guest editorial

Display Manufacturing on Flexible Substrates

by Greg Gibson

The vast majority of commercially available displays and related touch-screen technologies are currently manufactured on rigid glass substrates. For mature display technologies such as AMLCD, the consumer expects continued increases in display size and performance, with a simultaneous reduction in product price. These requirements are typically met both by advancements in the display technology and by continued improvements in display manufacturing. For emerging display technologies such as OLED, the focus is on commercialization, supported by manufacturing processes that can ultimately be driven down in cost to a point that supports the introduction of competitive mainstream products. The vast majority of these commercially available and emerging displays, and related touch-screen technologies, are currently manufactured on rigid glass substrates, which offer many advantages for both the final display product and the process steps used to manufacture that product.

However, display manufacturing on flexible substrates is a technology segment that is receiving increasing amounts of development and investment. The move toward flexible substrates is typically driven by the requirements of the final product, for instance, a flexible plastic display, or the efficiencies that can be realized when the manufacturing process can be executed on flex. Certainly, the recent market success of e-books has been a significant boost to the electrophoretic-display segment, but it is believed that additional market penetration can be achieved if this technology can be commercialized on flexible displays. Such a display, and the resulting end product, could be thinner and lighter than the glass-based product, while offering significantly increased resistance to breakage. Manufacturing on flex can also enable products with performance and cost points that simply could not be met by using glass.

The ultimate target of flexible-substrate manufacturing is, for many, the migration to a complete roll-to-roll (R2R) process, where most if not all of the manufacturing can be executed in a continuous or semi-continuous fashion. The promise of significantly increased throughput and reduced manufacturing cost is alluring, and indeed R2R manufacturing on flex has been demonstrated for certain applications such as cholesteric displays and electronic skins. However, for most flexible-display applications, there are many technical challenges preventing widespread migration to R2R, not the least of which is the difficulty in maintaining dimensional control and pattern registration accuracy on flexible plastic, and the general challenge of integrating a wide range of processes into a continuous line.

Flexible substrates can also be processed in a single-substrate manner, using either a carrier plate or in a free-sheet form. By using the carrier plate approach, the flexible substrate is attached to (or built on top of) a rigid glass carrier panel. This carrier plate (CP) is typically display glass that is matched to a standard AMLCD Gen size, thus taking advantage of the wide range of process equipment that is already available for display processing. Even so, the manufacturing equipment, and the processes performed, must be adapted to the unique characteristics of the laminated-carrier-panel/flexible-substrate assembly. In addition, there are special requirements for the ultimate separation of the flex substrate from the carrier and the final assembly of the flexible-display device. Despite these challenges, the CP approach offers the advantage of maintaining reasonable dimensional stability and overlay accuracy during

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suming to pull them apart. A promising start in this area, according to Allen, are Design for Disassembly initiatives, in which electronics are designed from the beginning to be taken apart quickly and safely. Such design features might include low or no-lead solder, modular electronics boards, and pieces that snap together (or apart) without glue. In most cases, such items would be disassembled by recycling specialists rather than consumers, but the latter alternative is possible as well.

Consumer Caring is Key

The recycling situation as it now stands is a tough challenge not only for the environment but for consumers and manufacturers. Progress has to start somewhere, however, and there are bright spots. First, companies such as Staples have made some headway in developing recycling programs that actually win customer follow-through. The office-supply chain received the Environmental Leadership Award from the National Recycling Coalition this year for initiatives recognized as an industry model. By making it easy for customers to return any brand of ink cartridges at any store, and offering a financial incentive ($3 a cartridge) to do so, the chain has made strides and reports that it is on track to recycle 50 million cartridges in 2009.

As long as bottom-line responsibility for recycling is hard to pinpoint (should it belong to the manufacturer, the waste hauler, the consumer?), the legislation remains difficult to enforce, but in the meantime, public opinion seems to be doing some of the work, both in alerting end users to the importance of recycling and in pointing out which companies are forwarding the cause. The very fact that so many electronic devices are stockpiled in homes and offices indicates that many people are not comfortable just tossing them into a dumpster. "Watchdog" agencies such as Greenpeace also report the names of companies not involved in recycling or not living up to their recycling claims. Greenpeace publishes a monthly ranking of the 18 top manufacturers of personal computers, mobile phones, TVs, and games consoles according to their policies on toxic chemicals, recycling, and climate change (http://www.greenpeace.org/international/campaigns/toxics/electronics/how-the-companies-line-up). None of them get "perfect" scores, but as of September 2009, Nokia, Samsung, and Sony Ericsson received the highest marks.

Time will tell whether such messages will reach beyond those who follow the news from political activists. Like other fundamental consumer behavior changes - consider how Americans began using fewer plastic shopping bags for the first time this year - electronics recycling will be most successful when end users' awareness and manufacturers' ability to make it easy for them to act on that awareness meet in the middle somewhere. ■

SID News

Dr. David Fyfe and Professor Sir Richard Friend Awarded the 2009 Institute of Physics Business and Innovation Medal

Dr. David Fyfe, CEO of Cambridge Display Technology and Professor Sir Richard Friend of Cambridge University were awarded the Institute of Physics' Business and Innovation Medal in October 2009 for "guiding the company Cambridge Display Technology (CDT) to a pre-eminent position in the development of light-emitting polymers and in the development of the technology for flat-panel displays and lighting." The prize was one of four gold medals awarded annually by the Institute of Physics (IOP) and is for outstanding contributions to the organization or application of physics in an industrial or commercial context.

Fyfe commented, "I am honored to receive and share this award with Sir Richard in recognition of our efforts in developing and commercializing this technology platform. The award is also recognition of the many scientists, investors, and supporters of CDT who have helped drive the technology to its leading position for the future of the displays and lighting markets."

The discovery that certain polymers can emit light when an electric current is passed through them was made by Jeremy Burroughes (Chief Technology Officer for CDT) under the guidance of Professor Richard Friend with assistance from Professor Donal Bradley at the University of Cambridge in the late 1980s. Realizing the potential for the technology, Friend and colleagues promoted the spinout of the intellectual property into CDT, which was initially funded by the University, as well as various business "angels" and local venture capitalists. Fyfe joined CDT in 2000, leading its expansion from a laboratory-based research company to one that built a manufacturing process development line near Cambridge and entered the manufacture of ink-jet printers in California to enable CDT's technology to be applied on an industrial scale. ■

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processing, with the potential of producing manufacturing quantities of rugged, flexible, plastic displays as the end product. This issue contains an interesting overview of one such approach to the flexible-display market, "Flexible E-Book Displays Produced in Standard TFT and Module Factories," by Ian French of PVI.

Free sheet or sheet-to-sheet (S2S) processing is also an emerging manufacturing process for certain applications. This technique uses flexible plastic in cut sheet form that is processed on highly modified (or completely unique) versions of display-manufacturing equipment. Due to the absence of a rigid carrier plate, there are limitations to overlay accuracy and registration using this approach, which will therefore limit the use for high-resolution displays. However, for certain applications, this approach offers unique advantages, such as the absence of a lamination/delamination step and the ability to produce units at very low cost. This approach also allows the use of many of the base technology and existing toolsets that have been developed for "conventional" display manufacturing and avoids the integration challenges of moving completely to R2R production. In "High-Volume Manufacturing of Photonic Components on Flexible Substrates," Dr. Robbie Charters of RPO provides a detailed description of the implementation of S2S processing for the manufacture of RPO's digital waveguide devices, which are being commercialized for touch-screen applications.

Flexible-substrate manufacturing, using the carrier plate or sheet-to-sheet approach, could be an important transitional technology for products that are ultimately produced on a roll-to-roll line. Alternately, the unique advantages of these approaches could offer long-term benefits and product characteristics that cannot be realized with any other method. Either way, the end products made possible by these methods should offer a compelling addition to the range of products based on their glass-based display cousins. ■

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