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Studies on physical properties of tin oxide films

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Abstract
This paper reports the study of some physical properties of thin films of tin oxide, such as the structural properties, surface morphology and optical transmission and reflection. The thin films of tin oxide were deposited by the method of thermal evaporation under vacuum. Transmission electron microscopy (TEM) was used to study the structural properties and the atomic force microscopy (AFM) method was used to study the surface morphology of thin films of tin oxide. The absorption and extinction coefficients of the investigated thin layers were determined from the transmittance and reflectance spectra recorded in the range of wavelengths between 190 and 1100 nm.

Keywords: thin films, thin oxide, structural properties, optical properties.

1. INTRODUCTION

In recent years, thin films of tin oxide have been intensively studied due to their multiple applications as transparent electrodes used in the construction of solar cells, gas sensors and photovoltaic and optoelectronic devices [1,2]. A large number of methods have been used to prepare thin layers of tin oxide such as spray pyrolysis, thermal evaporation, sol–gel method, electron beam evaporation technique and spray ultrasonic [3]. In the present work, the study of some physical properties of the thin films of tin oxide prepared by the technique of thermal evaporation under vacuum is reported.

2. EXPERIMENTAL

Tin oxide thin films were deposited on glass substrates by thermal evaporation under vacuum ($p=5\ 10^{-5}$ Torr) of tin oxide powder. The glass substrate was maintained at a temperature of 300 K during deposition of thin films. The thickness of tin oxide thin films ($d=0.60$ μm) was measured by interferometric method using a Linnik microscope. The surface morphology on the tin oxide thin films was investigated by Atomic Force Microscopy (AFM). Transmission electron microscopy (TEM) was performed on the study of microstructural properties of tin oxide films. The optical properties of tin oxide thin films were the studied from the transmission and reflection spectra in the spectral range 190-1100 nm. The transmittance T(%) and reflectance R(%) spectra were recorded in the wavelength range of 190-1100 nm using Perkin Elmer Lambda 35 UV-Vis double beam spectrophotometer.

3. RESULTS AND DISCUSSION

Fig. 1 shows the typical 2D and 3D-AFM images of surface of tin oxide thin films. As can be seen from Fig. 1, the surface of the investigated thin films is very smooth. The AFM study of surface morphology of thin films revealed a grain-like surface. Thin films are composed of uniform polycrystalline grains of similar shapes and sizes. The average roughness and root mean square roughness of the thin film surface were found to be around 1.28 nm and 1.63 nm, respectively. The average surface roughness of the film was around 1.3 nm.

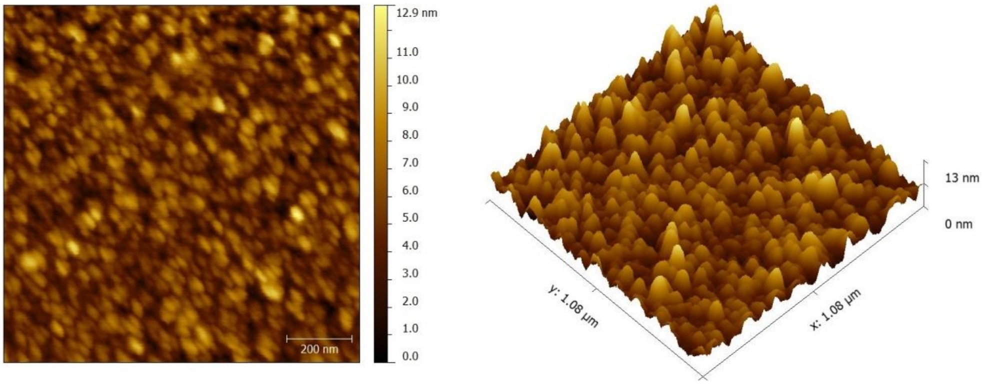

Fig. 1. 2D and 3D-AFM images of surface of tin oxide thin films

The stuctural properties of tin oxide thin films were investigated by electron diffraction studies. Figure 2 shows the selected area electron diffraction (SAED) pattern of the tin oxide thin film prepared at temperature of 300 K. The electron diffraction pattern shows that the analyzed thin layers have a polycrystalline structure. The interplanar distances, d_{hkl}, was evaluated using Bragg’s equation for different diffraction angles, $2\theta^{o}$, and the Miller indices of electron diffraction planes (*hkl*) are shown in table 1. The peaks corresponding to the electron diffraction on the crystalline planes (101), (111), (211), (310), (202) of the tin oxide thin films were in good agreement with the JCPDS Card No. 41-1445.

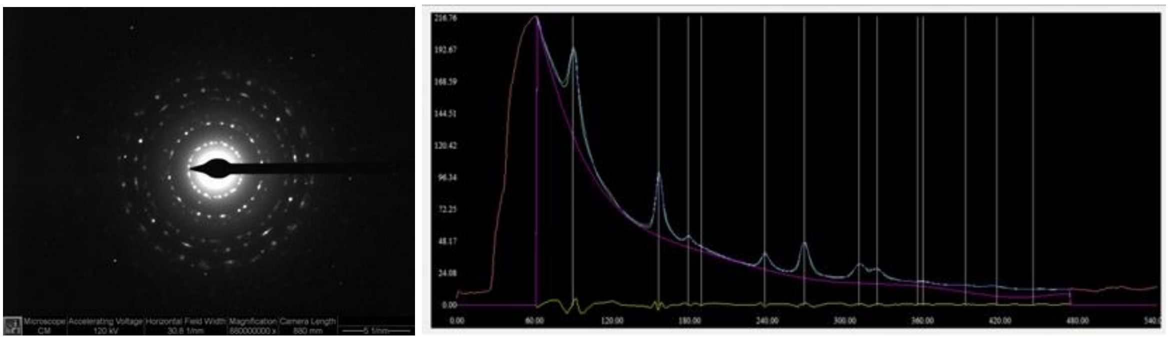

Fig. 2. The SAED pattern and the profil of diffraction peaks of tin oxide thin films.

Table 1. Interplanar distances, d_{hkl}, diffraction angles, $2\theta^{o}$, and the Miller indices, *hkl*.

Peak no.	d_{hkl} (Å)	2θ°	hkl
1	2.6195	0.7219	101
2	2.2781	0.8300	111
3	1.7151	1.1025	211
4	1.5209	1.2433	310
5	1.3123	1.4409	202

The optical transmittance (T%) and reflectance (R%) spectra of tin oxide thin films are shows in Fig. 3. The thin films present a transmittance value more than 80% of the transmittance and respectively a reflectance more than 20% in the visible and near-infrared wavelength ranges. The interference maxima and minima observed in the transmission and refractance spectra confirm the fact that the investigated thin films are homogeneous and have a uniform thickness throughout the substrate.

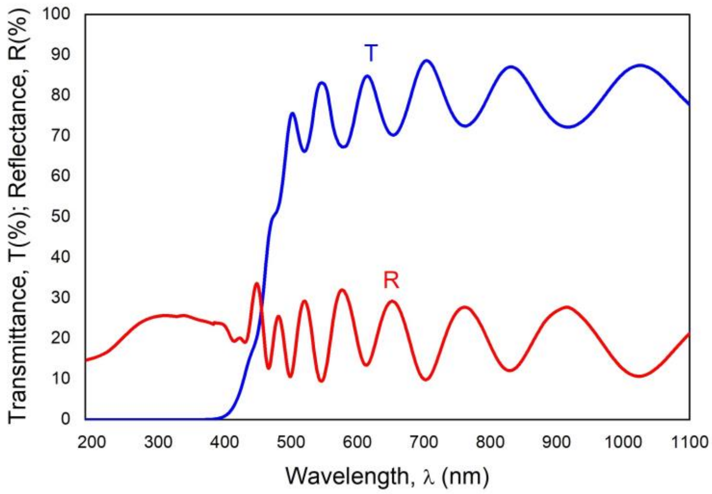

Fig. 4. The T(%) and R(%) spectra of tin oxide thin films

From the transmission and reflection spectra, the absorption coefficient, α, was calculated using the following relationship [4,5]:

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

The extinction coefficient, k, of the investigated tin oxide thin films was calculated with the relation [6]:

$$k = \frac{\lambda\alpha}{4\pi} \quad (2)$$

Fig. 4 shows the results obtained for the absorption coefficient and respectively for the extinction coefficient of the analyzed tin oxide thin films.

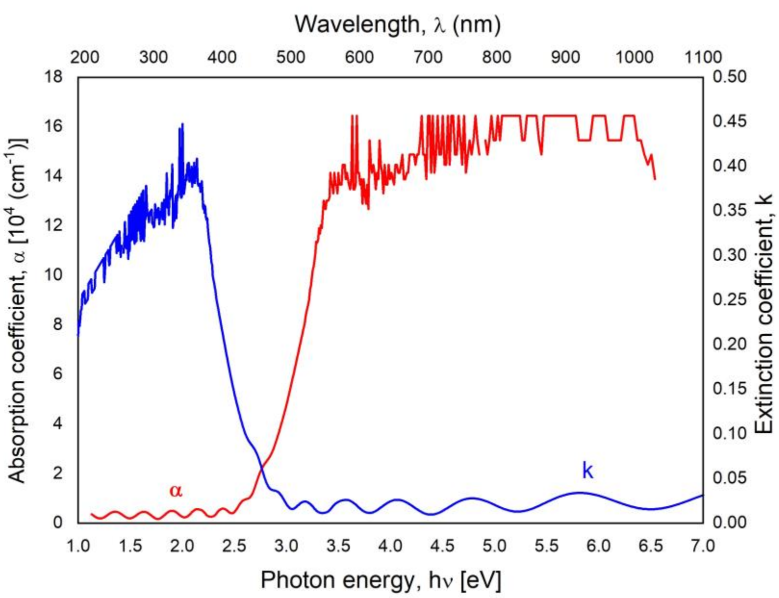

Fig. 4. The plots of α=f(hν) and k=f(λ) of tin oxide thin films

4. CONCLUSIONS

Thin films of tin oxide with a thickness of around 0.60 μm were deposited on glass substrates maintained at a temperature of 300 K by the method of thermal evaporation under vacuum. From the TEM and AFM analyses, it is found that the investigated thin layers of tin oxide are polycrystalline, very smooth and uniformly deposited on the entire surface of the substrate. The absorption and extinction coefficients of the tin oxide thin films were calculated from the transmission and reflection spectra recorded in the wavelength range of 190-1100 nm.

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