.

5:00pm **IJ+MN+TF-WeA10 Controlling the Evaporation and Material Deposition Process of Printed Drops by Systematic Substrate Modification**, ***V. Bromberg****, S. Gawande, T. Singler, Y. Sun*, Binghamton University

The evaporation dynamics of an inkjet-printed drop on a solid surface have been investigated experimentally. An inkjet-printed drop will generally evaporate in two modes – a continuous decrease in contact angle with a constant contact area, followed by a shrinking of the contact area at a constant contact angle. This evaporation process determines the internal flow and final deposition pattern of functional material being carried by the drop. In an effort to better understand this process, fluorescent microscopy was used to visualize the flow of colloidal material inside printed water drops. We have systematically examined the effects of substrate wettability in controlling the flow and deposition dynamics. It has been found that critical wettability values (as determined by the contact angle) exist which delineate the evaporation and deposition process into regimes of significantly different final deposit patterns. These critical values have been explored as functions of particle characteristics (volume fraction, surface functionality, size) and ambient conditions (relative humidity). A theory of particle kinetics within the three-phase contact line region has been proposed to explain the existence of these critical wettability parameters. These parameters have been used to suggest effective techniques for controlling the shape and structure of final deposition for inkjet printing functional material.

5:20pm **IJ+MN+TF-WeA11 Droplet Velocity Fluctuations in Thermally Stimulated Continuous Liquid Jets: Assessing the Effects of Nozzle Bore Geometry**, ***J.M. Grace****, G. Farruggia*, Eastman Kodak Company

The break-up of thin liquid jets into droplets, known and studied for over a century, has significant practical applications, including inkjet printing. Whether jets are stimulated in on-demand or continuous modes, noise in the stimulation and break-up process can generate fluctuations in drop velocity. As inkjet technology continues to advance to higher resolution and the requirements for control of drop placement become increasingly more stringent, the fundamental noise characteristics of the break-up process become of increasing interest. In this presentation, we study the spatial jitter of drops to infer the underlying velocity fluctuations in thermally stimulated continuous fluid microjets. We present measurements of jitter for fluids jetted from nozzles having different bore radii and bore lengths. The jitter appears to decrease for decreasing nozzle bore lengths. Analysis based upon observed break-off lengths and the implied initial radial perturbations of the jet is presented as a means to assess whether nozzle bore geometry has a fundamental effect on jitter. In addition, analysis based upon energy delivered to the jet during each drop formation period is presented to assess the importance of thermal coupling between heater and jet.

5:40pm **IJ+MN+TF-WeA12 Novel Dynamic Volume Control in Jetting of Complex Fluids**, ***G.E. Mårtensson***, *W. Holm*, Mydata Automation AB, Sweden

In conventional ink jetting applications, a pressure difference is used to ensure the continuous and prompt filling of the jetting chamber between jetting actuations. The delivery of precise fluid volumes utilizing inkjet-like drop-on-demand jetting technology is primarily controlled by the piezo voltage that actuates the jetting chamber (Gerhauser et al. 1983, SID 83 Digest). The jetting of large volumes, in excess of 1 nL, of complex viscous fluids is complicated by the difficulty of filling the ejection chamber quickly after the previous droplet ejection.

In order to ensure the delivery of fluid to the ejection chamber, a mechanism utilizing a helical viscous pump has been introduced and implemented by the authors. The fluid is fed to the helical pump from a reservoir of fluid stabilized by a regulated reservoir pressure. The flow rate is regulated by the speed of the driving surface of the viscous pump. The ejection mechanism consists of a piezo actuated piston that drives the fluid in the chamber through the nozzle on to the intended surface.

The ejected volume of fluid has been studied with respect to piezo voltage, V_p , pulse time, t_p , of the piezo signal and the angular speed of the helical viscous pump. The ejected volume has been estimated from digital photographs taken of the droplet, as well as via 3D profilometry methods. It has been shown in the experimental jetting setup that the volume of a jetted deposit is only affected to a minor degree, of the order of 5% of the goal volume, by the chosen piezo voltage, V_p , acting on the piston. This is also true for the chosen pulse time, t_p . The form of the ejected fluid droplet is affected by the pulse time, tp, only for relatively small volumes. Through imaging experiments, it has been shown that the speed of the ejected droplet has a nearly linear response to the piezo voltage, V_p .

The effect of the fluid's viscosity, represented by its dynamic shear modulus, G*, and its dependancy on rate of shear, $d\gamma / dt$, on the ejected volume was also studied. The effect on the delivered volume was slight for the range of non-Newtonian fluids available, in spite of a strong shear-thinning behaviour.

Authors Index

Bold page numbers indicate the presenter