The $Ge_1Sb_2Te_4$ thin film prepared by pulsed laser deposition

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The $Ge_1Sb_2Te_4$ thin film has been deposited by pulsed laser deposition. The X-ray was applied to show the crystallization of the annealed film. The surface of the annealed film was investigated by AFM. The lack of the Te-Te vibration mode near 150cm^{-1} from the Raman spectra of the annealed samples indicates a good crystallization.

1. Introduction

Chalcogenide materials based on GeSbTe (GST) are used as active layers of optical memory discs (DVD), they being under intensive research targeted to development alternative types of memories (Phase-Change RAM (PC-RAM) or Chalcogenide RAM (C-RAM)) to commercially successful semiconductor FLASH memories [1]. Optical and electrical data recording are based on reversible phase transformation between amorphous and crystalline phases [2] caused by laser or electrical pulses application. Detection of the data is based on contrast in reflectivity/resistance between amorphous and crystalline state.

The GST thin films are finding application in electronics for data storage media including future non-volatile memories [3-7] and thermoelectric energy conversion [8]. The GST film can be deposited by various methods, as radio frequency and DC magnetron sputtering [9], metal organic chemical vapor deposition, thermal evaporation [10], high power impulse magnetron sputtering HiPIMS [11], and by pulsed laser deposition (PLD) [12].

2. Experimental

For the preparation of GST films, pulsed laser deposition has been widely used for the deposition of various complex oxides and chalcogenide films. A number of parameters, such as growth temperature, pressure, laser fluency, laser spot area, and target-substrate distance, can be easily adjusted to achieve the desired film properties [12].

In this work the PLD method was used for $Ge_1Sb_2Te_4$ (GST-124) thin films preparation. The PLD set-up consisted of a vacuum chamber (p = 1.4x10^{-5}Torr) and optical laser system. Nd:YAG was used to produce 532 nm light with constant output energy of 110 mJ/pulse, with pulse duration of 10 ns and a repetition rate of 10 Hz. Energy density of the laser beam on the target was 0.4 Jcm^{-2}. The laser beam hit the bulk chalcogenide GST-124 target at an angle of 45°. Target was rotated and the distance target-substrate was 4 cm, substrate temperature at room temperature. Thin PLD films were deposited on Si substrates and then were annealed at 100-400°C temperature in vacuum.

3. Result and discussion

The thin film with a thickness of 120 nm was deposited in amorphous structure. The X-ray was applied to show the crystallization of GST-124 film. In figures 1and 2 are presented the X-ray pattern for GST-124 film annealed in the temperature range 100-400°C.

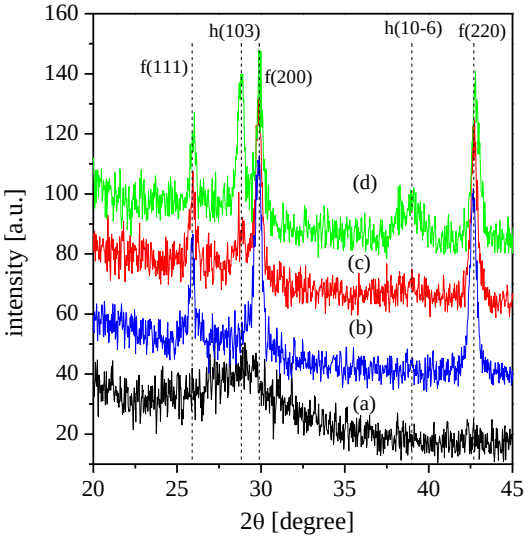

Figure 1. The X-ray pattern of GST-124 film, a) annealing temperature, T=150°C, b) T = 175°C, c) T = 175°C and d) T = 200°C.

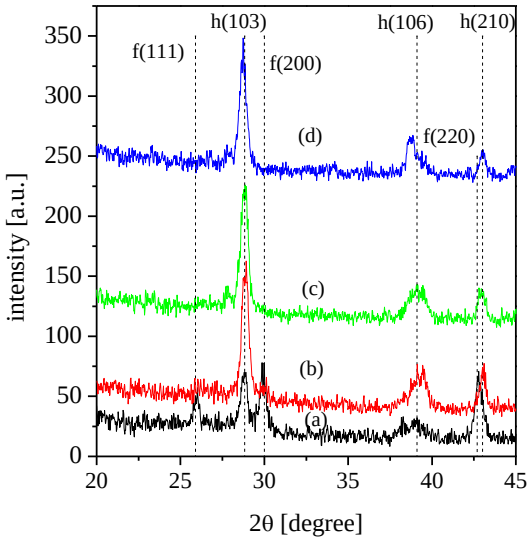

Figure 2. The X-ray pattern of GST-124 film, a) annealed temperature, T = 200°C, b) T = 225°C, c) T = 275°C and d) T = 375°C.

Figures 1 and 2 present the metastable phase face centered cubic (fcc) of GST-124 compound with main diffraction peaks, (200) at 29.8 degree, (220) at 42 degree, respectively, and small peak (111) at 25.9 degree. The hexagonal closed packed (hcp) phase presents three peaks, (103) at 28.8 degree, (106) at 39 degree and (210) at 43 degree, respectively.

Compared with GST-124 film obtained by HiPIMS method the first transition temperature from amorphous-fcc phases is around 160°C. The second transition from fcc-hcp phases appears at temperature of 225°C.

Images of the surface topography of annealed thin film were obtained using AFM method. It was observed an increase of the roughness with annealing temperature to T = 200°C.

An increase in the annealing temperature after T=200°C presented a decrease in the film roughness, and at high annealing temperature T = 350°C it was observed better compactness film surface.

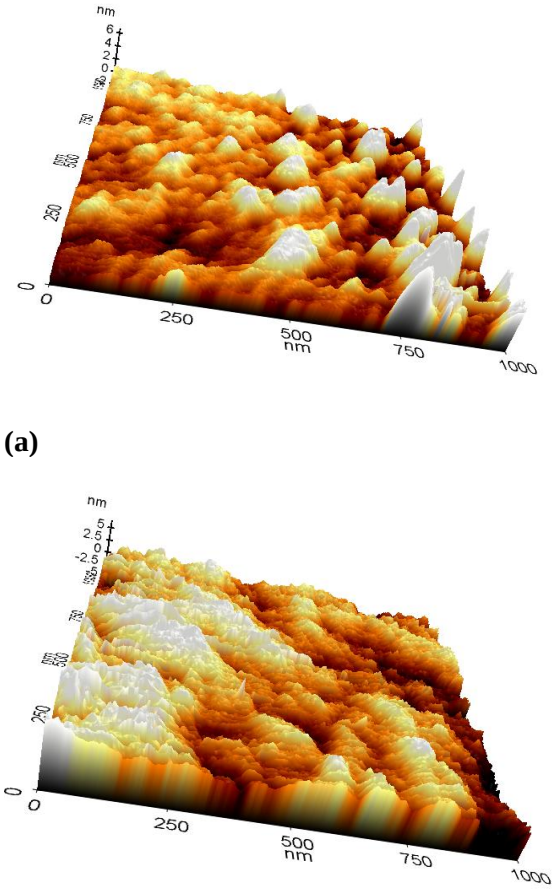

Figure 3. a) AFM image after annealing GST-124 film at T = 200°C; b) AFM image after annealing GST-124 film at T = 350°C.

Raman spectra were recorded at room temperature by confocal Raman microscope (Renishaw) with a diode DPSS visible laser at 532 nm. The single beam power of the laser was 50mW with 100%.

Raman spectra of the target and GST-124 film at various annealing temperatures, particularly to amorphous–fcc phase and fcc-hcp phase, respectively, were presented in figure 4.

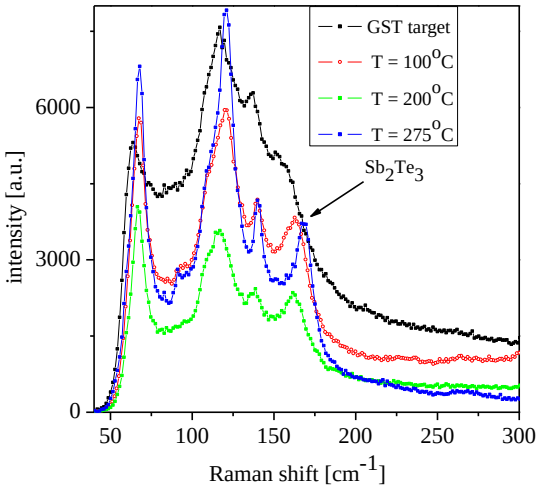

Figure 4. The Raman spectra of GST-124 target and deposited films on Si substrate at various temperatures.

In Raman spectra of GST-124 were identified four phonon vibration modes at ~69, ~122, ~139 cm^{-1} and shoulder around 160 cm^{-1}. The mode at 120 cm^{-1} could be attributed to the vibration of corner-sharing tetrahedral $GeTe_{4-n}$ (n=0, 1). The peak at 168 cm^{-1} can be assigned to Sb_2Te_3 phase. By heating of the film a phonon mode near 150cm^{-1} to the amorphous Te-Te stretching mode was not observed even at low annealed samples. The phonon mode at about 160 cm^{-1} indicates that the sample film is well crystallized.

4. Conclusion

The properties of film deposited by PLD are similar to those obtained by other methods. From X-ray and Raman measurements, we have clearly observed the good crystalline properties of GST-124 film.

5. References

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