Recent Advances in Niche Printhead Technology

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Abstract

Three recent developments in shear mode ink jet technology base are presented. The first is the use of sintered carbon as a structural element in new printhead designs. The second is the use of a filter between the pumping chamber and the nozzle. The third is an edge-shooter embodiment of the shear mode transducer. These advances are useful in the rapid development of printheads for niche markets.

Introduction

Engineering and manufacturing groups at Spectra have introduced printhead products which embody three recently developed enhancements. When combined with Spectra's technology base in piezo drop-on-demand ink jetting, these enhancements are expected to assist the development of a variety of printhead/ink systems developed for specific niche markets.

Carbon Structure

The first of these enhancements to Spectra's shear-mode piezo ink jet technology began with the selection of a material better suited to the requirements of this technology. The ideal material for a piezo ink jet printhead capable of jetting a wide variety of inks would have the following characteristics presented in Table 1.

Spectra's first generation jetting structures were built with etched metal laminates, bonded together to form a three-dimensional structure. Although this approach has many benefits, the candidate materials fall short relative to the ideal set of properties in a number of categories. For example:

- Metal laminates with low TCE also have poor thermal conductivity
- Metal laminates have tooling cycles of many weeks
- Fine features are limited to thin parts

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Table 1. Ideal Printhead Construction Material Properties

Low Thermal Coefficient of Expansion (TCE)	To match the piezo-ceramic for low stress bonds
High thermal conductivity	To reduce thermal gradients
Chemically inert	To minimize reactions with inks
Dimensionally stable	Parts must be precise, and remain undistorted through thermal cycling
Capable of both large and fine scale featuring	To facilitate close packing of jets in large arrays
Low cost and flexible in manufacturing	Simple tooling and processing speeds development cycles

Table 2. Typical Properties of Sintered Polycrystalline Carbon

Material Property (Typical)	**Value**
TCE (Thermal Coefficient of Expansion)	8.4×10^{-6} cm/cm/K
K (Thermal Conductivity)	1.1 Watt/(cm K)
Oxidation Threshold	450 C
Modulus of Elasticity	1.8×10^{6} psi
Yield Strength	10,000 psi
Density	1.8 gm/cm^3
Particle size	.5 to 3 micron

Silicon is a material commonly used in the construction of ink jet printheads, and is perhaps the ideal material for high volume manufacturing of miniaturized printheads. Piezo pumps based on bulk PZT can not be miniaturized to the scale of bubble jets. At the large size scale required by these pumps, silicon and the equipment required to pattern it are not economically attractive for low volume printhead manufacturing.

Sintered polycrystalline graphitic carbon also provides a good match to the list of ideal properties (Table 2). It is particularly distinguished, however, by being commonly fabricated by conventional forming processes with feature sizes measured in microns up to meters. This is particularly important in the construction of large "page-width" type printheads. Spectra has adapted several conventional forming processes, such as CNC milling, drilling, and grinding so that precision parts may be fabricated repeatably and inexpensively. This carbon is a dense, fine grained, friable material, so that machined surfaces are cleanable, and free of stresses that might cause mechanical distortion. CNC machined parts feed directly to printhead assembly cells, providing manufacturing flexibility, and extremely rapid design feedback during product development.

The Nozzle Filter

A second recent enhancement to Spectra printheads has been the implementation of a "last chance" filter between the pumping chamber and the nozzle (Figure 1). This filter (referred to at Spectra as a "rock-trap") typically has a small area, similar to that of the pumping chamber cross-section (300 micron × 300 micron, for example). The openings in the rocktrap are large, similar in size to the nozzle diameter, so it is only loaded by large particles that would likely cause an un-repairable clog. Electro-forming and laser drilling have proven to be cost effective ways to fabricate this part.

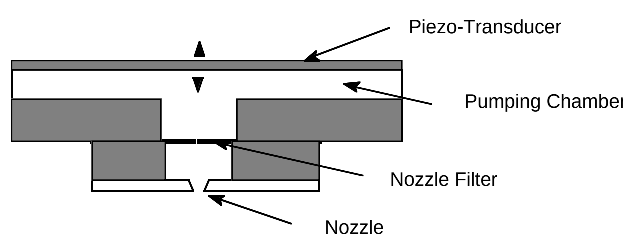

Figure 1. Nozzle Filter in a Planar Array

Filters in drop-on-demand ink jets are typically located upstream of the pressure generating element and are designed for very low flow resistance. The flow resistance of this rocktrap filter, although small compared to the nozzle, is much larger than could be tolerated upstream of the pumping element. If capillary refill were the only mechanism available to move ink from the reservoir to the pumping chamber, then the added flow resistance would reduce the maximum feasible jetting frequency. Capillary refill in Spectra's piezo jets, however, is dramatically augmented by mechanical pumping resulting from the piezo-electric displacement in combination with the variable impedance of the nozzle flow. The result is that the rocktrap filter flow resistance has an insignificant effect on the drop ejection frequency.

The rocktrap filter offers two important advantages for the design and manufacture of printheads in niche markets. First, the probability of ensuring that not a single nozzle clogging particle makes its way through the printhead to a nozzle during the life of a printhead is dramatically improved. This means that the selection of materials and processes is opened up, and the cleanliness requirements of the assembly may be reduced. Second, the rocktrap creates the opportunity to design an assembly with separable elements in the fluid path, so that a printhead may be assembled, disassembled, and re-assembled using simple modules as building blocks.

Three Dimensional Array Structure

The third new development in Spectra printheads has been the repackaging of the piezo-transducer arrays in a way that enables higher nozzle packing densities, and modular design of printheads.

The use of laminated metal plates as structural elements (as in Spectra and Tektronix 300 dpi printheads) leads naturally to thin, flat printheads in which the piezo-transducer is co-planar with nozzle plate. This planar packaging can have drawbacks in packing nozzles close together, as a significant area of transducer is required adjacent to each nozzle. If the piezo-transducer is turned on one edge, however, an "edge shooter" is created (Figure 2). In this edge shooter structure, the area of the transducer is no longer the limiting constraint to nozzle packing density.

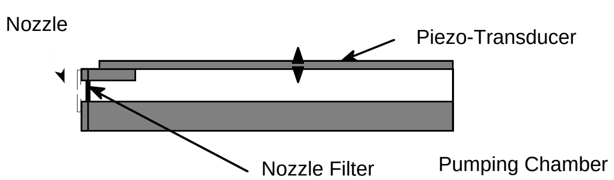

Figure 2. Edge Shooter Array with Nozzle filter

The three dimensional structural nature of machined carbon facilitates this repackaging. Flat, ground surfaces can be provided on any surface of the carbon, so good fluid seals for the piezo transducer and the nozzles can be designed on surfaces that are orthogonal to each other. In the Spectra 128 jet edge-shooter module, piezo-transducers are bonded to two opposed surfaces, and connections to the nozzles and reservoir are made on a third surface.

Putting it Together

The three developments described above are only incremental changes, when considered individually. When they are put together, however, they provide a platform for the development of dramatically new printhead architectures. The technical requirements of niche customers tend to demand unique combinations of printhead features and ink. This technology platform provides the flexibility and performance needed to meet these demands.

The precision and repeatability achievable with a carbon jetting structure has been first implemented at Spectra in a 160 jet 600 dpi printhead. This printhead features 160 jets patterned onto a single slab of PZT, interleaved for a nozzle spacing of approximately 0.5 mm (.018 in). It provides the frequency response, and the jet-to-jet uniformity required for a critical full color graphics arts application.

The combination of the carbon edge shooter array with a separable construction has enabled the design of a family of different printheads, all based on similar modular elements. The first Spectra printhead to use edge-shooter arrays contains two 128 jet transducer modules, which are combined in a manifold part to a single row of 256 nozzles on 250 micron (.010 inch) spacings. This is a greater than 2× reduction in the nozzle-to-nozzle spacing over any other Spectra 300 DPI printhead. This mono-color printhead is targeted to industrial marking applications.

Many applications do not require that all nozzles are in a single line. In these cases, an arbitrarily large number of modules may be placed on a single nozzle plate assembly (Figure 3). This provides three advantages for very large array construction. First, modular transducer subassemblies are simple and testable, facilitating high yield manufacturing of a large scale printhead. Second, the nozzle-plate subassembly is separable and testable, with the precise location of nozzles accurately determined in a single part. No critical alignments are necessary between the transducer modules and the nozzle-plate assembly. Finally, these large scale arrays can be disassembled and repaired if required, reducing the end-user cost of ownership.

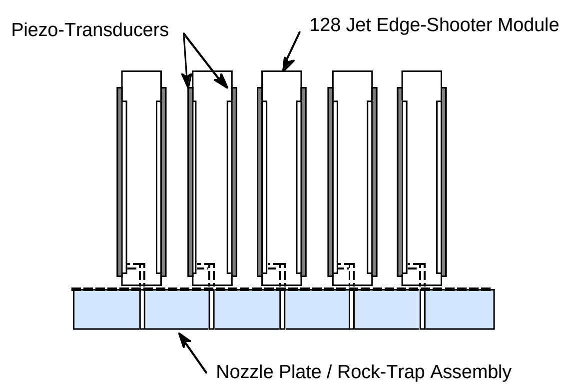

Figure 3. Modular Printhead, Arbitrary Width and Resolution

Tektronix has demonstrated, in the Phaser 340, that there is sometimes an advantage to a large printhead, as the size of paper has not been miniaturized over the years. Spectra's carbon technology platform provides a simple way to put together a printhead as wide as the substrate demands, and a modular array approach makes it feasible to consider putting the jets in such a page-width head on pixel centers. Applications in which wide printheads are advantaged (such as label printing and continuous web printing) are likely to grow in number and importance during the coming years, and this carbon technology platform can facilitate this growth.