The Photosensitive Insulating Materials as a Passivation Layer on a-Si TFT LCDs

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Abstract

The photosensitive poly-siloxane material used as the passivation layers for the conventional back channel etched (BCE) thin film transistors (TFTs) has been investigated. Through the organic material, the TFT array fabrication process can be reduced and higher aperture ratio can be achieved for higher LCD panel performance. The interface between the organic passivation layer and the back channel of the amorphous active region has been improved by the back channel oxygen treatment and the devices exhibits lower leakage current than the conventional silicon nitride passivation layer of BCE TFTs. The leakage currents between Indium-tin-oxide (ITO) pixels and the TFT devices and its mechanism have also been investigated in this paper.

1. Introduction

Hydrogenated amorphous silicon thin-film transistors (a-Si:H TFTs) have been widely used as switching devices in active-matrix liquid-crystal display(AMLCDs), particularly in TFT-LCDs. Many efforts have been made to improve the performance and the fabrication throughput of TFTs. Therefore, remarkable advances have been made in the fabrication process of high performance and low cost TFTs in LCD applications.

Although a-Si:H TFTs can be fabricated with a variety of structures and materials, the most popular structure is the inverted-staggered TFT, which uses silicon nitride (SiN_x) film as the gate insulator, intrinsic amorphous silicon (a-Si:H) film as the active layer, and phosphorous-doped amorphous silicon(n^+a-Si:H) film as source/drain contact layer.

The SiN_x passivation layer for TFTs was widely deposited by plasma enhanced chemical vapor deposition (PECVD). If a material can process both property of photoresist and insulating spin on glass (SOG), it will be an effective is an effective candidate for the passivation layer on TFT LCDs, Recently, the photosensitive insulating SOG materials have been developed as the passivation layers on TFTs. Azuma has reported that the photosensitive insulating materials can replace the PECVD SiN_x or SiO_2 layer as the passivation layer on TFTs [1].

In this paper, the electrical characteristics of TFTs with two types of passivation and the electrical properties of organic material have been investigated. The experimental results show that SiN_x passivation layer on TFTs can be replaced by organic materials. Therefore, the process of TFT array fabrication can become simpler as compared with that using PECVD SiN_x film as passivation layer of TFTs.

2. Experiment

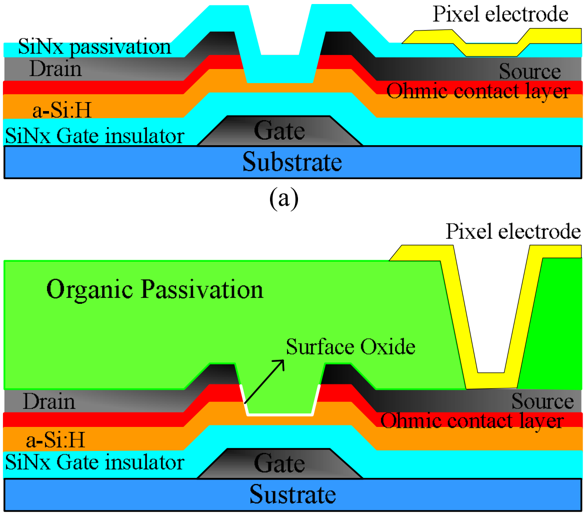
The inverted-staggered back-channel-etched TFTs with various materials of passivation layers were fabricated and used in this study.

Following the deposition and patterning of multi-layer Ti/Al/Ti gate electrodes on the glass substrates, the tri-layer of SiN_x/a-Si:H/n^+ a-Si:H was then deposited on the gate electrodes consecutively within the same vacuum pump-down using plasma-enhanced chemical vapor deposition (PECVD). The drain and source electrodes were made of multi-layer Ti/Al/Ti metals and defined using photolithography with the photoresist as a mask. A passivation layer were deposited or coated on the back channel as the protected layer. The indium-tin-oxide (ITO) was then deposited and patterned as the pixel electrodes on the passivation layer. The thickness, material, and related process of various layers for the TFT fabrication were summarized in Table 1.

Two types of passivation layers were used in this study. One was the SiN_x film used as a passivation layer of the a-Si:H TFT control sample as shown in

Fig. 1(a) and the other was the organic film made of poly-siloxane photo-sensitivity materials as shown in Fig. 1(b). Before the organic passivation layer was spun on, the back channel of TFT was dealt with the oxygen plasma treatment [2], and then an oxide layer of about 3nm to 5 nm was formed in the back channel interface, as shown in Figure 2.

The Agilent 4156 precise semiconductor parameter analyzer was used for the electrical characteristics measurement.



(a)

(b)

Figure 1 Schematic cross-sectional view (a) with SiN_x passivation layer and (b) with organic passivation layer, respectively.

Table 1 Materials and manufacturing processes of TFTs with (a) PECVD SiN_x film or (b) organic passivation.

(a)

Layer	Material	Process	Thickness(nm)
Gate Electrode	Ti/Al/Ti	Sputter	70/180/20
Gate Insulator	SiNx	CVD	340
Active layer	a-Si:H		180
ohmic contact layer	n+ a-Si:H		40
Soorce/Drain electrode	Ti/Al/Ti	Sputter	100/180/50
Passivation Layer	SiNx	CVD	300
Pixel electrode	ITO	Sputter	55

(b)

Layer	Material	Process	Thickness(nm)
Gate Electrode	Ti/Al/Ti	Sputter	70/180/20
Gate Insulator	SiNx	CVD	340
Active layer	a-Si:H		180
ohmic contact layer	n+ a-Si:H		40
Soorce/Drain electrode	Ti/Al/Ti	Sputter	100/180/50
Passivation Layer	Organic	Spin on	2000
Pixel electrode	ITO	Sputter	55

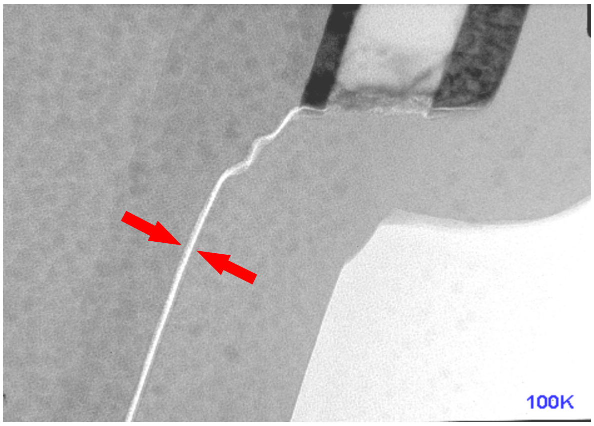


Figure 2 The thin oxide is formed on the back-channel surface by oxygen plasma treatment.

3. Results and Discussion

Figure 3 shows the transfer characteristics of TFTs in dark environment. It shows that the leakage current of BCE TFTs with organic passivation layers is one order of magnitude lower than that of the standard BCE TFTs with silicon nitride passivation layers. Figure 4 shows the transfer characteristics of TFTs under backside illumination of 2500 nit. The TFTs with organic or SiN_x passivation layers exhibit almost the same level of photo-leakage current. Although the oxygen plasma treatment is used to improve the interface of the back channel region and organic passivation layer for the anti-water absorption of the active layer, the interactive effects between back channel and front channel after long time operation should be clarified. Figure 5 shows the transfer characteristics of the testing devices before and after bias temperature stress (BTS) [4]. The devices are applied a voltage bias of 20 V to gate electrodes to prevent the charge traping [5], and the source/drain contact are grounded to guarantee the worst case for normal TFT operation [6]. The stress temperature is ramped to 60℃ to precipitate the degradation of TFT performance. The threshold voltage shift is caused by the meta-stable instability or weak bond broken [7 -9]. From Figure 5, the threshold voltage V_{TH} shift of TFTs with organic passivation layer exhibits almost the same performance with that of the control sample TFT. The threshold voltage shift is about 6 V for both types of TFTs after 12 hours stressing.

The leakage current between TFT devices and the ITO pixel regions are the important index for a good passivation layer, and a proper passivation layer should effectively isolate the leakage current of TFTs. A rectangular-shape sandwiched structure of top metal/passivation layer/ITO with $1000 \times 1500\ \mu\ m^2$ area is used to examine the leakage current between TFT devices and ITO pixels. Since the operation of most TFT-LCDs is under the backside illumination, it is important to clarify the effect of passivation layers on the photo-leakage current.

Figure 6 and Figure 7 show J-E characteristics under dark and backside illumination of 2500 nit. The bias is applied to the top metal and it sweeps from –30V to 30V. Although with the same electric fields, the organic passivation exhibits larger leakages, in real process, the thickness of organic film is coated to be thicker than SiN_x film which reduces the photo leakage to an acceptable quantity compared to that of the control sample.

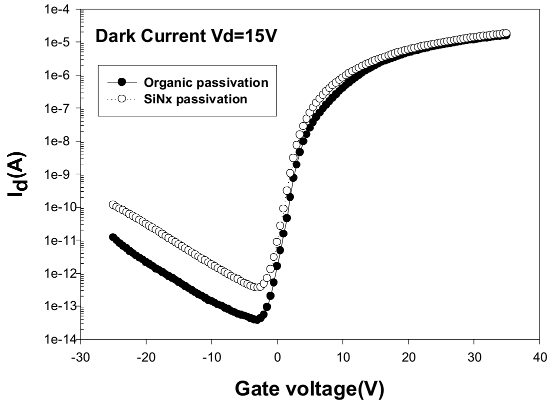


Figure 3 Id-Vg Characteristics (Vd =15V) of TFTs in dark environment.

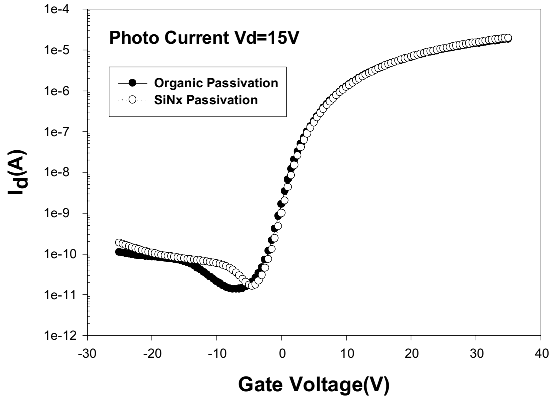


Figure 4 Id-Vg Characteristics (Vd=15V) of TFTs under backlight illumination of 2500 nit.

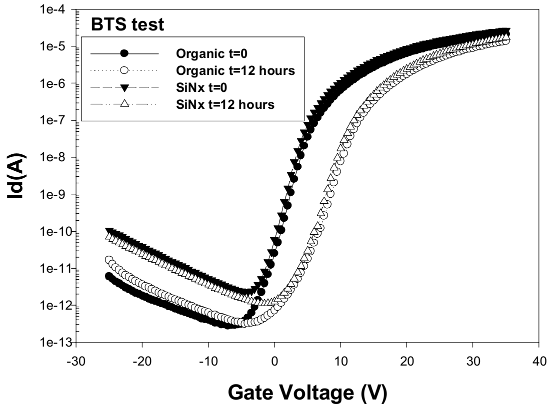


Figure 5 Id-Vg Characteristics (Vd =15V) show the threshold voltage shift after BTS test with Vgs =20 V, 60℃, for 12 hours.

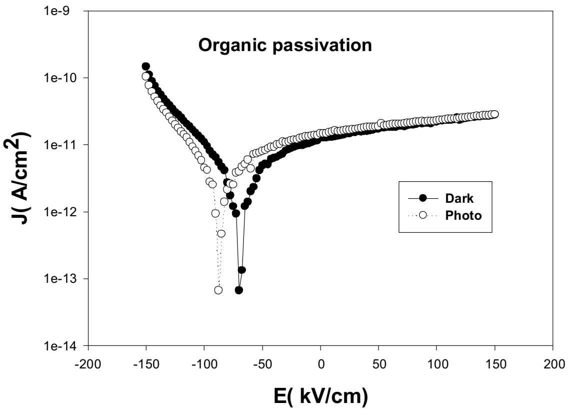


Figure 6 J-E Characteristics of 2·μm-thick organic dielectric film under dark environment and illumination of 2500 nit.

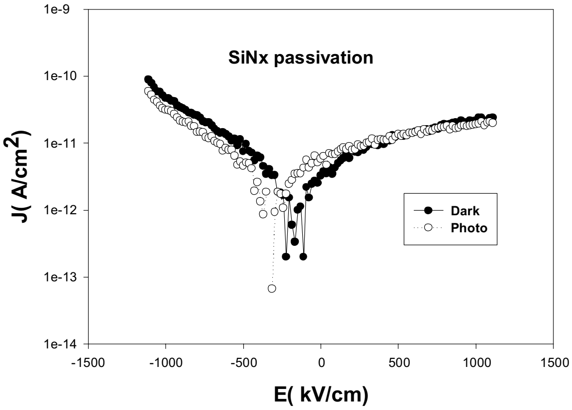


Figure 7 J-E Characteristics with of 0.3·μm-thick SiN_x dielectric film under dark environment and illumination of 2500 nit.

4. Conclusion

In this work, the organic passivation layer is made of poly-siloxane materials and the oxidation between back channel and passivation layer interface can improve the anti-water absorption. The reduced off current of organic passivated TFTs can be explained by the mechanism of surface charging effect [3]. However, the effect is insignificant for TFTs operating under backside illumination.

Both the reliability of organic passivated TFTs and the leakage current of passivation layer between TFT devices and ITO pixels have been studied. The organic passivated TFTs exhibit the comparable threshold voltage shift and leakage current to that of the standard BCE TFT control samples. Therefore, the organic passivation material is reliable not only to simply the TFT-LCD fabrication process but also to increase the LCD aperture ratio, and improve the LCD performance.

5. References

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