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Study on Light Induced Leakage Current Related to Amorphous Silicon TFT Design

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Abstract. We investigated the effect of amorphous silicon pattern design regarding to light induced leakage current in amorphous silicon thin film transistor. In addition to conventional design, where amorphous silicon layer is protruding outside the gate electrode, we designed and fabricated amorphous silicon thin film transistors in another two types of bottom gated structure. The one is that the amorphous silicon layer is located completely inside the gate electrode and the other is that the amorphous silicon layer is protruding outside the gate electrode but covered completely by the source and drain electrode. Measurement of the light induced leakage current caused by backlight revealed that the design where the amorphous silicon is located inside the gate electrode was the most effective however the last design was also effective in reducing the leakage current about one order lower than that of the conventional design.

Introduction

A popular application field of hydrogenated amorphous silicon thin-film transistors (a-Si:H TFTs) is switching elements for active matrix-liquid crystal displays (AM-LCD). LCD panels should be assembled with back-light, so that the leakage current of a-Si:H TFT caused by back-light illumination should be reduced to avoid the stored charge in pixel capacitor from discharging during a frame period [1]. It is well known that the leakage current of a-Si:H TFT is severely increased by illumination of light into the channel [2,3]. The inverted staggered structure, so called bottom gated structure, is widely employed to reduce the back-light induced leakage current because the gate electrode shields the channel region from the back side illumination [4]. It has been accepted that the light induced leakage current can be ignored in bottom gated a-Si:H TFT. However the shielding effect of the bottom gated structure is not perfect and may allow the increase of light induced leakage current as the brightness of backlight is increased for TV application. It is important to examine the position where the light induced leakage current increase is dominant and the relationship between the detailed design and the light induced leakage current.

In this study, bottom gated a-Si:H TFTs are fabricated in various types of design and the light induced leakage current was measured under backside illumination. It is verified that the light induced leakage current can be increased when a-Si:H layer protrudes outside the bottom gate electrode and that the generation of the light induced leakage current is concentrated at a local point in the protruding region, so that the area of the protruding region has little relationship with the magnitude of the light induced leakage current. A proper designing manner is suggested in the viewpoint of reduction of the leakage current as well as mass production.

Experimental Procedure

The inverted staggered TFTs were fabricated on corning 1737 glass substrates. 200nm-thick chromium (Cr) film was deposited by DC magnetron sputtering and patterned to serve as the gate electrode. Next, amorphous SiN, a-Si:H and n^+a-Si:H layers were deposited by using a plasma enhanced chemical vapor deposition (PECVD) method and patterned in island shape. The thickness of each layer were 350nm, 200nm and 50nm respectively. Another 200nm-thick Cr film was sputtered and patterned to form the source and drain electrodes. Next, the n^+a-Si:H layer was etched by using dry etch method. In this time, the patterned metal films were used as a mask to etch back the channel to isolate the source and drain electrodes of the TFT. Finally, a passivation layer of 200nm-thick amorphous SiN was deposited by PECVD and pad holes were opened to measure the electrical characteristics of the TFT.

The I-V measurement of a-Si:H TFT was carried out using Agilent 4156B with probe positioning system. Samples were located inside a shielding chamber blocking external light source and the light induced leakage current was measured with only the backside illuminating source located under sample.

Results and Discussion

In order to investigate the cause of leakage current generation due to back side illumination, a-Si:H TFTs were fabricated in two types of design, as shown in Fig. 1. The a-Si:H TFT designed in type I has conventional bottom gated structure, where a-Si:H layer protrudes from both edges of the gate electrode. The a-Si:H TFT designed in type II has the same bottom gated structure, but a-Si:H layer locates completely inside the gate electrode edge.

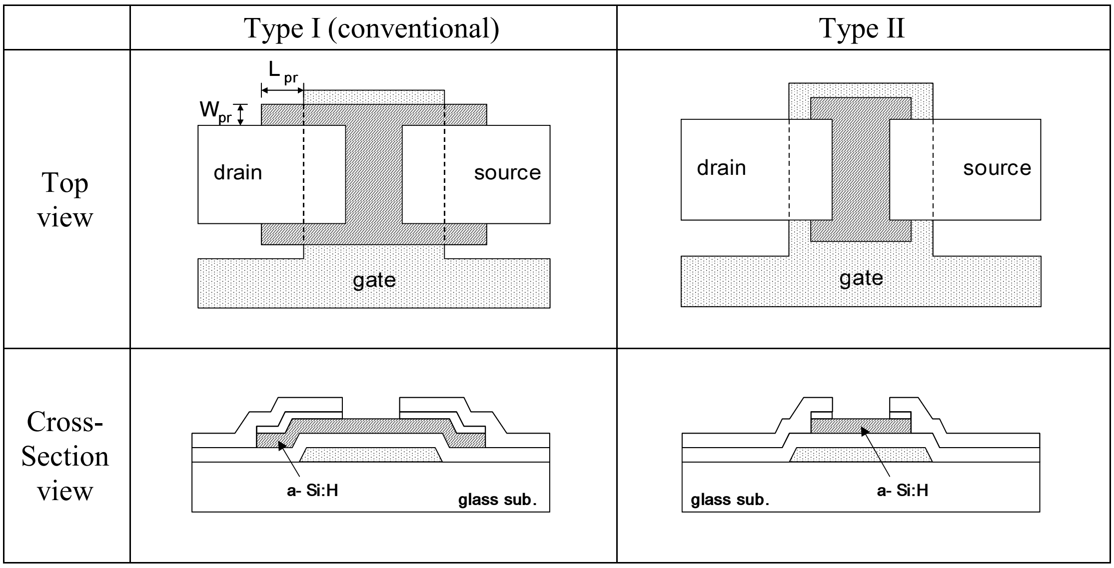
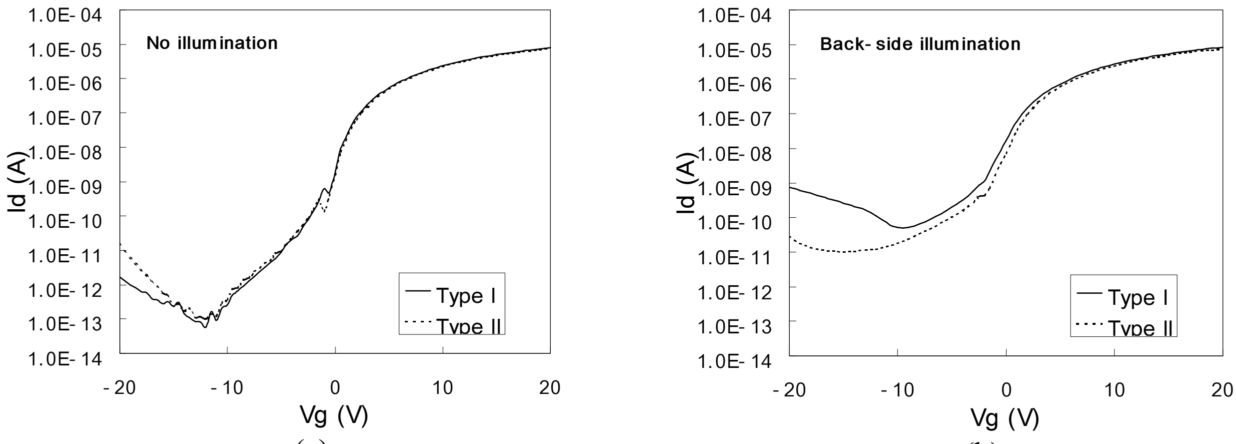


Fig.1. Comparison of two types of a-Si:H TFT design

Figure 2(a) shows I_d-V_g characteristics of each TFT under dark state where no back-side illumination was applied. All the fabricated TFT has the same channel length of 5μm and width of 40μm. The characteristics of each TFT are nearly the same and the dark leakage current shows very low magnitude lower than 10^{-12}(A). However, when back-side illumination is applied, the leakage current of each TFT show very large difference in magnitude as shown in Fig. 2(b). Figure 2(b) was obtained by measuring I_d-V_g characteristics under back-side illumination. The intensity of back-light was about 8000cd/m^2 comparable to that of LCD-TV back-light. The light induced leakage current of the conventional type I TFT is much higher than that of the type II TFT. It is clear that the protrusion of a-Si:H layer outside the gate electrode is the source of the light induced leakage current.



(a) (b)

Fig.2. I_d-V_g characteristics of Type I and Type II TFTs
(a) under dark state, (b) under back-side illumination

However, the exact location where the leakage current is generated cannot be ascertained. Therefore the design of type I was varied in two points of view such as the protruding length (L_{pr}) and width (W_{pr}) as illustrated in Fig. 1. Figure 3 shows the I_d-V_g characteristics of type I TFTs which have the different L_{pr} and W_{pr}. From Fig. 3, we can see that the protruding length and width, related to the area of protruding region, have minor effect in the magnitude of the light induced leakage current. The above result reveals that electron-hole pair generation, which is the source of light induced leakage current, is concentrated at a local point in the protruding region. It can be thought that the local point may exist near the gate edge. This can be explained as follows. Electron-hole (e-h) pair generation arises in the same magnitude in overall protruding region, however, existence of the lateral electric field near the gate edge helps separating electrons and holes to result in the leakage current so that the electrons flow into drain electrode through a-Si:H and n^+a-Si:H and the holes flow into source electrode through the hole channel accumulated by the negative gate bias.

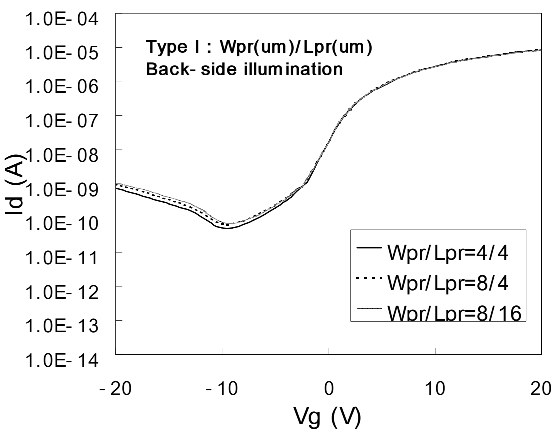


Fig.3. I_d-V_g characteristics of Type II TFTs

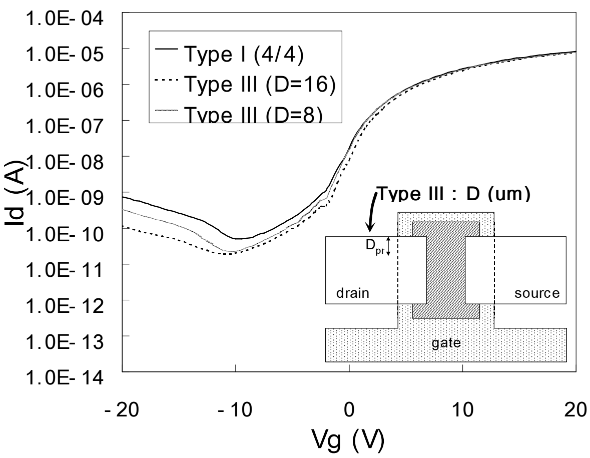


Fig.4. Comparison of I_d-V_g characteristics between Type I and Type III

Type I TFT has disadvantage in the reduction of the light induced leakage current, however it has some advantage in the viewpoint of mass production. This is because the a-Si:H layer protruding outside the gate edge prevents the source and drain electrodes from step-opening because it provides smooth step-coverage. Therefore, we investigated the light induced leakage current in another type of TFT design. The type III design is the same in the protrusion of a-Si:H layer, however the protruding region is completely covered by source and drain electrodes. In type III, electrical potential of the protruding a-Si:H layer is almost fixed by the drain voltage. Therefore the lateral electric field formed between the e-h pair generating point and the channel is weaker than that in the major leakage current generating point, which is adjacent to gate edge, of the type I TFT.

Figure 4 compares the I_d-V_g characteristics of type I TFT and type III TFT. The type III TFT has one order lower magnitude of the light induced leakage current. The light induced leakage current of type III TFT is also dependent on the design of the protruding a-Si:H layer. We varied the distance from the protruding region edge to the source and drain electrode edge. As the distance gets smaller, the light induced leakage current increases. This is due to the upper mentioned mechanism that the light induced leakage current formation is closely related to the lateral electric field. The distance from the gate edge to the channel edge is also related to the magnitude of the light induced leakage current. However, to reduce the light induced leakage current, expanding the distance increases the parasitic capacitance between the gate and the source and drain which deteriorates the LCD image quality. Therefore it is more effective to control the distance between the protruding region edge and the source and drain electrode edge. The type III TFF reduces the light induced leakage current compared with the type I TFT and it helps also the step coverage of source and drain electrode so that it maintains the advantage of preventing the step-open problem.

Conclusions

We investigated the relationship between amorphous silicon pattern design and the leakage current caused backside illumination. The conventional design where the amorphous silicon layer protrudes outside the gate electrode showed considerable increase in leakage current when the brightness of back-light was increased. The design where the amorphous silicon layer is located completely inside the gate electrode was the most effective in reducing the light induced leakage current. Although the amorphous silicon protrudes outside the gate electrode, if the protruding region is completely covered by the source and drain electrode, the light induced leakage current was reduced about one order lower than that of the conventional design.

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