The stability study of ITO film deposited by thermal atomic layer deposition

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Metal oxide thin-film transistors (TFTs), especially InGaZnO TFTs have attracted considerable attention for 3D dynamic random access memory (DRAM) applications, owing to their lower off-state leakage and suitable carrier mobility. A thin Tin-doped In_2O_3 (ITO) has been employed as an inserting layer at contact region to reduce the Schottky barrier from IGZO channel, so as to get higher on-current. [1] Given the promising potential of ALD-grown ITO thin film for 3D DRAM applications, investigating its thermal stability and the impact of contact materials on its performance are critical for back-end-of-line (BEOL) compatibility evaluation.

In this work, the thermal stability of ALD-grown ITO film was systematically evaluated via annealing experiments. The film is stable after annealing in an N_2 atmosphere at 600 °C, and has a mixed polycrystalline–amorphous phase structure. Prolonged annealing time, however, induced a significant increase in oxygen-related defects. When the annealing temperature was elevated to 800 °C, the ITO films became rough and initiated decomposition. Considering that ITO may come into contact with interconnect materials (e.g., TiN and W) during subsequent process integration, the effect of TiN deposition on ITO property was also investigated. Deposition of TiN at 530 °C in a hydrogen-containing ambient caused partial damage to the ITO film. In contrast, no obvious changes in ITO properties were observed after annealing in N_2 at 600 °C, indicating that reducing gases (e.g., H_2) can degrade ITO stability. At 400 °C (without H_2), TiN deposition did not cause significant ITO damage; nevertheless, a slight reduction in ITO thickness was detected. This thickness loss is speculated to result from reactions between the byproduct HCl and the ITO surface, as well as the breaking of In–O and Sn–O bonds due to oxygen scavenging by TiN. Collectively, the results demonstrate that the temperature, atmosphere, and process byproducts of subsequent steps all contribute to ITO film damage or thickness loss. This study provides reliable experimental data to guide the integration of ITO for advanced 3D DRAM applications.

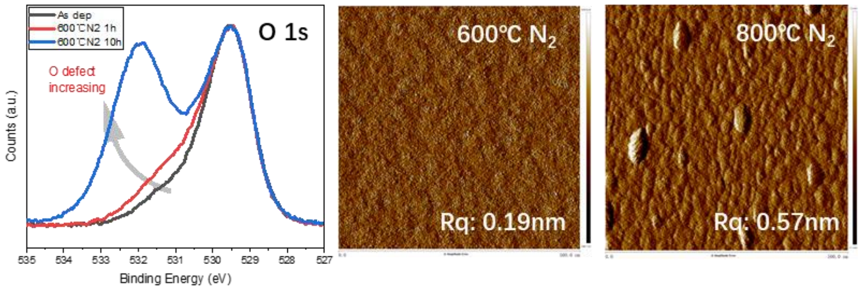

Fig.1 XPS spectra and AFM images of ITO films after annealing.

[1] Q. Hu, C. Gu, et al., Adv. Mater. 2023, 35(20): 2210554