

Highly stable Zn-In-Sn-O TFTs for the Application of AM-OLED Display

Min Ki Ryu*, Sang-Hee Ko Park, Shin Hyuk Yang, Woo-Seok Cheong, Chun-Won Byun, Sung Mook Chung, OhSang Kwon, Eunsuk Park, Jae Kyeong Jeong, Kyoung Ik Cho, Doo-hee Cho^a, Jeong-Ik Lee^a, and Chi-Sun Hwang

Transparent Display Team, OLED Lighting Team^a, ETRI, Daejeon 305-700, Korea
TEL:82-42-860-6276, e-mail : ryumk@.etri.re.kr.

Abstract

Highly stable bottom gate thin film transistors (TFTs) with a zinc indium tin oxide (Zn-In-Sn-O:ZITO) channel layer have been fabricated by rf-magnetron co-sputtering using a indium tin oxide (ITO:90/10), a tin oxide and a zinc oxide targets. The ZITO TFT ($W/L=40\ \mu\text{m}/20\ \mu\text{m}$) has a mobility of $24.6\ \text{cm}^2/\text{Vs}$, a subthreshold swing of $0.12\text{V}/\text{dec.}$, a turn-on voltage of -0.4V and an on/off ratio of $>10^9$. When gate field of $1.8 \times 10^5\ \text{V}/\text{cm}$ was applied with source-drain current of $3\ \mu\text{A}$ at 60°C , the threshold voltage shift was $\sim 0.18\text{V}$ after 135 hours. We fabricated AM-OLED driven by highly stable bottom gate Zn-In-Sn-O TFT array.

1. Introduction

Transparent oxide thin film transistors (TFTs) hold great promise for a variety of electronic applications, including active-matrix (AM) liquid crystal displays, organic light-emitting diode (OLED) displays¹, and flexible and/or see-through displays, because they not only have high mobility but also can be fabricated uniformly at low temperature in a large-area with a low production cost. For the display application, the stability requirement is more stringent for driving OLED than for driving AMLCD. In AMLCDs, the TFT functions as a digital switch with a low duty cycle ($\sim 0.1\%$), and a threshold voltage (V_{th}) shift of a few volts can be tolerated². In AMOLED pixels, however, an increase of the V_{th} of the driving TFT reduces the OLED driving current to decrease the brightness of the pixel. Therefore, it is very important to get high stability of TFT under bias stress with high mobility. Here we report highly stable bottom gate ZITO TFTs that is superior to any other oxide TFT. Furthermore, we fabricated transparent ZITO TFT (TTFT) array and integrated OLED on the TTFT array to result in

high aperture ratio of 2.5" bottom emission AM-OLED.

2. Experimental

We have fabricated the bottom gate TFTs with the active layer composed with Zn-In-Sn-O (ZITO). The schematic diagram of the bottom gate ZITO TFT structure is shown in Fig. 1. An alkaline-free glass was used as a substrate. Gate and source/drain electrodes were deposited with 150 nm-thick ITO (indium tin oxide). A gate insulator of Al_2O_3 was formed by atomic layer deposition (ALD) method at 150°C and its thickness was 180 nm. A ZITO layer was formed by co-sputtering of an ITO(90:10), a SnO_2 and a ZnO targets with an off-axis type RF magnetron sputter at room temperature. The sputtering was performed in the atmosphere of Ar and O_2 mixed gas with the chamber pressure of 0.3 Pa. The protective layer and passivation layer were 23 nm-thick Al_2O_3 deposited by PEALD method using trimethyl aluminum (TMA) and oxygen plasma. All patterning processes were performed by photo-lithographic method and wet etching process. The annealing was performed at 300°C in O_2 atmosphere. The electrical characteristics of the TFTs were measured with the semiconductor parameter analyzer (Agilent B1500A) in darkness.

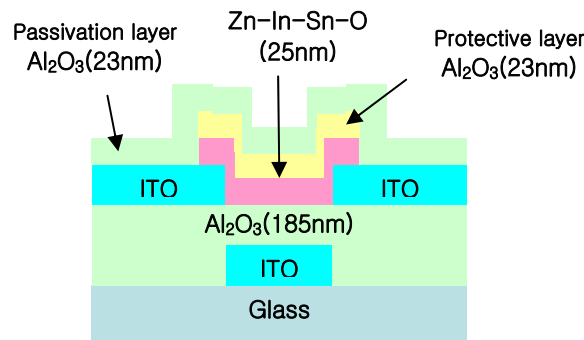


Fig. 1. Cross sectional view of bottom gate ZITO TFT.

3. Results and Discussion

Fig. 2 shows the transfer characteristics of the ZITO TFT. The measurement was carried out by varying the V_{GS} value from -10V to 20V and then back to -10V. An excellent SS of 0.12V/decade, V_{on} of -0.4V, and high on/off ratio of $>10^9$ as well as a high μ_{FE} of 24.6 cm^2/Vs were achieved.

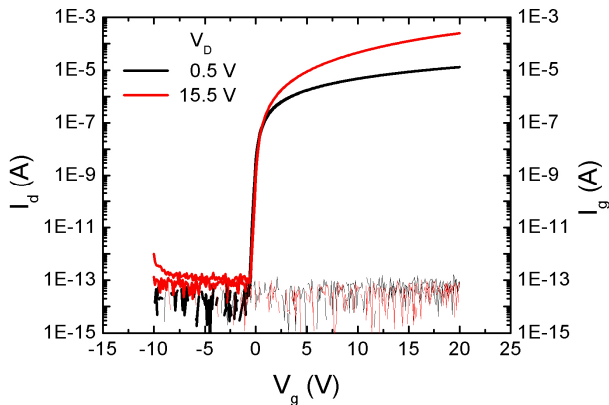


Fig. 2. The transfer characteristics of the ZITO TFT ($W/L=40 \mu\text{m}/20 \mu\text{m}$). The measurement was carried out by varying the V_{GS} value from -10V to 20V and then back to -10V.

To measure bias stress stability, we applied gate voltage was 3.5 V with source-drain currents of 3 μA at 60°C which is sufficient to provide drain current required to drive a typical OLED pixel.

In Fig. 3(a), bias stressing was interrupted in order to measure the transfer characteristics. Saturation mobility μ_{FE} and V_{th} were obtained in the saturation regime by extracting the axis intercept and the slope above V_{th} from $I_D^{0.5}$ vs V_G plot, respectively. The same slopes for the 0 second, 100K seconds, and 135 hours means that the mobility is almost unchanged during bias stress. Considering most of oxide TFTs with high mobility showed change of mobility under bias stress due to the defects creation in the active bulk film, our ZITO active film seems to be relatively stable. In Fig. 3(b) the time dependence of ΔV_{th} for selected samples is presented on a logarithmic time scale. Transfer curve shifted to positive way under bias stress. We are under investigation to clarify the mechanism of V_{th} shift under bias stress.

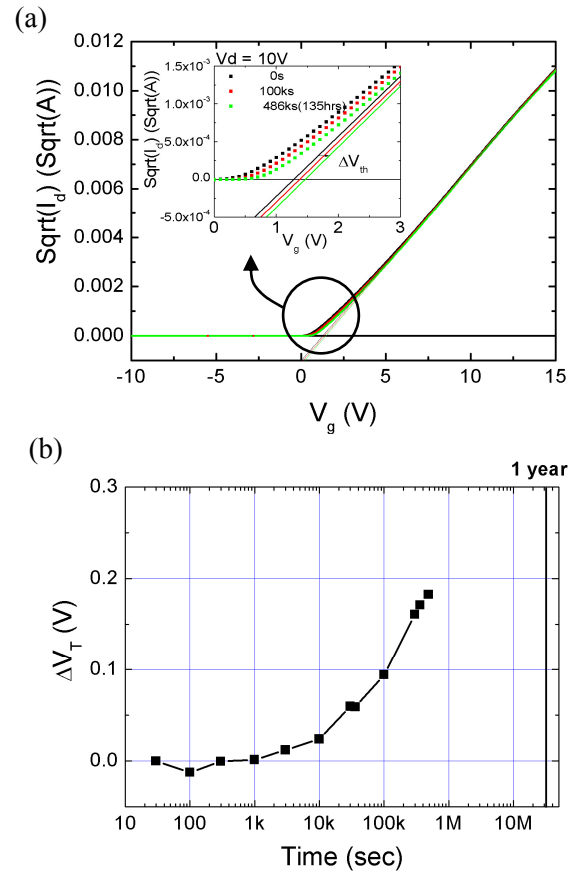


FIG. 3. (a) $I_D^{0.5}$ vs V_G plot used to extract V_{th} , ΔV_{th} , and μ_{FE} during bias stress test at 60°C and (b) the corresponding time dependencies of ΔV_{th} for selected samples.

3. Impact

We developed that high stable bottom gate oxide TFT. The ZITO TFTs ($W/L=40\mu\text{m}/20\mu\text{m}$) has a mobility of 24.6 cm^2/Vs , a subthreshold swing of 0.12V/dec., a turn-on voltage of -0.4V and an on/off ratio of $>10^9$. When operated at a gate field of $1.8 \times 10^5 \text{ V/cm}$ with source-drain currents of 3 μA , the V_{th} shift is $\sim 0.18 \text{ V}$ after 135 hours at 60°C. While most of oxide TFT with mobility higher than 15 cm^2/Vs showed relatively poor bias stress stability, our ZITO TFTs have excellent stability even with high mobility. We will demonstrate AM-OLED with ZITO TFT.

5. Acknowledgement

This work was supported by the IT R&D program of MIC/IITA. [2006-S079-04, Smart window with transparent electronic devices].

6. References

1. Sang-Hee Ko Park, Chi-Sun Hwang, Leong-Ik Lee, Sung Mook Chung, Yong Suk Yang, Lee-Mi Do, and Hye Yong Chu, Proc. SID'06, p 25, 2006.
2. Bahman Hekmatshoar, Kunigunde H. Cherenack, Alex Z. Kattamis, Ke Long, Sigurd Wagner, and James C. Sturm, Appl. Phys. Lett. **93**, 032103 (2008).