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The low frequency noise analysis in bottom-gated ZnO Thin film Transistors with different active layer thickness

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1. Introduction

ZnO-based TFTs have attracted much attention for flexible display as they can be fabricated on plastic substrates and at low temperature and have the ability to be used to produce highly uniform and large-area displays with low production cost [1-2]. In addition, the high mobility characteristics have indicated that these devices could play roles in both the driver device of AMOLED and the switching device of AMLCD [3-4]. However, ZnO-based TFTs used as the driver device in AMOLED particularly have difficulty with the instability of the threshold voltage resulting from gate bias [5].

Thus, to find out the definite reason for the threshold voltage shift, we carry out the low frequency noise (1/f noise) characteristics analysis in ZnO TFTs with different active layers, which is used in the trap analysis of various TFTs such as a-Si:H, poly, organic and IGZO TFTs [6-8].

2. Device structure and Experiments

In order to fabricate bottom-gated ZnO TFTs, Ti gate layer (100nm) on the SiO_2/Si substrate is deposited by RF magnetron sputter at room temperature. Si_3N_4(200nm) film as gate insulator and the active layer with different thicknesses (40nm, 80nm) is deposited subsequently at the low temperature, using PECVD and RF magnetron sputtering. Afterwards, the passivation layer, insulation film between layers and contact/metal pad are formed. The schematic of the bottom-gated ZnO TFT structure used in this paper is shown in Fig. 1.

The low-frequency noise measurements are performed at room temperature using Dynamic Signal Analizer(35670A) preceded by a low-noise current-voltage converter, a low noise voltage amplifier(SR570) and Agilent 4156C.

3. Result and Discussion

Fig. 2 shows the transfer characteristics of ZnO TFTs. The curve of ZnO TFTs with 40 nm and 80 nm shows the n-type characteristics with the field effect mobility of 0.117 $cm^2 \cdot V^{-1} \cdot S^{-1}$ and 0.276 $cm^2 \cdot V^{-1} \cdot S^{-1}$, the subthreshold slope (SS) of 6.01 V/decade and 5.48 V/decade, and the threshold voltage(V_{th}) of 10.7 V and 8.68 V, respectively. In case of threshold voltage shift by a gate-bias stress of 20V, the device with a film thickness of 40 nm is more degraded as shown in Fig. 3.

Fig. 4 shows the XRD spectra of the ZnO films. The grain sizes are 146 Å in the active layer thickness of 40nm and 196 Å in the active layer thickness of 80nm. That is, the grain size of the films is increased as the film thickness of ZnO is thicker [9].

In order to characterize the quality of the active layer, the 1/f noise measurement is carried out in the frequency range of 1~1000 Hz as a function of the gate overdrive voltage and with applied drain voltage V_d = 1.5 V. As shown in Fig. 4, the drain current noise S_{ID} for all transistors shows 1/f behavior. To evaluate the dominant mechanism of 1/f noise in ZnO TFTs, the dependence of input-referred noise spectra density S_{VG} and normalized drain current spectra density at a fixed frequency (20, 40Hz) is investigated on the gate overdrive voltage. Fig. 5 and Fig. 6 reveal the carrier mobility fluctuation characteristics in which the noise level is dependent of the gate bias in all devices [10-11]. Afterwards, because the total resistance of TFTs is a sum of channel resistance R_{ch} and series resistance R_s (source plus drain resistance) [12], we analyze the normalized drain current noise (S_{ID}/I_D^2) on lengths (10, 30 and 50 ㎛) to find out the resistance dependence of different active layers. As shown in Fig. 7, the S_{ID}/I_D^2 indicates that all devices are more dependent on the R_{ch}.

Fig. 8 shows the plot of the S_{ID}/I_D^2 versus the gate overdrive voltage. The noise level of the S_{ID}/I_D^2 on gate overdrive voltage of 3 V in all devices is almost similar. But, when the gate overdrive voltage increases to 21V, the noise level of the S_{ID}/I_D^2 exposes the definite difference. It may be due to surface scattering which is dominant in the high electric field. Finally, we extract the Hooge's parameter (a_H), in which the material with good quality has a low a_H value and thus corresponds to a 1/f noise and vice versa [13]. Fig. 9 shows that the extracted a_H's are about 0.2 and 0.4 for devices with the active layer thickness of 80nm and 40nm, respectively. These extracted parameters are reasonable, compared with the Hooge,s parameters reported in various TFTs as shown in Table. 1.

4. Conclusions

In this paper, 1/f noise is analyzed to characterize the quality of the active layer of ZnO TFTs having two different thicknesses of 40 nm and 80 nm, which is closely related with V_{th} instability. All devices expose the carrier mobility fluctuation characteristics in which the input-referred noise spectra density S_{VG} and normalized drain current spectra density S_{ID}/I_D^2 are dependent on the gate overdrive voltage. In addition, the normalized drain current spectra density S_{ID}/I_D^2 indicates that all devices are more dependent on the R_{ch} and the surface scattering. Finally, the extracted Hooge's parameter (a_H) indicates that the ZnO film of 80nm with the larger grain size has better quality than that of 40nm with the smaller grain size, which explains well the inferior V_{th} instability of the ZnO film of 40nm.

Acknowledgment

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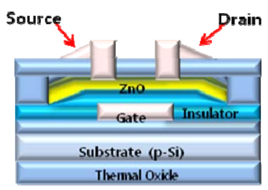

Fig. 1. Cross section of bottom -gated ZnO TFTs.

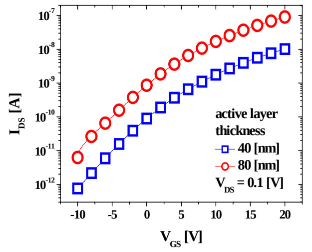

Fig. 2. Transfer characteristic of ZnO TFTs with different active thicknesses.

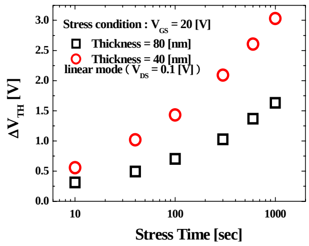

Fig.3. Vth shift as a function of time for different active layer thicknesses.

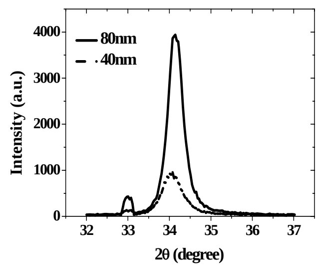

Fig. 4. XRD spectra of the Zn films as a function of the film thickness.

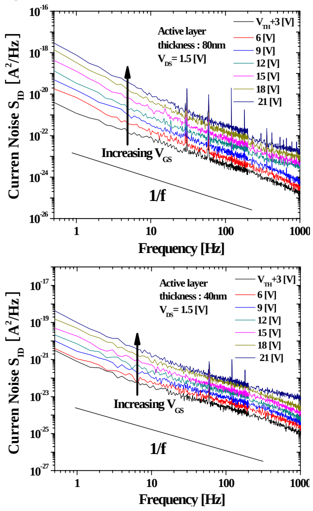

Fig. 5. Drain current noise power spectral density SI of ZnO TFTs with different active layers. Here, W/L is 50 μm/10 μm

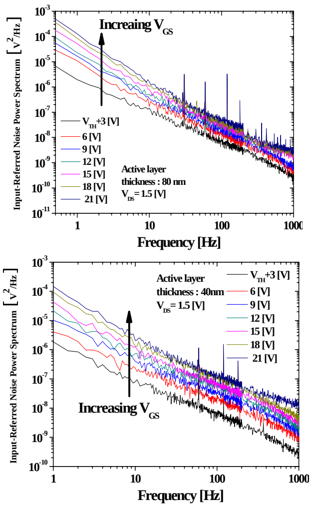

Fig. 6. Input-referred noise power spec trum of ZnO TFTs with different active layers at different gate-overdrive vol tage.

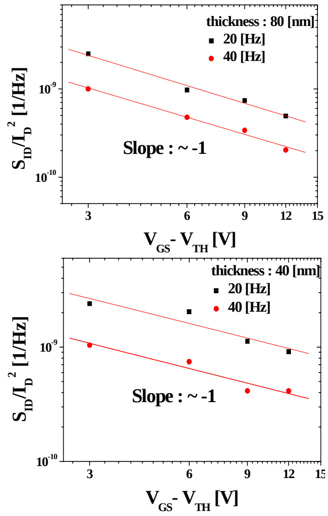

Fig. 7. The normalized drain current noise versus gate overdrive voltage of devices with different ZnO films at both fixed frequency(20, 40 Hz).

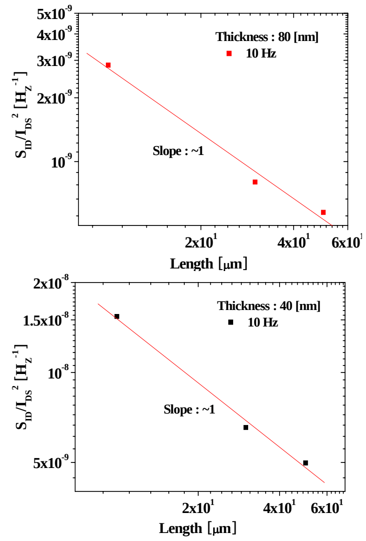

Fig. 8. The normalized drain current noise of ZnO TFTs on various chan nel length at fixed frequency(10 Hz).

Table. 1 : The mobility and Hooge's parameter of various TFTs.

	μ	a_H	**Ref.**
Organic	0.24	1.5	[14]
Poly-Si	190	0.01	[15]
ZnO (80nm)	0.28	0.2	This paper

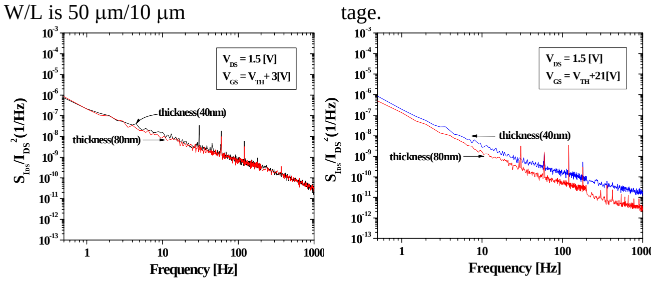

Fig. 9. The normalized drain-current noise spectral density (SI/IDS2) for ZnO TFTs with different thicknesses at gate-overdrive voltages (+3 and 21 V).

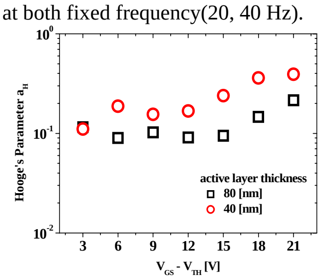

Fig. 10. Extracted Hooge's parameters versus gate overdrive voltage for devices with active layer thicknesses of 40 nm and 80 nm.