Novel Inkjet Print Head for Manufacturing Processes

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Abstract

Inkjet technology has been integrated into manufacturing processes due to (1) efficient material usage(environmentally friendly), (2) direct write process (an additive process), (3) speedy set-up (digital printing and no masks needed), (4) large area printing, (5) high productivity by increasing number nozzles and jetting frequency, (6) non contact printing for sensitive substrate, (7) print heads and jetting materials tailored for specific applications and (8) ultimately low capital investment . Also piezoelectric inkjet print heads have dominated in drop-on-demand (DOD) industrial and commercial market for last two decades, because they offer high jetting frequency, long life expectancy, and the ability to jet a wide range of fluids. Emerging market opportunities in production of flat panel display, solar cell, printed circuit boards and printed electronics will require highly flexible, reliable and robust design piezoelectric inkjet print heads. This paper focuses on some recent developments and some unique features such as high reliability, accurate orifice manufacture, replaceable orifice - chamber plates, inert print head bodies, individual orifice jetting performance calibration, and a highly flexible design to adapt to a wide range of drop volumes and jetting fluids. Trident's print heads (256Jet-D) has currently been released to meet these applications.

Introduction

To keep manufacturing processes simple, low cost, and environmentally friendly, a number of manufacturing research and development centers have been integrating inkjet deposition systems into production lines including flat panel display, solar cell, printed circuit boards, and printed electronics applications. The main reasons are: (1) efficient material usage(environmentally friendly), (2) direct write process (an additive process), (3) speedy set-up (digital printing and no masks needed), (4) large area printing, (5) high productivity by increasing number nozzles and jetting frequency, (6) non contact printing for sensitive substrate, (7) print heads and jetting materials tailored for specific applications and (8) ultimately low capital investment. Taking TFT-LCD industry as an example, its core processes include color filter pixelization, color filter black matrix application, polyimide (PI) coating, liquid crystal dispensing and light guide deposition of back light unit. They all can be digitally fabricated by the piezoelectric inkjet print head technology. The inkjet technology has advantages over the conventional photolithography process. There are 27 steps in making color filter and two third of materials will be wasted, conventionally. With inkjet technology, the processes will be simpler, the cost will be lower and the environmental pollution is less as well.

Versatile Trident's 256Jet-D (figure 1 & table 1) inkjet print head features a durable, serviceable design and stainless steel construction which allows for printing of a wide variety of direct write, printable electronic applications with up to five times higher resolution than possible with screen printing. It allows manufacturers to print exactly the amount of material they need, exactly where they need it, thus manufacturers save significant time and expense when compared to subtractive printing methods that waste valuable printing materials. The inert stainless steel construction is resistant to the corrosive, aggressive alkaline and acidic materials often used in the deposition of printable electronic components. With the ability to be heated to 70^{o}C and to jet fluids up to 30 cps, the 256Jet –D can print materials with twice as much viscosity as traditional inkjet systems, giving users wider flexibility in material loading and fluid formulation. Its rugged industrial design gives the print head a lifespan of more than 90 billion firings.

Figure 1. *256Jet-D print head*

Table 1. 256Jet-D specifications

	256Jet-D (inline)	256Jet-D (dual line)
# of addressable channels	256	256
nozzle spacing	0.397mm	0.794mm
Drop volume*	7-120PL	7- 120PL
Drop velocity	5-8 m/s @ 1mm standoff	5-8 m/s @ 1mm standoff
Drive voltage	< 90 volts	< 90 volts
Life expectancy	More than 90 billion jetting cycles	More than 90 billion jetting cycles

Note*: a wide range of drop volume can be covered by using different nozzle diameters and different actuator configurations.

Highly Flexible Design

The thin stainless steel diaphragm is bonded onto pzt actuator/back print head body and separates fluidic parts from print body as shown in Figure 2. The print head configuration is designed to make the nozzle/chamber plate repairable or replaceable and print head design highly flexible. The advantage includes (1) that because the orifice clogging is one of major failure modes in the field, the replaceable nozzle/chamber plate significantly extends the print head life and thus reduces the total cost of ownership; (2) that one can use only a print head body to cover a wide range of drop volumes with different nozzle/chamber plates (see Figure 3 for drop volume versus nozzle diameter curve); (3) that the adjustable restrictor plate is designed for a wide range of jetting fluid viscosity; that (4) the print head customization would be flexible and Table 2 summarizes the adjustable parameters and their main impacts; (5) and that two different nozzle/chamber plate configurations was design for two different nozzle spacing (Figure 4).

Table 2.Summary of the adjustable parameters & their impacts

	Adjustable parameters	Main impact
PZT actuator	• PZT material • Active length	• Voltage • Drop volume
Fluidic path	• Orifice size • Restrictor	• Drop volume • Viscosity

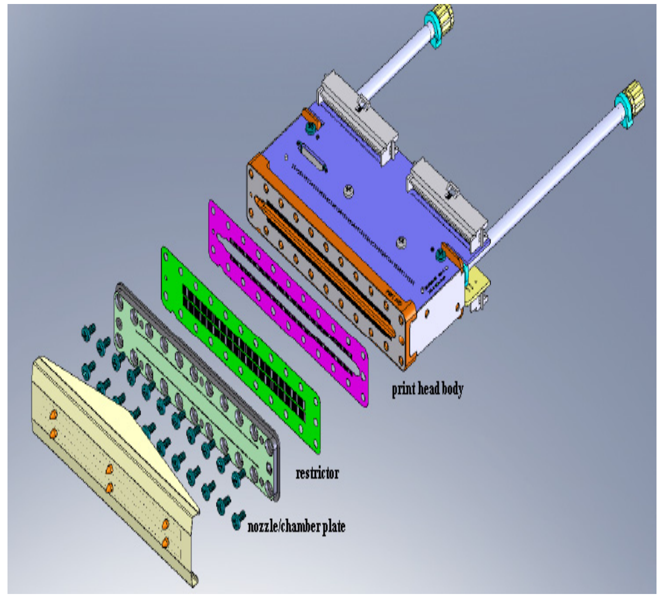

Figure 2. *Print head configuration*

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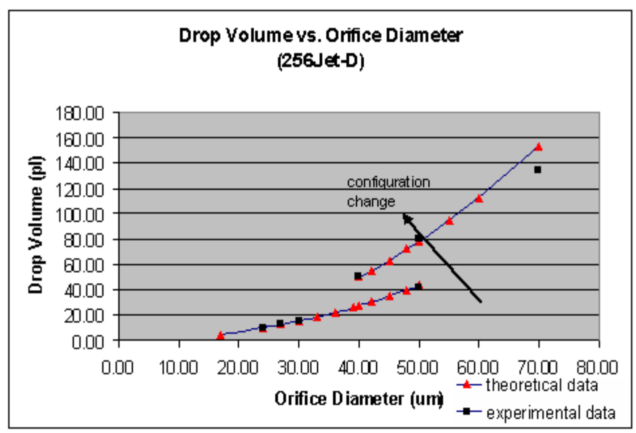

Figure 3. ***Drop volume versus orifice diameter***

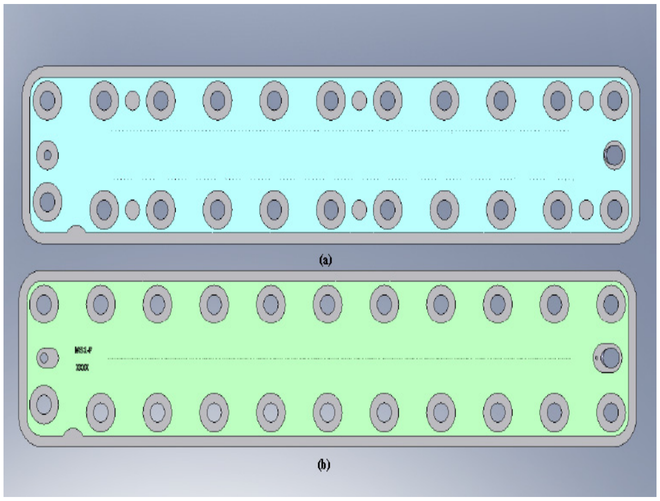

Figure 4. *Nozzle/chamber plate configuration:(a)dual line(b)inline nozzles*

Accurate Orifice Manufacture

Precise fluidic dispensing application requires a good control on uniformity of orifice diameter with tight dimensional and positional accuracy across the entire print head in order to generate accurate drop volume on the desired location for all jets. Figure 5 shows all the 256 nozzle position accuracy within ± 2 microns and Figure 6 shows all the nozzle diameter accuracy within ± 1.5 microns. Higher accuracy can be reached by implementation of MEMS technology.

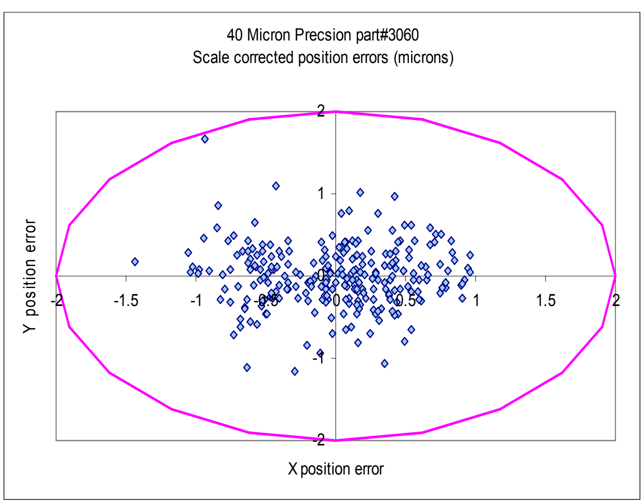

Figure 5. *Orifice position accuracy*

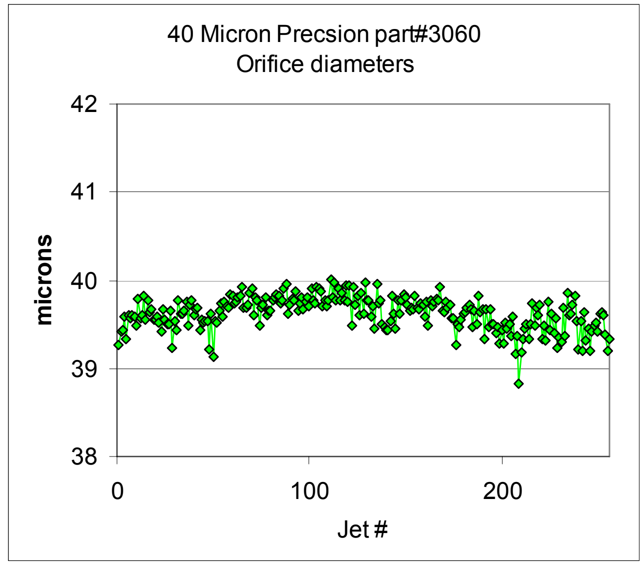

Figure 6. *Orifice diameter accuracy*

Jetting Material Flexibility

The inert stainless steel construction of the 256Jet-D print head is resistance to the corrosive, aggressive alkaline and acidic jetting materials often used in the deposition of printable electronic components. With the ability to be heated to 70^{0}C and to jet fluids up to 30 cps, the print head can print materials with twice as much viscosity as traditional inkjet systems, giving users wider flexibility in material loading and fluid formulation. Figure 7 shows that viscosity usually decreases when operating temperature increases and that traditional jettable viscosity is within 10 to 15 cps range corresponding operating temperature 40^{0}C for a given material.

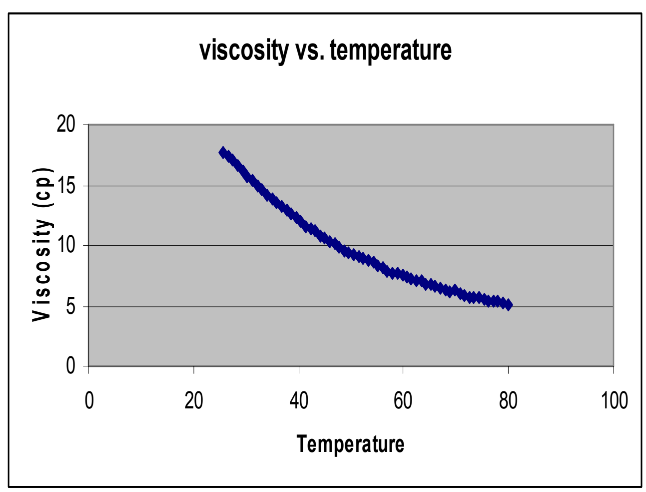

Figure 7. *Viscosity vs. temperature curve*

Conclusion

Trident's piezoelectric inkjet technology has unique features which make 256Jet-D print head ideal for manufacturing processes and they include:

1. Highly flexible design can be adapted to a wide range of applications.
2. Replaceable or repairable nozzle/chamber plate extends print head life and reduces the cost.
3. Inert stainless steel print head body is compatible with a wide range of jetting fluids.
4. The jetting print width can be up to 4 inches.

Author Biography

Ty Chen received his Ph.D. in Mechanical Engineering from University of Wisconsin at Milwaukee. He works as the R&D manager at Trident, an ITW company. His work has primarily focused on piezoelectric and other actuators, MEMS processes, and inkjet print head design and analysis for emerging markets. He is a member of IS&T.

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