Design of Crystalline InGaO Channels with High-Temperature Stability via Thermal ALD Process Parameter Variations

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Oxide semiconductors have garnered interest as potential materials to address the issues caused by the scaling down of dynamic random-access memory devices.[1] However, high-temperature stability is a critical requirement for applying oxide semiconductors to memory devices.[2] To overcome the challenges of high-temperature instability in oxide semiconductors, it is essential to maintain a similar crystal structure regardless of the annealing temperature. Here, we proposed an optimized crystalline InGaO (IGO) film for high temperature stability by engineering atomic layer deposition process parameters, ozone concentration, and deposition temperature. Our results reveal that high-temperature stability can be secured by using elevated ozone concentrations and deposition temperatures in IGO deposition. Notably, IGO deposited at 300°C shows little change in the main (222) intensity when annealed at 700°C compared to 400°C, and a highly c-axis aligned (222) plane is observed. The field-effect transistor with an IGO active layer deposited at 300°C showed minimal changes in electrical parameters after annealing at 700°C (μ_{FE}: 58.4 to 68.7 cm^2/Vs) and demonstrated excellent PBTS stability (ΔV_{th}: 0.15 V) at 3 MV/cm, 95°C. These outcomes suggest the possibility of utilizing oxide semiconductors in memory devices that require managing high-temperature thermal budgets.

References

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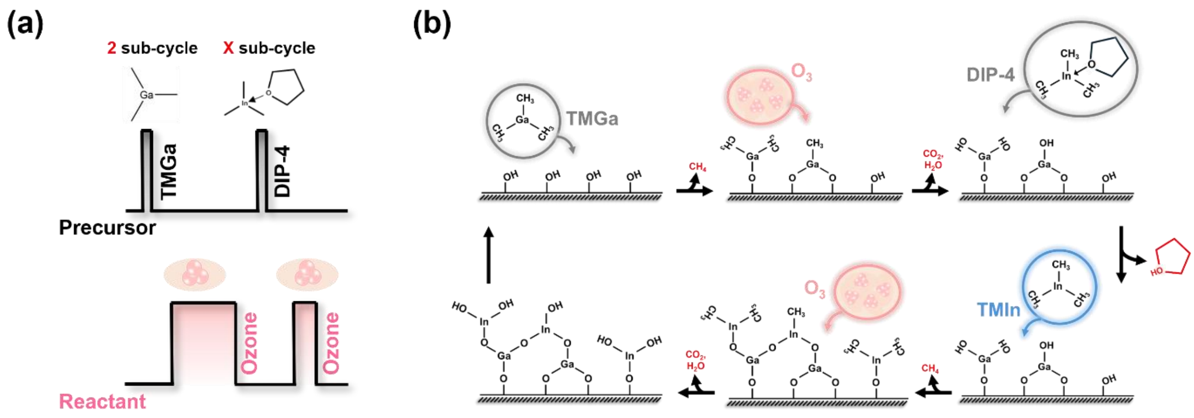

Fig. 1. Schematics of (a) supercycle sequence for IGO deposition and (b) the expected adsorption and oxidation processes using DIP-4 and TMGa precursors during ALD.

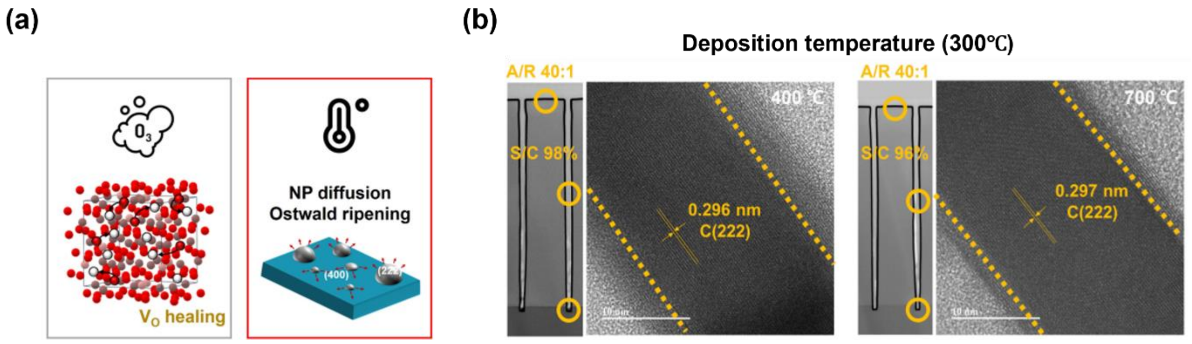

Fig. 2. (a) Schematics of grain growth during high temperature annealing via atomic rearrangement and nanoparticle diffusion and Ostwald ripening processes. (b) TEM images with 300 °C-grown IGO films deposited in deep trench structures after annealing at 400 and 700 °C.

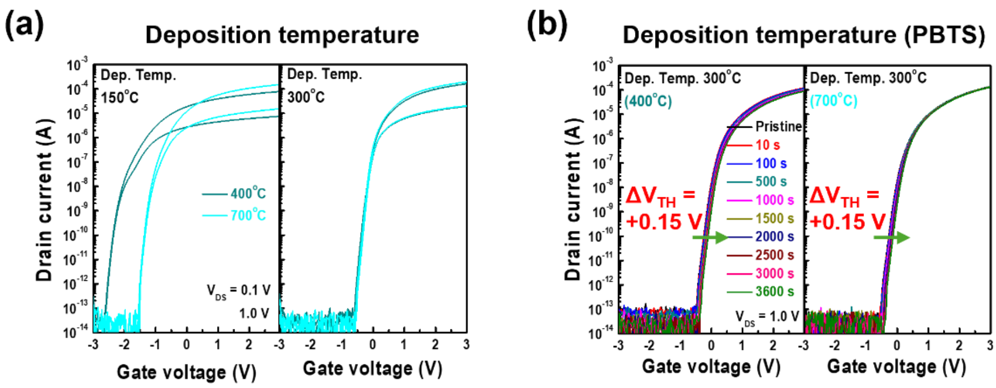

Fig. 3. (a) Representative transfer curves and (b) PBTS results of IGO FETs annealed at 400 and 700 °C, fabricated with growth temperatures of 150 and 300 °C.