High mobility In-Ga-Zn-oxide thin-film transistor with Sb$_2$TeO$_x$ gate insulator fabricated by reactive sputtering

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1. Introduction

One of the issues in the development of oxide semiconductor based thin-film transistors (TFTs) uses a low temperature gate insulator (GI) so as to be applied to flexible substrates [1]. Up to now, various gate insulators for the low temperature processing have been researched including Al$_2$O$_3$ by ALD [2], ZrO$_2$ by sol-gel method [3], Zn$_{0.7}$Mg$_{0.3}$O by reactive sputtering method [4], BST by sputtering [5], Mn-doped BST by sputtering [6], Y$_2$O$_3$ by sputtering [1], ZBN by sputtering [7], HfO$_x$, HfSiO$_x$ by ALD [8], TiOx by PEALD [9], and so on.

Sb$_2$Te$_{1-x}$ materials are the typical chalcogenide alloys, which show fast and reversible transitions between resistive amorphous and conductive crystalline phases. These materials are usually used for non-volatile memory called phase change random access memory (PRAM) [10], and for high-density optical recording media [11]. On the other hand, these materials could be easily oxidized by a reactive sputtering at the normal condition. In this study, we will fabricate a Sb$_2$TeO$_x$ gate insulator by a reactive sputtering method, using a metallic Sb$_2$Te target.

2. Experimental results

As a active channel, an indium-gallium-zinc oxide (IGZO, In:Ga:Zn=2:1:2, atomic ratio) semiconductor was deposited by the RF magnetron sputtering, using a ceramic target (ANP, 99.99% purity, 3 inches). Fig. 1 is indicating the schematic cross-section of IGZO-TFT with Sb$_2$TeO$_x$ GI. The TFT is a top-gate type (staggered) structure, where the source & drain electrodes were made by ITO (indium-tin oxide, In:Sn = 90:10, weight percent) via RF magnetron sputter, and gate was formed by Pt (t=100 nm).

![Fig. 1. The schematic cross-section of IGZO-TFT](image)

Sb$_2$TeO$_x$ could be obtained by a reactive sputtering at the condition of 20 mTorr, 50 W, 15% O$_2$ in the total gas (Ar + O$_2$), but as a function of the substrate temperatures from room temperature to 250 °C. Fig. 2 shows the transmittance of the glass substrate, and Sb$_2$TeO$_x$ film (t=100 nm) on the glass, where GI was fabricated at the condition of 250 °C. The transmittance of Sb$_2$TeO$_x$ film had a maximum point around the wavelength of 490 nm, showing a weak blue-like color.

![Fig. 2. Transmittance of a glass substrate, and glass/Sb$_2$TeO$_x$ (100 nm) (The reference is air).](image)

Figure 3(a) illustrates the dc transfer characteristic [log(I$_D$)-V$_G$] & gate leakage current [log(I$_G$)-V$_G$] curves of the IGZO-TFT after the annealing process at 200 °C-1 hour in O$_2$ ambient. The gate insulator was fabricated at 250 °C with the thickness of 100 nm. The transfer plot shows a drain current on-off ratio of $\sim 10^8$, a subthreshold-swing (SS) of 0.15 V/decade, and a saturated mobility of 22.41 cm$^2$/Vs. The gate leakage could be sustained at $10^{-13}$ A, up to about 7 V (gate voltage). The breakdown voltage increased with the film thickness and the growth temperatures.
Figure 3. The dc transfer characteristic [log(I_d)-V_g] & gate leakage current [log(I_g)-V_g] curves of an IGZO-TFT with a Sb$_2$TeO$_x$ gate insulator (a), the output [I_d-V_d] curves (b) after the annealing process at 200°C-1 hour in O$_2$ ambient, respectively.

Fig. 3(b) is showing the output curves of Fig. 3(a), where the classical MOSFET theory could be acceptable. These profiles can be applied to the low power consumption devices operated in the range low driving voltages.

3. Conclusions
Using a Sb$_2$TeO$_x$ gate insulator (100 nm) by a reactive sputtering, we could fabricate a low temperature IGZO-TFT. After the annealing process at 200°C-1 hour in O$_2$ ambient, the mobility of IGZO-TFT was 22.41 cm$^2$/Vs, and a drain current on-off ratio was ~ $10^8$.

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References