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Synthesis and characterization of TiO_2 doped SnO_2 thin film prepared by sol-gel method

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Abstract. In this work, preparation of titanium dioxide doped with tin oxide, SnO_2/TiO_2 thin films deposited onto silicon wafer via sol-gel method. Different amount of SnO_2 was added (5 ml, 10ml and 15 ml) into parent solution. The obtained films were annealed at different temperature which is 400°C, 500°C and 600°C for 1 hour. Morphological and surface topography of the SnO_2 doped TiO_2 thin films were studied using Scanning Electron Microscope (SEM) and Atomic Force Microscope (AFM). The annealed films shows non-uniform crack due to the mismatch of coefficient of thermal expansion (CTE) between SnO_2/TiO_2 thin films and silicon wafer.

1 Introduction

Nowadays, there are numerous application of titanium dioxide (TiO_2) that benefits the society such as cosmetics, foods, restraining and sterilizing virus, electrical devices and photocatalytic oxidation (PCO) under ultraviolet (UV) and visible light also known as a pollution control technology [1, 2]. Self-cleaning acitvity will occur when TiO_2 is being exposed under light source which will display a photocatalytically induced superhydrophilicity properites. The hydrophobic surface of the substrate will transform to hydrophilic surface after coated with TiO_2 where it will cause a uniform water film. This will prevent the adhesion of organic or inorganic components on the surface. Therefore, the cleanliness can be retained. TiO_2 thin film can be coated on the surfaces of various substrates such as metals, textiles, ceramics, fibres and glass that will exhibits self-sterilisation and self-cleaning properties when it is exposed to the light source.

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When TiO_2 is doped with metal oxide such as SnO_2, it will improve the efficiency of TiO_2 photocatalyst. By doping SnO_2 into TiO_2 thin films, hydrophilicity and photocatalytic activity of composite thin films would be improved due to the reduction of TiO_2 particle growth rate [3-6].

In this work, TiO_2 doped with SnO_2 thin films coated on silicon substrate were fabricated using a sol-gel dip coating technique. The thin films were annealed at 400ºC, 500ºC and 600 °C for 1 hour with the heating rate of 5 °C/min. X-ray Diffractometer (XRD) was used to study the phase composition of SnO_2 doped TiO_2 thin films while Scanning Electron Microscope (SEM) and Atomic force microscope (AFM) was used to observe the morphology and the surface topography of SnO_2 doped TiO_2 thin films, respectively.

2 Methodology

2.1 Materials

The main raw materials used to produce TiO_2 sol in these studies are titanium (IV) isoproxide (TTIP), $Ti(OC_3H_7)_4$, isopropanol, C_3H_8O and acetic acid, CH_3COOH. Tin-tetrachloride penta-hydrate ($SnC_4.5H_2O$) powder was used as the source of SnO_2 solution. The silicon wafer was used as a substrate.

2.2 Methods

Firstly, 0.5 ml titanium (IV) isoproxide (TTIP) and 10 ml isopropanol, C_3H_8O were stirred at room temperature for 20 minutes using magnetic stirrer. Then, 2.5ml of acetic acid was added into the solution while stirring to speed up the chemical reaction. SnO_2 solution was produced by adding 50ml of distilled water and 50 ml of ethylene glycol into 3.51g tin-tetrachloride penta-hydrate ($SnCl_4.5H_2O$) powder. The solution was dissolved for 10 minutes to make a 100 ml precursor mixture. The TiO_2 solution was mixed together with 5ml, 10ml and 15ml of SnO_2 respectively. The mixture was vigorously stirred for another 30 minutes at room temperature. The substrate used is silicon wafer (1 cm x 1 cm). The silicon wafers were washed in acetone using ultrasonic cleaner for 30 minutes. The TiO_2/SnO_2 sol were deposited on silicon wafer by using spin coating at 1500rpm for 30s. The coated samples were dried at 40ºC for 10 minutes. After that, the coated samples were annealed in muffle furnace for 1 hour with heating rate of 5°C/min at 400˚C, 500˚C and 600˚C. The TiO_2 doped with SnO_2 thin films were prepared by sol-gel method according to the amount of SnO_2 doping. In this study, the characterization of TiO_2 thin films was investigated by using Scanning Electron Microscope (SEM) and Atomic Force Microscopes (AFM).

3 Results and Discussions

Fig. 1 shows the XRD pattern of SnO_2 doped TiO_2 thin films. It can be seen that the diffraction pattern shows dual-phase of anatase and rutile with no existence of SnO_2. The samples were annealed at three different temperatures which are, 400˚C, 500˚C and 600˚C, respectively. The angle 2θ shifts towards lower angles with the increase of annealing temperature from 400 ˚C to 600 ˚C.

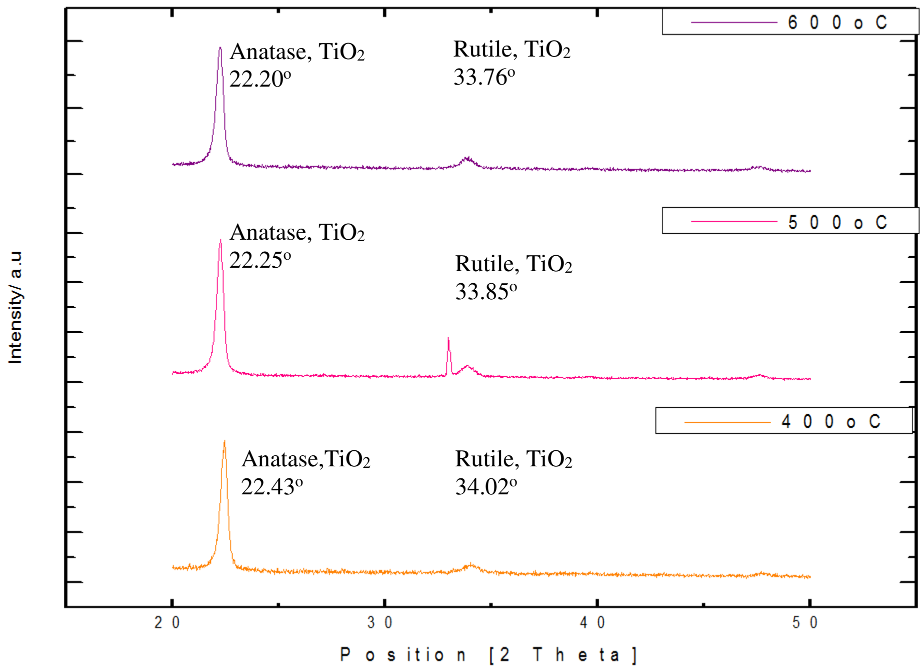

Fig. 1. XRD pattern of SnO_2 doped TiO_2 thin films which was annealed at 400ºC, 500ºC and 600ºC.

Fig. 2 and Fig. 3 show the micrographs of SnO_2/TiO_2 thin films that were coated on silicon wafer with different amount of SnO_2 added and annealed in muffle furnace at 400ºC, 500ºC and 600ºC for 1 hour. The micrographs show a non-uniform films with large flaky and large cracks film. It might due to the surface tension between the film and the air during the drying process [7]. It can be seen that as the annealing temperature increases, the distance between cracks become smaller. The higher the annealing temperature, the least cracks formed. To prevent crack from forming when annealed at high temperature, more layers of coating were deposited to ensure the coverage of substrate become better and formed a thicker film. It is well agree with the previous work by Abdul Razak et al [8]. From Fig. 2, it was observed that 5 ml SnO_2 doped with TiO_2 annealed at 400ºC has the most agglomerated region as compared to the samples annealed at 500ºC and 600ºC. Meanwhile, in Fig. 3 shows the micrograph of 10 ml SnO_2 doped with TiO_2 annealed at 500°C has the most agglomerated region as compared to the samples annealed at 400ºC and 600ºC. The micrographs show a Volmer-Weber growth. Volmer–Weber growth of SnO_2 doped TiO_2 thin films includes nucleation of 3-D islands, growth, impingement and coalescence of islands [4].

The surface topography of SnO_2/TiO_2 thin films was investigated by Atomic Force Microscopes (AFM). Typical topographical images of the surface of SnO_2/TiO_2 coatings are represented in 3D images. Fig. 4 shows the surface topography of 5ml SnO_2 doped TiO_2 thin films at different annealing temperature of 400ºC, 500ºC and 600ºC respectively. Fig. 5 shows the surface topography of 10ml SnO_2 doped TiO_2 thin films at different annealing temperature 400ºC, 500ºC and 600ºC respectively.

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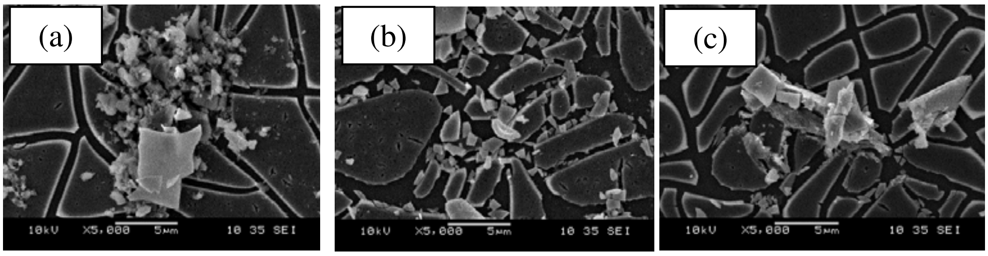


Fig. 2. SEM image of the surface morphology for 5 ml SnO_2 doped with TiO_2 thin films at temperature of (a) 400°C, (b) 500°C and (c) 600°C.

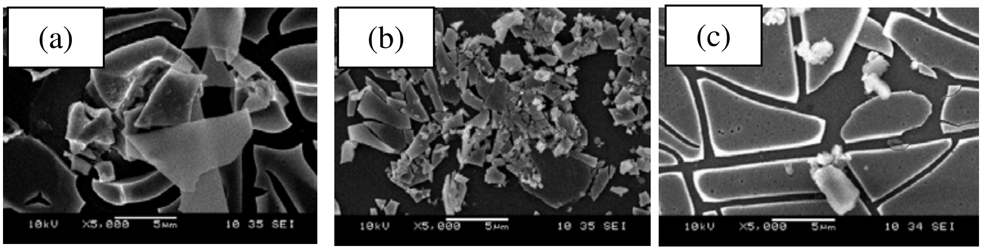
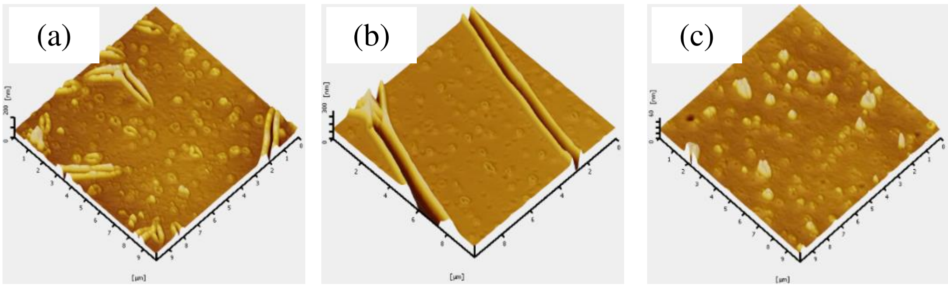
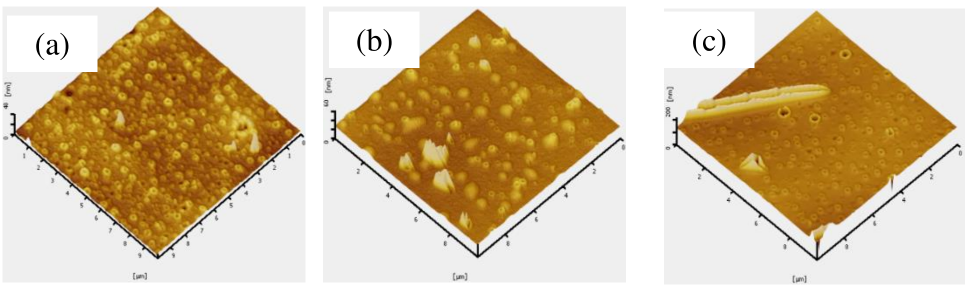


Fig. 3. SEM image of the surface morphology for 10 ml SnO_2 doped with TiO_2 thin film at temperature of (a) 400°C, (b) 500°C and (c) 600°C.



RMS=1.155nm RMS=3.677nm RMS=3.796nm

Fig. 4. The surface topography and 3D images of 5ml SnO_2 dope TiO_2 thin films at different annealing temperature of (a) 400°C, (b) 500°C and (c) 600°C.



RMS=1.570nm RMS=2.995nm RMS=9.937nm

Fig. 5. The surface topography and 3D images of 10 ml SnO_2 dope TiO_2 thin films at different annealing temperature of (a) 400°C, (b) 500°C and (c) 600°C.

It can be observed that the sample which was annealed at 600°C produce the highest value of roughness (RMS) while the sample annealed at 400°C produced the lowest value of roughness (RMS). This showed that the surface roughness (RMS) of the samples increased with the annealing temperature. It is well agreed that the presences of SnO_2 influenced the RMS value. As the amount of SnO_2 added increased, the RMS value also increased. This revealed that the RMS value was affected by annealing temperature and the amount of SnO_2 added into the parent solution.

4 Conclusion

In this study, SnO_2 doped TiO_2 thin films were prepared by sol-gel method. The XRD pattern shows the phase composition of SnO_2 doped TiO_2 thin films were dual-phase of anatase and rutile with no existence of SnO_2. The morphological characteristics of SnO_2 doped TiO_2 thin films have non-uniform cracks, agglomerate and the formation of Volmer-Weber growth. When the annealing temperature and the amount of SnO_2 increased, the surface roughness (RMS) value increased.

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References

1. W. Sangchay, Industrial Technology Lampang Rajabhat University Journal **2**, (2016)
2. W. Sangchay, Energy Procedia **89**, (2016).
3. S. Karuppuchamy, K. Nonomura, T. Yoshida, T. Sugiura, H. Minoura, Solid State Ionics **151**, 19 (2002).
4. H. Z. Yu and C. V Thompson, Acta Mater. **67**, (2014).
5. B. K. Kaleji and R. Sarraf-mamoory, Materials Research Bulletin **47**(2), (2012).
6. M. Shipochka A.Eliyas, I.Stambolova, V.Blaskov, S.Vassilev, S.Simeonova, K.Balashev, Materials Chemistry and Physics **220**, 249–259 (2018).
7. D S C Halin, M M A B Abdullah, N Mahmed, S N A Abdul Malek, P Vizureanu and A W Azhari, IOP Conf. Series: Materials Science and Engineering **209**, (2017).
8. K. Abdul Razak, D.S. Che Halin, M.M.A. B. Abdullah, M.A.A. Mohd Salleh, N. Mahmed, N.S. Danial, Solid State Phenomena **280**, (2018).