Will Displays Be Everywhere?

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Abstract

The concept of 'Ambient Intelligence' predicts a future where consumer electronic appliances will be characterized by their being seen only when necessary. One of the few visible embodiments will be displays, which will be omnipresent yet still blend seamlessly into the background. This requires a breakthrough in low-cost, reel-to-reel mass production of flexible displays, based on printing technology. This presentation focuses on several key developments that will lead the way towards that goal.

Introduction

Philips' vision on the future of consumer electronics is embodied by the concept of 'Ambient Intelligence'. This concept refers to an environment that is sensitive, adaptive and responsive to the presence of people in order to create the desired atmosphere and functionality. This will not be accomplished by adding more boxes, buttons and menu options to our homes, offices and cars, but by a multitude of interconnected embedded devices that are hidden in the background. These devices will provide us with information, communication and entertainment, triggered by and in response to, the individual's voice, gestures or even moods. (see Fig. 1) The drivers behind this development will be ubiquitous communications, distributed computing and intelligent interfaces.

Everywhere we turn, a display will be central to providing information. It will have to blend into the background of everyday objects, so that it will need to be extremely thin, low cost and lightweight. Also it will have to conform its shape to the surface in which it will be embedded. If space comes at a premium, a roll-up display will be indispensable.

Developments in Displays

The current speed of replacement of CRT-based monitors and increasingly also TVs by LCD displays is a clear indication of the dramatic progress that flat-panel displays have already achieved. However, an environment with ubiquitous displays requires a significant cost reduction for existing technologies such as plasma display panels, LCD, projection systems - just to name the most important. The ultimate cost reduction will come from a break-through in production technology, which will allow the manufacturing of displays on flexible substrates at high throughput in a continuous reel-to-reel process. Besides low cost, these displays will also be conformable, flexible or roll-up, which are valuable attributes by themselves.

Figure 1. With Ambient Intelligence, boxes will disappear

Several developments are taking place, which point the way towards low-cost reel-to-reel manufacturing. The first polymer Organic Light-Emitting Diode (polyLED) displays are appearing in the market, which are made using low-cost technologies like spin coating and ink jet printing. Especially the latter has a bright future in the area of patterned deposition of electronic materials, because of its versatility. However, its limitations with respect to achievable feature sizes requires the development of printing techniques that can attain resolutions of order one micron or even less. The so-called soft-lithographic technique of microcontactprinting is showing promising results in that direction.

The next stepping-stone being worked on is displays on flexible substrates. Although polyLED is a promising technology for application on such substrates, it is so sensitive towards moisture and oxygen that it requires highly impermeable substrates, which are still under development. For less sensitive technologies like liquid-crystal display (LCD) technology, first durable flexible displays have already been demonstrated. An important enabler for the manufacturing of flexible displays will be the use of polymer electronics for pixel switches and integrated display drivers. As the long-term goal, an all-plastic display in which the light-emitting polyLED and plastic electronic material have been deposited by printers in a reel-to-reel process, will enable the vision of Ambient Intelligence to become reality.

Ink Jet Printing of PolyLED Displays

Philips is the first company selling consumer products based on polyLED technology. PolyLED displays have certain attributes that make them prime contenders for sharing the market with present day LCDs: perfect viewing angle, high brightness and contrast, low voltage and a flat and thin form factor. At present, we are transferring the ink jet printing process to a pilot polyLED display factory. The ink jet process will be used for the high-resolution deposition of both the hole-conducting and light-emitting polymers in the polyLED device with multi-nozzle ink jet printers (20 picoliter drops). Issues that have been solved are the solvent- and acid-resistance of the multinozzle ink jet heads, very little nozzle-to-nozzle droplet volume variation, high droplet placement accuracy, cleaning and maintenance of the head in operation, suitability of substrates for retaining the printed droplets, rheological properties of the inks so that they can be be deposited using an ink jet procedure while retaining their functional characteristics (efficiency and lifetime), and the understanding layer thickness uniformity variations within a pixel.[1]

Figure 2a shows a dual-printer set-up for the printing of both hole-conducting and light-emitting polymer, fig. 2b shows the printed sub-pixels in three different colors.

Figure 2a. Inkjet printing set-up for polyLED

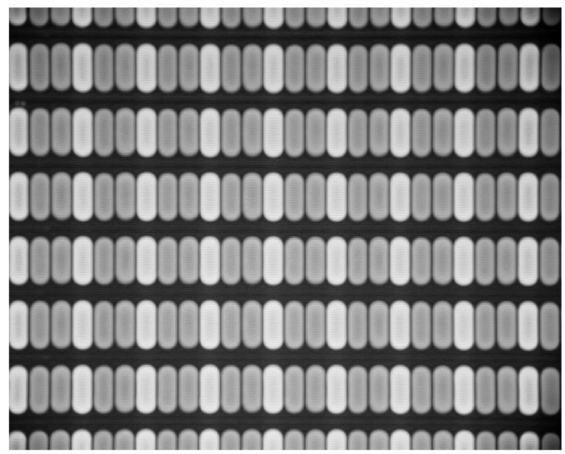

Figure 2b. Display pixels (66 x *200* µ*m)*

Micro-Contact Printing of Electronic Materials

Ink jet printing will not achieve the resolution required for printing pixel switches and drivers in active matrix displays. For that purpose we are studying micro-contact printing,[2] which has the potential of printing at resolutions of less than one micron. It is based on covering a thin metal film with a patterned self-assembling monolayer of organic molecules, using a UV-hardened poly-dimethyl-siloxane stamp. The mono-layer is then used as an etch mask for etching the pattern in the metal layer. Figure 3 shows an example of a gold source-drain layer of a thin film transistor printed on top of a gate structure with feature sizes of a few microns.

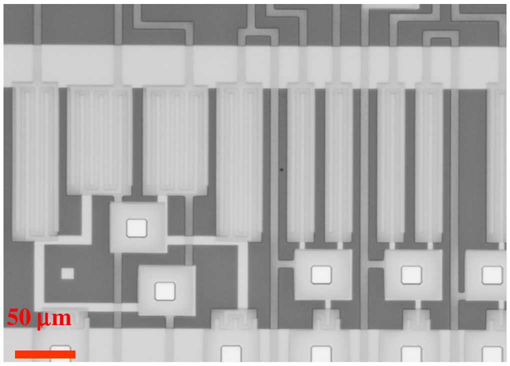

Figure 3. Micro-contact printed transistor structure

Flexible Displays

The first flexible displays to reach the market will be based on LCD technology, because it is reasonably insensitive to gases in the ambient and does not require expensive extra impermeable layers on the plastic substrates. Recently we showed the first passive-matrix cholesteric LCD type displays that can be bent to a radius of curvature of 20 mm.[3] Figure 4 shows a picture of this display, which has 64 x 64 pixels and the ability to show 16 monochrome grey scales. It has an electro-optical performance, which is comparable to that of a glass cell.

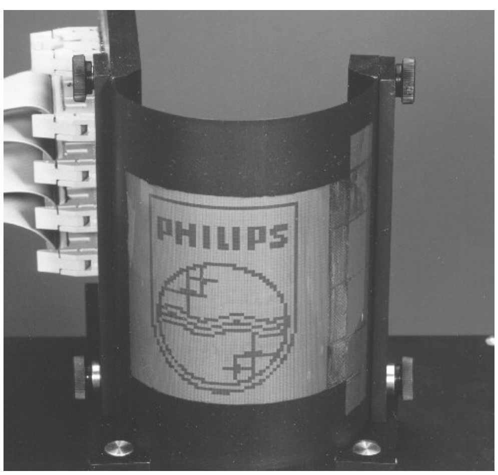

Figure 4. Flexible cholesteric LCD display

This display is bi-stable and consumes very little power. In addition to satisfying requirements of existing low-end applications, this technology opens up new markets for electronic displays, such as re-writable shelf-edge displays for electronic message stickers or billboards. Although this goes a long way towards ubiquitous low cost displays, ambient intelligence will require full-color high-performance displays of the active-matrix type, either in LCD or in polyLED technology. For these to be produced on plastic substrates, issues related to higher processing temperatures, among others, need to be resolved. Polymer electronics, which do not require high processing temperatures but suffer from lifetime and carrier mobility issues at the moment, may provide a solution.

A recent invention by Philips Research, so-called paintable displays,[4] may eventually even lead to displays painted on the wall. The technology is based on photo-enforced stratification, where a complex blend containing liquid crystal and a polymer-forming material, are phase-separated by exposure to UV irradiation. The blend is applied onto the substrates in one of the coating steps. UV irradiation causes the blend to split up in two separate parts: a liquid-crystal part directly on the bottom and a polymer part on top of it, covering the display. A top substrate is no longer necessary, reducing cost and yielding a very thin display, where the substrate can also consist of a plastic foil.

Conclusion

We have illustrated the developments in the area of inkjet and microcontactprinting and flexible displays with examples from our labs. In other labs around the world similar activities are taking place, adding up to a massive effort which has resulted in very encouraging progress towards the ultimate goal of reel-to-reel mass production of low cost flexible displays, which might become truly ubiquitous. We have mentioned a number of technological challenges that still need to be tackled.

References

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Biography

Maarten Buijs studied chemistry in Utrecht, between 1978 and 1983, where he also received his PhD in solid-state chemistry in 1987. A two-year postdoc at Harvard University in Cambridge, MA, followed. In 1989 he started working at the Philips Research Laboratories Eilndhoven, the Netherlands, working in the area of CRTs . After a two-year stay at the Philips Research Laboratories Briarcliff, NY, where he developed device physics for blue-laser diodes, he went back to Eindhoven to be involved in technology management at Philips International. Since 2001 he is responsible among others for research of flexible displays and printing of electronic materials as head of the 'Mechanics, Heat and Particle Optics' department in Philips Research Eindhoven.