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Growth and Characterization of ZnO based Transparent Resistive Random Access Memory Devices using Pulsed Laser Deposition

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Recently there has been a spurt in the research activities to develop next generation low power, low cost, high speed, rugged, nonvolatile and transparent resistive random access memory (RRAM) devices based on metal oxides' thin films and nanostructures[1, 2]. The memory effect in these devices is realized through the switching of the resistance of the device between two states of high and low resistances. Amongst the known metal oxides currently being explored for the development of RRAM, ZnO has been demonstrated to be a potential candidate. ZnO is an n-type wide bandgap semiconductor with wurtzite crystal structure and is highly transparent in the visible spectral region. Moreover its conductivity can be tailored in a broad range from metal like to insulator like by suitable impurity doping. Therefore it is possible to develop fully transparent RRAM devices entirely based on ZnO. In this paper we report the growth of novel transparent RRAM devices based on ZnO and its variants. We studied the resistive switching characteristics of these devices and associated conduction mechanisms responsible for the switching. The details of these studies will be presented and discussed in the talk.

About 250 nm thick film of Ga (~0.75%) doped ZnO (Ga:ZnO) with resistivity ~ 1×10^{-4} ohm-cm, grown by pulsed laser deposition (PLD) on Sapphire substrates at 500°C and in $1x10^{-4}$ Torr of Oxygen ambient using 3rd harmonic of a Q-switched Nd:YAG laser (355 nm, 6 ns and 10 Hz) at a fluence of ~ 0.6 J/cm^2, was used as transparent bottom electrode. A high resistive ZnO film of typical thickness ~ 90 nm was grown over it at room temperature using in-house developed DC discharge assisted PLD [3]. As a top electrode of the device, about 150 nm thick Ga:ZnO films with a diameter of ~ 300µm were grown in the same conditions as that of the bottom Ga:ZnO electrode. The crystalline quality and surface morphology of individual layers were studied using high resolution x-ray diffraction and atomic force microscope. The switching characteristics of these devices, their endurance and associated conduction mechanisms were studied through current-voltage (I-V) measurements in the top-bottom configuration using Kiethley 206 source measurement units.

The as grown RRAM devices appeared highly transparent and shiny to naked eyes with measured average transmission of ~ 80% in visible spectral region. High resolution x-ray diffraction measurements on ZnO and Ga:ZnO layers and structures revealed highly c-axis oriented growth. However the (0002) peak of ZnO layer was found to be rather broad compared to Ga:ZnO indicating presence of structural defects and strain, which is expected due room temperature growth. The atomic force micrograph of ZnO film showed smooth and particulate free surface of the film with irregularly shaped columnar grains of average size ~ 50 nm. The as grown devices were found to be initially in high resistance state (HRS) ~ 1.3 k-ohm?(measured?at ~0.16 V) and did not show any resistance switching behavior until the applied bias voltage was increased to ~ 3.5 V (initial forming voltage) with a current compliance of 10 mA at which the resistance of device dropped suddenly to a low value of ~ 120O (measured at ~ 0.16 V). The low resistance state (LRS) of device persisted even when the applied voltage was reduced to zero. After this initial forming process, which rendered the devise in LRS, as the voltage was swept again form 0 to 2 V switching of the device from LRS to HRS (ON state) was observed at a voltage of ~ 1.6 V. The RRAM device again switched to LRS (OFF state) at ~ 2.2 V as the voltage was swept from 0 to 2.5 volt. The repeatable nonvolatile switching of the resistance of RRAM device was obtained between LRS and HRS at small and well defined switching voltages with a narrow dispersion. The current conduction mechanism of the device in low and high resistance states is thought to be dominated by the Ohmic behavior and Poole-Frenkel emission respectively. Resistance ratios of the high resistance state to low resistance state were found to be nearly constant up to 10 test cycles. Further optimizations and studies of the device structures are underway to achieve better endurance and switching characteristics and understand the associated conduction mechanisms.

References:

[1] G. I. Meijer, Science 319, 1625 (2008).
[2] R. Waser and M. Aono; Nature Materials 6, 833 (2007).
[3] L. M. Kukreja, A. K. Das and P. Misra; Bulletin of Material Science 32 (3), 247 (2009)