Chapter 1

Introduction

1.1 Portable Display Technology

In the mobile work era, portable displays provide an access to working outside companies. It is the trend that portable displays are thin and power-saving. The global market prediction of small and medium size panel industry by institute for information industry, shown in Fig. 1.1, reveals that market capitalization will up to 219.8 hundred million USD in 2008. The applications of small and medium size panel, such as cell phones, require the flat panel display (FPD) with better performance. In addition to basic image quality, the required features of portable display include light weight, low power consumption, small form factor, sunlight readability, etc. While the mainstream of FPD industry is dominated by liquid crystal displays (LCDs) [1], the conventional transmissive LCDs seem inadequate to meet the requirements of portable displays due to size and power consumption.

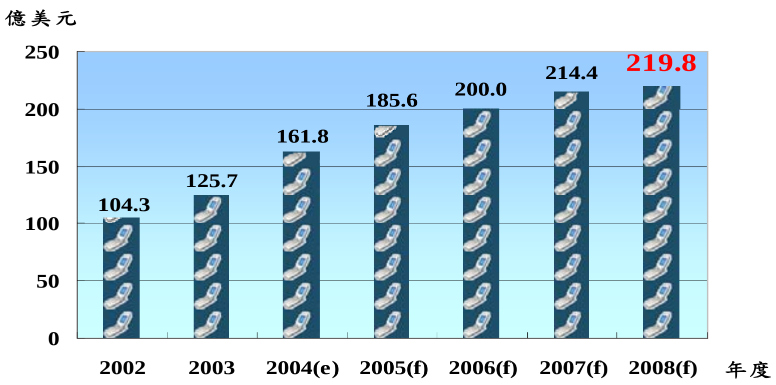

Fig. 1.1 Market survey of small and medium size panel

Therefore, several display technologies have been developed in order to meet the requirements which are mentioned above. For example: transflective LCD, OLED displays are two of the most competitive display technologies in portable display applications.

1.2 Liquid Crystal Displays

1.2.1 Transmissive Liquid Crystal Display

Liquid crystal displays are well developed and widely utilized for portable display applications. A transmissive LCD, which equipped with an illuminator called backlight is placed at the rear surface of the LCD panel, is used to exhibit information. However, a typical transmissive type LCD only has a light efficiency of about 4.94%, as shown in Fig. 1.2. In order to perceive better luminance, it is conventionally achieved by increasing the intensity of the backlight, but power consumption increases as well. In addition, the image of transmissive LCDs will be wash-out under brighter environment. Under strong sunlight ambience, transmisive LCDs enhance the backlight luminance to avoid the wash-out problem. However, the brighter backlight consumes more power consumption. As a result, transmissive LCD is not suitable for portable applications.

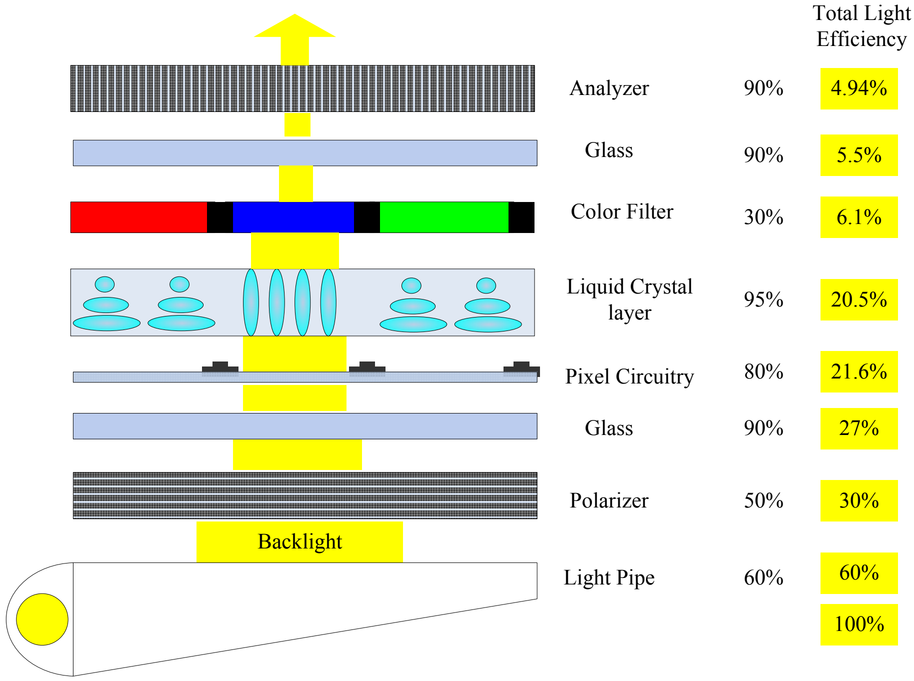

Fig. 1.2 Transmissive LCD

1.2.2 Reflective Liquid Crystal Display

Reflective liquid crystal display technologies are of increasing interest as the industry expects to develop the products with low power consumption and high brightness for portable display applications. The reflective LCD [2, 3], shown in Fig. 1.3, consists of a reflector and a liquid crystal panel. Thus, the incident beam of light passes through the LC cell and is reflected by the bottom reflector. The beam of light undergoes double passages through the LC layer twice before exiting the cell. The optical path difference between a transmissive LCD and a reflective LCD is shown in Fig. 1.4. It should be noted that the bottom reflector is the essential part in the reflective LCDs. On the whole, all transmissive LCDs can be employed for reflective LCDs. Due to the double passage of the beam of light, only one polarizer, the top polarizer, is needed to obtain polarization difference to switch between the bright state and the dark state. Because the image is exhibited by using reflector to reflect ambient light, the luminance of reflected light is close to that of the environment. Hence, the washout effect can be reduced substantially. Besides, the power consumption issue can be eliminated due to the removing of the backlight system. However, since the reflective type LCD uses the ambient light as the light source to display the images, the luminance of the reflected light highly depends on the ambient light, and always loses its readability in the dark environment. Furthermore, to control the optical properties of ambient light is difficult. As a result, the reflective LCD, which can not provide higher contrast ratio and color saturation under all environments, is limited for portable applications.

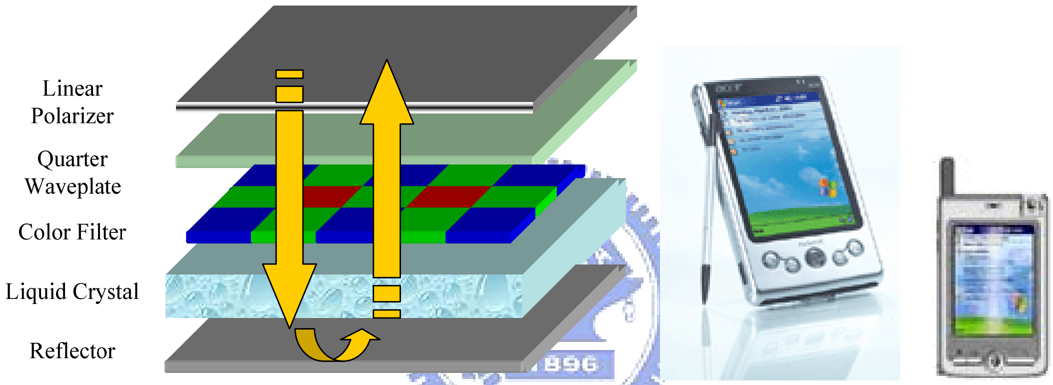

Fig. 1.3 Reflective LCD

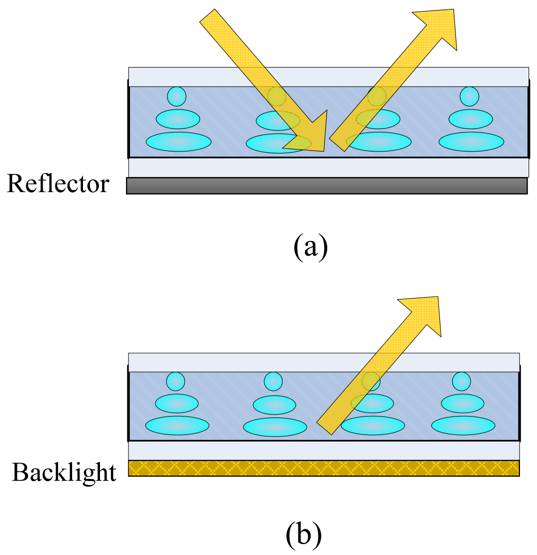

Fig. 1.4 (a) a reflective LCD (b) a transmissive LCD

1.2.3 Transflective Liquid Crystal Display

In order to solve the issues of transmissive and reflective LCDs, a structure which combines both characteristics of transmissive and reflective LCDs has been developed and named as transflective LCD [4, 5], as shown in Fig. 1.5. Nowadays, the transflective LCDs have been widely applied in the portable displays, such as mobile phones, portable digital assistants (PDA). The liquid crystal displays using both the transmitted light and reflected light are generally referred to transflective LCDs, which can provide better image quality under any circumstance. A transflective LCD which comprises a transflector between liquid crystal cell and glass substrate is shown in Fig. 1.5. The transflector functions partially transmission and reflection. In the transmissive mode, backlight passes through transflector to display information. On the other hand, ambient light is reflected by transflector to realize images in the reflective mode.

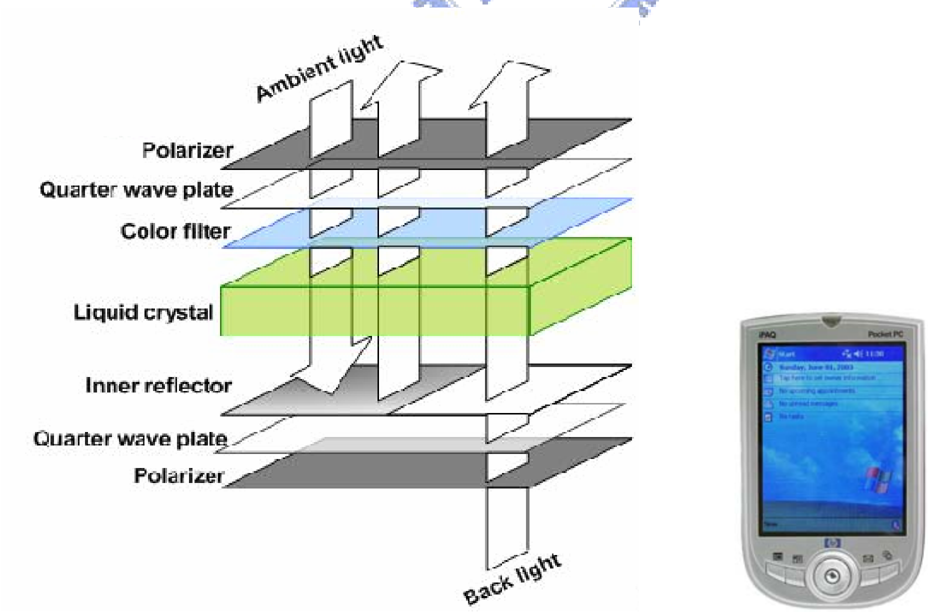

Fig. 1.5 Transflective LCD

1.3 Organic Electroluminescence Device

Electroluminescence (EL) is the generation of light by electrical excitation. The first report of EL from organic semiconductors was from Helfrich and Schneider in 1963 [6]. They demonstrated electroluminescence in thick (50μm to 1mm) crystals of anthracene. However, due to the high operating voltage (50~1000V) and the poor performance, these early devices were not practical. Breakthroughs of organic EL were made in 1980's by Tang, VanSlyke, and Chen [7,8]. They fabricated a dual-layer-device structure using molecular thin films (a few hundred angstroms) of 8-hydroxyquinoline aluminum (Alq3) as the emissive layer and aromatic diamine as the hole-transport layer. The organic layers were sandwiched between the anode ITO and the cathode Mg-Ag alloy. Its low operating voltage (<10V) and high luminance (up to 2000 cd/m^2) immediately attracted researchers to continuously improve the device performance for practical applications.

In 1990, Burroughes and the co-workers at Cambridge University successfully demonstrated a polymer-based OLED using the conjugated polymer with low voltage operating [9,10]. Again, this successful demonstration also triggered a lot of research on polymer light emitting diodes (PLED).

The operating voltage, brightness, and the color performance of current OLEDs are eligible for many display applications, either as backlight sources or directly as emitter in emissive displays. Compared with the currently dominant LCD technology, FPDs made of OLEDs have the inherent advantages of emissive displays, its wide viewing angle. In addition, due to the flexible nature of the OLED materials, flexible flat panel displays for portable electronics is made possible. The prototypes of OLED display have also been demonstrated in recent years.

The contrast ratio (CR) of OLED display exhibited by Samsung in 2005 can reach 5000:1 in dark ambience, while the contrast ratio of LCD is only 1000:1. The dark state of electroluminescence results from no light emission. On the contrary, the polarizers of LCD are used to block the backlight to display dim frame. Although EL displays have better optical performance than LCDs, EL displays also encounter the issue of sunlight readability. The multilayer structures of EL devices, especially the metal cathode, are surfaces with high reflectance. While operating outdoors or under bright ambience, the inactivated pixel will reflect the ambient light which makes the CR lower. Besides, the photoluminescence is induced because of the absorption of the UV in the sunlight. The phenomenon will induce a serious decrement of the contrast ratio of the EL displays and make the image illegible. This is called as wash-out phenomenon of EL devices.

1.4 Motivation and Objective of this thesis

Transflective LCDs can be operated indoors and outdoors, which portable displays demand. Under dim environment, transflective LCDs use backlight as light source to display images. While being operated in the bright ambient circumstance, the bright ambient light serves as light source due to reflector of the component. Therefore, the backlight is turned off and the power consumption is relatively low. Compared with reflective LCDs, the low aperture ratio of transflective LCDs is a main issue.

EL devices such as OLEDs and PLEDs, self-emissive devices, can be operated as backlight systems. Moreover, the devices have the advantages of high contrast ratio, high light efficiency, thinness, ultra-low response time, possibility of being flexible displays. However, as mentioned before, the wash-out phenomenon reduces image quality.

Every display has its own drawbacks in any viewing environment. Reflective LCDs are superior in bright ambient light, and EL devices perform well in the dusky environment. Since both displays are superior to the others in different ambient light, we present an emi-flective display which combine a reflective LCD and a top emission OLED in a structure by stacking two devices together. The cathode of top emission OLED is thin so that the light from OLED can pass through cathode, and ambient light can also be reflected by the cathode.

In such a stacking configuration, the pixel area of the hybrid display is not divided into the transmission region and the reflective region as transflective LCDs. Thus, the aperture ratio will not be decreased and the light efficiency is higher than the conventional transflective LCDs. In addition, there is no intermediate glass between the reflective LCD and the top emission OLED. The emiflective device with this configuration can be driven by only one circuitry backplane.

1.5 Organization of this thesis

The thesis is organized as following: the principles and the features of the proposed emiflective display and the pixel circuit for the emiflective display will be presented in **Chapter 2.** The mode of operation will also be discussed. **In Chapter 3,** the fabrication technologies to realize our emiflective device are summarized. The measurement equipments will be illustrated. **In Chapter 4,** the circuit simulation software will be used to simulate image uniformity. The simulation results concluding the effect of Vth variation, degradation of OLED are used to verify our proposed pixel circuit. **In Chapter 5,** the fabricated emiflective device will be demonstrated. Further, the measurement including optical and electrical performance will be evaluated. The summary of the dissertation and the future works are given in **Chapter 6.**