Effects of Laser Fluence on Structural Properties of SnO_2 Thin Films

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Abstract

In this study, SnO_2 thin films were grown by pulsed laser deposition (PLD) on glass substrates at sputtering pressure (10^{-3}) torr , with temperature substrate (300) ^oC and with different laser fluence (0.8 , 1.2 , 1.8)J/cm^2 . To examine the structure and morphology of the films, X-ray diffraction (XRD) and atomic force microscopy (AFM) methods were used respectively. From X-ray diffraction patterns of the SnO_2 films , it was found that the deposited films showed some differences compared with the laser fluence and the intensities of the peaks of the crystalline phases decreased with the decreased of laser fluence. From AFM images, the distinct variations in the morphology of the thin films were also observed.

Keywords: Tin dioxide , Pulsed laser deposition , Structural properties , Surface morphology , SnO_2 .

1. Introduction

Over the last few decades, tin dioxide (SnO_2) has been widely investigated recently for its interesting optical properties, electronic properties and good stability in the adverse environment. For its high refractive index, wide band gap and chemical stability, polycrystalline SnO_2 films are used for a variety of applications such as optics industry [1], dye sensitized solar cells [2], dielectric applications [3], self cleaning purposes [4] and photocatalytic layers [5]. The highly transparent SnO_2 films have been widely used as antireflection coatings for increasing the visible transmittance in heat mirrors [6]. A heat mirror is a device that exhibits high transmittance at short wavelength combined with high reflectance at long wavelength, has been developed for reflecting the solar heat in a warm climate or to prevent the escape of indoor heating in a cold climate. A heat mirror is usually constructed as a multilayer of dielectric materials/metal/dielectric materials. Au, Ag, Cu, Al or metal like nitrides such as TiN or ZrN is used as metal layers. As a dielectric material, SnO_2 is one of the mostly used materials for the purpose of antireflection coatings [4, 6]. SnO_2 can exist as an amorphous layer and also in one crystalline phases:), rutile (tetragonal). Only rutile phase is thermodynamically stable at high temperature. The refractive index at 500 nm for Rutile bulk titania is about

2.5 and 2.7 respectively [7]. There are many deposition methods used to prepare SnO2 thin films, such as electron-beam evaporation [8], ion-beam assisted deposition [9], DC reactive magnetron sputtering, pulsed laser deposition [6], Sol-gel methods [10], chemical vapor deposition and plasma enhanced chemical vapor deposition. The properties of the tin dioxide films depend not only on the preparation techniques but also on the deposition conditions. PVD (Physical vapor deposition) technology is still a mainstream production tool for functional coatings. Sputter deposition techniques are widely utilized methods to obtain uniform and dense SnO_2 thin films with well-controlled stoichiometry. Heat-treatment is one of the utilized ways to obtain better optical properties of SnO_2 films [11].

In this work, pulsed laser deposition was used to fabricate SnO_2 thin films with Rutile phase microscope on glass slides substrates. In most past researches, the as-deposited films were prepared as amorphous and they showed the annealing effects on structure properties. Here, the attempts have been taken to produce Rutile SnO_2 films on heated substrates

2. Experimental Details

SnO_2 thin films were prepared by pulsed laser deposition system with a tin dioxide target of 99.99% purity on glass substrates. The target was pressed less than 5 ton to form a target with 2.5 cm diameter and 0.4 cm thickness. Prior to deposition, the glass slides were sequentially cleaned in an ultrasonic bath with ethanol. Finally they were rinsed with distilled water and dried. The substrates deposited at different laser flounce (0.8 , 1.2 , 1.8)J/cm^2 with Oxygen pressure (10^{-3}) torr. The crystalline properties of the SnO_2 films were analyzed by an X-ray diffractometer (Model-PW1050, Philips) using Cu-Kα radiations (λ=1.54 Å). Data were acquired over the range of 2θ from 10^o to 90^o . The XRD method was used to study the change of crystalline structure. For morphological investigations, AFM images were recorded using Nanoscope IIIa and Dimension 3100 scanning probe microscope controller in a tapping mode.

3. Results and Discussion

3.1. Structure

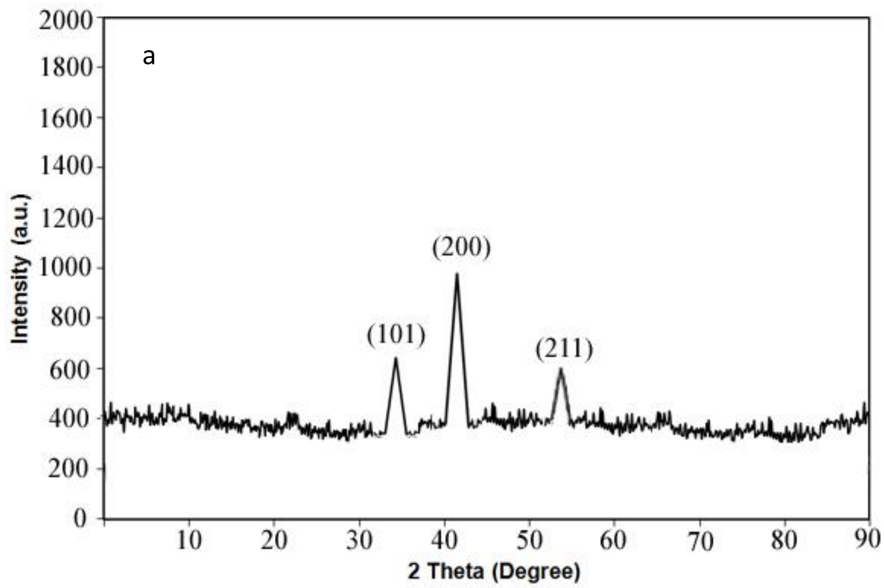
Fig. 1a shows the XRD measurements results of the different SnO_2 films deposition at (0.8 , 1.2 , 1.8)J/cm^2 on laser flounce at glass substrate 300 °C. While the laser flounce was 0.8 J/cm^2. It can be seen that the film is crystalline. Three diffraction peaks located at 2θ=35.1° , 2θ=42.2° and 2θ=54.25° are found, which belong to (R) rutile (101) , (200) and (211) peaks, respectively. When the laser flounce increased to 1.2 J/cm^2, as shown in curve (b) the peak becomes less stronger and sharper , Like this as shown in curve (c) . The grain size of the nanoparticles calculated by using scherrer formula as shown in table (1).

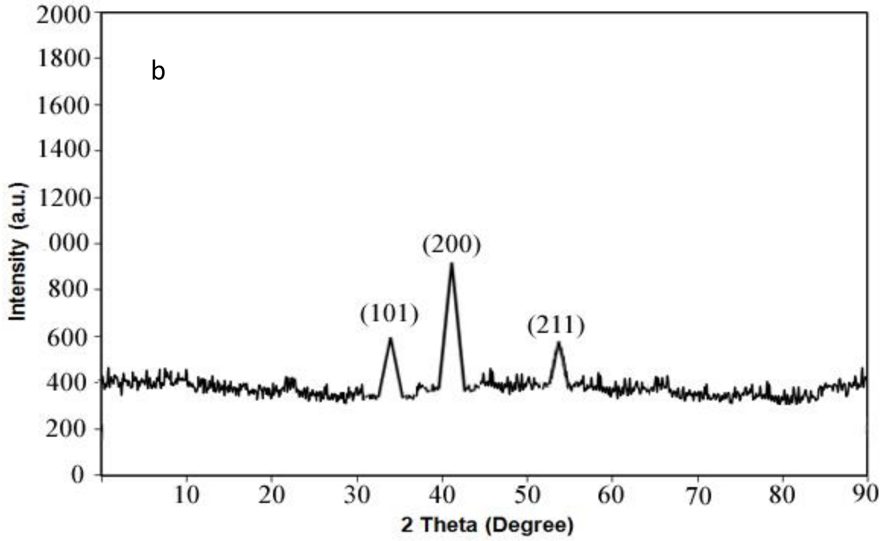
3.2 Morphology

The surface morphology of all the SnO_2 films is presented by AFM images in tapping mode shown in Fig. 2. shows AFM images of the SnO_2 pure thin films deposition at pressure (10^{-3}) torr , From the topographic images it can be seen that the films laser flounce 0.8 J/cm^{2}at appears to be more uniform than the topography of the sample laser flounce 1.2 J/cm^{2}and 1.8 J/cm^2, The RMS roughness also increased with increasing laser flounce , the section analysis shows that RMS roughness values are (3, 5 and 13 nm) for thin films deposition at laser flounce (0.8, 1.2 and 1.8)J/cm^2.

Table 1 . shows XRD results of SnO_2 films deposition at different laser flounce

laser flounce J/cm^2	2Θ (degree)	(hkl)	FWHM (rad)	Grain size (nm)
1.8	35.1 42.2 54.25	(101) (200) (211)	0.026 0.022 0.020	555 655 745
1.2	35.1 42.2 54.25	(101) (200) (211)	0.027 0.0314 0.0331	520.6 472.9 469.7
0.8	35.1 42.2 54.25	(101) (200) (211)	0.0331 0.0296 0.0261	438 500 595





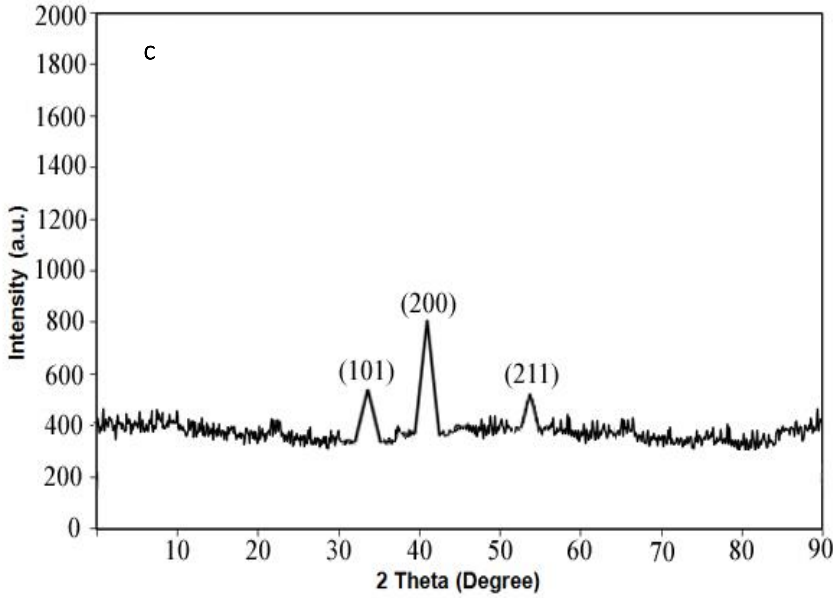
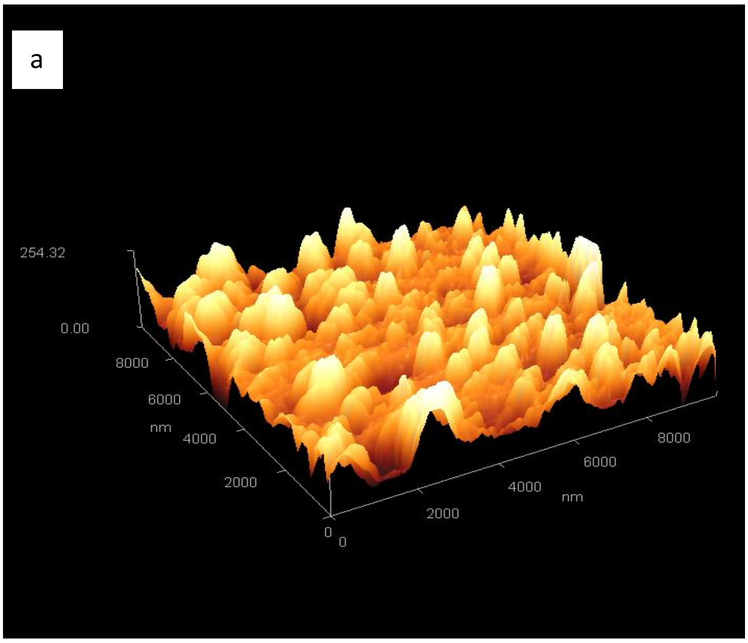
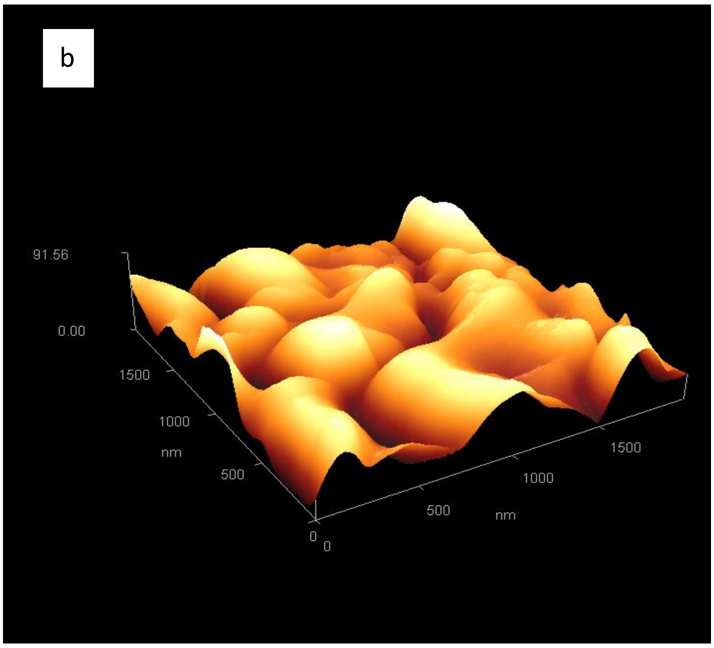


Fig.1 The XRD measurements results of the different SnO_2 films deposition at 10^{-3} torr on glass substrate temperature 300°C at laser flounce ,(a) 1.8 J/cm^2,(b)1.2 J/cm^2,(c)0.8 J/cm^2.



a
254.32
0.00
8000
6000
nm
4000
2000
0
0
2000
4000
6000
8000
nm



b
91.56
0.00
1500
1000
nm
500
0
0
500
1000
1500
nm

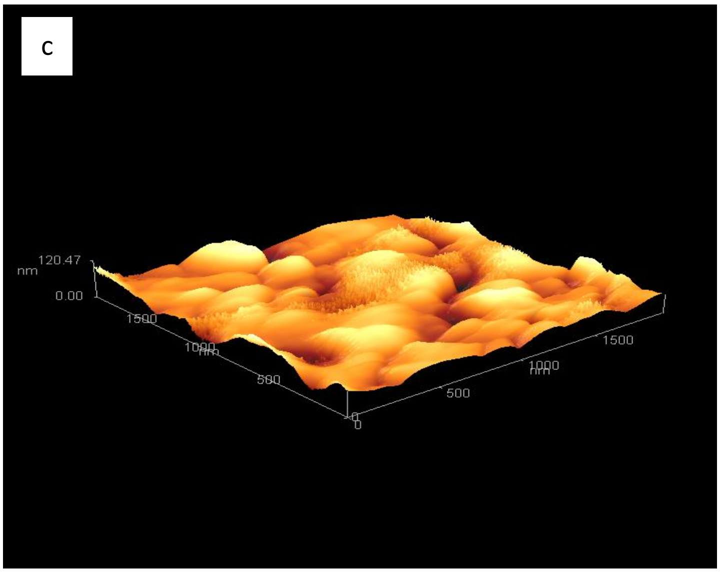


Fig 2 AFM image of of the different SnO_2 films deposition at 10^{-3} torr on glass substrate temperature 300°C at laser flounce ,(a) 1.8 J/cm^2,(b)1.2 J/cm^2,(c)0.8 J/cm^2.

4. Conclusions

The rutile phase tin dioxide thin films have been produced by pulsed laser deposition (PLD) on glass substrates at sputtering pressure of oxygen and different laser flounce (0.8 , 1.2 , 1.8)J/cm^2. The crystallization is found to increase slightly at increase laser flounce. AFM images also support the slow growth of crystallite sizes for grown films and deposition at 1.8 J/cm^2.

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