

The printed electronics value proposition

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Imagine you are a manufacturer. Your customer emails you a circuit component design with a certain desired attribute and wants you to produce it for them. And, by the way, they need the first shipment of 100,000 components out your doors tomorrow.

Simple. You print out the prototypes on your desktop printer, test them, send the data to your customer to confirm compatibility with the customer's system, receive acceptance, and alter your manufacturing line to produce these items by the afternoon shift, rolling them off by the hundreds of thousands per hour.

You have redefined JIT manufacturing and solidified your position as an ultra-responsive supplier to your customer base. Now imagine being able to do that for a myriad of different components, from RFID to printed circuit boards.

This may be a little far-fetched right now, but printed electronics will bring this to you soon enough. Just as transistors have brought advantages in the most unlikely places over the last half-century, printed electronics will cause a radical shift in how we handle everything from applications like supply chain tracking to less-obvious areas, such as the ability to print replacement components for home electronics devices.

Never fear, there is still plenty of time before we all print our TV remote controls on our desktop printers, yet even now the uses for printed electronics are expanding. In order to leverage these burgeoning opportunities, we need to understand the convergence of two different technologies and the advantages their union presents.

To see where the greatest potential for these two converging technologies – the graphics printing industry and the electronic materials industry – lies (and to avoid the hyperbole that can seep into discussions like this), we need to segment the electronics market. One

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straightforward segmentation is to divide the electronics industry into two areas:

- Lower-cost (even disposable) electronic components;
- Higher-cost, higher-performance components.

Within these two major subsegments, there are several key drivers affecting how graphics printing technology is pushing into the mainstream of electronics manufacturing. These include:

- Decreased costs (additive manufacturing, low-cost substrates, greater focus on cost reduction);
- Finer resolutions (component shrinkage, lower material usage);
- Expanded manufacturing capabilities (roll-to-roll processing for printing methods like gravure and others, digital manufacturing for inkjet printing, repair capabilities).

These drivers are pushing the technology leaders in electronics and electronics materials to develop new commercially viable solutions.

The market for printed electronics

In the next few years, the need to lower costs will be the primary factor fuelling the expansion of printed electronics applications. Printed electronics are already beginning to meet some cost targets without a major sacrifice in performance or capabilities. For example, printed electronics are making an impact in Radio Frequency Identification (RFID), driven by well-known initiatives like Wal-Mart's

mandate to its top 100 (and increasing) supplier base to have RFID capability. This is just the tip of the iceberg. As the tag costs are driven down, the applications expand to item-level tracking. Everything from record storage to store shelving to food and medicine tracking to fast-moving consumer goods (FMCG) are in play. This is a sleeping giant of an opportunity. In and of itself, this is large enough to drive component manufacturing toward printing (imagine, for example, the tagging of the approximately three trillion consumer goods manufactured worldwide).

Another market area that will be positively affected by printing electronics is electronic displays. Printing components for displays (e.g. LCDs and OLED conductive electrodes) and the potential to use flexible, lower-cost substrates, for example, creates a whole new set of affordable opportunities for display applications. Inkjet printed displays are already being shown (e.g. Epson's 42in prototype OLED display), as are electrodes and other components manufactured via inkjet, screen printing, and other printing processes. There are, of course, many other areas where printed electronics can play a role, but displays and RFID are two of the major areas that are positively affected by the ability to print their components and the devices themselves.

Why can printed electronics lower costs?

It is clear that lower cost is a prime driver for the mainstream adoption of electronics printing (e.g. the move



towards the 5¢ RFID tag). The important drivers mentioned earlier are the fact that printing:

- Is an additive manufacturing method;
- Can enable the use of lower cost, flexible substrates;
- Can reduce overall system costs.

It is important to keep the last point in mind throughout the discussion because, while certain components of a printing system (e.g. materials) may command a much higher price, the potential overall system cost reductions establish the value proposition.

Additive manufacturing simply means that the printed material laid down is the material that stays on the substrate and makes up the electronic component. There is no need to remove materials using harsh chemicals via complex, multi-step processes that create environmentally hazardous waste streams. All of these are replaced by a relatively simple one- or two-step process by which the electronic material is laid down and then post-treated, if necessary.

As the technology continues to improve, more of the incumbent manufacturing will have to evolve to compete with the printed electronics value proposition

Lower-cost substrates are one of the most tangible benefits of printed electronics. Moving away from the very durable, expensive substrates used in etching to lower cost, less durable substrates that are ‘good enough’ for high volume (even disposable) production is a key enabler of system cost reductions. The added benefit of flexible substrates with operational electronics opens up new doors in areas such as packaging and displays, where flexibility can be very desirable.

These come together to help lower overall system costs. Reducing waste streams and the amount/number of chemicals necessary for manufacture, along with the added cost savings of reducing variable manufacturing costs, creates the potential to realise significant savings up and down the supply chain, even before material reduction comes into play.

Finer resolutions

There are two main areas where resolution makes a difference. The first is in the shrinking of components. Resolution

is currently more of a factor in areas such as displays and, more generally, in areas where components are getting smaller and smaller. In some cases, processes like etching have advantages over printing technologies in the resolution capabilities, but these advantages are erased by technology and materials that can enable extremely fine line resolution (e.g. nanomaterials). Add to this the ability to use less material while still obtaining the desired functionality, and further cost reductions are possible. A simple maths calculation demonstrates this fact. If a line width is reduced from 60 microns to 20 microns, and line height is reduced from 40 microns to 20 microns, that represents a 6X reduction in material usage and a key cost saving opportunity (even if the actual material itself is more expensive).

Manufacturing capabilities

With the lower-cost focus of printed electronics goes the necessity for high-volume manufacturing capabilities to meet forecasted demand. Roll-to-roll

manufacturing of components is made possible through printed electronics, increasing the ability to reduce per unit manufacture cost and further drive system cost savings. It is important to keep in mind that this high-volume throughput requires not only the volume capabilities of the printing press; it also requires that same high-volume capability in the control systems, the material inputted and input systems, and the post-processing systems. Innovative solutions continue to be developed to make sure that the expansion of printed electronics is a truly viable option all along the value chain.

The last major added feature that printed electronics brings, particularly with inkjet, is performing commercial scale custom processes, such as repairing product defects as part of the manufacturing process. With the appropriate QC systems, the digital operation of an inkjet system can make pinpoint repairs on the fly, further reducing system (in this case, QC) costs.

This inkjet capability, or more generally the ability to digitally manufacture

circuits, can also be one of the key drivers of the cannibalisation of higher-end markets in the future, because of the increased functionality that comes with the digital manufacture. As multi-system heads are brought online and throughput is increased, necessary system changeovers can be justified.

Adoption

Some sections of the electronics market will not be affected as rapidly. Certain market segments may not be as well-suited for printed electronics, either because the complexity of their circuitry is such that printing is presently more difficult than methods such as etching, or because market demand is great enough to absorb the extra cost of current production methods (e.g. higher-end chips), or because the cost of conversion to a printed system can't be justified (yet!). This is the case for some higher-cost, higher-performance items.

These, however, are short-term roadblocks. As electronic printing and materials technology becomes more sophisticated and efficient, the higher-end areas (e.g. complete printing of transistors) will also be converted to a printed/additive manufacturing method on a commercial scale.

There are many facets to the market opportunity for printed electronics. The concentration here has been on the main value drivers for the conversion and adoption of electronics printing. Taking this further requires, at a minimum:

- Analysis and matching of specific printing systems to components where they may have a particular advantage;
- Continuing to solve the technical challenges that currently confront the printing of electronics;
- Addressing issues such as alternative technologies and potential competitive technology response, to name just a few.

Nonetheless, printed electronics is already carving out a growing sector in the lower-cost, high-volume applications. As the technology continues to improve, more and more of the incumbent manufacturing will have to evolve to compete with the printed electronics value proposition, or fall by the wayside. In the not too distant future, printed electronics will also take over areas where functionality trumps cost by providing a similar or better-performing solution at a significant cost savings, compared to alternative production methods. As this happens, the hyperbole that people hear now, analogous to that which might have been heard 50 years ago regarding transistors, may turn out to be not far-fetched after all. ■