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STUDY ON THE ELECTRICAL, STRUCTURAL AND OPTICAL PROPERTIES OF NANOSTRUCTURED TIO_2 THIN FILM PREPARED BY DIFFERENT SOL-GEL PRECURSOR

M. K. Ahmad[1, 4], N. A. Rasheid[1], A. Zain Ahmed[3], W. S. W. Zaki[4],
S. Abdullah[2] and M. Rusop[1,2]

[1]*Solar Cell Laboratory, Faculty of Electrical Engineering;*
Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia

[2]*NANO-SciTech Laboratory, Institute of Sciences;*
Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia

[3]*Research Management Institute (RMI);*
Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia

[4]*Faculty of Electrical and Electronics Engineering*
University Tun Hussein Onn Malaysia (UTHM), 86400 Batu Pahat, Johor, Malaysia

ABSTRACT

Two types of nanostructured Titanium Dioxide (TiO_2) thin films have been deposited onto silicon and glass substrates. Titanium Isopropoxide (TTIP) and Titanium Butoxide (TBOT) have been use as a precursor for the nanostructured TiO_2 thin films. Comparison of electrical properties, structural properties and optical properties of the two different type nanostructured TiO_2 thin films has been studied. Nanostructured TiO_2 thin films have been prepared by sol-gel method and deposited onto substrate using spin coating technique. For the electrical properties, nanostructured TiO_2 thin film using TTIP as precursor gives lower resistance compared to nanostructured TiO_2 thin film from TBOT. As for structural properties, there is no significant difference on the crystalinity and the crystallite size. Furthermore, both of the nanostructured thin films give crystalline anatase phase. Finally for the optical properties, transmittance percentage for TTIP based thin film gives higher percentage than TBOT based thin film. Both of transmittance properties of the nanostructured TiO_2 thin film are more than 80% and fully absorb UV light at 300nm of wavelength. The result suggested that TTIP based nanostructured TiO_2 thin film can be use in photo-voltaic application due to low resistance and high of transmittance properties.

INTRODUCTION

In recent years, an intense effort has been focused on the preparation of metal-oxide nanocrystals owing to their markedly different physical and chemical properties with respect to bulk materials. Particularly, Titanium Dioxide (TiO2) has been studied extensively as a photoelectrode for dye-sensitized solar cell [1-2], photocatalyst to deal with environmental pollution, water purification, wastewater treatment, hazardous

Corresponding Author: sumirpkj@gmail.com

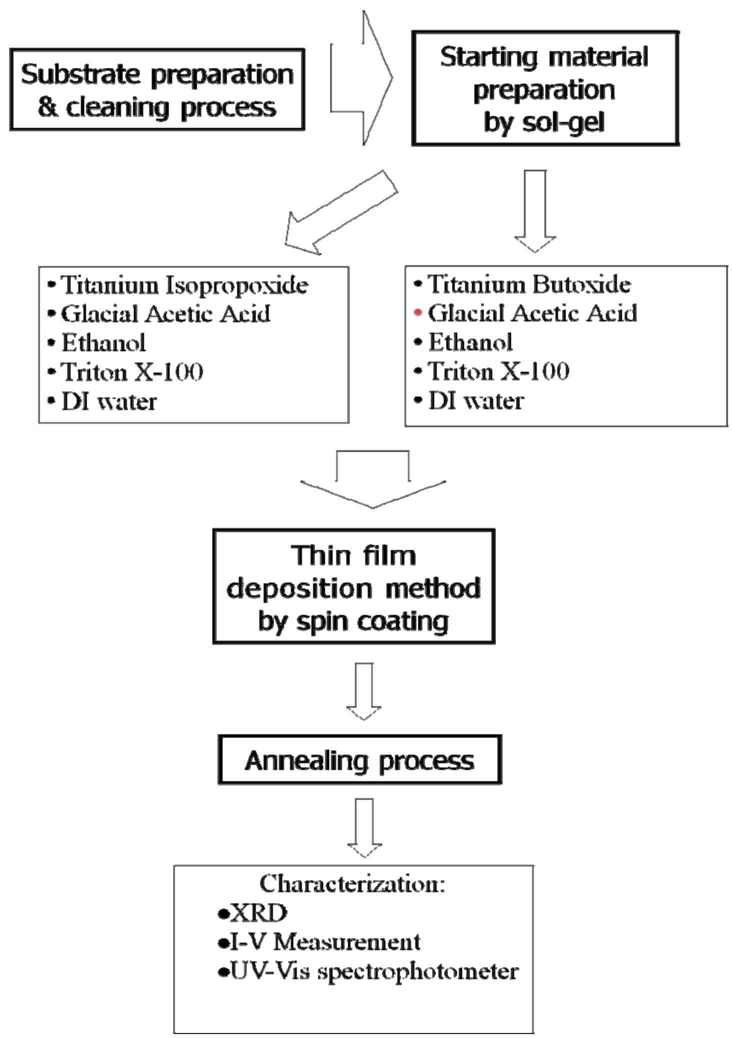
waste control, and air purification [3–5], due to its good characteristics of chemical stability, endurance, thin film transparency and lower production costs [6]. TiO_2 films have been often prepared by many kinds of method which are expensive such as pulsed laser deposition [7], reactive evaporation [8-9] and chemical vapour deposition [10]. Low cost preparation methods are the sol–gel processes [11-13], including dip or spin-coating [14] as the final step of preparation. Recently, sol–gel process is a novel technique for the preparation of nanocrystalline TiO2. It has been proved that through sol–gel process, the chemical and electrochemical properties of TiO2 can be modified to improve its efficiency. It provides a simple and easy means of synthesizing nanoparticles at ambient temperature at atmospheric pressure and this technique does not require complicated experimental set-up. Since this method is a solution process, it has all the advantages over other preparation techniques in terms of purity, homogeneity, felicity and flexibility in introducing dopants in large concentrations, stoichiometry control, ease of processing and composition control. Through sol–gel process, the growth of TiO2 colloids in sub micrometer range can be effectively controlled by hydrolysis and condensation of titanium alkoxides in aqueous medium [15]. This work reports a study on the preparation and characterization of nanostructured TiO_2 thin films using 2 kinds of sol-gel precursors; Titanium Isopropoxide (TTIP) and Titanium Butoxide (TBOT), which are suitable for photoelectrodes that is use in photovoltaic (PV) applications such as Dye-sensitized solar cell (DSC). The study involved the electrical, structural and optical properties.

EXPERIMENTAL METHOD

The substrate cleaning process was done followed as in our earlier experiment [16]. P-type silicon wafer and amorphous glass substrates were used as substrates. Both substrates were cleaned by the ultrasonically method. Nanostructured TiO_2 thin films were deposited onto substrates using sol–gel process and spin coating technique. Sol-gel concentrations were prepared at 0.2M. There are two kinds of starting material or precursor that we used; Titanium (IV) Isopropoxide (TTIP) [Ti $(OC_3H_7)_4$] (Aldrich) and Titanium (IV) Butoxide (TBOT) [Ti $(OC4H_9)_4$] (Aldrich). Firstly, TTIP was droped wisely into bikar containing ethanol while the solution is stirred by magnetic stirrer. Triton X-100 was added to the solution as stabilizer to the sol-gel to increasing the conductivity. Glacial Acetic acid was added into the solution which is act as chelating agent to the sol-gel. To complete the reaction in the sol-gel, DI water was added while stirring process is done. This procedure is repeated again using TBOT with same concentration. All the chemicals used were of AR grade and were used as received without further purification. The both sol-gels were heated at 50°C for 1h, using magnetic stirrer and then were continue stir for 3h at room temperature. Heating process is to increase the reaction process between the materials in the solution. The TiO_2 thin films were deposited on silicon and glass substrates by using spin coating technique. Spin coating was set at a withdrawal speed of 3000 rpm and for 30 seconds. The nitrogen (N_2) gas was supply at 60 psi. The TiO_2 solution was dropped 10 times onto the substrates and then dried in oven at 150°C for 5 minutes. The drop and dry process was repeated for 5 times onto the same substrate. Finally, the nanostructured TiO2 thin

Corresponding Author: sumirpkj@gmail.com

films using TTIP (TF-TTIP) and nanostructured TiO2 thin film using TBOT (TF-TBOT) were both annealed at 450°C for 1 hour in the furnace to obtain the TiO_2 thin film without any gases. The crystalline phase of the TiO_2 thin films was determined by an X-ray diffractometer (Rigaku DMAX 2000) using Cu Ka radiation. Optical transmission spectra were recorded in the wavelength range 200–1000 nm using UV–VIS–NIR Spectrophotometer (VARIAN 5000). The direct currents between two contacts were measured using Advantest source meter (R6243).



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RESULTS AND DISCUSSION

Electrical properties

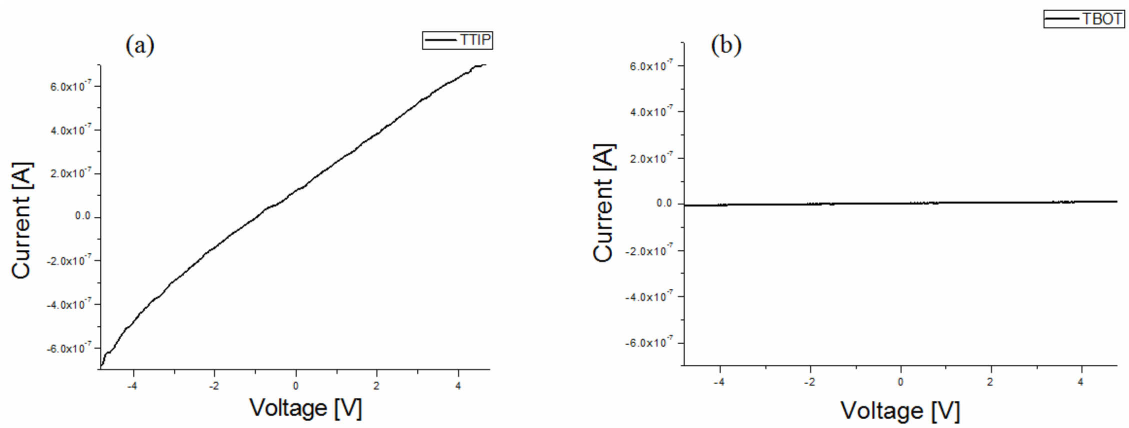

Figure 1: I-V measurement of nanostructured TiO_2 thin films with different sol-gel precursor: (a) Titanium Isopropoxide (TTIP) and (b) Titanium Butoxide (TBOT)

Current-Voltage (I-V) measurements were performed to the TiO_2 thin films structure to determine their electrical properties. Fig.1 (a) and (b) shows I-V characteristic of nanostructured TiO2 thin film using TTIP (TF-TTIP) and nanostructured TiO2 thin film using TBOT (TF-TBOT) as precursor, respectively. Current versus voltage graph has been plotted and it shows that TF-TTIP has higher current intensity compared to TF-TBOT. It can be said that with the higher current intensity of TF-TTIP, it has lower sheet resistance compared to TF-TBOT. With higher current intensity shows that the electron mobility is improved and can contribute to low resistivity if the thickness of the thin film is considered. Low current intensity in TF-TBOT shows that the electron mobility is lower compared to TF-TTIP. The reason for the electron mobility is lower compared with TF-TTIP, is due difficulty of electron to jump from one particle another particles. The size of particles and crystallinity of the thin film can contributed to the difficulty of electron to jump to other particles. As for bigger size of particles, the amount contact surface is less compared with small particles size. With small particles size and large amount of particles, the contact surface of the thin film is increased. With high contact surface area, electron can easily move to other particle and enhance the current flow in the thin film. For the crystallinity of the thin film, the characteristic of the thin film is amorphous or not can also be a main factor to the low electron mobility. Good crystalline thin film will enhance the electron mobility performance compared with amorphous thin film. As we look at chemical that we used in the making of sol-gel, the chelating agent and surfactant influences can be the important things. Suitable chelating agent and surfactant for sol-gel precursor will contribute to better electrical properties.

Corresponding Author: sumirpkj@gmail.com

Structural properties

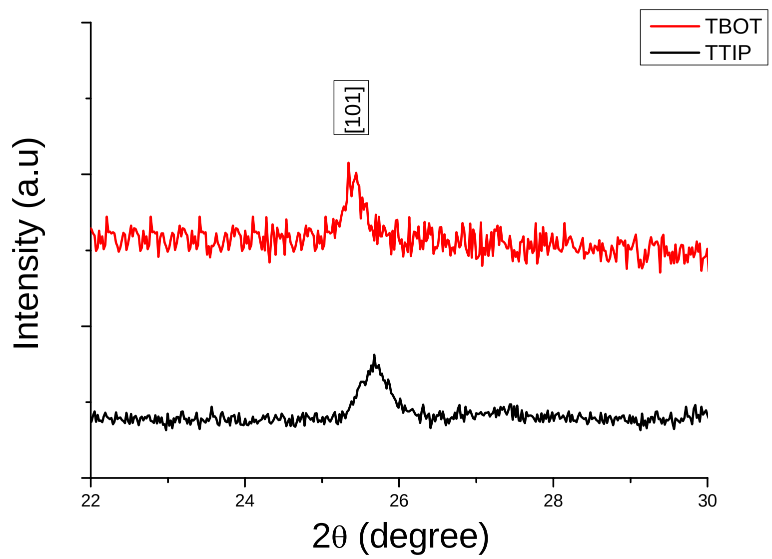

Figure 2: X-Ray Diffraction patterns of nanostructured TiO_2 films with different sol-gel precursor: Titanium Isopropoxide (TTIP) and Titanium Butoxide (TBOT)

The thin film XRD was carried out using Rigaku DMAX 2000 with Cu-Kα radiation and 2° grazing angle. Fig. 2 shows XRD patterns of TiO_2 thin films prepared at different sol-gel precursor, Titanium Isopropoxide and Titanium Butoxide which are annealed at 450°C for 1 hour. It showed that both TF-TTIP and TF-TBOT are monocrystalline thin film which has (101) planes peak of intensity. Both of the (101) peak were at 25.3°, and corresponded to anatase (101) crystal planes. It should be stressed that all peak observed can be assigned to specific lattice planes of the anatase phase of TiO_2, which corresponds to JCPDS Patterns No. 21-1272. From the XRD data, we can conclude that the both of the thin film are crystalline thin films and no significant differences in the intensity of the peak.

Optical properties

In order to understand the differences both TF-TTIP and TF-TBOT to the optical properties, optical transmittance studies were performed in the UV-visible-NIR region. Figure 3 showed transmittance spectra recorded with different sol-gel precursor. From the figure, it is clear that the both TF-TTIP and TF-TBOT are fully transparent in the visible region which is above 80% and start absorbing in between 350 to 400 nm and fully absorbed at 300nm of wavelength. As for TF-TTIP, the transparency percentage is slightly higher compared to TF-TBOT. It can be said that, TF-TBOT has less transmittance properties maybe due to the different size of particles in the thin film. With the different size of particles, it will maximize the light scattering of the thin film, and decreased the transmittance property of thin films.

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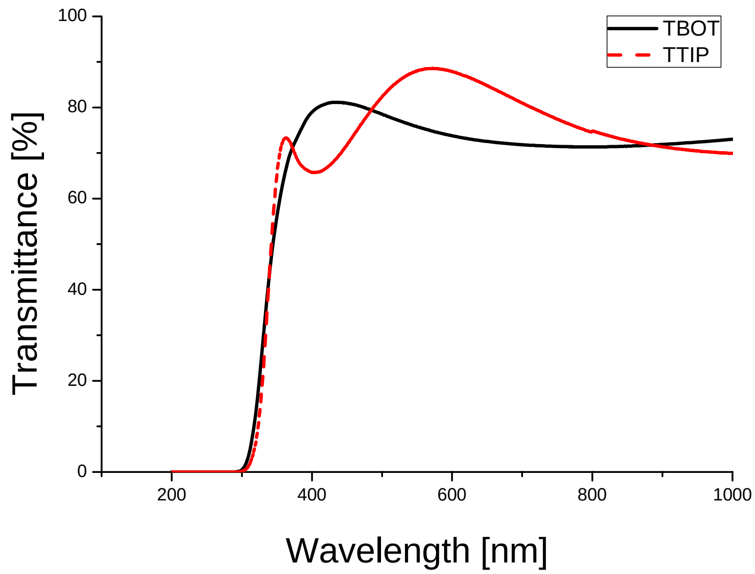

Figure 3: Transmittance spectra of nanostructured TiO_2 films with different sol-gel precursor: Titanium Isopropoxide (TTIP) and Titanium Butoxide (TBOT)

CONCLUSION

The electrical, structural and optical properties of nanostructured TiO_2 thin film using different sol-gel precursor, Titanium Isopropoxide and Titanium Butoxide, has been successfully studied. Electrical properties studies reveal that TF-TTIP gives higher current intensity and lower in sheet resistance compared to TF-TBOT. It is may be due to particles size effect and crystallinity of the thin film. For structural properties, both of the films show monocrystalline structure and has (101) planes peaks at 25.3° which is corresponded to anatase phase. There is no significant difference for both of the thin film. From the transmittance spectra, it shows that TF-TTIP gives higher transparency compared to TF-TBOT. It may be due to the different size of particles in the thin film. With the different size of particles, it will maximize the light scattering of the thin film, and decreased the transmittance property of thin films and both thin films have transmittance above 80%. It is maybe due to less light scattering when light is passing through TiO2 thin film. From the result of the experiment, the electrical properties give significant differences for both thin films, but for structural and optical properties, the differences are less to be seen. It can be concluded, that suitable usage of chemicals in sol-gel such as chelating agent and surfactant, is a major roles to produce good thin films for any applications needed.

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Corresponding Author: sumirpkj@gmail.com