Abstract #2172, 224th ECS Meeting, © 2013 The Electrochemical Society

Effect of sputtering pressure on the electrical characteristics of RF magnetron sputtering processed zinc tin oxide thin film transistors

Hong Woo Lee[1, 2], Bong Seob Yang[1], Seungha Oh[1],
Sang Jin Han[1, 2], and Hyeong Joon Kim[1]

[1] Department of Materials Science and Engineering,
Inter-university Semiconductor Research Center, Seoul
National University, Seoul 151-742, Republic of Korea
[2] Development Center (LCD), Samsung Display,
Asan-city 336-741, Republic of Korea

Recently Amorphous Oxide Semiconductor (AOS) thin films have been widely used as channel layers in a variety of applications such as liquid displays (LCDs) or organic light emitting diodes (OLEDs). Zinc-tin oxides (ZTO) film is one of the promising AOS materials because of high mobility and abundance in nature[1,2]. It has been notified that sputtering conditions of AOS thin films, especially pressure, affect electrical properties and stabilities of its thin film transistors (TFTs)[3].

ZTO channel layer was deposited on heavily doped p-type Si wafers with a 100-nm-thick thermal oxide by rf magnetron sputtering method, of which power density was fixed to 1.1 W/cm^2. The relative flow rate, O_2 / Ar + O_2, was fixed at 0.3. First, three samples, 0.2mT, 0.5mT and 5mT, were prepared at the working pressures of 0.2, 0.5 and 5.0 mTorr, respectively, to investigate the effects of sputtering pressure on the properties of ZTO TFTs. Second, another three samples with dual active layers were prepared by depositing two ZTO channel layers at different sputtering pressures consecutively: 0.5 mTorr – 5.0 mTorr (0.5-5mT), 5.0 mTorr – 0.5 mTorr (5-0.5mT) and 5.0 mTorr – vacuum – 5.0 mTorr (5-V-5mT). Then, the 100 nm thick tin-doped indium oxide (ITO) was formed as source/drain electrodes, and the channel region of 300 μm length and 1000 μm width and source/drain electrodes were patterned using a shadow mask. Finally the samples were annealed at 350 °C for 60 min in air atmosphere.

Figure 1(a) shows the transfer characteristics of ZTO TFTs prepared at different sputtering pressures. The sample 5mT, which was made at the conventional sputtering pressure (CSP) 5mtorr, exhibits the saturation mobility (μ_{sat}), threshold voltage (V_{th}) and subthreshold gate swing (SS) of 10.2 cm^2/V-s, 0.16 V and 0.35 V/decade, respectively. In the cases of low sputtering pressures (LSP) 0.2 and 0.5 mTorr, better electrical performances of the ZTO TFTs are shown: the μ_{sat}, V_{th} and SS of 22.5 cm^2/V-s, -0.72 V and 0.28 V/decade, respectively, for both cases. Since the LSP condition increases a film density compared to the CSP condition, the better electric performance of the LSP ZTO TFTs is attributed from the higher density of ZTO films[3]. As shown in Fig. 1(b), the LSP condition resulted in denser films and influenced the content of oxygen vacancy (V_o) as well. From the O 1s spectra of X-ray photoelectron spectroscopy (XPS), the ratio of V_o for the samples 5mT, 0.5mT and 0.2 mT were 16.8%, 12.1% and 12.9%, respectively. (not shown here) Although the sample 5mT contained higher carrier concentration due to more V_o, it showed lower saturation mobility. It means that the sample 5mTorr would have less mobility of carriers and consequently it should contain higher defect density. For the NBIS instability test, the LSP TFTs showed smaller V_{th} shift compared to the CSP TFTs. The SS as well as V_{th} instability is strongly associated with the density of defects such as interface traps and bulk traps[4,5].

The samples with dual active layers were electrically characterized to identify the trap, which influenced dominantly the electrical performance of ZTO TFTs. Figure 2 showed the transfer characteristics of the ZTO TFTs with dual active layers. The sample 0.5-5mT showed much higher stability of V_{th} than the sample 5-0.5mT, even though their difference was just the sequence of dual active layers and thus they had similar defect density, as shown in Fig. 2(b). Once the dense LSP layer was first deposited on the interface like the sample 0.5-5mT, the electrical stability of TFTs were significantly improved. It indicates that the interface traps play more important role on the electrical stability of TFTs compared to the bulk traps.

Meanwhile, the content of oxygen molecules in the sputtering system, which come out from the ZTO target during sputtering, increases with sputtering time, and they deteriorate the electrical stability of TFTs. For the sample 5-V-5mT, the additional pumping step between the continuous deposition processes at 5 mTorr was added. Since the deposition was halted during the additional pumping step, the content of oxygen molecules in the sputtering system should be much reduced. Therefore, the electrical stability of the sample 5-V-5mT was much improved, as shown in Fig. 2(b).

In summary, we fabricated the ZTO TFTs with single ZTO channel layer and dual ZTO channel layers, which were deposited at various sputtering pressures. The LPS channel layer showed better electrical performance and stability compared to the CPS one, suggesting that the LPS channel layer had higher film density and lower interface trap density. The oxygen molecules coming out from the target during sputtering should be reduced to achieve better electrical performance and stability of active channel layer in ZTO TFTs, because of their harmful effect.

Reference

[1] R. L. Hoffman, J. Appl. Phys., 95, 5813 (2004)
[2] K. Nomura *et al.*, Nature, 432, 488 (2004)
[3] M. S. Huh *et al*., J. Elecrochem. Soc. 157, 429 (2010)
[4] R. Laiho *et al*., J. Appl. Phys. 103, 123709 (2008)
[5] M. Chowdhury *et al*., Appl. Phys., 97, 173506 (2010)

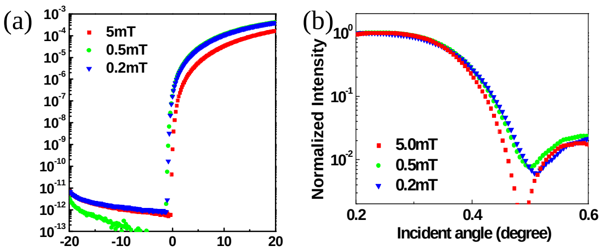

Figure 1. (a) Transfer characteristics and (b) XRR results of ZTO samples fabricated at different pressures.

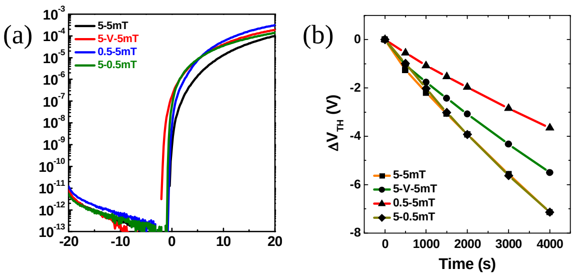

Figure 2. (a) Transfer characteristics and (b) V_{th} shift trends with NBIS of the ZTO samples with dual layers deposited at different sputtering pressures.