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Effects of Composition Ratio on Solution-processed InGaZnO Thin-Film Transistors

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Oxide-based thin-film transistors (TFTs) employing indium gallium zinc oxide (IGZO) and zinc tin oxide (ZTO) are promising devices for active-matrix display applications because of high mobility, visible light transparency, and good uniformity [1, 2].

Solution-processed oxide TFTs employing spin-coating, dipping, and ink-jet printing have attracted considerable attentions because vacuum-deposition processes, such as rf magnetron sputtering and pulsed laser deposition, require complicated and high manufacturing cost processes. Solution-processed oxide TFTs are also suitable for large-area, high-throughput, and flexible display [3].

In solution-processed oxide TFTs, the composition ratio of precursors should be controlled carefully because the electrical characteristics of TFTs are sensitive to the composition ratio of precursors. However, the effects of composition ratio on solution-processed IGZO TFTs are scarcely reported.

The purpose of this paper is to investigate the electrical characteristics such as threshold voltage and saturation mobility of solution-processed IGZO TFTs with various composition ratio of precursors and to analyze the effects of composition ratio on solution-processed IGZO TFTs.

We fabricated solution-processed IGZO TFTs with annealing temperature of 350 °C on active layer. IGZO TFTs with inverted staggered structure were fabricated on wafer substrates as Figure 1. Heavily boron doped p-type silicon wafer substrate of 760 µm was used as the gate and gate insulator was fabricated with Silicon dioxide (SiO_2) of 2000 Å using thermal oxidation.

The precursor-based solution of IGZO for active layer was prepared with various composition ratio in order to observe the effects of composition ratio of precursors. The precursor-based solution of IGZO was dissolved with In nitrate hydrate ($In(NO_3)_3{\cdot}xH_2O$, FW of 390.91, Aldrich), Ga nitrate hydrate ($Ga(NO_3)_3{\cdot}xH_2O$, FW of 255.74, Aldrich), and Zn acetate dihydrate ($Zn(C_2H_3O_2)_2{\cdot}2H_2O$, FW of 219.5, Aldrich) powders in 2-methoxyethanol ($C_3H_8O_2$) of 3mL as 7:1:2, 6:3:1, and 5:1:4 of composition ratio. The mixed IGZO solution was stirred at 75 °C for 1 h to promote the dissolving process.

After spin-coating, IGZO films were annealed at 350 °C for 1 hour by hot-plate annealing process and cooled down to the room temperature. The thicknesses of IGZO films decreased from 400 Å to 250 Å during annealing due to the solvent and halide residue were evaporated.

Finally, 300 nm thick indium tin oxide (ITO) film as source and drain electrodes was deposited by dc sputtering.

Transfer characteristics of solution-processed IGZO TFTs according to composition ratio are shown in Figure 2. Threshold voltage of solution-processed IGZO TFTs was -0.43 V, 3.86 V, and 11.12 V with the composition ratio of 7:1:2, 6:3:1, and 5:1:4 respectively. Saturation mobility of solution-processed IGZO TFTs was 1.4 $cm^2/V{\cdot}sec$, 0.84 $cm^2/V{\cdot}sec$, and 0.3 $cm^2/V{\cdot}sec$ with the composition ratio of 7:1:2, 6:3:1, and 5:1:4 respectively.

The threshold voltage of solution-processed IGZO TFTs increased and the saturation mobility decreased with decreasing In composition ratio as shown in Figure 3 because In increase the electron concentration and mobility of IGZO active layer. In recent reports of sputter-processed oxide TFTs, In is known as In 5s orbitals mainly form conduction band bottom so that In has a role in the increase of the electron concentration and mobility [4]. It is confirmed that In_2O_3 shows the electrical characteristics of conductor in Figure 2.

When Ga composition ratio increased 6:3:1, the off-current was decreased as shown in Figure 2 because Ga compensate carriers generated by In inclusion and suppress formation of oxygen vacancies.

When Zn composition ratio increased to 5:1:4, the hysteresis was decreased as shown in Figure 2 because Zn modulate the shallow tail state below conduction band and reduce the interstitial states between channel and insulator.

In conclusion, the effects of composition ratio of precursors on solution-processed IGZO TFTs at low annealing temperature of 350 °C were successfully analyzed. When In composition ratio increased, the threshold voltage decreased and saturation mobility increased because of the increase of electron concentration. When Ga composition ratio increased, the off-current was decreased because of the suppression of formation of oxygen vacancies. When Zn composition ratio increased, the hysteresis was decreased because of the reduction of interstitial states between channel and insulator.

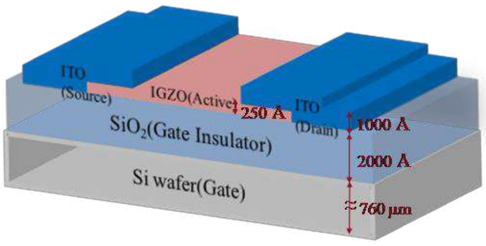


Figure 1. Structure of solution-processed IGZO TFTs

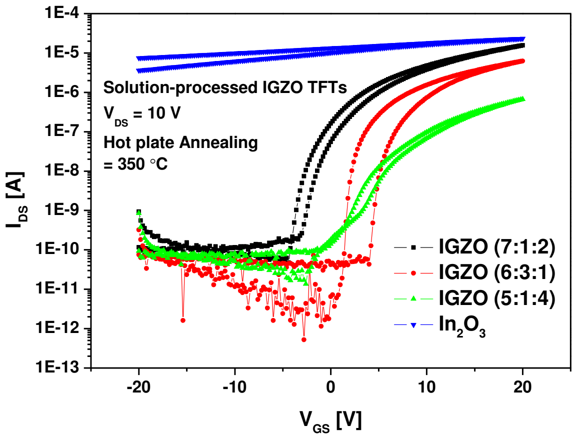
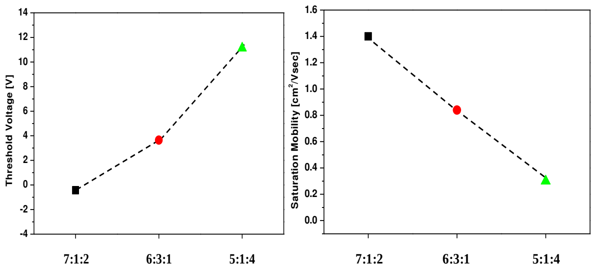


Figure 2. Transfer characteristics of solution-processed IGZO TFTs according to composition ratio



(a) (b)

Figure 3. (a) Threshold voltage and (b) Saturation mobility of solution-processed IGZO TFTs according to composition ratio

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