Impact of Silicon MEMS on Future Ink Jet Printhead Architectures

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Abstract

To further expand industrial ink jet opportunities, printer equipment builders and integrators have placed increased demands on piezoelectric printhead manufacturers. This includes requirements for improved reliability and ease of use, higher resolution, greater precision, and more operating modes. This paper describes how Spectra's next generation printhead product family, M-Class, incorporates the inherent benefits of silicon MEMS fabrication technology, a highly capable jet design, and a flexible printhead array architecture to address these needs.

Introduction

While the present means of printhead construction has served existing industrial ink jet markets well, Spectra recognized in 2001 that a fundamentally new fabrication technology would be needed to meet the challenges of emerging digital printing and precision materials deposition – silicon MEMS. Inherent in MEMS fabrication techniques are sub-micron control of key structural geometries, which is critical for achieving uniform performance across all channels. Silicon is a desirable construction material with high resistance to mechanical abrasion and good robustness to chemical attack. Using Spectra's unique Shaped Piezo Silicon™ capability, the PZT crystal is brought into intimate contact with a thin silicon membrane to form the pumping chamber. The result is a highly efficient, high resonant frequency jet design with no contact between the jetted material and the PZT.[1]

The benefits of this approach are manifold. Precise control of the nozzle shape and absolute position permits higher drop placement accuracy over greater throw distances. The robust silicon structure lends itself to highly reliable operation and long service life. The use of silicon MEMS reduces the size and mass of the jetting structure considerably. Another inherent benefit of silicon MEMS is design flexibility. The native drop size or other jetting characteristics can be changed simply by changing the photo-lithographic masks use to define the critical jet dimensions – no new fabrication processes need to be developed. Finally, the cost model for silicon MEMS tracks similarly to IC industry, such that after the high initial outlay for the fabrication facility, the device cost declines as volume increases.

The M-300/10 Jet Module

After processing, individual die are separated from a silicon MEMS wafer and assembled into Jet Modules in order to facilitate the integration into larger printhead structures. The first building block for the M-Class family of printhead products is the M-300/10 Jet Module. This model provides 304 independent channels, arranged in a single row at 180-dpi nozzle spacing. The jet module is designed to eject a 10pl drop at a nominal 8m/s drop velocity when jetting fluids in the 10 to 14 cPs range. The material set was selected not only for compatibility with a broad range of ink chemistries, including solvent-based, UV curable, and aqueous inks, but also for aggressive maintenance fluids necessary to ensure a long service life. Operating temperature while jetting can be up to 70°C. Other desirable attributes include superb drop straightness, excellent channel-to-channel uniform-ity, high frequency/high productivity operation, and a maximum PZT excitation amplitude of 44 volts.

The complete M-300/10 jet module is shown in Figure 1. It features a built-in 25-micron inlet filter screen, which is in addition to the last chance filter included within each channel. Precision registration points have been added to the outside of the package, which can absolutely reference the nozzle locations to within a few microns.

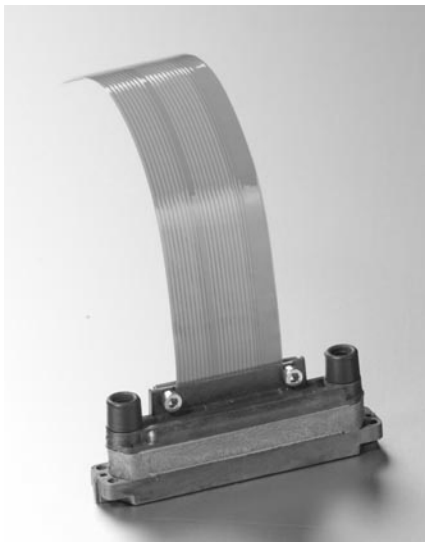

Figure 1. M300/10 Jet Module

These two features, an inlet filter and precise registration points, enable field replacement with reduced risk of catastrophic contamination or the need for additional alignment. The jet module also features dual ink ports, permitting easier flushing, quick color changeovers, and ink re-circulation. A heater and thermistor is included within the assembly to maintain precise control of the ink viscosity while jetting. The custom driver ASICs are double buffered to permit the high speed data transmission necessary to support the jet module's fast frequency response.

The high resonant frequency of M-300/10 jet design produces an ink jet that is extremely responsive to PZT excitation waveform. These waveforms can be tailored for specific inks and printer operating modes to maximize the jet module performance. The potential areas of optimization include higher frequency operation, improved drop formation, or accommodation of a wider latitude of ink properties. The inherent properties of the jet design, coupled with high-speed image data transmission to the custom driver ASICs, permit the use of grayscale operation in addition to binary operation. Upstream printhead controller circuitry support these capabilities by including a data path that supports multiple bits per pixel, implementing the high-speed logic needed to control the portion of the wave train going to each channel, and providing a programmable, arbitrary waveform amplifier to drive the PZT.

The M-Class Printhead

The M-300/10 Jet Modules are the core component for an entire family of M-Class printhead configurations. Common attributes of these printhead models include a means to precisely align multiple jet modules with respect to one another as well as to reference features at the printhead mounting points. An on-head ink reservoir with a versatile ink level sensor is also included. Sophisticated controller circuitry provides integral thermal management, flexible PZT drive capability, and high speed image data handling.

Two classes of M-Class printhead models have been devised. For printing applications demanding a robust printhead packaging solution, simplified fluid and electrical interface, and the integrity of a fiber optic data connection, Spectra offers the Integrated Printhead Product Line. The M-Class Quad is the first printhead model in this product line. Featuring 1200 channels, the monochrome Quad is configured to print a 720-dpi single pass swath at run speeds in excess of 1.5 m/s. Multiple printheads can be efficiently stitched together to produce the desired print width, making the Quad printhead an effective building block for high performance single pass print engines. A second class of printhead models is available for machine builders and integrators who do not require a full packaged solution. For those customers with the technical capability to embed M-Class technology deeply into their printers, Spectra offers a Modular Printhead Product Line. This product line features reduced size and mass for scanning applications, discrete electronic control and data path boards, and modular support components. This option still provides the same integral ink reservoir, ink level sensors, programmable drive amplifier, and precisely aligned M-300/10 jet modules as the Integrated Printhead Product Line. Particular attention has been made to enhance the serviceability of this package. The Hex Modular Printhead Package is the first offering in this product family, comprising six M-300/10 jet modules, each with its own dedicated ink reservoir. The Hex package is particularly well suited as the foundation of a scanning printer platform.

While both the Integrated Printhead and Modular Printhead Product Lines offer unprecedented choice, Spectra recognizes that the Quad and Hex will not satisfy every digital printing need. Consequently, infrastructure is being put in place to accommodate custom printhead options. Within the M-Class family, customers will be able to specify the number of jet modules and the number of colors, the jet module arrangement, and choose between a static or recirculating ink manifold. Combined with the option of either an Integrated or Modular Printhead, the M-Class product platform provides an extremely flexible architecture for current and emerging digital printing needs.

Summary

Despite impressive achievements over the past decade, the demands of industrial printing applications continues to tax the capabilities of existing piezo ink jet products. Shaped Piezo Silicon™, employing silicon MEMS fabrication techniques, is a significant technological breakthrough that promises to meet the challenges of current and emerging digital printing applications. M-Class, Spectra's first product family to embrace this technology, includes the monochrome Quad Integrated Printhead, the Hex Modular Printhead Package, and the flexibility for customers to tailor unique solutions for applications requiring the latest innovation in piezo ink jet technology.

References

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Biography

Marc Torrey has more than 20 years experience working with piezo ink jet printheads. He has a diverse background in printhead design, prototype fabrication, system integration, and engineering in high performance industrial applications. Having worked at Spectra since its founding, Marc managed Spectra's sales and technical support activities in Europe and is now responsible for product planning and the commercial introduction of Spectra's next generation printhead technology.