Characterization of Copper Saturated-Ge_xTe_{1-x} Solid Electrolyte Films Incoperated by Nitrogen for Programmable Metalization Cell Memory Device

Soo-Jin Lee, Soon-Gil Yoon, Sung-Min Yoon*, Byoung-Gon Yu
Chungnam National Univ. *Electronics & Telecommunications Research Institute

Abstract : A programmable metallization cell (PMC) memory structure with copper-saturated GeTe solid electrolyte films doped by nitrogen was prepared on a TiW bottom electrode by a co-sputtering technique at room temperature. The $Ge_{45}Te_{55}$ solid electrolyte films deposited with various N_2/Ar flow ratios showed an increase of crystallization temperature and especially, the electrolyte films deposited at N_2/Ar ratios above 30% showed a crystallization temperature above 400°C, resulting in surviving in a back-end process in semiconductor memory devices. The device with a 200 nm thick $Cu_{1-x}(Ge_{45}Te_{55})_x$ electrolyte switches at 1 V from an "off "state resistance, R_{off}, close to 10^5 to an "on" resistance state, R_{on}, more than 2orders of magnitude lower for this programming current.

Key Words : PMC-ReRAM, Chacogenide, Solid-electrolyte

1. Introduction

different emerging memory technologies have been investigated with respect to their inherent technical limits, such as scalability potential, switching power, non-volatility, and aspects of their reliability.[1] It has been demonstrated that a programmable metallization cell (PMC) memory has great promise for use as a low energy non-volatile solid state memory.[2-3] The key attributes include low internal voltage, low power consumption, and the ability of storage cells to be physically scaled to the minimum possible area. However, GeTe that is one of candidate solid electrolytesmaterials have a low crystallization temperature of about 250°C.[4]For PMC applications, metal saturated-GeTe electrolytes should survive at temperatures above 350°C because back-end-of line flow in semiconductor device processing is performed above 350°C. The crystallization temperature above 350°C in GeTe films is required for PMC device applications. also, silver is difficult to be used because of contaminate semi-conductor production line. So we studiedCu as both the mobile ionic species and the oxidizable electrode is that it is already widely applied as interconnect in advanced integrated circuits and hence the techniques and processes for its use are already in place.

2. Experiment

Figure 1 show the schematic diagram of programmable metallization cell memory device. For a bottom electrode, TiW (200nm) structures were deposited on SiO_2 by a dc magnetron sputtering. After the deposition of TiW, an interlayer dielectric of SiO_2 (100 nm) was grown by ECR sputtering using SiH_4 and O_2 gases. Contact holes and bottom electrode contacts were patterned using a reactive ion etch (RIE) process. Typical contact hole sizes are 0.5 x .5, 1 x, 2 x, and 5 x ㎛. Programmable metallization cell material of Ge-Te (200 nm) and Curich layer (300 nm) were deposited using rf magnetron sputtering at room temperature followed by lift-off lithography. Finally, W (100 nm) top electrodes were deposited using dc magnetron sputtering and electrodes with 100 x 00㎛^{2} were patterned using lift-off lithography.

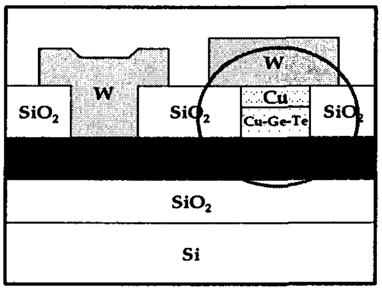

Fig. 1. Schematic diagram of programmable metallization cell memory device.

3. Result and Discussion

Figure 2 show the resistance of GeTe films abruptly dropped at specific temperatureswith increasing nitrogen concentration in films. An abrupt variation of resistance at a specific temperature means a crystallization of the GeTe electrolytes. From the results, films deposited at 30% are considered to have a crystallization temperature of above 400°C. Figure 3 show the Current-Voltage property and Resistance-Voltage property of a PMCM device Programming compliance current was 1mA and voltage sweep was -1.5V to +2.0V to -1.5V and device diameter was 0.5 ㎛ Device switches at 1.0V from an off state resistance, R_{off}, close to 10^5 Ω to an on resistance state, Ron

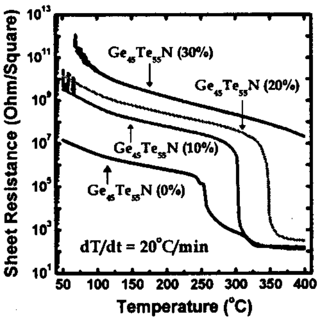

Fig. 2. relationship between the sheet resistance and temperature in GeTe films deposited with various N_2/Ar ratios.

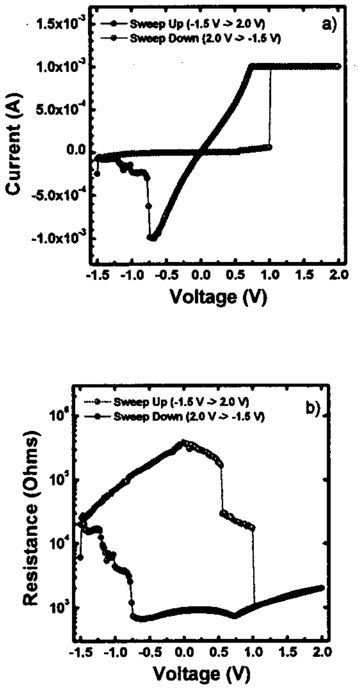

Fig. 3. (a) Current-Voltage property and (b) Resistance-Voltage property of programmable metallization cell memory device.

4. Summary

A PMC memory with copper-saturated GeTe solid electrolyte films doped by nitrogen was prepared by a co-sputtering technique at room temperature. The $Ge_{45}Te_{55}$ solid electrolyte films deposited with an increase of N_2/Ar flow ratios showed an increase of crystallization temperature. and PMC memory device with copper doped $Ge_{45}Te_{55}N$ solid electrolytes shows reproducible memory characteristics based on resistive switching at threshold voltage of 1.0V with high R_{off}/R_{on} ratios.

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