Novel 3-D MEMS Approach to Digital Printing Electronics

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Abstract

An industry push to increase display pixel resolution, demand for improved jetability of complex fluids, and requirement for longer ink jet service life has mandated the advancement of new technologies to meet these demands. Digital technology is being explored as a route to improving manufacturing flexibility, decreasing manufacturing cost and reducing waste of expensive materials.

Spectra is responding to new manufacturing challenges by continuous improvement in current ink jets and by designing ink jet modules with single crystal silicon Micro-Electro-Mechanical (MEMS) manufacturing processes. As a result the SX-128 has improved drop placement accuracy, jetting operability, and chemical resistance. Recent developments with MEMS processes are enabling the efficient development of a new ink jet product family capable of servicing a broad range of dispensing applications. This presentation will describe the results of improvements to the SX-128 as well as initial results with our new M-class^{tm} dispensing modules.

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.

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.

Applications for Ink Jet Precision Dispensing Printheads

The use of ink jets for digitally patterning electronic fluids is driven by at least three factors:

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.

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 Spectra'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).

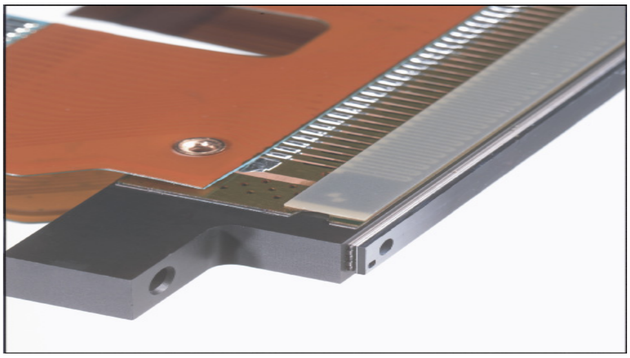

Figure 1. SX-128 with Silicon Nozzle Plate

MEMS-Based Material Deposition Technology and Modules

To meet the ever increasing demands for improved drop placement accuracy and throughput, Spectra 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]

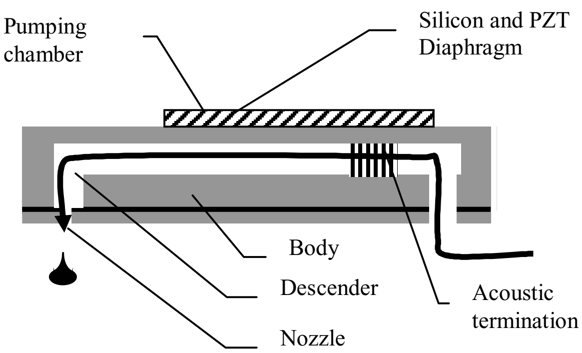

Figure 2. Schematic for new MEMs piezo ink jet.

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. Spectra 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.

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.

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Biography

Dr. Creagh is currently Business Development Director at Spectra, Inc., Hanover, New Hampshire. Spectra, a Markem independent subsidiary, designs, manufactures and markets ink jet printheads and inks for industrial, graphic arts and commercial applications. Linda joined Spectra in 1985 as Director of Ink Development after 10 years ink jet development with Xerox R&D. Before Xerox, she was involved in liquid display research at Texas Instruments. She has a number of technical publications and more than 15 US and foreign patents in the fields of ink jet technology and liquid crystal displays. Linda works in Spectra's Materials Deposition Division, which is based in Santa Clara, California.