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Optical Properties of Nano-structured TiO_2 Thin Films Deposited by Sol-Gel Dip Coating Method

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Abstract

In this work, the sol–gel dip coating technique was used to prepare nano-structured titanium dioxide (TiO_2) thin films onto glass substrate with different annealing temperatures, and the effects of annealing temperatures on optical properties of thin films were investigated. Optical constants such as optical band gap and thicknesses of thin films were determined from the measured transmittance spectra in wavelengths between 300 and 1100 nm. Calculations on the annealed thin films showed that, as the annealing temperatures varies, optical band gap ranges from 3.33 to 3.69 eV, thickness ranges from 48 to 375 nm and transmittance ranges from 81% to 98% in the visible region.

Keywords: TiO_2, Sol-Gel Process, Optical Properties, Annealing Temperature

INTRODUCTION

Titanium dioxide (TiO_2) thin films are extensively studied due to their interesting chemical, electrical and optical properties (high band gap, transparent to visible light, high refractive index and high dielectric constant) which are considered for various optical applications such as high refractive index component of multilayer optical filter, gas sensors, antireflective coating, photocatalysts, planar waveguides, integrated optical amplifiers.

A number of methods have been employed to prepare TiO_2 thin films; including e–beam evaporation [1], sputtering [2], chemical vapor deposition [3], and sol–gel process [4]. Sol-gel method has emerged as one of the most promising process as it is particularly efficient in producing thin, transparent, homogenous layers on various substrates at low cost and it allows the choice of refractive index and thickness of the layer by changing elaboration conditions. In general, the preparation conditions of TiO_2 films in sol-gel process can strongly affect physical properties of the film [5]. Therefore, it is necessary to study systematically the optical properties of sol-gel TiO_2 thin film as a function of the preparation conditions.

In this paper, the effect of annealing temperature on the optical properties of nano-structured TiO_2 thin films prepared by sol gel dip coating process is reported.

EXPERIMENTAL PROCEDURE

In order to prepare a TiO_2 solution, first, 2.4 ml titanium tetraispropoxide [(Ti $(OC_3H_7)_4$, Merck] was added in 25 ml ethanol [C_2H_6O, Merck] and the solution was kept in a magnetic mixture for 1 h. Then, 5 ml glacial acetic acide [$C_2H_4O_2$, Merck] and 25ml ethanol were added in the solution, and after each additive component was added, it was mixed in the magnetic mixture for 1 h. As the final step, 1.5 ml triethlyamine [$(C_2H_5)_3N$, Merck] was added in the solution, and the final solution was subjected to the magnetic mixture for 1 h. The dipping process was performed using a homemade motorized unit and each sample was dipped into the solution five times at 200^0C, 300^0C, 400^0C, 500^0C, 600^0C and 700^0C annealing temperatures on glass substrate. The optical characterization is investigated for different annealing temperatures using Shimadzu 3600 UV-VIS-NIR Spectroscopy at room temperature.

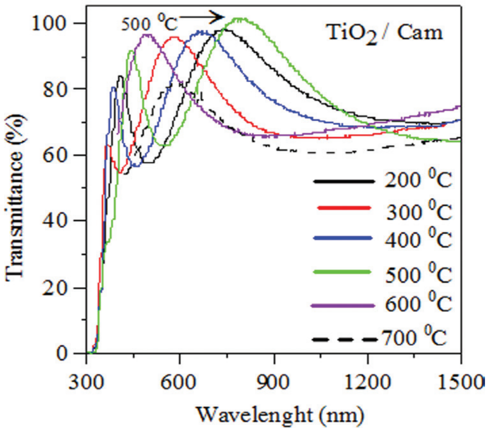

Fig. 1. UV–VIS spectra of the TiO_2 thin film for various annealing temperatures.

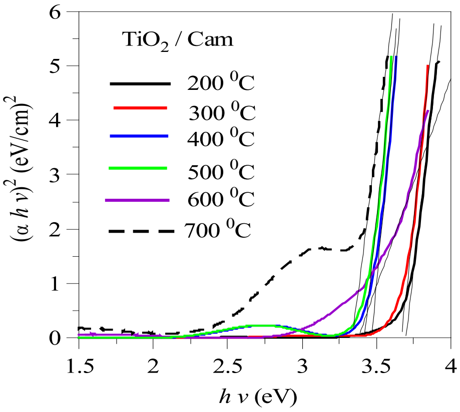

Fig. 2. The plot of $(\alpha h\nu)^2$ vs. $(h\nu)$ of the TiO_2 thin film for various annealing temperatures.

RESULT AND DISCUSSION

Fig. 1 shows the UV–VIS spectra TiO_2 thin films for different annealing temperatures in wavelength range 300–1500nm. The transmission of the thin films of titanium oxide increases with the increase in annealing temperature. This can be linked with the formation stage of anatase and with the decrease in the grain size [6].

The optical band gap of the film was calculated by the following relation [7]:

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

where A is an energy-independent constant between 10^7 and 10^8 m^{-1}, E_g is the optical band gap and r is a constant, which determines type of optical transition, r = 1/2, 2, 3/2 or 3 for allowed direct, allowed indirect, forbidden direct and forbidden indirect electronic transitions, respectively [7]. The $(\alpha h\nu)^{1/r}$ vs. $h\nu$ curves were plotted for different r values and the best fit was obtained for r = ½. The film at various annealing temperatures shows a direct allowed transition. As seen from Fig. 2, the optical band gap was determined by extrapolating the linear portion of the plots to $(\alpha h\nu)^2=0$. The optical band gaps of the thin film were found to be 3.69, 3.66, 3.47, 3.41, 3.37 and 3.33 eV at five layers 200⁰C, 300⁰C, 400⁰C, 500⁰C, 600⁰C and 700⁰C annealing temperatures, respectively. The thicknesses of TiO_2 film were also determined from transmittance measurements in Fig.1 and found to be 375, 260, 102, 93, 76 and 48 nm, respectively. The optical band gap decreases with the increasing annealing temperatures. The decrease in the optical band gap is attributed to the lowering of the interatomic spacing, which may be associated with a decrease in the amplitude of atomic oscillations around their equilibrium positions.

CONCLUSION

In summary, the effect of annealing temperature on the optical band gap and thickness of TiO_2 thin films has been investigated. The optical band gap and thickness decrease with the increasing annealing temperatures The most significant result of the present study is to indicate that annealing temperatures can be used to modify in the optical properties of TiO_2 thin films.

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REFERENCES

[1] Wang Y L, Zhang KY. 2001. Study of the growth morphology of TiO_2 thin films by AFM and TEM. Surface and Coatings Technology, 140, 155-160.

[2] Takeda S, Suzuki S, Odaka H, Hosono H. 2001. Photocatalytic TiO_2 thin film deposited onto glass by DC magnetron sputtering. Thin Solid Films, 392, 338-344.

[3] Ha H Y, Nam S W, Lim T H, Oh H, Hong S A. 1996. Properties of the TiO_2 membranes prepared by CVD of titanium tetraisopropoxide. Journal of Membrane Science, 111, 81-92.

[4] Hu L, Yoko T, Kozuka H, Sakka S. 1992. Effects of solvent on properties of sol-gel derived TiO_2 coating films. Thin Solid Films, 219, 18-23.

[5] Brinker C J, Scherer G W. 1990. *Sol–Gel Science,* Academic Press, San Diego.

[6] Assim E M. 2008. Optical constants of $TiO_{1.7}$ thin films deposited by electron beam gun J. Alloy. Compounds 463, 55-61.

[7] Mott N F, Davis E A. 1979. *Electronic Process in Non-Crystalline Materials,* Calendron Press, Oxford.