Diverging Ink Jet Technologies and Applications

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Abstract

It has taken years for ink jets to move from the laboratory to the home, office and commercial workplace. Commercial ink jet printing literally began on the floor with Miliken's carpet printers in the 1970's, but it was not until HP's ThinkJet that enabled everyone to inexpensively print from PC's did ink jet printing become a common term. Now we are seeing many markets utilizing a wide variety of ink jets in ways unthinkable 30 years ago. These applications include every form of graphics arts printing, product decoration and even fabrication of products and components.

This presentation will discuss recent advances in drop-on-demand piezo ink jet technology with particular emphasis on designs intended for dispensing functional fluids rather than printing inks. Recently new methods of constructing printheads have been introduced and these tools are enabling new applications in areas as diverse as biotechnology, nanofluid development and flexible organic electronics. We know from looking at billboards and address labels that ink jets produce valuable graphic arts products, but it remains to be seen if ink jets can move from industrial and university labs into volume manufacturing of products such as displays and biochips.

Introduction

Drop-on-demand (DOD) ink jets began to impact our world in the 1980's as the technology moved from producing relatively low quality digital images for coding and marking, addressing and carpet patterns to being the key to very low cost desk top printers. At the same time as HP and Canon were investing in high volume production lines to make thermal ink jet cartridges for the burgeoning SOHO market, others were developing the technology necessary to make piezo-based DOD ink jet printheads reliable enough to begin to displace traditional printing approaches for case coding and proofing. Over the next twenty years digital color printing technologies have "evolved to meet intense customer demand for lower price per page, greater reliability/image quality, and a broad range of applications." [1] Figure 1 illustrates the expanding market penetration for both thermal and piezo DOD ink jets.

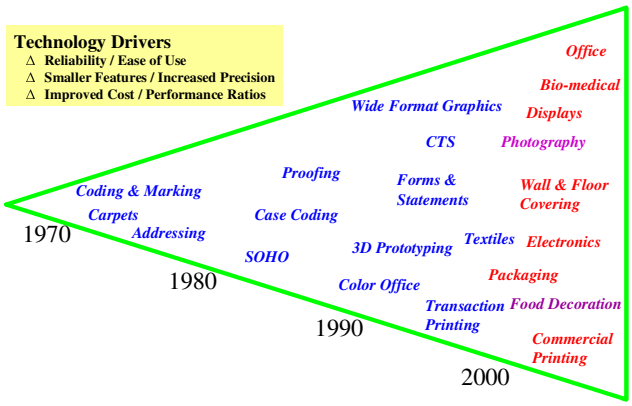

Figure 1. *The expanding ink jet market.*

Experience gained in these widely varied markets has enabled DOD ink jets to be considered for totally new market areas such as electronics, displays and biotech. Success in industrial graphics arts applications demonstrates piezo-based DOD ink jet technology can function reliably with high productivity in demanding manufacturing environments. It is this background that led to piezo DOD ink jets being evaluated as manufacturing tools in applications that require precision placement of precisely controlled amounts of functional fluids.

Applications for Manufacturing with Ink Jets

Virtually any manufacturing operation that requires the precise metering of materials to specified locations on substrates can take advantage of ink jets. In general, economic advantages can be anticipated if the material to be deposited is expensive, if management of waste fluid is at issue, and if variable patterns are desired particularly for short runs. Ink jet printheads offer the advantage of non-contact thus minimizing contamination. Ink jet deposition is suitable for small areas, but by analogy with wide format graphic arts printing, ink jet printheads also can be used to "paint" large substrates rapidly. Applications requiring deposition of small amounts of fluid in specific locations can take advantage of drops 10 picoliters or less in volume and drop placement accuracy that can be measured in microns. [2]

Presentations at Digital Fabrication'05 as well as numerous other conferences are a sign of the high interest in the capability of ink jet printheads to enable the printing of a variety of electronic components. [3] Many of these talks dealt with both the deposition and performance of active components such as TFTs [4], resistors and capacitors [5]. USDC has held a series of conferences focusing on opportunities for combining ink jet deposition, jettable fluids and flexible substrates as a route to low cost manufacturing of microelectronics and displays [6]. In each case, ink jet printing is seen to offer design flexibility, on demand production and rapid design testing. Ink jet printing is currently being evaluated as a means of both cost reduction and process improvement in the liquid crystal display (LCD) industry. Much of this work is not in the public domain, but there appear to be opportunities in the area of compliant and/or protective layers, alignment layers, and color filters.

For a few applications, ink jetting appears to be the only practical route. Conventional as well as digital printing methods have attracted a great deal of attention as robust and commercially attractive production techniques for polymer-based FPDs. Analog methods are relatively unattractive because of their inherent lack of flexibility and requirement for very high volume production to be cost effective. Digital technologies, and in particular ink jet, offer far more attractive solutions. Because ink jetting is an additive process, ink jets can deposit a series of solutions containing RGB light emitting polymers without requiring changes in masks, ablation of undesired material, etc. Figure 2 depicts how a manufacturing line for printing PLED displays might be configured.

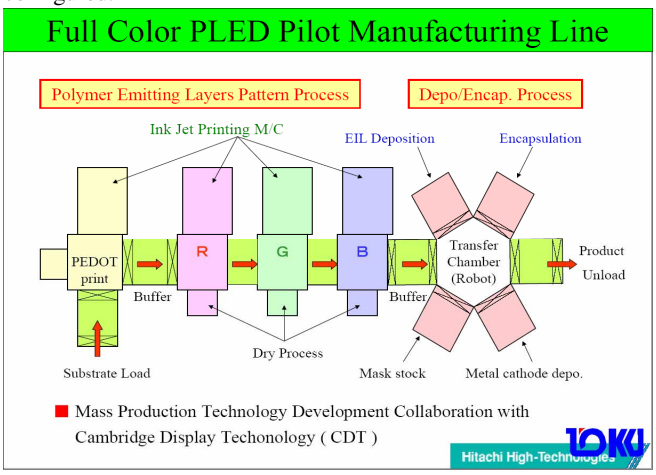

Figure 2. *Schematic of a PLED manufacturing line based on ink jets.*

Advantages for Manufacturing with Ink Jets

Piezoelectric DOD ink jet offers a promising combination of high productivity, high reliability and jetting uniformity characteristics (drop volume consistency, velocity characteristics and jet straightness) that are required for reliable manufacturing. Table 1 relates commercial requirements to ink jet characteristics.

Table 1. Relationship of Ink Jet Printhead Attributes to Application Requirements

Manufacturing Requirement	Piezo Ink Jet Attribute
Throughput, productivity	Number of usable jets Jetting frequency Reliability
Feature size	Drop volume Drop spread (mostly substrate)
Feature precision	Drop placement accuracy Drop volume control
Yield	Consistency and sustainability of performance Reliability and maintainability
Compatibility with application fluids	Robust material set

Tempting as it is to immediately determine the specifications for a specific piece of manufacturing equipment, that is not a cost or time effective approach. In particular, the printhead and the "ink" are interactive in terms of jetting performance and materials compatibility. Process development, fluid and substrate evaluation, and maintenance procedures all must be developed not only for each specific application but also for each fluid/printing system. In reality, practical manufacturing systems require the integration of precision hardware, application-specific "inks" and specially designed ink jet printheads.

Perhaps it is this complexity that is making the rate of adoption of ink jet manufacturing relatively slow. Despite large investments by major international corporations, ink jet manufacturing is only just beginning to move from R&D into prototype manufacturing.

Projections for market segment growth are very promising. Let's take flexible displays, an area in which ink jet manufacturing is expected to play a major role.

"Global market revenue for flexible display panels will reach $339 million in 2013, rising at a compound annual growth rate (CAGR) of 83.5% from $5 million in 2006, according to iSuppli. Market revenue will break the landmark $100 million level in 2011. Unit shipments will rise to 198 million in 2013, up from 364,000 in 2006." [7]

If ink jet manufacturing is to actually impact this market, then equipment should be put in place very soon. It is the purchase of manufacturing equipment that will signal the move of ink jet manufacturing from lab to the real world.

References

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[3] IMI Printing Electronics, October 2005 and IDTech's Printable Electronics, December 2005 are examples.

[4] S. M. Evans, Plastic Logic Ltd, at USDC Flexible Microelectronics and Displays Conference, February, 2003.

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[7] Jim Carone in Purchasing, June 26,, 2006.

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Author Biography

Martin Schoeppler is the VP of Corporate Strategic Business Development at Dimatix. He is a seasoned international executive with extensive electronics market experience and more than 25 years of senior management responsibilities in high technology marketing, sales and business development at Hewlett-Packard Co., Lumileds Lighting, and Agilent Technologies, Inc. He holds a BSEE degree from the University of Applied Science in Esslingen, Germany and studied Advanced Industrial Marketing at INSEAD in France.