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To understand the mechanism underlying the fast, reversible, phase transformation, information about the atomic structure and defects structures in phase change materials class is key. PCMs are investigated for many applications. These devices are chalcogenide based and use self heating to quickly switch between amorphous and crystalline phases, generating orders of magnitude differences in the electrical resistivity. The main challenges with PCMs have been the large power required to heat above crystallization or melting (for melt-quench amorphization) temperatures and limited reliability due to factors such as resistance drifts of the metastable phases, void formation and elemental segregation upon cycling. Characterization of devices and their unique switching behavior result in distinct material properties affected by the atomic arrangement in the respective phase. TEM is used to study the atomic structure of the metastable crystalline phase. The aim is to correlate the microstructure with results from electrical characterization, building on R vs T measurements on various thicknesses GST thin films.
To monitor phase changes in real-time as a function of temperature, thin films are deposited directly onto Protochips carriers. The Protochips heating holders provides controlled temperature changes while imaging in the TEM. These studies can provide insights into how changes occur in the various phase transformations even though the rate of temperature change is much slower than the PCM device operation. Other critical processes such as void formation, grain evolution and the cause of resistance drift can thereby be related to changes in structure and chemistry. Materials characterization is performed using Tecnai F30 and Titan ETEM microscopes, operating at 300kV. Both the microscopes can accept the same Protochips heating holders. The K2 direct electron detector camera equipped with the ETEM allows high-speed video recording (1600 f/s) of structural changes occurring in these materials upon heating and cooling. In this presentation, we will describe the effect of heating thin films of different thickness and composition, the changes in crystallinity and grain size, and how these changes correlate with changes in the electrical properties of the films. We will emphasize that it is always important to use low-dose and/or beam blanking techniques to distinguish changes induced by the beam from those due to the heating or introduction of an electric current.

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