

Evolving Digital Marking Technologies: Fight for Survival or New Battlegrounds?

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Abstract

The dominant digital printing technologies today and for the near future are based either on toner - delivered by electrophotography, magnetography or electron beam imaging - or ink jet processes using liquid or solid inks. All of these technologies have various shortcomings, both technical and cost limitations, leaving room for potential new technologies.

But can any new technology emerge and be successfully exploited now, or will we just see incremental development of existing technologies? The industry is littered with novel, innovative yet unexploited techniques that never quite made it. Has the shake-out of mainstream technologies already occurred or is there scope for new ones? Success requires that a new technology be both technically feasible and financially viable and any new technology would need significant advantages over existing ones. Can existing companies with well entrenched and successful technologies adopt new ones, or is it only newcomers and upstarts who can succeed?

This paper reviews the shortcomings of existing technologies, considers whether any new printing or marking applications exist, reviews some of the emerging yet still to be exploited technologies - such as ToneJet, TonerJet, AIP, Elcorsy, Direct Imaging, microfluidics and reusable paper, and assesses what the scope might be for these and other currently invisible contenders.

Introduction

A wide range of techniques have been developed to allow the digital printing of documents, with the most well established ones based on the use of either toners or ink jet. While these technologies have made fortunes for most of the current vendors, that was not always the case and many of the technology pioneers failed to successfully exploit these technologies. This has been particularly true with ink jet technology, where many of the entrants in the 1970's and early 1980's tried different actuator ideas and product concepts in the very early marketplace. By the end of the 1980's very few of these pioneers were still active in ink jet, and only a handful of companies were commercially exploiting the technology. But once this handful of companies had demonstrated the true potential of ink jet and in particular determined how to make money from it, the industry began to take off and new players emerged.

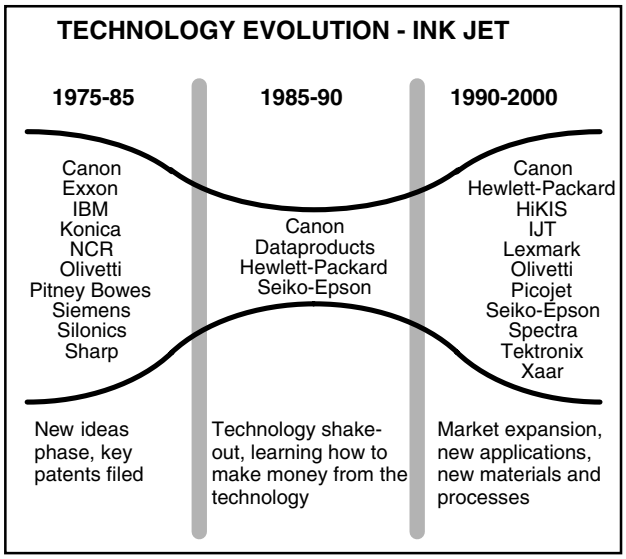

Figure 1. Technology evolution using ink jet as an example

Today most digital imaging technologies form an image by one of the five following methods:

Types of digital imaging technology in use

Imaging material format	Examples
Toner, as a powder or dispersed in an insulating liquid	Electrophotography, electron beam imaging, magnetography
Liquid ink, either with a dye in solution or pigment dispersion	Ink jet, ToneJet
Ribbon	Thermal mass transfer, diffusion and sublimation transfer
Gas or aerosol	Tonerjet, Acoustic Ink Printing (AIP), Sparkjet
Modification of coating	Direct thermal

By far the most popular methods use either toner technologies – such as electrophotography, magnetography and electron beam imaging – ink jet, or thermal transfer. The current and future limitations of these technologies are very application dependent. Note also that what constitutes a limitation depends on your viewpoint – what a user might see as a major limitation may be an advantage for a vendor, for instance the technology lock-in of consumables.

Maturing Technologies

Both of the current dominant technologies – electro-photography and ink jet have been with us for 30 or 40 years in one form or another. Naturally there have been continuous improvements to these processes, but even with desk-top ink jet technology, which many consider to be a recent phenomenon, there are signs that the technology is maturing. Fig 2 shows the number of maintenance station patents issued in the US over the last 20 years, and it can be seen that although there was a large number of new patents published in the mid-90's, the number is now starting to level out. We use as an example maintenance station patents rather than printhead patents, because the former indicates more accurately *product* development activity. We expect to see this leveling off to occur as designs and innovations are reused in products and hence the rate of patent activity slows down.

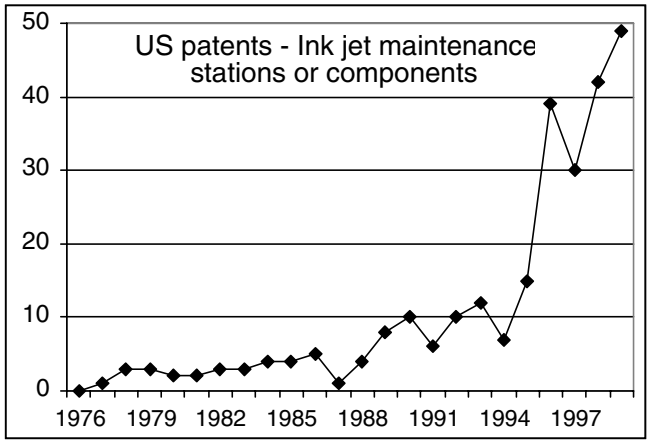

Figure 2. Rate of development of ink jet desk-top products as indicated by the publication rate of maintenance patents

Current Applications

Digital printing technology is used for a wide range of applications. These include SOHO (Small Office Home Office), consumer, corporate office, marking & coding, addressing, large format graphics, and commercial printing applications. The markets for digital printing are growing and profitable although competition is strong.

Limitations of Toner Technologies

Let us now consider how good these technologies really are for the applications they seek to serve. Firstly the toner technologies. Dry toner is an excellent way of producing high quality monochrome and color images although for color a high degree of sophistication and control is required. If we examine the boundaries of current performance, we find at the low end there are LED printers available for around $300 producing excellent monochrome image quality. The machines are reliable and compact. Color is available at much higher cost – approximately $2,000 at present, and color laser printers are bulky and use a multitude of consumables. Image quality is below offset quality at this price.

At the high-speed limits of the process we have monochrome printers running at several hundred pages per minute, now available as complete book production systems with in-line finishing. Although image quality is very good, current image resolutions of around 600 dpi limit the image quality that can be reproduced, and most customers could tell the difference between an offset printed book and a laser printed one. As we examine the economics of digital production printing we find that laser printers are cost-effective up to several hundred copies only. Compared to offset lithography the consumables cost of laser printers is higher and throughput is lower. The situation with color is similar, with digital color printers only economic for relatively short runs. As the market for these machines increases the cost of consumables is likely to fall. Offset litho inks are used across a broad range of machines with far less technology dedication to particular machines compared to toners. Even if the material and processing costs were the same for offset inks and toners, which they aren't, it is therefore unlikely that toner will ever fall to the price of ink.

To summarize, the high component costs and consumables, particularly for color printing generally limit toner technologies.

Limitations of Ink Jet Process

Ink jet has emerged into a wide range of markets during the 1990's, offering high quality color for desk-top applications, and is increasingly used for a wide range of industrial and commercial applications. At the low-end of the market we are getting close to the maximum image quality that the eye can see, and with the price of products dropping below $50 it is difficult to see much more room for improvement. Some propose the introduction of free printers, but of course 'free' in this context means you pay for the printer with the consumables. This is not to say that there is no room for improvements in current products, but most of these will come from better product design and keener pricing than new printhead technologies.

At higher speeds more suitable for mainstream office use, ink jet technology is currently limited by the ink technology. Liquid ink design is still a compromise between high image quality and fast dry times. It is not just the overall dry time that is limited, but the rate at which colors

can be laid down on top of each other or adjacently without a deterioration in image quality.

At the very high-speed end of the ink jet market products are few and far between. Binary continuous ink jet is used for high-speed web printing, and although the operating costs are very low, the product cost is high and the image quality is lower than conventional printing. Page-wide arrays of drop on demand ink jet actuators are proposed to print at high speed with a higher image quality and at a lower product cost. These certainly have the potential of printing at hundreds of pages per minute but will require considerable improvements in printhead manufacturing accuracy and ink developments to succeed.

To summarize, ink jet ink technology and the ability to make reliable page-wide arrays presently limit ink jet technology.

Emerging Applications

Up to now most of the applications for digital printing technologies could be summarized as printing information in some form. But we are currently seeing new applications emerging that involve the decoration of materials – printing textiles, wall and floorcoverings, ceramics, laminates, packaging and so on. Elecrophotography and ink jet is being adapted for these applications and there is a considerable market potential. In most cases the biggest differences between these emerging applications and current applications is a much higher duty cycle, higher consumption of imaging materials and a much wider range of substrates. To extend electrophotography to some of the wider formats required by these emerging applications will be a challenge. With the development of a wider range of ink jet inks, ink jet technology will probably penetrate these new markets much faster and to a greater degree. But ink jet is limited by the same problems as mentioned before. The properties of inks that can be used is limited, although for industrial applications a wider range of solvents can be compared to office markets, and technologies such as UV-curable inks employed.

Emerging Technologies

So, are there any emerging digital printing technologies that could outstrip the performance of current technologies – in particular toner technologies or ink jet for either current or emerging applications? There are many emerging technologies, and here we have focussed on the better known ones that have been under development for a number of years and therefore might be close to market.

ToneJet[1]

Liquid toner is ejected using highly asymmetric fields from an array of stylii at the front of a printhead. In principle this could offer the image quality seen with liquid toner electrophotography, but in a simple single stage imaging process using low-cost printheads. From the patent literature we can see it has been under development for over 8 years by a number of companies, but there are no known products yet.

Tonerjet[2]

An array of electrically-gated orifices either block or accelerate charged powder toner to directly form an image on a substrate, which is subsequently fused. The process eliminates many of the consumables of electrophotography, which makes it particularly attractive as an alternative to the colour laser printer.

AIP[3]

This process uses RF focussed acoustic waves to generate a fine mist of droplets from the surface of a liquid, in a similar fashion to a nebuliser. A page-wide array of emitters should be lower cost than an equivalent electrophotographic process, and capable of very high resolution imaging. Xerox PARC has been developing this technology for nearly a decade, and there are patents from some other vendors too.

Electrocoagulation[4,5]

An array of addressable electrodes cause a large increase in ink viscosity under an applied field. Unimaged ink is removed with a doctor blade prior to a contact transfer of the image to a paper substrate. The process uses modified offset ink and is capable of high imaging speeds.

Direct Imaging[6]

The use of a photoreceptor and imaging system for a toner process is eliminated by making a directly imageable drum with an array of addressable ring electrodes. In conjunction with low-cost simple toners the process promises lower operating costs than established toner technologies.

Microfluidics[7]

There are proposals to directly move liquids in fine channels using electric fields in microscopic scale silicon devices. By moving the liquid to the surface of a chip, the ink can transfer when the substrate is brought into contact.

Reusable Paper[8,9]

Several technologies are under development that allow reversible imaging, that is an image can be formed on a substrate but can then be erased and a new image written. Techniques to achieve this use reversible thermal chemistry, and physical techniques to either reflect, refract or absorb light.

Scope for New Technologies

So, what are the success factors required of a new technology? We could summarize the issues very simply as – better image quality, lower costs and higher speeds. The imaging quality of existing digital technology is already very high, in some cases exceeding offset lithography or silver halide imaging. Even if a new process offers a large

reduction in costs or higher speeds, it is debatable whether users will be interested if image quality is sacrificed. In fact up to now users have shown a strong preference for a compromise of print speed over image quality.

Apart from the reusable paper concepts, all of the emerging technologies reviewed above focus solely on the *delivery* technology of imaging material, and use existing or modified inks or toners. However, we feel it is the materials themselves that require the innovations and breakthroughs if higher speeds and lower costs are to be achieved.

To implement an emerging technology, enough funds must be found to develop and manufacture products. With a new process this carries considerable risk and funding is required for a number of years. Most new processes take roughly 10 years of development from concept to revenues, requiring a very long-term view to be taken either by established vendors or venture-funded start-ups. Some large vendors are happy to take such a long-term view, considering the new technology will form the core of their business in the future. Others seem so well entrenched with their existing processes that making a transition to a new technology base is unlikely.

Conclusions

A fight for survival for existing digital printing technologies? Toner technologies and ink jet are limited by the processes themselves, but also by the materials used. We have reviewed some of the emerging digital imaging technologies but generally they are not addressing any of the material issues. Therefore do these emerging technologies threaten existing technologies? While most of the new technologies reviewed have advantages in one part of the market or another, we don't see any of them having a broad impact on the market at this present time.

New battlegrounds? There certainly are emerging new markets for digital printing, in particular the decorative printing of a wide range of substrates. Of the current technologies ink jet promises the most, providing productivity can be increased. None of the emerging technologies reviewed has anything more to offer the decorative markets over ink jet.

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Biography

Mike Willis is Managing Director and founder of Pivotal Resources, a Cambridge UK-based technical and marketing consultancy. Mike is also editor and publisher of *Directions*, a bi-monthly report that monitors ink jet patents to glean commercial intelligence, a service subscribed to by most of the major players.

Mike has over twenty years experience of conventional and electronic printing, imaging technology and markets, and works for major, minor and prospective players from Europe, North America and Asia. Projects have included the development of major new ink jet technology, high-speed page printers, office and industrial products, due diligence, competitive analysis and positioning, strategic and project planning, technology sourcing and the identification of new opportunities.

Prior to Pivotal Resources, Mike had worked in a number of roles with consultancies and manufacturers including Arthur D Little, Cambridge Consultants, the Generics Group, Gestetner and Xaar. Mike graduated from the Polytechnic of Central London with a degree in Photographic Sciences.