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Laser Energy Effects on Optical Properties of Titanium Di-Oxide Prepared by Reactive Pulsed Laser Deposition

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ABSTRACT

In this Work, Laser energy effects on optical and morphological properties of TiO_2 thin film has been carried out using Reactive Pulsed Laser as a Deposition technique (RPLD). Q-switched Nd-YAG laser with (λ=1.06µm, t =7nsec) and different energies have been used to ablate pure Titanium target and deposited thin films on glass substrates with constant substrate temperature of (343K). The optical properties of the films prepared include Optical transmit ion and absorption measurement, surface uniformity measurement and FTIR structure of these films. The results films show that high transparency reached to about (85-98) % can be achieved with TiO_2 film which itself decreases sharply with the increasing of Laser energy while the optical band gap is (3.7-3.9) eV at optimum Laser energy in all results (800mJ), the FTIRstructure result at 800 mJ is the optimum and peaks absorption of TiO_2 are (408.91, 439.77, 524.64) cm^{-1}.

Keywords: Titanium di-oxide, Thin films, Laser deposition.

تاثير طاقة الليزر على الخصائص البصرية لاغشية اوكسيد التيتانيوم المحضرة باستخدام تقنية الترسيب بالليزر النبضي

الخلاصة

في هذا العمل، تم دراسة تأثيرطاقةالليزرعلىالخصائص البصرية والشكلية لاغشيةثاني أكسيد التيتانيوم TiO_2 , الرقيقةالمنماة باستخدام تقنية الترسيب بالليزر النبضي(RPLD).حيث تم استخدام ليزر النديميوم–ياك النبضيNd-YAG الذي يعمل بتقنية عامل النوعية ذو طول موجي (λ=1.06nm) و امد نبضة (t=7nsec) عند طاقات مختلفة لتشظية اهداف معدن التيتانيوم وترسيبه على قواعد زجاجية عند درجة حرارة (343K).ان الخصائص البصرية للاغشية المنماة تشمل حساب الامتصاصية و النفاذية و معرفة مدى انتظامية السطح و كذلك الخصائص التركيبية للمادة حيث اظهرت نتائج الخصائص البصرية لاغشية اوكسيد التيتانيوم ان نسبة النفاذية عالية و

تتراوح ما بين% (98-85) وانها تقل بحدة مع زيادة طاقة الليزر. كما و ان فجوة الطاقة البصرية تتراوح ما بينeV(3.7-3.9) و ان افضل النتائج كانت عندما طاقةالليزر تساوي(800 mJ). اما نتائج الخصائص التركيبية للاغشية (FTIR) تبين ايضا اعلى قمة امتصاص لاوكسيد التيتانيوم عند طاقة ليزر تساوي 800 mJ.

INTRODUCTION

Pulsed laser deposition (PLD) is extensively used in the deposition of various materials including oxides, nitrides, superconductors, self organized complex oxide quantum dot etc. [1]. The quality of the film deposited depends on various parameters like laser wavelength, energy, fluency, ambient pressure of the gas, substrate, target-substrate distance, and thermo physical properties of the target material which include density, mass, absorption coefficient etc. the optimization of these parameters to obtain a high quality film for a desired application is therefore an integral part for PLD.

In recent years, TiO_2 thin film has attracted much attention because of its chemical, electrical and optical properties [2-3]. It is known that the TiO_2 crystal usually has three different crystallographic structures: rutile (tetragonal), anatase (tetragonal), and brookite (orthorhombic) [4]. Two of them, rutile and anatase, are commonly used in photocatalysis and the TiO_2 with anatase structure shows a higher photocatalytic activity [5−6]. This unique photocatalytic property makes it suitable for the oxidation of organic pollutants and other contaminants from wastewater or drinking water supplies [7−8].

EXPERIMANTAL WORK

Undoped TiO_2 thin films were deposited on cleaned glass substrates by using pulsed Nd: YAG laser by pulsed laser deposition technique, Fig. 1 shows the schematic diagram of PLD system used in this study [9, 10]. Pulses of Q-switchedNd:YAG laser with pulse duration 7 ns and λ= 1064 nm were focused through 12 cm focal length of converging lens onto a high puritytitanium target (99.999% provided from Fluka com.) at 45° angle of incidence. The target rotated with frequency of 1 Hz. The pulse laser energy between (700 – 1000)mJ was used. All films were produced using 70 laser shots and deposited at substrate temperature of 70°C (this growth temperature was optimum) in background gas oxygen with a pressure 50 mbar, this background gas was let into the vacuum chamber through a needle valve. The film thickness was measured by a stylus profilometer. The transmittance of the films was investigated in spectral range (300-800) nm using UV-VIS (SP8001) Shimatzu double beam spectrophoto-meter. The crystal structure of the grown films was analyzed with FTIR system (Shimatzu 8400 S). The morphology of the films was studied using optical microscope. The Atomic Force Microscope of these films was studiedusing ShimatzuAA3000Scanning ProbeMicroscope.

RESULTS AND DISCUSSION

The optical absorption of TiO_2films on glass prepared by reactive PLD were measured by UV-Vis spectrophotometer.Figure (2) shows the optical Absorption peaks, these peaks have as lightly blue shift with the increase of laser power due to increase in particle size. In fact, increasing the fluency means delivering more energy that implies ablating larger amount of material, because of the plasma plume becomes more intense and the TiO_2 particles cloud becomes bushy. Most likely, this means that big particles will be present due to longer growth time and to the high probability of deposited particles muster. In other words, atoms and nanoscale particles deposited under laser radiation tend to muster during and after the laser pulse. This reality leads to generate of larger particles that becomes more distinguished when the density of the TiO_2 particles increases further with increasing the fluency.

The band gap energy E_g is found by plot $(\alpha h\nu)^2$vs. hν as shown in figure (3). The calculated band gap energies are among (3.7- 3.9) corresponding to the (1000, 900, 800, and 700 mJ) are higher than the bulk TiO_2, because of increasing in particle sizes reason due to the quantum confinement effect and increase of surface/volume ratio.

The TiO_2 has been grown on a glass substrate at oxygen pressure 20mbar and substrate temperature 70 °C. Figure (4 (a & b)) shows theAFM images of the TiO_2thin films deposited at different laser energies (800, and 1000) mJ. The surface morphology of the TiO_2thin films asobserved from the AFM micrographs proves that the grains are uniformlydistributed with individualcolumnar grains extending upwards. This surface characteristic is important from the topographic images it can be seen that the films deposited at 800 mJ appears to be more uniform than the topography of the sample deposited at 1000 mJ. The Root Mean Square (RMS) roughness and Roughness average (R_a) increased with increasing laser energy, the section analysis shows that RMS roughness values are (18 & 26.3) nm, Roughness average (11.2 & 16.5) nm and the average diameter of particles size (229.95 & 243.20) nm for thin films deposited at(800,1000)mJ respectively. The particle size shown in figure (5 (a & b).

In figure (6(a)) gives the FTIR result for film prepared at laser energy 800 mJ, we can recognize the absorption peak at (408.91, 439.77,524.64) cm^{-1} which related to the Ti-O-Ti bonds , beside the absorption bonds between 563.21 cm^{-1}& 740.6 cm^{-1} are assigned for O-N=O deformation which are very intense in IR spectra and the absorption pick at 1080.14 cm^{-1} is relate to C-O=Ti bands, also the O-H Figure (6(b)) gives the FTIR result for film prepared at laser energy 1000 mJ, we can recognize the absorption peak at (408.91) cm^{-1} which related to the Ti-O-Ti bonds, beside the absorption bonds 594.08 cm^{-1}& 686.66 cm^{-1} are assigned for O-N=O deformation which are very intense in IR spectra and the O–H group and the band around 1589.34 $cm^{-1}$for bending vibration of H–O–H group it indicates the existence of water on the surface of TiO_2[11,12]. An increasing the formation ability of the TiO_2 molecule could be recognize obviously by using the optimum laser energy (800 mJ).We can recognize the other peaks in figure 6(a & b) is related to glass substrate.

CONCLUSIONS

Highly transparent of TiO_2 films have been prepared on glass substrates by reactive PLD. Structural, and optical, characteristics of the films as a function of laser energy had been investigated .The FTIR structure result at 800 mJ is the optimum and peaks absorption of TiO_2 are (408.91, 439.77,524.64) cm^{-1}. The films deposited at oxygen pressure of 50 mbar have increasing band gap energies with increasing laser energies but at 800 mJ show the best results in all measurements so this laser energy is the optimum under the conditions used in this work.

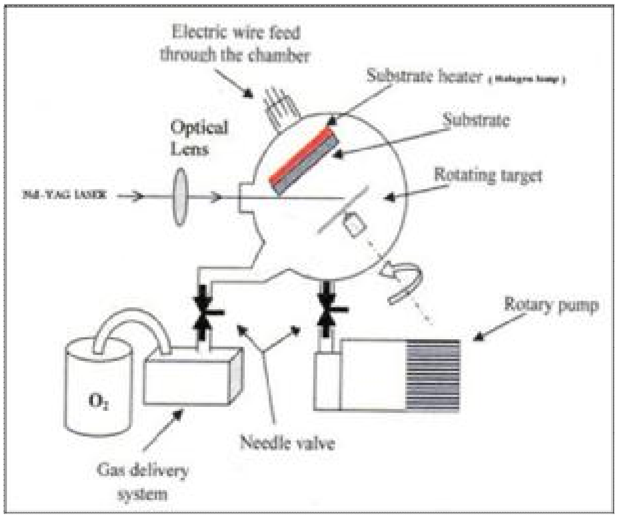


Figure (1). A-Schematic diagram of the PLD System used [9, 10].

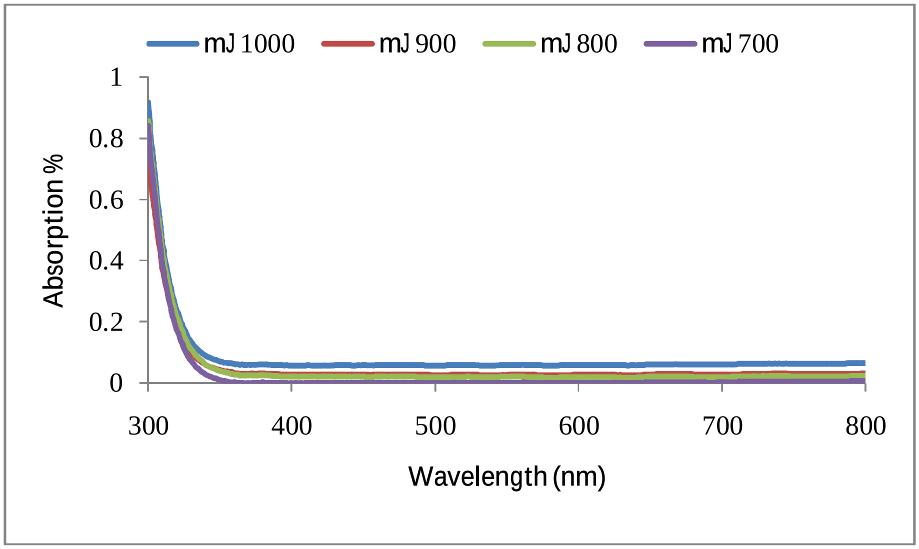


Figure (2): Optical Absorption as a function of wavelength for TiO_2/glass at different laser energy between (1000-700) mJ.

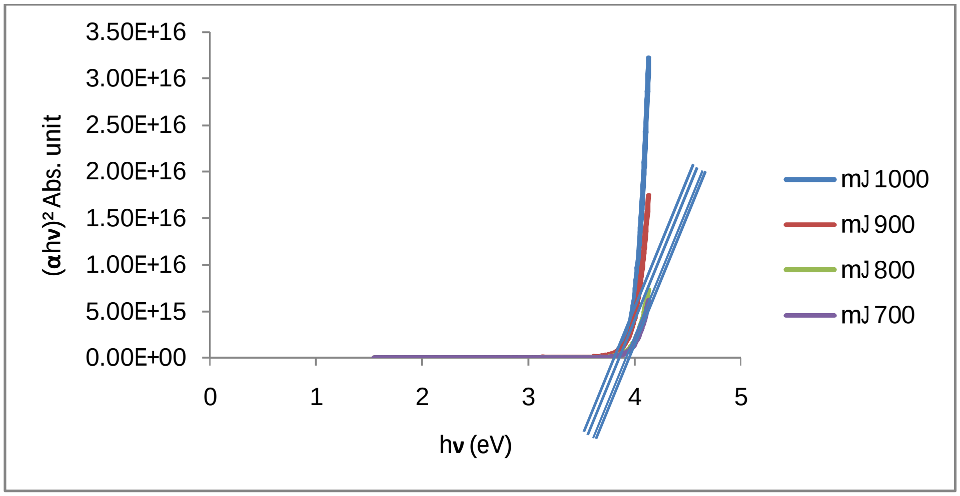
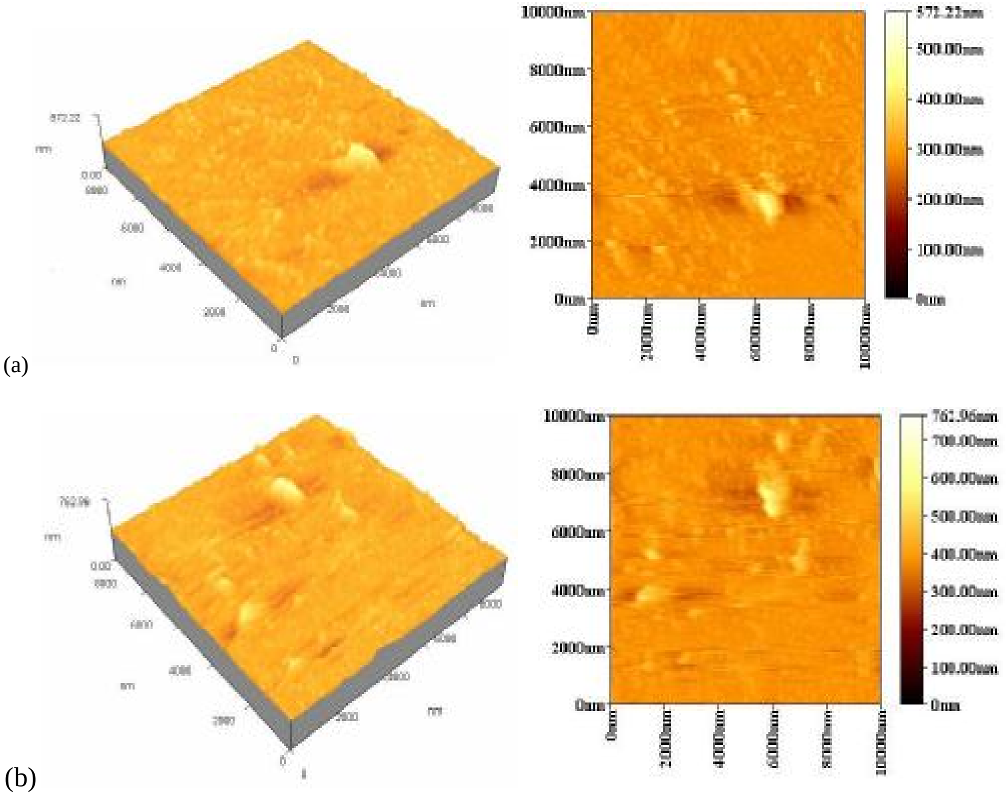


Figure (3): A plot of $(\alpha h\nu)^2$ verses photon energy (hν) of the TiO_2/glass thin films at different laser energy between(1000-700) mJ.



(a)

(b)

Figure (4): AFM micrographs of the TiO_2/glass thin films at different laser energy a) 800mJ, b) 1000 mJ.

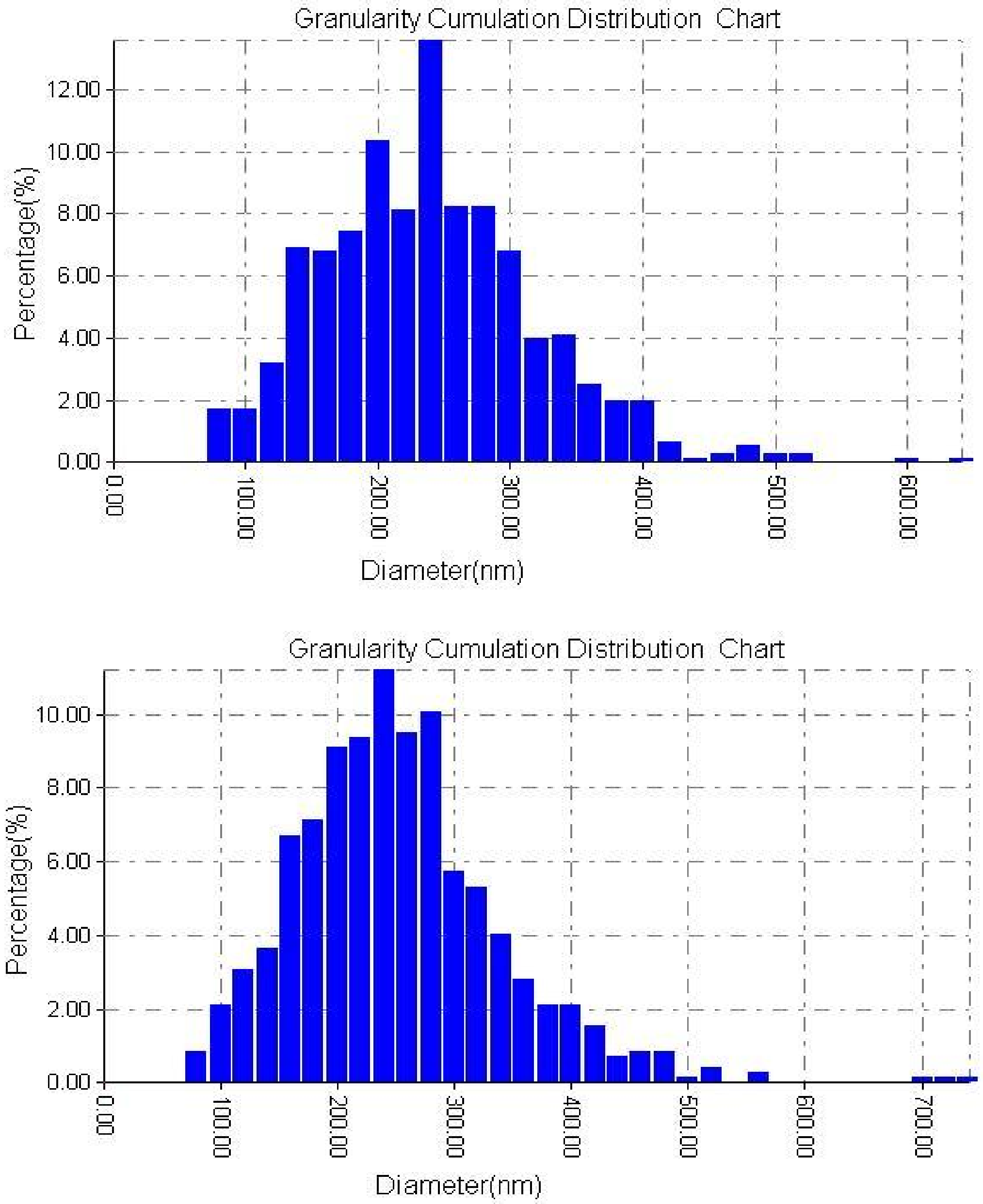


Figure (5): AFM particle size of the TiO_2/glass thin films at different laser energy a) 800 mJ

Figure (6): FTIR structure of the TiO_2/glass thin films at different laser energy a) 800 mJ, b) 1000 mJ respectively.

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