1

Introduction

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1.1 Toward Flexible Mobile Devices

Displays and how we use them have gone through some major changes already in the twenty-first century. Mobile displays have developed from displaying text and some rudimentary graphics to highly interactive, high-resolution devices capable of streaming high-definition video. In addition to the advances in the display technologies, mobile devices also have high-resolution cameras, multiple internal sensors, powerful computer processers, multiple communication chips, and large area rechargeable batteries. Against this backdrop the requirements for flexible displays to be used in many mobile device applications far exceed those near the turn of the century. However, despite these challenging requirements, there are now beginning to be commercial products with amazing capabilities. An example of the type of approach that can be used to develop commercial foldable displays is described by Meng-Ting Lee et al. in Chapter 9. The significant improvements in organic light-emitting diodes (OLEDs) have opened possibilities in the development of foldable displays.

While improvements in OLEDs have been critical to recent developments in flexible displays there are a range of other critical components that would also need to be flexible for the development of truly mobile devices. One particularly important development has been in the field of transparent conductive coatings where metallic nanowires are becoming a commercial reality with important flexible properties. This is described in detail by Jean-Pierre Simonato in Chapter 5. For some applications an outer surface of glass would be very useful as an oxygen and moisture barrier or to protect underlying layers. Some examples of flexible glass are discussed in Chapter 8 by Armin Plitchta et al. For truly flexible devices large flexible power sources such as batteries will be needed, and flexible batteries are discussed in Chapter 13 by Nicholas Winch et al.

These are certainly exciting times for the development of flexible mobile devices. We have highlighted some of the key developments we discuss in this book that could be incorporated into such a device, but we will also need to understand how flexibility impacts functionality such as the rich touch input we expect. Some important aspects of integrating touch in mobile devices is described by Darran Cairns and Anthony Weiss in Chapter 15.

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1.2 Flexible Display Layers

It is likely that polymer films will be used widely in flexible displays, and this raises myriad challenges, not least of these being durability. For applications where a polymer film is part of the outermost surface of the device, cuts and abrasions of the outermost polymer layer can reduce display performance. One approach to mitigate for this is to use self-healing polymers, which is discussed by Progyateg Chakma et al. in Chapter 7. One vitally important issue is damage to inorganic layers in a flexible display which can lead to cracking this is discussed by Yves Letterier in Chapter 16.

Mechanical damage is not the only thing to be considered in flexible display components. It is also important to tune the optics of polymer for the application and to mitigate for the underlying properties of polymer substrates. This can be achieved through the design of engineered polymer films as described by Bill McDonald in Chapter 2 and through the design of optical coatings as described by Owain Parri et al. in Chapter 3. The ability to tune properties in multiple ways opens a range of ways to design display components.

Two additional layers that play critical roles in the development of flexible displays are optically clear adhesives, discussed by Albert Everaerts in Chapter 6, and the thin film encapsulation layer used to protect OLEDs, discussed by Robert Jan Visser and Lorenza Moro in Chapter 12. Optically clear adhesives allow components to be laminated with minimal optical losses and enable complex stacks to be engineered and assembled. We discussed earlier how OLEDs are enabling advances in flexible devices but for OLEDs to have reasonable lifetimes they must be encapsulated—and it is this encapsulation that had enabled OLEDs to become a display of choice in flexible applications. One additional component that is required for flexible devices is a flexible backplane and Zachary A. Lamport et al. describe flexible backplanes using organic transistors in Chapter 4.

1.3 Other Flexible Displays and Manufacturing

We discussed earlier how our expectations of mobile devices has changed with expectations for high-fidelity video and computing power necessitating flexible batteries and touch sensors with a high-resolution display. We have also highlighted how OLEDs have become widely used in large part because of these expectations. However, not all devices need to play high-resolution video or require significant computing power. For applications such as e-readers the requirements are very different with low-power consumption and high-contrast ratio being more important than speed. Two important technologies that have found important niches are cholesteric liquid crystal displays, described by Deng-Ke Yang in Chapter 10, and electronic paper, described by Guofu Zhou in Chapter 11. There are currently some commercial products that can be manufactured on flexible substrates even if they are not ultimately used in a flexible form factor.

For several years roll-to-roll manufacturing has been advanced as a justification for flexible electronics because of the ability to fabricate devices in volume. There are a number of challenges with roll-to-roll fabrication and some of these are highlighted by Greg Potoczny in Chapter 17. More recently robotic deposition and direct writing is opening new approaches to manufacturing allowing for precise deposition of coatings and circuitry. This manufacturing approach is discussed by Kostas Sierros and Darran Cairns in Chapter 18.

Finally, we also include two chapters related to applications. Uwadiae Obahiagbon et al. detail some applications of flexible displays in medical applications in Chapter 19. We expect this to be an exciting area moving forward. In Chapter 14, Gerwin Gelinck describes his work on large area flexible x-ray detectors, which we believe will be useful in incorporating additional sensing in flexible devices and displays.