The State of Inkjet Printheads & Applications (Abridged)

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Introduction

From its beginnings with William Thomson Lord Kelvin's invention of a continuous inkjet to record signals from the Atlantic cable, applications for devices that emit liquids have grown to include the reproduction of complex images, the digitally controlled building of three-dimensional objects, the precise formulation of medicines, the fabrication of photo-voltaic thin film cells and even the printing of human organs. Inventions of dispensing mechanisms for jetting fluids have continued since Lord Kelvin's initial device, which have enabled application growth.

In 1997, Hue Le, President of Picojet, published a comprehensive and seminal review of inkjet print heads, their history, application and technologies [1]. The following paper not only updates Mr. Le's exposition with reference to new developments, but also analyses the demands of current and prospective applications for inkjet dispensing mechanisms and the ability of current print head technology to satisfy those demands.

Applications for inkjet dispensing have evolved from recording signals to printing full-color images to fabricating prototypes, products and human organs. Digitally controlled inkjet dispensing technology offers the promise of reducing costs and time for manufacturing prototype, sample and saleable products. Drop on demand type inkjet systems can reduce the amount of waste that analogue print and dispensing methods produce. They also offer the ability to dispense liquids and substances in liquid suspension precisely. They have offered graphic arts applications more cost effective use of process color printing for short and medium print runs than analog print methods afford. Complexes of digitally controlled inkjet dispensers used in concert could build products that either reduce or eliminate the cost of assembly. Such systems could also enable the manufacturing of products closer to market with significant saving in transportation cost and reduction of fuel consumption. Digital printing has also enabled just-in-time delivery of printed products and digital fabrication may also provide rapid production for just-in-time delivery of fully formed products. Digital printing and fabrication can reduce the need for large product inventories and thus minimize the risks associated with long-term inventory retention. They would also permit the tailoring of products to meet individual and group customer requirements. Digital inkjet printing and fabrication methods match the general trend from analog to digital process control. They permit digital execution of digital design files directly without the need to translate from analog to digital.

Categorizing Inkjet Print Head Technologies

The way in which print heads process fluids categorizes heads as either Continuous (CIJ) or Drop-on-demand (DoD) inkjet (See chart below). We can further categorize CIJ heads as Hertz, Binary Deflection, Multi-deflection, or Microdot, and DoD heads as Thermal (TIJ), Piezo (PIJ), Acoustic, or Electrostatic. The position of the actuator in TIJ heads defines them as either Side Shooter or Rear Shooter. The position and action of the actuator(s) and the configuration of their ink channels define PIJ heads as Bend, Shear, Push or Squeeze mode.

New inkjet technologies have superseded older technologies for current applications. For example, lower-cost, high-resolution PIJ printers have substantially replaced higher-priced Hertz CIJ ones for color proofing and photographic reproduction. PIJ printheads that operate at higher frequency of drop generation are replacing lower frequency ones. Market demands for better performance and cost effectiveness drive this process of continual improvement. Refined manufacturing techniques developed for printed circuit board and computer production have also assisted in the advance of inkjet technology. An increasing number of inkjet printhead manufacturers, including HP, Epson, Dimatix and Silverbrook now employ Micro-electro-mechanical Systems (MEMS) processes, which create PC boards, to fabricate printheads. In turn, inkjet technology is helping to print electronic circuits with conductive inks, masks and markings.

A number of factors are driving the rise of Drop-on-Demand (DOD) inkjet and the decline of Continuous inkjet. CIJ heads typically require more assembly and carry a higher cost. They also use low viscosity fluids that primarily employ high-solvents. They also waste a greater percentage of ink than DOD methods. Many piezo DOD printheads can also dispense higher viscosity fluids that can carry more robust binders than CIJ heads. Economic, environmental and work safety concerns now favor DOD inkjet over CIJ. Industrial applications tend to favor PIJ heads over TIJ and other DOD systems, but HP and its SPS division have penetrated label, marking, coding and some other industrial application markets with its low cost replaceable TIJ heads. HP SPS OEM customers have extended the range of fluids TIJ can shoot to include alcohol-based UV-curable inks. HP has also extended the application range of its TIJ 4 technology with its development of latex-based inks and curing system.

Current Offerings From Leading Printhead Providers

The development of inkjet and other fluid dispensing technologies necessitates years of commitment, refinement and trial and error testing. Some companies are positioned financially to invest for the long-term required while other companies may not have the resources to invest in such long-term development. Printhead development typically requires about three to five years from original concept to customization. Manufacturing inkjet printheads consistently at yield rates greater that 90% within acceptable commercial tolerance can add months to over a year until a model produces profit. The complexities and demands of contemporary inkjet print head manufacture require extreme precision and environmental controls in order to reproduce print heads that will perform within acceptable ranges of consistency and effectiveness. All nozzles, fluid (ink) channels and actuators must be able to produce virtually identical results for the same instruction many thousand times per second. The dispensing fluid must recharge fluid channels at a rate that allows the print head to dispense its fluid at as high a frequency as possible without starving the printhead of sufficient fluid to perform as intended. The design, configurations and composition of fluid channels, pumping and actuating mechanisms are critical for increasing the rate at which ink channels recharge with fluid after drop ejection and their frequency of print head drop generation.

Existing and potential applications determine the relevancy of fluid dispensing technologies, which will attract investment for their development primarily based on their capacity to deliver applications in a manner resulting in return on investment within an acceptable period.

The following key companies provide inkjet printheads for current applications. A number are also poised and committed to deliver improvement and advances in inkjet dispensing technologies.

Dimatix (PIJ)

The Fujifilm Dimatix Santa Clara team developed two materials printers: the DMP-2800 and the DMP-3000. The Dimatix DMP-2800 uses a 16-nozzle Dimatix MEMS printhead with a 1.5 ml disposable fluid cartridge that users can fill. Dimatix offers its MEMS head in 1 and 10 picoliter drop versions. The DMP-3000 can use the 16-nozzle MEMS head, Dimatix SX3 128-nozzle 8 pl head or SE3 128-nozzle 35 pl head interchangeably. The 1 pl MEMS head "can deposit features as small as 20 µm (20 millionths of a meter) to fabricate products such as organic thin-film transistors (TFTs) and printed circuits" according to the Company[2]. The SX3 and SE3 heads feature "a silicon nozzle plate with a non-wetting coating is compatible with the aggressive fluids used in electronics and other fabrication applications."[2]

Fujifilm Dimatix's Q-class Sapphire and Polaris offer modular design and adjustable electronics that enables Dimatix to offer OEMs custom printhead solutions. The Sapphire series 256-nozzle heads offer single color binary and grayscale operation. Dimatix also offers the 1024-nozzle ScanPAQ 2.5 head with four rows of Q-Class heads. The Polaris series heads feature 512-nozzle heads. The Q-class series reportedly will be able to produce drop volume ranging from under 10 pl to over 150 pl. The Sapphire series can also operate at temperatures up to 90°C enabling the firing of fluids with higher viscosities at room temperature.

At Drupa 2008, Dimatix introduced its MEMS Samba head for use on the high-speed Fujifilm Jetpress 720 inkjet press. Dimatix designed the 2048-nozzle head as modular units that easily align to form page-width and wider large format arrays. The Company has yet to release the Samba for OEM use. The Samba head prints 1,200 dpi images in single-pass. This robust head circulates its inks or other print fluids within the head but outside of the firing channel thus obviating crosstalk issues between channels.

The vision that Fujifilm Dimatix has announced for its growth in the Inkjet Industry involves manufacturing printheads to meet the requirements of applications including graphics, electronics, photovoltaics, displays, life sciences, chemical deposition, 3-D object fabrication and optics.

Epson (PIJ)

Epson refined its piezo inkjet technology for its TFP (thin film piezo) printhead using MEMS processing. The Company reduced the spacing (pitch) between nozzles in each row from 141 microns to 71 microns. It reduced the effective distance for 2-row heads from 71 microns to 35 micros. The TFP manufacturing improvements increased native resolution to 360 dpi and enabled lower cost production, higher print speed and an increase in addressable applications.

HP (PIJ and TIJ)

When HP purchased Scitex Vision, it also acquired the Aprion PIJ printhead and the team that developed it. It directed this group to develop a new MEMS printhead that eventually became the X2 PIJ head, which HP Scitex employed for its XL2200 roll-to-roll and FB6500 and FB7500 flatbed printers. The high rate of accuracy in manufacturing these heads enables their precise linking into large arrays. The printhead features 64 nozzles per head with two-sided actuators on the chips on either side of each firing chamber. It fires 50 pl drops with viscosity up to 15 cP at frequencies up to 30kHz. Each head prints a 32.5 mm swath with a native 100 dpi. The X2 is very compact, measuring 8x64x1mm. Its electronic packaging uses anodic bonding that does not use adhesives and forms a permanent bond. Its silicon nozzle plate and head construction provides a durable composition resistant to most fluids and inks.

At Drupa 2008, HP unveiled its T300 Color Inkjet Web Press. This high-speed in-line duplex single-pass TIJ printer used HP's TIJ-4 Edgeline Scale-able Printing Technology (SPT) printheads. The 10.795mm (4.25-inch) wide head "uses five (5) silicon printhead chips, each with 2,112 nozzles placed in a staggered configuration." Each printhead can print "two colors of ink and has 10,560 nozzles – 5,280 per color."[3] The Edgeline produces a 1,200 dpi native resolution.

HP employed a similar SPT 10.795mm (4.25-inch) wide head, HP 789 Designjet printhead, for its Latex Inkjet HP Designjet L25500, HP Scitex LX600 (formerly called HP Designjet L65500) and LX800 printers.

Kodak (TIJ and CIJ)

Kodak has developed a very fast new inkjet technology in the Stream hybrid printhead that it first demonstrated at Drupa 2008. It has since integrated the Stream Printhead on to web offset presses to add variable data printing at a throughput rate of 305 m/min. The head prints durable black-pigmented ink in a 10.566 cm (4.16-inch) print swath at resolution of 600 dpi in a single pass.

Kodak has targeted direct mail personalization, coupons, commercial gaming and insert markets for this device.

Kyocera PIJ

In 2002, Kyocera began developing its 2,656-nozzle KJ4 stainless steel PIJ printhead initially in conjunction with Brother Industries. Kyocera later assumed exclusive control of the printhead and eventually brought two versions of the head to market, one for UV-curable and one for water-based inks. The KJ4 offers a print width of 108 mm (4.25 inches). Kyocera configured its design to enable linking them to form an array. It can function either as a binary or grayscale head 5 gray levels and four drop sizes from 4 pl. to 21 pl. It has a native resolution of 600 dpi.

Miyakoshi Printing Machinery Co., Ltd. used Kyocera's KJ4 printheads in its MJP600 printers, which have been in commercial use since April 2007. Miyakoshi also supplied Oce with similar high-speed inkjet commercial printers. These printers print at linear speeds of up to 150 meter per minute. Both companies exhibited their lines of these devices at Drupa 3008 at the Dusseldorf Messe. Also, another company exhibited a coating device at Drupa 2008 that Amica of Beijing had integrated. At the Japan Graphic Arts Show in October of 2009, Kyocera introduced an improved version of its KJ4 that improved its operating frequency from 30 kHz to 60 kHz. The newly developed printhead, KJ4B-JF06, offers the following print speeds at the specified resolutions: 600 by 360 dpi (330m/min. at 40 kHz), 600 by 600 dpi (200 m/min at 40 kHz), and 1,200 by 1,200 dpi (150m/min at 60 kHz).

Textile equipment manufacturers MS and Reggiani have constructed textile roll-to-roll textile inkjet print systems using KJ4 printheads. Xennia and it parent company, Ten Cate, have partnered with Reggiani to develop its entry.

Panasonic (PIJ)

Impika, the inkjet integration company located in Aubagne, France, adopted the Panasonic 420 PIJ printhead for use in its Impika I-600 series printers. The Panasonic heads have 800 nozzles per head and yield a native 600 dpi. They can print in binary mode using 11 pl drops or in grayscale using 4 levels with three drop sizes: 3, 11, and 14 pl. They operate at a maximum frequency of 30 kHz. The Impika I-600 printer uses an array assembly containing 29 Panasonic 420 PIJ heads that creates a print swathe of 474mm (18.66 inches). It can print 600dpi full color roll-to-roll PE, PP, PET, paper and flexible carton rolls at rates up to 75m/min using water-base inks. It can print one or two color images on rolls at throughput speeds up to 150m/min.

Ricoh Printing Systems America (RPSA) (PIJ)

Since 1962, the company that is now RPSA, in Simi Valley, California has pioneered inkjet PIJ development. It currently offers three primarily stainless steel PIJ printheads: Gen 3 E1 96-nozzle, Gen 3 E3 192-nozzle binary PIJ heads, and the Gen4 384-nozzle head. All of these heads use a push mode PIJ configuration.

Agfa recently debuted its Jeti 1224 UV HDC using Ricoh Gen 4 grayscale printheads for printing UV curable inks on flexible and rigid media such as reinforced and pressure sensitive vinyl, canvas, fabrics, foam board, corrugated board, lenticular panels, tile, drywall, glass, sheet metal and paper. This device enables printing a wide range of applications including not only signs and banners, but also tables, architectural panels, doors, flooring, skis and snowboards, transportation panels, and nameplates.

Mimaki engineering is also using RPSA Gen 4 grayscale heads on its TX 400-1800 textile printer series using dye and pigmented ink sets. Mimaki is offering this printer as a roll-to-roll device for direct printing with disperse dye for soft signage and also an adhesive belt model for general roll fabric printing. The Ricoh heads provide high resolution and adequate color saturation.

The RPSA Gen 3 and 4 printheads offer stainless steel durability and resistance to corrosion. They can process a wide range of fluids and inks. At frequencies of 30 kHz for binary and 20 kHz for grayscale printing, they provide speed for faster throughput and with Gen 4 grayscale for photographic quality.

Xaar (PIJ)

OEMs use Xaar printheads primarily for sign and billboard print markets. Xaar has also developed packaging, ceramics, marking and coding, flooring, interior design and other industrial applications, particularly with its 1001 printhead. A number of inkjet developers have adopted the Xaar-1001 for industrial development projects including, electronics, displays, 3-D rapid prototyping, and printing on glass and ceramics with nano-particle frits.

Xaar offers eight printhead models: Xaar-126, Xaar -128, Xaar-318, Xaar-500, Xaar-760, Xaar-1001, Electron and Proton, with a total of seventeen head versions. The Xaar-318 (which is the Toshiba Tec CA4) offers 8 standard grayscale levels (7drop) and a maximum of 16 (15drop). The Xaar 760 offers 6 gray levels (5drop) and the Xaar 1001 offers 8 (7drop). All of the other models and versions are binary.

Conclusions

A number of trends mark the inkjet market. PIJ and some TIJ printheads are replacing many of the CIJ system for marking and coding due to the high print resolution associated with drop-on-demand printing. Stainless steel nozzle plates are gaining favor over capton nozzles for improved nozzle shape consistency and stainless steel's resistance to the impact of head strikes. Mostly stainless steel PIJ printhead composition has also gained favor, as evidenced with Kyocera, Picojet, Ricoh and Trident heads, for its ability to tolerate a greater range of chemicals including water-based ones. Other printhead manufacturers have adopted MEMS technology to improve printhead resistance to ink and fluid chemistry, refine tooling precision, increase nozzle packing and print resolution. Overall, the number of nozzle per printhead is increasing. Newer DOD printheads will typically double the number of nozzles of their predecessor heads, consequently increasing print speed while reducing printhead alignment and servicing time.

With increased air quality and worker hazardous chemical exposure awareness and restrictions, we have witnessed the growth of low toxicity solvent-based inkjet inks, UV-cure and, more recently, mostly aqueous-based latex inks for both TIJ and PIJ heads.

The Print Industry is moving to single-pass inkjet for commercial printing application for its ability to satisfy increasing demand for shorter print runs and variable date printing cost effectively. Single-pass commercial inkjet page wide print devices, such as those from Miyakoshi, Oce, Fujifilm, HP, Kodak and Impika are replacing litho-offset printers.

As demands to manufacture with sustainably reducing waste and processes carbon footprints, we are likely to see a larger place for drop-on-demand inkjet deposition. Industry has begun to use inkjet to produce electronic circuitry, thin film photovoltaic cells, video display screens, optic lenses, and 3-D prototyping and manufacture, in addition to bio-medical applications.

References

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[2] http://www.dimatix.com/divisions/materials-deposition-division/materials-printer-dmp-3000.asp

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