Growth and characterization of In-Sb-Te thin films

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ABSTRACT

We report on the deposition of In-Sb-Te thin films by metallorganic chemical vapor deposition. In particular, the effect of the growth parameters on the film properties is investigated. Deposition of In-Sb-Te films with thickness ranging from 30 to 150 nm is accomplished, and their morphological, structural and electrical properties are shown and discussed.

Key words: InSbTe, phase change, thin films.

The incorporation of In into conventional Ge-Sb-Te (GST) has been demonstrated to improve the physical properties of these phase change materials [1]. In this regard, In-Sb-Te (IST) alloys look promising for phase-change memory (PCM) applications owing to lower reset current, higher crystallization temperature (290 °C) and higher melting temperature (626 °C) than GST (130 °C vs. 600 °C, respectively) [2],[3]. Further, multilevel data storage has been achieved by employing IST materials in a PCM cell [4], where 4 resistance levels (corresponding to the different crystalline phases) were obtained. It is known that In-Sb-Te exhibits several crystallization temperatures. The lowest crystallization temperature corresponds to the In-Sb transformation, while the higher corresponds to the In-Te phase change. Finally, the crystallization speed has been proven to be in the 50 ns or shorter timescale [5].

In this work, we investigated the effect of growth parameters on the deposition of IST thin films. To this end, a metallorganic chemical vapor deposition (MOCVD) tool, featuring N2 as carrier gas, was employed. The use of MOCVD is thought to be beneficial in terms of: i) better step coverage in trenched/patterned substrates; ii) industrial scalability; and iii) compositional control.

The following precursors were employed for the IST deposition: *trimethylindium-solution* for In, *trisdimethylaminoantimony* for Sb, and *diisopropyltelluride* for Te. The deposition temperature, pressure, and precursors flow were optimized so as to achieve low film roughness, compact grains morphology, and best step coverage. However, the satisfactory precursor dissociation required the deposition temperature to be no lower than 260 °C. As a result, the as grown films were (partially or fully) crystalline. The deposition was carried out on both flat SiO_2(50 nm thick)/Si substrates and patterned substrates, featuring trenches in SiO_2. The morphology is shown in the following SEM images, where a good step coverage is evidenced.

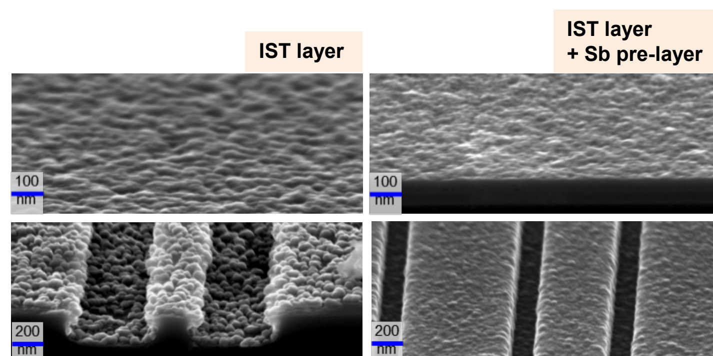

Figure 1 - Morphology of IST films

Notably, the conformality of the film was remarkably improved by pre-treating the substrate with the Sb precursor beforehand (as shown in the Fig. 1, right). The film thickness could be controlled from ≈ 30 to ≈ 150 nm, while preserving a good conformality. Composition could be tuned as a function of the deposition conditions, ranging from $In_3Sb_{2.8}Te_{0.8}$ to $In_3Sb_{0.6}Te_{1.9}$.

The XRD analysis (Fig. 2) indicates that the as deposited layers are mostly crystallized within the cubic structure of the $InSb_{0.9}Te_{0.1}$ phase. A bump on the left of the main peak is the witness of the presence of an amorphous component. After annealing at 450 °C, the crystallized fraction increases, the amorphous bump disappears and also the In_4Te_3 phase is found to develop. The XRR data (Fig. 3) show a significant improvement of the roughness of the samples pre-treated with Sb; unchanged electron density, and thickness control down to ~ 30 nm.

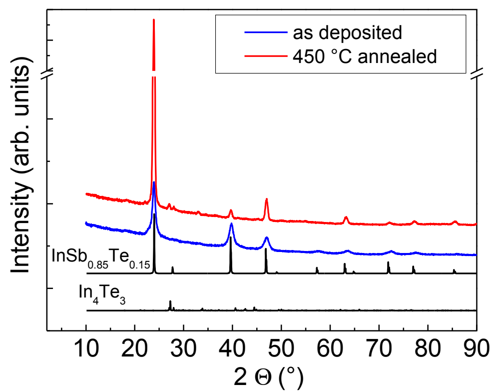

Figure 2 – XRD data

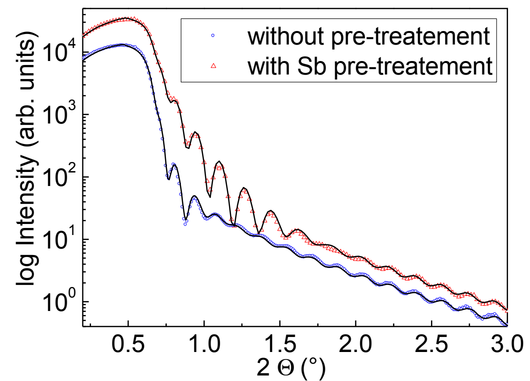

Figure 3 – XRR data

The crystallization temperature could be determined by resistivity measurements during thermal annealing in a vacuum chamber. However, since the as-deposited films were (partially or fully) crystalline, the resistivity drop (which goes along with the phase transition) could not be clearly detected. A small (≈ 1 order of magnitude) drop from 100 to 10 mΩcm is thought to be related to the full crystallization of the phase-separated compound In-Sb-Te (which crystallizes at higher temperatures than In-Sb and In-Te).

Integration into test structures is in progress in order to assess the switching properties of this material and to evaluate the performances of PCM cells.

REFERENCES

1. Shin et al., Appl. Phys. Lett. 93, 021905 (2008)

2. L. Men et al., Mater. Sci. Eng. B 47, 18 (1997)

3. Y. Maeda et al., J. Appl. Phys. 64, 1715 (1988)

4. Kim et al., Phys. Status Solidi RRL 3, 103 (2009)

5. J. Ahn et.al, Nano Lett. 10, 472 (2010)