Electric and Optical Studies on Non-thermal Recording Mechanism of $GeTe/Sb_2Te_3$ Superlattice Phase Change Material

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ABSTRACT

The recording mechanism of $GeTe/Sb_2Te_3$ superlattice phase change material (GeTeSL) was studied electrically and optically. The dependence of the electric reset power on the reset pulse width (t_w) shows that GeTeSL consumes less power for shorter pulses, while the power does not depend on t_w in GeSbTe. Optical studies using femtosecond laser pulses show that the xy-polarized light can reset GeTeSL with the lower power than the z-polarized light. These results indicate that the reset mechanism of GeTeSL is not thermal but driven by some vectorial parameters such as the electric field.

Key words: phase-change memory, superlattice phase-change film, interfacial phase-change memory, non-thermal recording

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. Recently “interfacial phase-change memory” (iPCM) with the superlattice (SL) structure has been proposed to suppress the switching power drastically[2,3]. This type of iPCM must be candidate for next-generation non-volatile memory.

This paper reports and discusses the results on the recording mechanism of iPCM studied electrically and optically, and proposes the non-thermal recording mechanism.

2. EXPERIMENT

The following film structure was used for electrical studies; substrate / TiN (1 nm) / Sb_2Te_3 (10 nm) / [GeTe (1 nm) / Sb_2Te_3 (4 nm)]$_8$ / TiN (50 nm). The substrate has the bottom electrode connected with the W plug with the diameter of 100 – 200 nm. The electric pulses were induced through the probes in contact with the bottom electrode and the top TiN electrode. The film structure used for optical studies was as follows; glass substrate / TiN (1 nm) / Sb_2Te_3 (5 nm) / [GeTe (1 nm) / Sb_2Te_3 (4 nm)]$_4$ / SiO_2 (50 nm). The central wavelength of the femtosecond laser pulse was 800 nm. The transmittance of the sample was measured by He-Ne laser to detect the switching of the sample. The sample with $Ge_2Sb_2Te_5$ (GST) was also measured for comparison.

3. RESULTS AND DISCUSSIONS

Fig. 1 shows the relationship between the reset pulse width t_w and the reset power measured for GeTeSL and GST devices. In calculating the reset power, the voltage induced to the film itself was used. This figure shows that the reset power does not depend on t_w for the GST device, which is reasonable because of the thermal recording. On the other hand, the reset power was decreased for the short pulses for the GeTeSL device. This result indicates that the reset mechanism in the GeTeSL device is not dominantly a thermal mode.

To see this phenomenon in more details, the experiments using the femtosecond laser pulses were performed. A z-polarizer (z-pol) was used to produce the polarization of the laser light in the z direction. In other words, the laser polarization was xy (z) direction without (with) z-pol. The optical absorbances were measured for both samples with and without z-pol, whose differences were within 5% (41 – 46%). The result shown in Fig. 2 shows that GeTeSL was optically switched at about half of the laser fluence of GST without z-pol (Fig. 2(a)) while GeTeSL were switched at almost the same or a little higher fluence of GST with z-pol. This means that the xy polarization enables the low power switching of GeTeSL. This result indicates that some vectorial parameter is involved in the low power switching of GeTeSL.

One of the candidates for this “vectorial parameter” is the electric field because the electric field can commonly work for both electric and optical experiments. This might be reasonable because the SL structure has the orientation in the z direction. This non-thermal recording mode might enable the low-power switching in SL materials because this mode does not require Joule’s heat. Further studies, however, are necessary to pursue the detailed mechanism.

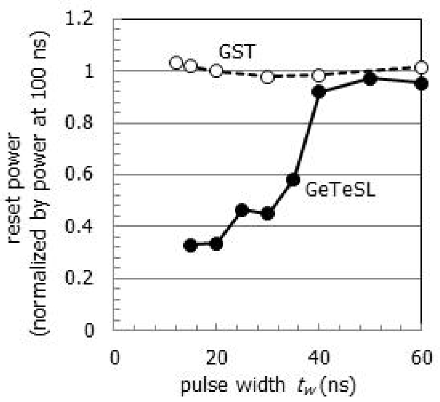

Fig. 1 Reset pulse width t_w vs reset power. Reset power is normalized by the power at t_w = 100 ns.

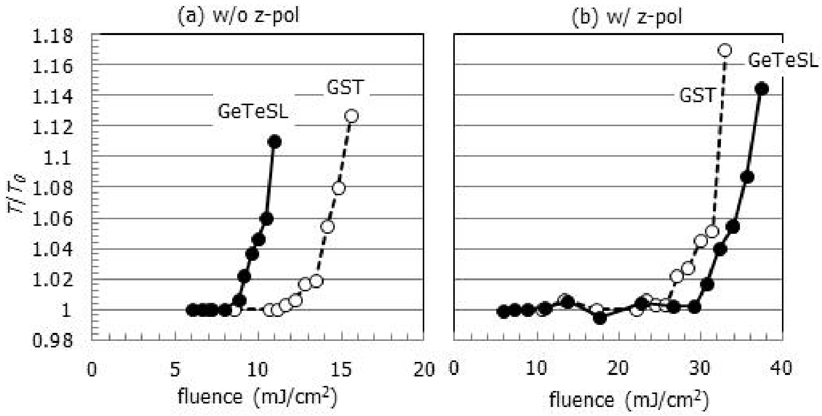

Fig. 2 Laser fluence vs transmittance (a) without and (b) with z-pol. Transmittance is normalized by initial transmittance T_0.

4. CONCLUSION

The recording mechanism in the superlattice phase change material $GeTe/Sb_2Te_3$ was investigated electrically and optically. The experimental results indicate that the recording mechanism is not thermal but driven by some vectorial parameter such as the electric field.

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Biographies

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