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Influence of deposition temperature on the surface morphology and optical spectra of Sb_2O_3 thin films

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Abstract
Sb_2O_3 thin films were deposited by vacuum thermal evaporation technique at substrate temperature 298 K and 498 K. The surface morphology was investigated by atomic force microscopy (AFM) and vertical scanning interferometry (VSI). The optical transmission and reflection spectra of the Sb_2O_3 thin films were recorded in the spectral range 190-1100 nm. From these spectra, the absorption coefficient and the band gap energy of the investigated thin films were calculated.

Keywords: Sb_2O_3, thin films, morphology, roughness, optical spectra, band gap energy

1. INTRODUCTION

Antimony oxide (Sb_2O_3) is an important semiconducting compound owing to its practical applications as conductive and optical material [1]. Sb_2O_3 exhibits a large and direct band gap energy located in the ultraviolet region [2]. Due to its electrical and optical properties Sb_2O_3 may have application as the humidity sensor [3] and photovoltaic applications [4]. In previous research, we have studied some structural, electrical and optical properties of Sb_2O_3 thin films prepared by thermal evaporation technique [3,5].

In this paper, the influence of deposition temperature on the surface morphology and optical properties of Sb_2O_3 thin films obtained by physical vapor deposition in vacuum is investigated.

2. EXPERIMENTAL

Sb_2O_3 thin films, with thickness d=0.55 μm were deposited onto glass substrates with a rectangular shape of 15 mm×30 mm, by thermal evaporation under vacuum of Sb_2O_3 polycrystalline powder. The pressure in the evaporation chamber was kept below 3×10^{-5} torr during the deposition of the films. The substrate temperature (T_S) during deposition was kept constant during film growth at 289 and 498 K.

The surface morphology of the Sb_2O_3 thin films was analyzed by atomic force microscopy (AFM) in non-contact mode and vertical scanning interferometry (VSI) using a coherent scanning interferometer. The optical transmittance (T) and reflectance (R) were recorded, in the spectral range 190-1100 nm, by using a Perkin Elmer Lambda 35 UV-VIS double-beam spectrophotometer. The optical band gap (E_g) of the investigated Sb_2O_3 thin films, were determined from the optical transmittance and reflectance spectra.

3. RESULTS AND DISCUSSION

The AFM-2D images of the Sb_2O_3 thin films deposited at 298 K and 498 K substrate temperatures are shown in Fig. 1. The VSI-3D images of the top surface of the Sb_2O_3 thin films are shown in Fig. 2 and the VSI-X and Y profiles are shown in Fig. 3.

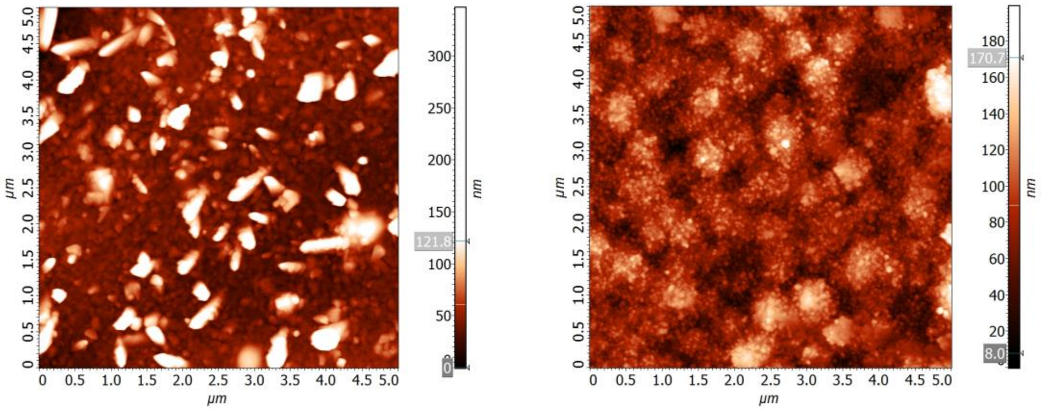

Fig. 1. AFM-2D images of the Sb_2O_3 thin films: (a) T_S=298 K and (a) T_S=498 K

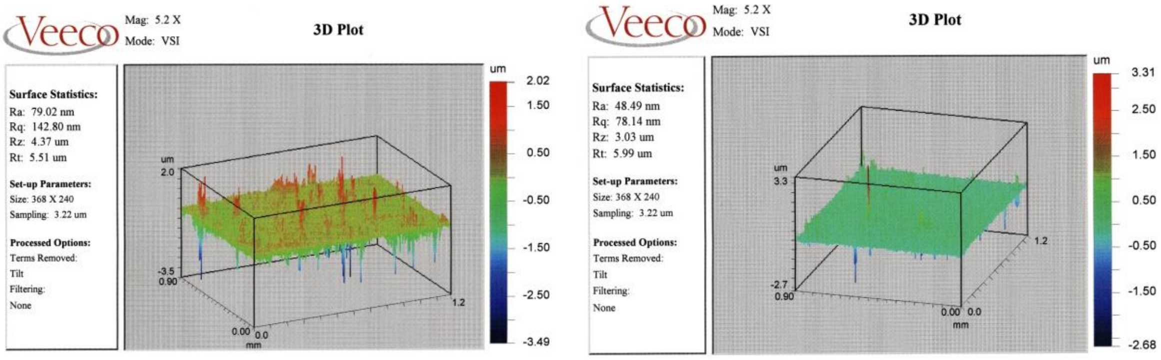

Fig. 2. VSI-3D images of Sb_2O_3 thin films: (a) T_S=298 K and (a) T_S=498 K

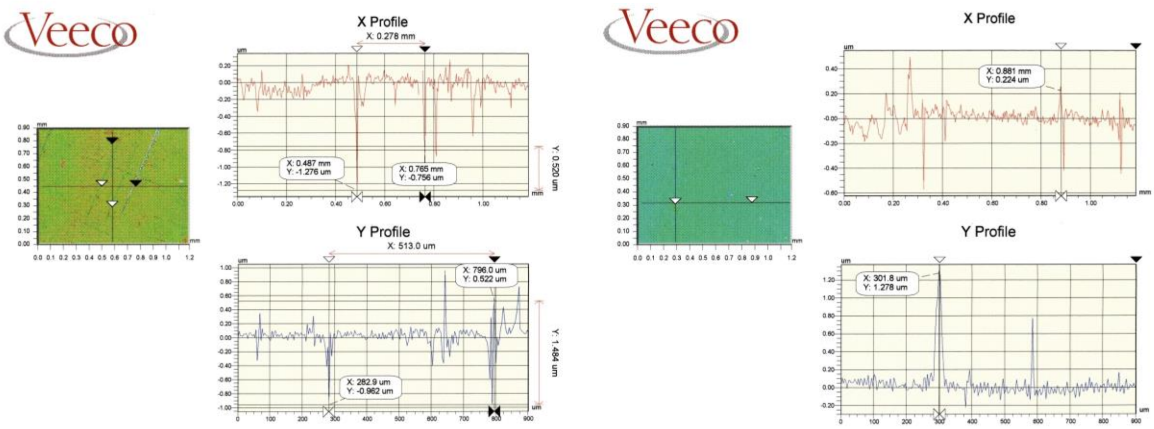

Fig. 3. VSI-X and Y profiles of Sb_2O_3 thin films: (a) T_S=298 K and (a) T_S=498 K

From the AFM images (Fig. 1) it can be observed that with the increase of the substrate temperature from 298 K to 498 K, the surface morphology of the Sb_2O_3 thin films changes significantly.

As can be seen in Fig. 1, the thin film deposited at the substrate temperature of 498 K (Fig. 1 b) is more compact than that deposited at the temperature of 298 K (Fig. 1 a), showing a more uniform distribution of crystallites on the substrate. Therefore, this phenomenon leads to a decrease in the surface roughness of the thin films. The roughness parameters of the surfaces of the analyzed thin films were determined from the VSI measurements. Thus, the average roughness, R_a, decreases from 79.02 to 48.49 nm, the root mean square roughness, R_q, decreases from 142.80 to 78.14 nm and the average maximum height of the profile, R_z, decreases from 4.37 to 3.03 nm, when the deposition temperature increases from 298 K to 498 K (Fig. 2).

Fig. 4 shows the optical transmission and reflection spectra recorded in the 190-1100 nm wavelength range of Sb_2O_3 thin films, deposited at substrate temperatures of 298 K and 498 K. From Fig. 4 it can be seen that thin films deposited at a temperature of 498 K exhibit higher optical transmittance and reflectance than thin layers deposited at a temperature of 298 K. This increase in the values of transmittance and reflectance may be due to the decrease in the surface roughness of the thin films when the deposition temperature increases from 298 to 498 K. The appearance of interference fringes in transmittance and reflectance spectra of Sb_2O_3 thin films deposited at 498 K indicates the excellent surface quality and the homogeneity of this films.

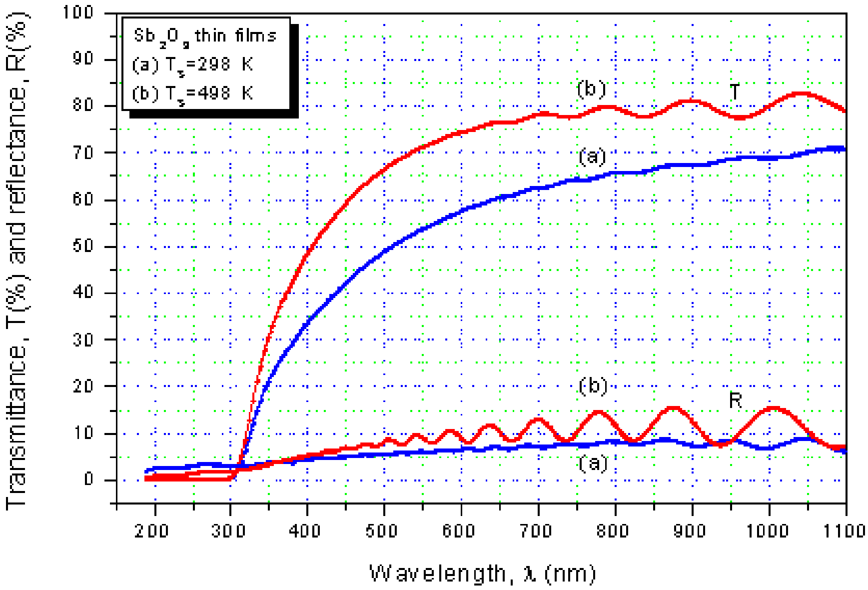

Fig. 4. Spectral dependences of the transmittance, T, and reflectance, R:
(a) T_S=298 K and (a) T_S=498 K.

The band gap energy values, *Eg*, were determined using the following relationship [6]:

$$(\alpha h\nu)^2 = A(h\nu - E_g) \tag{1}$$

where *A* is a characteristic parameter independent of photon energy, $(h\nu)$ is the incident photon energy and α is the absorption coefficient calculated from the transmittance and reflectance spectra using the relationship [6]:

$$\alpha = \frac{1}{d}\ln\left\{\frac{(1-R)^2 + \left[(1-R)^4 + 4R^2T^2\right]^{1/2}}{2T}\right\} \tag{2}$$

Fig 5 shows the dependence of $(\alpha h\nu)^2$ vs. $(h\nu)$. By extrapolating the linear portion of the curves, the value of the band gap energy, E_g, was estimated.

From Fig. 5 it can be seen that the band gap energy, E_g, increases from 3.72 to 3.81 eV when the deposition temperature increases from 298 to 498 K. A lower value of the band gap energy corresponding to the thin films deposited at a temperature of 298 K compared to those deposited at 498 K can be correlated with the structural imperfections of these thin films, as can be observed by AFM and VSI measurements.

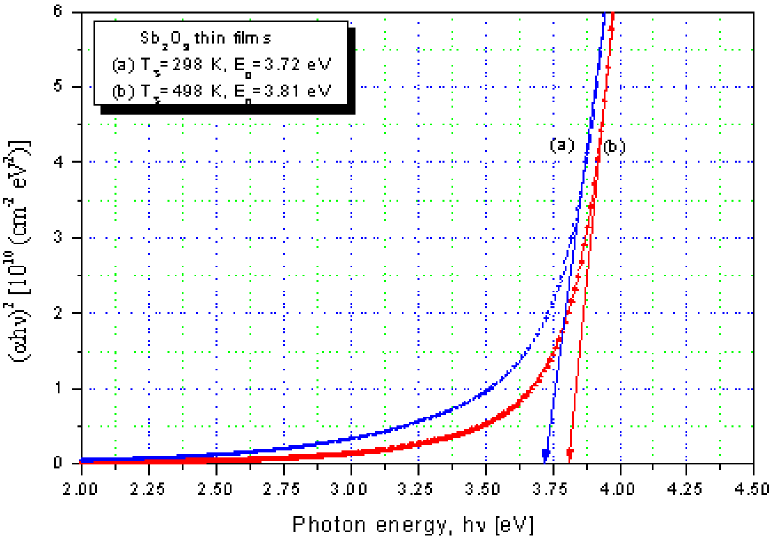

Fig. 5. Plots $(\alpha h\nu)^2$ vs. $(h\nu)$ for Sb_2O_3 thin films: (a) T_S=298 K and (a) T_S=498 K.

4. CONCLUSIONS

Sb_2O_3 thin films were deposited by vacuum thermal evaporation. The substrate temperature during deposition was kept constant at 298 and 498 K. The surface morphology of the thin films thus obtained was analyzed using atomic force microscopy (AFM) technique and vertical scanning interferometry (VSI) method. From the AFM and VSI analyses it was found that the surface roughness of the Sb_2O_3 thin films decreases when the deposition temperature increases. This leads to an increase in transmittance and reflectance which causes an increase in the band gap energy.

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