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Uniform Deposition of Titanium Dioxide Films by Chemical Vapor Deposition (CVD)

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Abstract— Titanium is a lightweight metal with an outstanding combination of properties which make it the material of choice for many different applications. This paper investigates the structure, surface characteristics and electrical properties of the Titanium Dioxide (TiO_2) thin film, deposited by chemical vapor deposition (CVD). The deposition temperature was 1000˚C with 3 different positions of the glass substrates. The surface morphologies were examined using a field emission scanning electron microscope (FESEM) and an atomic force microscopy (AFM). In order to investigate the structural properties, the TiO_2 thickness was measured using a surface profiler. The optical properties of TiO_2 were measured using an ultraviolet visible spectroscopy (UV-Vis). The surface morphology was found to be sensitive to the deposition parameters and the growth TiO_2 is more uniform when the position of substrate is closed to the starting material.

I. INTRODUCTION

Energy sources such as coal, oil and natural gas is a popular source used nowadays. However, these non-renewable resources and energy sources is limited because there will always diminish every day. Therefore, the technology used to renew energy sources such as wind and solar power. Sunlight can be renewed by converting light into energy. Sunlight or solar energy can be used for heating and lighting, electricity generation, solar cooling, and a variety of commercial and industrial uses [1, 2]. Solar cell (also called Photovoltaic) system is one promising option for future energy needs in a variety of technologies that are being developed at present. Solar cell also is a very fascinating because of high conversion efficiency produced by porous titanium dioxide (TiO_2) electrodes consisting of nanometer sized particles [3, 4]. Titanium is preferred choice because of its higher strength to weight ratio, its corrosion resistance and its compatible expansion coefficient and electromotive force potential with graphite.

At present days, chemical vapor deposition (CVD) technique proved to be one of the best in producing of thin-film deposition in nano-form and is a lot of advantageous over other deposition techniques. CVD produces high purity and conformal coating at a moderate deposition rate [5]. To deposit desired material using CVD, Several parameters such as gas flow rate, precursor concentration, deposition temperature, pressure and substrate positioning should be considered for repeatable and high quality film.

In this work, the influence of substrate positioning was investigated. The surface morphologies, structural and optical properties were characterized [6].

II. EXPERIMENTAL DETAILS

The TiO_2 films were synthesized using CVD technique on glass substrate. Before deposition process, the glass substrates were cleaned using acetone and placed on ultrasonic bath, in order to eliminate the organic residue. After that the glass substrate was rinsed with DI water and dried with nitrogen gas.

The TiO_2 film was prepared using titanium powder mixed with graphite and placed into alumina boat. Then, the alumina boat was inserted into the chamber. In order to investigate the effects of substrates position, three locations were used including 18 cm, 21 cm and 24 cm from the alumina boat (starting material). Chamber were heated by ramping with three different temperature levels from 300˚C, 600˚C and 1000˚C with argon (Ar) gas flow to eliminate the atmospheric gas [7]. Then, Oxygen (O_2) gas was supplied into the chamber when the temperature was achieving 1000˚C. The deposition process was kept at 1 hour. All samples were characterized using atomic force microscopy (AFM), field emission scanning electron microscope (FESEM) and ultraviolet visible spectroscopy (UV-Vis).

III. RESULTS AND DISCUSSION

A. Surface morphology

Fig. 1 shows the three dimensional AFM images of the three different substrate position at 18 cm, 21 cm and 24 cm. The images were recorded at the scan rate of 1Hz on 3µm x 3µm in truly non-contact mode. The average roughness for image in Fig. 1(a-c) is 7.588 nm, 9.965 nm and 13.581 nm, respectively. This indicates that TiO_2 surface morphology is influenced by the substrate position. It is observed that the thin film has good roughness if substrate is closed to the starting material. The surface morphology if Fig. 1 (a) is more uniform compared to the rest.

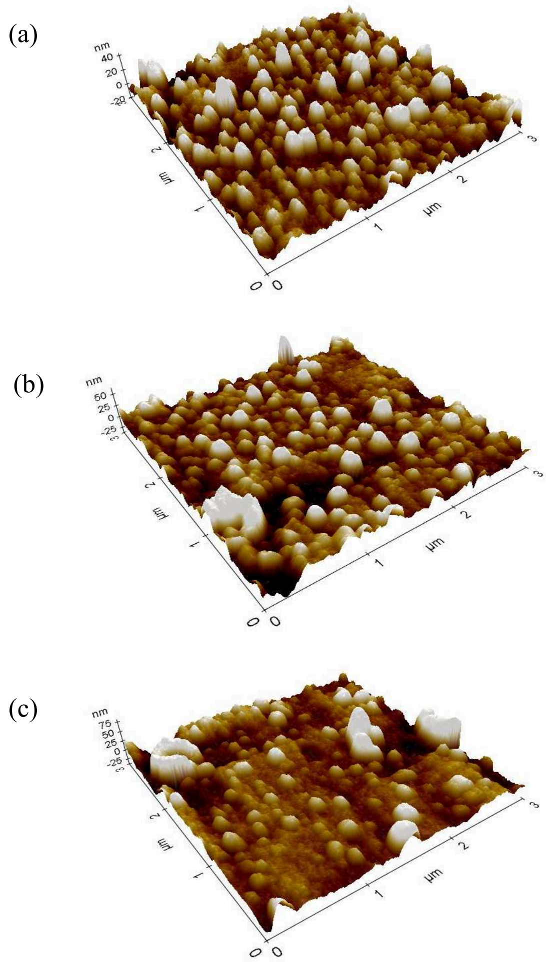

Fig.1. Atomic force microscopy (AFM) images of chemical vapor deposited (1000˚C vaporizing temperature) TiO_2 thin film at three difference placed a) 18cm, b) 21cm and c) 24cm from center of chamber.

The sample thickness was measured using a surface profiler and the average thickness of sample (a-c) is 35.457 nm, 31.805 nm and 25.2145 nm, respectively.

Fig. 2 shows the FESEM images of the TiO_2 thin film grown at 1000˚C. Fig. 2(a) shows uniform distribution of square-like TiO_2 particles. Whereas, Fig 2(b-c) shows the uniformity degradation as the position of the substrate was increased farther from the alumina boat.

B. Transmittance measurement

Fig. 3 shows the optical transmittance of the TiO_2 thin films deposited at 1000°C with three difference position of substrate which are a=18 cm, b=21 cm and c=24 cm. The average thickness of all film is 30.8257 nm. The measurement was performed at a wavelength ranged from 300 nm to 800 nm. Peak for a=101.48%, b=96.49% and c=98.79%. The best transmittance for this substrate is 95% and above. All peak of a, b and c will measure at a wavelength ranged from 333 nm to 340 nm. Observation to the graph, graph decreased after reaching a peak and until a=69%, b=70.72% and c=76.65%.

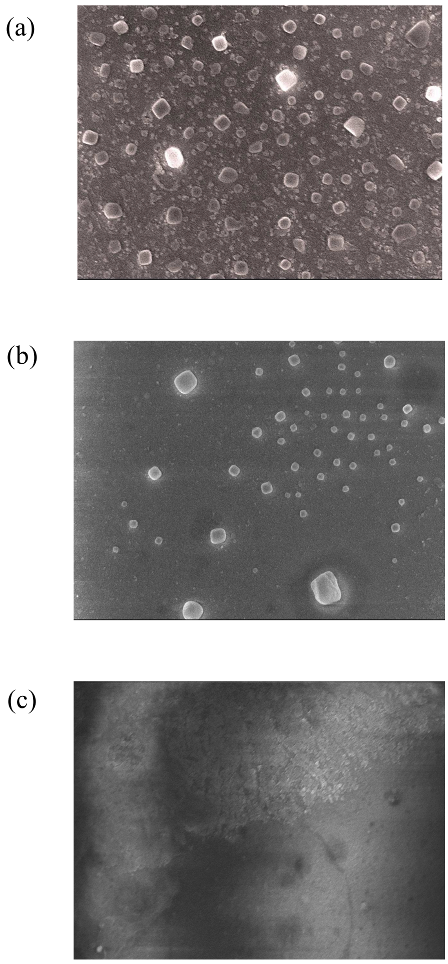

Fig. 2. Scanning electron microscopy (SEM) images of chemical vapor deposited (1000˚C vaporizing temperature) TiO_2 thin film with three difference placed of substrate. a), b) and c) is x30,000 magnification.

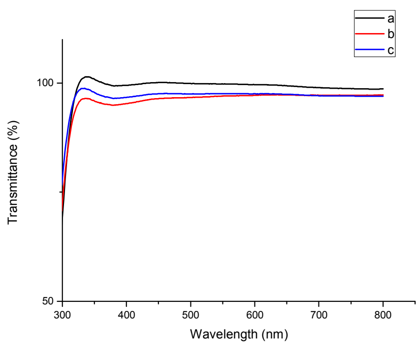

Fig. 3. Plot of transmittance versus wavelength for chemical vapor deposited (1000 ˚C vaporising temperature) TiO_2 thin films with difference distance a=18 cm, b=21 cm and 24 cm.

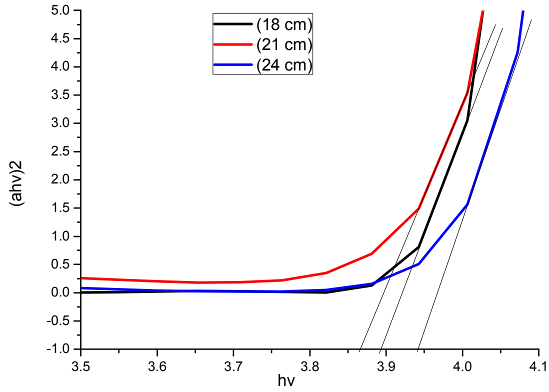

Fig. 4. . (Color online) $(\alpha h\nu)^2$ vs. hν plot of TiO_2 films with different position of substrate.

The optical band gap energy of the films is calculated using the classical relationship for near edge optical absorption in semiconductors.

$$\alpha h\nu = K\,(h\nu - Eg)^{n/2}$$

Where K is a constant, hν is photon energy, Eg is the optical band gap and "n" is a constant equal to 1 for direct band gap and 4 for indirect transitions. $(ah\nu)^2$ vs. hν plot of as-deposited TiO2 thin film is shown in Fig. 6.

The direct band gap is difference for each sample, three band gap shows the distance from center of chamber is 18 cm, 21 cm and 24 cm. Band gap for 18 cm = 3.89 eV, 21 cm = 3.86 eV and 24 cm = 3.94 eV.

CONCLUSION

The uniformity of TiO_2 films was investigated using different substrate positions which are 18 cm, 21 cm and 24 cm from the starting material with average thicknesses of 35.457 nm, 31.805 nm and 25.2145 nm, respectively. The deposition temperature was fixed at 1000˚C using a chemical vapor deposition technique. The thin film has an average peak transmittance of 98.92%. The uniformity of the film was obtained using substrate position of 18 cm from the starting material. The uniformity could be enhanced by optimizing other parameters such as the deposition time, mass of the starting material and gas flow rate

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