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The Switching Characteristics of a-Si TFT Fabricated by Ion Doping Technique

Yasuhiro Mitani, Hirohisa Tanaka, Hiroshi Morimoto,
Mitsuo Ishii, and Katsunobu Awane
Liquid Crystal Laboratories, Liquid Crystal Display Group, Sharp Co.
2613-1 Ichinomoto-cho, Tenri-shi, Nara, Japan

We examined the switching characteristics of amorphous silicon thin-film transistors by a large area ion doping technique without mass-separation. The off-current of the ion-doped TFTs was reduced by increasing the acceleration voltages of the ion doping. Under illumination, the photo-current of the ion-doped TFTs was 1~2-figures lower than that of the conventional P-CVD deposition-doped TFTs. We believe that the ion-doped TFTs can be well applied to the switching elements of liquid crystal displays.

INTRODUCTION

Amorphous silicon thin-film transistors (a-Si TFTs) have been widely applied to switching elements of active matrix liquid crystal displays(LCDs). The LCD technology trends have shown a clear tendency that display size larger and picture resolution higher[1) 2)]. A new TFT fabrication process of a large area ion doping technique without mass-separation[3) 4)] have been presented recently to catch up these trends. This technique have several advantages, for instance, self-aligned TFT fabrication, clean junction formation, dust free, high throughput, etc., in comparison with a conventional P-CVD deposition doping technique. In the previous works, the switching characteristics of TFTs by the ion doping technique were discussed mainly in the on-region of the drain current versus gate voltage(Id-Vg) characteristics. However, the characteristics of deeply biased off-region of the Id-Vg characteristics and illuminated condition weren't reported by anyone. In case that TFTs are used as switing elements of LCDs, the Id-Vg characteristics in the off-region is one of the most important point.

In this paper we present the measurement results of the detailed Id-Vg characteristics, specially, off-current and photo-current, of the a-Si TFT fabricated by the ion doping technique without mass-separation. We also discuss the model of the off-current and the photo-current in detail.

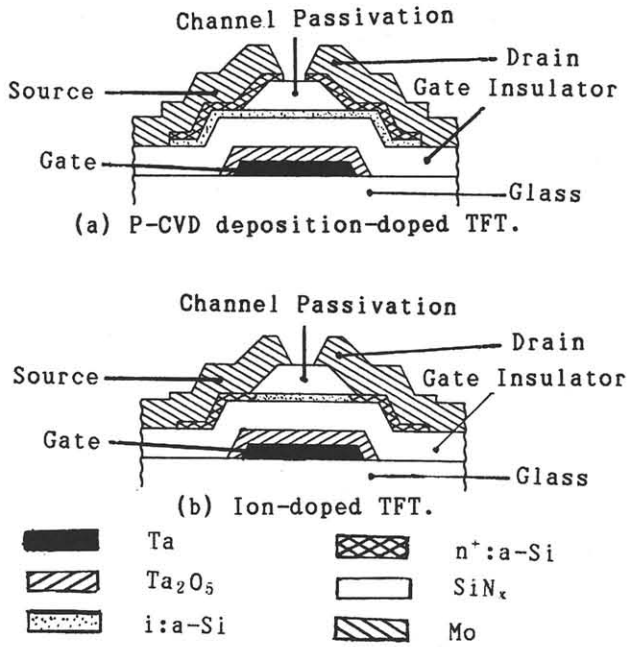


Fig.1. Schematic cross-sectional diagrams of a-Si TFTs.

TFT FABRICATION

Two type TFTs were fabricated. One was by the ion doping technique and the other was by the P-CVD deposition doping technique. Schematic cross-sectional diagrams of both the a-Si TFTs with an inverted staggered electrode are shown in Fig.1. On Corning 7059 Glass, a gate electrode of Ta was

formed. A double-layered gate insulator of anodized Ta_2O_5 and SiNx was fabricated. An i:a-Si and a SiNx passivation layer were successively deposited by a P-CVD method. Before source and drain electrodes of Mo were formed, source and drain contact regions were formed by the ion doping technique or the P-CVD deposition doping technique. We used a large area ion doping apparatus, which could be irradiated onto the sample without mass-separation. The ion doping conditions were as follows; doping gas was 5% PH_3 in H_2, acceleration voltages were 5~30kV, and total ion dose was $5\times10^{15}cm^{-2}$. On the other hand, in case of the P-CVD deposition-doped TFT, the phosphorus-doping conditions of n^+:a-Si were as follows; depositting gas was 1.2% PH_3 in SiH_4, RF-power concentration was $0.015W/cm^2$, and gas pressure was 35Pa.

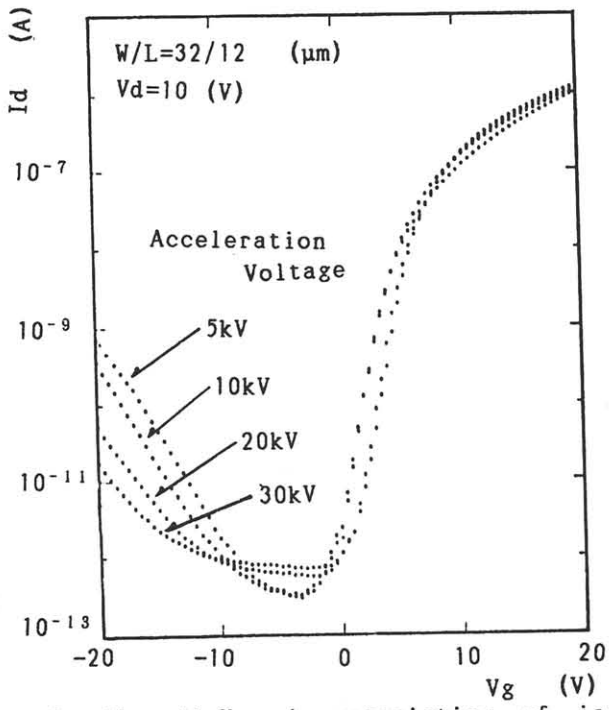
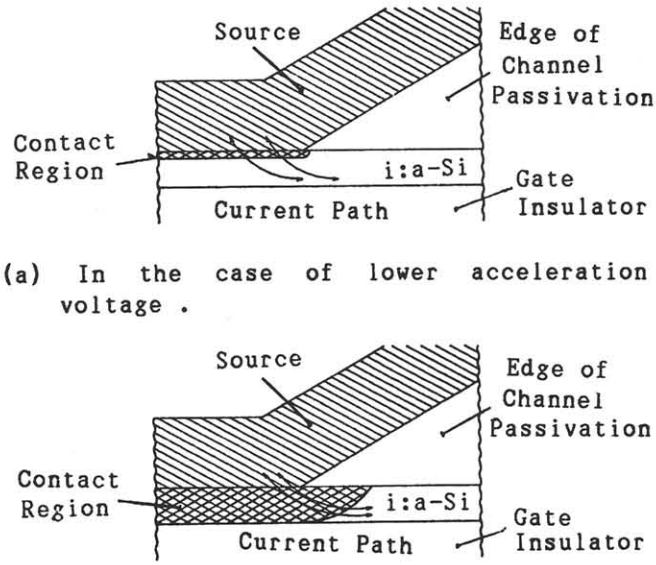


Fig.2. The Id-Vg characteristics of ion-doped a-Si TFT for various acceleration voltages.

RESULTS AND DISCUSSIONS

Figure 2 shows the typical Id-Vg characteristics of a-Si TFT as a function of acceleration voltages. There is a remarked off-current increase below the gate voltage of -10V as the gate voltage decreases. The off-current shows a rapid decrease, for instance, 1~2-figures decrease as the acceleration voltage increased from 5kV to 30kV. It is generally required for the LCD applications that the off-current is lower. Therefore, the higher energy doping is favorable to those applications.



(a) In the case of lower acceleration voltage .

(b) In the case of higher acceleration voltage .

Fig.3. Ideal schematic diagrams of the channel passivation layer edge of ion-doped TFT.

These results may be illustrated in Fig.3. The channel passivation layer has tapered edge which angle measured about 30° by using SEM cross-sectional view. It supposed that the phosphorous impurities are doped into the a-Si layer and also that under the edge of the channel passivatiuon layer. In case of the lower acceleration voltage, the current path in the contact region is short as shown in Fig.3.(a). The contact region couldn't suppress the hole current. On the other hand, increaseing the acceleration voltage, the current path in the contact region becomes longer as shown in Fig.3.(b). Then, the contact region could suppress the hole current. The off-current was lowered to the level available for the LCD application.

In the LCD applications the a-Si TFTs are illuminated from the gate side by a back light system. Figure 4 shows the Id-Vg characteristics of the a-Si TFT under the illumination of a fluoresent lamp from the gate side. The illumination intensity is 10000lux. The photo-induced off-current(photo-current) of the ion-doped TFT

was 1~2-figures lower in the off-region of the Id-Vg characteristics than that of the P-CVD deposition-doped TFT.

It is well known that the a-Si TFTs have a marked photosensitivity producing an increase in the off-current[5]. We assumed that the off-current increase is caused by the collected photo-induced-carriers created in the semiconductor region close to n^+-i junction. As shown in Fig.1. though the semiconductor region of the ion-doped TFT is not directly illuminated because of the gate electrode shadow. Therefore, the photo-current is less in the ion-doped TFTs.

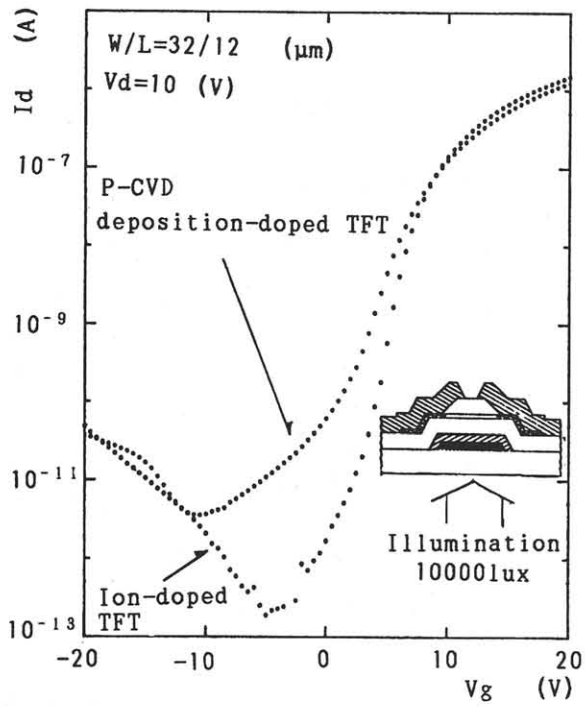


Fig.4. The Id-Vg characteristics of a-Si TFT under the illumination.

Ion-doped TFT Acceleration voltage:30kV

CONCLUSION

We have presented disscusion of the switching characteristics in the a-Si TFT fabricated by the ion doping technique. We have shown the off-current decrease by increasing the acceleration voltages of ion doping. The off-current shows 1~2-figures decrease as the acceleration voltage increased from 5kV to 30kV. Because the current path in the contact region becomes longer due to increase the acceleration voltage, the contact region could suppress the hole current. Beside, the ion doping technique offers a considerable advantage of the less photo-current in comparison with the P-CVD deposition doping technique. It is clearly shown that the a-Si TFT fabricated by the large area ion doping technique can be well applied to the active matrix LCDs.

ACKNOWLEDGMENTS

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