

DEPOSITION AND PHASE TRANSFORMATION OF SILVER ANTIMONY TELLURIDE THIN FILMS BY DC MAGNETRON SPUTTERING

Natchanun Prainetr^{1,2}, Athorn Vora-ud^{1,2}, Somporn Thaowonkaew²,
Mati Horprathum³ and Tosawat Seetawan^{1,2,*}

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Abstract

Ternary silver antimony telluride (Ag-Sb-Te) thin films on glass substrates were completely deposited by DC magnetron sputtering. We proposed the good DC magnetron sputtering the base pressure and work pressure at 3×10^{-5} Torr and 2.6×10^{-2} Torr, respectively and the Ar atmosphere flow at rate of 30 sccm and sputtering power of 40 W. Moreover, we can have annealed thin films at the temperature range 300 to 500°C under Ar atmosphere for 30 min for study phase transformation. It was found that, the thin films show phase transformation from amorphous to cubic structure of Sb₇Te and AgSbTe₂ when increased annealing temperature. The crystal structure, crystallite size, lattice strains, lattice parameters and the peak intensity ratio of the (2 2 0) peak with the sum of all the peak, $\sum(h k l)$ are analyzed.

Keywords: Key physical characteristics' factors, freight transportation routing, Delphi method, fuzzy analytic hierarchy process

Introduction

Recently, silver antimony telluride (Ag-Sb-Te) have attracted attention due to their potential applications in sensor, optoelectronic and thermoelectric devices (Berri *et al.*, 2012; Kima *et al.*, 2016). These compounds have a narrow bandgap energy, very low thermal conductivity and inducing thermoelectric properties (Kima *et al.*, 2016; Wojciechowski

¹ Program of Physics, Faculty of Science and Technology, Sakon Nakhon Rajabhat University, 680 Nittayo Road, Mueang District, Sakon Nakhon 47000, Thailand, Tel. & Fax +66-4274-4319. E-mail: t_seetawan@snru.ac.th

² Thin Films Laboratory, Center of Excellence on Alternative Energy, Research and Development Institution, Sakon Nakhon Rajabhat University, 680 Nittayo Road, Mueang District, Sakon Nakhon 47000, Thailand.

³ National Electronics and Computer Technology Center, National Science and Technology Development Agency, Pathumthani 12120, Thailand.

* Corresponding author

et al., 2008). A combination of modern thin films and nanoscale technologies has built forward TE materials (Hmood *et al.*, 2013). The various deposition techniques such as molecular beam epitaxy (Peranio *et al.*, 2012), evaporation (Hatsuta and Takemori, 2016), screen-printing (Kim *et al.*, 2014), etc. But, we select the design of thin films, the enhancement of microscale TE devices. In particular, their thin films were investigated represent performance of the obtained films.

In this study, we synthesis Ag-Sb-Te thin films using DC magnetron sputtering on glass substrate with various annealing temperature. We thoroughly investigated about to the crystal structure of the deposited thin films for basic information lead to thermoelectric materials.

Materials and Methods

Ag-Sb-Te thin films were deposited on glass substrates ($1 \times 2.5 \text{ cm}^2$) by DC magnetron sputtering, diameter of target at 59 mm and 3 mm thick. The base pressure in the system was 3.0×10^{-5} Torr and the working pressure was 2.6×10^{-2} Torr. The sputtering power was 40 W and the argon atmosphere flow at rate of 30 sccm. The substrates on glass of $1 \times 2.5 \text{ cm}^2$ area were cleaned with acetone and deionized water in an ultrasonic washer, each for 30 min. After that, the annealing temperature was proceeded under Ar atmosphere for 30 min. The X-ray diffraction (XRD) was considered the crystal structure and crystallite size of thin films.

Results and Discussion

The XRD patterns are shown in Figure 1. It shows X-ray diffraction data of Silver antimony telluride thin films at annealing temperatures from 300-500°C. We find peaks according to Sb_7Te and AgSbTe_2 , while the XRD pattern of thin films annealed at 300°C is similar to the films annealed at 350°C and 400°C. The main peak position at 28.6720° ,

42.0245° has been according to the (106), (220) of Sb_7Te , AgSbTe_2 , respectively.

As the annealing temperature at 450°C, we observed two small peaks according to Te and Sb at 27.5623° , 40.0770° has been according to the (101), (104), respectively. When the annealing temperature at 500°C, we observed small peak of AgSbTe_2 increase due to AgSbTe_2 phase was transformed Ag-Sb-Te and these are changes structural bonding into the cubic structure at annealing temperatures increase. We found the (220) peak of the films moved forward a slight angle when the annealing temperatures increase. This mean that the film undergo the strain at high annealing temperatures (Park *et al.*, 2015).

The crystal structure of these compounds is shown in Figure 2. The crystal structure of AgSbTe_2 is specify to a rock salt structure with the space group $Fm\bar{3}m$ (#225) (Wojciechowski *et al.*, 2008; Zhang *et al.*, 2010; Berri *et al.*, 2012). The AgSbTe_2 has cubic consisting the Ag atom are positioned at the (0, 0, 0) position, the Sb atom at the (0.5, 0.5, 0.5) position and Te atom at the (0.25, 0.25, 0.25) position (Berri *et al.*, 2012). The six

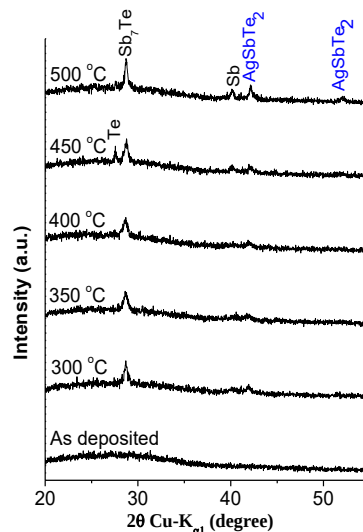


Figure 1. X-ray diffraction patterns of Ag-Sb-Te thin films at various annealing temperatures

Ag atoms located at the face center from an octahedron with side length of 3.04 Å and the ordering of Ag and Sb on a face centered cubic lattice (Jung *et al.*, 2012). The bond length of Ag-Sb, Sb-Ag and Ag-Te are 3.0400, 2.6327, and 2.6327 Å, respectively. This is consistent belong to the family structure. The lattice parameter is 6.078 Å with the calculated by Power cell program while the calculated lattice parameter of Ag-Sb-Te thin film at different annealing temperatures, as shown in Table 1.

The results for the calculated lattice parameter of Ag-Sb-Te thin film were consistent the calculated lattice parameter by Power cell program.

The crystal size and lattice strain of Ag-Sb-Te thin films are shown in Figure 3. From Figure 3, it is apparent that the grain size increases from 90-187 nm, indicating the grain sizes of film increased as annealing temperature increases. On the other hand, the lattice strain decreases as the annealing temperature increases. Therefore, the grain

sizes and lattice strain dependence on annealing temperature (Park *et al.*, 2015; Hatsuta and Takemori, 2016).

We analyzed the XRD intensity ratio of Ag-Sb-Te thin films, as shown in Figure 4. The XRD intensity ratio was estimated by the peak intensity ratio of the (220) peak to the sum of all the peak, $\sum(hkl)$. As annealing temperature at 500°C, approximately constant at 0.2 and as annealing temperature at 300-450°C, the XRD intensity ratio gradually decreases. This indicates that the crystal structure changes gradually due to annealing temperature increases.

Conclusions

We investigated the phase transformation of Ag-Sb-Te thin films on glass substrates which the thin films were deposited by DC magnetron sputtering and annealing temperature from 300-500°C under Ar atmosphere for 30 min. The film has the cubic structure and space

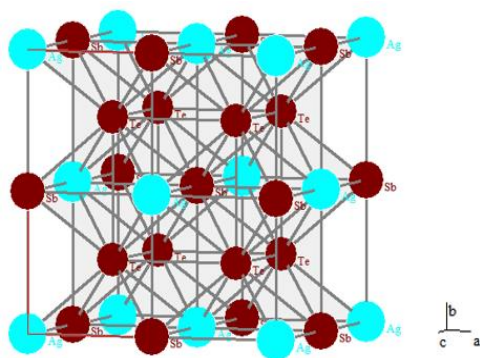


Figure 2. The crystal structure of AgSbTe₂ thin films

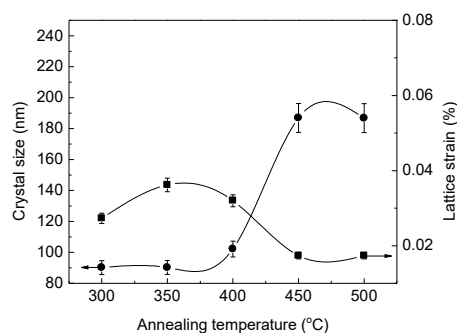


Figure 3. The crystal size and lattice strain of Ag-Sb-Te thin films as various annealing temperatures

Table 1. The calculated lattice parameter of Ag-Sb-Te thin film at different annealing temperatures

Annealing temperatures (°C)	FWHM (°)	Crystallite size (nm)	lattice parameter (Å)
300	0.6373	90.174	6.0386
350	0.7333	90.259	6.0526
400	0.7700	102.23	6.0303
450	0.5025	186.90	6.0450
500	0.3992	186.82	6.0515

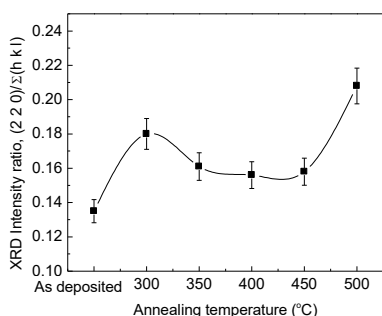


Figure 4. XRD intensity ratio of Ag-Sb-Te thin films as various annealing temperatures

group $Fm\bar{3}m$ (#225). The results for the calculated lattice parameter of Ag-Sb-Te thin film were consistent the calculated lattice parameter by Power cell program. It is apparent that the crystallite size increases from 90–187 nm and the lattice strain decreases as the annealing temperature increases.

Acknowledgements

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