Introduction to System-on-Chip and its Applications

Individual Project Report

OLED

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Outline

1 Introduction

In recent years, with the advancement of science and technology, the popularization of personal computers, networks, smartphones, and information dissemination, displays have become an indispensable role in human-computer interaction. OLED is one of the popular technologies which is used to create digital displays in devices such as television screens, computer monitors, and mobile devices, for example, smartphones, handheld game consoles, and VR monitors. The advantages of OLED are as follows, Lower cost in the future, Lightweight and flexible plastic substrates, better picture quality, better power efficiency, and faster response time. However, OLED has a few disadvantages, such as a short lifespan and overall luminance degradation. Even though there are some shortcomings of OLED, the OLED display market is expected to grow quickly in recent years.

An organic light-emitting diode (OLED), also known as an organic electroluminescent diode, is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. The structure of the basic OLED is shown in Figure 1. There consists of several layers of organic materials sandwiched between the Cathode and Anode. When a voltage is applied across the OLED, a current of electrons flows from the cathode to the anode, adding electrons to the emissive layer and taking them away, or creating electron holes at the anode. At the boundary between these layers, electrons find holes, fall in, and emit light. The color of the light depends on the type of organic molecule in the emissive layer. For example, red and green light are now created with phosphorescent organic compounds, also known as PHOLED that have greater quantum efficiency than the fluorescent compounds traditionally used in OLEDs. The most advanced OLEDs use electron and hole injection and transport layers to modulate electron movement.

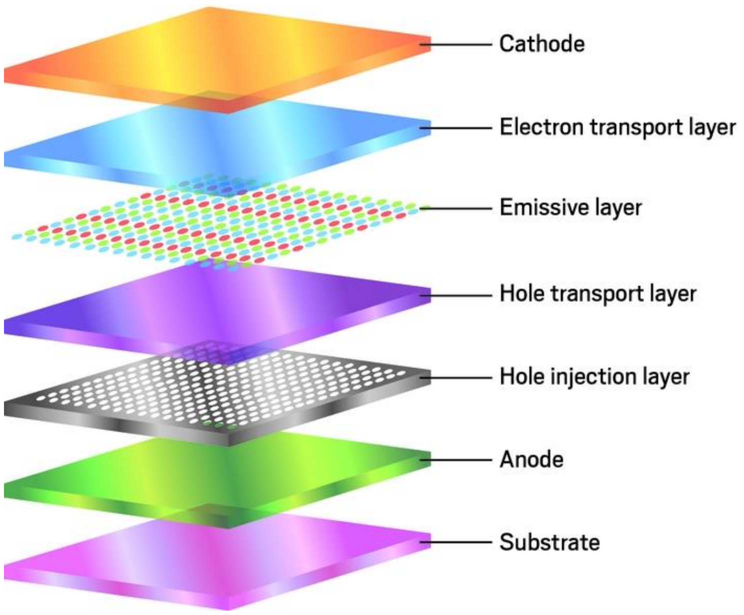

Figure 1 OLED structure

2 Technology

2.1 OLED

A typical OLED is composed of several organic layers, an Electron transport layer, an Emissive layer, a Hole transport layer, and a Hole injection layer, between two electrodes, the anode and cathode, all deposited on a substrate. During the operation, a voltage is applied across the OLED such that the anode is positive with respect to the cathode. As a result, current flows from the cathode to the anode through the organic layers. This process gives electrons to the emissive layer and removes electrons from the conductive layer. Removal of electrons from conductive layer leaves out holes that need to be filled with electrons in emissive layer. The holes jump to emissive layer and will recombine with electrons. As electrons drop into holes, they release their extra energy as light. In this way, light emission takes place in the OLED device. The schematic of a bilayer OLED as shown in Figure 2.

Unlike LCDs that use the backlight, OLEDs do not require backlighting like LCDs. LCDs work by selectively blocking areas of the backlight to make images that you see, while OLEDs generate light from organic material. Thus, OLEDs is low power consumption, thinner, and are more flexible. Furthermore, OLEDs can have high contrast and vivid color. And because OLED can be turned off, it can produce a true black but LCD cannot.

2.2 PMOLED vs. AMOLED

OLED displays are of two types; PMOLED (Passive Matrix Organic Light Emitting Diode) and AMOLED(Active Matrix Organic Light Emitting Diode) as shown in Figure 3.

PMOLED consists of a control scheme in which you are able to control every single line displayed on the screen one by one. It does not contain any storage capacitor, due to which most of the pixels in the line are off. So as to compensate for the display and make it bright, you have to use more voltage. AMOLED uses TFT(Thin Film Transistor) that acts as the active component causing the substrate to store more energy. By using AMOLED the displays can be controlled easily as they have their own storage capacity and are able to display high resolutions easily in relation to PMOLED. As shown in Figure 4, AMOLED has more advantages than PMOLED, such as lower power consumption, higher refresh rates and contrast rates, and higher resolution and display panel size.

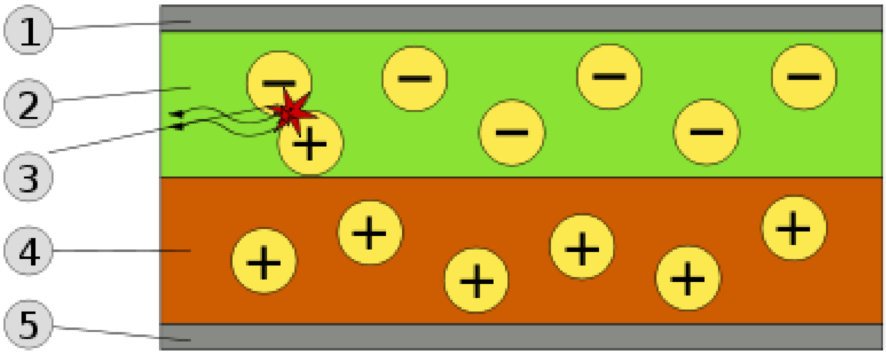

Figure 2. Schematic of a bilayer OLED: 1. Cathode (−), 2. Emissive Layer, 3. Emission of radiation, 4. Conductive layer, 5. Anode (+)

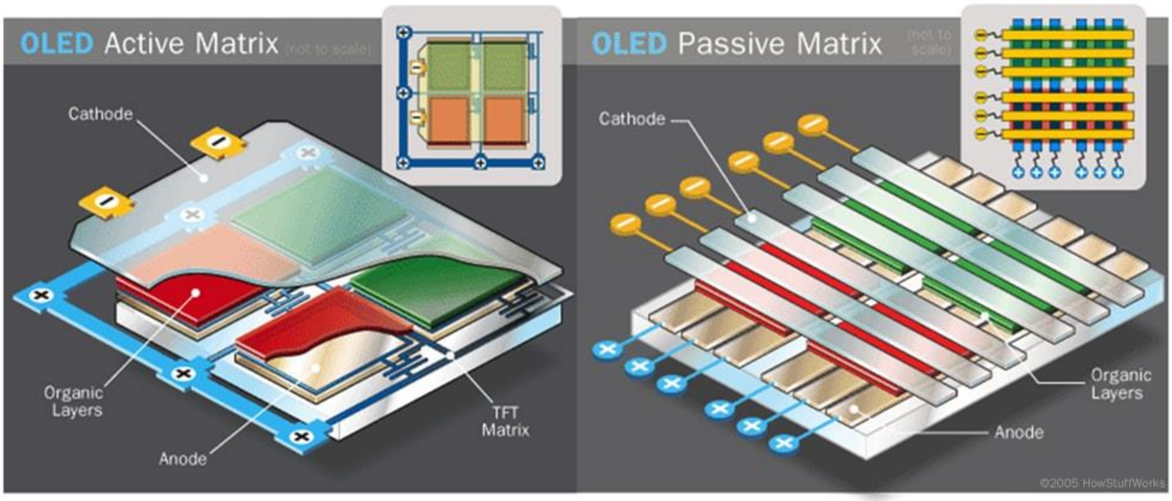

Figure 3. AMOLED vs. PMOLED

特點	PMOLED	AMOLED
發光方式	瞬間高亮度發光	連續驅動發光
能耗	耗電量大，發光組件的老化速度快	驅動電壓及耗電量低
發光壽命	發光壽命短，不適合大尺吋	發光壽命和亮度提升容易
顯示品質	實現高亮度、高解析度較難，需要外接驅動電路	易實現高亮度、高解析度，可將驅動電路IC化、小型化
材料及生產成本	低	高
驅動電路設計	容易	複雜

Figure 4. PMOLED vs. AMOLED

2.3 LCD

LCD structure is as shown in Figure 5, a liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers. Liquid crystal display is composed of several layers which include two polarized panel filters and electrodes. A polarizer is an optical filter that lets light waves of a specific polarization pass through while blocking light waves of other polarizations. Because LCD can't emit light itself, normally a backlight is placed behind an LCD screen in order to be seen during the dark environment. As shown in Figure 6, the principle behind the LCDs is that when an electrical field is not applied to the liquid crystal molecules, the molecules twist 90 degrees in the LCD cell. When the light from the backlight passes through the first polarizer, the light is polarized and twisted with the liquid crystal molecular layer. When it reaches the second polarizer, it is blocked. The display will be black. When an electric field is applied to the liquid crystal molecules, they are untwisted. When the polarized light reaches the layer of liquid crystal molecules, the light passed straight through without being twisted. When it reaches the second polarizer, it will also pass through, the viewer sees the display which will be bright.

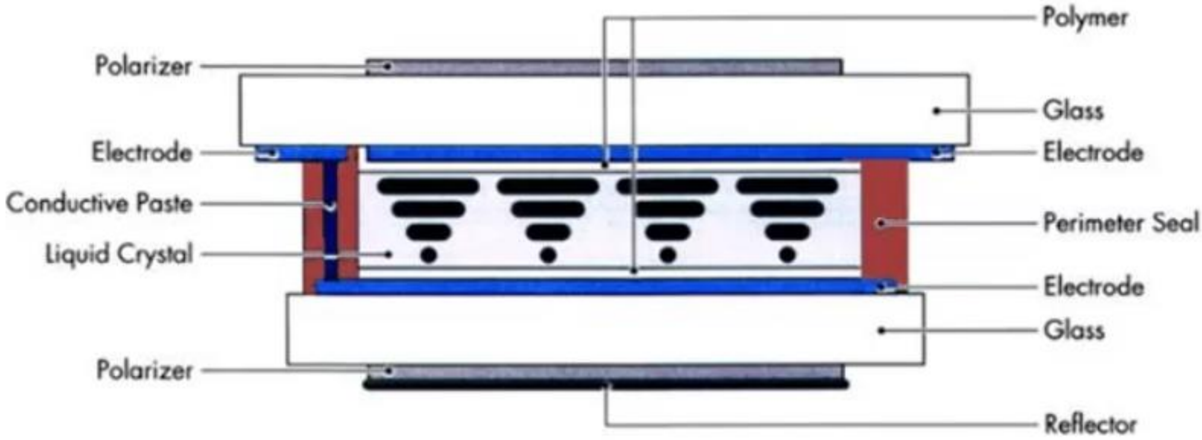

Figure 5. LCD structure

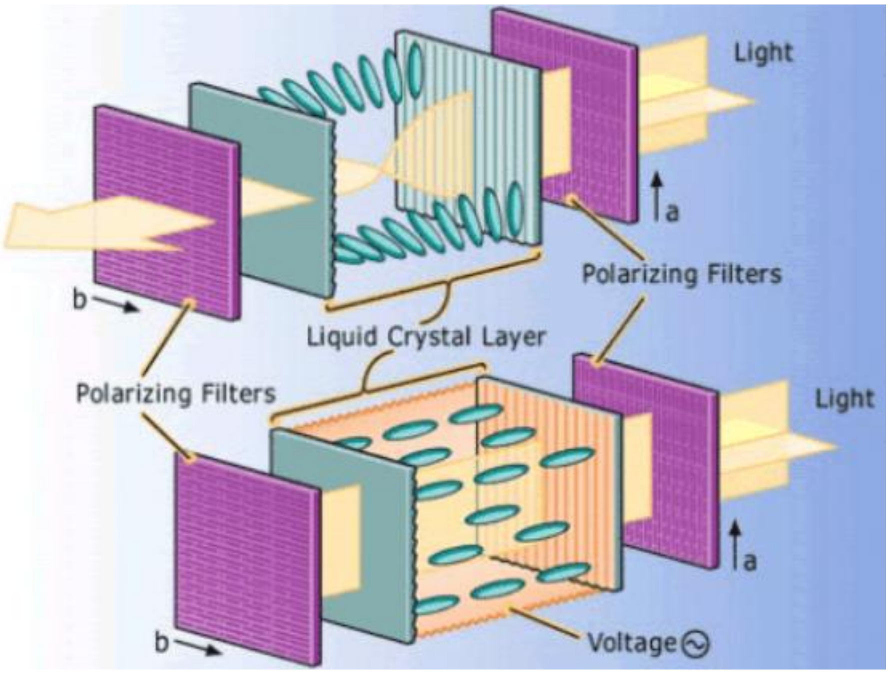

Figure 6. LCD working principle

2.4 OLED vs. LCD

There are several main differences between OLEDs and LCDs. For example, color contrast, brightness, viewing angles, lifespan, black levels, burn-in problem, and price. The structure difference between LCD and OLED and comparison table of OLED and LCD are as shown in Figure 7 and Figure 8. Contrast refers to the difference between the lightest and darkest parts of an image. Most LCDs will have a built-in backlight to make their images visible. Therefore, backlight make you still able to see light coming through on image are meant be dark on an LCD display. However, OLEDs deliver a drastically higher contrast by dynamically managing their individual pixels. When an image on an OLED display uses the color black, the pixel just shuts off completely, thus OLEDs can present much higher contrast that of LCDs. Furthermore, as OLEDs are self-illuminating, they have no backlight. This means LCDs are able to produce brighter images due to their powerful backlights. In addition, having a wide viewing angle is important for displays that you don’t always view straight on. Wide viewing angles allow the screen to stay consistent and retain its quality no matter where the viewer is looking at them from. As mentioned before, OLED displays have no backlight. This means the display is much thinner than LCD displays and their pixels are much closer to the surface of the display, giving them an inherently wider viewing angle. However, lifespan and burn-in are two major problems of OLED. Due to the static image being displayed for too long a time, the organic material in these displays can leave a permanent afterimage on display, known as burn-in, which may seriously affect the lifespan of OLED displays.

	OLED	LCD
Contrast	Best	Good
Brightness	Good	Best
Viewing angle	Best	Good
Black level	Best	Good
Resolution	Best	Best
Refresh rate	Best	Best
Energy consumption	Best	Best
Lifespan	Best	Best
Burn-in	Good	Best
Price	Good	Best

Figure 7. OLED vs. LCD Feature Comparison Table

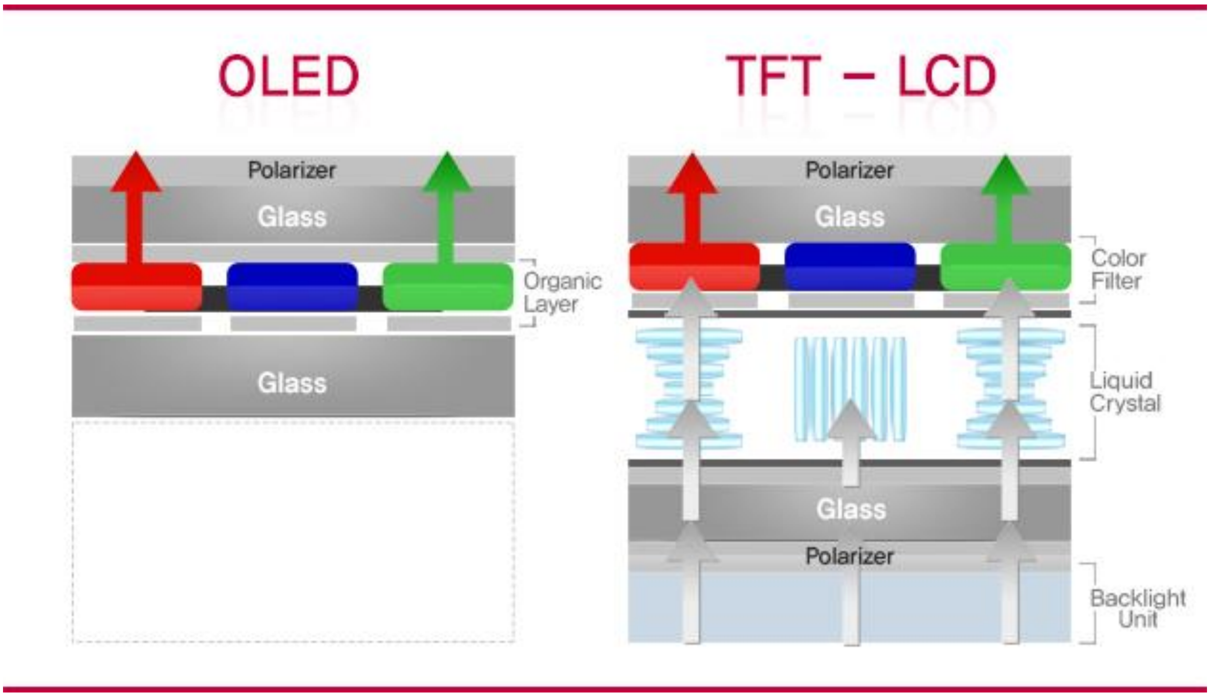

Figure 8. Structure difference between LCD and OLED.

3 Industry Analysis

Organic light-emitting diode (OLED) technology is used in a variety of industries, including television and smartphone displays, lighting, and wearable devices. One of the main advantages of OLED technology is its ability to produce deep blacks, high contrast ratios, and wide viewing angles, which make it a popular choice for displays in televisions and smartphones. OLED displays are also thin and flexible, allowing for the creation of curved and foldable devices. In addition, OLEDs have a fast response time, making them suitable for use in high-speed video applications. OLEDs are also used in the lighting industry as panels or tubes and offer energy-efficient and aesthetically pleasing lighting solutions. In the wearable device industry, OLEDs are used in smartwatches, fitness trackers, and other wearable technology due to their small size, low power consumption, and ability to display clear and bright images. However, OLED technology also has some limitations. One of the main drawbacks is that OLED displays can degrade over time, leading to a decrease in brightness and color accuracy. In addition, OLEDs are sensitive to heat and moisture, which can shorten their lifespan. Finally, OLEDs can be more expensive to manufacture than other display technologies. Overall, OLED technology offers a number of advantages, but it also has some limitations that should be considered when deciding whether to use it in a particular application.

The OLED market is expected to continue to grow in the coming years due to increasing demand for OLED displays and the potential for further applications of OLED technology. However, the OLED market also faces some challenges. One of the main challenges is the high cost of OLED manufacturing, which can make OLED displays more expensive than other types of displays. The OLED market size from 2021 to 2030 (source: https://www.precedenceresearch.com/oled-market) is shown in Figure 9. The global OLED market size was estimated at USD 37.6 billion in 2021 and is expected to be worth around USD 214.8 billion by 2030, poised to grow at a CAGR of 21.37% over the projection period 2022 to 2030.

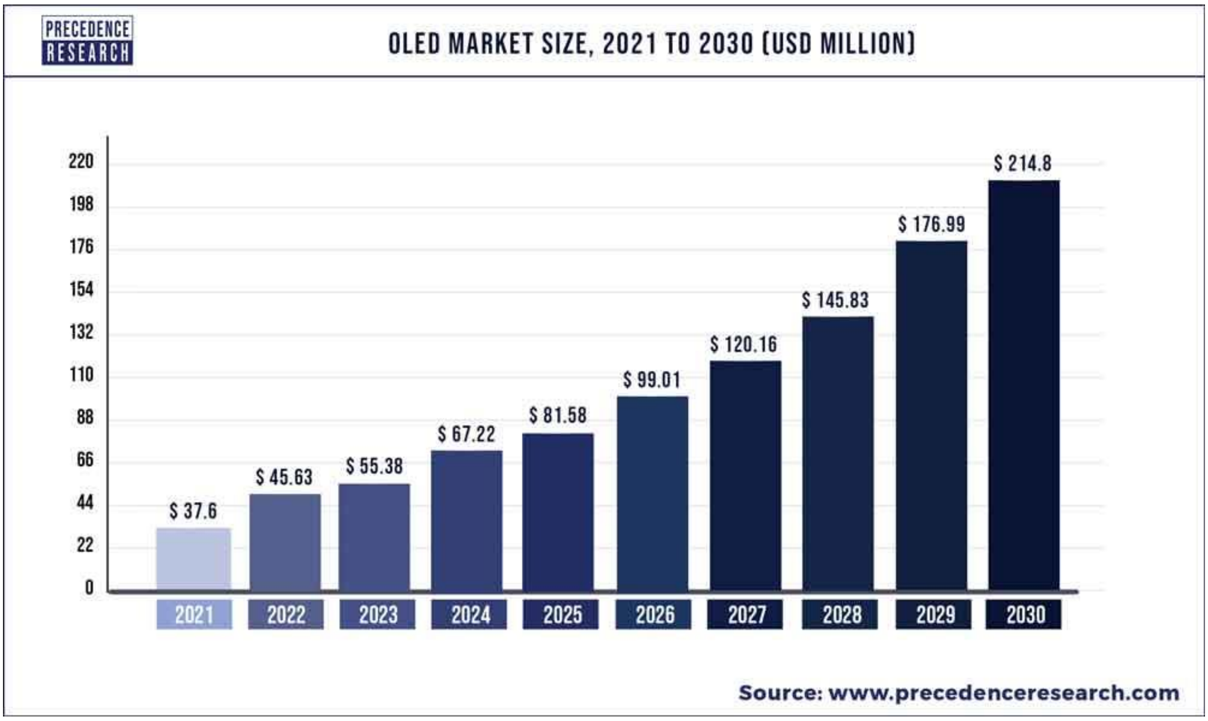

Figure 9. OLED Market Size, 2021 To 2030 (USD Million)

The SWOT analysis is as shown in Figure 10. Brightness, high contrast, response time, and thinner are some strengths of OLEDs. However, there are also several weaknesses, such as Lifespan, image retention (burn-in), and stroboscopic effect. Stroboscopic effect is caused by PWM, which is a technique used to control the intensity of a light or the speed of a motor by turning the power on and off rapidly. One advantage of PWM is that it allows for precise control over the output, as the width of the pulse can be finely adjusted. Another advantage is that it is energy efficient, as the power is only delivered to the load during the "on" time of the pulse. However, PWM can also produce a flickering effect, which may be noticeable to some people and may cause eyestrain or headaches in some cases. Micro LED, provide long lifespan and avoid burn-in problem, which are the disadvantages of OLEDs, is believed to be the next-generation display technology, may become the main threat of OLEDs.

Figure 10. OLED SWOT analysis.

4 Application

4.1 Smartphone

In order for a display panel to work correctly, it needs a display driver IC (DDI), which controls the display pixels. This tiny semiconductor chip is responsible for sending signals to the TFT (thin film transistor) and serves as the connection between the application processor (AP) and the display panel in electronic devices such as smartphones.

The terms COG, COF, and COP describe the method of attaching a display driver IC (DDI) to a display or circuit board. The technique used for attaching the DDI to the substrate of a display panel will vary based on the substrate material and the method of attachment. As shown in Figure 11. Chip on glass (COG) is the most common and cost-effective screen packaging technology. It was widely used before the trend of full screen displays. Most mobile phones used COG technology because the chip was placed directly on the glass, which resulted in a low utilization rate of the phone's space and a low screen ratio. Many simple mobile phones still use COG technology. In other words, COG is a commonly used, budget-friendly screen packaging method that was popular before full-screen displays became the norm. It is not as space-efficient as other methods and does not allow for high screen ratios. "Chip on film" (COF) is a packaging technology that places the IC chip for the screen on a flexible printed circuit board (FPC) and then bends it to the bottom. This method is more space-efficient than chip on glass (COG) because it can reduce the size of the frame and increase the screen ratio. In other words, by placing the chip on a flexible FPC and bending it to the bottom, this technology allows for a smaller frame and a higher screen ratio compared to COG. Chip on plastic (COP) is a new screen packaging technique that involves bending a part of the screen to create a nearly borderless effect and reduce the size of the frame. This method requires the use of an OLED flexible screen because the screen must be bent. COP was first introduced with the release of the Apple iPhone X and is a relatively new screen packaging process. In other words, COP is a new way of packaging screens that involves bending the screen to create a borderless effect and requires the use of an OLED flexible screen. It was first introduced in the Apple iPhone X.

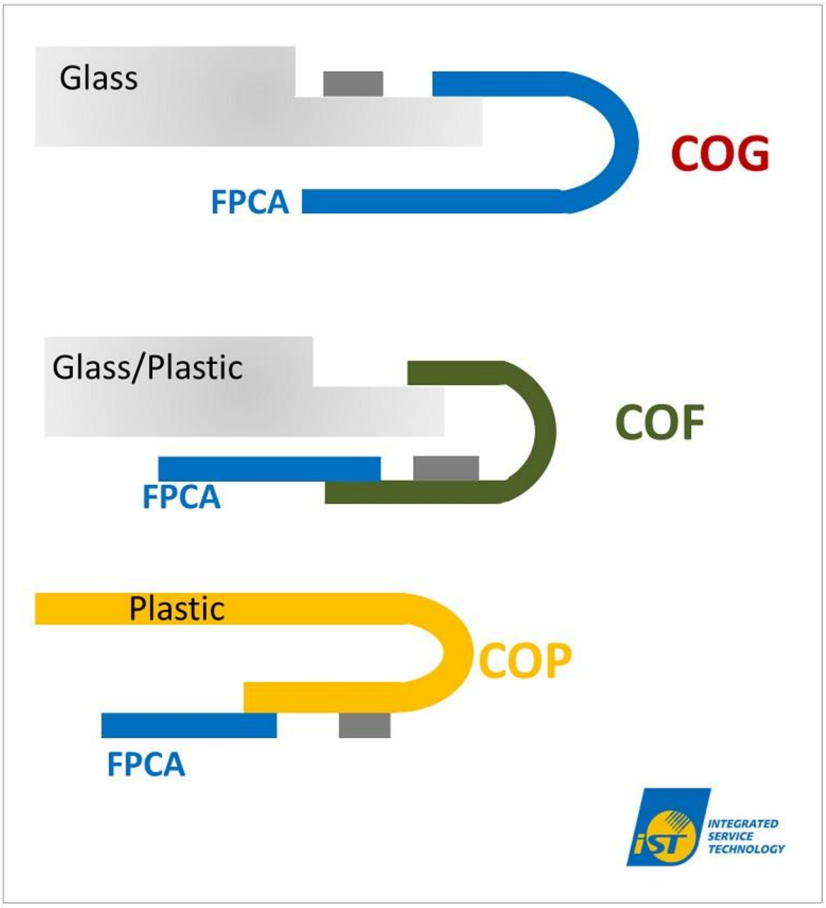

Figure 11. COG, COF, COP in mobile phone screen packaging.

4.2 Others

Organic light-emitting diode (OLED) technology is used in a variety of applications. Such as display screens, wearable devices, medical devices, etc. Take wearable devices for example. As shown in Figure 12, OLEDs are used in smartwatches, fitness trackers, and other wearable technology due to their small size, low power consumption, and ability to display clear and bright images.

Overall, OLED technology is used in a variety of applications due to its ability to produce vibrant and high-quality images, as well as its flexibility and energy efficiency.

Figure 12. Wearable OLEDs.

5 Conclusion

Organic light-emitting diode (OLED) technology has become increasingly popular in recent years due to its ability to produce deep blacks, high contrast ratios, and wide viewing angles. OLED displays are also thin and flexible, allowing for the creation of curved and foldable devices. In addition to its use in television and smartphone displays, OLED technology is also used in the lighting industry as panels or tubes, and in wearable devices such as smartwatches and fitness trackers. While OLED technology offers many benefits, it also has some limitations. OLED displays can degrade over time, leading to a decrease in brightness and color accuracy. In addition, OLEDs are sensitive to heat and moisture, which can shorten their lifespan. Finally, OLEDs can be more expensive to manufacture than other display technologies. However, Micro-LCD, which is believed to be the next-generation display technology, can overcome the shortcomings of OLED. Thus, OLED must find other advantages over Micro-LCD. In summary, OLED technology is a promising and innovative solution for a variety of applications, but it is important to consider its limitations when deciding whether it is the best choice for a particular application. In addition, once the Micro LEDs are mature, they will be a great threat to OLEDs.

6 References

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