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Future Trend of Flat Panel Displays and Comparison of its Driving Methods

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Abstract- **This paper will review principles and driving methods for various type of flat panel displays (FPDs), such as liquid crystal displays (LCDs), organic light emitting displays (OLEDs) and plasma display panels (PDPs). For long time, Cathode ray tubes (CRTs) including CRT projection displays were the only device capable of exhibiting moving picture images applicable to TV receivers. To improve bulky and heavy structure of CRT, FPDs have been developed and are now available in the market. LCDs created various applications of displays, because of its size variation and high-resolution capability. It is essential to understand the operational principle of the display in order to meet the needs. The need of high image quality is increasing and the demand of portability is also increasing as visual information is provided in various media other than TV broadcasting. It is important to optimize the display specifications according to its application. There is a trend of adding new value to the display such as integrating input function and flexibility. The review will also include newly introduced Surface conduction electron emitter display Surface conduction electron emitter displays (SEDs). Furthermore, this paper will introduce aspects of future displays and trends in terms of specifications.**

I. Introduction

Electronic displays have spread widely around the world together with the development of TV broadcast and information technology during the 20th century,. Information displays are essential for human society as a man-machine interface and it is further expected that new displays would bring new ways of obtaining visual information.

Typical displays widely used today are CRT (Cathode ray tube), LCD (liquid crystal display), PDP (Plasma display panel) and projection display. Among them CRTs was the only display for half of the century. Its bulky and heavy structure limited enlarging screen area of CRT less than 40 inches in diagonal size. After a long time of effort in FPD (Flat panel display) development, dot-matrix LCD (Liquid crystal display) came into the market in 1980s. Late 1990s, color PDP (Plasma display panel) was realized for TV use after 30 years of research and development. Major projection display was a CRT projector for a long time, however projectors with a new display engine using LCD or DMD (digital micro-mirror device) have been increasing recently. Nowadays, the display market is occupied by those four major displays, and share of FPD grows year by year. In this situation, research and development on new information displays is still continued aiming for either higher picture quality or new application.

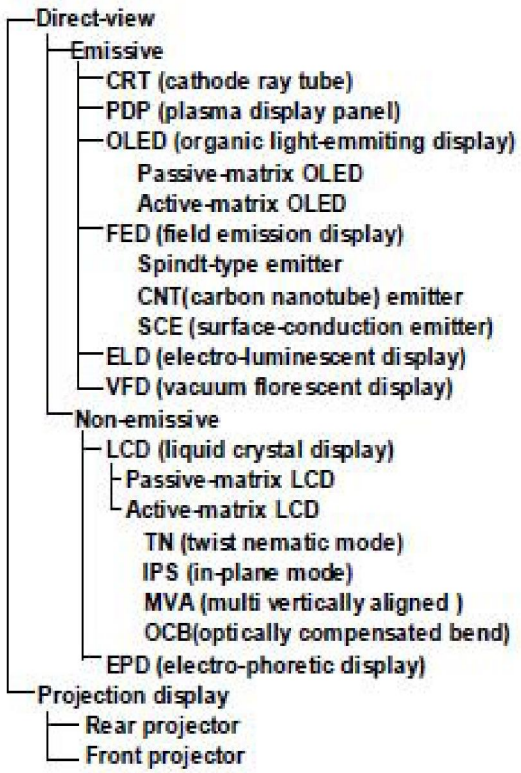

Figure 1, Classification of Displays

FPD technologies emerged by the driving force of mobile PCs and mobile phone. It is also motivated by its feature, mainly flatness, which would enable the use of the space effectively. FPDs are penetrating CRT market and it

is also creating its own market as devices for man machine interface. Including the displays under development, Fig. 1 shows the classification in terms of operational principle. Generally there are direct view and projection type.

The direct-view displays are classified into emissive displays and non-emissive ones. The non–emissive displays like an LCD needs light source and has capability of a reflective display. In view points of driving method, the direct view displays are categorized into a simple-matrix display and an active-matrix display (AM-display). AM-display needs a switching device in each pixel and provides a memory function, which prevents the deterioration of picture quality even for higher resolution display. The detail is introduced latter.

The projection displays are classified into a rear projector and a front projector. The performance of projection displays depends on not only the display engine but also on the optical system including a screen. While the CRT projector has been the most popular one for a long time, the LCD and the DMD projector gradually increases because of high-resolution image. In this paper the direct displays are discussed.

II. Principle of various flat panel displays

It is important to understand the structure and its principle of typical FPDs in order to direct the development of the device to the appropriate application. Each FPDs are based on different technology. In this section principles of typical flat panel displays are introduced.

The schematic view of LCD structure is shown in Fig.2, where screen area is arranged with pixels in x-y matrix and each pixel consists of a TFT (thin-film transistor) and a pixel electrode. This type of LCD is called an active-matrix (AM) LCD and the operation is similar to analog dynamic memory. TFT writes and holds the charge provided through the signal line into the capacitor filled with liquid crystal (LC). The advantage of AM-LCD is that the liquid crystal layer is stably driven during hold period. If the on/off current ratio of TFT is suficient, LCD with a large number of pixels can be realized without deterioration of picture quality.

OLED display has the similar structure with TFT-LCD. Light emitting diode is formed on pixel electrode instead of LC layer and formed by either vacuum deposition of monomer materials or ink-jet printing of polymer materials. Light emitting layer is a pn diode formed with organic materials. AM drive allows OLED to operate in a small current for long lifetime. The advantage of OLED is not only emissive display but thin and light-weight compared to LCDs, since OLED does not need a back light unit. Technical issues of OLED are lifetime of organic materials and improvement of pixel circuits for gray scale control especially in low luminance image. In addition, further development of process technology related to OLED layers is needed in viewpoint of uniformity on a large substrate. Some small OLEDs have already come into the market, however, the target application of OLED is TV.

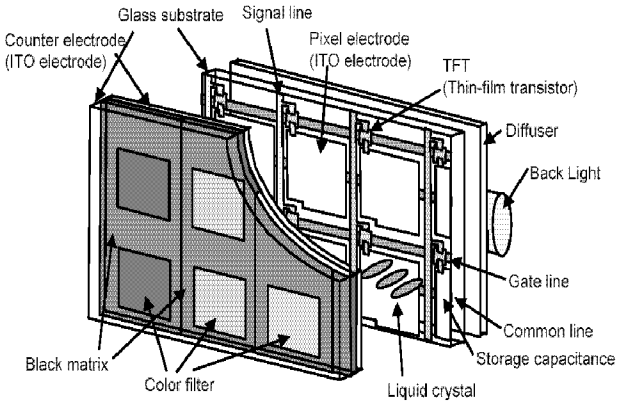

Fig. 2. Cross sectional view of Active Matrix LCDs (AM-LCD)

Figure 3 shows principle of AC-PDP operation and the schematic cross sectional view of a pixel. Space for gas discharge is surrounded with the bottom and the top substrates and the barrier ribs of approximately 100um height. The driving scheme consists of three periods, a writing period to accumulate charges on the surface of dielectric layer, a sustaining period to continue discharge, and an erasing period to neutralize surface charge. The number of discharges controls brightness during the sustaining period. On the bottom substrate, data electrodes formed in vertical direction, protection insulation layer and phosphor layer are formed with the barrier ribs defining pixel space. On the top substrate, sustaining ITO electrodes formed in the horizontal direction, protection insulation layer and evaporated MgO layer are formed. Discharge space is filled with He-Xe gas.

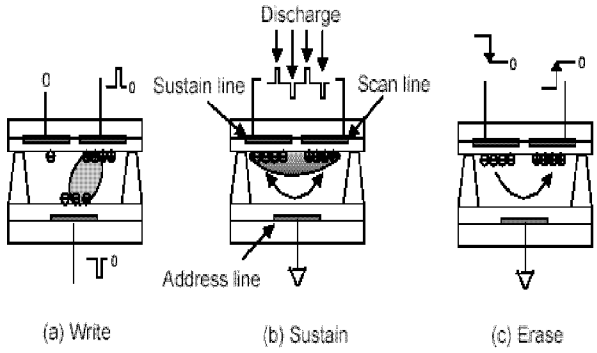

Figure 3, Drive scheme of AC-PDP

Field Emission Display (FED) is a thin CRT, which has a cold emitter at each pixel and an emitted electron beam excites phosphor. A field emitter is the key device and several types have been developed. Typical examples are Spindt type emitter based on thin film process, CNT (carbon nono-tube) emitters, and MIM (Metal-insulator-metal) emitters. Among them, SCE (Surface conduction electron emitter) shows excellent characteristics and comprises the SED (Surface conduction electron emitter display).

Figure 4 shows operational principal of SED and schematic cross sectional view. On the rear glass plate each pixel contains a field emitter, which consists of thin PdO film of about 10nm thick with narrow gap in the order of nm. Emitters operate at about ten volts and flows electron current between nanogap. On the face glass plate red, green and blue phosphors are patterned by screen print. Thin Al metal layer is deposited on the phosphor layer and is applied high voltage of 10kV. Several percents of emitted electrons are reached to the faceplate and excite phosphors. Therefore light emission is the same as that of CRT and SED exhibits the similar picture quality to CRT.

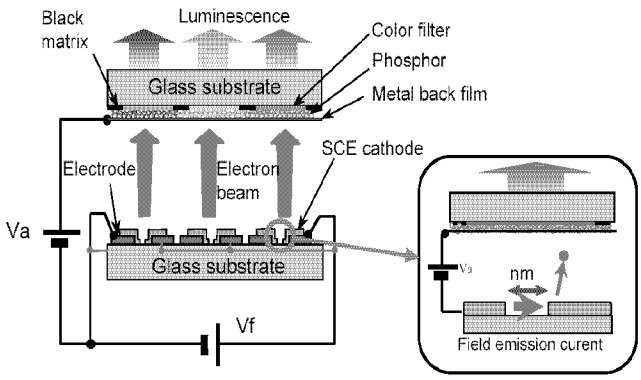

Fig. 4. Operational principle of SED

III. Specification of FPDs

Image quality, display size and power consumption are most important and common factors to describe FPD specification. Priority of specification differs significantly according to the application. For example, image quality and display size are crucial specifications for TV application while power consumption is of more important in terms of mobile application.

Important parameters for image quality are resolution, grey level, response time, contrast and viewing angle. Resolution is given by the number of pixels and it is standardized in several formats (Table 1.). One pixel consists of three sub-pixels corresponding to the primary colors, typically red, green and blue. In terms of manufacturing and considering the total power consumption, dots in consideration should be 3 times the number of pixels. The conventional NTSC TV system is close to VGA and SVGA. High definition TV system uses XGA or Full HD format.

Table 1. Display format

Format		Pixels (H x V)	Number of pixels
VGA	Video graphic adapter	640 x 480	307,200
SVGA	Super VGA	800 x 600	480,000
XGA	Extended graphic array	1024 x 768	786,432
SXGA	Super XGA	1280 x 1024	1,310,720
UXGA	Ultra XGA	1600 x 1200	1,920.000
QXGA	Quadra XGA	2048 x 1538	3,145,728
QSXGA	Quadra SXGA	2560 x 2048	5,242,880
QUXGA	Quadra UXGA	3200 x 2400	7,680,000
HDTV	High definition TV	1920 x 1080	2,073,600

The requirement of resolution and display size are linked by the visibility of human eyes and related how the display is used. Generally, small display size requires small pixel size in order to obtain high resolution while large pixel size is acceptable of large size display. It is needless to say that higher the resolution is better. However in some applications, high resolution ends in over specification. This is one of the reasons there is still many chance for new type of display to appear.

Other than resolution and display size, there are many scales for describing image quality. Ability to produce high grey scale level is important for display. Grey level is linked with the color representation of a display. Fast response time is important especially at presenting moving image. Contrast is also referred as contrast ratio, the ratio of the higher luminance divided by the lower luminance. Higher grey level, faster response and high contrast ration will result in better image quality. In application such as LCD TVs where the display is watched in various angle, picture uniformity is throughout wide viewing angle is essential. It is critical to achieve high level of image quality. However, there is always a balance between high image quality and the cost.

Power consumption is important for displays regardless of the type of display. Screen efficacy usually described in lm/W, brightness in Cd/m^2, and Average power consumption are one of the important parameters in terms of power. It gives significant impact on mobile display where power is provide by battery. There is a growing demand of Low power consumption is there is a need of bearing a battery with its as many functions are integrated in the equipment. Fig.5 shows the power

consumption in terms of screen size. Power consumption increases as the diagonal size increase. Empirically it is roughly proportional to D^2.

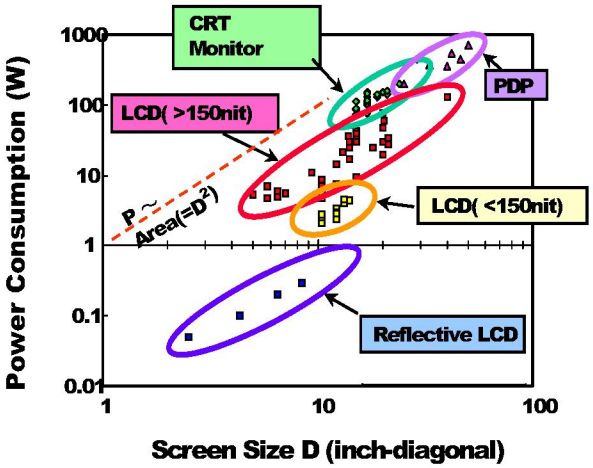

Fig. 5. Power consumption of various display size

Power consumption, as it is in the case of image quality, it strongly depends on the display method. The basic block diagrams of displays are almost identical for FPDs, as it is driven in matrix. Horizontal (X-) and vertical (Y-) driver is connected to the panel. The control unit provides the signal to X and Y drivers. There are displays that act as a capacitive load to driver ICs, such as, LCDs and PDP. There are also displays that act as diode load, such as OLEDs and SEDs. Power consumption is affected by driving method (e.g. refresh rate) for the same type of display. Therefore each driving method must be optimized and developed to obtain low power consumption.

The understanding the portfolio of power consumption of a display is essential in optimizing the total power consumption. For example, backlight of a LCD module consumes almost 75% of the whole module. This would mean that the reduction of power on driver circuit is less likely to give impact. While for the reflective type LCDs where there is no backlight, optimizing the power on driver circuit is efficient. For OLEDs, the luminous efficacy of the light emitting diode would determine the power consumption. This indicates high efficacy of light emitting material.

In terms of driving power consumption, similar to CMOS power consumption, display power consumption is expressed as follows.

$$TPC = SPC + DPC$$
$$= CV^2f + V^2/R$$

Where, TPC is the total power consumption, SPC is the static power consumption and DPC is the dynamic power consumption. C is the driving capacitance, V is the driving voltage, f is the frequency and R is the resistance. Since C is related to the size of the display and f is related to the number of pixels.

Reduction of driving voltage is more efficient than reducing the capacitance or the frequency of the driver. As it is shown in Fig. 5, as there is a strong demand in large size monitors and TV screen, in order to be competitive in power consumption, decrease of driving voltage is most efficient.

It must be noted again that the reduction of power consumption is related to the display method. Portfolio of power consumption on a display must always be taken account.

IV. Future trend of flat panel display

CRTs still dominate the world market in terms of sales. FPDs are creating new area of market because of portability and space efficiency. Fig. 6 shows a very brief history and the trend of future display. There are two directions of evolution in future display. One direction is the trend that the display application expanding. Major demand is receiving TV broadcasting. In the future, there is a strong need of obtaining visual information outside the office and home. Although the expansion of display application is occurring, the conventional applications do not vanish. Therefore, displays evolves in each category while new applications appear or displace the conventional visual device.

In the case of TV and monitors, larger diagonal size and higher picture quality would be the important specification. FPDs have the advantage that the depth of the display does not increase as much as that of CRT as the diagonal size increases. For FPDs, it must still compete with the CRT image quality in order to win the market.

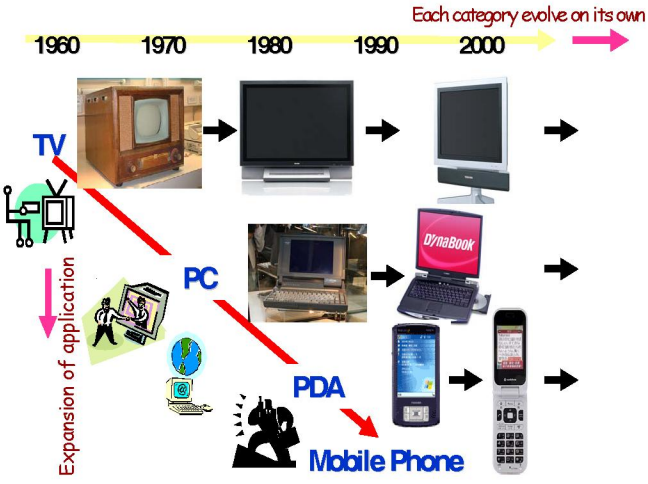

Fig. 6. Evolution of displays

In the case of mobile phone and mobile PCs, low power consumption would be the strong need. It is needless to say that the picture quality is important. However, in the real application, power consumption requirement can surpass the image quality. The situation is directly link to how the power is supplied to the display. When the power is supplied by the battery, low power consumption determines the mobility of the device.

Fig. 7(a). Input display

(b). Flexible display

Although this paper will not go far into the issue of manufacturing cost, it is one of the most important factors which determine whether the display is successful in the market. In the presence of the cost pressure, it is a necessary trend to add value to the display. Functions not provided in conventional displays are added.

There are so many challenges being made in recent research. One example is the input display. Conventional display provides images. Therefore act as output device. Input display as shown in Fig.7 (a) is an example of value added display. A photo-detector is implanted in each pixel of LCD. The picture placed on the surface of the display is scanned through the photo-detector.

Another technology being investigated is the flexible display (Fig.7 (b)). This concept is to realize a paper-like display. There are so many challenges made in this area. However the application is not simple since we already have sheet of paper, which is the strongest competitor. However the challenge is worthwhile if it is possible to provide moving picture on such a flexible display. This would distinguish flexible display to a paper. The image quality, power consumption and the cost are the factors whether it would be competitive in the market.

V. Summary

The principles and driving methods for various type of flat panel displays (FPDs), such as liquid crystal displays (LCDs), organic light emitting displays (OLEDs) and plasma display panels (PDPs) are reviewed. Display specifications are also reviewed. It is essential to understand the operational principle of the display in order to meet the needs. The need of high image quality is increasing and the demand of portability is also increasing as visual information is provided in various media other than TV broadcasting. It is important to optimize the display specifications according to its application. There is a trend of adding new value to the display such as integrating input function and flexibility.

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