

Preparation of Cobalt Doped DSC using Spray Pyrolysis Deposition (SPD) Technique

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Keywords: Titanium Dioxide, nanorods, nanoflower, Hydrothermal, Dye-sensitized Solar Cell

Abstract. Dye-Sensitized Solar Cell (DSSC) has been prepared using Cobalt doped Titanium Dioxide (TiO₂). The preparation of Cobalt doped TiO₂ were done using spray pyrolysis method. Cobalt doped TiO₂ thin film were annealed at 500°C for 3hours and the effects of Cobalt as a dopant, towards the surface morphology and structural properties have been studied. Finally, I-V measurement of DSSC was done under illumination of AM 1.5 and 100mW/cm².

Introduction:

A nanostructured Titanium dioxide (TiO₂) thin film gives high transmittance and good refractive index in the visible region with chemical stability and good durability in environments [1]. Due to promising in optical, electrical, chemical and structural properties TiO₂ thin films have been widely used for many applications such as photocatalyst [2], multilayer optical coating [3], thin film devices for solar cell [4] and also in sensor applications [5]. TiO₂ films are used in many electronic applications due to their high dielectric constant [6]. Many studies have been studied, which is found that the properties of transition metal oxides can be enhanced by doping, which widens their potential applications. Many attempts have been made to modify the physical, chemical and optical properties of TiO₂ thin films by doping with transition metal oxides. In this study, we have successfully prepared TiO₂ thin film doped with ion Co and used in DSC application. The electrical, structural and surface morphology were all characterized in this study.

Experimental

Silicon, glass and FTO coated glass were used as substrate in this experiment. All of the substrates are cleaned with acetone and ethanol using ultrasonic cleaner. 0.3g of P25 TiO₂ powder was mixed with 5.5ml of acetic acid and then mixed with 20ml of TiO₂ colloid solution (TAYCA TKC-302). The solution was well stir using ceramic mortar for about 5 minutes. 0.1g of Cobalt Nitrate was added into the solution which acted as a dopant in the TiO₂ thin film. This solution was continuously stirred for another 5minutes. For better dispersion of TiO₂ solution, 30ml of ethanol was added into the solution. Finally, 5 drops of non-ionic surfactant (Triton X-100) was used in the solution to enhance the conductivity of TiO₂ thin film.

The thin film deposition method was done using SPD method. All of the substrates were put onto 150°C of hot plate. The TiO₂ solution was sprayed using 0.3MPa of gun pressure and one time sprayed contained 0.5ml of TiO₂ solution. All of the solution was used in this preparation. The thin films were then annealed at 500°C for 3 hours. The TiO₂ thin film was immersed in 3mMol concentration of N719 ruthenium dye for about 14 hours.

The thickness of the film was measured using surface profiler (DEKTAK 3). The structural properties was done using X-ray Diffractometer (RINT Ultima III-Rigaku) and the surface morphology image was observed using FE-SEM (JSM-7001F JOEL). The solar cell efficiency was measured using solar simulator under 1.5AM (Bunkoh Keiki-JUSCO).

DSC was prepared using FTO coated glass and Pt coated glass as electrode and counter electrode. The dye solution was prepared at 3mMol which is contained of Acetonitrile, ButylAlcohol and Ruthenium Dye (N719). The electrolyte that we used called DPMM electrolyte which contained of 0.6M of 1,2-Dimethyl-3-propylimidazolium iodide, 0.1M LiI, 0.5M of 4-tert-Butylpyridine, 0.1M of Guanidine Thiocyanate, 0.85ml of Acetonitrile, 0.5ml of Valeronitrile and 0.05M of I₂

Result and Discussions

The surface morphology of the film was analyzed using Field Emission Scanning Electron Microscopy (FE-SEM). The images of TiO₂ thin films which doped with Co are shown in Fig.1 (a) until 1 (c). An average size of TiO₂ particle can be observed in Fig.1 (a). The TiO₂ thin film shown very good porosity and the pores were well organized in the TiO₂ thin film. There is no Co particles can be observed at any SEM images. The sizes of the particles were about below 50nm as were shown in Fig. 1(c). The thickness of film was measured using surface profiler (DEKTAK 3) which gives 30μm of thickness.

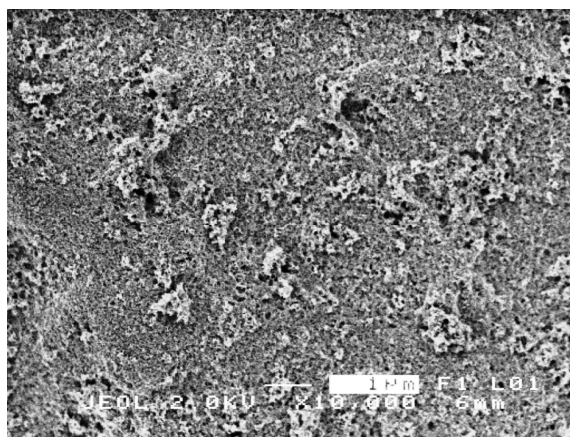


Fig. 1(a) SEM image of Co doped TiO₂ thin film at x10000 magnification annealed at 500°C

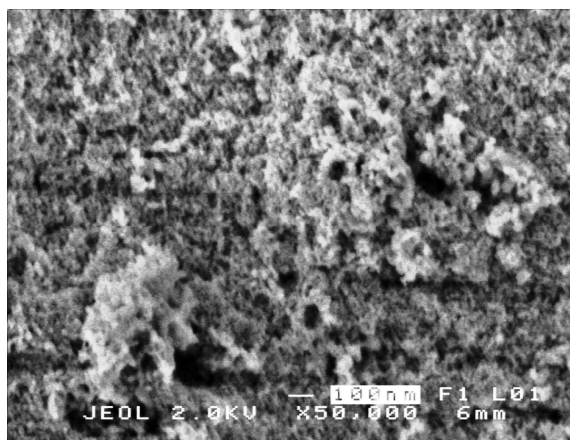


Fig. 1(b) SEM image of Co doped TiO₂ thin film at x50000 magnification annealed at 500°C

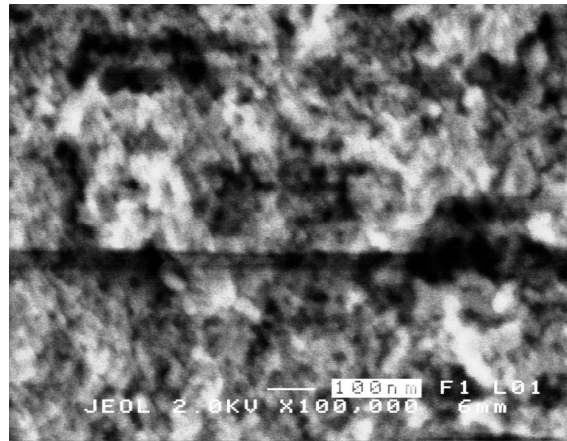


Fig. 1(c) SEM image of Co doped TiO_2 thin film at x100000 magnification annealed at 500°C

The structural properties of TiO_2 thin film were carried out using Rigaku RINT Ultima III with $\text{Cu-K}\alpha$ radiation and 2° grazing angle. Fig. 2 shows XRD pattern of Co doped TiO_2 thin film which annealed at 500°C for 3 hours. From the graph, it showed that prepared TiO_2 thin film was nanocrystalline and has 3 peaks which at 25.3° , 37.9° and 48.0° corresponded to anatase peaks. These peaks contribute to anatase phase (101), (004) and (200) crystal planes. This result agrees with Zhang et al.[7]. All peaks observed were corresponded to JCPDS Patterns No. 21-1272. There are no additional peaks which corresponded to Co, which can be observed in the XRD pattern.

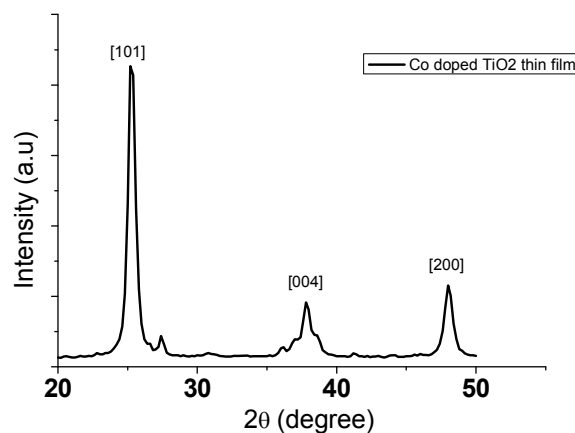


Fig. 2 XRD pattern of Co doped TiO_2 thin film annealed at 500°C

Current-voltage measurement was performed to measure the efficiency of DSC. The DSC was assembled following this configuration: $\text{FTO/CoTiO}_2 + \text{dye} + \text{electrolyte/Pt}$. From the I-V graph it shows that prepared DSC using Co doped TiO_2 thin film does not gives high efficiency. It is only gives 0.20% of efficiency. It is lower compared to other researchers [8].

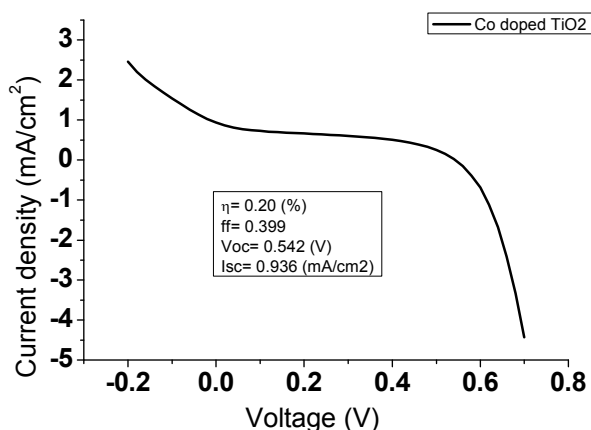


Fig. 3 I-V measurement of Co doped TiO₂ thin

Conclusion

We had successfully prepared Co doped TiO₂ thin film and used it in DSC application. From the I-V result, Co doped TiO₂ thin film DSC gave lower efficiency compared to other researcher although the surface morphology and the structural properties shows no significant differences to conventional DSC application. This included particle sizes were below 50nm and high crystallinity in anatase phase. This result was beyond difference with our earlier study about Co doped TiO₂ thin film [9]. In our earlier study, we found out that Co doped TiO₂ thin film gave high electron mobility which refer to electrical properties of Co doped TiO₂ thin film. In Co doped TiO₂ thin film, many excess of electrons were adsorbed at TiO₂ particles, which can enhance the electron mobility. With this idea, we thought when TiO₂ was doped with Co and use in DSC application; it can also enhance the efficiency of the solar cell. Unfortunately, it gave opposite result. The composition of Co, TiO₂, dye and electrolyte maybe become main reason. The electron mobility was increase in Co and TiO₂ composition, but when Co, TiO₂ and dye solution were combined, the Co gives resistance in TiO₂ thin film. It can prove by low current intensity, Isc in Fig. 3. With this, we can say that Co was not good candidate as a dopant in TiO₂ based DSC application. By controlling the amount and size of the dopant itself, the solar cell efficiency should be enhanced. This is our aim study in future.

Acknowledgements. The authors would like to thank to Ministry of Education (MOE), Malaysia and Universiti Tun Hussein Onn Malaysia (UTHM) for financial support (FRGS Vot1213).

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