Extended Abstract

Recently, solution-processed metal oxide thin film transistors (TFTs) have attracted great attention due to their potential applications in low cost, transparent, easily-processable, flexible, and large-area electronic devices. Among the solution-processed metal oxide semiconductors, indium-based oxides have been extensively studied as channel materials for the fabrication of high-performance TFTs. Despite good electrical performances of indium-based materials, many research groups have endeavored to develop indium-free high performance oxide semiconductor alternatives since indium is becoming scarce and expensive. Zinc-tin-oxide (ZTO) is one of promising substitute but the device performance of ZTO TFTs is still lower than indium-based oxide TFTs. The fabrication of high-performance solution-based ZTO TFTs has been attempted using combustion processing, alkali metal doping, or ultraviolet (UV) photo-annealing approaches. UV photo-annealing, in particular, has emerged as a potential method by promoting the dissociation of organic components and the acceleration of M-O-M condensation reactions under UV irradiation.

Here, we report a facile route to the fabrication of high-performance solution-based indium-free metal oxide TFTs by introducing zinc oxide (ZnO)/ tin oxide (SnO2) bilayer heterostructure in the active channel. It has been known that stacking active layers of conductive front layers and relatively less dense back layers could improve the metal oxide TFT device performance. However, all stacked active layers examined to date have been prepared using indium-based materials. In our ZnO/SnO2 TFTs, a thin SnO2 layer was employed as an indium-free main front layer to improve the channel conductance by increasing the SnO2 carrier concentration. The ZnO back layer, with a carrier concentration lower than that of SnO2, was deposited on top of the SnO2 layer to reduce the off-currents of the bilayer TFTs. After UV photo-annealing, followed by heat treatment, the ZnO/SnO2 bilayer TFTs showed excellent performances with dramatically enhanced mobility values over 15 cm² V⁻¹ s⁻¹ and operational stabilities to external gate-bias stress. From transmission electron microscopy analysis, we confirm that the improvement of device performance originates from relative Sn-rich zone at the interface between channel and dielectric layer, and Zn-Sn-mixed zone between ZnO and SnO2 layer. Thin Sn-rich channel plays a key role as a main current path and diffused Zn atoms at Zn-Sn-mixed zone stabilize the device performance. In addition, we also successfully demonstrate high-performance ZnO/SnO2 bilayer TFTs by introducing new type of Sn precursor. The optimized devices based on the new Sn precursor exhibit excellent mobility exceeding 20 cm² V⁻¹ s⁻¹.

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References