Low-Power Switching in Phase Change Memory using $SnTe/Sb_2Te_3$ Superlattice Film

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ABSTRACT

$SnTe/Sb_2Te_3$ superlattice material is proposed to achieve low-power switching for phase-change memories. GeTe in well-known $GeTe/Sb_2Te_3$ superlattice material was replaced with SnTe. XRD data showed the SnTe(111), SnTe(222), and $Sb_2Te_3(00x)$ (x=3, 6, 15) peaks, although the SnSbTe-alloy peaks were greatly dominant. The consumed power for reset was approximately 1/10 – 1/15 compared with that of a $Ge_2Sb_2Te_5$ device, and which was also almost equal to or lower than that of a $GeTe/Sb_2Te_3$ superlattice device. The endurance of about 10^5 times was confirmed.

Key words: phase-change memory, superlattice phase-change film, interfacial phase-change memory, $SnTe/Sb_2Te_3$

1. INTRODUCTION

A phase-change random access memory is expected to be the next generation non-volatile solid-state memory[1]. One of the problems to overcome for a phase-change memory, however, is the reduction of consumed power for resistance switching. Recently "interfacial phase-change memory" (iPCM) with the superlattice (SL) structure has been proposed to suppress the switching power drastically[2]. In a $GeTe(111)/Sb_2Te_3(001)$ SL film, Ge atoms reversibly switch between octahedral and tetrahedral sites depending on the applied voltages and/or currents. This mechanism has been confirmed with both experiment[2] and theoretical first principle calculation[3]. This type of iPCM must be candidate for next-generation non-volatile memory.

This paper proposes another SL material "$SnTe/Sb_2Te_3$" for low-power switching of a phase-change memory. The experimental results on this material are reported. The perspectives on this material are also discussed.

2. EXPERIMENT

The film structure was as follows: substrate / Sb_2Te_3(10 nm) / [SnTe (1 nm) / Sb_2Te_3 (4 nm)]$_9$ / W(50 nm). The structure of the substrate is described in reference 4. All the films were deposited by sputtering. The substrate temperatures of the chalcogenide films were 200ºC. The top W(50 nm) electrode was sputtered at room temperature. XRD analysis was carried out to identify the phases of the sputtered film.

3. RESULTS AND DISCUSSIONS

XRD data of the above-mentioned film is shown in Fig. 1. This data shows the SnTe(111), SnTe(222), and $Sb_2Te_3(00x)$ (x=3, 6, 15) peaks with the SnSbTe-alloy peaks. The SnSbTe-alloy was dominantly formed in this film. Figure 2 shows the measurement results on the dynamic voltage, the dynamic current, and the read resistance of the $SnTe/Sb_2Te_3$ device. Figure 2(b) shows the two-step change in resistance. This might be due to the low-quality film with the alloy phase. In this two-step change, we cannot define which should be the reset. If we define two reset powers P_{rst1} and P_{rst2} ($P_{rst1} < P_{rst2}$), this data reveals P_{rst1} = 2.4 mW and P_{rst2} = 3.6 mW, while the reset powers of $Ge_2Sb_2Te_5$ and $GeTe/Sb_2Te_3$ devices were 36 mW and 3.6 mW, respectively. Therefore, the consumed power of $SnTe/Sb_2Te_3$ was demonstrated to be about 1/10 – 1/15 compared with that of $Ge_2Sb_2Te_5$, and to be almost equal to or lower than that of $GeTe/Sb_2Te_3$. Figure 3 shows the data on endurance of $SnTe/Sb_2Te_3$ device. At least 10^5 cycles were confirmed although the resistance fluctuation was observed during the 10^3 – 10^4 cycles which recovered again.

The mechanism of low-power switching in this film is not clear. The same mechanism as GeTe/Sb_2Te_3 might work[2,3], i.e., Sn switching considering the following two matters; (1) Both GeTe and SnTe have the same NaCl-type crystalline structures, which grow in their [111] directions on Sb_2Te_3(001) in the SL. (2) Sn is reported to increase the mobility of atoms in Sn-doped GST[5]. The resistance fluctuation in the endurance remains as a problem to be solved. This must be due to the poor-quality film (Fig. 1). The amount of the alloy phase is considered to be reduced by decreasing the substrate temperature because the crystallization temperature of SnTe is lower than room temperature. The further lower-power switching is expected to be obtained in such an improved film, i.e., in a higher-quality film.

4. CONCLUSION

The low-power resistance switching was demonstrated with SnTe/Sb_2Te_3 superlattice film, which was about 1/10 – 1/15 lower than that of $Ge_2Sb_2Te_5$. The endurance was confirmed to be higher than 10^5 times.

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Biographies

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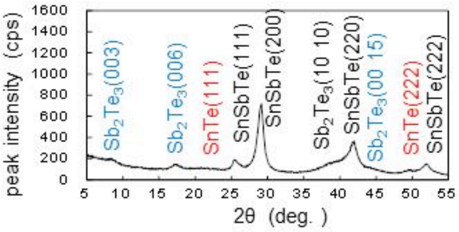

Fig. 1 XRD data of SnTe/Sb_2Te_3

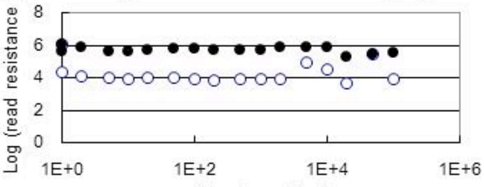

Fig. 3 Endurance of SnTe/Sb_2Te_3 device.

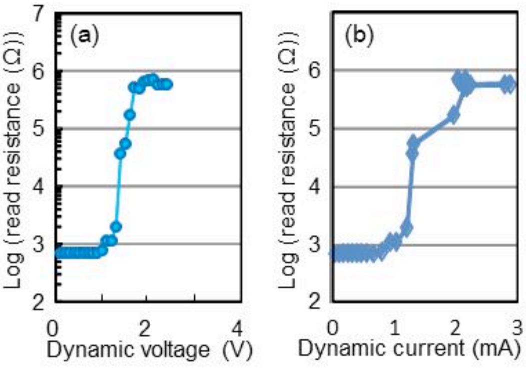

Fig. 2 Electric properties of SnTe/Sb_2Te_3 SL device. (a) Dynamic voltage and (b) dynamic current vs read resistance.