Chapter1

Introduction

1.1 Background

Thin-film transistor (TFT) liquid-crystal displays (LCDs) has become the master stream in flat-panel display industry due to its thin thickness, light weight, high resolution, less power consumption, and low radiation. Most of TFT-LCDs use amorphous thin-film transistors (a-Si TFTs), which are well-known for the particular advantages including:

1. Without laser annealing, the a-Si TFT is suitable for large panel fabrication.
2. The cost is reduced because less manufacturing masks are required.
3. Intensive researches and studies have been reported for a long time.

The recent technology trend of a-Si TFT LCD is to realize the so-called high-value added display or sheet computer having input functions. Among various applications, the touch panel has drawn much attention and its development is growing up in incredible speed.

The earliest touch panel is resistive type, which uses two ITO films biased and dot spacers holding the structure between them. Fig. 1-1 shows the structure of resistive touch panel. When touching, the pressure of the external force makes the upper ITO layer contact with the lower ITO and the voltage drop at that touching point becomes zero. Consequently, the touching input function can be realized by recognize the site of the short circuit. Although the resistive touch panel operation is simple, the physical abrasion and lower photo penetration can not be accepted.

Following the resistive touch panel, Surface Capacitive Touch Panel (SCT), shown in Fig. 1-2, is adapted. Anatomically, the most significant difference between SCT and resistive touch panel is that the SiO_2 layer is deposited on the upper ITO film to strengthen the surface scratch resistance. The touch panel function is carried out by shaping up the current path due to conductive human body when touching. Even if the SCT lasts longer than resistive touch panel, the problems of noise and static electricity need to be overcome. Besides, SCT is greatly affected by the conditions of the human body and circumstances.

The third kind of touch panel is optical touch panel. In early stages, the optical touch panel worked by applying the infrared emitters and sensors. A sketch map of infrared optical touch panel is shown in Fig. 1-3. When the path of infrared is blocked by some object such as fingers, the sensor receives no signal so that the touching position can be obtained. The disadvantage of this type of optical touch panel is the extraneous expenses of infrared devices.

In recent years, another type of optical touch panel called embedded optical touch panel is published based on the same principle of photo path of IR sensors. As the name suggests, it uses the existing TFTs embedded in the panel as the photo sensors to realize the touching functions with the truths that the amount of the light reaching the TFTs depends on that the photo path is kept out or not and that the currents of the a-Si TFTs vary with the intensity of the ambient light illuminated on it, as shown in Fig. 1-4 [1]. The advantage of this kind of optical touch panel is that its integration of light sensor reduces module complexity and the location of the sensors close to the pixel array simplifies integration in produces. Since the sensors are fabricated on the glass substrate using the same fabrication process, fabrication costs can be saved.

Although the embedded optical touch panel seems perfect, there is a limit in it with the fact that it is only in the **OFF** region that the currents of the **conventional** a-Si TFTs vary with the intensity of the ambient light illuminated, which restricts the magnitude of current. In other words, we must use an amplifying circuit in the panel in order to read out the small current signal in off region, which increases the cost of fabrication process. As a result, in this thesis, we propose to use another non-conventional structure called **Gap-Gate type** TFTs as photo sensors instead of the conventional type. The greatest advantage of Gap-Gate TFTs is that the photo effect exists in both on and off regions and we will discuss the two regions individually to find the best operating range.

1.2 Motivation

In this thesis, we attempt to develop an integrated optical sensor into the display by using the photo sensitivity of a-Si TFTs. In such a way, without any change of manufacturing processes, the cost of added optical sensing function can be reduced.

In previous works, the photo-sensitive leakage current of conventional a-Si TFTs is used to be the sensing signal, but it has the problem that the current signal is too small to be read out. As a result, we try to bring in the Gap-Gate type TFT to be the sensing device, which has better photo sensitivity in both the on and off current regions and can be made by the same fabrication processes as conventional a-Si TFTs. Therefore it can be employed to realize the touching function integrated in panel with minimized extra cost.

1.3 Thesis Organization

In chapter 2, the circuit implementation of the integrated touch panel is described. The conventional 2T1C signal readout circuit with source follower and another improved one are used for operating in the off and on regions of Gap-Gate TFTs respectively. Then, in order to find the best sensing conditions and stability, we compare the operating regions of Gap-Gate TFTs in the following two chapters; the photo effect of the off region for both front light and back light are intensively analyzed in chapter 3, along with the comparison of conventional type of a-Si TFTs; in chapter 4, owing to the degradation of the currents of a-Si TFTs under photo illumination with time past, , we conduct some experiments to examine the photo reliability of Gap-Gate a-Si TFTs and some correction method is proposed to modify the degradation effectively. In chapter 5, the final conclusion of the feasibility to realize the optical touch panel with a-Si TFTs is given.

The thesis organization is listed below:

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1.1 Background

1.2 Motivation

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Chapter 2: Sensing Array Circuit

2.1 Structure of a-Si TFTs

2.2 Operation Regions

    2.2.1 Operation in the OFF Region

    2.2.2 Operation in the ON Region

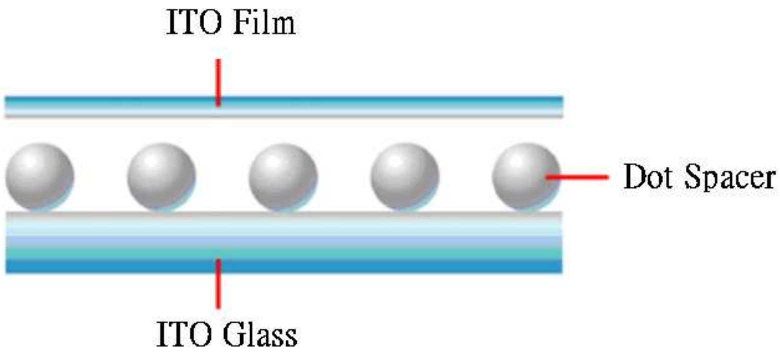

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Fig. 1-1 The cross-section view of the resistive touch panel

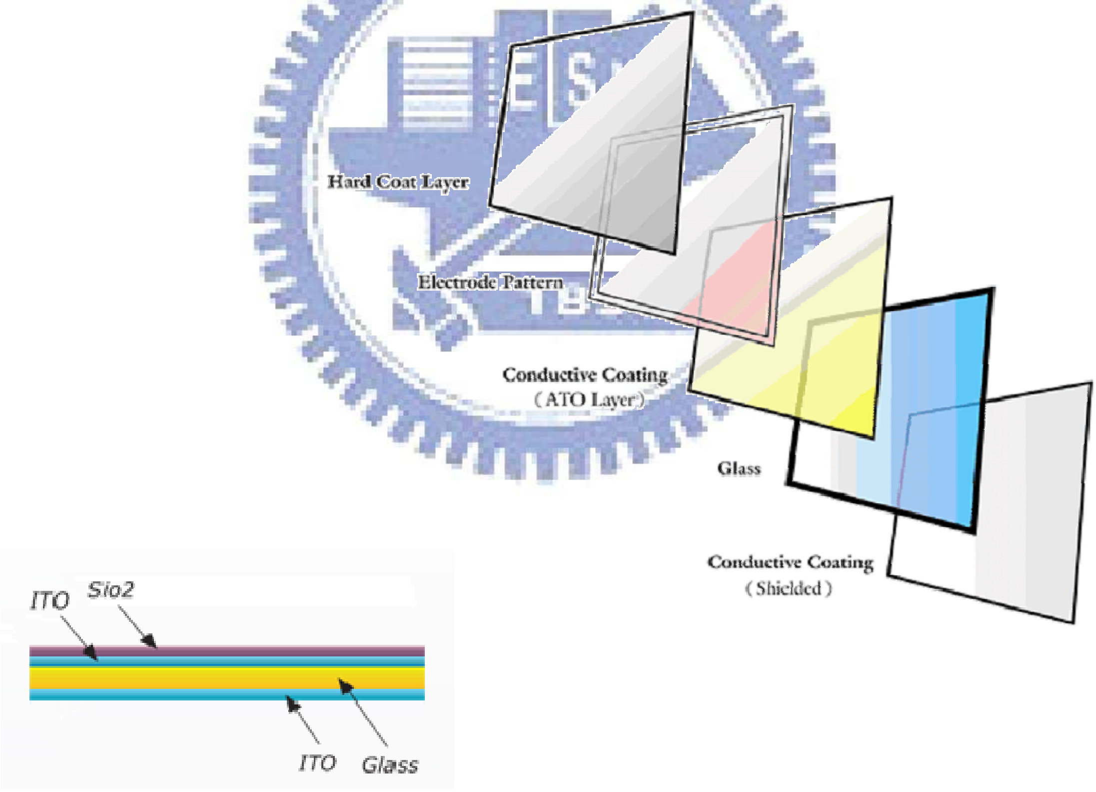

Fig. 1-2 The structure of SCT in cross-section view

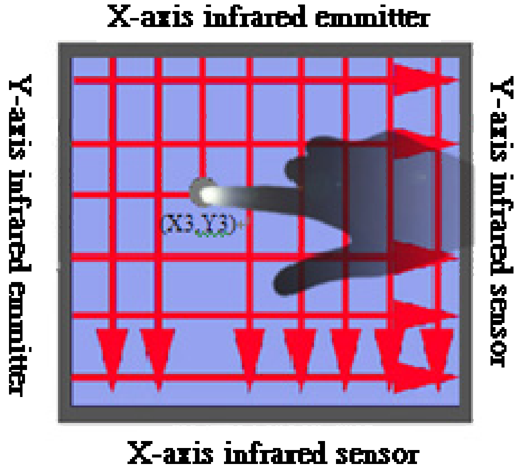

Fig. 1-3 The traditional optical touch panel using infrared emitters and sensors

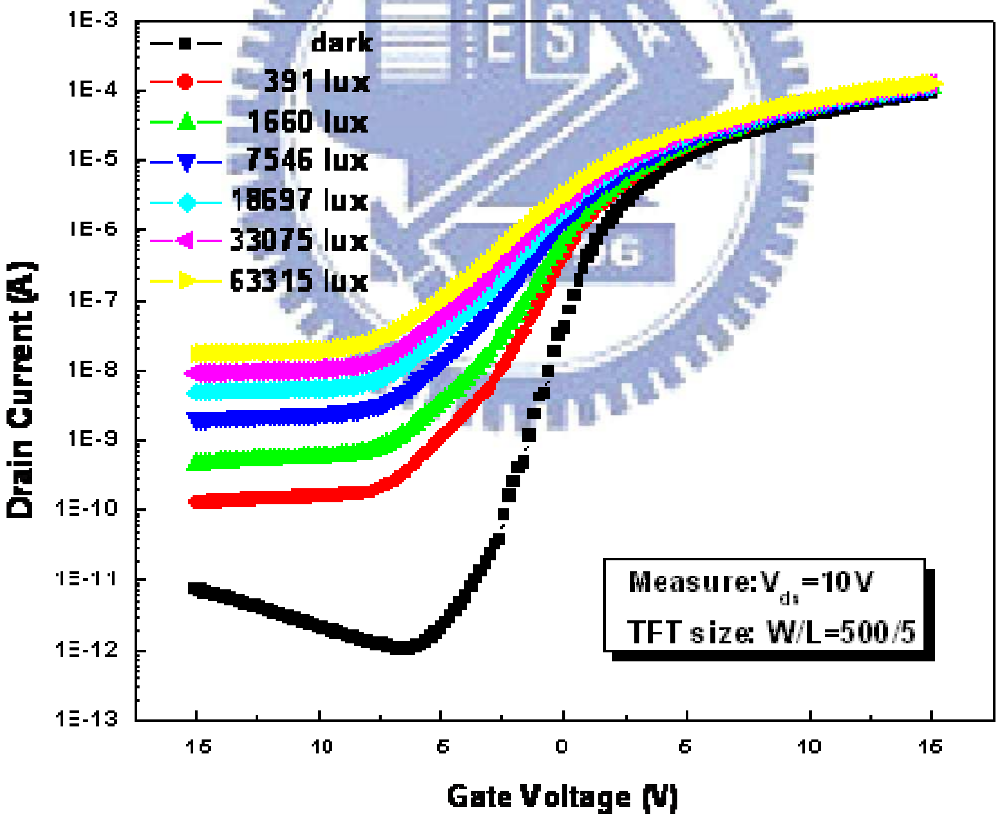

Fig. 1-4 The ID-VG characteristic curve of traditional a-Si TFTs

Chapter2

Sensing Array Circuit

2.1 Structures of a-Si TFTs

There are two kinds of a-Si:H TFTs are introduced in this thesis, i.e., conventional type and Gap-Gate type. The conventional a-Si:H TFTs are usually designed as bottom-gate inverted staggered structure and fabricated on the glass substrates. The cross-section view of a conventional-gate a-Si:H TFT is shown in Figure 2-1(a). After the deposition and patterning of gate metal on the glass substrate, three layers, i.e., silicon nitride (SiNx, 350 nm), a-Si:H, and n^+ a-Si:H films, were successively deposited in a plasma enhanced chemical vapor deposition (PECVD) system. After making the source/drain electrodes, the n^+ a-Si:H region with length (L) of 5μm between the source/drain electrodes was etches off by a reactive ion etch. Then, a passivation layer was used to cap the channel region.

The structure of a Gap-Gate TFT is shown in Figure 2-1(b) [2]. The most important difference between conventional TFTs and Gap-Gate TFTs is that the source contact of the latter is recessed from the gate electrode to form a highly-resistive gap region. In other words, there is a length of a-Si:H active layer which is not overlapped with the gate metal electrode. Because the similarity of structures, Gap-Gate TFTs can be fabricated in the same process as the conventional TFTs and can be successfully applied in active-matrix LCDs.

For the optical touch panel, the TFTs devices play the most important role in the whole design. As a result, a detailed analysis and standard assessment of the effect of illumination on the a-Si TFTs electrical performances are necessary before the device is applied to be used as a photo-sensor. In our research, in order to increase the signal-noise ratio (SNR), we hope the dark current ($ID_{\_dark}$) is lower and the photo current ($ID_{\_photo}$) is higher. That is, we want to select a TFT device by considering the high ratio of ($ID_{\_photo}/ID_{\_dark}$), which is marked as $R_{L/D}$ [3].

In this chapter, only the primitive evaluation of the performances for illumination effects on the a-Si TFTs is conducted. The more detailed study of the photo effect of TFTs will be discussed in Chapter 3.

2.2 Operation Region

The magnitude of the sensing signal to be fed to the readout part is a critical issue in the peripheral circuit design for the touch panel. The basic concept is that the signal must be large enough so that it will not be confused by the unwanted noise. In the world of electronic circuit, the signal means the currents or voltages, and here it is the drain currents of the TFTs that we are interested in. According to the experience, for example, the drain current needs to be $3x10^{-8}$ A at least in order to read out the signal correctly. By the way, we focus on the illumination below 10000 Lux, because the actual intensity of ambient light in our living environment is no more than 10000 Lux.

Figure 2-2 (a) shows the ID-Vg curve of a conventional TFT in the dark as well as irradiated at six different levels of halogen lamp illumination from the front side. The devices are biased in the ON, subthreshold, and OFF regions, in the range of V_{gs}=-15~+15V. Figure 2-2 (b) shows the ID-Vg of a Gap-Gate TFT, for which the experimental conditions and the bias voltages are the same as those of Figure 2-2 (a). Considering the possible threshold voltage shift of TFTs, subthreshold region is not suitable for practical use. Thus we will only focus on the ON and OFF regions. The spectrum of the halogen lamp we use is shown in Fig. 2-3.

2.2.1 Operation in the OFF Region

Figure 2-2 (a) shows that the drain current of a conventional TFT, of which the aspect ratio W/L is 500µm/5µm.Under 7546-Lux illumination, which is close to the general operating environment, the OFF current is about 1.6x10^{-9} A. Therefore, to get enough signal current of 3x10^{-8} A, the W/L should be increased by 20 times, i.e., 10000µm/5µm. Obviously, it is difficult to produce such a giant device in the practical panel without impinging the pixel aperture ratio. As for a Gap-gate TFT with W/L=500µm/5µm, although the drain current in the OFF region is slightly higher than a conventional one by two time under 7546-Lux illumination, it is also ineffective to reduce the device size to a degree that is really applicable. However, with the method of embedded amplifying circuit to be described in section 2.3.1, we can still use the current in the OFF region,

2.2.2 Operation in the ON Region

Figure 2-2 (a) shows that there is almost no photo effect for a conventional TFT in the ON region. On the contrary, under 5440-Lux illumination, the ON current of a Gap-Gate TFT with W/L=500µm/5µm, can be up to 1.2x10^{-6} A which is much larger than what we want by 40 times, as shown in Figure 2-2 (b). It means that we can directly use the Gap-Gate TFTs as the photo sensor with the reasonable size because it offers a sufficient current signal in ON region. Also, it implies that the opening ratio of the panel can increase. Furthermore, the cost can be reduced because no special low-noise circuit consideration is needed to deal with the small current signal.

2.3 The Readout Circuit

2.3.1 The Readout Circuit for OFF Current

The readout circuit so-called 2T1C circuit in a pixel was previously proposed [4-6] to amplify the small current signal. It was fabricated on the glass substrate using a-Si technology for verification. The circuit and its light-sensing operation are shown in Fig. 2-4 (a). The TFT T1 is a photo sensing transistor, which is used to sense the light. The source electrode of T1 is connected to one terminal of C_s and the gate electrode of T2, where we marked as node A. The other terminal of C_s is grounded. The TFT T2, together with a resister between the source of T2 and ground, forms the readout circuit as a source follower.

The operating principles can be described as two period shown in the timing diagram. In the first period, which is also called charging period, the gate signal of T1 is "High" and T1 is turned on. Thereby, the input voltage (V_{in}) "High" is stored in C_s and the voltage of node A (V_A) is charged to "V_{in_High}". In the other period, also called discharging period, the gate voltage of T1 is applied "Low" so that T1 is turned off and operating in the OFF region while sensing operation. At the same time, Vin becomes "Low" and the photo leakage current drained away through T1. As a result, the voltage V_A is discharged by the photo leakage current of T1. It is noted that the current through the gate of T2 is low enough to be regarded as ideal as zero. The magnitude of V_A can be observed by the source-follower circuit composed by T2 because the voltage V_{out} is equal to V_A minus the threshold voltage of T2.

In actual operation, for example, we can apply 10V and -10V to T1 as "High" and "Low" respectively. For V_{in}, we can put in 5V and let it discharge through T1 to 0V. The output voltage V_{out} of the source-follower circuit can be measured by oscilloscope during discharging period in the dark and under illumination, as shown in Fig. 2-4 (b) and (c), respectively. The discharging rate of V_A which is due to the photo leakage current of T1 is equal to the discharging rate of V_{out} and can be expressed as dV/dt. Consequently, the slope (dV/dt) of the waveforms can reflect the drain current under illumination and in the dark, so that the illumination intensity can be sensed.

Although the previous readout circuit is effective, there are still several disadvantages for it. First, the 2T1C circuit needs extra control bus to operate the photo transistor in proper region. Fortunately, considering the incorporation of our circuit design into pixel, we can try to use the existing buses in the TFT-LCD pixel array but avoid adding new buses. Second, though we regard T2 as an ideal TFT with no gate current, actually the source-follower circuit is still a load to T1 and will make an impact on the photo leakage current to a degree. The third disadvantage, also the worst one, is that the 2T1C circuit occupies too large area and makes the aperture ratio poor.

2.3.2 The Readout Circuit for ON Current

In this thesis, we introduce another sensing circuit for the ON current operation, as shown in Fig. 2-5. A Gap-Gate TFT in every pixel acts as the sensing TFT. It is connected in series to a normal TFT with conventional structure. The scan bus is connected to the gate electrodes of these TFTs. The drain end of this pair of TFTs is connected to a high voltage VDD and the source end is connected to the data bus. When the ambient front light illuminates on the panel, only one scan line is selected to switch on the photo “ON” current. More than one thousand of the other photo currents are pinched to the low “OFF” current of the normal TFTs. The aperture ratio is easily made larger than that of the pixel circuit with source follower.

In the peripheral, an OP amplifier is used to integrate the current signal. It is possible to us the existing OP amplifier buffer in the IC driver, and thus the total cost can be preserved.

In this configuration, the only “ON” current can be much higher than the sum of the other one thousand OFF currents, so that the effects of TFT leakage current can be neglected.

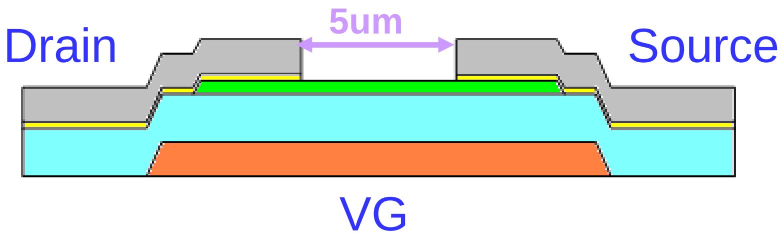

Fig. 2-1(a) The cross-section view of a conventional-Gate a-Si structure

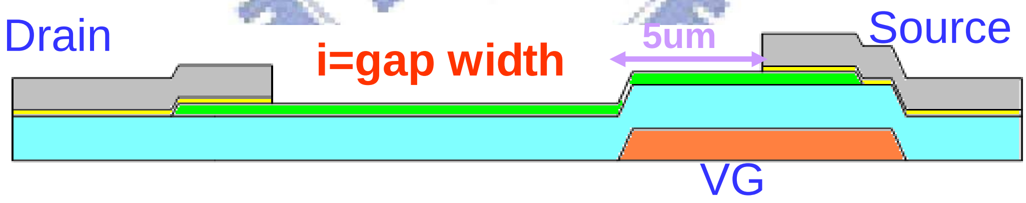

Fig. 2-1 (b) The cross-section view of a Gap-Gate a-Si structure

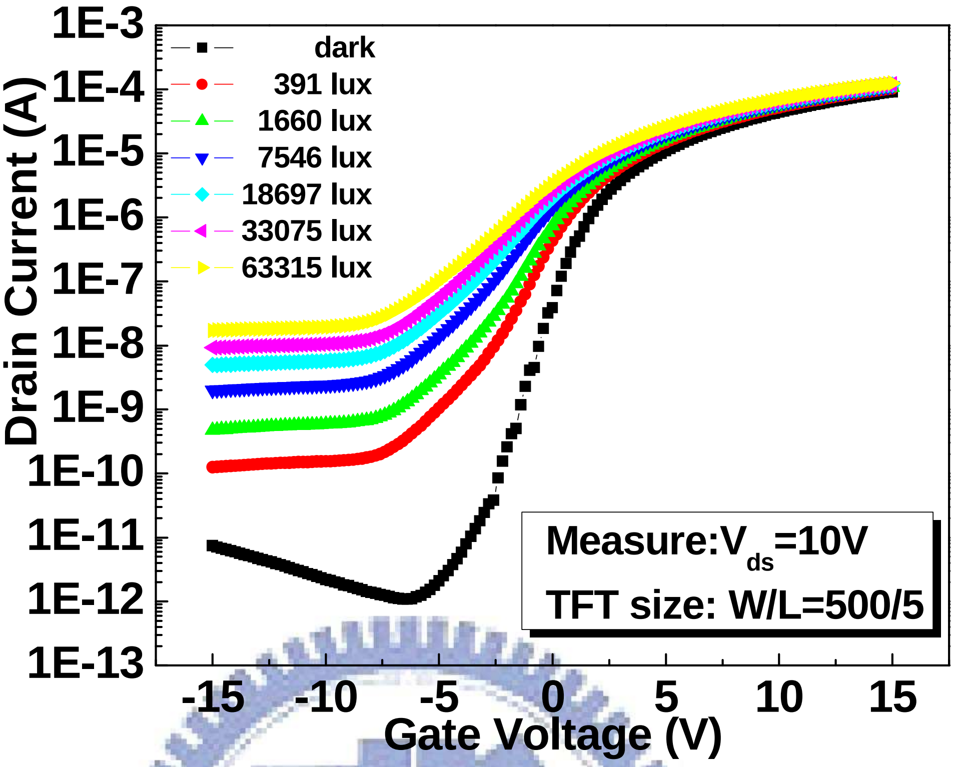

Fig. 2-2 (a) Conventional-gate TFT transfer characteristics in the dark and under illumination at V_{ds}=10V

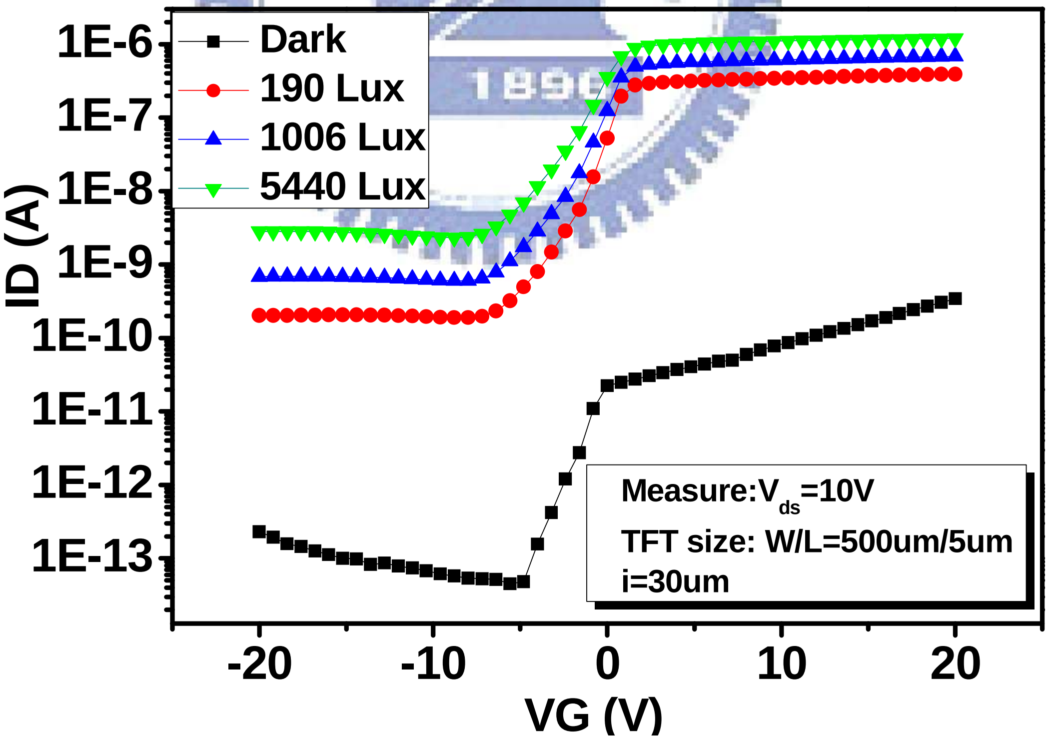

Fig. 2-2 (b) Gap-Gate TFT transfer characteristics in the dark and under illumination at V_{ds}=10V

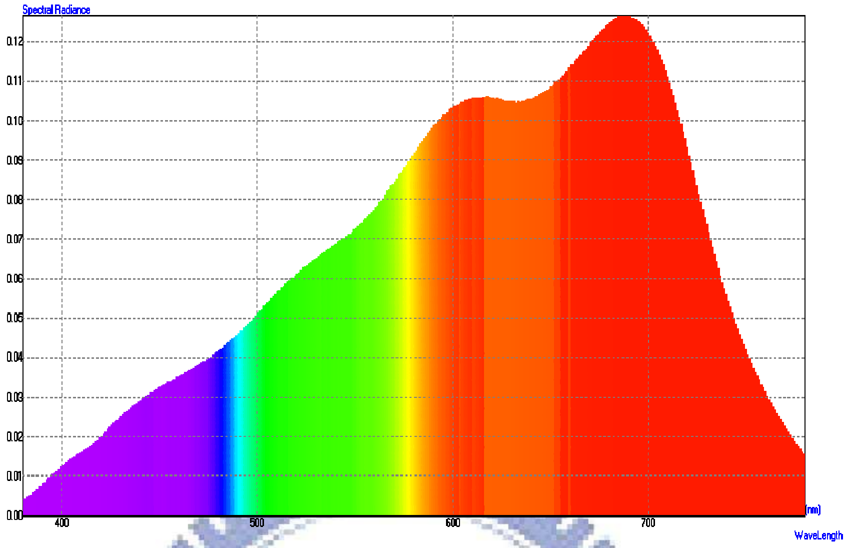

Fig. 2-3 The spectrum of the halogen lamp which is used in the experiment

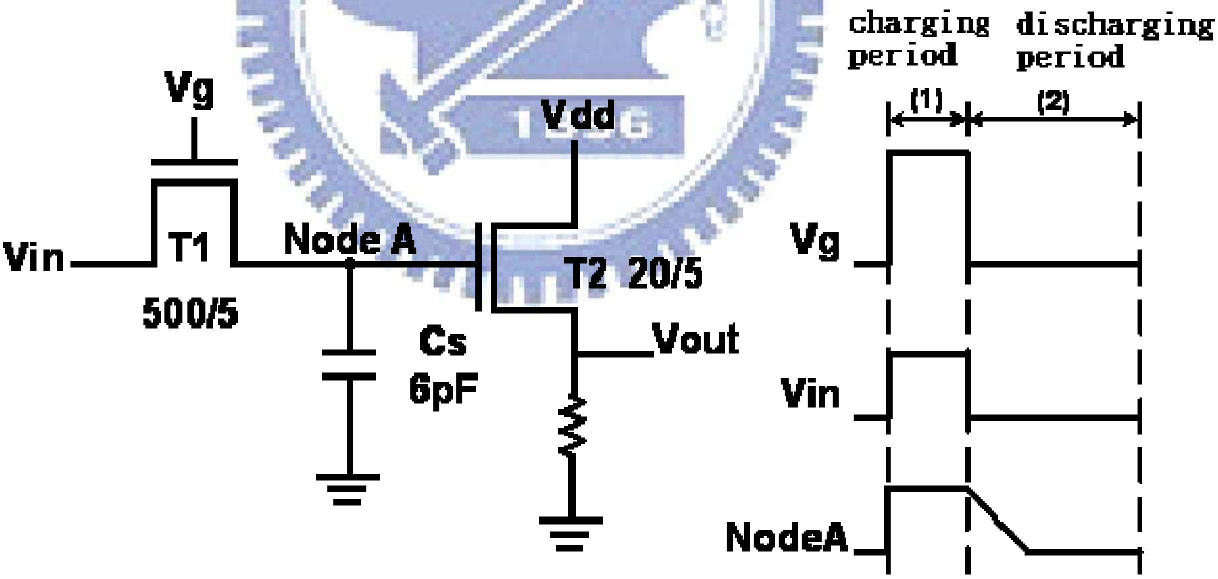

Fig. 2-4 (a) Source follow as the readout part of sensor

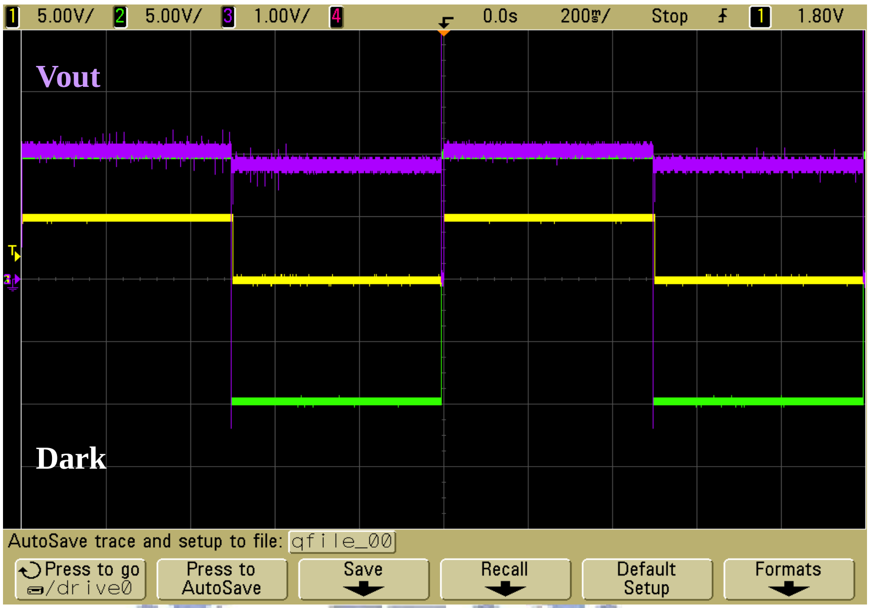

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Fig. 2-4 (b) The result of the light sensing circuit in the dark

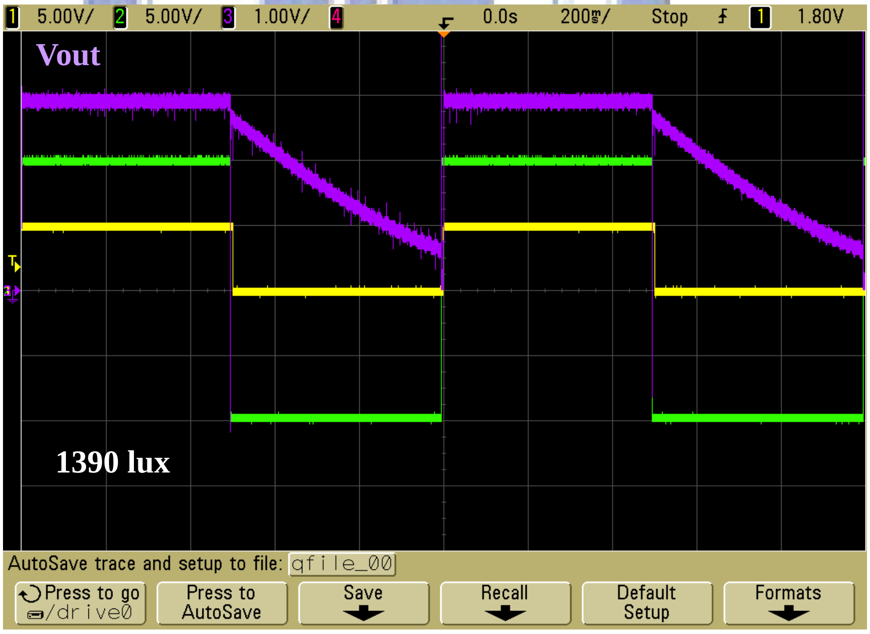

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Fig. 2-4 (c) The result of the light sensing circuit under illumination

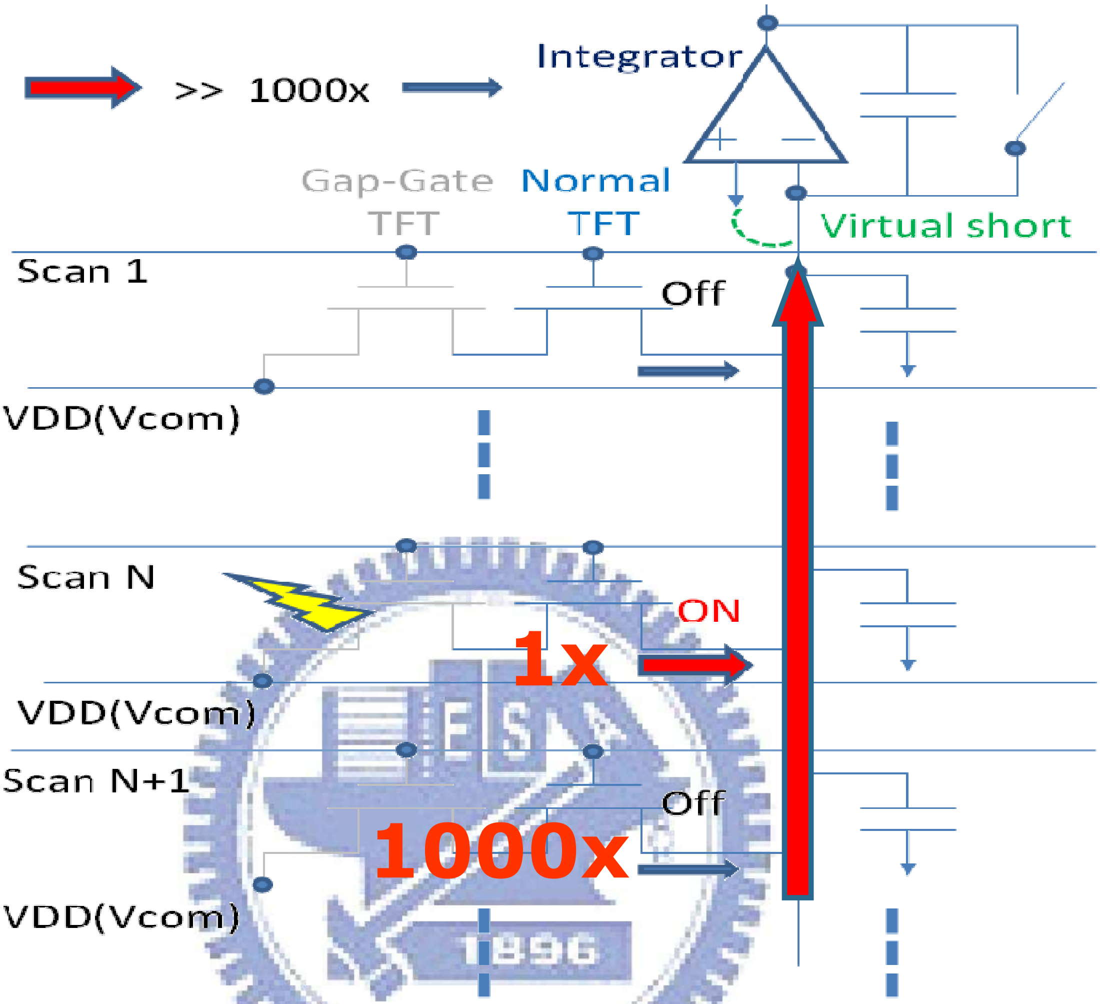

Fig. 2-5 The improved sensing array circuit of optical touch panel.

Chapter3

Using OFF Region of Gap-Gate TFTs

In Chapter 3, we pay attention to the off region of Gap-Gate TFTs. At the beginning, we discuss the effect of the front light illumination on TFTs in section 3.1. Because the type of TFTs we use is Gap-Gate, there are two additional issues in practical application. First, the gap region, i.e., the part of active layer which does not overlap with gate metal in the structure of Gap-Gate TFTs (referring to Figure 2-1), can be shined by the back light. This is a greatly different feature compared with conventional TFTs where the active layers are completely shielded by the gate metals from the illumination of back light. As a result, we address the back light effect of Gate-Gate TFTs and make a study in section 3-2. The second issue of Gate-Gate TFTs is that we wonder how the gap length has an impact on the drain current. The relation between the gap length and drain current can help us to operation the touch panel in better conditions by adjusting the gap length and is investigated in section 3-3. In the last section of Chapter 3, we try to briefly explain the behaviors of the current signal under front-light and back-light illumination in off regions

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3.1 Front Light Effect for OFF Region

3.1.1 Definition of Unit-Lux Current

Figure 3-1 shows the relationship between photo leakage current and illumination intensity under different drain biases for traditional TFTs. It is indicated that the photo leakage current increases with the illumination intensity and keeps good linear dependence. Furthermore, we find that the character of linearity is always tenable in the off region and only the slope would be different when we change the measure conditions such as drain bias, gate bias, and temperature. The slope of the current-Lux curve was firstly named as Unit-Lux Current, (ULC in abbreviation.) and used as an important index for analyzing the photosensitivity of the leakage current in the previous paper [7]. The meaning of ULC is the photo leakage current induced per unit-photo lux. Here, we use the same definition of ULC in the analysis for the photosensitivity of a-Si TFTs.

3.1.2 Relationship Between ULC and Bias Voltage

After defining the important parameter Unit-Lux Current, we would like to know the relationship between it and the bias voltages of TFTs. The experiment conditions are shown in Table 3-1. For the purpose of comparison, both conventional and Gap-Gate TFTs are illuminated in the dark as well as six different levels of halogen lamp. What we concern with is how the Unit-Lux Current changes with drain bias and gate bias under front light illumination, so we performed the experiment by recording the leakage current level under V_D sweep with three different fixed gate voltages and V_G sweep with three different fixed voltages of drain.

The experimental results of conventional TFTs with drain bias and gate bias are shown in Figure 3-3 (a) and (b), respectively, while Figure (c) and (d) are for Gap-Gate TFTs. Comparing Figure 3-3 (a) and (c), an obvious point of reflection happens to the Unit-Lux Current of conventional TFTs near VD=5V and an approximate skew line appears to the Unit-Lux Current of Gap-Gate TFTs. Consequently, we can refer that the Unit-Lux Current of Gap-Gate TFTs is more linear than that of conventional TFTs. As to the comparison of Figure 3-3 (b) and (d), both results of conventional and Gap-Gate TFTs indicate that the Unit-Lux Current is independent of extremely negative gate bias and increases rapidly as gate voltage approaches to subthreshold region. The physical mechanism in the subthreshold region is that a weak conducting channel is just formed when the gate bias is close to the positive voltage enough. Considering the threshold voltage variation, the subthreshold region is not suitable for practical application, and thus we sit aside without further discussion.

3.1.3 Temperature Effect of ULC under Front Light

The actual operational temperature of display panel may be up to 60 Celsius degree in normal environment. For this reason, the variation of temperature is needed to take into account of when the TFTs are used. The experiment in section 3.1.2 is performed at normal temperature (25 Celsius degree) and in this section we repeat the same experiment but at another three temperatures (35, 45 and 55 Celsius degree). Figure 3-4 shows the relationship between Unit-Lux Current and bias voltage including drain bias and gate bias at different temperatures under front light illumination, which appears the same tendency as at 25 Celsius degree. A further analysis is shown in Figure 3-5, exhibiting that an error of Unit-Lux Current up to minus 17.4% occurs if temperature changes from 25 Celsius degree to 55. Obviously, the issue due to temperature change is worthy to notice and we will meet it again in the experiment of back light in the next section.

3.2 Back Light Effect for OFF Region

The reason why we study the effect of back light on Gap-Gate TFTs in this section is that the gap region is not blocked by gate metal is illuminated by the back light. On the other hand, the conventional TFTs are not shined and thus not affected by the illumination of back light, as Figure 3-6 showed [8]. Figure 3-7 shows the experiment content of back light and we analyze the Unit-Lux Current in the same manner as we do in front light experiment previously. The experiment is perform in the dark and only five different levels of Light Emitting Diode (LED) instead of halogen lamp.

The effects of the gate and drain voltages on the back light ULC are showed in Figure 3-8 (a) and (b). They indicate similar tendency as those of the front light shown in Figure 3-3 (c) and (d). Namely, the Unit-Lux Current is dependent of the drain bias, independent of extremely negative gate bias, and increases rapidly as gate voltage approaches to subthreshold region.

We also need to examine the effect of the temperature to the Unit-Lux Current of back light. The experiment of back light is repeated three times at 35, 45 and 55 Celsius degree and the results are shown in Figure 3-9, which reveals that an error up to plus 17.7% occurs if temperature changes from 25 Celsius degree to 55. As a result, the instability due to temperature variation is a critical issue. The temperature needs to be well maintained in a sufficiently small range so that the error of Unit-Lux Current can be accepted and some calibration of temperature can be performed after several frames.

3.3 The Effect of Gap Length Variation for OFF Region

In order to realize if gap length affects the drain current or not and find the appropriate size of TFTs, we designed the experiment by using two Gap-Gate TFTs with the same structure except the gap length of 5um and 30um. The experiment is performed in the dark and under three different levels of halogen lamp.

The results of experiment are shown in Fig 3-10. The leakage currents in off region are almost the same for the two kinds of Gap-Gate TFTs with different gap lengths, which imply that the leakage current in off region is independent of the gap length. More precisely speaking, the photo current is not predominated by the gap region and the mechanism of current in off region may be the same as that of conventional TFTs.

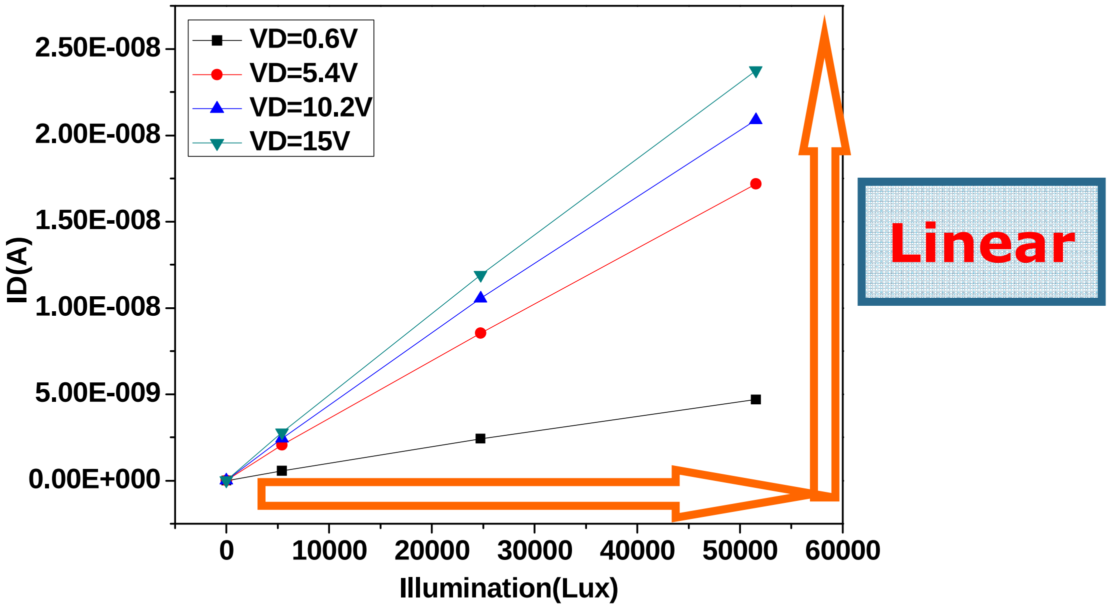


Fig. 3-1 Relationship between photo leakage current and illumination intensity under different drain biases for traditional TFTs

EXPERIMENT	Gate Bias (V)	Drain Bias (V)	Illumination Intensity (lux)
VG step VD sweep	-5	0.6 ~ 15	0 (Dark) 1006 5440 13600 24752 51544
	-7.5		
	-10		
VD step VG sweep	-10~0	0.6	
		5.3	
		10	

Table 3-1 The experimental conditions of front light

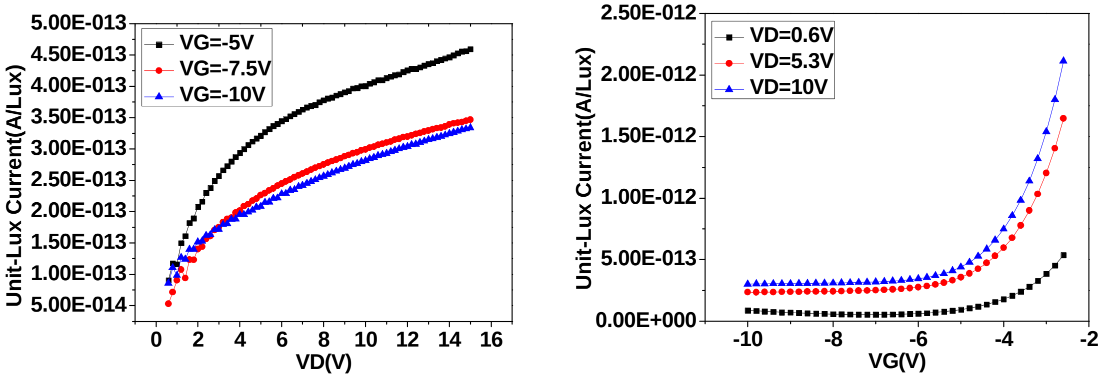


Fig. 3-2 (a) and (b) Unit Lux Current of **conventional** TFTs with drain bias and gate bias respectively under front light illumination

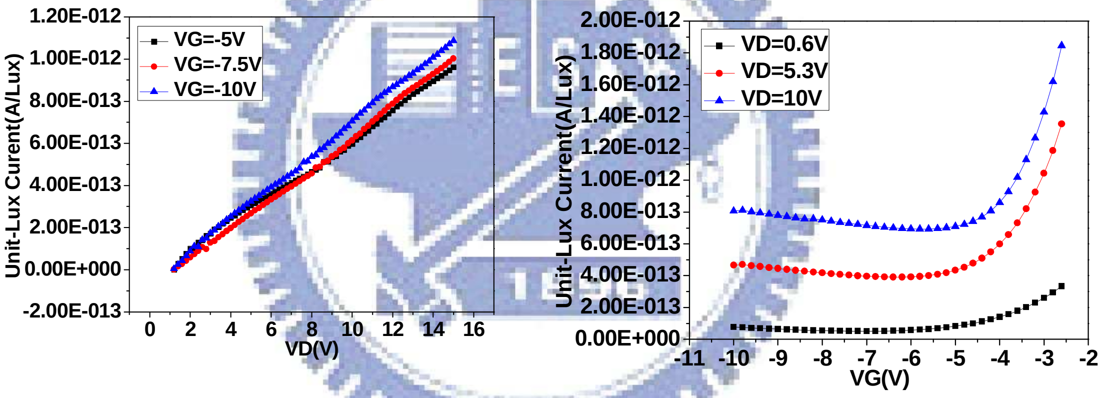
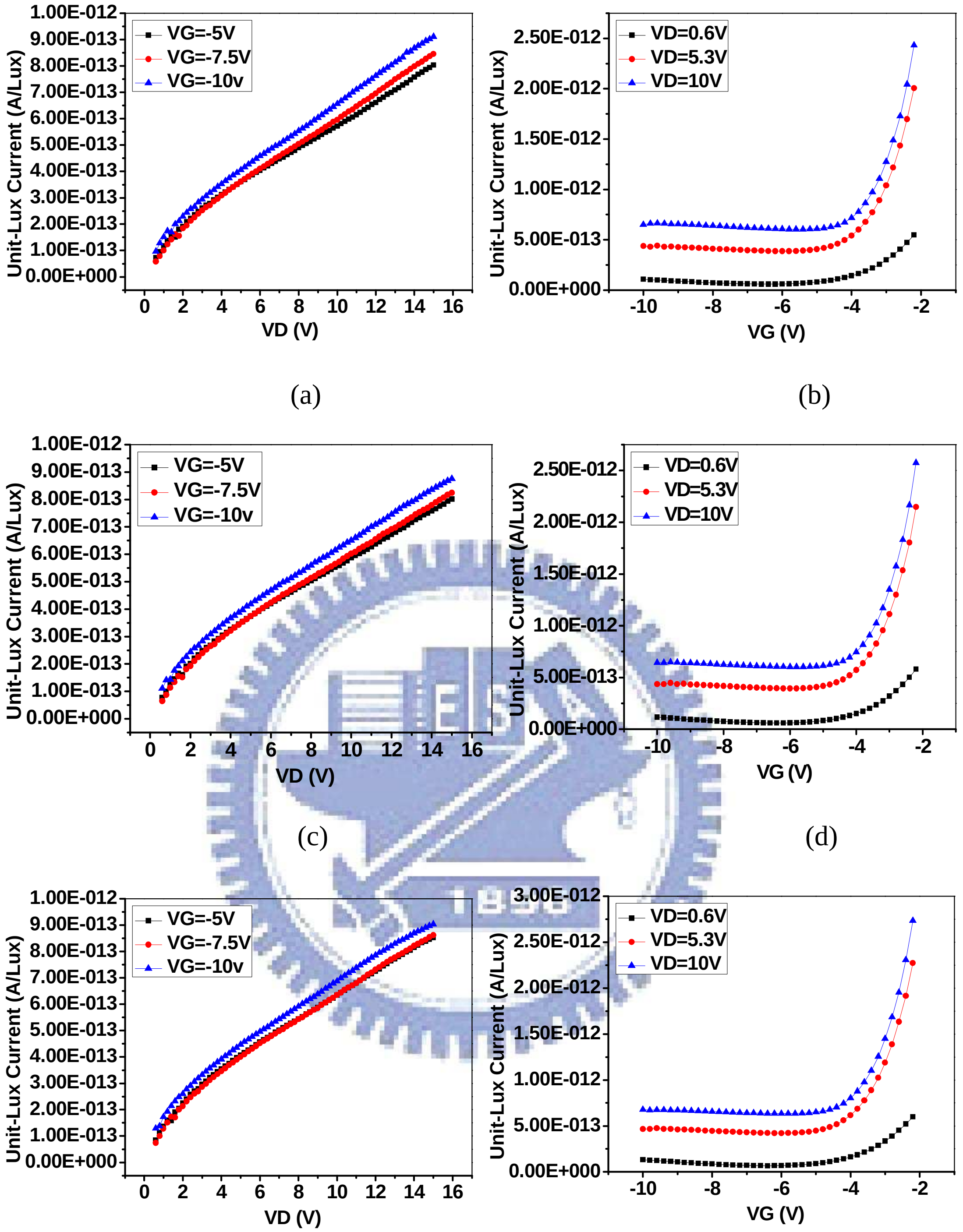


Fig. 3-2 (c) and (d) Unit Lux Current of **Gap-Gate** TFTs with drain bias and gate bias respectively under front light illumination



(a) (b)

(c) (d)

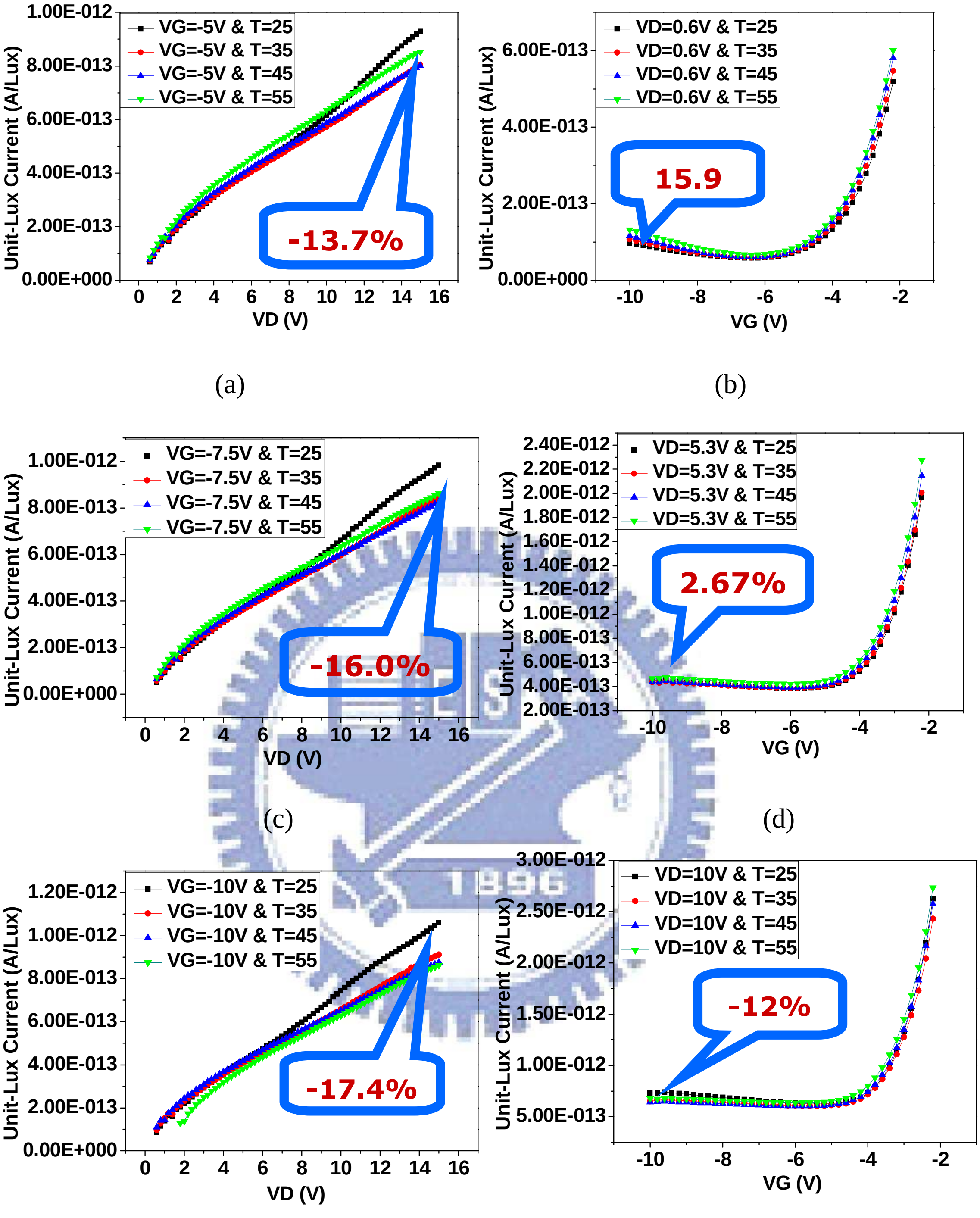
(e) (f)

Fig. 3-3 (a) and (b) ULC with VD and VG respectively at 35 Celsius

(c) and (d) ULC with VD and VG respectively at 45 Celsius

(e) and (f) ULC with VD and VG respectively at 55 Celsius

under front light illumination



(a) (b)

(c) (d)

(e) (f)

Fig. 3-4 (a), (c) and (e) ULC comparison at different temperature at VG=-5, -7.5 and -10 V respectively under front light illumination

Fig. 3-4 (b), (d) and (f) ULC comparison at different temperature at VD=0.6, 5.3 and 10V respectively under front light illumination

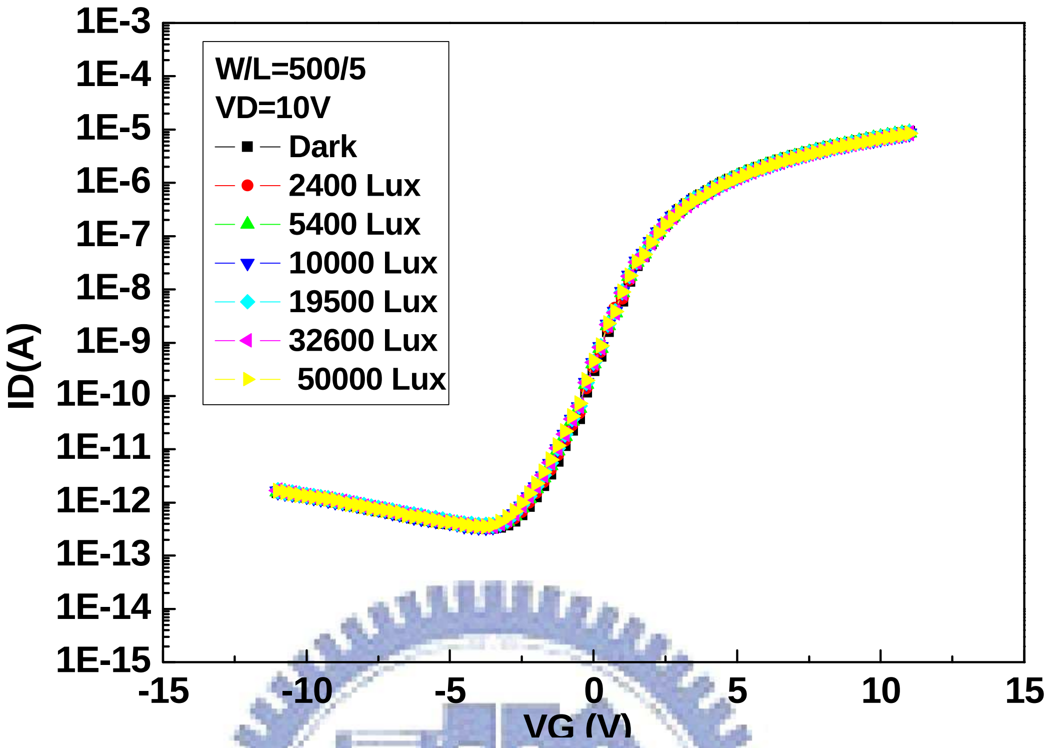
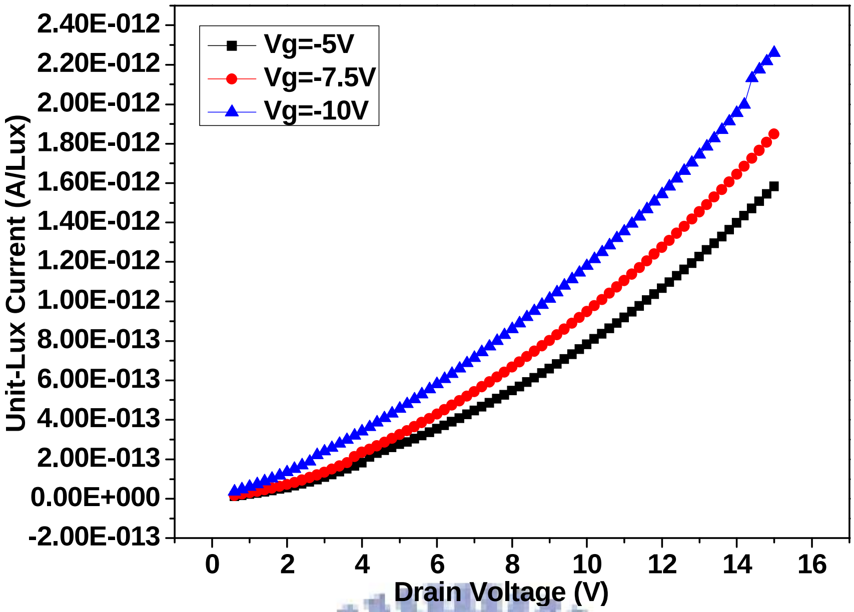


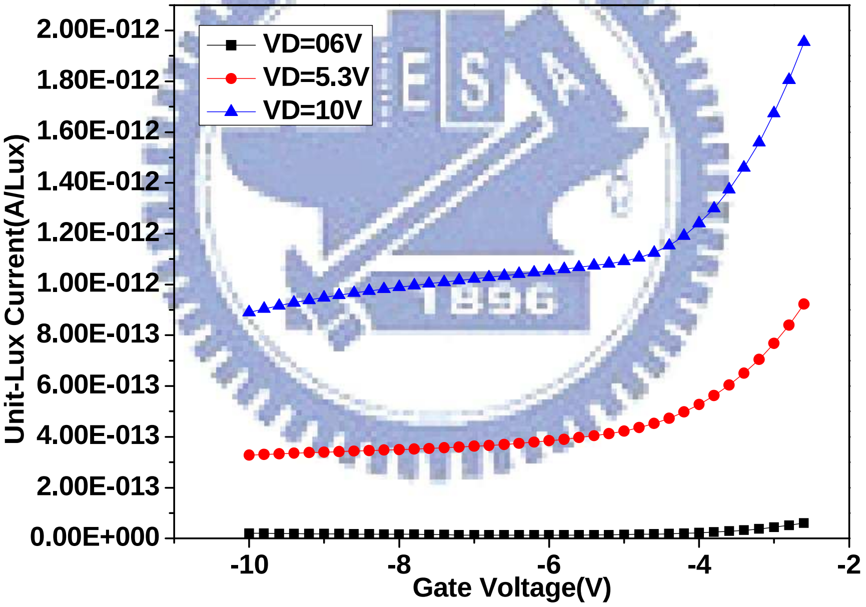
Fig. 3-5 The conventional TFTs are not affected by the illumination of back light.

EXPERIMENT	**Gate Bias (V)**	**Drain Bias (V)**	**Illumination Intensity (lux)**
VG step VD sweep	**-5**	**0.6 ~ 15**	**0 8870 17230 24700 32700 44400**
	-7.5		
	-10		
VD step VG sweep	**-10~0**	**0.6**	
		5.3	
		10	

Table 3-2 The experimental conditions of back light

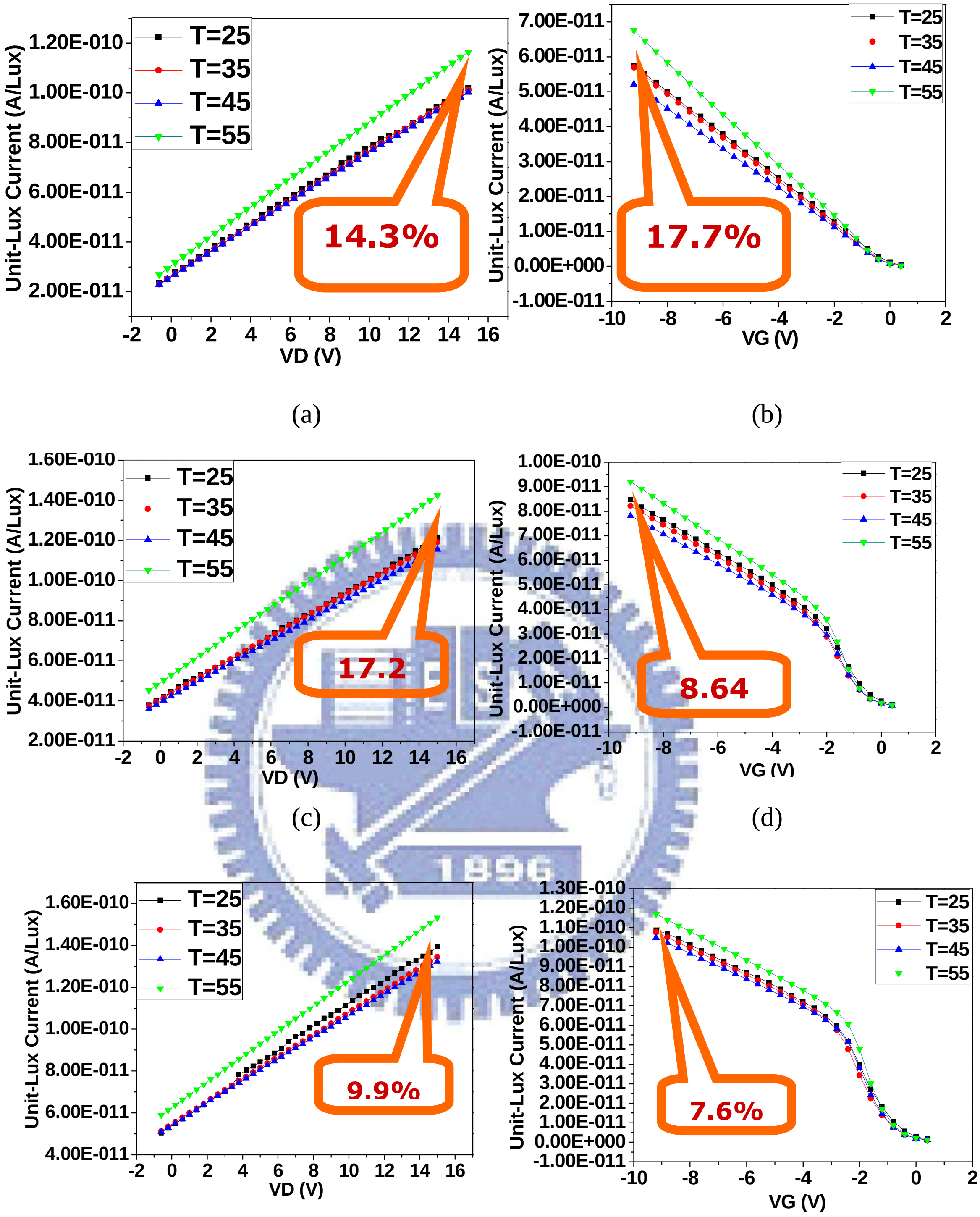


(a)



(b)

Fig. 3-6 (a) and (b) Unit-Lux Current of **Gap-Gate** TFTs with drain bias and gate bias respectively under back light illumination



(a) (b)

(c) (d)

(e) (f)

Fig 3-7 (a), (c) and (e) ULC comparison at different temperature at VG=-5, -7.5 and -10 V respectively under back light illumination

Fig 3-7 (b), (d) and (f) ULC comparison at different temperature at VD=0.6, 5.3 and 10V respectively under back light illumination

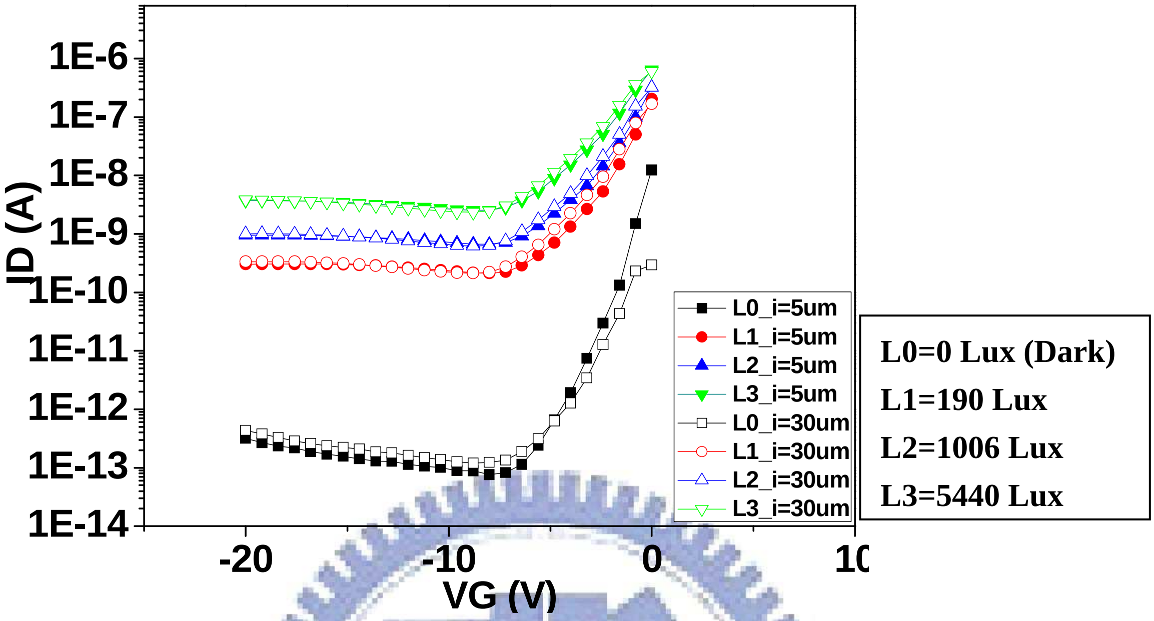


Fig 3-8 The photo effect of two TFTs with gap length =5um and 30um respectively

Chapter4

Using on Region of Gap-Gate TFTs

According to the previous study and our own experiments, there is no photo effect in the on region of conventional TFTs. Hence, in chapter4, we only concentrate on the on region of Gap-Gate TFTs as photo sensors in touch panel. First, the photo effect in on region is investigated. Then, the reliability of on region becomes another pending issue because the current in on region degrades seriously under illumination for a long time. For this reason, we attempt to bring up a correction of current degradation and solve the issue effectively.

4.1 Photo Effect for ON Region

Figure 4-1 shows the relationship between photo current and illumination intensity under different drain biases for a Gap-Gate TFT with gap region of 30um. Referring to Figure 4-1, we notice that although the currents increase with illumination, the increasing trend is not linear. The definition of ULC in chapter 3 is not suitable here since the ULC is meaningful only based on the linearity of current with illumination. Therefore, ULC cannot be used as the parameter of photo effect in on region of Gap-Gate TFTs.

It is kept in mind that the gap region is under the illumination by the back light, which becomes an issue when we operate the Gap-Gate TFTs in the on region. This issue will be discussed in more detail in section 4.3.

4.2 Reliability

4.2.1 Photo Stress

According to the previous research, it is known that there is the reliability issue of current degradation in the conventional TFTs, namely, Staebler-Wronski effect or SW effect in abbreviation. The predominate explanation of the effect is that the illumination leads to the creation of additional meta-stable states in the band gap of amorphous silicon, by breaking the weak bounds of the hydrogen atoms to the silicon, which decreases the life time of excess carriers and thus reduces the photo conductivity [9-11].

Operating the Gap-Gate TFTs in on region, the problem of reliability is also of great importance. Figure 4-2 (a) shows the result of experiment in which the Gap-Gate TFT is stressed for 4800 seconds by the continuous illumination of the halogen lamp with intensity of 13600 Lux. It is observed that after photo stress, the currents in on region degrade in the dark as well as irradiated at six different levels of halogen lamp. Furthermore, it is observed incidentally that there is almost no current degradation in off region of Gap-Gate TFTs. That is why we do not mention about reliability in chapter 3.

Another experiment with longer but weaker photo stress is performed and the result is shown in Figure 4-2 (b).In this experiment, the stress time is up to 300 hours and the intensity is about 6000 Lux, which is more close to general operating environment of display panels. It can be seen that the currents degrade not only in the on region but also in the off region. Although the currents in both on and off regions degrade, the margin of degradation in on region is much critical than that in off region. Therefore, we still focus on the reliability in on region rather than in off region.

4.2.2 Electric Stress

In additional to the stress of illumination, another possible cause that the photo current may degrade is the bias voltage. Hence, an experiment of electrical reliability is performed to test the photo current characteristic of Gap-Gate TFTs. According to the previous research, the TFT characteristics do not change obviously after bias voltage stress, unless the temperature is raised up to more than 60 Celsius degree. In our experiment, the Gap-Gate TFT is stressed by drain voltage of 20 Volt for 3000 seconds at 60 Celsius degree, and then the drain current is measured under 50000 Lux illumination with V_{DS} equal to 10 volt and V_{GS} equal from -10 to 10 volt. The result of experiment is shown in Figure 4-3 and it is observed that the most current variation owing to electric stress occurs in the subthreshold region, where we do not intend to operate. There is almost no current degradation in both on and off regions. As a result, the issue of electrical reliability is off the point in this study. Only the current degradation due to the long-term illumination need to be considered.

4.3 The Correction Method of Current Degradation

4.3.1 Correction Concept

In order to use Gap-Gate TFTs as photo sensors in touch panels, there are two issues to be overcome. One is the illumination of back light on the gap regions. The other is the current degradation caused by illumination for a long time. Since the photo induced current change in time, what we need to develop is a method to eliminate the time factor, as shown in Figure 4-4. Assuming that inputs go through the function box yet to be developed, they become new outputs with no time relevance. It is mandatory to find some special relation or parameter between input 1 and input 2 that is unchanged before and after the photo stress. Surveying the first issue about illumination of back light and the back light intensity in an LCD panel is in control, an idea come across our mind to take advantage of it. When the gap is illumination only by the front light, a current signal can be treated as the input 1. When the gap is illumination by the front light and back light at the same time, another current signal can be treated as the input 2. Both signals contain the information of front light intensity. If we can find something with the invariance of time from the two signals, we may develop the correction method of the current degradation.

4.3.2 The Experiment and A New Parameter R

Based on the concept discussed above, an experiment is designed to check the feasibility of correction method. A gap-Gate TFT is stressed by 13600 Lux illumination for 4800 seconds. During the stress, two measurements are performed each time at 0, 600, 1200, 2400, and 4800 seconds. One is the current under illumination of front light only and the other is that under illumination of both the front light and the back light. In the measurement, the intensity of front light includes darkness and 4 different levels while that of back light is fixed 5070 Lux, which is the usual intensity of an LCD back light.

The results of experiment are shown in Figure 4-5 (a) ~ (e) corresponding to the five different stress times, respectively. The X-axis of the curves is the intensity of front light and the Y-axis is the current level. It is observed that the tendency between the two curves in each picture is similar, which implies the possibility of finding a new parameter from the two signals.

A further analysis is shown in Figure 4-6, in which we define a new parameter R as $(I_D\_FL+BL_{Fixed}) / (I_D\_FL_{Only})$ to be the Y-axis index. It is observed that new parameter R with the same intensity front light at different stress time cluster intensively around a point, which reveals that the parameter R is excellently invariant against the photo stress.

The errors of the new parameter R and conventional parameter I_D owing to photo stress are shown in Figure 4-7(a) and (b) respectively for comparison. The error of I_D is up to 40%, but that of R is only a half. In addition, another merit of R is that the effect of the back light on the on current of Gap-Gate TFTs is incorporated. As a result, the new parameter R we define in this thesis is more suitable to be photo sensing signal than the direct usage of I_D.

To accomplish the correction method in the actual practice, the magnitudes of (I_D_FL+BL_{Fixed}) and (I_D_FL_{Only}) can be measured when the Back Light Unit (BLU) of panel is turned on and off respectively. For advanced LCD TV displays, BLU is turned off for the purpose of removing the blur of animation [ref], which is becoming a built-in technology. In this scheme, there is no need of any additional modification to get the information of (I_D_FL+BL_{Fixed}) and (I_D_FL_{Only}).

4.4 The Effect of Gap Length Variation for ON Region

We are again interested in if the gap length of the Gap-Gate TFT affects its current in the on region or not. An experiment about the relationship between gap length and on current is performed by using two Gap-Gate TFTs with the identical structure except the gap length to be 5um and 30um respectively. The experiment is conducted in the dark and under three different levels of halogen lamp. The result is shown in Figure 4-8, which indicates that the on current of the Gap-Gate TFT with gap length equal to 5um is always larger than that with 30 um no matter in the dark or under illumination. Referring to the discussion of section 3-3 that the leakage current in off region is independent of the gap length, the on current is quite different. This result supports that the on current is dependent greatly of the gap region. It implies that the photo current degradation is mainly owing to the defects in the gap, which can explain the same trend of ($I_D\_FL+BL_{Fixed}$) and ($I_D\_FL_{Only}$).

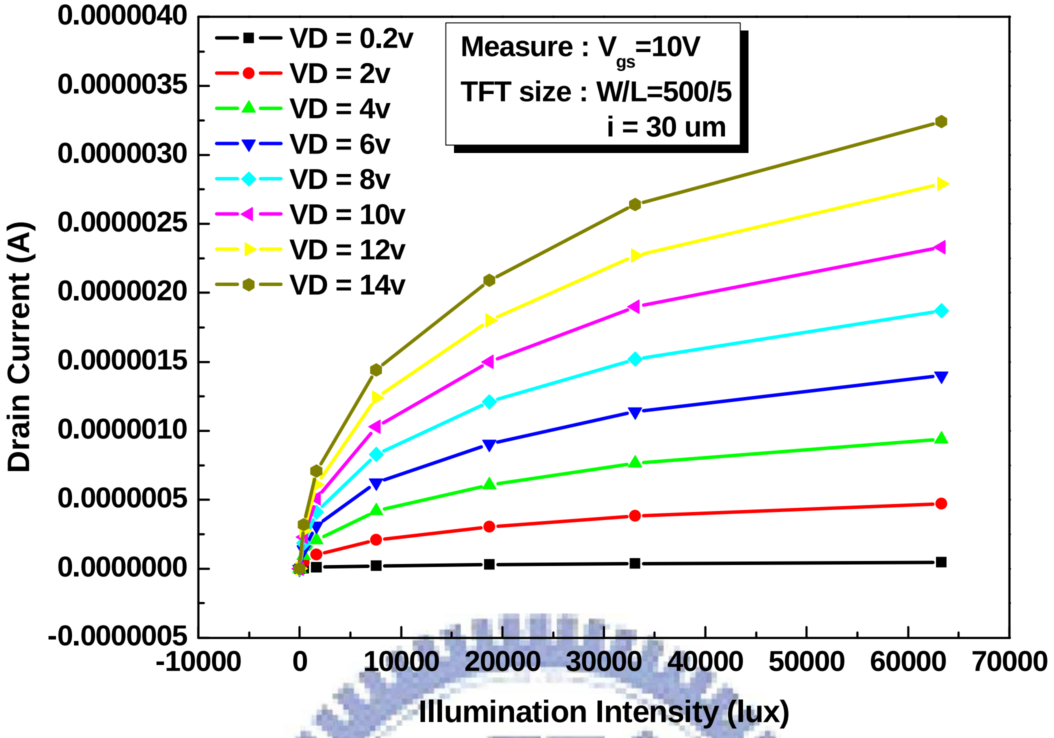


Fig. 4-1 The Drain current with illumination intensity in on region

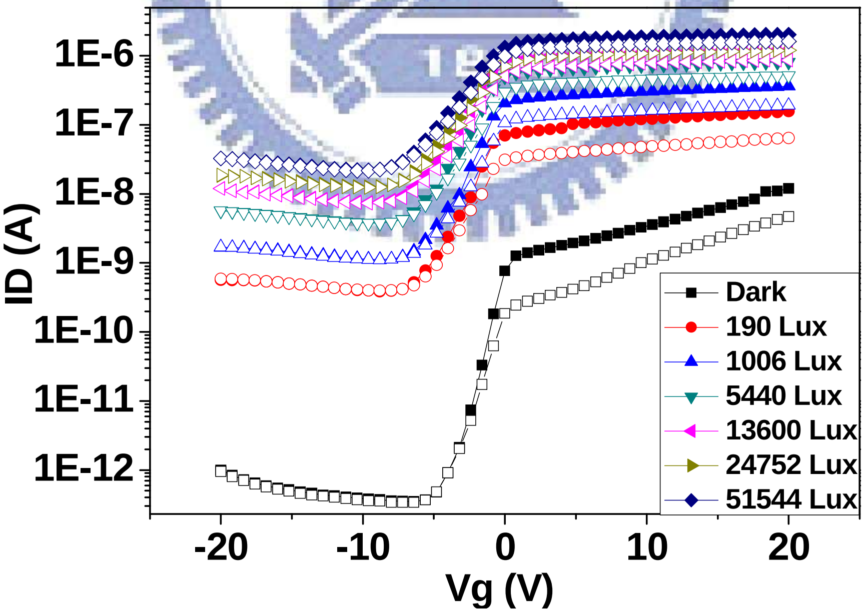


Fig. 4-2 (a) The current degradation under 13600 Lux stress for 4800 seconds

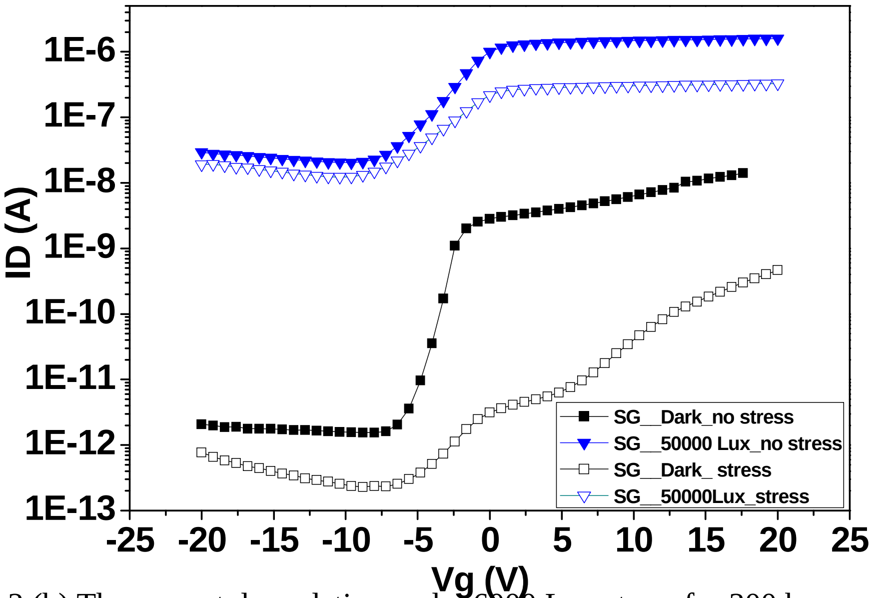


Fig. 4-2 (b) The current degradation under 6000 Lux stress for 300 hours.

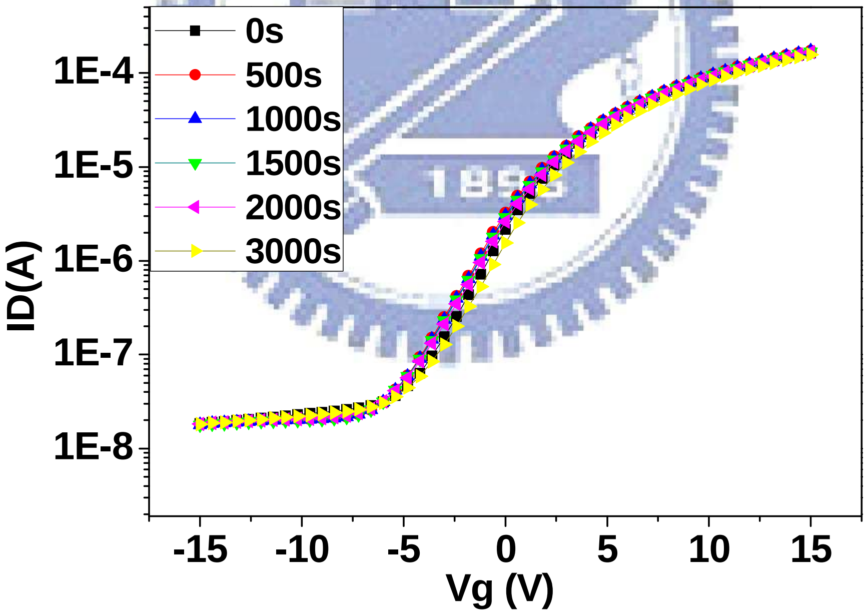


Fig. 4-3 The electric stress with Vd=20V for 1000 seconds

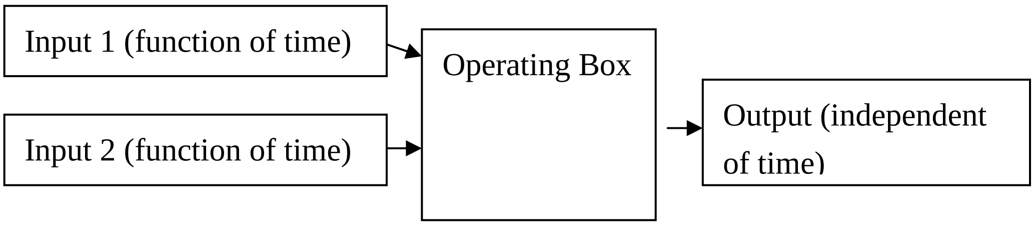


Fig. 4-4 The concept of correction method of current degradation

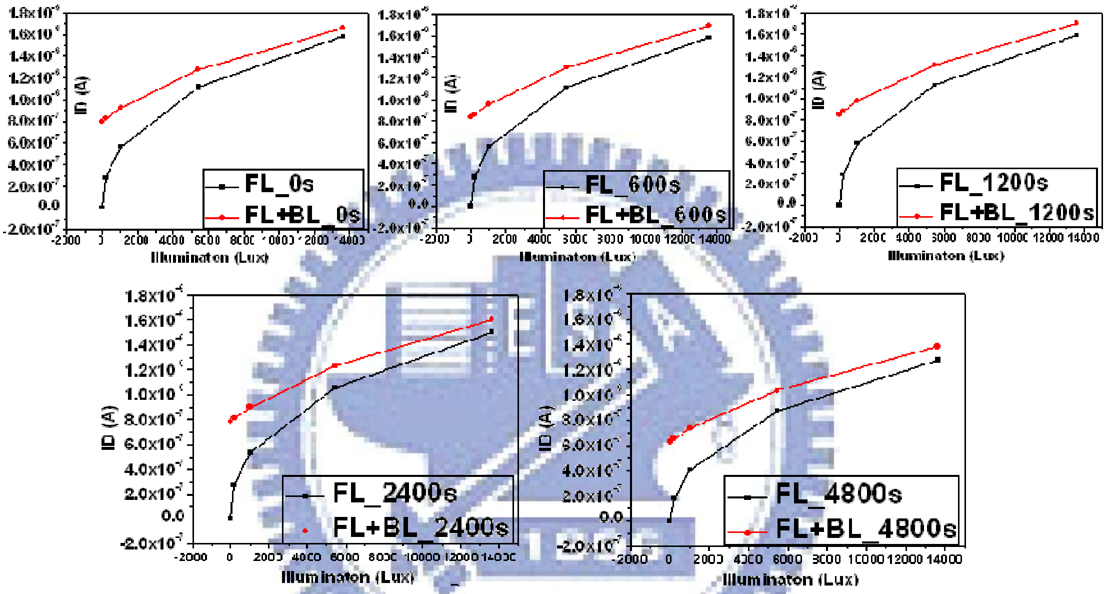


Fig. 4-5 (a)~(e) corresponding to five different photo stress times of a-Si TFTs

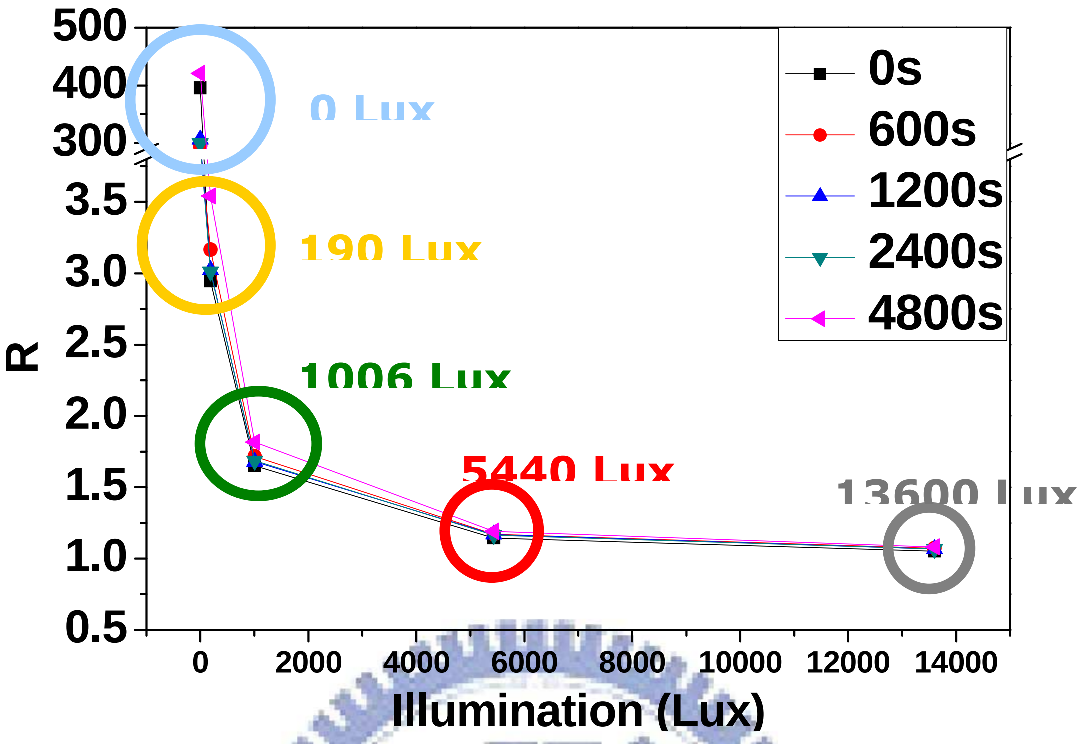


Fig. 4-6 The new parameter R with illumination intensity

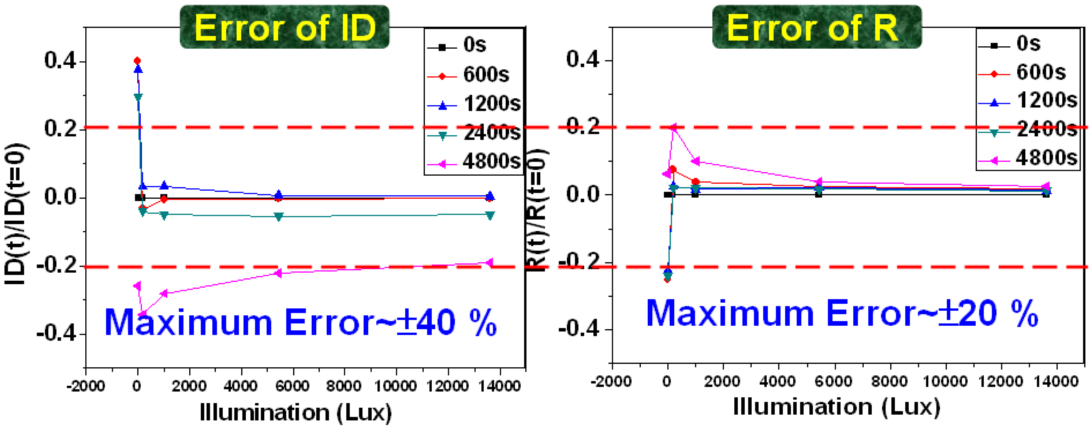
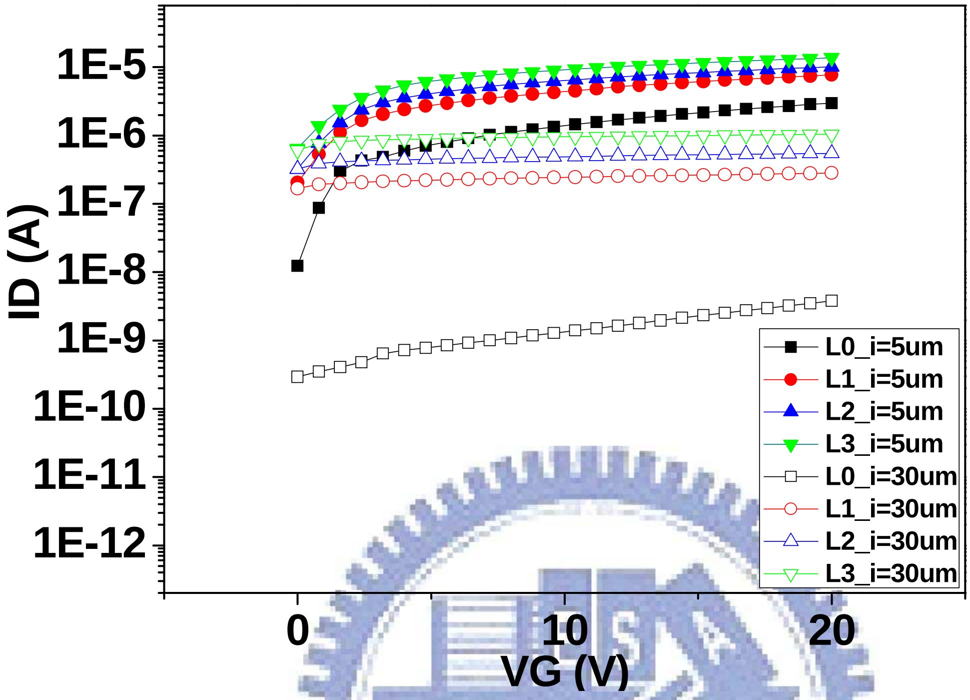


Fig. 4-7 The comparison of I_D and R



L0=0 Lux (Dark)
L1=190 Lux
L2=1006 Lux
L3=5440 Lux

Fig. 4-8 The effect of gap length variation for on region with gap length =5um and 30um respectively

Chapter5

Summary and Conclusion

In this thesis, we discuss the history of touch panel in the beginning and analyze the advantages and disadvantages of all kinds of touch panels. Aiming to the low cost and ease of integration, we decide to design the touch panel using Gap-Gate TFTs as photo sensors and study the feasibility. The photo effect of Gap-Gate TFTs occurs not only in on but also off regions so that we can realize the function of touching in both two regions. In chapter 2, the circuit of readout is investigated. In order to readout the small signal in off region, the conventional 2T1C circuit with source follower is used, of which the aperture ratio is reduced due to the additional source follower. The improved readout circuit is brought up for on region and good at large current signal, higher aperture ratio and less cost. The photo effect in off region is profoundly studied both for front light and back light in chapter 3, in which a parameter Unit-Lux Current (ULC) is use to describe the photo effect. According to the result of experiment, it is found that the temperature variation is an important variable of stability for the parameter Unit-Lux Current. In chapter 4, we try to use the on region of Gap-Gate TFTs as sensors in touch panel but two issues need to be solved, namely, the illumination of back light and the current degradation. Fortunately, a correction method is found to overcome the two issues at the same time. Consequently, we prefer to use the on region of Gap-Gate TFTs as photo sensors in the design of touch panel than off region. The compatibility of the correction method and the advanced LCD TV promises the practical application of the proposed integrated touch panel.

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