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Design of Solution-Processed ZnO/SnO_2 Heterostructures for High Performance Thin Film Transistors

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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.[1],[2] Among the solution-processed metal oxide semiconductors, indium-based oxides have been extensively studied as channel materials for the fabrication of high-performance TFTs.[1],[2] 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.[3],[4] The fabrication of high-performance solution-based ZTO TFTs has been attempted using combustion processing, alkali metal doping, or ultraviolet (UV) photo-annealing approaches.[1-3] 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 (SnO_2) bilayer heterostructure in the active channel.[5] 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.[6] However, all stacked active layers examined to date have been prepared using indium-based materials. In our ZnO/SnO_2 TFTs, a thin SnO_2 layer was employed as an indium-free main front layer to improve the channel conductance by increasing the SnO_2 carrier concentration. The ZnO back layer, with a carrier concentration lower than that of SnO_2, was deposited on top of the SnO_2 layer to reduce the off-currents of the bilayer TFTs. After UV photo-annealing, followed by heat treatment, the ZnO/SnO_2 bilayer TFTs showed excellent performances with dramatically enhanced mobility values over $15\ cm^2\ V^{-1}\ s^{-1}$ 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 SnO_2 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/SnO_2 bilayer TFTs by introducing new type of Sn precursor.[7] The optimized devices based on the new Sn precursor exhibit excellent mobility exceeding $20\ cm^2\ V^{-1}\ s^{-1}$.

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