Perspectives on Plastic Electronics Markets and Applications

J. Norman Bardsley
DisplaySearch, Danville, CA 94526, USA

Abstract
In this paper, we discuss the potential applications for electronic systems on flexible substrates. The barriers to the successful development of commercial markets are analyzed. For each promising application, the critical technical features are identified. Ways to bridge the gap between research and commercialization are suggested.

1. Introduction
The successful development of a plastic electronics industry depends on more than the solution of a set of difficult technical challenges. The identification, establishment and capture of suitable markets are just as hard, despite all the magazine articles that have been written about the bright future of flexible electronic systems.

Microelectronic systems can be used to support many functions. Some of the more important are:

- Displays, to present information visually
- Speakers, to give information through sound
- Sensors, to gather information
- Antennas, to receive information
- Memory, to store information
- Processors, to manipulate information
- Batteries, to store energy
- Photovoltaics, to capture and convert energy
- Light sources

In almost all successful products, several functions need to be combined to make up a system that meets a well-defined need and provides value to a potential customer. Our task is to find applications in which these functions can be built into flexible packages and thereby offer substantial benefits to the user, with respect to performance, reliability or ease of use.

To date, we are aware of no devices for which the performance in flexible systems exceeds that available in similar devices on rigid substrates. Reliability can be enhanced. For example, displays on unshielded glass break easily if they are dropped. However, in most cases, it has proved to be easier to place a glass-based display in a protective casing than to build a display on a flexible substrate. For purchasers of cell phones and MP3 players, ruggedness is no longer a primary factor in model selection.

Because of the complexity of the whole product cycle, involving R&D, product design, strategic and point-of-sale marketing, support, service, management, and company shareholders who expect profit, the cost of manufacturing a product often comprises only a small fraction of the selling price. So it is usually more difficult to design a new product to meet price points than is anticipated by scientists and engineers. This partially explains the huge variation in predictions for the size of the flexible display market around 2010, from $18M (US) to $10B.

In this talk, we will review some of the most promising applications, working upwards in size and cost

2. Promising Applications: Small Size
2.1 RFID Tags
Radio Frequency Identification (RFID) tags represent one of the largest markets for flexible electronics (measured in terms of units) and perhaps one of the most predictable. The value of the total market, including systems and services is forecast to rise from $2.3B in 2005 to $27B in 2015. Individual customers could account for more than 20% of this total. For example, the national ID project in China could cost $6B.

One of the major events of 2005 in the RFID industry is the installation and testing of the distribution tracking system at Walmart. 600 retail stores and 12 distribution centers are being equipped with readers and reporting systems, and 300 suppliers are cooperating in tagging shipments. The biggest problem has been reading RFID tags on individual cases on fully loaded pallets, with read rates averaging 66%. Wal-Mart suppliers are working out the best position of the tag on the case for maximum readability, which varies according to the contents of the case.

Deliveries of UHF tags in the spring of 2005 were estimated by IDTechEx to be around 13M per month, at an average cost of ~$0.20 (20c). The annual production for 2005 is forecast to be 300-400M. So tag manufacturing represents a very small fraction of the total business.

The manufacturing of RFID tags can be accomplished completely on flexible substrates by roll-to-roll manufacturing. The process flow used by Alien Technologies, a company which set out originally to make flexible displays, will be outlined in the talk. However, plastic is used almost exclusively as a substrate. The functional materials are currently composed of inorganic materials, such as silicon and metals.

The success of RFID tags will depend almost entirely on cost and the reliability of the signaling and reading systems. The target price to drive the next major expansion phase for intelligent tags is almost always quoted as 5c. Costs less than 1c will allow almost all individual items to be tracked. However, if very high levels of reliability could be assured, there will always be niche markets for higher-cost systems.

2.2 Smart Cards

Most of us carry many plastic cards in our wallets and leave far more at home. These cards achieve very little except to store a few bits of information and transmit this information in a prescribed manner for particular transactions. Smart cards that could either store and display more information, could simultaneously act on behalf of several institutions, or could offer greater security for the holder and sponsor could add substantial extra value. Such cards need to add a simple display to the memory, intelligence, power and communications capability of an RFID tag.

Despite broad interest in prototypes, smart cards have not yet appeared on the market. One problem is clearly cost. Capture of large markets is needed to get the fabrication cost of such devices to an acceptable level, which is probably around $1. This cannot happen unless a company is prepared to absorb considerable losses during the learning period, or can develop the manufacturing processes and improve yield on higher value products.

A similar situation pertains in respect to the ancillary equipment and information network that is required to update the data that will be shown on the cards. The incentive to develop this infrastructure is weak until there is an obvious demand for the product and large volume manufacturing capability.

2.3 Smart Labels

Smart labels can add value in several ways. They can monitor the environment, for example if equipped with a temperature or moisture sensor, and can warn against degradation of the product being labeled. They can be updated or reused, as in shelf labels in retail stores, by wireless from a remote location. However, a shelf label that can be used for one product after another will rarely compete in cost with fixed signs that are thrown away as they are replaced. The value must come through the additional functionality or, for example, through enabling the operation of a more efficient system for stock control in a retail operation. Examples will be shown in the talk, involving both medical and retail applications.

2.3 Hand-Held Devices

Many have hoped that flexible electronics systems could capture a significant fraction of the market for hand-held devices, such a cell phones and MP3 players. However, the technical capabilities of the microelectronics in these gadgets have increased so rapidly that the main functions cannot be supported by polymer electronics, or even by silicon on a plastic substrate. So, although companies like Nokia and Apple are always ready to consider new technologies, they have not yet been motivated to adopt plastic electronics. One notable exception is the universal remote control from the U. K. company, Pelikon. A single layer of plastic is used to act as a display and a keypad in a very user-friendly fashion.

2.4 Wrist-Worn Devices

One of the disadvantages of hand-held devices is that they occupy the hand. If the same functionality could be provided in a flexible package that can be wrapped around the wrist, or perhaps hidden behind the lapel of a jacket, the device could be less intrusive.

One approach to this end is to add functionality to watches. This is being pursued by leading Japanese companies. Another is to design fashion accessories that are functional as well as decorative.

3. Medium-Size Applications

3.1 Displays in Vehicles

The minimal amount of useful flexibility is conformability to curved surfaces. Perhaps the largest market opportunity is for displays on the dashboards of automobiles and small boats, or on the

backs of seats in cars, aircraft and trains. Such displays are eagerly awaited by manufacturers of high end vehicles and could spread rapidly to high-volume products. Environmental requirements are more demanding for such applications, but should not rule out the use of plastic substrates.

3.2 Informational Signs

Signs displaying alphanumeric information and simple graphics, such as icons, are prime candidates for "electronic paper technologies". Again close collaboration is required between display makers and system developers to make sure that up-to-date information can be displayed. Projects involving Gyricon SmartPaper™ Technology will be used to illustrate these opportunities.

3.3 Toys and Games

No one can doubt the success of microelectronics manufacturers in selling video games. However, these have almost always used rigid devices and have not led to opportunities for flexible electronics. The U.S. company, T-Ink, has shown that printed electronics opens up opportunities to transform traditional board games to electronic form. Unfortunately, although the price premium for such products can be $15-25, the cost of the printed electronics needs to be kept well under $5. So far, T-Ink has primarily used speakers, rather than displays, to support interaction between the players and the intelligent game board.

Clearly, flexible substrates would be very helpful in allowing displays to be added to soft toys.

3.4 Electronic Books

Electronic books are another promising market for "e-paper" displays. However, the first implementations have been fabricated on glass substrates. Most exploratory e-book systems appear to have failed to meet the expectations of their proponents, but the cause of the disappointing sales is probably due to business and content availability issues, rather than the physical rigidity of the device. These issues must be solved before electronic books on plastic substrates can be commercially successful.

A promising route to establishment of successful models for e-books would be to focus on the educational market, either for elementary students in developed countries, college students in under-developed countries or technical training for security personnel.

4. Applications for Large Devices

4.1 Dynamic Advertising

Electronic billboards, usually constructed using arrays of LED tiles, have attracted a lot of attention, since their content can be adjusted to match the interests of the people who are expected to view the displays at any given time. However, these boards are extremely expensive and are difficult to assemble and disassemble. Studies of return-on-investment (RoI) show that one can often recover the direct manufacturing cost of the electronic displays within two years, but this is only a small portion of the total system cost.

One way to reduce costs is to move back from the matrix drive structure to direct drive of segmented displays. The U.K. company, eLumin8, has established a lucrative niche business by supplying custom-designed EL panels for promotional purposes.

4.2 Photovoltaics – Solar Cells

Large area solar cells - suitable for installation on the roofs of buildings – provide a second example of a successful electronic product that is manufactured by roll-to-roll processing on flexible substrates. The process used by Iowa Thin Film Technologies (ITFT) to make a-Si solar cells will be outlined. ITFT plans to diversify into other applications, in conjunction with Hewlett-Packard.

5. Implications for Technology

The main message from veterans in the business community is that flexibility alone does not justify a significant price premium. One can escape cost constraints only by enabling completely new markets.

Since the performance of the whole system is more important than that of its components, system integration is critical. Packaging of displays and, in particular, the simplicity and reliability of the electrical and mechanical connections are crucial to product acceptability. Wherever possible, fabrication of the components should be compatible, so that the dream of inexpensive printed electronic systems is realized.

6. Acknowledgements

Out thanks go to the U.S. Display Consortium, for supporting the studies by the author and the development of enabling technology for flexible electronic.