(Digital Presentation) Investigation of Top Electrodes Impact on Performance of Transparent Amorphous Indium Gallium Zinc Oxide (a-InGaZnO) Based Resistive Random Access Memory

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Abstract

The traditional von Neumann architecture limits the increase in computing efficiency and results in massive power consumption in modern computers due to the separation of storage and processing units. The novel neuromorphic computation system, an in-memory computing architecture with low power consumption, is aimed to break the bottleneck and meet the needs of the next generation of artificial intelligence (AI) systems. Thus, it is urgent to find a memory technology to implement the neuromorphic computing nanosystem.

Nowadays, the silicon-based flash memory dominates non-volatile memory market, however, it is facing challenging issues to achieve the requirements of future data storage device development due to the drawbacks, such as scaling issue, relatively slow operation speed, and high voltage for program/erase operations. The emerging resistive random-access memory (RRAM) has prompted extensive research as its simple two-terminal structure, including top electrode (TE) layer, bottom electrode (BE) layer, and an intermediate resistive switching (RS) layer. It can utilize a temporary and reversible dielectric breakdown to cause the RS phenomenon between the high resistance state (HRS) and the low resistance state (LRS). RRAM is expected to outperform conventional memory device with the advantages, notably its low-voltage operation, short programming time, great cyclic stability, and good scalability. Among the materials for RS layer, indium gallium zinc oxide (IGZO) has shown attractive prospects in abundance and high atomic diffusion property of oxygen atoms, transparency. Additionally, its electrical properties can be easily modulated by controlling the stoichiometric ratio of indium and gallium as well as oxygen potential in the sputter gas. Moreover, since the IGZO can be applied to both the thin-film transistor (TFT) channel and RS layer, it has a great potential for fully integrated transparent electronics application.

In this work, we proposed amorphous transparent IGZO-based RRAMs and investigated switching behaviors of the memory cells prepared with different top electrodes. First, ITO was choosing to serve as both TE and BE to achieve high transmittance. A multi-target magnetron sputtering system was employed to deposit all three layers (TE, RS, BE layers) on glass substrate. I-V characteristics were evaluated by a semiconductor parameter analyzer, and the bipolar RS feature of our RRAM devices was demonstrated by typical butterfly curves. The optical transmission analysis was carried out via a UV-Vis spectrometer and the average transmittance was around 80% out of entire devices in the visible-light wavelength range, implying high transparency. We adjusted the oxygen partial pressure during the sputtering of IGZO to optimize the property because the oxygen vacancy concentration governs the RS performance. Electrode selection is crucial and can impact the performance of the whole device. Thus, Cu TE was chosen for our second type of device because the diffusion of Cu ions can be beneficial for the formation of the conductive filament (CF). A ~5 nm SiO_2 barrier layer was employed between TE and RS layers to confine the diffusion of Cu into the RS layer. At the same time, this SiO_2 inserting layer can provide an additional interfacial series resistance in the device to lower the off current, consequently, improve the on/off ratio and whole performance. Finally, an oxygen affinity metal Ti was selected as the TE for our third type of device because the concentration of the oxygen atoms can be shifted towards the Ti electrode, which provides an oxygengettering activity near the Ti metal. This process may in turn lead to the formation of a sub-stoichiometric region in the neighboring oxide that is believed to be the origin of better performance.

In conclusion, the transparent amorphous IGZO-based RRAMs were established. To tune the property of RS layer, the sputtering conditions of RS were varied. To investigate the influence of TE selections on switching performance of RRAMs, we integrated a set of TE materials, and a barrier layer on IGZO-based RRAM and compared the switch characteristics. Our encouraging results clearly demonstrate that IGZO is a promising material in RRAM applications and breaking the bottleneck of current memory technologies.