Chapter 1

Introduction

1.1 Overview of Low-Temperature Polycrystalline-Silicon Thin-Film Transistors (LTPS TFTs) Technology

Low temperature polycrystalline-silicon (LTPS) thin film transistors (TFTs) have attracted much attention in the application of the pixel circuits and the integrated peripheral circuits of active matrix liquid crystal displays (AMLCDs) [1.1]-[1.8] , active matrix light emitting diodes (AMOLEDs) [1.9]-[1.14] and 3-D integrated circuits [1.15], [1.16]. Compared with amorphous Si TFTs, poly-Si TFTs supply higher current drive capability and better reliability. Besides, it can offer the flexibility of being used in the peripheral driving circuitry of AMLCD panel [1.17]-[1.20] to achieve the goal of system-on-panel (SOP) which is the integration of all the components on the same glass substrate, such as active displays, driving circuits, memory, and central processing unit (CPU), etc.

The maximum temperature of fabricating LTPS TFTs is below 600°C which is the common glass transition temperature. This important feature was adopted to replace expensive quartz with large area, low cost glass for many active matrix display and commercial applications.

Recently, a large amount of research and investigation reported that many characteristics of poly-Si TFTs is being improved nowadays. In the process of fabricating

LTPS TFTs, crystallization of a-Si has been considered the most important procedure for excellent performance of TFTs. There are two critical aspects in fabricating high quality poly-Si thin film transistors at low temperature, first is to produce low defect-density polysilicon films and film/gate dielectric interface for the active area. Second is to incorporate and activate dopants sufficiently for the source-drain junctions/contacts. Among many crystallization techniques such as solid phase crystallization [1.18], [1.19], metal induced crystallization [1.20], [1.21], continue wave laser crystallization [1.22]-[1.24], etc., excimer laser crystallization is viewed and adopted as the mainstream technology for mass production of LTPS TFTs nowadays because of low temperature process, and the capability for making high performance poly-Si TFTs [1.25]- [1.27].

Since laser crystallization is a rapid melting and growth process (tens of nanoseconds), it allows glass or plastic substrates to be free from deformation or distortion. The major advantage of excimer laser is that the strong absorption of laser light in the silicon film. Consequently, most of laser energy is absorbed close to the surface of the silicon thin film and the thermal strain on the substrate is much lower. The transformation processes of excimer laser crystallization can be divided into three crystallization regions according to the applied laser energies [1.28], [1.29], including the partial-melting regime, completely-melting regime, and near completely-melting regime (so called super-lateral growth). The sizes of the grains in poly-Si TFTs may be different for many reasons, such as energy density variations across the laser beam area, non-uniformities in the silicon film thickness, and even the random pattern of grains themselves [1.30].

In the following part, several important parameters and some typical phenomena of poly-Si TFTs are indicated as follows:

●**Field-effect mobility**: Mobility, which is the electron or hole drift velocity is proportional to the electric field in the semiconductor material such as Si and Ge etc. The electron or hole field-effect mobility of poly-Si TFTs is extracted from the maximum transconductance (g_m) in the linear region of Id-Vg curve at V_{ds} = 0.1 V, which unit is $cm^2/V \cdot s$. The above the average field-effect mobility of n-type and p-type LTPS TFTs are 100 $cm^2/V \cdot s$ and 80 $cm^2/V \cdot s$.

●**Leakage current**: In the off state of the device (Vgs = 0V), there are still current flow from drain to source which is so called leakage current. This is because the effects of carrier generation and recombination can be obtained by trap levels that lead to increase leakage current. At low drain field, thermionic emission is the dominant leakage mechanism. As the drain bias increase, the thermionic field emission becomes the dominant leakage mechanism. It is considered that band-to-band tunneling is the dominant leakage mechanism at the high drain bias [1.31]. When poly-Si TFT is utilized as the switching transistor, leakage current must be suppressed under 1pA [1.32].

●**Threshold voltage**: The threshold voltage, defined as the gate voltage required to achieve a normalized drain current of $I_{ds} = (W/L)\times 10^{-8}$ A at V_{ds} = 0.1 V is a function of the fixed charges in the gate dielectric film, the defect density in the Si active layer, the doping level in the Si active layer, and the work function of the gate electrode. Devices with more defects require additional gate bias voltage to fill the defects in the channel before the device turns on. Thus, the threshold voltage can be reduced by increasing the grain size.

●**Sub-threshold swing**: When the gate voltage is below the threshold voltage and the transistor channel is in weak inversion region, the corresponding drain current is called the sub-threshold current. The sub-threshold swing in the Id-Vg characteristics is specified the reciprocal of the slope at V_{ds} = 0.1 V.

●**On/off current ratio**: The on/off current ratio is calculated by the maximum current over the minimum current at |Vgs|=20V in the Id-Vg curve at Vds=5V. Devices with large on/off current ratio possess better switching behavior.

●**Kink effect**: The anomalous current increasing in the output characteristics at high drain-source voltages (Vds) is often referred as “kink effect”. Kink effect is due to the impact ionization occurring in the high electric field region close to the drain and is further enhanced by the parasitic bipolar transistor effect [1.33].

●**Hot carrier effect**: The hot carrier effect is induced by the presence of intense electric fields at the drain junction, decided mainly by the abruptness of the lateral doping profile and carrier can gain the energy from this high electric field and breaking weak bonding between Si atoms easily. Hot carrier effect known to produce interface states and oxide trapped charges, depending on spatial distribution, can strongly influence the effective electrical fields as well as the current flow [1.33]. When the transistors operate at high drain bias, hot carrier induced degradation produce electrical instability of poly-Si TFTs which shortens device lifetime.

In order to improve the electrical performance and reliable quality of poly-Si TFTs, a lot of different structures compared with conventional self-aligned thin film transistors were proposed, such as offset-gate structure TFTs [1.34], [1.35], dual-gate structure TFTs [1.36], lightly doped drain (LDD) TFTs [1.37], [1.38], gate overlapped lightly doped drain (GOLDD) TFTs [1.39]-[1.41], and field-induced-drain (FID) TFTs [1.42]. These drain field relief architectures settle several undesired effects, including large off-current, kink effect, and hot carrier effect. Since larger grain represents less defect traps of the grain boundaries, large grain poly-Si thin films always have possession of high performance poly-Si TFTs. Therefore, there are also varied techniques to obtain larger grain size, such as selectively floating a-Si layer [1.43], two-dimensionally position-controlled [1.44], phase-modulated method [1.45], dual-beam excimer-laser [1.46], grain filter method [1.47]-[1.48], sequential later solidification (SLS) [1.49]-[1.51], and so on.

With the rapid maturity and improvement of the device characteristics, the poly-Si TFTs are widely used in not only pixel switch but also driving circuitry. In addition to pixel elements, poly-Si TFTs also can be used as data driver, scan driver, memory, DC/DC converter, and so on [1.52]-[1.62]. In the following sections, more detail information and issues about LTPS TFTs applied in active matrix organic light emitting diodes (AMOLEDs) and system on panel (SOP) are discussed.

1.2 Overview of the Organic Light Emitting Diode (OLED) Displays

Nowadays, many flat panel displays (FPDs) are already developed to be video product extensively, such as cathode ray tubes (CRTs), liquid crystal displays (LCDs), plasma displays (PDPs), field emission displays (FEDs), organic light emitting diodes (OLEDs), and so on. Among these products, liquid crystal displays is the most universal and capable of mass production for large area displays now. However, there are still some issues like the image sticking, high power consumption, small viewing angles, and expensive peripheral components needed to be solved. On the contrary, organic light emitting diode (OLED) displays are progressively researched and investigated nowadays due to various appealing advantages such as fast response time (in μsec scale), wide viewing angle (about 160-180 degrees), compact, simple structure, light weight and the promise of flexible displays on plastic substrates [1.63]-[1.66].

The organic light emitting diode (OLED) with high efficiency was first reported for display applications by C. W. Tang and S. A. Vanslyke in 1987 [1.67]. The organic light emitting diode is basically formed as sandwiched structure, including anode, hole-transporting layer, light emission layer, electron-transporting layer, and cathode. The most popular anode material is indium-tin-oxide (ITO) since not only have a large work function but also be transparent to visible light. About the cathode, AlLi and MgAg alloys possessing small work function are commonly used to inject electrons effectively. When the voltage bias applied to OLEDs, holes injected from the anode will pass through the hole-transporting layer and electrons pass through the electron-transporting layer from the cathode. The lighting-emitting layer between the hole and electron transporting layer is the place where the carriers recombine to form excitons and producing the visible light when the excited state is transformed into the ground state. Because of the light emission process, the brightness of the OLED devices is proportional to the current density passing through it.

1.2.1 Passive Matrix OLED and Active Matrix OLED

OLED displays can be categorized into passive matrix OLEDs and active matrix OLEDs from its driving methods. Each pixel in passive matrix consists of the scan line, data line, and emissive organic material in between [1.68]. Since active switching devices are not required in pixels, the passive matrix OLED with low cost, simple fabrication process, and high yield can be obtained. When the scan line is selected, data line is applied the corresponding image data current to light every diode. The problem with this method is that the diode receives the pulse data signal only in a short time available for diode to illuminate, therefore, the light pulse have to be extremely bright [1.69]. When the image quality gets better and the resolution gets higher, the high current and voltage are needed for the light pulse. However, higher current and voltage drops in row/scan and column/data line would cause higher power dissipation. As the power is not used in luminance, the light emitting efficiency will drop rapidly. On the other hand, the large current flow through OLED will accelerate the lifetime degradation. Moreover, the crosstalk issues still exist in passive matrix driving which limit the high quality display applications.

Therefore, the active matrix driving method is more practical for high resolution display to get better efficiency. The purpose of active driving is to provide a constant current source supply to OLED, replacing the pulse high current method in passive driving. In active matrix driving method, the pixel provides constant current through the entire frame time, allowing for reducing display voltages and peak current at least two orders of magnitude lower than that of passive matrix driving for equivalent brightness [1.70].The active matrix OLED consists of thin film transistors and capacitor array on the substrate.

The simplest structure has a transistor series with the OLED [1.70] which supplies specific current for OLED throughout the frame time. This allows for much lower current levels, but causes the settling times to be much longer. Higher yield and simple driving approaches can be obtained in this active driving method. However, it has no capability of storing the data voltage. For AMOLED, at least two thin film transistors and one capacitor are needed to store data voltage in each pixel, the purpose is that to illuminate continuously throughout the entire frame [1.71]-[1.72]. The first transistor is used as addressing switch transistor (switching TFT) to transmit data voltage to the gate node of another transistor. The second transistor (driving TFT) operates as a current source provider, transfers the data voltage into data current for diode lighting. The brightness of OLED, which is proportional to diode current from power supply line passing through driving TFT, can be modulated by varying data voltage refreshing in each frame time. This driving method is also called conductance control gray scale (CCG) [1.9].

1.2.2 Emission Structures for AMOLED

There are four emission structures reported nowadays for AMOLED including bottom emission, top emission, transparent emission, and double sided emission which will be discussed in detail as follows.

- **Bottom Emission**

The anode material of bottom emission structure AMOLED is the transparent anode (ITO) connected with driving transistors, deposited in organic luminescent layer and the thick reflective metal cathode on the top surface is to increase light emission efficiency and stability [1.73]. The emitting light generated from organic luminescent layer eventually passes through the transparent ITO and glass substrate in spite of reflecting from cathode or directly passing through the transparent anode. Since the transistors, capacitors, data line and scan line fabricated on substrate consist of metal which achieve certain thickness hindering the light coming through. This will lead to smaller light emission area ratio which means smaller aperture ratio of the AMOLED. Therefore, the luminance efficiency is decreased as the active area is reduced. When the same brightness is required in different displays, higher supplied voltage must be applied to get the larger current in the smaller aperture ratio device. This behavior will cause the higher power consumption and accelerate the device degradation.

- **Top Emission**

On the other hand, if the base anode material of AMOLED is nontransparent metal and the cathode material is semitransparent metal; the light will be reflected by the base nontransparent metal and illuminate through the top surface finally. The major advantages of top emission compared with bottom emission are that the aperture ratio will not be changed or reduced by the numbers of thin film transistors and capacitors. This unique property gives designers elasticity when they design the back panel. Besides, the nontransparent substrate also can be used as the display substrate in top emission structure.

The light is a multiple reflection of the emission between anode and cathode resulting in a change of the shape of emission spectrum caused by interface [1.74]. Advantage of this micro-cavity effect is to enhance and improve color saturation. However, the effect must be well controlled and calculated to avoid generating color shift. The situation raises the process complexity of top emission fabrication process.

- **Transparent Emission**

The transparent emission structure uses the semitransparent cathode and transparent anode to emit the light through both top and bottom side, so it is also called top and bottom emission or dual emission. One of the benefits is that the OLED doesn't need circular polarizer because the cathode is transparent not reflective [1.66], [1.75]. In addition, the display is thin and lightweight with the two displays of the inside and outside. An image can be seen both from top and bottom sides of the display with the same brightness.

- **Double Sided Emission**

The sub-pixel area of double sided structure is divided into two regions, which consists of top emission and bottom emission. The disadvantages of transparent emission images shown on both sides of the display are the same and they are mirror images to each other [1.76]. The double sided structure was proposed to be capable of displaying two independent images solving the limited product applications of dual emission. Two types of OLED structures, top and bottom emission are fabricated on the same panel. To show the different images simultaneously, the image mixer is needed to integrate the different pictures and transfer signals to the image processor. Nevertheless, this method will increase the number of process steps and only about half emission area can be obtained.

1.2.3 Driving Architecture Comparison between AMLCD and AMOLED

The inner structure of liquid crystal display is surrounded by two pieces of glass substrate, including transparent electrodes, alignment layer, liquid crystal, color filter, and spacer etc. Because liquid crystal is non-emissive material, backlight is obligated to supply light source. By means of polarizing filter, the un-polarized light can be controlled towards the specific direction. The transparent electrode is ITO usually connected with liquid crystal and switching transistor, providing a voltage for twisting liquid crystal. The alignment layer is composed of organic material in the cause of aligned the liquid crystal arrangement. There are many kinds of liquid crystal for the same purpose that when the voltage is applied to the two terminals of liquid crystal, the liquid crystal will twist. The twist angle is dependent on the external voltage source deciding the amount and direction of light. In order to achieve full color for display, the three fundamental colors: red, green, blue must be collocated. Color filter is composed of these three fundamental colors to deploy any kind of color to show full color. The spacer is formed by silicide or organic resin in sphericity to control the thickness of liquid crystal.

Considering the AMLCD, a pixel element contains a single active switch and one capacitor. The active switch can be either a diode (two-terminal device) or a transistor (three-terminal device). Amorphous silicon (a-Si) and poly-crystalline silicon (poly-Si) transistors were developed for this active switch used in the early 1980s. When the scan line is selected during frame time, the data signal will pass through the switching transistor and be stored in the capacitor. The tilt angle of liquid crystal is determined by magnitude of the supplied voltage. Since the active transistor device acts as a switch, the display uniformity wouldn't be affected by the varied characteristic of transistor.

On the other hand, OLED is a emissive device, the pixel circuit of AMOLED consists of two transistors and one capacitor mentioned in 1.2.1 section. When the scan line is selected during frame time, the data are sampled by the switching transistor and stored in the capacitor. The data voltage form is transferred by the driving transistor into current in order to drive the diode. Since the current is a function of characteristic of driving transistor, variations of the characteristic across the panel will produce serious non-uniform image brightness in the display. This issue becomes a crucial problem in high definition and large size panel in the prospective display.

1.2.4 Comparison of Transistor Types: A-Si TFTs vs. LTPS TFTs

There are many researches using a-Si TFT or poly-Si TFT as the backplane for AMOLED [1.10], [1.11], [1.77]-[1.79]. The advantages of a-Si TFT backplane are lower manufacturing cost, cheaper equipment, less process steps and high yield attractive for the industry. However, the small grain size and disorderly grain texture of a-Si TFT limits the device mobility (< 1 cm^2/Vs). On the contrary, the electron (or hole) mobility of poly-Si TFT is two orders higher than that of a-Si TFT due to thousands Å order grain size. Since OLED is a current driven device, higher current flow means the higher brightness. Thus, the poly-Si TFT backplane owns brighter picture than a-Si TFT in the same device dimension. To increase brightness, the W/L ratio of a-Si TFT must be enlarged which occupies the OLED emission area and leads to small aperture ratio in bottom emission structure. As the resolution getting higher in high quality display, the pixel pitch becomes smaller which maybe confine a-Si TFT design and image quality. On the contrary, the powerful driving feature of poly-Si TFT provides the possibility of integrating driver system and reducing the driver IC cost.

The OLED current is determined by the driving transistor, the threshold voltage of a-Si TFT shifts obviously after long term display operation. Therefore, the same input data voltage result in different output current after a long time. On the contrary, the threshold voltage of LTPS TFT is quite stable [1.78].

The weaknesses of LTPS TFT are the uniformity problem and the equipment cost. The non-uniform electrical characteristics of transistor result in the non-uniform brightness from pixel to pixel. It is difficult to control the critical picture uniformity within acceptable margin simply from the fabrication process. From the view of circuit design, the compensation pixel circuits will be studied and discussed in this dissertation.

Considering a-Si TFT and LTPS TFT, each has its own advantages and disadvantages in mentioned topics. The display products develop towards high quality and low cost, tradeoff must be decided by the designers. In general, LTPS TFT has excellent performance and lower cost in small size panel, a-Si TFT shows well-established technology and better uniformity in large size panel.

1.3 System on a Panel (SOP) Issues in LTPS TFT

The advantages of integrating poly-Si TFTs circuits in the panel are not only it can allow pixel pitch to go beyond the bonding pitch of IC chips, but also permit to integrate a variety of circuitry not merely drivers [1.80]. However, the poly-Si TFT LCD module still costs a lot and consumes much power since it needs high driving speed and a wide voltage range analog interface [1.81]. If the TFT driver achieves full digital interface of transistor to transistor logic (TTL) or a lower voltage level, the cost of LCD module will be reduced and power consumption will be decreased.

1.3.1 Concept of System on a Panel

In short, the meaning of system on panel can be defined as the entire system integration on a single substrate including active matrix displays, integrated peripheral circuits, memory circuits, and controller circuits [1.81]-[1.84]. The first system on panel prototype was proposed by Sharp Corp. and Semiconductor Energy Laboratory Co. in 2004, which realizes the integration of CPU, an audio circuit, a graphic controller, and memories on the liquid crystal display by continuous grain silicon (CGS) technology. CG silicon fabricated in low temperature by catalyst assists solid phase crystallization, which doesn't subject to the effects of variations in laser density [1.85]. This crystallization method offers superior reliability and uniformity. The 8-bit CPU contains about thirteen thousand TFTs and operates at 3MHz with 5V voltage supply.

Various kinds of voltage or signal losses come into existence in the module because the system has to transfer enormous data between the large scale circuits at high frequency [1.81]. If the large scale circuits can be entirely integrated in the same substrate without sacrificing functional properties, the total performance will be improved and the power consumption will be diminished theoretically. More importantly, the size, weight, and cost of the system will be cut down which is beneficial to the consumers.

There are two main considerations to achieve the goal of system on panel. First, the properties of poly-Si TFTs must be improved such as better mobility (~200cm^2/Vs), lower sub-threshold swing (~0.1V/dec), lower threshold voltage(~±0.7V), higher on/off current ratio (~10^{10}) are needed. Second, the circuit interconnection technique needs to be promoted. When shrinking the transistor size, excellent uniformity and reliability are critically required for the development of SOP.

1.3.2 Peripheral Circuitries across the Panel

Many researches have been proposed and realized the system on panel (glass or plastic substrate) by means of device techniques, novel material and driving method [1.1], [1.86]-[1.87]. The functional blocks are introduced in this section. The full-functional system is a complicated system comparising a LCD, a CPU, an audio circuit, a graphic controller, ROMs, RAMs, a voltage generator, and a clock generator [1.83].

Considering the performance and the cost in present technology, integration of the LCD part with scan drivers, data drivers, timing controller, DC/DC converter, reference voltage driver, and interface circuit are beneficial and practical for business works. The interface circuit contains three functions [1.88]-[1.89]: divides the 6-bits string data signal into odd band and even band, delays the sending LSB with reference to its MSB, and synchronizes the output signal before inputting into data driver. The reference voltage driver is used to provide the various gamma reference voltages to the digital-to-analog converter (DAC) circuits. A counter and an output generating circuit compose the timing controller, which decodes the output from the counter to control signals at corresponding time. The charge pumping DC/DC converter circuit [1.90]-[1.92] is designed to generate high voltage level supplying voltage to the interface circuit, reference voltage driver, common voltage driver, timing controller, gate/scan driver, and source/data driver.

In general, the data driver contain many parts, including data receiver, data register, shift register (S/R), level shifter (L/S), digital-to-analog converter (DAC), and analog buffer. While the scan driver contains shift register, level shifter, and digital buffer. The data entering the source driver is received by timing controller; the data specification can be classified into three categories: traditional transistor transistor logic (TTL), reduced swing differential signal (RSDS) that is extensively used, mini low voltage differential signal (mini-LVDS) for high frequency application in the future. The function of data register is received the signal from data receiver. Sample and hold registers compose the data register which receives serial data and send parallel data. Basically, the shift register is a series D type Flip-Flop, it outputs one pulse signal in every clock cycle when start pulse signal inputs first D type Flip-Flops [1.93]-[1.95]. The level shifter is a digital circuit holding the 3.3V voltage swing, and then outputs about -10V to 20V [1.96]. The simple schematic of level shifter is four transistors and one inverter, a pair of opposite signal input. The lowest voltage is pulled down from 0V to -10V, and the highest voltage is pulled up from 3.3V to 20V. Since the digital signal 0 or 1 only is transmitted from the front end interface, analog signal is needed to drive the liquid crystal to show gray level. Therefore, digital-to-analog converter [1.97] is requested to generate 64 or 256 gray scales depending on specification through the divided voltage. The analog buffer is indispensable to drive the large RC loading of the scan line or data line.

The system on panel can not represent the catchword of low cost and high performance nowadays because of the yield rate. Therefore, it must strike balance between cost and performance according to the product specification.

1.3.3 Critical Issues of System on a Panel

System on panel has the great potential for eliminating the printed circuit boards (PCBs), the tape automatically bonding (TAB) or chip on glass (COG) or chip on film (COF) and reducing the module assembly process and equipment costs. System on panel is definitely suitable for high resolution applications because the pixel pitch is not restricted by the terminals [1.98]. However, in order to meet the requirement of system on panel, several qualities in the process and electrical characteristics of LTPS TFT need to be further improved. There are several critical issues of system on panel, such as uniformity, electrical characteristic performance, process design rule, power consumption, reliability, yield, and so on which are discussed in the following article.

●**Uniformity**

LTPS TFTs crystallized by ELC process suffer from poor uniformity compared with a-Si or crystal Si devices due to the narrow laser process window for producing large-grain poly-Si film. The fluctuation of pulse-to-pulse laser energy density and non-uniform laser beam profile lead laser energy density difficult to hit the super lateral growth (SLG) region in large area. The grains are randomly distributed in the device channel region so that electrical characteristic of TFTs suffers large variations, especially in the small dimensions.

●**Electrical Characteristic Performance**

As we know, the major image quality of display overwhelmingly is dependent on the fundamental device electrical characteristics. The most effective approach for improving the electrical characteristic performance of LTPS TFTs is to reduce the defect traps in the poly-Si thin films and the poly-Si thin film/gate oxide interface. During 2001~2002, the mobility of Sharp Corp. is 200 cm^2/Vs which push forward to 300 cm^2/Vs in 2003~2004, and to 400 cm^2/Vs in 2005~2006 presently, which the logic frequency reaches 20-30 MHz [1.84].

To further improve the electrical performance of LTPS TFTs, scaling down the dimensions is an effective approach. When the devices are scaled down, the short channel effect must be well controlled. Besides, the gate oxide thickness is also reduced hardly to meet the requirements such as breakdown voltage, leakage current, etc. Therefore, high quality with uniformity gate oxide and poly-Si thin film plays significant roles in next generation LTPS TFTs.

●**Process Design Rule**

The process design rules of TFT circuits are looser than single crystal Si MOSFETs.

There are several reasons for this subject [1.99]: First, due to the fabrication of TFTs is on large area substrate so that the processes such as etching and photolithography are restricted. Second, under high drain bias situation, short channel effects are relatively severe in TFTs rather than that in MOSFETs, which increase difficulties in designing small dimensions especially. Third, twisting the polarities of liquid crystal needs a total voltage range of about 10V. Therefore, the supply voltage at least 15V is required in large area devices, which represents that the broader line width are needed.

In 2001~2002, the design rule of Sharp Corp. is 3 μm which is pushed forward to 1.5 μm in 2003~2004, and to 0.8 μm in 2005~2006 presently. In conclusion, the technologies including photolithography, cleaning and etching must be pushed forward and developed for the display mass production so that the design rule is suitable and endurable for the system on panel.

●**Power Consumption**

There are several types of integrated data drivers for LCDs [1.81]: point-a-time analog driver, line-a-time analog driver, decoder type digital driver, and D/A converter type digital driver. The point-a-time driver has the simplest configuration, but high speed and wide voltage range is required that consumes a large amount of power. The line-a-time has sufficient driving capability to drive large TFT-LCDs, but it is difficult for poly-Si to achieve good uniformity. As for full digital interface applications such as personal computer, the digital type makes the total circuit system simple and requires lower power consumption. In addition to driving method, there are several methods for reducing the power dissipation such as enhancing the LED or backlight efficiency, lowering the row and column resistance etc.

●**Reliability**:

The stability and reliability of device electrical characteristics under long-term operation play a significant role in integrated circuit applications [1.100]. The crystallized poly-Si thin film contains strain bonds (tail state) and dangling bonds (deep state) which need passivation process by hydrogenation, deuterium, oxygen, and nitrogen. However, the hydrogenation passivation process, for example, also generates a lot of weak Si-H bonds in poly-Si thin film. These weak bonds can easily be broken during device operation, which will result in the huge variation in device characteristics. Since thin film transistors in peripheral circuits are subjected to high pulse voltage compared with that of pixel TFTs [1.101]. Consequently, high stability and reliability are strongly demanded for the peripheral circuits. One of the most serious reliability problems is hot carrier effect because of the carrier trapped in the Si film/oxide interface or within oxide causing threshold voltage shift and transconductance lowering [1.101]-[1.104].

For this reason, the reliability of LTPS TFTs must be taken into consideration carefully when they are applied to circuitry.

●**Yield**:

For system on panel applications, the additional process steps and the additional mask steps are needed to fabricate the driver circuits. Besides, these integrated circuits are designed in minimum size to reduce the panel size, which will be closely fabricated as possible. This will drop the yield rate and raise the cost. The most important thing is striking a balance between performance and capitalized cost.

1.4 Motivation

When the TFT device characteristic is further improved and dimension is scaled down in the future, variations become the dominant issue in mass production. Device variations are a major limitation for manufacturing the high quality display. Therefore, device and circuit variation compensation techniques play important roles in development of system on a panel. At first, multi-channel device structure with slicing layout method is investigated to improve the uniformity. After that, pixel compensation circuits for AMOLEDs and source follower type analog buffers for system on panel are discussed and developed in this dissertation.

1.4.1 From the Aspect of Device Structures – Interdigitated Layout and Multi-channel Structure to Improve Uniformity between LTPS-TFTs

With the mature of display technology, many researches have been reported that the fewer the grain boundaries within the channel region, the better the electrical characteristic of LTPS-TFTs will be. However, an increase in the average grain size leads to an increase in variations in the number of grains. This tough problem will degrade the uniformity of electric quality of low temperature poly-Si TFTs seriously. In this section, the uniformity and electrical performance of interdigitated layout and multi-channel structure with slicing layout method are investigated. Only layout method must be modified without changing the original process and additional masks.

1.4.2 From the Aspect of Circuit Design -- Pixel Compensation Circuits for AMOLEDs and Source Follower Type Analog Buffers for System on Panel

Due to the LTPS TFT suffers huge variations, the AMOLED displays non-uniform picture resulted from the varied characteristics of driving transistor, and the output buffers of column drivers cause the real output voltage not to achieve the target value leading to the wrong gray scale and the bad uniformity as they are integrated into the glass substrate.

In this part, in order to further enhance the image uniformity of active matrix OLEDs, the different driving methods have been compared and evaluated. Though digital driving methods can compensate the variation of threshold voltage and mobility, it is not suitable for them to be applied to high resolution products due to the limited process ability or the high driving speed. Therefore, by means of analog voltage programmed circuits, new pixel circuits for compensating the variation of threshold voltage in LTPS TFTs are studied.

Among the many data driving circuits employing LTPS TFTs, the output buffer is indispensable to drive the large load capacitance of the data bus. However, comparing to the MOSFETs, the LTPS TFTs suffer from poor electrical characteristics and huge device-to-device variation mainly due to the non-uniform grain structure and size across the whole glass substrate. Since thousands of output buffers are necessary for a poly-Si TFT-LCD, it is very essential to develop novel analog buffers dealing with the device non-uniformity. Electrical characteristic variations of LTPS-TFTs will cause the real output voltage not the target value and lead to the wrong gray scale. In the analog buffer section, different types of analog buffers are investigated and compared to find excellent candidate for the output buffer circuit for the “System on Panel” application.

1.5 Dissertation Organization

In chapter two, the uniformity and performance of interdigitated layout and multi-channel structure with slicing layout method are investigated and discussed. Only layout method can be modified without changing the original process. Besides, the mechanism of improving uniformity and electrical performance is elaborated in detail.

In chapter three, all the pixel compensation circuits for AMOLED were categorized and discussed. According to the compensation principle, these pixel circuits can be simply classified into digital driving, analog driving and novel driving circuits. Dimensional effects of transistors and storage capacitor in the conventional pixel circuit were simulated, the transistor slicing method with multi-channel structure are used to enhance uniformity. To overcome the problems caused by spatially non-uniform characteristics between thin film transistors across the panel, two new pixel circuit designs for active matrix organic light emitting diodes based on the low-temperature polycrystalline silicon thin-film transistors were proposed and verified by SPICE simulation.

In chapter four, conventional pixel circuit with two transistors and one capacitor is fabricated and measured. After that, the proposed pixel circuit has been fabricated to compare with conventional pixel circuit. In order to measure the impacts of each component on individual pixel circuit, a measurement system and additional probes were set up to evaluate the anode voltage of OLED successfully.

In chapter five, several design considerations for analog buffer for displays are listed and discussed. Furthermore, operational amplifier type and source follower type analog buffers using low-temperature polycrystalline silicon thin film transistors for AMLCDs and AMOLEDs will be compared and simulated. An active load is added and a calibration operation is applied to study the effects on the source follower circuit. Source follower type threshold voltage compensation circuit with two n-type thin film transistors, a capacitor, and four switches structure is proposed to enhance image quality for the display. The threshold voltage difference of driving TFTs and the unsaturated of output voltage are eliminated in this circuit.

In chapter six, the multi-channel structure mentioned in chapter 2 is applied to the driving TFT in the conventional source follower to improve the uniformity of output voltage performance in this section. The transistor operation mode region is also discussed in detail. The proposed circuit is capable of minimizing the variation from both the signal timing and the device characteristics through the simulation and measured results. Bias voltage of the active load corresponding data voltage is also discussed in detail.

Finally, summary and conclusions as well as recommendation for further researches are given in chapter seven and chapter eight, respectively.