Study on crystal structure of Cu-Sb_2Te film for phase-change memory application

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ABSTRACT

Effect of Cu addition on crystal structure of Sb_2Te was studied by in situ x-ray diffraction (XRD) measurement. The crystallization temperature of amorphous Cu-Sb_2Te film increased with the increase of Cu concentration. The Cu-Sb_2Te films with Cu concentration of 10, 14, 19 mol. % crystallized into a uniform structure with hexagonal Cu_7Te_4, rhombohedral Sb, and hexagonal Sb_2Te phases. The lattice parameters of Sb phases are more sensitive to the annealing temperature compared to those of other two phases.

Key words: XRD, crystallization, temperature

1. INTRODUCTION

The device properties of PCRAM depend mainly on phase change behaviors of the embedded Chalcogenide materials, such as GeTe-Sb_2Te_3 pseudobinary alloys. $Ge_2Sb_2Te_5$ (GST) is the most widely used due to its relatively good trade-off between thermal stability and crystallization speed.[1] However, switching speed of GST-based PCRAM is insufficient to satisfy the requirement of dynamic random access memory (DRAM) (around 10 ns).[2] Compared with GST, Sb-rich Sb-Te materials have many advantages such as low melting point and fast crystallization.[3,4] However, it is difficult to guarantee a satisfactory data-retention time at 80 ^oC due to its relatively low crystallization temperature. Recently, Cu is extensively used for the high-speed interconnecting technology due to its many advantages such as the improved reliability. However, few studies have reported Cu-doping in Sb_2Te for high-speed PCRAM.[5]

2. EXPERIMENTS

300-nm-thick Cu-Sb_2Te films were deposited on Si (100) substrates by magnetron cosputtering using separate Cu, Sb, and Te targets of 50 mm in diameter. The concentration ratio of Sb to Te was fixed to 2:1. Three samples with Cu concentration of 10, 14, and 19 mol. % were prepared. The crystal structure of Cu-Sb_2Te film was analyzed by in situ x-ray diffraction (XRD) (PW3040/60 X' Pert Pro, PANalytical) at the heating rate of 20 ^oC/min.

3. RESULTS & DISCUSSION

The complex crystallization process of Cu-Sb_2Te film with 10 mol. % Cu (denoted by 10 mol. % Cu for short) was revealed by in situ XRD, as shown in Fig. 1(a). No diffraction peak appeared for 10 mol. % Cu at room temperature, suggesting the as-deposited sample being in amorphous state. As the temperature increased, diffraction peaks started to appear at 150 ^oC, and it became more obvious at 160 ^oC. Thus, the crystallization temperature may range from 150 to 160 ^oC. It is shown that 10 mol. % Cu crystallized into hexagonal Cu_7Te_4, rhombohedral Sb and hexagonal Sb_2Te phases with a single step as the temperature increased to 350 ^oC. The diffraction peaks of rhombohedral Sb phase shifted obviously toward a small angle upon heating, while both hexagonal Cu_7Te_4 and Sb_2Te peaks had a weak shift. Thus, the lattice parameters of rhombohedral Sb would increase significantly with the increasing temperature. Cu-Sb_2Te film with 14 mol. %

Cu had the same crystal structure as 10 mo.% Cu, as shown in Fig. 1(b). The crystallization temperature of 14 mol. % Cu is about 180 ^{o}C higher than that of 10 mol. % Cu. The Sb peaks shifted obviously toward a small angle, indicating an increase in lattice parameters. Figure 1(c) shows the in situ XRD patterns for 19 mol. % Cu. Diffraction peaks of both Cu_7Te_4 and Sb_2Te phases started to appear at 180 ^{o}C. The phase separation of Sb from Cu-Sb_2Te was suppressed for 19 mol. % Cu, and thus the Sb peaks didn't appear until the temperature increased to 300 ^{o}C. Figure 2 shows the TEM image of 14 mol. % Cu annealed at 280 ^{o}C for 2 min. With agglomerated shape, the separate black domain distributed uniformly on the film surface. These grains were confirmed to be Sb crystallite by the means of high resolution TEM. A selected area electron diffraction (SAED) pattern is shown in inset in Fig. 2. The polycrystalline rings could be identified as the embedded hexagonal Cu_7Te_4, rhombohedral Sb and hexagonal Sb_2Te phases which were consistent with the XRD results.

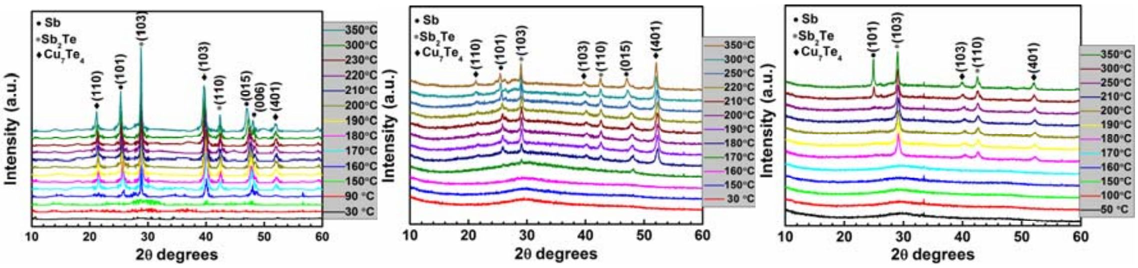

Fig. 1 XRD patterns of Cu-Sb_2Te films with Cu concentration of 10 (a), 14 (b), and 19 (c) mol. %

4. CONCLUSION

The crystallization temperature of Cu-Sb_2Te increased with the increasing concentration of Cu. The Cu-Sb_2Te film crystallized into a uniform structure with hexagonal Cu_7Te_4, rhombohedral Sb, and hexagonal Sb_2Te phases. Compared to Cu_7Te_4 and Sb_2Te phases, the lattice parameters of Sb phase increased significantly as the temperature increased. Phase separation of Sb was suppressed to some extent when the Cu concentration increased to 19 mol. %.

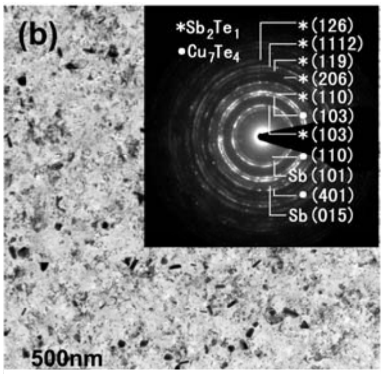

Fig. 2 TEM image of Cu-Sb_2Te film with 14 mol. % Cu annealed at 280 ^{o}C for 2 min.

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