Hydrogenated Amorphous Silicon Film Transistor Fabrication with Back-channel-oxidized Method

Meng Chen[1], Zhengxing Xu[2], Zhixiong Jiang[1], Shiyu Dong[1], HantaoYang[1], Lingzhi Wu[2], Houkuan Sun[2], Lei Guo[2], Wufeng Ren[2], Wu Cao[1], Hongyuan Xu[1], Jun Seo[2]

chenmeng02@tcl.com

[1] TCL China Star Optoelectronics Technology Co., Ltd Shenzhen, China

[2] Shenzhen China Star Optoelectronics Semiconductor Display Technology Co., Ltd Shenzhen, China

Keywords: amorphous silicon, thin film transistor, back-channel-oxidized method;

ABSTRACT

An a-Si:H thin film transistor was fabricated with back-channel-oxidized (BCO) method. The mobility of the BCO TFT was 0.42 cm^2/V·s, and stability characteristic was comparable with back-channel-etched (BCE) type TFT. It were studied that different n+ layer thickness, oxidation time and pre-treatment influenced BCO TFT device characteristics. The BCO method would be a competitive technology for TFT fabrication process in mass production like liquid-crystal displays in the future.

1 Introduction

Hydrogenated amorphous silicon (a-Si:H) is widely used as active material in active-matrix liquid-crystal displays (AMLCDs). In addition, a-Si:H can be easily prepared and deposited over a large area at low temperatures, offering sufficient field effect mobility for thin film transistor liquid crystal displays (TFT-LCDs). In the mass array production of liquid crystal displays, the TFT type of inverted staggered and back-channel-etched(BCE) structure is typically applied to array process for the consideration of low cost. A typical BCE TFT structure is depicted in Fig.1a. However, a relatively thicker amorphous silicon layer has to be deposited for the reason of back channel damage in the TFT fabrication. Moreover, the thicker silicon layer would lead to larger photo leakage current as amorphous silicon is photo-sensitive. In the mass production, amorphous silicon remaining thickness of TFT inner channel and its uniformity should be controlled and monitored for the production quality, especially in the large size LCDs such as 85"/98" and large generation production line like G8.5 and G11. In previous work of Kazushige [1], the back-channel-oxidized (BCO) method was proved to be feasible through decreased back channel damage in TFT fabrication. Furthermore, it has a limiting oxidation depth of silicon by oxygen plasma oxidation [2]. In order to improve TFT characteristics and amorphous silicon remaining thickness uniformity, back-channel-oxidized method was used to TFT fabrication and its TFT characteristics were studied in this paper.

2 Experiment

The TFTs employed in this work possessed a conventional bottom gated, inverted staggered structure. The cross-sectional view of BCO TFT was shown in Fig.1b. Following the deposition and patterning of gate metals with Al/Mo, the SiNx, gate insulator interface layer, a-Si:H and n+ a-Si:H(n+ layer) were subsequently deposited as gate insulator, active layer and ohmic contact layer, using plasma-enhanced chemical vapor deposition process. Our n+ layer thickness was about 5-10nm as oxidation has limiting depth. Conventional UV photolithography process which applied to TFT structures pattern was used in our study. After drain/source electrode pattern formation, we used oxygen plasma for TFT back channel oxidation instead of conventional etching gas like SF6/NF3/CF4 which included F radical to etch n+ layer. Finally, the contact holes of the devices were opened by dry etching. Overall, the width and length of these fabricated TFT devices were 50 and 4 μm respectively. The general TFT of BCE type was also fabricated in comparison.

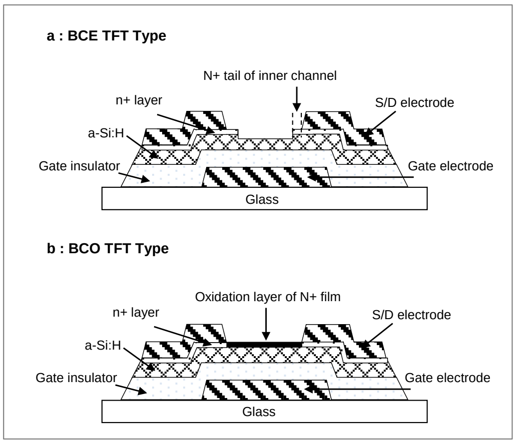

Fig. 1 Typical cross-sectional view of BCE TFT (a) and BCO TFT (b)

After fabrication completed, the TFT devices electrical characteristics were confirmed by transfer and output IV curves measurement. BCO TFTs threshold voltage, sub-threshold swing and mobility were extracted by transfer characteristic curves, and compared with conventional BCE TFTs, as well as threshold voltage shift of both

TFTs in stability test. It were studied that different n+ layer thickness, oxidation time and pre-treatment process before oxidation influenced TFT devices characteristics since the oxidation depth and oxidation capacity are critical.

3 Results and Discussions

Fig.2 showed the BCO and BCE TFTs transfer characteristic curves with *Vds* 15V were shown in Fig.2. The BCO TFT off state current (Ioff) with *Vgs* -10V is higher than BCE TFT, meantime the Poole-Frankel leakage current is lower than later. The reason of the higher Ioff of BCO TFT could be the high density of back channel defects. While the Poole-Frenkel current is lower than BCE could be explained by the pinning effect of back channel defects. The On state current (Ion) with *Vgs* 25V is lower than BCE TFTs. That maybe be explained that decreasing of n+ tail at inner channel, which was descripted in Fig.1, lead to increase the actual channel length, then Ion decreased. BCO TFT output characteristic curve was shown in the Fig.2b, which revealed that the current crowding did not occur. It turned out that the n+ layer thickness of 5~10nm still has tolerable ohmic contact performance. The device characteristics of BCO and BCE TFT which were extracted from the transfer curves were listed in Table 1.

The gate bias thermal illumination stress results of BCO TFT were shown in Fig.3, in comparison with BCE TFT. The measurement conditions were temperature 80 °C, illumination 6000 nits, positive/negative gate voltage bias +/-30V, and *V*ds 0V, respectively. The stress time was from 0 second to 2000 seconds, successively. Threshold voltage shift (*ΔVth*) were calculated and listed in Table 1. It could be concluded that the stabilities of BCO and BCE TFT had no significant differences. The off state and Poole-Frenkel area leakage currents of BCO TFT were nearly constant with stress time while BCE TFT shifted as the normal stress tendencies [3].

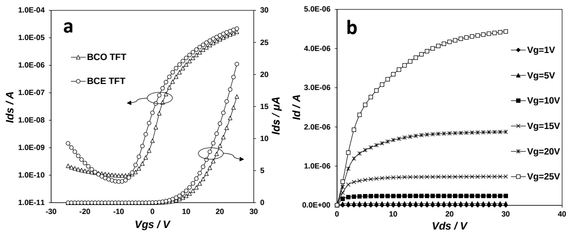

Fig.2 BCO and BCE TFT transfer characteristic curve(a) and output characteristic curve(b) of BCO TFT

Table 1 characteristics of BCO and BCE TFT

	μ (cm²/ Vs)	*Vth (V)*	*SS (V/dec)*	*ΔVth_ NBTIS (V)*	*ΔVth_ PBTIS (V)*
BCO TFT	0.42	1.49	1.96	-4.58	5.03
BCE TFT	0.50	0.49	2.67	-4.36	5.17

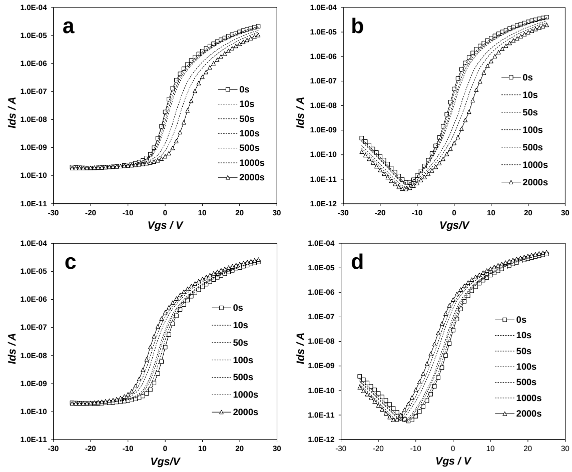

Fig.3 positive/negative gate bias thermal illumination stresses of BCO and BCE TFT with stress times: BCO TFT positive (a) / negative(c), BCE TFT positive (b) / negative (d)

It were studied that different n+ layer thickness, oxidation time and pre-treatment influenced BCO TFT device characteristics. Fig.4a showed the different n+ layer thickness of BCO TFT characterastics curve result. It was found that Ioff increased rapidly with the incresing of the n+ layer thickness. The oxidation capasity might be not strong enough so the oxidation process should be improved as the process window is not wide enough. Fig.4b showed oxidation time characterastics curve results, which showed that Ioff decreased with oxidation time increased, and would have a saturation of oxidation. Fig.4c showed the influence of pre-teatment before the back channel oxidation process. With pre-treatment circumstance, the leakage current was obviously lower than W/O pre-treatment performance. Before dry process, some residues like $SiMo_x$ or SiO_x would stop the oxidation. After pre-treatment by SF6 gas, the residues were removed and oxidation could successfully accomplish.

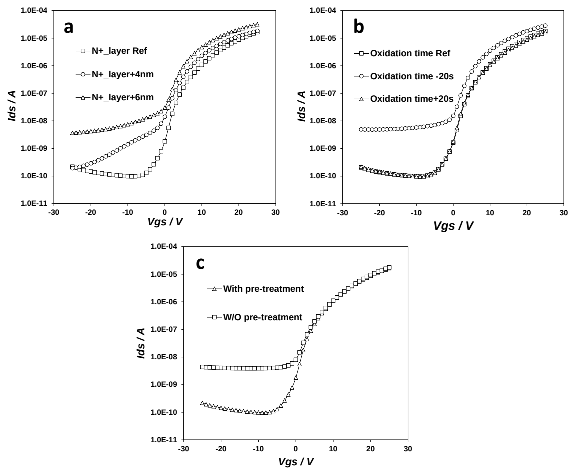

Fig.4 influences of BCO TFT characteristics with different n+ layer thickness (a), oxidation time(b) and pre-treatment(c)

4 Conclusions

An a-Si:H thin film transistor was fabricated with back-channel-oxidized(BCO) method. The mobility 0.42 $cm^2/V\cdot s$, threshold voltage 1.49V, sub-threshold swing 1.96V/dec of BCO TFT, and stability characteristics was comparable with back-channel-etched (BCE) TFT. It were studied that different n+ layer thickness, oxidation time and pre-treatment influenced BCO TFT device characteristics. The process window of BCO method is not wide enough currently and need further tuning. The BCO method would be a competitive technology for TFT fabrication process in mass production like liquid-crystal displays in the future.

References

[1] Kazushige, Takechi, Naoto, et al. Back-channel-oxidized a- Si:H thin-film transistors[J]. Journal of Applied Physics, 1998, 84(7):3993-3993.

[2] Masuda A , Morimoto A , Kumeda M , et al. Novel oxidation process of hydrogenated amorphous silicon utilizing nitrous oxide plasma[J]. Applied Physics Letters, 1992, 61(7):816-818.

[3] Powell, M. J. The physics of amorphous-silicon thin-film transistors[J]. Electron Devices IEEE Transactions on, 1989, 36(12):2753-2763.