Printable Electronics Market Outlook: An Applications-Based Assessment

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Chapter One: Introduction

1.1 Background to this Report

It has been several years, since printable electronics broke away from thick-film screen printing and began to address new applications. Although there are many such applications, what all these new applications have in common is that they involve relatively sophisticated and complex electronics, typically distributed over a large area and—potentially at least—a flexible substrate. While the old thick-film paradigm was something very close to coating, what the current printable electronics offers is more like what the semiconductor industry expects from its manufacturing processes: thin-film deposition and finely-tuned patterning. (Although at a scale that is several orders of magnitude greater than what the conventional semiconductor industry can now expect.)

The migration from thick-film electronics to thin-film printable electronics has been made possible by major new developments at both the materials level and at the manufacturing level. At the materials level, we are now seeing commercialized active inks whose functionality has been improved by basing them on nanoparticles and stable inks have been made out of organic materials for the first time. The search goes on, of course, for better materials, with a wide range of areas being considered: ITO inks, silicon inks, dielectric inks, etc. At the level of manufacturing, ink-jet has shown itself to have impressive characteristics for creating functional devices and arrays and higher throughput systems—gravure and especially flexo—are being prepared with volume manufacture of printable electronics in mind. However, there are still plenty of open questions about how well printing is suited to high-volume thin-film electronics; some very prominent so-called "printable electronics" firms actually tend to use non-printing techniques quite extensively when they move to volume production.

These issues are analyzed fully in other NanoMarkets reports. In this report, we examine the evolution of the printable electronics industry from the applications perspective. Just as the conventional semiconductor industry addresses an extremely broad range of applications that mostly share only manufacturing techniques and raw materials—embedded processors for appliances, high-definition DVD players, and PCs, for example—so printable electronics appears to address markets that are fairly disparate. Areas to which printable electronics have been targeted include televisions, cell phone displays, signage, lighting, sensors, batteries, photovoltaics, smartcards, RFID, etc. These areas are at least as broad as those with which the conventional semiconductor industry is involved.

But as printable electronics moves out of the world of R&D and into the world of commercial products, business development managers, marketing executives, product planners and investors, must make important decisions about which applications to focus on. While (say) printed cell-phone displays and printed sensors may have a lot in common at the level of materials and manufacturing, they are part of different value chains with completely different sets of marketing characteristics, customer bases, etc. It therefore becomes imperative for managers in this field to understand which applications promise high value added, strong growth and sizeable addressable markets. (All three characteristics are not always found in the same applications.)

It is the main objective of this report to provide such understanding, by examining all the major applications areas to which printable electronics apply and analyzing their business potential. Our analysis in this report is based on NanoMarkets' ongoing primary and secondary research in this rapidly growing area. NanoMarkets has been analyzing and forecasting the PE sector since the sector's birth. We firmly believe that within the next couple of years PE will become an industry addressing huge applications markets with sophisticated products, much as the semiconductor industry does now. However, we have also concluded that the opportunities in this sector will vary considerably from application to application.

1.1.1 Displays, Signage and Printable Electronics

In one way or another, displays dominate the potential new business revenues from printed electronics. Indeed, newcomers to the field might be forgiven for thinking that printed electronics was a sort of side show to the display industry. It is certainly more than this, but the focus of much of the printable electronics business is certainly on display-related applications (including signage).

Color filters for LCD displays are already routinely printed, but this is a tactical issue. Printable electronics also seems to present some key strategic options for the display industry both from a manufacturing and from a new product perspective. This is important, because the display industry is bumping its head up against major limitations in both areas. In manufacturing, the current paradigm based on batch processing of LCD displays on glass substrates is running out of steam, because there are obvious limits to how large the sheet of glass being processed can be. In the market area, the display industry has seen good years as old CRTs were abandoned in favor of LCD FPDs, especially in the computer monitor sector but also for TVs.

The display industry can expect to get a bump from the switch to HDTV as consumers swap out their analog TVs for digital ones. In the U.S. analog broadcasting will be gone completely by early 2009. But the display industry is looking for a new generation of displays, where the difference between the old and the new is as different as LCD is from CRT.

Printable electronics seems as if it can offer a solution to both these strategic concerns of the display industry. Where roll-to-roll printable electronics can be applied to display making it seems to promise improved economics. This type of manufacturing would require flexible substrates, but this in turn would enable entirely new kinds of display; flexible and rollable ones. Perhaps these new flexible and rollable displays are what the display industry is looking for. They would allow mobile computers and (especially) cell phones to operate with much larger displays than at present. When these displays are not in use, they can simply be rolled up and stored in purse or pocket. Printing has been brought to bear principally on two kinds of display, OLEDs and e-paper.

OLED displays: OLED displays are now routinely manufactured by deposition processes for mostly low-key applications; primarily sub-displays for cell phones and the small displays used in MP3 players. The hope of the OLED industry is always that it would be able to break away from such low-end products to provide main displays for cell phones and to televisions. OLEDs offer bright, vibrant colors that are what the worlds of mobile video and HDTV would seem to require and there are some signs that the OLED display industry is taking off. OLED main displays are no longer a complete rarity and ultra-thin OLED TVs made their debut at this year's Las Vegas Consumer Electronics show to enormous fanfares. However, the volume of OLED displays of all kinds currently being shipped is still very low compared with alternative displays technologies and shipments actually fell in the second half of 2007 as OLED firms in Asia retooled for the next-generation of AM OLED displays.

OLED displays are also quite expensive and the hope is that by applying printing technology to OLEDs the price can be brought down significantly. However, there are still significant technical challenges in making printable OLEDs that have the high performance of their vapor deposition created cousins.

E-paper and flexible backplanes: By contrast, e-paper is now routinely printed. The "mind-share" leader in the e-paper space, E-Ink, in particular has developed an electrophoretic ink from which e-paper front planes are printed in large numbers. Other kinds of e-paper technology also utilize printing to some degree.

The "poster boy" application for e-paper at the present time is e-book readers. However, with the single-purpose handheld device going into decline, it seems unlikely that this kind of device has much of a future in its present form. It is much more likely that the book reader will be reinvented as a specialized roll-up display for cell phones and laptops; this is the direction that the current development work of both Plastic Logic and Polymer Vision seem to be pushing the technology.

Such roll-up displays, however, would require a flexible backplane, something that has only begun to be commercialized. The current generation of book readers uses a flexible frontplane with a backplane on a rigid glass substrate. Flexible backplanes are being commercialized fast, but currently use OTFTs that lack the performance that could take them beyond the e-paper niche and enable the support of AM LCD or OLED displays. The hope is that these flexible backplanes will have much higher performance given time. However, what role printing will have in the future of flexible backplanes is, as yet, unclear. As some backplane firms have ramped up to full-scale production, they seem to be making far less use of printing technology than one might have expected a few years back.

But returning to the topic of e-paper itself, e-book readers are certainly not the only applications in which e-paper would be useful and standalone book readers will probably not be the largest application for e-paper in the long run. The ability to read e-paper in bright sunlight and e-paper's low power consumption, makes e-paper an excellent choice for certain kinds of signage, especially point-of-purchase signs. And electrochromic displays—which NanoMarkets has taken to fall under the e-paper heading—are being planned for use in smartcards.

1.1.2 Printable Electronics as "Greentech"

While printable electronics may or may not be the answer to the display industry's strategic problems, it does seem to have two applications that overlap with what has been called "greentech." These applications are OLED lighting and thin-film photovoltaics. As such, some firms in the printable electronics space are likely to be subject to the huge investor interest that now permeates the whole alternative energy/energy saving sector.

Lighting: Printable lighting has a long history. Electroluminescent (EL) lighting has been used in backlighting and the automobile industry for many years. EL lighting has also gone through a technological evolution in the recent past from a thick-film to a thin-film technology, which will give it some staying power. But the brightness of EL technology makes it a poor substitute for other competitive technologies in most applications. E-paper may also be thought of as a reflective backlighting technology, but it is not really treated as a lighting technology in the literature.

Printed lighting generally refers to OLED lighting and all of the strictures about the use of printed OLEDs discussed above apply. However, OLED lighting has some very attractive features as a business and NanoMarkets believes that it may now outpace OLED displays in size and growth. It certainly has its challenges but at the same time avoids all the complexities associated with active matrix displays. It also faces less competition; HB-LEDs and OLEDs compete for lighting applications, but HB-LEDs are more like spotlights and OLEDs are more like floodlights. Finally, there are several government-funded programs in the U.S., Europe and Japan that support next-generation solid-state lighting of which OLED lighting would be a part.

Photovoltaics: Thin-film photovoltaics (TFPV) is a well-established industry and offers a number of advantages over conventional PV, which uses crystalline PV. These advantages include including lower cost and lighter weight (making it easier to create viable rooftop panels.) However, most TFPV is created using deposition techniques, although a few firms have begun to examine the possibility of printing PV for a number of different applications using other materials.

As with many of the applications discussed above, the role of printing is not entirely clear in the future of TFPV. One firm, Nanosolar, has extensively promoted printing for its CIGS-based TFPV and has built a plant that apparently makes use of printing for an important part of the fabrication process. Printing would also seem to have a big role to play in organic photovoltaics (OPV), which uses materials very similar to those used in OTFT backplanes and OLED displays. Printing is therefore a natural for use with OPV. However, current manifestations of OPV have low energy conversion efficiencies and also have challenges when it comes to environmental stability. For these reasons, the timetable for use of OPV in real world applications is far from clear.

1.1.3 Printable Electronics and the Next IT Wave

As if providing partial solutions to the display industry's problems and the energy crisis were not enough, printable electronics seems to be a potential enabling technology for the next wave of IT. This concept goes by many names, but involves the idea of ubiquitous embedded processors and sensors and the idea that through the medium of these devices intelligence can be extended to a wide variety of objects and appliances.

A key, not so hidden, assumption of all this is that low-cost processing and memory must be widely available. Printed electronics can contribute in this area through a number of applications of which, by far, the most important is RFID. Smartcards are another related product that actually use similar technology to RFID at the present time, although the focus of the printed electronics in the smartcard area is supplying them with small electrochromic displays to provide one-time passwords. Printed sensors are also important to the future of "ubiquitous computing," but printed sensors have a role that extends beyond and into biomedicine. Finally, printed batteries may have a role as power sources for many such devices, but their economics remain in question.

RFID: RFID is already being used in numerous different applications and RFID tags have been touted as the way forward to much greater efficiencies in inventory management. For this to happen, however, RFID tag prices must drop to a point where they can be widely deployed at the item level in the manner of the universal barcode

Printing is said to be a way to achieve this goal. Printing is already used routinely to produce antennas for RFID, but the production of complete RFID tags using printing is only just beginning; it is most notably being pioneered by PolyIC, although other firms (e.g. Motorola) are involved. The printed RFID tags that appeared in 2007, however, have limited functionality when compared to the average commercial tag, which is fabricated using conventional semiconductor technology. It is likely to be a few more years before printed tags can match the performance of these more conventional tags.

Sensors: Printing electrodes for sensors of various kinds is now widespread as is the printing of various type of DNA testing devices. However, most of the firms involved with such applications do not really think of themselves as being in the printed electronics industry. The idea of the printed sensor as part of printed electronics has largely been spearheaded by one firm, NANOIDENT. Its initial products are optical biosensors. In terms of commercial development, another firm with a high degree of visibility is Cypak, which has created a number of sensor-enabled printable electronic products in commercial use today in the smart packaging area.

Perhaps the most interesting of the opportunities in the sensor area is the obvious advantages that printing technology would have in the creation of sensor arrays. These would provide a high degree of redundancy for sensing devices. However, finding inks that have the sensitivity and discrimination needed for sensing particular substances or conditions is not an easy task—they are seldom commercially available and may be hard to formulate.

Batteries: Printed batteries are beginning to appear and could be used to drive many of the other printed devices mentioned above. They are potentially very thin and flexible and (again potentially) could be printed in line with other electronics devices created with printing. However, at present printed batteries cost more than many completely conventional button batteries, so their application is largely restricted to applications where their flexibility really matters. For the most part these are niche applications, such as medical patches. One area where printed—or at least thin-film—batteries would seem to have a good future is in the next generation of smartcards, which will have onboard batteries. (Most smartcards today use either induction—just as RFID tags do—or contact with a reader to derive their power.)

1.2 Objectives and Scope of this Report

Based on the above, it is clear that printed electronics will have a profound impact on many different applications and that it has important tie in with key megatrends such as quest for alternative energy sources and the next wave of information technology. In this report we analyze and quantify all of the major applications areas to which printed electronics applies. These are the ones that we have already reviewed in this chapter: OLED displays, e-paper, signage, display backplanes, lighting, RFID, smart cards and tickets, photovoltaics, batteries and sensors. These are not the only applications in which printable electronics can be deployed, but they will account for the overwhelming majority of the revenues generated by printed electronics in the next decade. In this report we have not examined applications for the older form of printed electronics; the so-called "thick film electronics."

There is already a fairly complex value chain in place in the printable electronics market. At the bottom of this chain are the equipment and materials companies. There are also firms whose principle objective is to develop the printable equivalent of processors and memories. Above that level are firms whose goal is to develop the applications and products listed above. And finally there are the end-user segments in which these applications/products are (or will be) used. In this report we are principally concerned with the top two levels in this chain. However, we also note that at this early stage of development of the printable electronics industry there is a lot of overlap between the levels either in terms of the product/marketing strategies of individual firms or through the many partnership arrangements that have emerged in the printable electronics business in the past three years.

While the main objective of this report is to indicate where the opportunities are in the various applications areas to which printable electronics has been applied, we have also drawn on Nanomarkets' experience with materials and manufacturing in order to analyze where printable electronics can and cannot meet the needs of particular applications sectors. In addition, where the brief history of printable electronics has shown up strategic failures, we discuss why these have occurred.

Another major goal of this report is to provide detailed forecasts of these segments. Last but not least, we have, where appropriate, presented an account of the roles and strategies of important firms and other organization active in the market and their apparent successes and failures. It is far too early in the evolution of the printable electronics market to begin to talk about "market shares." However, where a firm has some kind of current dominance in a market covered, we have identified it as such.

This report is entirely international in scope. The forecasts are worldwide forecasts and we have not been geographically selective in the firms that we have covered in the report or interviewed in order to collect information. This is not to say that the printable electronics is particularly homogenous in terms of its geography. In Europe, Germany has been a focus of both the chemical industry and the printing/printing equipment industry, which gives this country a special place in the discussion. In the U.K., important work on organic electronics has been done at Cambridge University that has led to some of the most important firms in this discipline being established in this area. The fact that some of the biggest applications for printable electronics relates to displays has given the Asian consumer electronics sector a special role in this market. Finally, the preeminence of U.S. financial sources—both venture capitalists and government sources—has also helped to shape the market.

1.3 Methodology of this Report

Our assessment of the various applications for printable electronics is based on the ongoing research program conducted by NanoMarkets in this space. NanoMarkets has published specialized reports on almost all of the applications areas covered in this report and this report draws heavily on this research, although our analysis has been revised and information brought up to date where necessary.

The primary research on which this report is based came from NanoMarkets' ongoing interview program in which we conduct regular interviews with key executives throughout the entire printable electronics value chain—including manufacturers of equipment and materials and of devices and subsystems themselves. The secondary research drew on the World Wide Web, commercial databases, trade press articles, SEC filings and other corporate literature to fill out what is going on in this sector. NanoMarkets' researchers have also been frequent attendees and speakers at important trade shows and conferences.

1.4 Plan of this Report

Chapter Two looks at printed displays and signage, Chapter Three considers printed lighting. Chapter Four is on printed sensors, Chapter Five covers RFIDs, Chapter Six reviews photovoltaics, Chapter Seven printed batteries and the final chapter presents an eight-year forecast of the entire printed electronics sector.