Transparent InGaZnO-Based Resistive Random Access Memory

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The major focus of artificial intelligence (AI) research is made on biomimetic synaptic processes that are mimicked by functional memory devices in the computer industry [1]. It is urgent to find a memory technology for suiting with Brain-Inspired Computing to break the von Neumann bottleneck which limits the efficiency of conventional computer architectures [2].

Silicon-based flash memory, which currently dominates the market for data storage devices, is facing challenging issues to meet the needs of future data storage device development due to the limitations, such as high-power consumption, high operation voltage, and low retention capacity [1]. The emerging resistive random-access memory (RRAM) has elicited intense research as its simple sandwiched structure, including top electrode (TE) layer, bottom electrode (BE) layer, and an intermediate resistive switching (RS) layer, can store data using RS phenomenon between the high resistance state (HRS) and the low resistance state (LRS). This class of emerging devices is expected to outperform conventional memory devices [3]. Specifically, the advantages of RRAM include low-voltage operation, short programming time, great cyclic stability, and good scalability [4]. Among the materials for RS layer, indium gallium zinc oxide (IGZO) has attracted attention because of its abundance and high atomic diffusion property of oxygen atoms, transparency, and its easily modulated electrical properties by controlling the stoichiometric ratio of indium and gallium as well as oxygen potential in the sputter gas [5, 6]. Moreover, since the IGZO can be applied to both the thin-film transistor (TFT) channel and RS layer, the IGZO-based fully integrated transparent electronics are very promising [5].

In this work, we proposed transparent IGZO-based RRAMs. First, we chose ITO to serve as both TE and BE to achieve high transmittance in the visible regime of light. All three layers (TE, RS, BE layers) were deposited using a multi-target magnetron sputtering system on glass substrates to demonstrate fully transparent oxide-based devices. I-V characteristics were evaluated by a semiconductor parameter analyzer, and our devices showed typical butterfly curves indicating the bipolar RS property. And the IGZO-based RRAM can survive more than 50 continuous sweeping cycles. The optical transmission analysis was carried out via an UV-Vis spectrometer and the average transmittance around 80% out of entire devices in the visible-light wavelength range, implying high transparency. To investigate the thickness dependence on the properties of RS layer, 50nm, 100nm and 150nm RS layer of IGZO RRAM were fabricated. Also, the oxygen partial pressure during the sputtering of IGZO was varied to optimize the property because the oxygen vacancy concentration governs the RS and RRAM performance. Electrode selection is crucial and can impact the performance of the whole device [7]. Thus, Cu TE was chosen for our second type of device because the diffusion of Cu ions can be beneficial for the formation the conductive filament (CF). Finally, 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.

In conclusion, the transparent IGZO-based RRAMs were established. To tune the property of RS layer, the thickness layer and sputtering conditions of RS were adjusted. In order to engineer the diffusion capability of the TE material to the RS layer and the BE, a set of TE materials and a barrier layer were integrated in IGZO-based RRAM and the performance was compared. Our encouraging results clearly demonstrate that IGZO is a promising material in RRAM applications and overcoming the bottleneck of current memory technologies.

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