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Received on: 05/11/2017
Accepted on: 25/06/2018
Published online: 25/12/2018

Optical Characterizations of RF-Magnetron Sputtered Nanocrystalline TiO_2 Thin Film

Abstract- *TiO_2 nanocrystalline thin films are widely used as antireflection coating in solar cell, in this paper, RF magnetron sputtering technique is used to prepare TiO_2 thin film on glass substrates, TiO_2 thin films deposited under different powers (75,100,125 and 150) Watt for (1.5) hour resulted in different layer thickness (62.5,88,118 and 132.6) nm respectively. The optical properties examined by UV-VIS spectroscopy. TiO_2 thin films exhibit a high transparency in the region from about ٣50 nm above, we suggest that these results indicate the most suitable growing conditions for obtaining high quality sputtered TiO_2 thin films with higher transparence performance for solar cell application. the optical absorbance coefficient for all films were genuinely high esteems coming to above 10^4 cm^{-1}, which implies that there is allowed direct transitions, the energy gab reach to the typical value of the bulk TiO_2 (3.5) eV.*

Keywords- *Titanium dioxide, Thin films, RF sputtering, Optical properties.*

How to cite this article: A.K. Sadkhan, "Optical Characterizations of RF-Magnetron Sputtered Nanocrystalline TiO_2 Thin Film," *Engineering and Technology Journal,* Vol. 36, Part B, No. 2, pp. 156-159, 2018.

1. Introduction

The production of TiO_2 thin films is one of major researches in photovoltaic area to limit the optimum conditions for sputtering TiO_2 thin film on different substrates. Many of methods have been used to prepare TiO_2 thin films as DC or RF sputtering, chemical vapor deposition and sol-gel process,etc.[1].

TiO_2 can be found in three main crystalline phases Anatase (tetragonal), Rutile (tetragonal) and Brookite (orthorhombic). The first two phases have excellent photocatalytic and antibacterial properties[2]. Rotile TiO_2 has some good properties over Anatase phase like as higher dielectric constant, , higher electric resistance, higher chemical stability, higher refractive constant [3]. high chemical and thermal stabilities, higher refractive index (Anatase=2.488, Rutile=2.609, Brookite=2.538), low absorbance and low dispersion in visible and near-infrared spectral area [4]. TiO_2 (Anatase) is an n-type semiconductor, thin films of TiO_2 utilized as optical coating, solar cell, integrate circuits, heat reflecting layer and waveguides have also been shown to be resistance to corrosive and mechanical attack and show stability over lengthy time span duration [5].The application of these thin films include great important areas as renewable energy production represented by solar cell, smart window, gas sensors, photoconductive, hydrogen production, etc [6].

2. Experimental

RF sputtering method (CRC-600,USA-Toor com) used to prepare TiO_2 thin films with different working conditions as shown in table (1) where, P_1 is the base vacuum pressure and P_2 is the working argon pressure of vacuum sputtering chamber, T is the substrates temperature which was in the rang (55-65) due to the sputtering processes.TiO_2 target with purity 99.99% has been used to prepare a thin films.

Table 1: The working conditions of TiO_2 thin films preparing via RF sputtering method

Power(W)	Thickness (nm)	P_1 (Torr) $\times10^{-3}$	P_2(Torr) $\times10^{-3}$	Substrate temp. T°(C)	Sputtering time t(hour)
75	62.5	7.45	7.45	55	1.5
100	88	7.9	7.9	60	1.5
125	118	7.12	7.12	58	1.5
150	150	7.15	7.15	65	1.5

https://doi.org/10.30684/etj.36.2B.11
2412-0758/University of Technology-Iraq, Baghdad, Iraq

The TiO_2 thin film examined by UV-VIS spectroscopy (UV-2601 PC Shimadzu software 1700-1650) to study the optical properties measurements, the absorption (A), transmition (T) and energy gab for TiO_2 thin film deposited on the glass substrates calculated for spectrum range of (200-1100) nm as equations (1) and(2): [6]

$$T= I_T \backslash I \quad ...(1)$$

$$A= I_A \backslash I \quad ...(2)$$

Where I_T is the intensity of the rays transmitting through the film, I_A is absorbed light intensity and $I_\circ$ is the intensity of the incident rays.

The absorbance coefficient (α) was specified from the region of high absorbance i.e. at the fundamental absorbance edge of the films by equation (3):[7].

$$\alpha = \frac{2.303 \times A}{t} \quad .....(3)$$

where t is the thickness of TiO_2 thin films, The extinction coefficient (K_o) equal to equation (4)[7].

$$Ko = \frac{\alpha \lambda}{4\pi} \quad ......(4)$$

Where λ : is the wavelength of incident rays, E_g values is computed by extrapolation of the straight line of the plot of $(\alpha h\nu)^2$ versus photon vitality for various power as appeared in figure (4).

3.Results and discussion

Figure (1) display the optical transmittance spectra of TiO_2 thin films in the wavelength domain of 200-1100 nm prepared at different power, the transmittance pattern of all deposited thin films increases with the increase of wavelength (λ). In addition the transmittance decreased with the growing power, which is due to growing the thickness of thin films and shifting towards longer wavelength (lower energies) the thickness increment is explained according to the fact that increasing of thickness approach the structure of samples from bulk material[9].

Figure (3) shows the absorbance coefficient as a function of wavelength for TiO_2 thin films deposited at various power. It is obvious that the films have high absorbance coefficient at short wave length at 350 nm, then decrease at various rates reliance on the films structure to reach fixed values at long wavelength which it above 400nm, where the films progress toward becoming transparence at this wavelength, it can be observed that the optical absorbance coefficient for all films were genuinely high esteems coming to above 10^4 cm^{-1}, which means that there is allowed direct transitions. Hence the film has potential application in photovoltaic device.

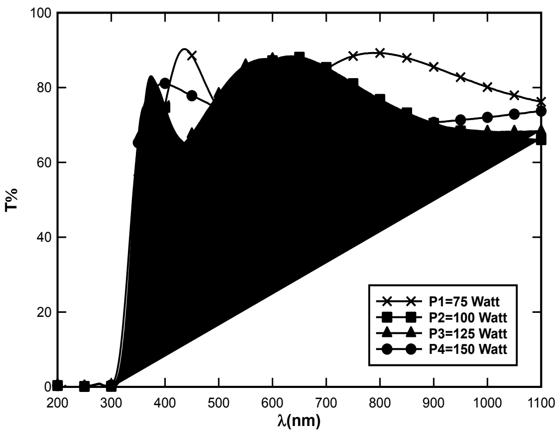

Figure (1) Transmittance as an element of wavelength for TiO_2 thin film at various sputtered power

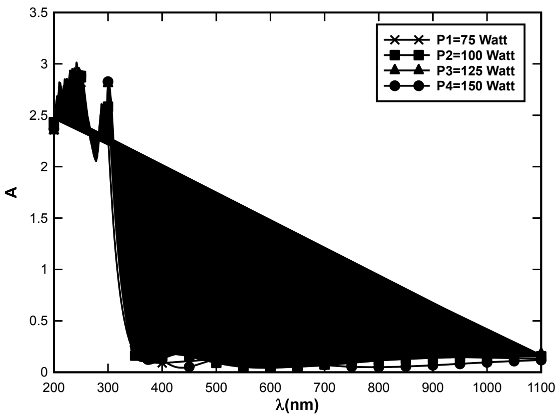

Figure (2) Absorbance as an element of wavelength for TiO_2 thin film at various sputtered power

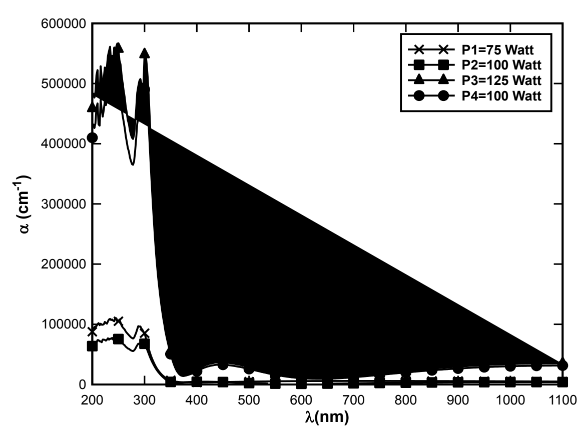

Figure (3) Absorbance coefficient as an element of wavelength for TiO_2 thin film at various sputtered power

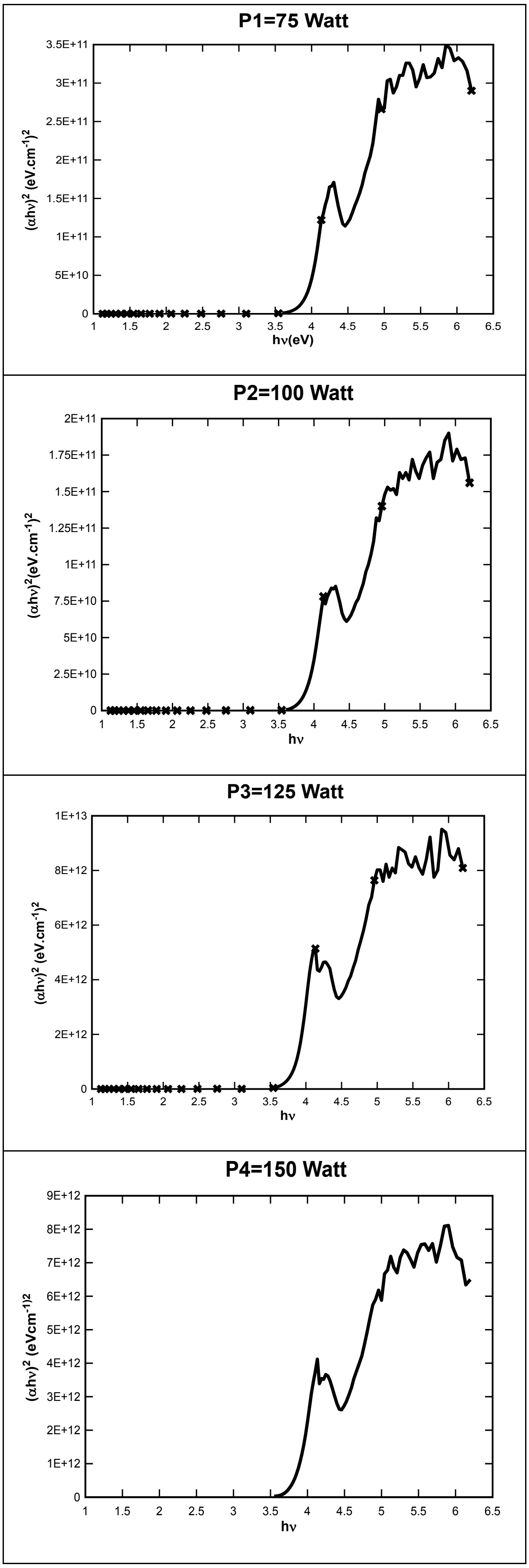

Figure (4) $(\alpha h\nu)^2$ as an element of energy of photon for TiO_2 thin film at various sputtered power

The energy gap amount based on films crystal structure in general, the arranging and distribution of atoms in the crystal lattice, also it is influenced by crystal regularity, it is reach to the typical value of the bulk TiO_2 (3.5) eV. Energy gap E_g value is calculated by extrapolation of the straight line of the plot of $(\alpha h\nu)^2$ versus photon energy for different sputtering parameters. The linear dependence of $(\alpha h\nu)^2$ with $(h\nu)$ indicates direct band gap[2],[5].

The behavior of the extinction coefficient (K) with different power can be shown in figure (5).

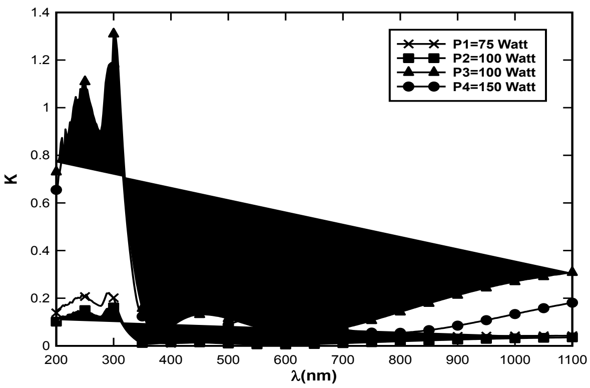

Figure (5) Extinction Coefficient as an element of wavelength for TiO_2 thin film at various sputtered power

4.Conclusion

We have investigated the optical properties of TiO_2 thin films for solar cell application. RF Magnetron sputtering technique was used efficiently grow TiO_2 thin films to deposited on glass slices. The optical transitions of TiO_2 are direct and the amounts of optical energy decrease with the increase of sputtering power which related to increase the resulted films thickness[2].

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