How we can control weakly-bonded oxygen introduced by sputtering deposition for amorphous In-Ga-Zn-O thin-film transistor

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Amorphous oxide semiconductors (AOSs) have much preferable properties for developing flexible displays and devices compared to conventional hydrogenated amorphous silicon.[1] We also reported that high temperature (≥300°C) annealing in ozone (O_3) atomosphere incorporates weakly-bonded oxygen to amorphous In-Ga-Zn-O (a-IGZO) films and causes large hysteresis on the operation of thin-film transistor (TFT) arising from bistable trap states.[2] Similar phenomena are observed also by conventional sputtering if very high oxygen partial pressures are employed. There are some reports that suggest the instability for illumination stress[3] and bias stresss[4] come from interstital oxygen/excess oxygen, but their correlation has not yet been demonstrated.

Here, we report that bistable trap states originating from weakly bonded oxygens are formed in unannealed a-IGZO channels deposited at room temperature (RT) if the oxygen flow ratio (R_{O2}) during deposition is larger than the optimal value (~3% for our standard sputtering). Bottom-gate, top-contact a-IGZO TFTs were fabricated on SiO_2/c-Si substrates without a back-channel passivation layer. The a-IGZO channel was deposited by radio-frequency magnetron sputtering at varied R_{O2} and subjected to O_2 annealing. Excess/weakly-bonded oxygens were detected by thermal desorption spectrum (TDS) measurements.

It was found that the unannealed TFT deposited at, for example, R_{O2} = 10% (Fig. 1 (a)) showed a small turn-on voltage (V_{on}) in the virgin curve (black line) while changed to large V_{on} in the 2nd and 3rd measurements (red and blue lines, respectively). Furthermore, it is seen that difference between the initial and 2nd V_{on} (ΔV_{on}) decreases with increasing annealing temperature (T_{ann}). Figure 2 shows TDS signal for various T_{ann}. As a result, the total O_2 desorption amount up to 400°C decreases with increasing T_{ann} from 4.8×10^{18} cm^{-3} for the unannealed film to 3.8×10^{18} cm^{-3} for the 200°C-annealed film. More details including the relationship among R_{O2}, ΔV_{on}, hystresis ΔV_{th}, O_2 desorption, and subgap states will be discussed at the conference.

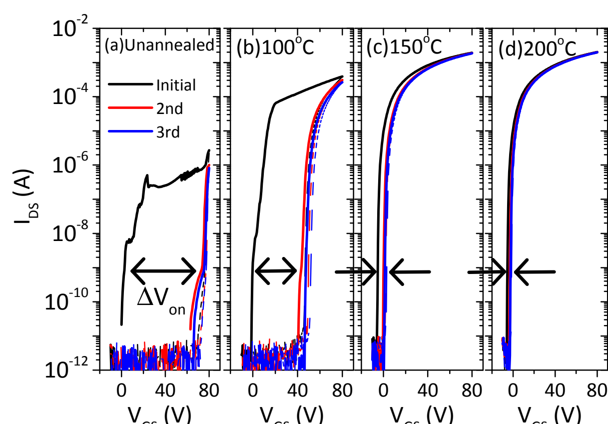

Fig. 1. Cyclic measurements of transfer curve of a-IGZO TFT deposited at R_{O2} = 10%.

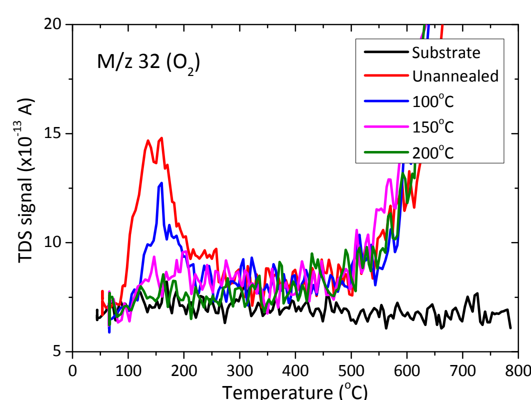

Fig. 2. TDS for IGZO films deposited in R_{O2} = 10% for various T_{ann}.

References

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