Electrical Characteristics of Aluminium Doped Nanostructured TiO_2 Thin Film by Sol-Gel Method Spin Coating

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Abstract-- **The study have been conducted on Electrical Characteristics of Aluminum Doped Nanostructured TiO_2 Thin Film. In this research, it have been prepared by a method known as Sol-gel method using the Titanium Butoxide as a precursor. This research have been investigated on the different concentration of Aluminium doped Nanostructured Titanium Dioxide (TiO_2) thin film from 1% to 5% by (molar percentage). The expected results in terms of electrical characteristics of the Aluminium doped Nanostructured TiO_2 thin film layer have been studied. The influences of different concentration of aluminium on the surface morphologies and electrical characteristics of the nanostructured TiO_2 were characterized by Scanning Electron Microscopy (SEM) and Current-Voltage (I-V) measurement. The optical properties of different concentration of aluminium of the nanostructured TiO_2 was characterized by UV-VIS Spectroscopy as well.**

I. Introduction

Titanium (IV) oxide (TiO_2, also known as titania) is one of the most efficient n-type semiconductors [1]. Recently, nanosized titanium dioxide materials have attracted much interest due to their wide application in many fields such as, ceramic microporous membranes, dye-sensitized solar cells, catalysis, humidity and fiber-optic cable sensors and photocatalysis by TiO_2 for the treatment of water and air pollutants [2,3]. TiO_2 has many interesting physical properties which make it suitable for thin film applications [4]. Because of their good transmittance in the visible region, high refractive index and chemical stability, TiO_2 films have found wide application for various optical coatings [5]. The high dielectric constant of TiO_2 opens prospects for the use of TiO_2 thin films in microelectronic devices, e.g. in capacitors or as a gate dielectric in metal-dielectric-semiconductor devices. The desirable optical and electrical properties of titanium (IV) oxide are heavily dependent upon the size of particles and their surface characteristics. Doping of TiO_2 with various elements has been reported to improve their electrical conductivity for use in optoelectronic device [6]. There are many type of dopant that have been used to enhance the conductivities of TiO_2. The group III in periodic table such as Al is the types of dopant that can make a better conductivity to TiO_2 thin films [7,8]. Titanium butoxide have been chosen because of its commercial viability and low cost.

The introduction of doping can change morphological and spectroscopic characteristics of the sample [9]. In the earlier studies, TiO_2 were prepared by many techniques including sol-gel process, pyrolysis, reactive sputtering, electron beam evaporation, plasma-enhanced chemical vapor deposition, atomic-layer deposition, molecular beam epitaxy, hydrothermal technique [10,11]. This paper describes the preparation of titanium dioxide thin films by the sol-gel process. The structural, electrical and optical properties of deposited thin films are also studied [12,13].

The sol gel method has many advantages over the other technique due to excellent compositional control, homogeneity on the molecular level due to the mixing of the liquid precursors, lower crystallization temperature and its simplicity [14,15]. Moreover, the micro structural properties such as the pore size, pore volume and surface area of the film can be tailored by the control of sol gel variables [16]. Furthermore, sol-gel spin-coating method has been chosen because this technique can deposit thin film layer by layer. The sol-gel method differs from most methods for fabricating composite oxide films by its effectiveness and cheapest. It does not require complicated special equipment and enables the film properties to be varied over wide ranges. It can be deposited over large areas at room temperature, which makes it compatible with low-cost and highly benefiting electronic semiconductor devices [17]. All the parameters are strictly controlled since a small change in one of the parameters such as temperature, reaction time or concentration can significantly influence the results.

II. METHODOLOGY

The experiment was done using glass as substrate in this project. Before film deposition, the substrates were ultrasonicly cleaned in acetone and methanol for 10 minutes respectively. Then, it were thoroughly rinsed with de-ionized water. After that, the substrates were dried with nitrogen blower. TiO_2 thin films were deposited on the substrates by using a spin-coating method at room temperature.

There are two solutions needed in this project. The first solution is for the TiO_2 only. The TiO_2 nanostructures of 0.2 mol were grown from solutions prepared using ethanol 25 ml as a solvent, titanium butoxide 3.4 ml as a precursor, glacial acetic acid 2.5 ml, H_2O 0.18 ml and triton x 1 drop. The solution was mixed thoroughly with a hotplate magnetic stirrer for 1 hour in 60°C and then the solutions are further stirred for another 1 hours in the room temperature. The second solutions used for this project are TiO_2 doped with Aluminium 1% to 5% by (molar percentage). The TiO_2 nanostructures of 0.2 mol were grown from solutions prepared using ethanol 25 ml as a solvent, titanium butoxide 3.4 ml as a precursor, aluminium nitrate according to the percentage of needed, glacial acetic acid 2.5 ml, H_2O 0.18 ml and triton x 1 drop.

The purpose we add glacial acetic acid is to get a transparent solution. Referring the aluminium nitrate percentage, 1% is equal to 0.02152 g, 2% is equal to 0.04303 g, 3% is equal to 0.06455 g, 4% is equal to 0.08606 g and 5% is equal to 0.1075 g. Then, the solution was mixed thoroughly with a hotplate magnetic stirrer for 1 hour in 60°C and then the solutions are further stirred for another 1 hours in the room temperature. The solution for thin film was dropped onto the surface of glass substrate and the thin film was deposited by using the spin coating technique with 3000 rpm for 1 minutes. Each layer had 1 drop of solution at the center before spin-coater is running and 10 drop of solution while spin-coater is running. After being deposited by spin coating, the films were dried at 150°C for 5 minutes to evaporate the solvent and remove organics residuals. The procedures from coating to drying were repeated 5 times so that the desired layer of 5 layer of the film was reached. Then the films was inserted into furnace and annealed at 500°C for 1 hour.

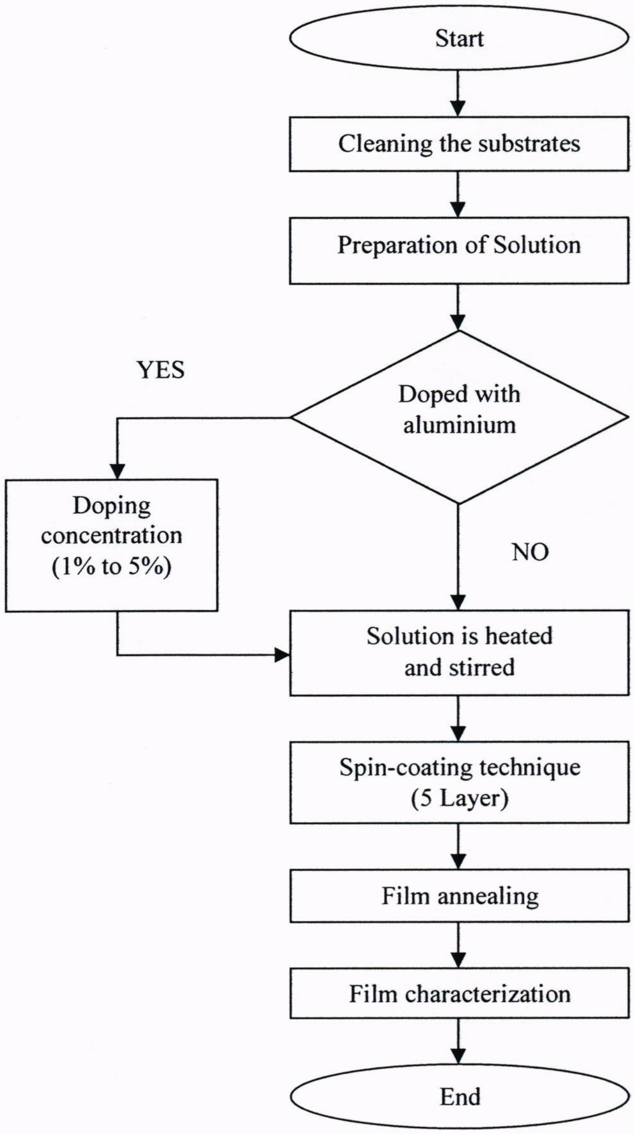

Figure 1 : Flowchart of preparation of Aluminium doped nanostructured TiO_2 thin film by using sol-gel method spin coating.

The surface morphologies were characterized using the scanning electron microscope equipment and the electrical properties were measured by using current-voltage (I-V) measurement. The surface morphologies and electrical measurement were carried out for the structures prepared at different concentration of doping agent. The I-V measurements are taken while the samples in dark condition.

III. RESULT AND DISCUSSIONS

A) SEM Characterization

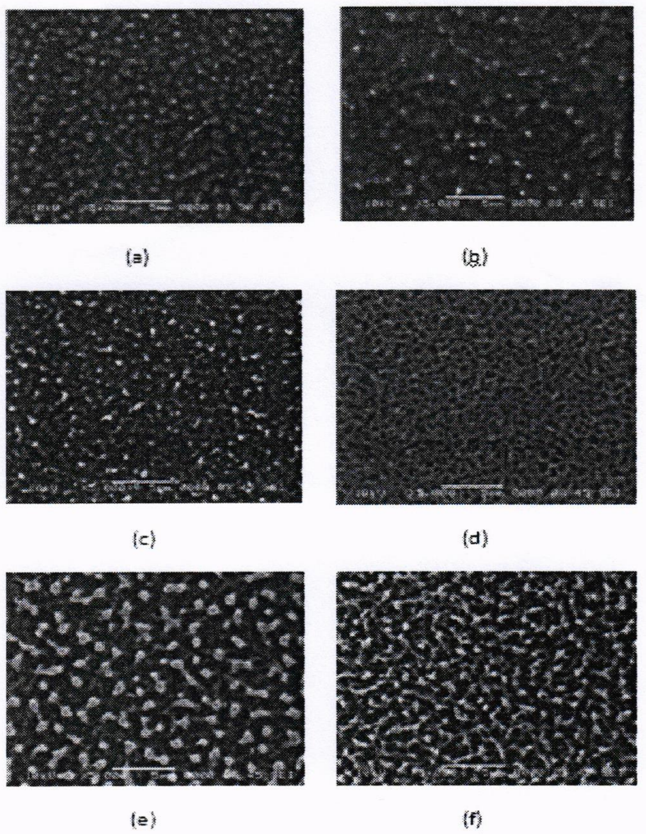

Figure 2: Sem images of electrical characteristics of aluminium doped nanostructured TiO_2 thin film by sol-gel method spin coating at 5K magnification. Fig. (a) is undoped TiO_2, fig. (b) is Al 1% doped TiO_2, fig. (c) is Al 2% doped TiO_2, fig. (d) is Al 3% doped TiO_2, fig. (e) is Al 4% doped TiO_2 and fig. (f) is Al 5% doped TiO_2.

Fig. 2 shows that the surface morphology of the electrical characteristics of aluminium doped nanostructured TiO_2 thin film by sol-gel method spin coating. The growth mechanism is when the concentration of doping Aluminium increased, the energy of the sample increased. Other than that, the conductivity were also increased and the resistivity were decreased. This is because Aluminium is one of the agent of conductivity. From the literature studies it is well known that Al is conductive material and have many advantages when doping with TiO_2. Al is an excellent heat and electricity conductor and in relation to its weight is almost twice as good a conductor as copper. The SEM image observation shows that the TiO_2 doped Al 5% of concentration producing higher dense particle of nanostructured rather than undoped TiO_2.

B) UV-VIS Spectroscopy

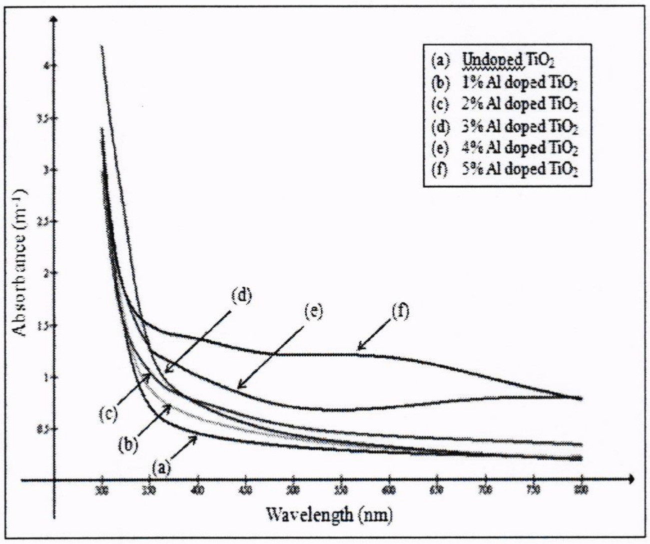

Figure 3: The graph above shows absorbance versus wavelength of Aluminium doped nanostructured TiO_2 thin film.

The optical characteristics such as absorbance measurements of Aluminium doped nanostructured TiO_2 thin films have been carried out by UV-VIS Spectroscopy in the range of 300 nm to 800 nm. As we can see, the value of absorbance was increase rapidly within wavelength of 300 nm and 350 nm. The existence of strong absorption into the visible range is clear. During 350 nm to 800 nm, sample (f) is the highest which is aluminium 5% molar percentage doped nanostructured TiO_2 thin film and the lowest is sample (a) which is TiO_2 thin film. The doping of noble metals and transition metals can make the forbidden band smaller than of TiO_2 and make the absorption peak move to the visible light area [18].

C) I-V Measurement

The electrical conductivity of the aluminium doped nanostructured TiO_2 thin film on glass substrates were carried out by the concentration dependence conductivity by simulated the I-V Measurement. The electron-beam evaporated gold electrodes (Length = 0.1 mm, Thickness = 150 nm, Width = 3 mm, Area = 3 mm x 150 nm) as shown in fig. 4 were sputtered on top of the thin films deposited on glass substrates to achieve the ohmic contacts between the thin films and the top contact.

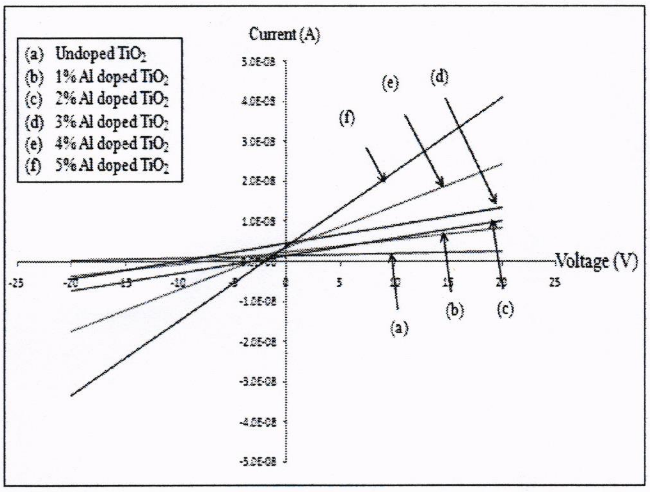

Figure 4: Current-voltage (I-V) characteristics of the aluminium doped nanostructured TiO_2 thin film deposited on glass substrates thin films deposited at different concentration of aluminium.

The current voltage was measured at room temperature in dark by a two-point probe resistance measurement method. The resistance of thin films was obtained by implement the values current and voltage from Fig. 4 to the (1). The resistivity of thin films is proportional to the value of the resistance in (2). Fig. 5 shows that by increasing the doping concentration of aluminium, the resistance and resistivity of thin film will be increased until 4% of molar percentage of doping aluminium. After that, it start to decreased after 4% of molar percentage of doping aluminium. The highest value of resistivity is at 4% of molar percentage of doping aluminium.

$$V = IR \quad (1)$$

Where V is the voltage, I is the current and R is the resistance. Refer to the (1), the voltage is proportional with the current.

$$\rho = \frac{RA}{L} \quad (2)$$

Where ρ is the resistivity, A is the thickness of thin film multiply by width of Au and L is the distance between Au electrodes. The study of electrical resistivity is one of the most important ways to address many issues concerning the electronic structure and properties of thin films.

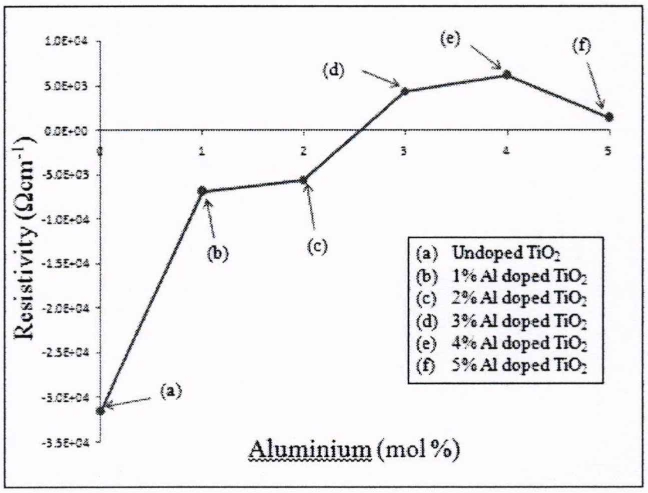

Figure 5: The graph shown resistivity versus molar percentage of aluminium.

The relationship between conductivity and resistivity is written in (3) and (4).

$$\sigma = \frac{L}{RA} \quad (3)$$

$$\sigma = \frac{1}{\rho} \quad (4)$$

Where σ is the conductivity, L is the distance between Au electrodes, R is the resistance, ρ is the resistivity and A is the thickness of thin film multiply by width of Au. Fig. (4) shows that conductivity is inversely proportional to the resistivity.

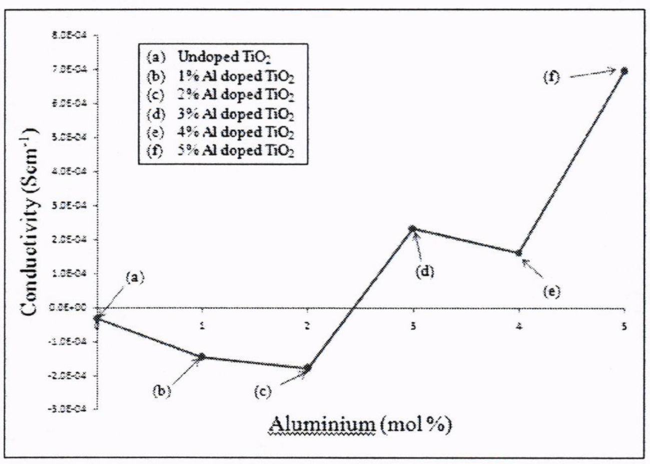

Figure 6: The graph shows conductivity versus molar percentage.

It was observed that conductivity of thin films increase when the molar percentage of doping aluminium were increased. The graph shows that the lowest point of the sample is at point 3 which is sample of 2% molar percentage of aluminium doped nanostructured TiO_2 thin film and the highest point is at sample 6 which is 5% molar percentage of aluminium doped nanostructured TiO_2 thin film. After point of sample 5, the graph start to increased.

IV. CONCLUSION

This project is written primarily to help researchers and industry professionals who need to develop brand new important technologies in this area. Anyone involved in electronics material science will ultimately need to understand the relation of this new technology into the important development for the next better electronics components, and this project proposal may gives a comprehensive view of the best ways to achieve this. Aluminium doped nanostructured TiO_2 Thin Film are successfully grown by using the Sol-Gel Method at different doping concentration of aluminium. According to the SEM studies, the energy of electron becomes increase when the concentration of aluminium increased. By using the sol–gel method, amorphous as well as crystalline coatings can be obtained with a very good control of the composition and stoichiometry (energy). The smaller crystallite size of nanocrystalline TiO_2 gives larger bandgap due to the quantum size effects. Other than that, when the concentration of Aluminium doped nanostructured TiO_2 increased, the conductivity of thin films also increased. So, we can conclude that the properties of Titania depends on size, morphology and crystalline conditions. The use of a semiconductor fabrication line is the preferred manufacturing process because of the potential to reduce cost.

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