Digitally Printing Electronics with Piezo Ink Jet

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Abstract

As an effort to reduce cost and lead-time and to increase flexibility and responsiveness, manufacturers are using digital printing in numerous process steps. Typically, these processes require the precise dispensing of various fluids. Piezo ink jet printheads are proving to be reliable tools for depositing active materials such as light emitting polymers (LEP) for mobile phone displays and color filter inks for liquid crystal displays. Ink jets are also being used to provide uniform coatings of polyimide alignment layers and spacers for LCDs. Success with legend printing on PCBs using ink jets has encouraged the design of equipment for directly printing both etch resist and solder mask for PCBs. Development of printers for passive components such as capacitors and resistors is underway.

This paper will present the attributes of an ink jet printhead designed to a precision deposition tool and discuss how it is being used to digitally print electronic and flat panel display components. Status of commercialization of digital printing will be discussed along with issues to be resolved before wide adoption takes place.

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 a die or photomask thus eliminating steps expensive in both time and money. Ink jet printheads offer the advantage of non-contact, thus minimizing contamination. Table 1 lists some of the areas that are already considering ink jets as part of their manufacturing.

An idea of the economic possibilities for precision dispensing are indicated by considering just one market, LCD color filters. More than 70 million LCD flat panel displays are sold yearly, 85% of these have a color filter. One Japanese manufacturer produces at the rate of 1.1 million ft^2 color filter per month. These color filters could be printed with ink jet printheads.

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.

A robust manufacturing process requires both precision and reliability to place material accurately and consistently. For example, as an integral tool in manufacturing LEP displays, the piezo ink jet must maintain tolerances necessary for precise fluid dispensing into the display pixels, have robustness to attain sufficient life, and not compromise the active ingredient the electronic fluids.

The benefits of directly dispensing electronics fluids can be summarized as indicated in Table 2.

Table 1. Some Opportunities for Manufacturing Electronics with Piezo Ink Jet Printheads

Flat Panel Displays	Light Emitting Polymers (LEP)
	LCD Spacers
	LCD Color Filters
	LCD Back-planes
	LCD Alignment Layers
	e-Paper and e-Poster
Organic Electronics	Thin Film Transistors (TFT)
	Bio- and Chem-sensors
	Large Area Solar Cells
	Dielectric Polymers
	Etch Mask
Printed Circuit Boards (PCB) & Traditional Electronics	Solder Mask
	Legend
	Conductive Traces
	Inductors
	Solder Interconnects
	Adhesives
	Micro-optics
	Embedded Resistors and Capacitors

Table 2. Benefits of Digitally Dispensing Electronic Materials

Increased Functionality of Existing Systems
Novel Design Opportunities
Design Simplification
Flexibility
Fabrication Directly from CAD/CAM
Component Reduction
Simplified Manufacturing
Efficient Use of Materials

3. Ink Jet Printheads for Dispensing Electronic Fluids

The vast majority of drop-on-demand ink jet printheads are bubble" or thermal ink jets that are designed to eject small drops of ink to create complex images of near photographic quality in home and office environments. 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 the precise metering and deposition requirements of material and the 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 This printhead also is appropriate for use in a variety of electronics manufacturing applications. In order to meet drop volume uniformity requirements for flat panel display manufacture, each channel in a SX-128 jet printhead can be individually calibrated with special electronics and software.

Experience with the SX-128 in a variety of display manufacturing programs, we have identified areas for improvement: nozzle plate, external protection and maintenance system. To improve the SX-128 nozzle plate we are utilizing our silicon MEMS technology to produce a very dimensionally precise structure (Figure 1).

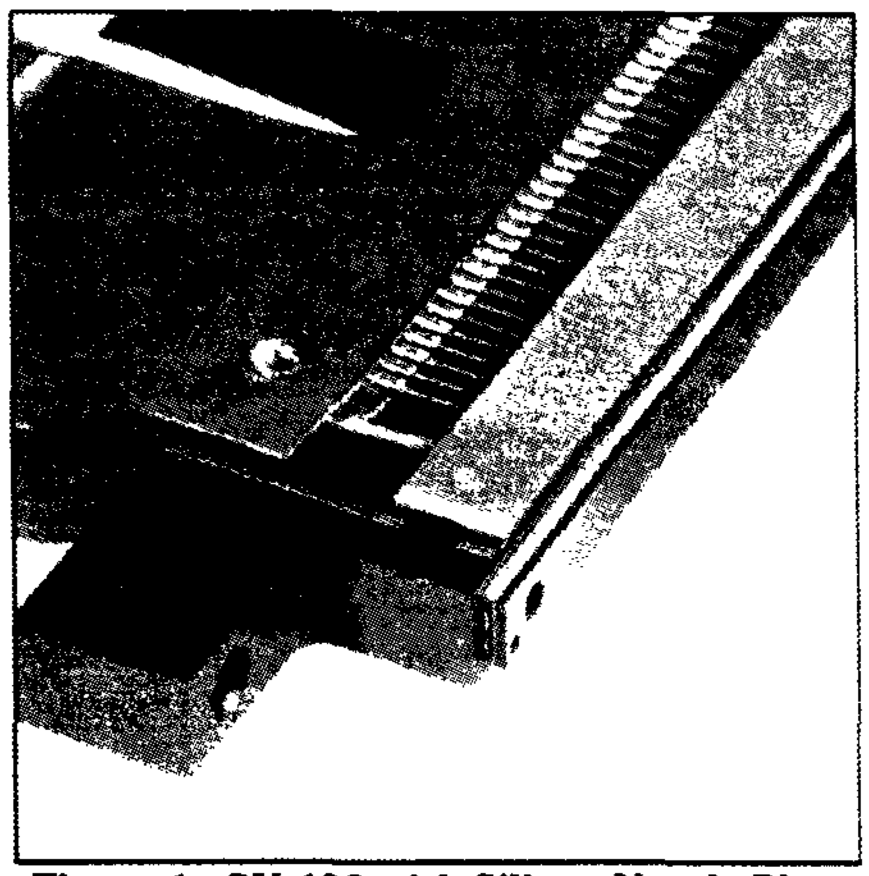

Figure 1. SX-128 with Silicon Nozzle Plate

To provide an example of the importance of material compatibility, consider manufacturing LEP –based displays. The first digital material deposition step is to jet PEDOT within a display pixel. With a pH of 1.5, PEDOT is an aggressive fluid that can etch metals. Figure 2 shows four damaged copper traces intended to make the electrical connection of four jets to the PZT. The original parylene coating protecting the copper has been damaged and thus PEDOT could etch away the electrical connection to the PZT.

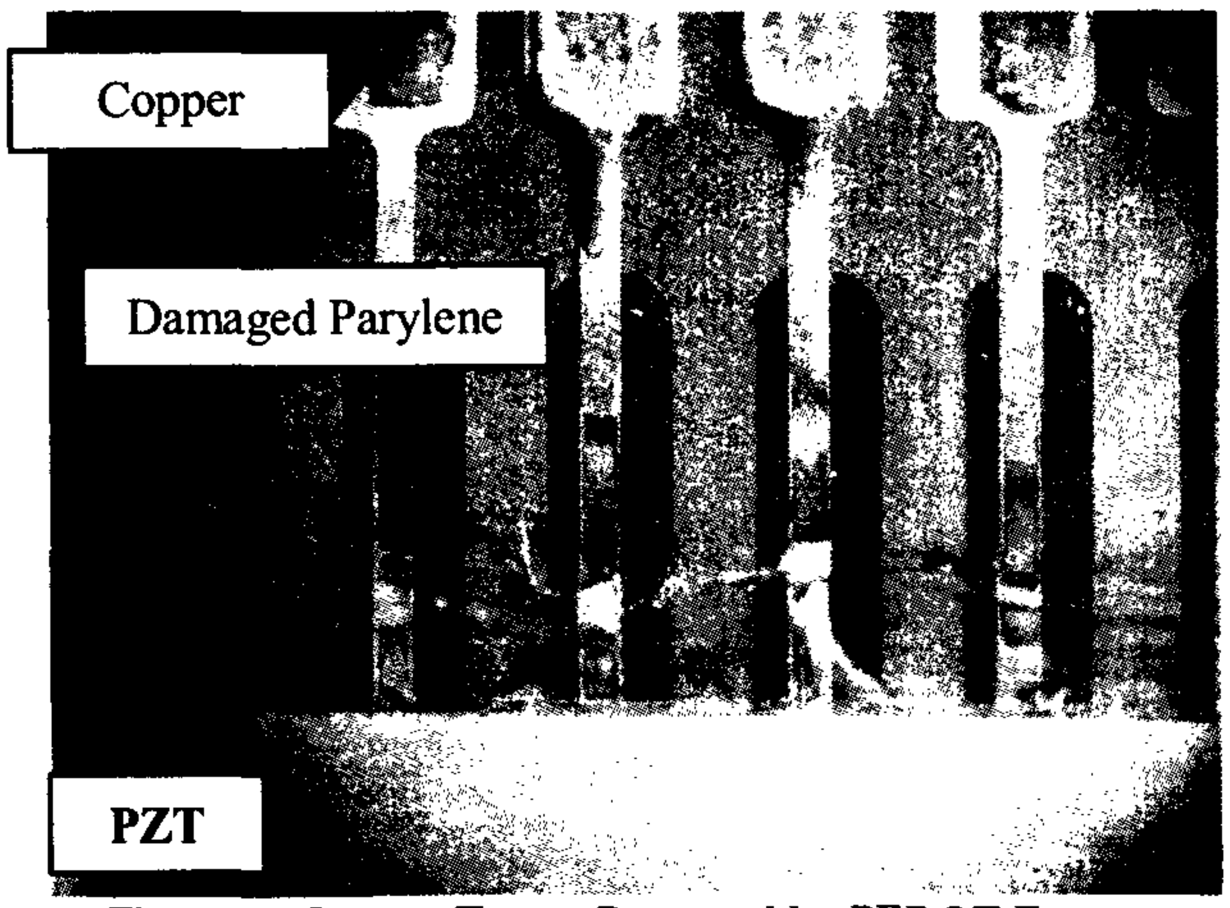

Figure 2. Copper Traces Damaged by PEDOT Exposure

The importance of having effective maintenance programs is illustrated by looking at SX-128 performance using a maintenance routine that ensures jetting fluids are not allowed to dry in the nozzle or on the nozzle plate prior to being jetted. This approach positions the printhead so that the nozzle plate is submerged in pure solvent. Indeed, this approach prevents drying in the nozzle, but there are unintended consequences. The negative pressure is required to prevent fluid from dripping from the nozzles draws solvent into the pumping chamber itself, diluting the jetting fluid. Even small changes in the fluid to be jetted affect drop velocity as illustrated in Figures 3 and 4.

Figure 3 shows the drop velocity of each jet in an SX-128 with all jets firing with the same fire pulse. This is a typical velocity profile for a piezoelectric micro-pump jetting LEP at a steady state.

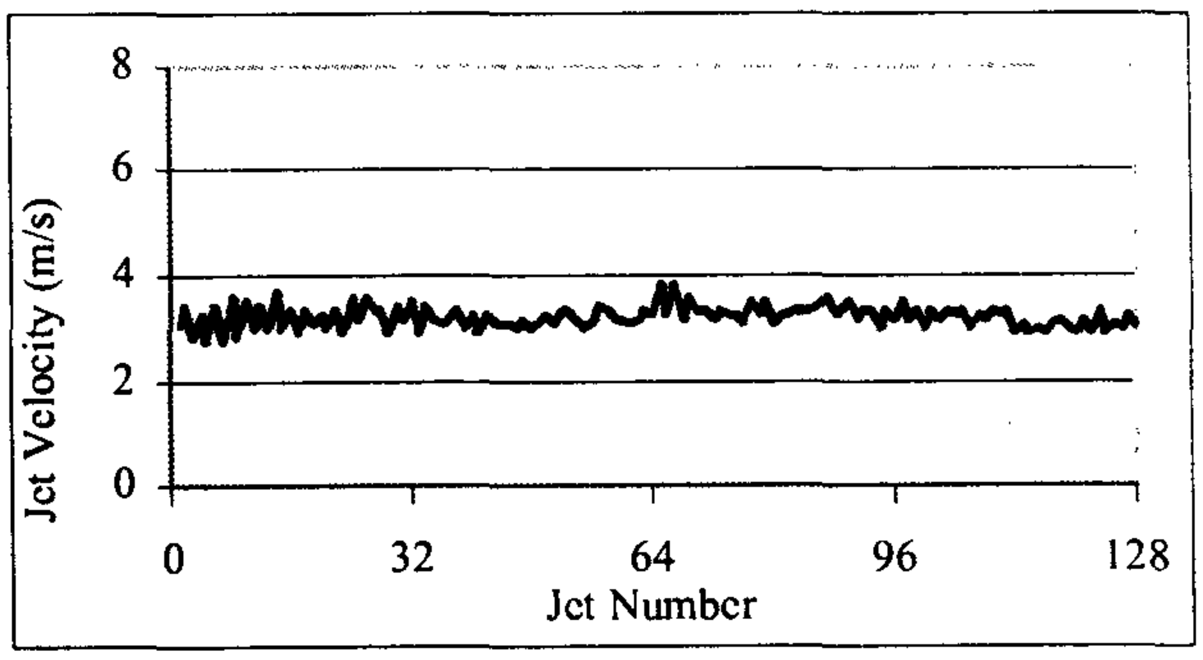

Figure 3. Typical Jet Velocity Profile Jetting LEP

Figure 4 shows a jet velocity profile of the same piezoelectric micro-pump after soaking the nozzle plate in solvent. Jets 80-128 are traveling faster than Jets 1-48. This velocity profile is the result of solvent being drawn non-uniformly into the pumping chambers. The fluid in the faster jets is more diluted than the slower jets, changing the viscosity of the fluid and that changes the jetting velocity.

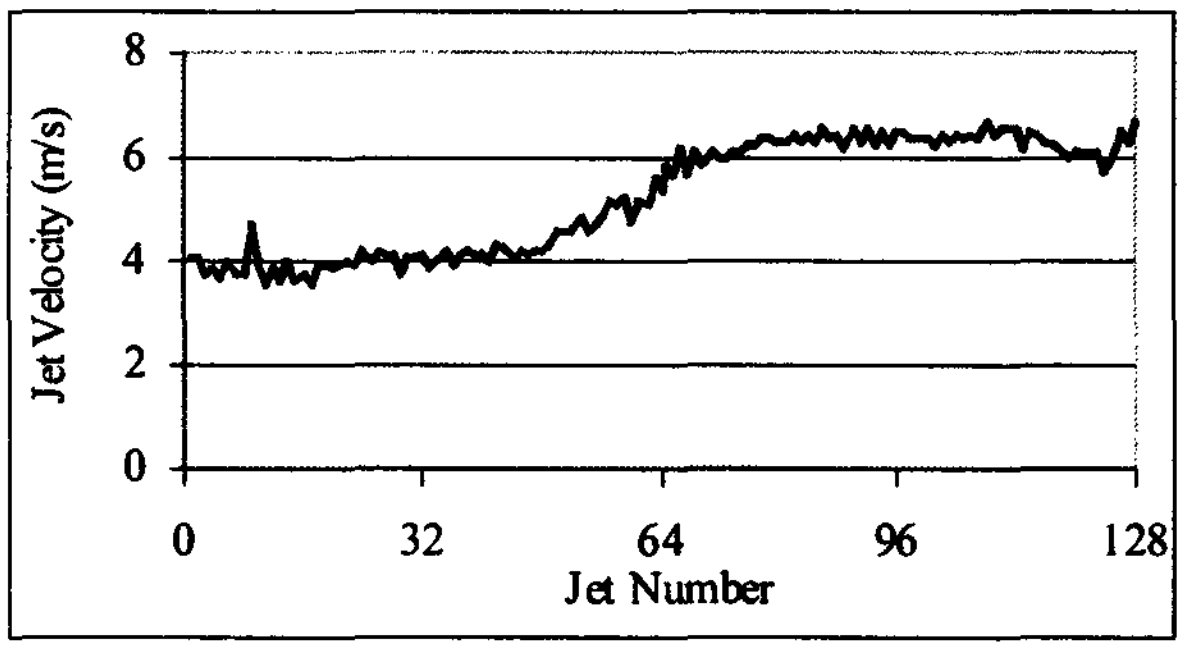

Figure 4. Typical Jet Velocity Profile Jetting LEP

This example demonstrates the importance of designing a maintenance system that can maintain both the ink jet and display fabrication fluid in a reliable and consistent manner.

4 Conclusion

Ink jet printheads are now being 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.