Voltage-Pulse-Induced Expansion of Chalcogenide Superlattices Measured by Scanning Probe Microscopy

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Interfacial phase-change memory topological materials such as (GeTe)/(Sb_2Te_3) chalcogenide superlattices (CSL) have been the promising candidate material for next generation of nonvolatile memory. [1] As the resistivity switching in the CSL films involves a structural phase transition,[1] evaluation of CSL deformation by voltage pulses are of particular importance for using CSL films in sensors, switches and memory elements. Here, we measured the expansion of SL films caused by voltage pulses employing the multimode scanning probe microscope (MSPM).[2,3]

We measured films consisting of 8-nm-thick $[(GeTe)_2/(Sb_2Te_3)]_4$ and 7-nm-thick GeTe prepared by sputtering on Sb_2Te_3(3 nm)/Si substrates at 240ºC. In our setup [Fig.1(a)] the metal SPM probe was placed in a pre-defined location, and the structural phase transition was activated by voltage pulses (Vwrite) with an amplitude of 2 - 5 V and a duration of 10 ms - 3 s applied to the sample. The probe height position (Z) and the current were recorded as a function of time during the local excitation. To minimize film deformation by the SPM probe, a small gap maintained in the non-contact SPM mode by keeping a shift of the SPM sensor resonance frequency (Δf) in ultrahigh vacuum at room temperature.[2].

Fig. 1(b) shows a typical CSL response where the CSL expansion (Z-jump) coincided with the conductance state change at 96.1 s. The CSL expansion varied from -150 pm to +1000 pm for different pulse voltage amplitudes and positions along the granular film [Fig. 1(c)]. On average, the CSL expansion was +3.5% in accord with the solid-solid transition mechanism.[1,3] Interestingly, at Vwrite <+2.5 V the switching delay was >10 ms, suggesting a ferroelectric-like behavior where the structural phase transition and corresponding low-to-high conductance switching activated by strong electric field. Though, details of GeTe and Sb_2Te_3 layer stacking are responsible for observed variations. The work was supported by Japan Science and Technology Agency (JST/CREST). [1] J. Tominaga *et al.*, Adv. Mater. Interfaces **1** (2014) 1300027; [2] L.Bolotov et al., JJAP 50, 04DA04 (2011); [3] L.Bolotov et al., JJAP 55, 04EK02 (2016).

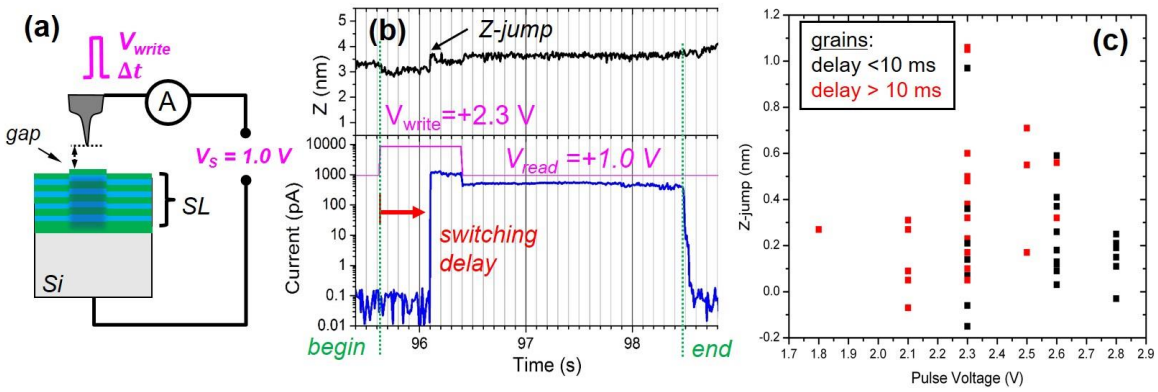

Fig.1 (a) Experimental MSPM setup. (b) Time evolution of probe height (Z) and SPM current upon a voltage pulse. (c) CSL expansion vs. pulse voltage amplitude for different probe position along the CSL film.