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The chacolgenide based on Ge-Sb-Te doped with Aluminium

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Abstract

This paper presented the deposition of chalcogenide $Ge_1Sb_2Te_4$ (GST-124) with aluminium (Al) atom as dopant by using of pulsed laser deposition (PLD) method. The thickness of the film is 200nm. The crystalline structure of the film is measured using the X-ray diffraction. It was observed that the Al dopant in a cubic structure is presented into GST-124 matrix after the annealing temperature of 250^{o}C. The scanning electron microscopy (SEM) image shown small inhomogeneities on the film surface in as-deposited state.

1. Introduction

During the last years the chalcogenide based on GeSbTe (GST) have been used for phase-change random access memory (PRAM) due to their excellent properties such as thermal stability, cyclability and crystallization speed.

The increasing requirements of low power consumption, good data retention and challenge of reducing the RESET current for PRAM applications [2], the performance of the mostly adopted GST still needs to be improved.

In recent years, for the $Ge_2Sb_2Te_5$ (GST-225) alloys have been proposed for use in PRAM due to their excellent properties with respect to thermal stability, cyclability and crystallization speed.

The GST film can be deposited by various methods, as radio frequency and DC magnetron sputtering [3], metal organic chemical vapor deposition, thermal evaporation [4], high power impulse magnetron sputtering HiPIMS [5] and by pulsed laser deposition (PLD) [6, 7].

In present, a great effort has been made by doping the chalcogenide based on GST with various elements, such as nitrogen [8, 9], oxygen [10], silicon [11], silicon oxide [12], bismuth [13], silver [14], antimony [15] in order to modify the material properties for phase change applications.

In this paper, the chalcogenide GST-124 doped with aluminum (Al) was done by PLD method. It fact, this method offers a simple and easy process to control, with a high deposition rate and preserved stoichiometric transfer from the target material to the thin films. Nevertheless, by PLD method, a number of parameters such as pressure, laser fluence, laser spot area and target-substrate distance can be easily adjusted to achieve the desired film properties [16-19].

2. Experimental

In this paper, thin films based on GST-124 doped with Al were prepared by PLD. The base pressure in the vacuum chamber was p = 7.8x10^{-7} Torr. The Si substrate was kept at room temperature during deposition. The film was deposited using a Nd:YAG laser with a second harmonic wavelength of 532 nm and a constant output power of 0.400 J, the laser pulse width was 10 ns and a repetition rate was 10 Hz. The energy density of the laser beam on the target surface was 400 mJcm^{-2}.

The target and the substrate are positioned parallel to one another at a distance of 4.7 cm. On the GST-124 target is placed a small Al target, in order to obtain a doped thin film. To obtain a good uniform deposition of GST-124 doped with Al over the entire substrate and to avoid craters in the target, during the deposition process, the target is rotated and tilted and the substrate is rotated, respectively. After deposition, the Al doped GST film was annealed in vacuum on the temperature range of 125-350°C. The heating and the cooling rate was constant at 5^{o}C/min.

To investigate the crystallinity of the thin film, the X-ray diffraction (XRD) spectra were performed using a Shimadzu model 6000 diffractometer operating at a wavelength of 1.5418 A (Cu Kα, 40 kV, 30 mA) under grazing incidence of $\theta = 1°$ and 2θ in the range of 20-50^{o}.

3. Result and discussions

In figure 1, the Al doped GST-124 films were annealed in the temperature range of 150-200^{o}C and show a crystalline metastable phase, face cubic centered (fcc), and the film annealed at temperature 150^{o}C has a minor amorphous phase with a broad and weak peak originating between 26 and 29 degrees. The metastable phase fcc of GST-124 film presents the main diffraction peaks, (200) at 29.8 degree, (220) at 42 degrees, respectively, and a small peak (111) at 25.9 degree.

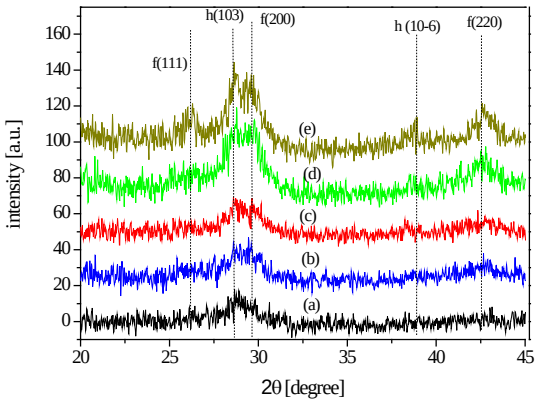

Figure 1. The X-ray pattern of Al doped $Ge_1Sb_2Te_4$ thin film at different annealing temperatures, a) T=150^{o}C, b) T = 175^{o}C, c) T = 200^{o}C, d) T = 220^{o}C and e) T=250^{o}C.

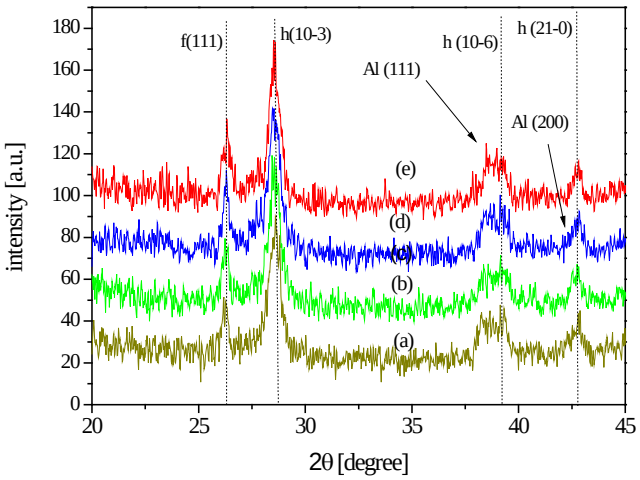

Figure 2. The X-ray pattern of Al doped $Ge_1Sb_2Te_4$ thin films at different annealing temperatures a) T=270°C, b) T = 290°C, c) T = 310°C, d) T = 330°C and e) T=350°C.

From figures 1 and 2, in the temperature range of 175-290°C, the GST-124 films show a mixing between fcc and hexagonal closed packed (hcp) phases. An increase in the annealing temperature higher than 290°C the metastable fcc structure has been fully transformed to a more stable hexagonal structure. After the annealing temperature of T = 250°C, a small peak of Al at 38 degrees it can be seen. This small peak is characteristic to Al dopant in a cubic structure. If the annealing temperature is further increased, the GST-124 show a mixing between the cubic and the hexagonal structures while for the Al dopants incorporated in the GST matrix, a diffraction peak at 38 degrees became higher. Looking in details to the X-ray spectra, it can be seen another diffraction peak is presented at 44 degrees. One may conclude, that the Al dopant became more visible at higher temperature since at low temperature could not be presented into crystalline structure. These preliminary results show that the Al is incorporated into GST-124 matrix at temperature higher than 250°C.

Investigation of the sample surface with a scanning electron microscopy showed that the sample in as-deposited state is amorphous and has small inhomogeneities as is shown in figure 3.

The recent studies [20–22] reported that the Al atoms form covalent bonds with Sb or Te and reduce the atomic diffusivity, that could provide sufficient amorphous stability for phase-change films. The Al atoms could form covalent bonds with Sb or Te in Al-doped GST film, then the stability of GST will significantly be improved. In these studies, the authors reported that Al atoms doped in GST chalcogenide can suppressed the crystalline phases by increasing the atoms dopants. In the present case, since the Al dopants are in small concentration, the hexagonal stable phase become present at relatively low temperature of 220°C. Moreover, in the case of undoped GST-124 film at temperature of 200°C [7] a mixing of fcc and hexagonal phases is presented. For the present study since the Al dopants are in small concentration, it seems that do not modify considerable the properties of GST-124.

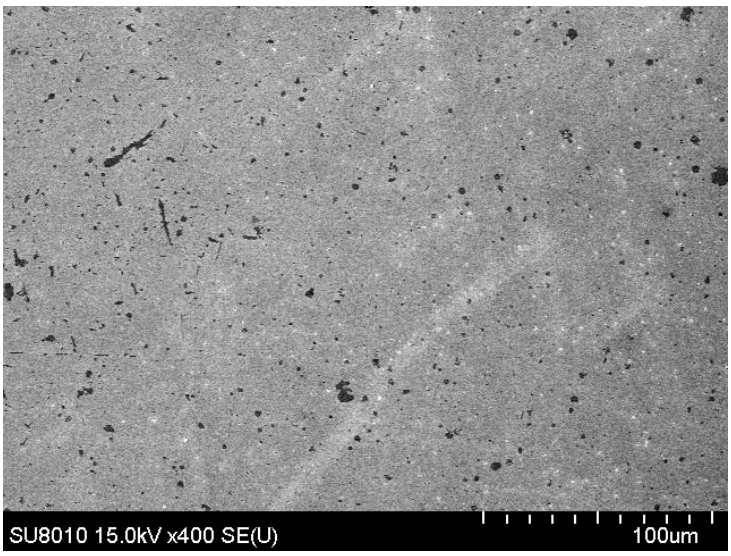

Figure 3. SEM image of an as-deposited amorphous sample.

4. Conclusions

The Al doped $Ge_1Sb_2Te_4$ thin film was deposited by PLD at room temperature. Phase change transitions from the amorphous to fcc and further to stable hcp structures occurred at temperature of 150 and 225^{o}C, respectively. It was observed that the Al dopant in cubic structures is stable in the $Ge_1Sb_2Te_4$ matrix after a temperature of 250^{o}C.

5. References

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