Chapter 1

Introduction

1.1 MOTIVATION

1.1.1 LCD Industry and LTPS Technology [1], [2]

The liquid-crystal display (LCD) industry has shown rapid growth in five market areas, namely, notebook computers, monitors, mobile equipment, mobile telephones, and televisions. For high-speed communication networks, the emerging portable information tools are expected to grow in following on the rapid development of display technologies. Thus, the development of higher specification is demanded for LCD as an information display device. Moreover, the continual growth in network infrastructures will drive the demand for displays in mobile applications and flat panels for computer monitors and TVs. The specifications of these applications will require high-quality displays that are inexpensive, energy-efficient, lightweight, and thin.

Amorphous silicon (a-Si) thin-film transistors (TFTs) are widely used for flat-panel displays. However, the low field-effect mobility (ability to conduct current) of a-Si TFTs allows their application only as pixel switching devices; they cannot be used for complex circuits. In contrast, the high driving ability of polycrystalline Si (p-Si) TFTs allows the integration of various circuits such as display drivers. Eliminating LSI (large-scale integration) chips for display drivers will decrease the cost and thickness of displays for various applications.

There are high-temperature and low-temperature poly-Si TFTs, defined by the maximum process temperature they can withstand. The process temperature for high-temperature poly-Si can be as high as 900°C. Hence, expensive quartz substrates are required, and the profitable substrate size is limited to around 6 in. (diagonal). Typical applications are limited to small displays. The process temperature for low-temperature poly-Si (LTPS) TFTs, on the other hand, is less than 600°C, which would allow the use of low-cost glass substrates. This makes possible direct-view large-area displays—for example, UXGA (ultra extended graphics array) monitors of up to 15.1 in. (diagonal) with a resolution of 1600 x 1200 pixels. For this reason, LTPS technology has been applied successfully to not only small-sized displays, but also medium- and large-screen products.

1.1.2 System-on-Panel Displays

LTPS TFT-LCD technology has some features of system integration within a display. It can make a compact, high reliable, high resolution display. Because of this property, LTPS TFT-LCD technology is widely used for mobile displays. Fig. 1.1 shows the system integration roadmap of LTPS TFT-LCD [3], [4].

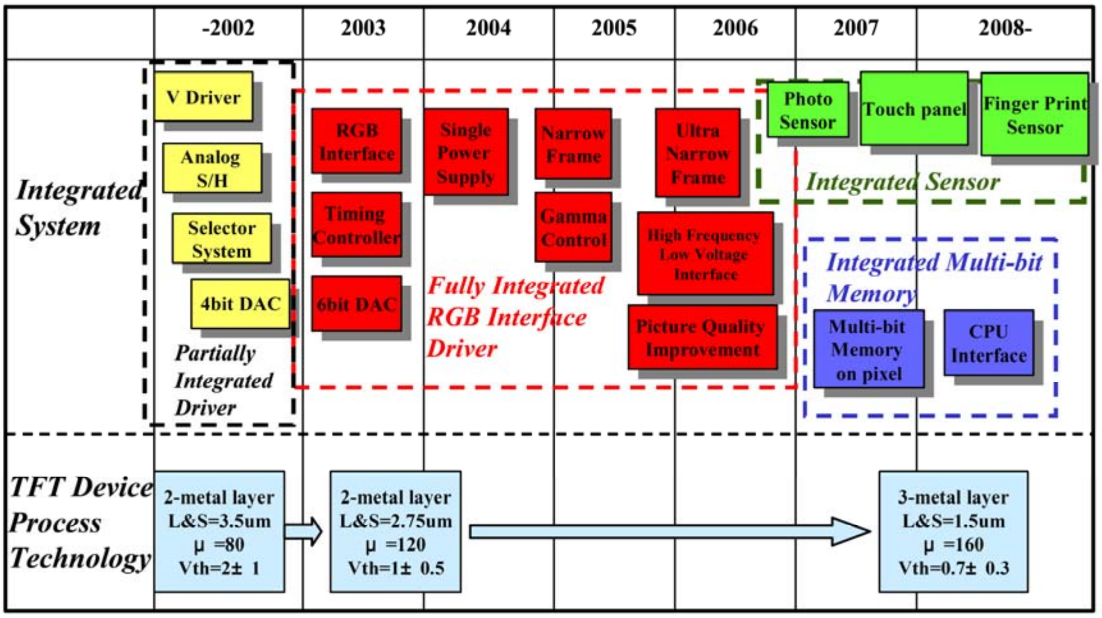


Fig. 1.1 System integration roadmap of LTPS TFT-LCD.

System-on-panel (SOP) displays are value-added displays with various functional circuits, including static random access memory (SRAM) in each pixel, integrated on the glass substrate [3]. Fig. 1.2 shows the basic concept of pixel memory technology. When SRAMs and a liquid crystal AC driver are integrated in a pixel area under the reflective pixel electrode, the LCD is driven by only the pixel circuit to display a still image. It means that no charging current to the data line for a still image. This result is more suitable for ultra low power operation. Eventually, it may be possible to combine the keyboard, CPU, memory, and display into a single "sheet computer". The schematic illustration of the "sheet computer" concept and a CPU with an instruction set of 1-4 bytes and an 8b data bus on glass substrate are shown in Fig. 1.3, respectively [1], [5]. Fig. 1.4 shows the roadmap of LTPS technologies leading toward the realization of sheet computers. Finally, all of the necessary function will be integrated in LTPS TFT-LCD. Although the level of LTPS is as almost the same as the level of the crystal Si of 20 years ago, actual operation of 50MHz with 1μm design will be realized near future [6].

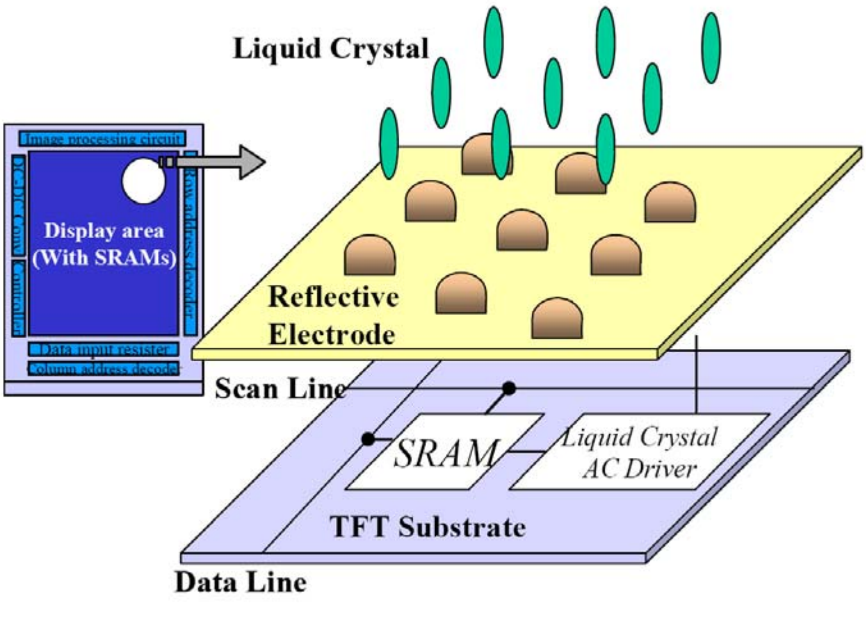
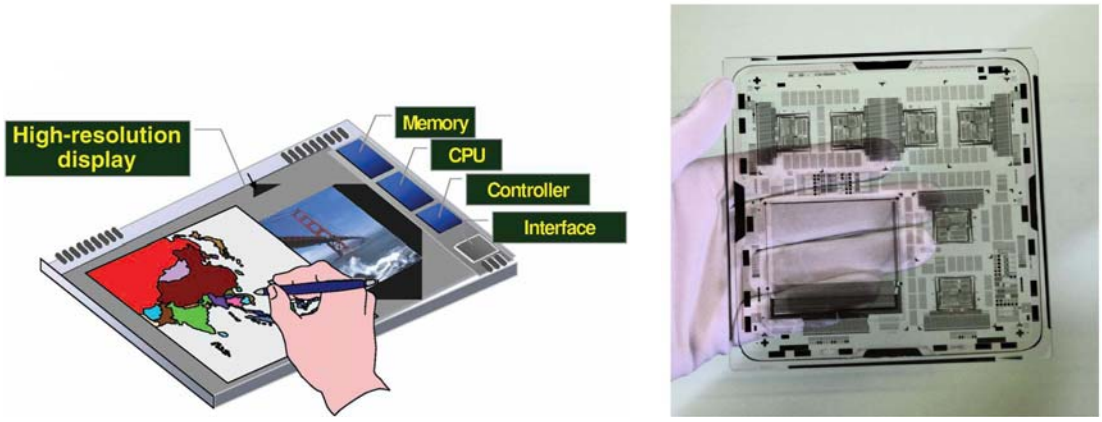
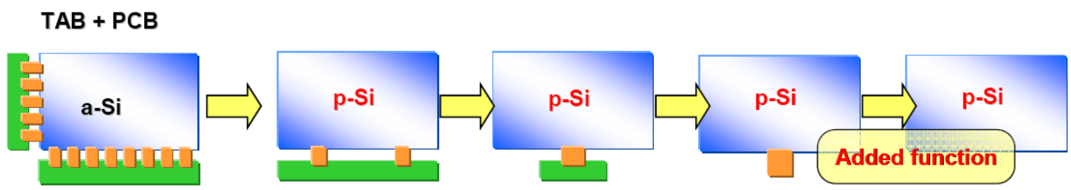


Fig. 1.2 Basic concept of pixel memory technology.



(a) (b)

Fig. 1.3 (a) The schematic illustration of the "sheet computer" concept and (b) a CPU with an instruction set of 1-4 bytes and an 8b data bus on glass substrate.



Year	'98~ 01	'02~ 04	'05~ 07	'08~
Generation	1st Gen .	2nd Gen .	3rd Gen.	4 th Gen.
Mobility(cm2/Vs)	100	150		300~500
Integrated function	LCD Driver	D/A converter Pixel memory	DC/DC Converter Digital I/F Photo-sensor	DSP/CPU Frame memory
Key technology Design rule	ELA, I/D 4-5μ m	Flat-ELA C/H Dry 3μ m	Fine lithography S i-line D ry 1.5μ m	Crystallization Planarization <1μ m

Fig. 1.4 The roadmap of LTPS technologies leading toward the realization of sheet computers.

1.1.3 The Advantages of the SOP LTPS TFT-LCD Displays

The distinctive feature of the LTPS TFT-LCD is the elimination of TAB-ICs (integrated circuits formed by means of an interconnect technology known as tape-automated bonding). LTPS TFTs can be used to manufacture complementary metal oxide semiconductors (CMOSs) in the same way as in crystalline silicon metal oxide semiconductor field-effect transistors (MOSFETs). Fig. 1.5 shows the cross sectional structure of a LTPS TFT CMOS. For a-Si TFT-LCDs, TAB-ICs are connected to the left and bottom side as the Y driver and the X driver, respectively. Integration of the Y and X drivers with LTPS TFTs requires PCB (printed circuit board) connections on the bottom of the panel only. The PCB connection pads are thus reduced to one-twentieth the size of those in a-Si TFT-LCDs. The most common failure mechanism of TFT-LCDs, disconnection of the TAB-ICs, is therefore decreased significantly. For this reason, the reliability and yield of the manufacturing can be improved. Decreasing the number of TAB-IC connections also achieves a high-resolution display because the TAB-IC pitch (spacing between connection pads) limits display resolution to 130 ppi (pixels per inch). A higher resolution of up to 200 ppi can be achieved by LTPS TFT-LCDs. Therefore, the SOP technology can effectively relax the limit on the pitch between connection terminals to be suitable for high-resolution display. Furthermore, eliminating TAB-ICs allows more flexibility in the design of the display system because three sides of the display are now free of TAB-ICs [1]. Fig. 1.6 shows a comparison of a-Si and LTPS TFT-LCD modules. The 3.8" SOP LTPS TFT-LCD panel has been manufactured successfully and it is shown in Fig. 1.7.

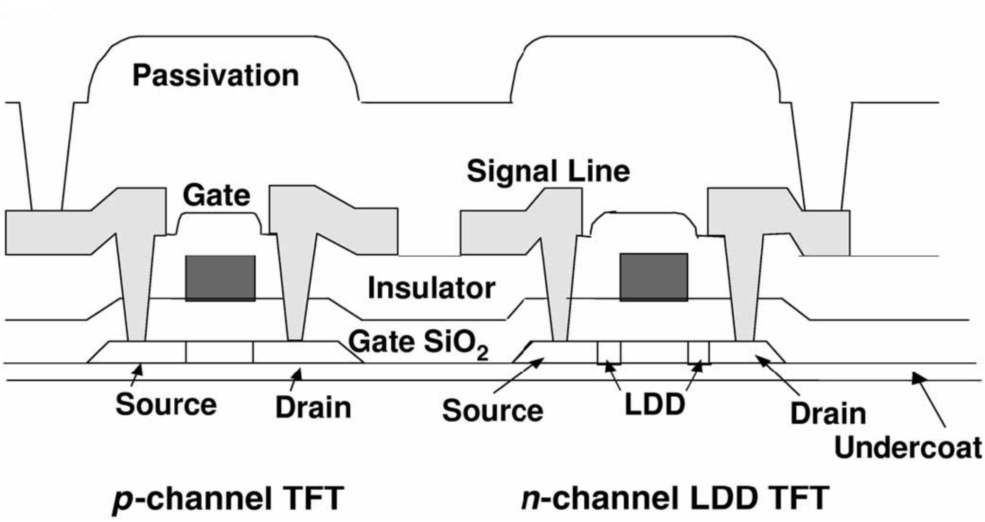
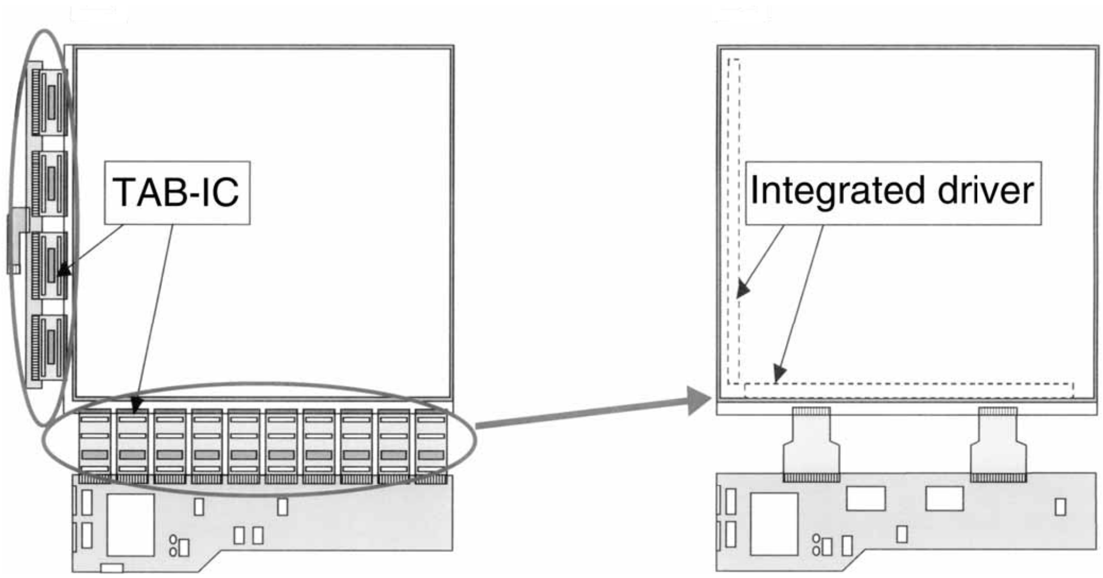


Fig. 1.5 Schematic cross-section view of the structure of a LTPS complementary metal oxide semiconductor (CMOS). LDD = lightly doped drain.



(a) (b)

Fig. 1.6 (a) Comparison of an amorphous silicon TFT-LCD module and (b) a low-temperature polycrystalline silicon TFT-LCD module.

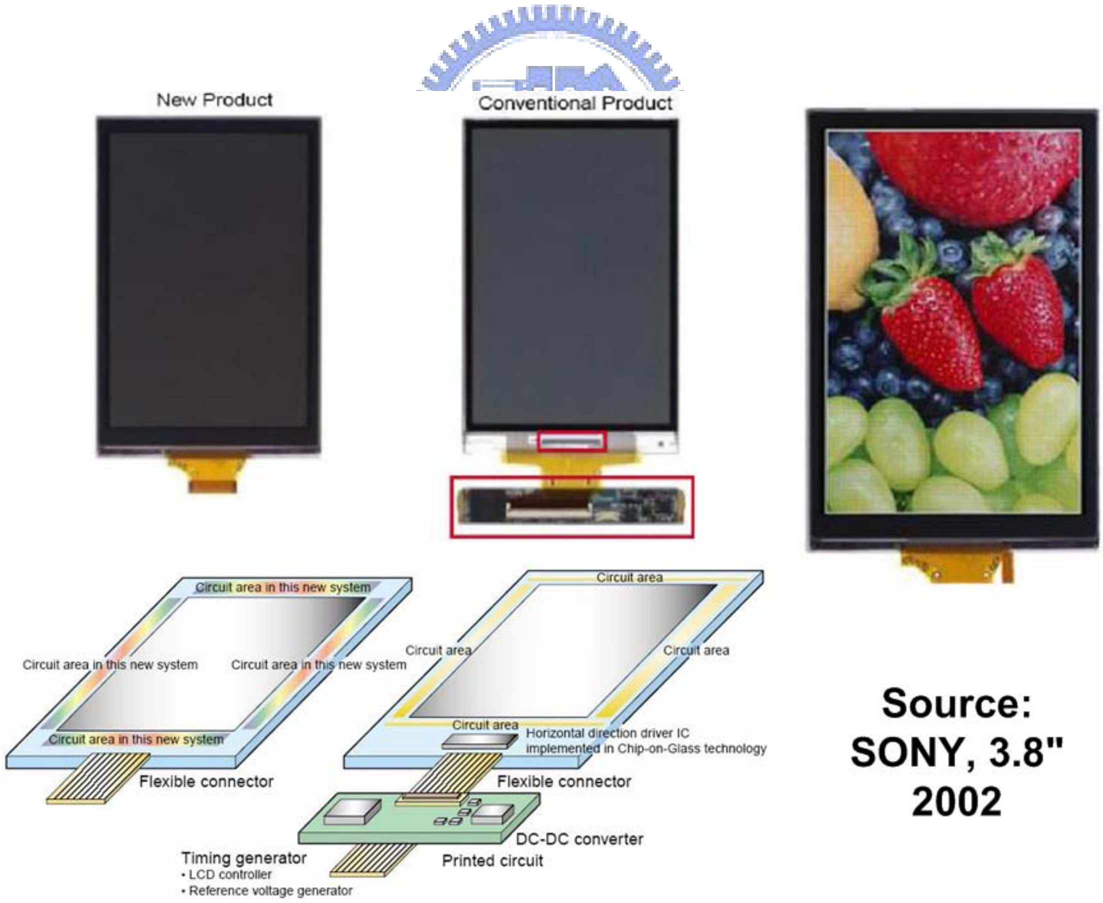


Fig. 1.7 The comparison of new SOP technology product and conventional product. The new 3.8” SOP LTPS TFT-LCD panel has been manufactured by SONY corp. in 2002.

1.1.4 Future Application of "Input Display" [6]

SOP technology also has a potential of integration of input function other than output function of display, which will pave the way for future displays. These various ways of integration are totally expressed by SOP technology. The input display technology opens opportunities for new applications for personal and business use. The new technology is scalable up and down, and can be applied to diverse products, from cellular phones to personal computers. The full scope to our imagination concerning future use of "Input Display" is shown in Fig. 1.8. Its wide range of usage will include recording of text or images for on-line shopping and the like, without a scanner device saving personal data and images to a computer, and personal identification, auto-power control with photo-sensor (or ambient light sensor, shown in Fig. 1.9) suitable for extremely low power cellular phone, detecting the position of finger or pen for some touch-sensing (a new touch-panel is shown in Fig. 1.10), and so on.

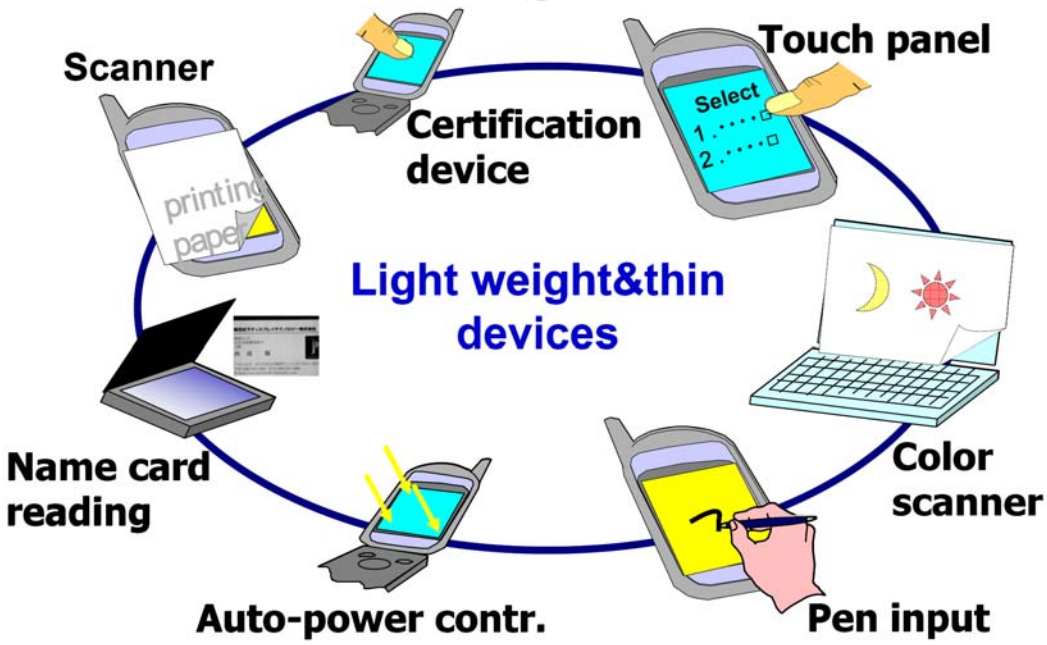


Fig. 1.8 Future application of "Input Display".

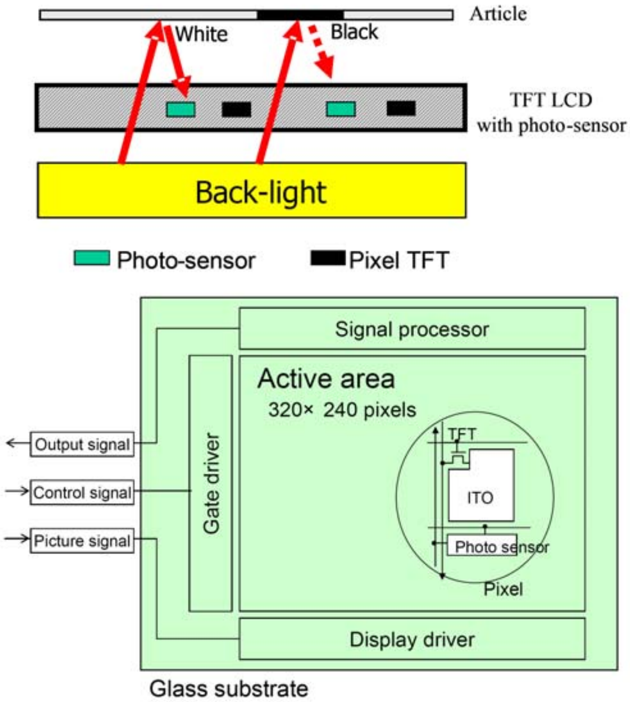


Fig. 1.9 The principle and structure of the photo-sensing display.

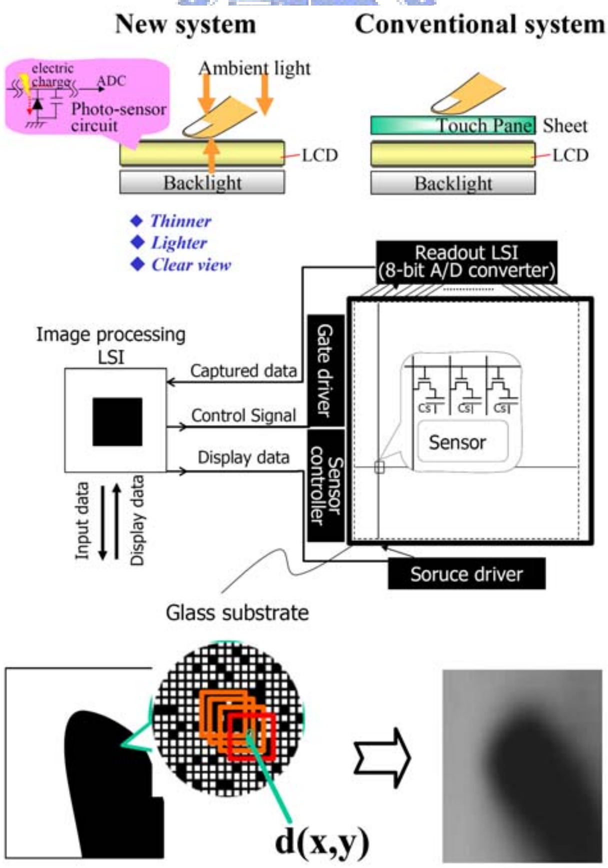


Fig. 1.10 The system architecture and image-capturing finger of this new touch-panel.

According to above discussion, it can see that the fabrication cost will gradually be lowed and SOP (system on panel) will be implemented step by step in the future. Such integration technology contributes to shorten the product lead-time because lengthy development time of ICs can be eliminated. Actually, this integration level has been proceeding from simple digital circuits to the sophisticated ones such as digital-to-analog converters (DACs) [6]. Moreover, LTPS technology is compatible with OLED, which is another promising display device [1]. Therefore, design of driving circuits for TFT-LCD in LTPS technology is worthy expecting in the future. In this thesis, a novel 6-bit folded R-string DAC with gamma correction for on-panel data driver and an on-panel analog output buffer for data driver with suppressing device characteristic variation technique have been proposed in LTPS technology.

1.2 Thesis Organization

In chapter 2, some background knowledge of thin-film transistor liquid crystal displays, like liquid crystal display structure, driving method in TFT-LCD panel and periphery circuit block, will be introduced. The nonlinearity relationship between luminance and human visual system (HVS) and gamma correction will also be discussed in chapter 2. A novel DAC with gamma correction for on-panel data driver will be proposed and verified in chapter 3. Moreover, the analysis and comparison of the many kinds of DAC circuits will also be introduced in this chapter particularly. In chapter 4, an on-panel analog output buffer for data driver with consideration of device characteristic variation will be proposed. Besides, the simulation and measurement results of this proposed analog output buffer will be discussed in this chapter. The last chapter recapitulates the major consideration of this thesis and concludes with suggestions for future investigation.