ARGON ION INDUCED CHANGES IN ANTIMONY TELLURIDE THIN FILMS USING DENSE PLASMA FOCUS DEVICE

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1. Introduction

The Dense Plasma Focus (DPF) has been established as an intense source of fusion neutrons, x-rays, electrons and energetic ions with several hundred *keV* [1]. This paper reports the use of the highly energetic, pulsed argon ion beam (from the 3.3kJ UNU/ICTP PFF)[2], for modifying antimony telluride (Sb_2Te_3) films. Antimony telluride is used as a thermoelectric material is being investigated as a phase change optical material.

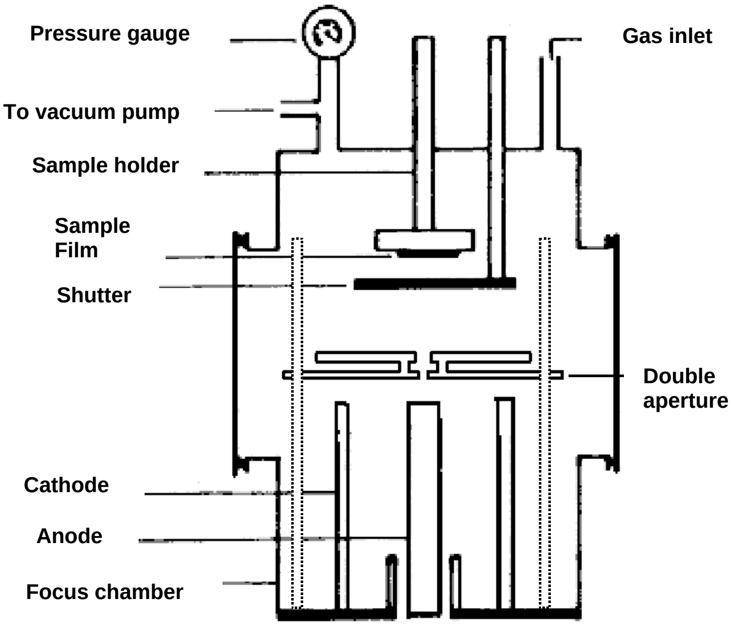


Figure 1. Experimental setup.

2. Experiment

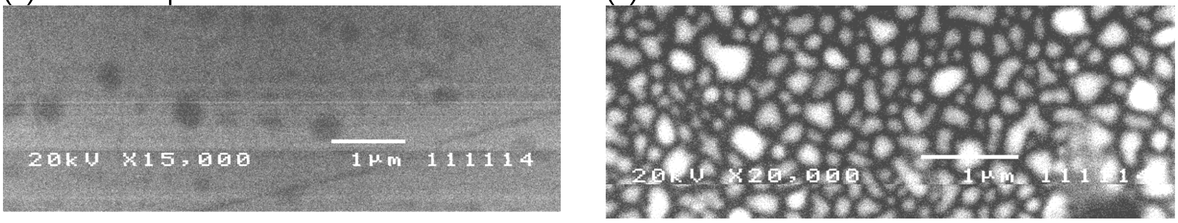
The thin films (0.41μm thick) were deposited, at University of Delhi, on glass substrates using thermal evaporation technique. The experiment was set up as shown in Figure 1. The samples were placed downstream of the anode using an axially movable sample holder to vary the exposure distance and hence the ion fluence. A combination of two apertures of diameter 3 mm and 4 mm, separated by a distance of 1.0cm, were placed at 2.0cm beyond the anode to attenuate blast wave effects. The focus was operated in 1mbar of argon with a 14kV charging voltage.

3. Results and analysis

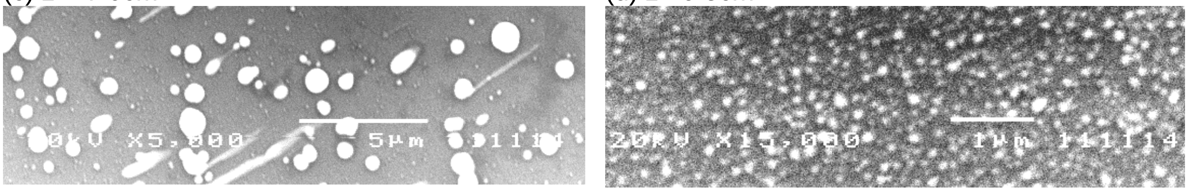
The exposed samples were then analysed using Scanning Electron Microscope(SEM), Atomic Force Microscope(AFM), X-ray Diffractometer(XRD), X-ray Photoelectron Spectrometer (XPS).

Figure 2 shows typical SEM micrographs of samples at a few different distances.

(a) Before exposure (b) z = 4.5cm



(c) z = 7.0*cm* (d) z= 9.5*cm*



(e) z = 10.7*cm*

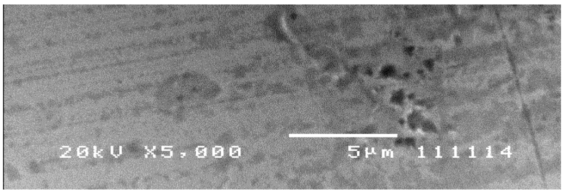


Figure 2. (a) to (e) SEM micrographs of Sb_2Te_3 films on glass substrate

Although the crystal grains of the unexposed sample and the sample exposed at z = 10.7 cm were too small to be observed even at a magnification of X15,000. SEM micrographs of the other samples revealed grain morphologies, of both Sb_2Te_3 and large white pyramidal grains of Sb_2O_3.

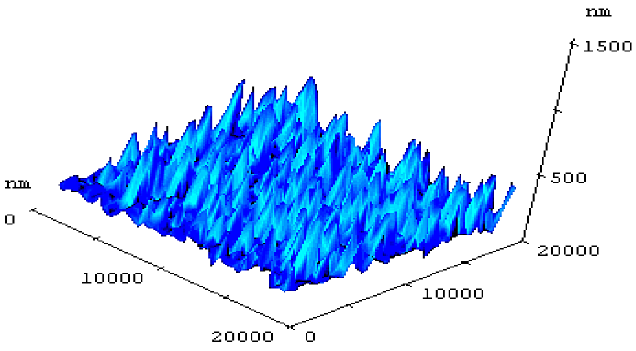


Figure 3. AFM image of a sample exposed at 5 cm

Figure 3 shows a typical AFM scan of an exposed sample(5cm). The surface roughness was obtained in this way from the various samples.

Figure 4 shows some raw XRD scans (using Cu Kα radiation) of the samples exposed at various distances. The crystal structure is inferred by comparing with references of known peaks. The Miller indices of the prominent peaks are indicated only on the diffractograms for distances of *z* = 5.0 cm and *z* = 6.5 cm for clarity.

The chemical composition of the films is analysed using the XPS. Figure 5 shows the deconvoluted $3d_{5/2}$ peak of antimony. Both peaks show a shift from elemental Sb peak (533eV) due to bonding with Te. Antimony is found to exist both in a stoichiometric (Sb_2Te_3) as with as non-stoichometic phases of Sb_xTe_{1-x}, with x = 0.6 in general.

The plots of the ratio between that of pure $Sb_{5/2}$ to $Sb_{3/2}$ (Figure 6) too reveals that oxidation has taken place for samples kept at distances ≤ 8.0 cm.

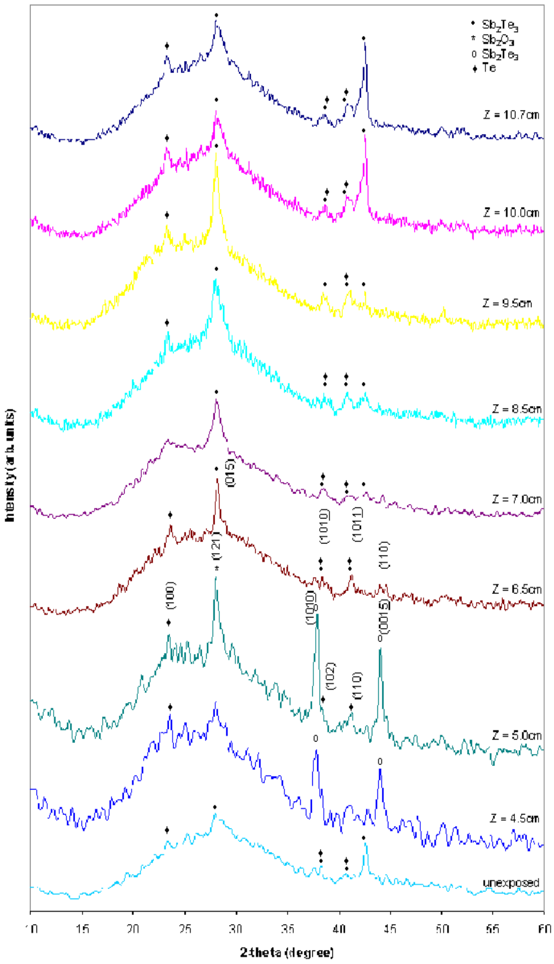


Fig. 4. XRD scans

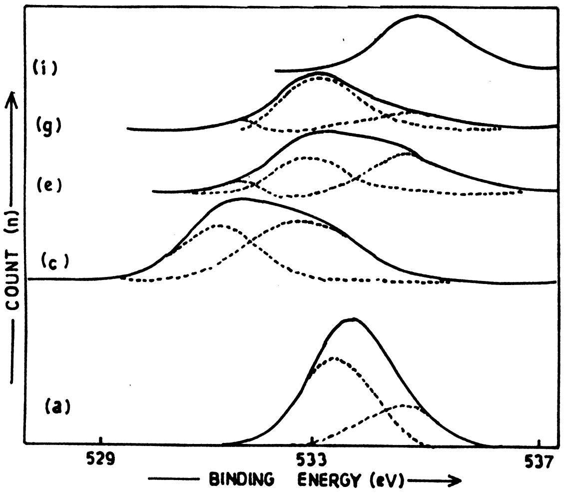


Fig. 5. XPS scans – $3d_{5/2}$ peaks of antimony

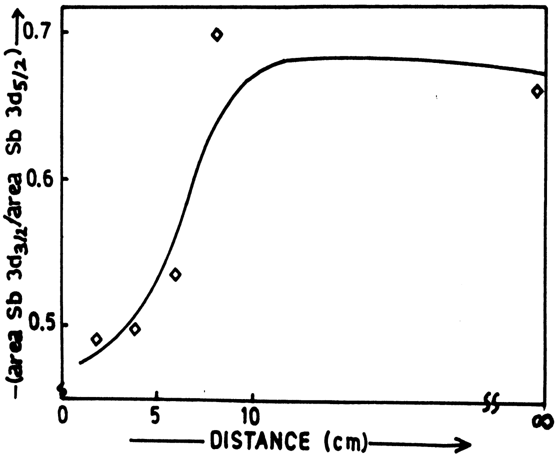


Fig. 6. Plots of the ratio between pure $Sb_{5/2}$ to $Sb_{3/2}$ peaks

In general, the XPS data suggests that the high energy ions, at smaller distances of exposures, breaks the bonding of Sb_2Te_3 and encourages oxidation, however this oxidation disappears as the distance of exposure is reduced to 8.0cm, resulting in a single stoichiometric Sb_2Te_3 film.

4. Conclusion

The XPS and SEM studies on Sb-Te films irradiated with energetic argon ions revealed that for smaller distances of exposures, ion irradiation is seen to encourage the formation of antimony rich non-stoichiometric phase along with antimony oxide (Sb_2O_3). Exposure at higher distances is found to cause negligible oxidation and the film is seen to go to a complete stoichiometric phase. An increase in the crystallization of Sb_2Te_3 crystals for films placed at further distances from the anode. AFM and SEM studies indicate that the surface of the films which were exposed at greater distances were reasonably smooth. Studies using the XRD also revealed that a preferred direction of orientations of crystals were encouraged by ion irradiation at distances between 9.0cm to 10.0cm.

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References

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