ABSTRACT:

Ultrafast Thermal Response of Phase Change Ge-Rich Ge-Sb-Te Thin Films Probed by Time-Resolved X-Ray Diffraction

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Phase-change memory (PCM) is a promising type of non-volatile memory currently being explored by several companies for a wide range of applications, including storage-class memory, in-memory computing, neuromorphic computing, and embedded non-volatile memory (eNVM) for microcontrollers. PCM operates based on the reversible transition between amorphous and crystalline phases, which exhibit significantly different electrical resistivities. Certain applications, such as those in the automotive sector, require materials with elevated crystallization temperatures. For example, an optimized germanium-rich germanium-antimony-tellurium (Ge-Sb-Te) alloy (GGST) demonstrates a crystallization temperature exceeding 350°C [1]. However, this composition does not correspond to a single phase within the equilibrium Ge-Sb-Te ternary phase diagram. As expected, the amorphous mixture separates into pure Ge and cubic $Ge_2Sb_2Te_5$ (GST) upon crystallization [2].

In a mushroom-type PCM memory cell phase phase transition occurs thanks to Joule heating within the GGST material and a dome of transformed material defines the final resistance. The transition speed (in the ns -µs range) and the energy efficiency are highly dependent on the diffusion of heat in the system, which itself depends on the cell architecture and surrounding materials. In the aim of probing in situ and in a time resolved way the thermal response of GGST films, we have performed pump-probe experiments -combining laser excitation (800 nm) with X-ray diffraction probing at 100 ps time resolution - on ID09 beamline at ESRF synchrotron radiation facility. These experiments evidence a transient and reversible strain response of the films, which decays on a time scale of 1-100 ns depending on the film thickness. Thermal diffusion FEM simulations allow rationalizing these observations and bring interesting conclusions on the influence of thermal barriers and temperature gradients.

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