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The effect of nitrous oxide plasma treatment on the bias temperature stress of metal oxide thin film transistors with high mobility

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ABSTRACT

In this work, the effects of nitrous oxide plasma treatment on the negative bias temperature stress of indium tin zinc oxide (ITZO) and indium gallium zinc oxide (IGZO) thin film transistors (TFTs) were reported. ITZO TFTs were more suitable for the back channel etched-type device structure because they could withstand both Al- and Cu-acid damage. The initial threshold voltage range could be controlled to within 1 V. The root cause of poor negative bias temperature stress for ITZO was likely due to a higher mobility (~3.3 times) and more carbon related contamination bonds (~5.9 times) relative to IGZO. Finally, 65″ active-matrix organic light-emitting diode televisions using the ITZO and IGZO TFTs were fabricated.

1. Introduction

Flat plane display (FPD) using amorphous oxide semiconductors (AOS) is a technology that is being actively developed in recent years. High performance FPDs using transparent amorphous oxide semiconductors (TAOS) have been called the next generation of displays. Thin film transistors (TFTs) using TAOS are considered an attractive alternative to poly-Si TFTs because such transistors provide much better large area uniformity and improved device characteristics, including threshold voltage (V_{th}), an amorphous structure, and higher field effect mobility compared to poly-Si TFTs [1–4]. Among several candidates, amorphous indium gallium zinc oxide (IGZO) is favored because the elements In, Zn, and Ga can enhance electron mobility, produce an amorphous microstructure, and suppress undesirable free electron formation in the channel, respectively [2].

For next-generation displays requiring ultrahigh resolution and high frame rate, a mobility of ~10 $cm^2/V\,s$ observed in IGZO TFTs is not sufficient for the integrated driving circuit. Fukumoto et al. from Sony reported an 8” amorphous indium tin zinc oxide (ITZO) panel during International Display Workshops [5]. ITZO has a higher mobility than IGZO at >~30 $cm^2/V\,s$, which is more suitable for the next-generation displays [6,7]. The high mobility of ITZO TFT results in a higher driving current under the same electric field, making it more suitable for driving an AMOLED TV. In other words, the same driving current can be achieved using a lower driving voltage or a smaller device size.

In this paper, a nitrous oxide (N_2O) plasma treatment was used on both the IGZO and ITZO back channel. After fine tuning the production process, the negative bias temperature stress (NBTS) improvements were found. Finally, 65” IGZO and ITZO FHD AMOLED TV were fabricated.

2. Experimental

Cleaned Gen6 ($1850 \times 1500\ mm^2$) glass was used as the substrate in this study. Molybdenum/aluminum was used as the bottom gate, and SiO_x was used as the gate insulator (GI) layer. IGZO and ITZO were deposited as the oxide semiconductor active layers by a DC-type sputtering system. O_2/Ar gas ratio were fixed at 5% and 20%, respectively. Fig. 1 shows the schematic cross-section of bottom gate oxide TFTs used for this study, including (a) etch-stop (IS) and (b) back-channel etched (BCE) structures. After patterning

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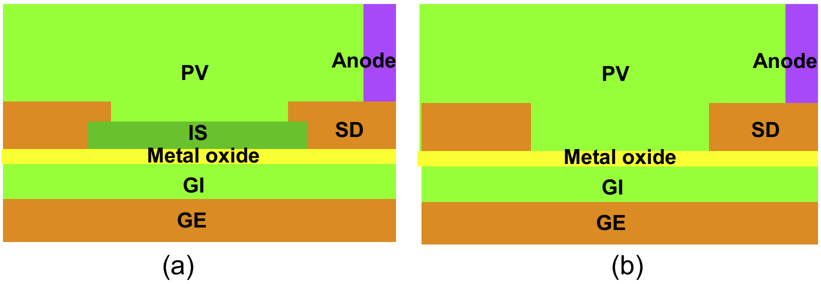


Fig. 1. Schematic cross-section of (a) IS and (b) BCE type ITZO TFTs.

the oxide semiconductor active layers, the surface of the back channel were treated with N_2O plasma.

The molybdenum/aluminum/molybdenum was used as source/drain electrodes. SiO_x/SiN_x was used as passivation layers (PV) and N_2O, SiH_4 and NH_3 were used as the precursors. A 300 °C post air (CDA) annealing for 2 h was processed. Finally, an ITO was used as anode electrode. The initial transfer characteristics were measured at room temperature with an Agilent E5270B precision semiconductor parameter analyzer. The stress characteristics of the oxide TFTs were measured at 60 °C for 14.4 ks in air while they were placed in a dark box. Gate and drain voltages are biased at −15 V and +10 V, respectively. The morphology, thickness and etch rate were examined by scanning electron microscopy (SEM) and tunneling electron microscopy (TEM). The composition and bonding status were examined by ESCA/XPS. Pre-sputter was performed to remove the surface layer oxide in case of contamination. The main etching mechanisms of HNO_3-based (for Al and Mo etch, so-called Al-acid or PAN etch) and H_2O_2-based (for Cu and Mo etch, so-called Cu-acid etch) etchant are as follows:

HNO_3-based (Al acid):

$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^- \quad (1)$$

$$2Mo + 6H^+ \rightarrow 2Mo_3^+ + 3H_2 \quad (2)$$

$$H_3PO_4 + 2H_2O \rightarrow 2H_3O^+ + HPO_4^- \quad (3)$$

$$2Mo_3^+ + 3HPO_4^{2-} \rightarrow Mo_2(HPO_4)_3 \rightarrow 2MoPO_4 + H_3PO_4 \quad (4)$$

H_2O_2-based (Cu acid):

$$Mo + 2H_2O_2 \rightarrow MoO_2 + 2H_2O \quad (5)$$

$$MoO_2 + H_2O_2 \rightarrow MoO_{2^-} + 2H^+ \quad (6)$$

Fig. 2(a) and (b) shows the cross-sectional SEM views of ITZO after Al and Cu etch, respectively. No clear thickness difference was observed, indicating that ITZO would not be removed during the SD electrode patterning, and that Al- and Cu-acid etch had high

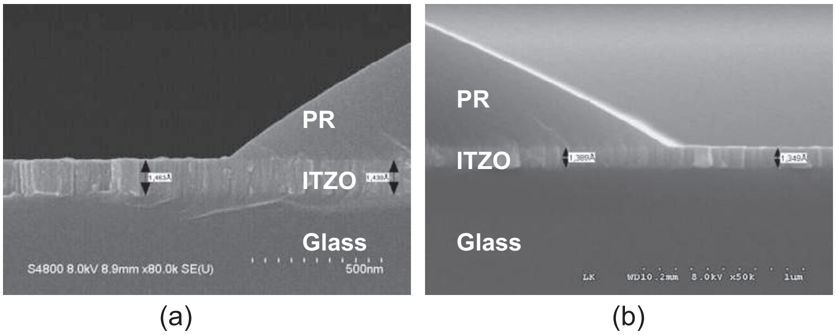
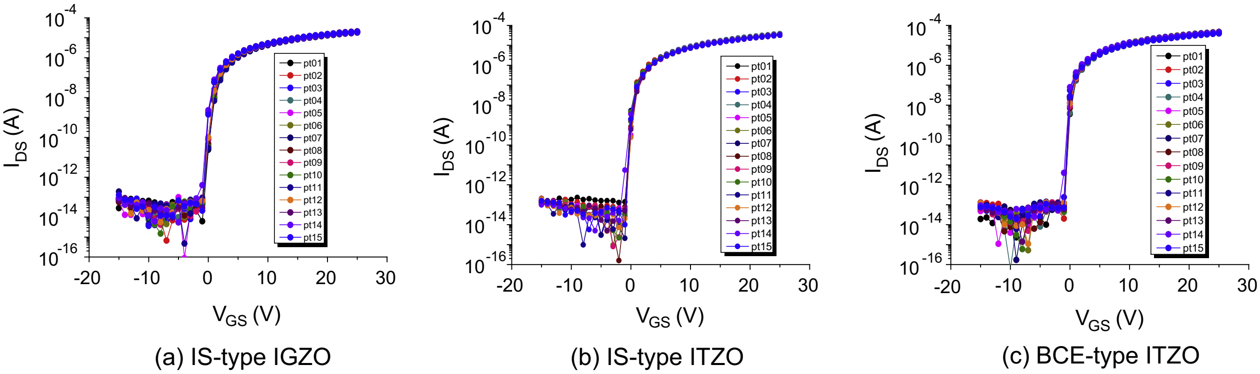


Fig. 2. The SEM cross-sectional views of ITZO/glass after (a) Al- and (b) Cu-acid etch.



(a) IS-type IGZO (b) IS-type ITZO (c) BCE-type ITZO

Fig. 3. The normalized transfer curve map of IGZO and ITZO TFTs.