Piezoelectric Inkjet Print Head Technology for Precision Dispensing Application

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Abstract

Flat Panel Display (FPD) technologies have been sweeping through the market which includes TVs, desktop monitors, notebook PCs, digital cameras, portable DVD, and so forth . Among them, TFT-LCD is dominating and approaching large size (above 40 inches). Its core components include a PI layer and color filter which can be digitally fabricated by the piezoelectric inkjet print head technology.

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 FPD market opportunities will require precise fluidic dispensing with tight dimensional and positional accuracy. 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 two print heads (PixelJet and 256Jet) have currently been developed to meet these applications.

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Introduction

FPD technologies mainly include Thin Film Transistor Liquid Crystal Display (TFT-LCD), Plasma Display Panel (PDP), Organic Light-Emitting Diode (OLED), Surface-conduction Electron-emitter Display (SED), and Field Emissive Displays (FED) and the flat panel market is expected to reach 100 billion US dollars in 2007 and 120 billion US dollars in 2010, led by TFT-LCD at an 83% - 85 % share [1]. The challenges in TFT-LCD are how to make it bigger, brighter, wider, lighter and less costly with higher contrast ratios and improve viewing angle performance. The LCD TV market is moving forward to above 50-inch panels and thus it is necessary to build eighth generation fabrications which increase productivity by 2.7 times compared to sixth generation. Therefore, inkjet print technology has advantages over the conventional processes in terms of PI coating and color filter. For example, 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.

Trident has been involved in those areas and designed two print heads which are 256Jet and PixelJet shown in figure 1 and figure 2, respectively. Their unique features include (1) high reliability, (2) accurate orifice manufacture (3) replaceable orifice – chamber plates, (4) inert print head bodies, (5) individual lead for jetting performance calibration, and (6) a highly flexible design to adapt to a wide range of drop volumes and jetting fluids. The specifications are shown in Table 1.

Figure 1. *256Jet print head*

Figure 2. *PixelJet print head*

Table 1. 256Jet and PixelJet specifications

	256Jet	PixelJet
# of addressable channels	256	64
Orifice spacing	0.397mm	0.743mm
Drop volume*	7-40 PL	10-60 PL
Drop velocity	5-8 m/s @ 1mm standoff	5-8 m/s @ 1mm standoff
Drive voltage	< 90 volts	< 90 volts
Straightness	< 0.5 degree	< 0.5 degree
Life expectancy	More than 90 billion jetting cycles	More than 90 billion jetting cycles

Note*: a range of drop volume can be covered by using different orifice diameters.

High Reliability

Figure 3 shows the channel drive voltage change of 256Jet print head after 90 billion drop jetting at constant drop velocity 11 m/s. There is little change between initial data and after 90 billion drops. It is demonstrated that print heads can reach more than 90-billion actuations without performance degradation.

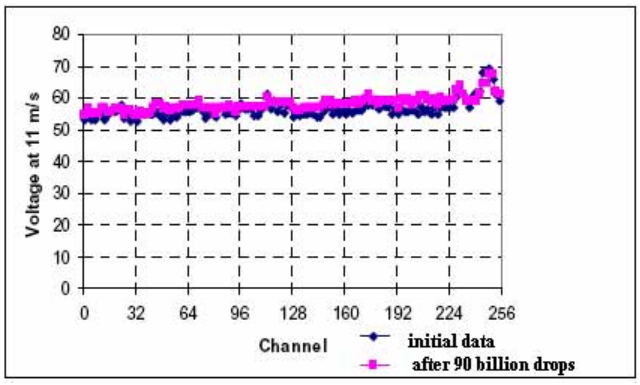

Figure 3. *Initial data vs. after 90 billion drop data*[2]

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 4 shows all the 256 orifice position accuracy within ± 2 microns and Figure 5 shows all the orifice diameter accuracy within ± 1.5 micron. Higher accuracy can be reached by implementation of MEMS technology.

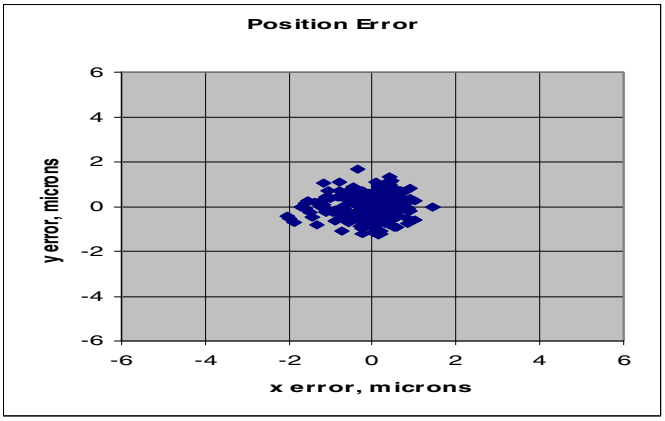

Figure 4. *Orifice position accuracy*

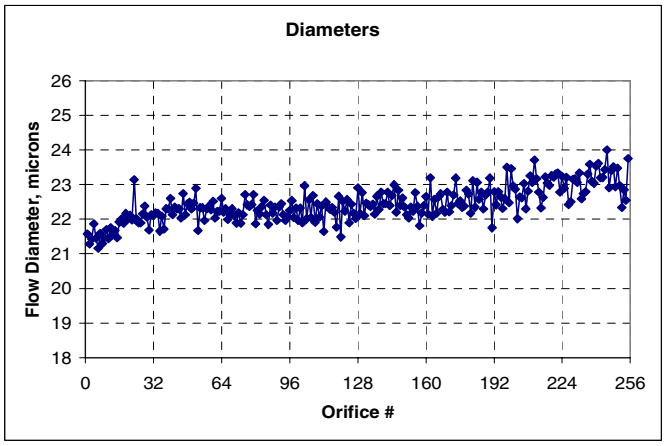

Figure 5. *Orifice diameter accuracy*

Replaceable Orifice-Chamber Plate and Highly Flexible Design

The thin stainless steel diaphragm is bonded onto pzt actuator/back print head body and separates fluidic parts as shown in Figure 6. The print head configuration is designed to make the orifice/chamber plate (CPOP) 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 CPOP significantly extends the print head life and thus reduces the total cost of ownership; (2) that one can

use only a print head to cover a wide range of drop volumes with different CPOPs (see Figure 7 for drop volume versus orifice diameter curve); (3) that the adjustable restrictor plate is designed for a range of jetting fluid viscosity; and that (4) the print head customization would be flexible and Table 2 summarizes the adjustable parameters and their main impacts.

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

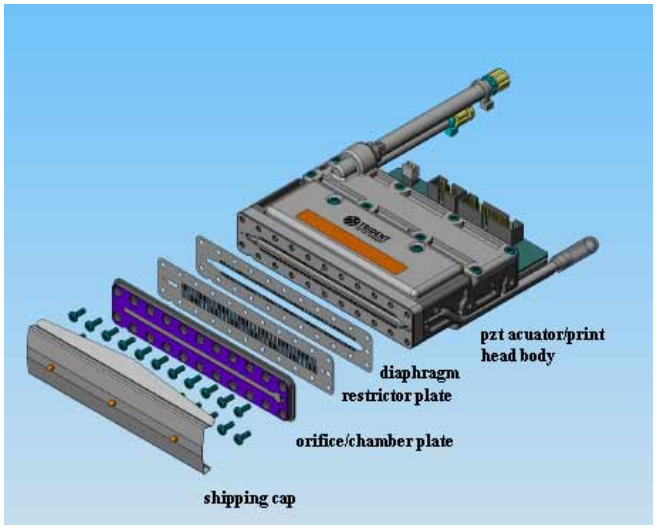

Figure 6. *Print head configuration*

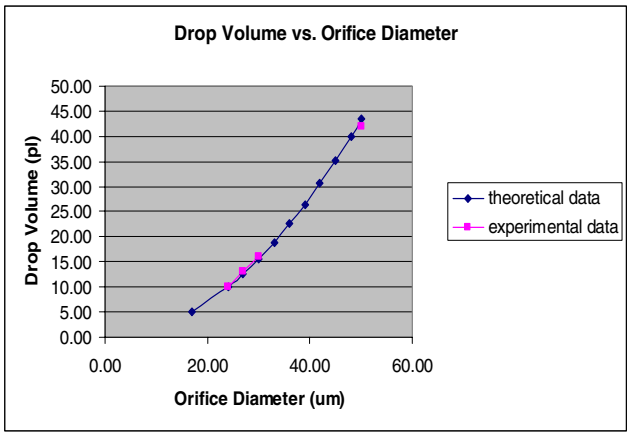

Figure 7. ***Drop volume versus orifice diameter***

Table 2: Adjustable parameters and their impacts

Jetting Performance

The print heads have been tested and measured the drop velocity variation over jetting frequency and jetting straightness. The results show in Figure 8 and Figure 9, respectively. In Figure 8, the velocity is constant over the frequency up to 9 KHz and in Figure 9 the jetting straightness is less than 0.5 degree in only one direction measurement. With the electronics capable of individually adjusting the waveform and drive voltage, the drop volume variation across the entire channels can be controlled within ± 2% (see Figure 10).

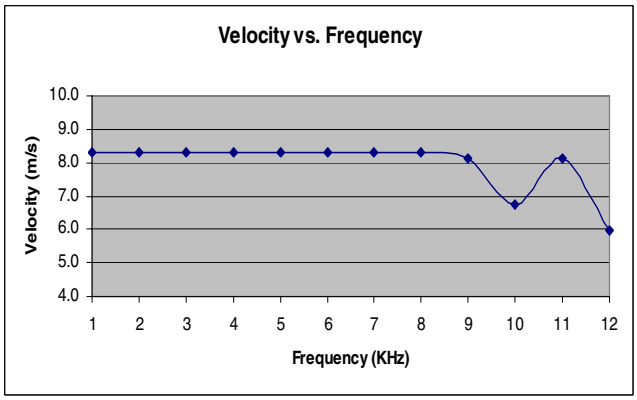

Figure 8. *Velocity variation over jetting frequency*

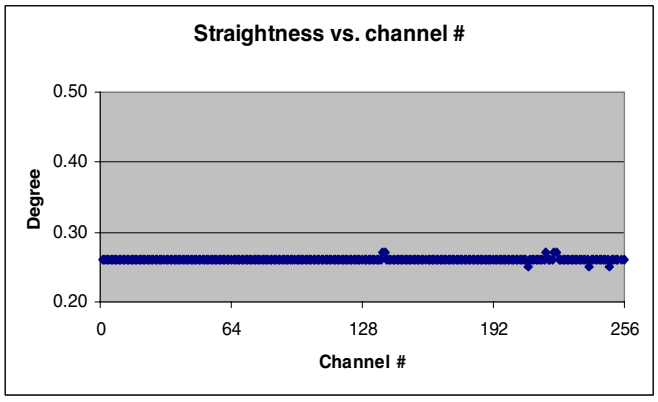

Figure 9. *Jetting Straightness*

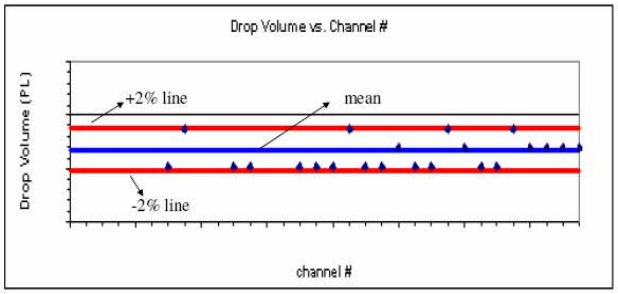

Figure 10. *Drop volume control*

Conclusion

Trident's piezoelectric inkjet technology has unique features which make these print heads ideal for flat panel display fabrication and they include:

1. Highly flexible design can be adapted to a wide range of application (different drop volume and jetting fluid viscosity).
2. Replaceable CPOP extends print head life and reduce the cost.
3. Drop volume variation can be controlled within ± 2% with individual channel drive control.
4. Drop velocity variation over frequency is constant up to 9 KHz.
5. Inert print head body is compatible with a wide range of jetting fluids.
6. The jetting print width can be up to 4 inches.

References

[1] R. Young, DisplaySearch's FPD Market Outlook, 2006 DisplaySearch Taiwan FPD International Conference, 2006.

[2] Y. Zhou, Recent Advances in Highly Durable Piezoelectric Inkjet Print Head Technology, Proc, NIP20, 855 (2004).

Author Biography

Ty Chen received his Ph.D. in Mechanical Engineering from University of Wisconsin at Milwaukee. He has worked at Trident, an ITW company, since 2001. His work has primarily focused on piezoelectric and other actuators, MEMS processes, and inkjet print head design and analysis. He is a member of IS&T.

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