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Improvement in the Bias Stability of Zinc-Tin Oxide Thin-Film Transistors by Hafnium Doping

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The influence of hafnium (Hf) doping on negative-bias temperature instability in zinc-tin oxide thin-film transistors was studied. Hafnium-zinc-tin oxide TFTs exhibited a turn-on voltage (V_{ON}) that shifted from 0 V to -1 V with negligible changes in the subthreshold swing and field-effect mobility after 3 h of total stresses. The enhanced improvement of the V_{ON} shift (ΔV_{ON}) was attributed to the reduction in the interface trap density, which may result from the suppression of oxygen-vacancy-related defects by the Hf ions.

Key words: Amorphous oxide semiconductor, hafnium-zinc-tin oxide ZnO-based TFT, negative-bias temperature instability (NBTI)

INTRODUCTION

Transparent thin-film transistors (TTFTs) that incorporate oxide semiconductors such as ZnO, InGaZnO (IGZO) or HfInZnO (HIZO) are attracting attention due to their great potential for application in flat-panel displays.[1–6] Oxide-based TFTs are suitable switching elements for transparent active-matrix liquid-crystal displays (AMLCDs) and active-matrix organic light-emitting diode (AMOLED) panels.

There have been many reports on ZnO-based oxide TFTs, and amorphous InGaZnO is one of the most promising active materials. Recently, manufacturing processes for oxide semiconductor-based thin-film transistors have been systemized by many companies. Especially, the process for IGZO-TFTs has been prepared for manufacture by companies such as Sharp, LG Display, and Samsung Electronics. However, there are still several issues related to the manufacturability of oxide TFTs for active-matrix backplanes. Specifically, the negative-bias temperature instability (NBTI) of ZnO-based TFTs is unresolved, as ZnO-based TFTs usually contain defects in the active channel layer and deep-level defects in the channel/insulator interface. Any shift in the turn-on voltage (V_{ON}) of the driving transistor in on- or off-bias stressed conditions will cause an increase in the output drain current, leading to device malfunction. As a result, a negative gate bias at least 500 times greater than the positive gate bias is applied to real operating TFT arrays in commercial AMLCD devices to maintain the off-state of the device. Thus, device degradation due to NBTI is a critical issue that must be resolved. There have also been recent reports regarding light-induced bias instability of metal-oxide TFTs aimed at the implementation of oxide TFTs in high-end TFT-LCD panels, which have the largest market volume among various active-matrix displays.[7] The effects of light-induced negative-bias instability in Hf- and In-doped ZnO TFTs were reported using a cation combinatorial approach[8] as well as the influence of device configuration on the light-induced negative-bias thermal instability of gallium-indium-zinc oxide (GIZO) transistors.[9] However, materials such as indium (In) and gallium (Ga) have some disadvantages, including toxicity, element scarcity, and indium extraction in hydrogen plasma.[10] Thus, there is a need for In-free and Ga-free oxide semiconductors that are inexpensive and nontoxic. Zinc-tin oxide (ZTO) is regarded as one of

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