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Enhancement-mode MOCVD Grown ZnO TFTs on Glass Substrates Using N_2O Plasma Treatment

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1. Introduction

ZnO TFTs are under active research for employing them in future transparent display systems because they posses better electrical characteristics and transparency compared to Si based TFTs. Even though different growth techniques have been employed to realize ZnO TFTs, metal organic chemical vapor deposition (MOCVD) method has its own advantages such as good reproducibility and it can be used realize ZnO heterostructure devices. However, only a couple of reports are available on MOCVD grown ZnO TFTs [1-3]. Enhancement-mode of device operation is preferable to depletion–mode because the circuit design is easier, and power dissipation is minimized when enhancement-mode TFTs are employed [4]. Moreover, off-current level should be as low as possible to achieve high contrast ratio in AM-OLED displays [5], and low off-state leakage current is a requirement to control AMLCDS [6]. The reported TFTs fabricated using MOCVD grown ZnO as channel layer exhibited depletion-type device characteristics [1,2] with considerable current between source and drain even when the gate voltage is zero, indicating high concentration of carriers in the channel. Recently, Jo *et al* [3] reported growth interruption technique to achieve enhancement-mode MOCVD ZnO TFTs. In this work, we report the effect of N_2O plasma treatment on the electrical performance of MOCVD grown ZnO TFTs on glass substrates. The N_2O plasma treatment changed the operation of as-fabricated TFTs from depletion-mode to enhancement-mode. Also, it remarkably improved the performance of TFTs in terms of off-current, on/off current ratio, and subthreshold slope.

2. Device Fabrication

Bottom-gated TFTs were fabricated using MOCVD grown ZnO channel at 350°C and PECVD Si_3N_4 gate dielectric at 300°C on Corning 1737 glass substrates coated with indium tin oxide. Here ITO acted as the bottom gate electrode and Ti/Pt/Au the source/drain electrodes. The schematic cross-sectional view and the top view of the fabricated TFTs are shown in Fig. 1. The SEM image and XRD spectrum of the grown ZnO film are shown in Fig. 2.

3. Results and Discussions

I_D-V_{DS} and I_D-V_{GS} characteristics of the as-fabricated TFTs with W/L=200/20 μm are shown in Fig. 3(a) and Fig. 3(b) respectively. The higher drain current of 24 μA at a V_{GS} of 0 V indicates that the device operation is depletion-type. This suggests high concentration of carriers in the as-grown undoped ZnO channel. The off-current, on/off current ratio and subthreshold slope are 0.6 nA, 10^6 and 5 V/decade respectively. In order to see the influence of N_2O plasma on the device performance, we have subjected the as-fabricated TFTs to N_2O plasma at 300°C for 665 seconds in a PECVD chamber. The output and the transfer characteristics obtained after the N_2O plasma treatment are shown in Fig. 4(a) and Fig. 4(b) respectively. After the N_2O treatment, the drain current at zero V_{GS} has decreased drastically from 24 μA to 15 pA, and the device operates as enhancement-mode. This suggests a decrease of carrier concentration in the ZnO channel layer. Also, the N_2O treatment has improved the on/off current ratio to higher than 10^8, and the off-current now is only 0.1 pA. Also, it may be noted that there is a slight decrease in the ON current value. The subthreshold slope has improved dramatically from 5 to just 0.65 V/decade. The change of device operation from depletion-type to enhancement-type and the improvement of off-current 0.6 nA to 0.1 pA may be due to the incorporation of oxygen into ZnO film from the N_2O plasma. Since oxygen vacancies act as n-type dopants [7], the reduction of oxygen vacancies can decrease the carrier concentration in the channel. The influence of N_2O plasma on the as-fabricated TFTs for different durations is shown in Fig. 5. The characteristics of another set of TFTs fabricated using ZnO channel grown at slightly higher temperature of 450°C and PECVD SiO_2 gate dielectric shown in Fig. 6, indicates similar trend observed for the previous set of TFTs, but with higher field effect mobility.

4. Conclusions

The post-processing of N_2O plasma treatment on the as-fabricated ZnO TFTs changed the device operation from depletion-type to enhancement-type. It improved off-current and on/off current ratio of the devices by more than two orders of magnitude. The off-current of the devices decreased from 0.6 nA to 0.1 pA and the on/off current ratio increased from 10^6 to 10^8. It can be concluded that oxygen present in the N_2O modifies the ZnO channel layer during the N_2O plasma treatment. Oxygen vacancies, acting as n-type dopants in the ZnO were reduced by the N_2O plasma treatment, resulting in better device performance.

Acknowledgment

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References

[1] J. Jo *et al*, Jpn. J. Appl. Phys. **46** (2007) 2493
[2] J. Zhu *et al*, J. Electronic Materials **37** (2008) 1237
[3] J. Jo *et al*, Appl. Phys. Express **1** (2008) 041202
[4] E. M. C. Fortunato *et al*, Appl. Phys. Lett. **85** (2004) 2541
[5] J. W. Park *et al*, IEEE Electron Device Lett. **30** (2009) 362
[6] C. W. Chen *et al*, IEEE Electron Device Lett. **26** (2005) 731
[7] B. Yao, *et al*, J. Appl. Phys. **99** (2006) 123510

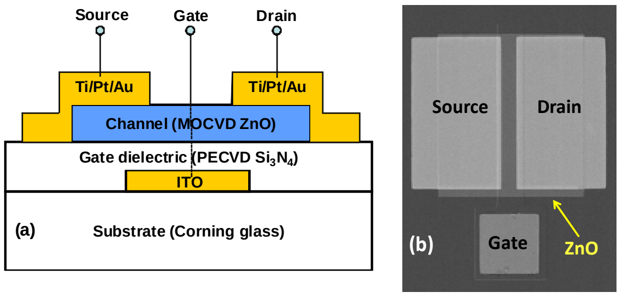

Fig. 1 Fabricated bottom-gated MOCVD grown ZnO TFTs.
(a) Schematic cross-sectional view, and (b) SEM top view.

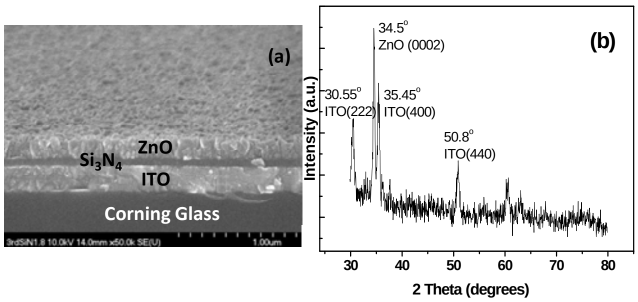

Fig. 2 MOCVD grown ZnO films on Si_3N_4/ITO/galss substrates. (a) SEM image and, (b) XRD spectrum.

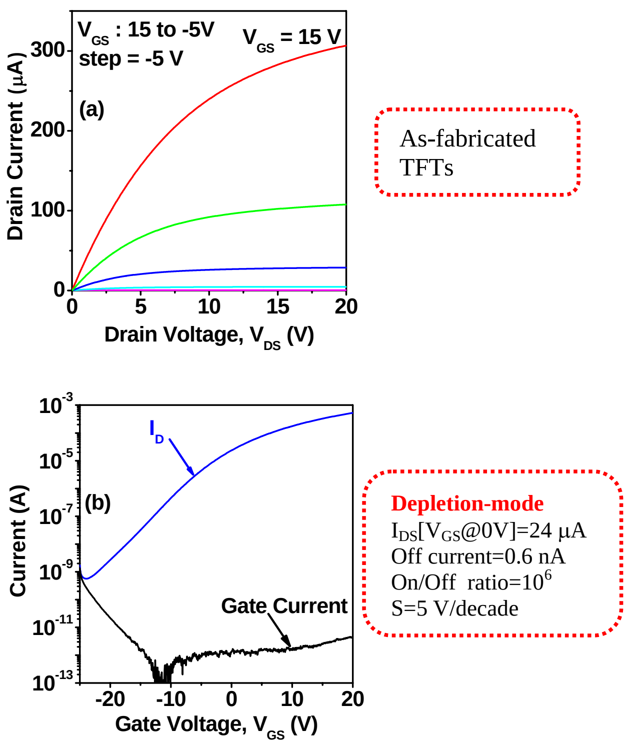

Fig. 3 Characteristics of ZnO TFTs with W=200 μm and L=20 μm. (a) Output characteristics with V_{GS} from 15 to –5 V in steps of –5 V, (b) transfer characteristics and gate leakage current at V_{DS} of 10 V.

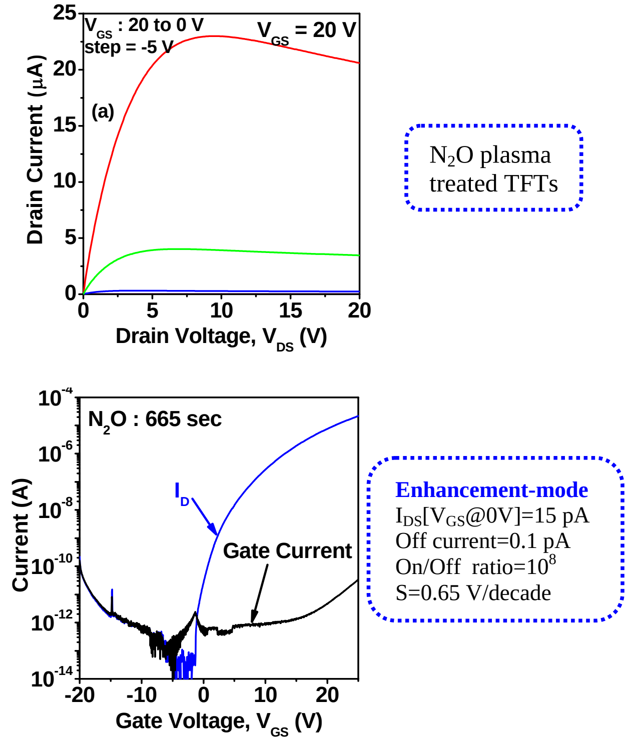

Fig. 4 Characteristics of ZnO TFTs after the N_2O plasma treatment. (a) Output characteristics with V_{GS} from 20 to 0 V in steps of –5 V, (b) transfer characteristics and gate leakage current at V_{DS} of 10 V.

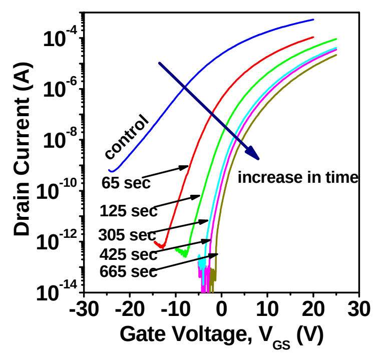

Fig. 5 Transfer characteristics of ZnO TFTs after the N_2O plasma treatment for different durations.

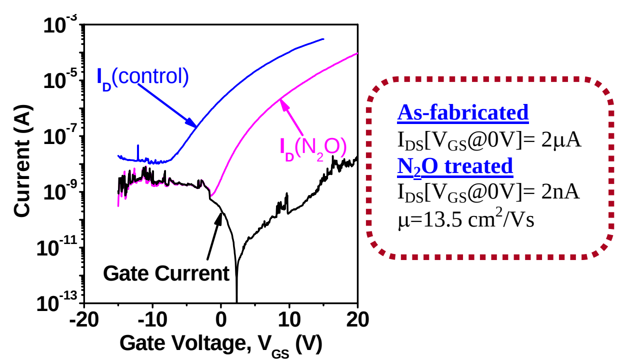

Fig. 6 Transfer characteristics of ZnO TFTs before and after the N_2O plasma treatment. (ZnO grown at 450°C and PECVD SiO_2 gate dielectric)