Ink Jet Tools for Precision Materials Deposition

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Abstract

Purpose-built ink jet printheads are being recognized as useful tools in manufacturing where precision deposition is required. Ink jet technology is a non-contact, non-contaminating digital process compatible with clean rooms. New manufacturing applications are driving printhead designs to smaller drops, increased productivity. This paper describes Dimatix's new tools designed to facilitate development of manufacturing processes for both rigid and flexible substrates and development of new electronic fluids.

1. Introduction

Almost any manufacturing operation that requires the precise metering of materials to specified locations on substrates is a candidate market for industrial ink jet printheads. Ink jet technology offers economic advantages in cases where the material to be deposited is expensive, management of waste fluid is an issue, and variable patterns are desired. Digital deposition potentially eliminates the need to create photomasks, eliminating steps expensive in both time and money. Ink jet printheads offer the advantage of non-contact, thus minimizing contamination.

2. Manufacturing Requirements

Practical manufacturing systems require the integration of precision hardware, application-specific "inks," and specially designed inkjet print heads. The overall printing system ultimately dictates reliability and productivity, two keys to successful manufacturing. In particular, the system must enable a maintenance regimen appropriate for the jetting fluid and the application.

3. Applications for Ink Jet Precision Dispensing Printheads

The use of ink jets for digitally patterning electronic fluids provides at least three advantages:

1. It is an additive process to accurately deposit material in one step
2. It is a digital process with the capability to write data and continuously change the output
3. It provides a non-impact method to deposit significant quantities of material [1]

The suitability of a printhead for a given application is determined by a variety of factors. Some of these are the availability of jettable fluids, desired feature size and thickness, productivity or printing speed, absence of satellites. Feature size is determined by drop volume and by the interaction of jetting fluid with the substrate.

4. Ink Jets for Dispensing Electronic Fluids

Commercial and industrial ink jet printers utilize piezo-based drop-on-demand ink jets to print with the high reliability rates required by production equipment. This makes piezo ink jet technology an ideal match for electronics and FPD manufacture where precise metering and reliability requirements for a robust production process are of great importance.

Working from Dimatix's experience in manufacturing printheads for industrial and commercial markets, we designed a printhead, SX-128, to meet the production requirements for display applications.

Now that the SX-128 is used in a variety of display manufacturing programs, we identified areas for improvement: nozzle plate, external protection and maintenance system [2]. For example, to improve the SX-128 nozzle plate we are utilizing our silicon MEMS technology to produce a very dimensionally precise structure (Figure 1).

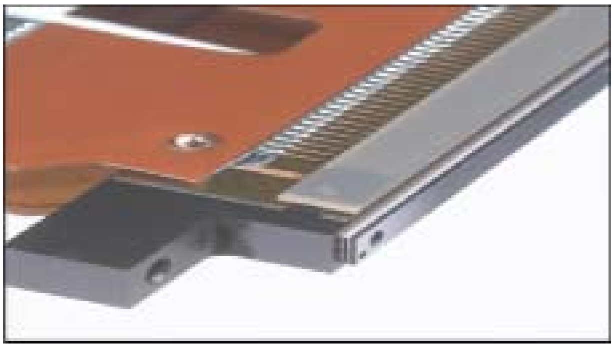

Figure 1. SX3: Improved SX-128 with Silicon Nozzle Plate and Durable Non-Wetting Coating

Specifications for the SX3 are given in Table 1. The durable non-wetting coating is designed to improve jetting characteristics and to make maintenance easier.

Table 1. SX3 Operational and Physical Parameters

Specification	
# of Addressable Jets	128
Nozzle Spacing	508 microns [0.020”]
Drop Volume	12 Picoliters
Adjustment Range	10-12 Picoliters
Drop Volume Variation	<2% w/ TDC electronics
Nominal Jet Velocity	8 m/sec
Spot Location (all sources)	+/- 10 microns @ 1mm
Compatibility	LEP/PEDOT/PPV, etc.
Drop Velocity Variation	+/- 5% without turning
Operating Frequency	Up to 10kHz to specification

5. MEMS-Based Material Deposition Technology and Modules

To meet the ever increasing demands for improved drop placement accuracy and throughput, Dimatix is now developing a MEMS based technology which will drive the performance factors and flexibility of material deposition to the next level of reliability and accuracy. The major steps in the fabrication process are the following:

1. Final wafer is fabricated from a three wafer stack-up, two silicon wafers and a PZT structure.
2. Dies are then separated from the wafer to produce deposition heads with the targeted amount of nozzles.

Other than the integration of the PZT into the wafer stack, all other processes are either IC based or MEMS processes. Examples of these processes are metal sputtering, wafer grinding and chemical-mechanical polishing, as well as deep reactive ion etching (DRIE) and silicon fusion bonding. Photolithographic process is used to define the planar geometries. An example of the basic structure is shown in Figure 2 [3].

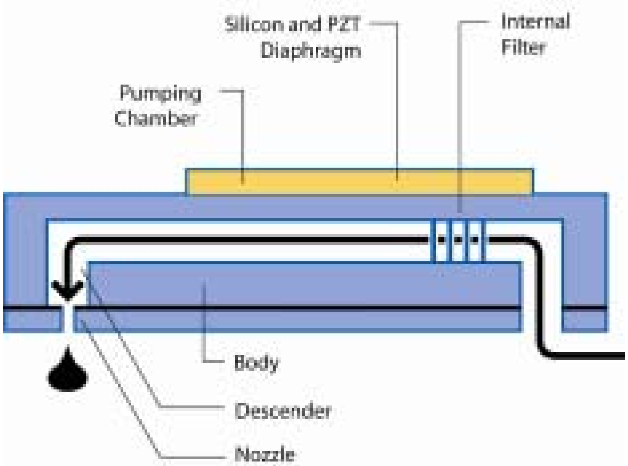

Figure 2. Schematic for new MEMS piezo ink jet

Silicon material, the base material for the MEMS processes, is a superior mechanical material with properties enabling a wide variety of deposition materials and inks. Dimatix has demonstrated superior resistance of the shaped piezo silicon to a wide variety of jetting formulations for aqueous inks, solvents and both highly acidic and basic fluids. In addition, the technology used to fuse the various layers of wafer material is also very resistant to chemical attack; a very common problem in many jetting systems used today. Finally and equally important is the fact that the outer surface is also made of silicon, which is a very hard material to allow frequent wiping and the jetting or deposition of abrasive suspensions without damage.

The nozzle structure provides diameter dimensions and quality consistent from nozzle to nozzle and device to device. This is a significant improvement for piezo inkjet technology. This controlled DRIE process improves jet straightness and eliminates most placement errors.

The MEMS architecture, integrated with silicon processes, enables a highly flexible design of different nozzle diameters and droplet properties. This new architectural approach allows additional scaling of nozzle spacing, drop sizes as well as overall fluidic dimensions to be part of the product design, aimed towards the specific applications.

6. Conclusion

Ink jet printheads are currently used both in R&D and on pilot lines to digitally print a variety of electronic devices. Experience in the field is enabling continuous improvement to the design of printheads to improve reliability and performance. Experience also demonstrates the importance of overall equipment design and fluid formulation to the performance of material deposition systems. MEMS processing is a powerful process for the advancement of performance parameters for precision micro-fluidic dispensing applications from printing to electronic materials deposition. Key features of MEMS processed devices are dimensional uniformity, processing flexibility and silicon's excellent application specific properties. The processing flexibility allows easy accesses a wide array of device. Coupled with the principles of micro-fluidic scaling, this dimensional design space permits the efficient design and development of a large range of jet dimensions with an associated wide range of performance parameters. As new applications develop, it will be necessary to consider new printhead designs to meet their specific requirements.

7. References

[1] James, Mark. "Manufacturing Printed Circuit Boards Using Ink Jet Technology," IPC 2003.

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[3] Menzel, Chris, Bibl, Andreas, and Hoisington, Paul. "MEMS Solutions for Precision Micro-Fluidic Dispensing Applications," Imaging Science & Technology Non-Impact Printing 20 Conference, November 2004.