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Study the Influence of Tin Oxide SnO_2 Doping on the Optical and Structural Properties of Titanium Oxide TiO_2

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Abstract

Titanium dioxide thin films, along with varying tin oxide ratios, were applied onto quartz substrates through pulsed laser deposition. The samples included pure TiO_2 and doped versions ranging from 5% to 25%. The deposition parameters were kept constant at an energy level of 1000 mJ and a frequency of 6 Hz. Analysis via atomic force microscopy revealed that higher doping percentages correlated with increased surface roughness and grain diameter, indicating larger particle growth. Additionally, the absorption coefficient rose with higher doping ratios, peaking at 25% SnO_2. This increase in absorption coefficient accompanied a decrease in the optical energy gap due to thicker film deposition, leading to higher absorbance and lower transmittance.

Keywords: Atomic Force Microscope (AFM), Atomic Optical Properties, Optical Properties, Tin Oxide, Titanium Oxide.

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Introduction

The term thin film is a description of one or several layers of atoms of one or several substances whose thickness may not exceed one micron [1]. Titanium Dioxide TiO_2 is a non-toxic, chemically pure n-type semiconductor characterized by the presence of an energy gap between $(3.04 - 3.46)$ eV, and it has various applications, such as in humidity sensors for defogging systems on rear windows and in white wood coatings [2,3]. Titanium Dioxide exists in three phases: Anatase, Rutile, and Brookite [4]. The Anatase phase is an n-type semiconductor. When heated to approximately 1000ºC, Anatase transforms into the Rutile structure, which is a p-type semiconductor. Rutile is the most prevalent form of Titanium Dioxide, while Anatase is rare in nature and occurs at around 600ºC [5]. Tin dioxide (SnO_2) is a transparent n-type semiconductor material with a wide energy gap (3.6-4) eV at 300 K. It combines high optical transparency with low resistance, making it useful in solar cells and other electronic devices [6].

Experimental Work

Titanium oxide powder (TiO_2) with a high purity of (99.99 %) was compressed, and then doped with SnO_2 whose purity was (98.8 %), using different doping ratios (5,10,15,20 & 25) %. After that, the mixed powders were compressed with a pressure of (2 ton) using a hydraulic press to prepare samples weighing (2 gm) in the form of tablets, and then deposit them on quartz substrates using PLD (Nd: YAG) optical laser system, energy (1000 mJ), wavelength (1064 nm), frequency (6 Hz), distance of (2 cm) between the sample and the quartz substrate, the number of pulses used were (450) pulses, low pressure (1 mbar), at laboratory temperature. then the membrane was annealed with a thermal oven and for two hours with an atmosphere of oxygen, at 1000°C.

Results and Discussion

a. Optical Properties

1. Absorption

The absorption spectrum varies with different doping ratios. The increase in absorption with increasing doping ratios is attributed to the localized levels formed by the SnO_2 dopant atoms in the original TiO_2 material between the valence and conduction bands. Additionally, the intensity and number of laser pulses play a role. When the laser is applied to the target material, particles are ablated from the target material, and this ablation increases with the number of pulses. Consequently, the thickness of the thin films deposited on glass substrates from the underside increases with the increase in absorbance. and it's also observed that absorption decreases with increasing wavelength, and the maximum absorption occurs at shorter wavelengths. This behavior indicates that the films exhibit increased absorption at shorter wavelengths within the visible region. Absorption at longer wavelengths is minimized because the incident photon energy is lower than the band gap energy of the semiconductor. This is consistent with the study [7]. Illustrates the Variation of the Absorption Spectrum of Pure Titanium Oxide (TiO_2) Films and those doped with tin oxide shown in Figure (1).

2. Transmittance

Figure (2) shows a chart of the transmittance spectra within the wavelength range (300-1100) nm for pure and doped titanium oxide films for several ratios. Transmittance in the pure sample appeared at the highest value of more than (80%), and then gradually decreased in the transmittance spectrum of all films with an increase in SnO_2 ratios. That indicates a reverse proportion between them and is due to an increase in the thickness of the film due to increased SnO_2 ratios [9].

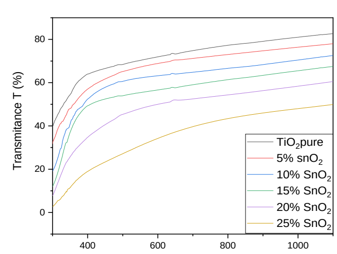

Figure 1: Illustrates the Variation of the Absorption Spectrum of Pure Titanium Oxide (TiO_2) Films and those DOPED with Tin Oxide

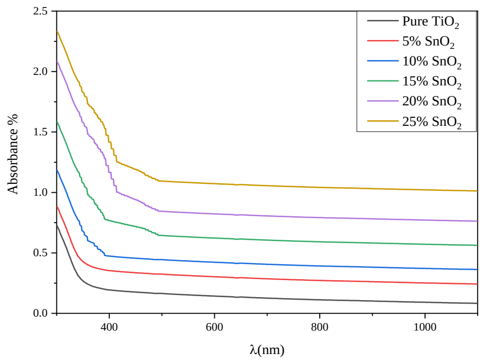

Figure 2: Illustrates the Variation of the Transmittance Spectrum of Pure Titanium Oxide (TiO_2) Films and those Doped with Tin Oxide

3. Energy Gap

The direct bandgaps of the thin films gradually decrease with increasing doping ratios, ranging between (2.75-3.3) eV as shown in the figure (3) illustrating the values of the optical energy gap. The reason for the decrease in the energy gap values is the increase in SnO_2 doping ratios, which in turn leads to the appearance of secondary levels between the valence and conduction bands. These secondary levels enable electrons to occupy them during their transition from the valence band to the conduction band. This aligns with the study [8].

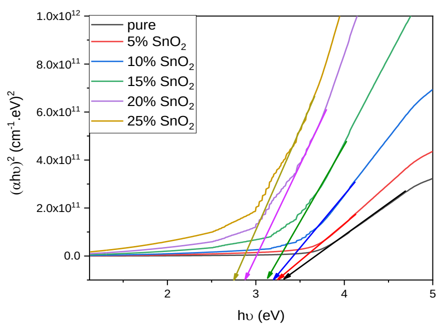

Figure 3: Illustrates the Values of the Energy Gaps for Pure Titanium Oxide (TiO_2) Films and Those Doped with Tin Oxide (SnO_2)

b. Structural Properties

1. Atomic Force Microscope (AFM)

The atomic force microscope measurement results illustrated a change in the surface shape and roughness of the titanium oxide films depending on the increase in the doping ratios. This means that increasing the ratio of SnO_2 results in an increase in the regularity and arrangement of the atoms and their growth in size and an increase in the value of the root mean square of the films. This in turn results in an increase in the roughness of films and the growth rate of the size of the particles [10]. At the same time, increasing the doping ratio leads to an increase in the surface roughness and particle diameter. So, the increase in the surface roughness leads.

To an increase in the particle size growth [11], as clarified in Table (1) and in figure (4).

Table 1: The Results of the Atomic Force Microscope

Samples	RA (nm)	RMS (nm)	G_sA (nm)
TiO_2 Pure	2.96	4.12	38.15
SnO_2 (5%)	8.87	12.1	71.53
SnO_2 (10%)	10.5	15.8	73.83
SnO_2 (15%)	12.7	16.3	87.42
SnO_2 (20%)	14.2	18.1	90.07
SnO_2 (25%)	14.7	18.4	95.37

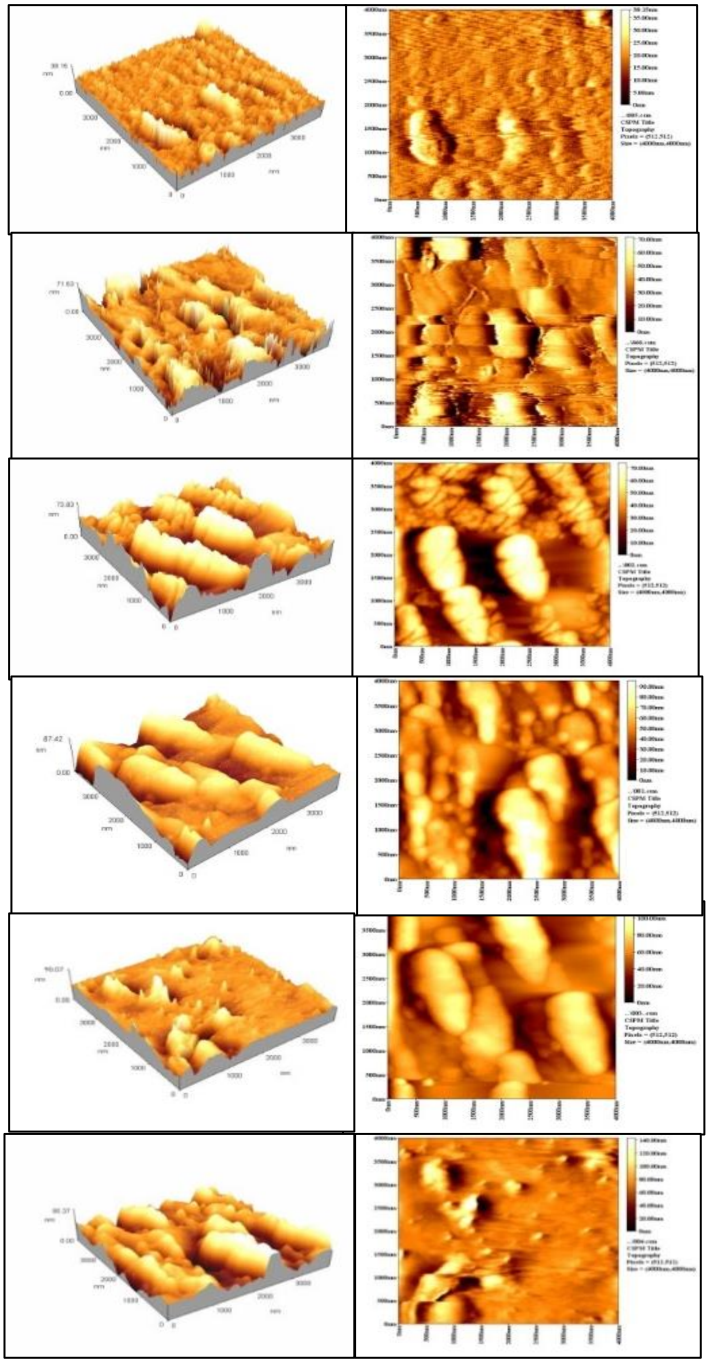

Figure 4: Illustrates the Results of the Atomic Force Microscope

Conclusions

In this research, titanium dioxide Nano films were prepared using the pulsed laser deposition (PLD) technique to investigate the impact of tin oxide on certain structural and electrical properties.

The absorption spectrum of pure (TiO_2) and (SnO_2) doped films increased with increasing doping ratios and with shorter wavelengths. However, the energy gaps decreased with increasing doping ratios, as well as the Transmittance.

The atomic force microscope illustrated an increase in the regularity and arrangement of the atoms, along with the root mean square value of the films leading to an increase in the roughness.

References

Tribble, A. (2002). Electrical Engineering Materials and Devices. *University of Lowa*.

Jia-zhen, Y.A.N., & Qing-Gong, S. (2005). Research on rutile nano-titanium dioxide for weatherability modifying of white wood coating. *Journal of Functional Materials*, *1*, 2.

Lee, K.R., Kim, S.J., Song, J.S., Lee, J.H., Chung, Y.J., & Park, S. (2002). Photocatalytic Characteristics of Nanometer-Sized Titania Powders Fabricated by a Homogeneous-Precipitation Process. *Journal of the American Ceramic Society*, *85*(2), 341-345.

Mineiro, S.L., Nono, M.D.C.D.A., Kuranaga, C., & Silva, M.D. (2005). Humidity sensitive characteristics of ZnO-TiO_2-Ta_2O_5 ceramic. *In Materials science forum, Trans Tech Publications Ltd, 498,* 293-298.

Chen, Z., & Lu, C. (2005). Humidity sensors: a review of materials and mechanisms. *Sensor letters*, *3*(4), 274-295.

Lide, D.R. (2009). *CRC Handbook of Chemistry and Physics*. Boca Raton, Florida: CRC Press. 90^{th} ed., 1-2804.

Lin-Vien, D., Colthup, N.B., Fateley, W.G., & Grasselli, J.G. (1991). *The handbook of infrared and Raman characteristic frequencies of organic molecules*. Elsevier.

Omar, N.A.S., Fen, Y.W., & Matori, K.A. (2017). Europium doped low cost Zn2SiO4 based glass ceramics: A study on fabrication, structural, energy band gap and luminescence properties. *Materials Science in Semiconductor Processing*, *61*, 27-34.

Muhammad, A., & Hussein K. (2011). Investigation of the optical and electrical properties of chemically deposited CdO nano-thin films. *Journal of the College of Basic Education*, *17*(68).

Ahmad, R.A., Noori, A.J., Ibrahim, I.M., & Ibrahim, E.S. (2019). Synthesis and characterization of CdO1-x ZnOx for solar cell applications. *Digest Journal of Nanomaterials and Biostructures*, *14*, 15-22.

Munef, R.A., & Atallah, F.S. (2016). Study The Molarity Influence on the structural properties of titanium oxide (TiO_2) Prepared with (Sol-Gel). *Tikrit Journal of Pure Science, 21*(2), 162–170.