

FABRICATION OF NON REFLECTING FILM BASED ON POLYSTYRENE AND METHYL METHACRYLATE USING SPIN COATING TO INCREASE A LIGHT TRANSMISSION ON ITO GLASS

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Graphical abstract



Abstract

Thin films are developed for multi-purposes, such as optical waveguides, corrosion resistant coating, car tinting, and glass coatings. Each thin film is created and designed with a specific purpose and function. The purpose of this research was to fabrication anti-reflective films on glass Indium Tin Oxide (ITO) usually used as an electrode in Dye-sensitized Solar Cell (DSSC). In this research, the material used involved solution 100.12 g/mol Methyl Methacrylate (MMA) and 3% Polystyrene(PS) with a spin coating method. In this study, polystyrene and methyl methacrylate solution dripped on ITO glass was then rotated at 1000, 1500, 2000 and 2500 rpm. This study shows that polystyrene and methyl methacrylate materials can be used as an anti-reflection coating on the ITO substrate by a spin coating method. The methyl methacrylate material is good for anti-reflection coating at 400-475 nm wavelength region, while the polystyrene material is good for 475-700 nm wavelength. The addition of a 3% polystyrene coating on ITO glass can increase light transmission at a wavelength of 475-700 nm by 1.14% when compared to ITO glass without a polystyrene coating. The highest light transmission of 90.11% occurs at a wavelength of 420 nm when the ITO glass is coated with methyl methacrylate.

Keywords: Thin film, ITO, nonreflecting, mma, polystyrene

Abstrak

Lapisan tipis dikembangkan untuk berbagai keperluan, seperti pandu gelombang optik, lapisan tahan korosi, pewarnaan mobil, dan lapisan kaca. Setiap film tipis dibuat dan dirancang dengan tujuan dan fungsi tertentu. Tujuan dari penelitian ini adalah untuk membuat film anti-reflektif pada kaca Indium Tin Oxide (ITO) yang biasanya digunakan sebagai elektroda dalam Dye-sensitized Solar Cell (DSSC). Dalam penelitian ini, bahan yang digunakan melibatkan larutan 100,12 g/mol Methyl Methacrylate (MMA) dan 3% Polystyrene (PS) dengan metode *spin coating*. Dalam penelitian ini, larutan polistiren dan metil metakrilat yang diteteskan pada gelas ITO kemudian diputar pada 1000, 1500, 2000 dan 2500 rpm. Studi ini menunjukkan bahwa bahan polystyrene dan metil metakrilat dapat digunakan sebagai lapisan anti-refleksi pada substrat ITO dengan metode spin coating. Bahan metil metakrilat baik untuk lapisan anti-refleksi pada daerah panjang gelombang 400-475 nm, sedangkan bahan polystyrene baik untuk panjang gelombang 475-700 nm. Penambahan lapisan polistiren 3% pada kaca ITO dapat meningkatkan transmisi cahaya pada panjang gelombang 475-700 nm sebesar 1,14% bila dibandingkan dengan kaca ITO tanpa lapisan polistiren. Transmisi cahaya tertinggi 90,11% terjadi pada panjang gelombang 420 nm ketika kaca ITO dilapisi dengan Methyl Methacrylate.

Kata kunci: Lapisan tipis, ITO, antirefleksi, mma, polystyrene

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1.0 INTRODUCTION

Thin film coating has been developed in various fields of technology, such as optical waveguides[1], Thermoelectric[2, 3], anti-reflecting [4–6], anti-corrosive coating[7, 8], manufacturing of Dye sensitized solar cells (DSSC)[9, 10] and solar cell[11]. The research about DSSC is one study to find alternative energy sources, namely by utilizing photosensitizers/dyes to convert sunlight (photons) into electrical energy[12, 13].

DSSC is the development of a type of solar cell that consists of working electrodes, electrolyte solutions, and counter electrodes[14, 15]. The work electrode consists of a semiconductor such as TiO₂ coated by a Dye that serves to increase the conversion of sunlight into electrical energy or as the photosensitizer (light absorber)[9, 16]. The general problem faced in the study of DSSC is that the efficiency produced is still relatively small. So far, research on increasing the efficiency of DSSC has been carried out by developing Dye (chlorophyll) types from various plant species, oxide semiconductors, and electrolytic materials [12, 17, 18]. The electrical energy generated in the DSSC depends on the amount of sunlight that is passed by the working electrode, so the larger the light is transmitted the greater the light is absorbed by the photosensitizer [19].

In this study try to give the solution to the problem by making an anti-reflection layer on the ITO glass in order to increase light transmittance, when applied as a work electrode in DSSC. The anti-reflection layer has also been applied to solar cells to increase light transmission on the surface of solar panels [20, 21]. The material used in this study as an anti-reflection layer is polystyrene (PS) and Methyl Methacrylate (MMA) using the spin coating method. The selection of PS and MMA materials is based on thin layer interference where in order for total transmission to occur (non-reflecting) the wave reflected from the second surface must undergo a phase change of π rad. This can occur if the second medium has a refractive index greater than the first medium, mathematically it can be written $n_1 < n_2 < n_3$ where n_1 is the air refractive index, n_2 is the thin layer index (PS / MMA) and n_3 is the substrate refractive index (ITO). In this study the PS, MMA and ITO materials used have a refractive index of 1.59, 1.49 and 2.1[22]. The thin layer characterization was carried out using UV-Vis transmission spectra, optical microscopy and Scanning Electron Microscope (SEM).

2.0 METHODOLOGY

In this research, the materials used for making anti-reflection coatings are 3% polystyrene (Sigma-Aldrich) and solution 100.12 g/mol methyl methacrylate (Merck, Germany). The spin coating method was used in the coating process[23–26]. A non-reflection film design is shown in Figure 1.

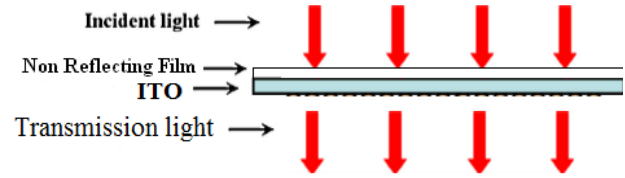


Figure 1 Design of non-reflecting layer on ITO glass

The solution of 3% polystyrene was made of 0.75 grams of powder Polystyrene and 27.95 ml of toluene. It was mixed with a magnetic stirrer for 5-6 hours until the solution became homogeneous. The ITO glass coated by MMA and polystyrene 3% with a spin speed of 1000, 1500, 2000, and 2500 rpm for 60 seconds[27–29]. ITO glass has two surfaces: conductor surface and non-conductor surface, therefore before the surface layer is checked first using an ohmmeter to determine the properties of both surfaces. The surface to be coated is a non-conductor surface. After ITO glass was coated with polystyrene and methyl methacrylate and then heated on a hot plate at a temperature of 80°C for 15 minutes[30]. Characterization of polystyrene and methyl methacrylate layers is done by measuring the thickness of each layer, transmission and absorption values, and observation of the surface of the coating. Measurement of thickness is done by pixel shift method resulting from observation using the optical microscope show in Figure 2. In the thickness measurement, the first step is to determine the value of 1 pixel in units of micrometers. The results of observation by optical microscope the thickness of the layer in a pixel unit, so to get in units of micrometer then the value of the thickness is multiplied by the value of 1 pixel in units micrometer.



Figure 2 Observation and measurement of layer thickness with an optical microscope

The transmission and absorption values were obtained by measuring using the UV-Vis spectrometer (Genesys 10S UV-Vis) at wavelength (300-700) nm[27]. The cross-sectional view of the polystyrene and methyl methacrylate surfaces on ITO glass can be

determined by testing using Scanning Electron Microscope (SEM) (FEI Inspect S50).

3.0 RESULTS AND DISCUSSION

Figure 3 (a) is an observation of an ITO glass which has been coated with methyl methacrylate, while in Figure 3 (b) it is an ITO glass which has been coated with polystyrene material. Observation of these two layers using an optical microscope with 600x magnification. The observation process with an optical microscope is used to calculate the thickness of the layer by shifting the micrometer scale to the vertical direction. By shifting the scale of the micrometer, the position of the image on the monitor will shift in pixels, so that the value of 1 pixel is obtained in units of micrometers as described in the methodology.

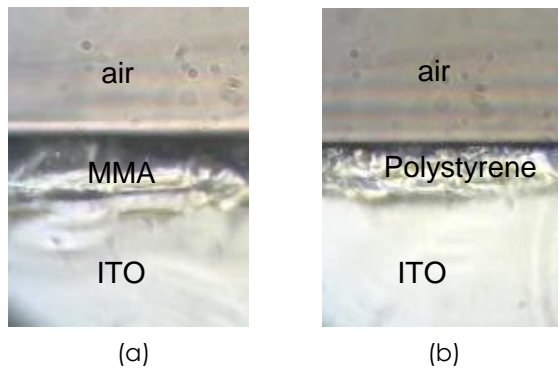


Figure 3 The observation of a thin layer (a) material MMA, (b) material Polystyrene

Figure 3 shows the surface differences and thickness between polystyrene and methyl methacrylate layers. This difference is caused by polystyrene and methyl methacrylate which have different homogeneity and viscosity so that the distribution of polystyrene solutions and methyl methacrylate which spread on the surface of the ITO glass is different. Figure 3 also shows that the methyl methacrylate layer has a smaller thickness compared to the polystyrene layer. The results of the calculation of the thickness of the polystyrene and methyl methacrylate layers are shown in Table 1 and Figure 4.

Table 1 The results calculation of thickness polystyrene and methyl methacrylate coating

Speed (rpm)	thickness of the layer (μm)	
	polystyrene	methyl methacrylate
1000	9.554	9.091
1500	8.653	7.522
2000	7.547	6.987
2500	7.407	6.410

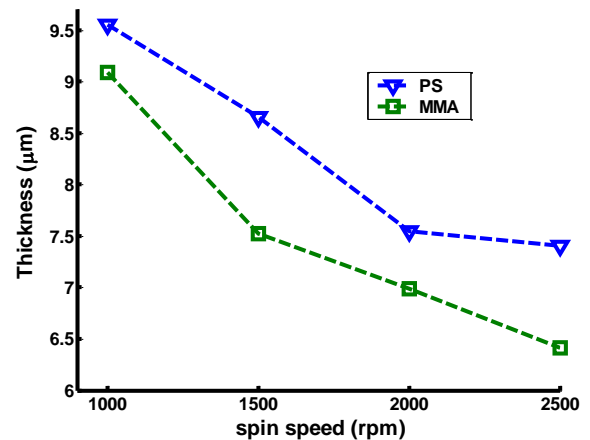
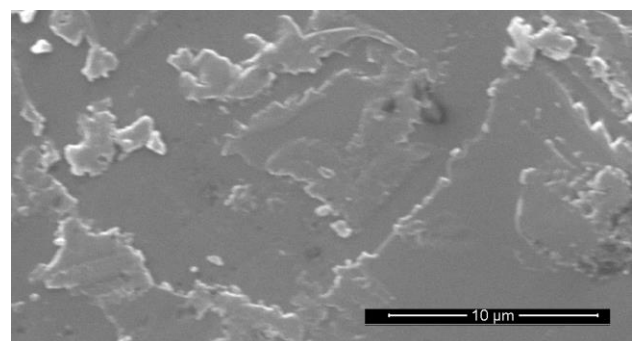
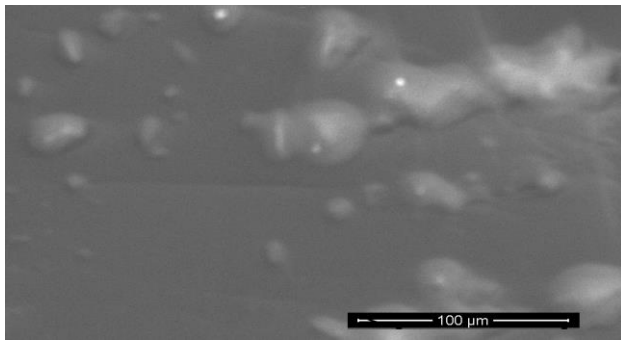


Figure 4 The graph of layer thickness vs spin speed

Figure 4 shows that at the same rotation speed can produce different thicknesses of methyl methacrylate and polystyrene. This difference is caused by the thickness of the coating results using the spin coating method not only influenced by angular velocity but also influenced by the nature of the superimposed material[28]. The material properties that affect the thickness of the layer are viscosity and solution concentration[29]. From the measurement it appears that at the same rate the MMA layer has a smaller thickness than the polystyrene layer, this indicates that the MMA solution used has a smaller viscosity than 3% polystyrene solution. The homogeneity, concentration, and viscosity of the solution not only affect the thickness of the layer but also affect the level of flatness as shown in Figure 5.



(a)



(b)

Figure 5 The observation of layers (a) polystyrene and (b) methyl methacrylate using SEM

Figure 5 (a) is the result of observation of polystyrene layers using SEM with a magnification of 10000x, and Figure 5 (b) is the result of observing the coating of methyl methacrylate using SEM with a 1000x magnification. Based on surface observations, the methyl methacrylate layer is finer than the polystyrene layer. The difference in evenness between the two surfaces shows that a solution of methyl methacrylate has a higher homogeneous level compared to polystyrene solutions [6, 27]. The flatness difference between the two layers is caused by the polystyrene solution used in this study is in the form of powder which has been dissolved with toluene as described in the research method, while methyl methacrylate from the beginning has been in the form of a solution with an assay of 99% and a density of 0.942-0.944 at a temperature of 20°C / 4°C, not a powder like polystyrene. This different state of solution is what causes the difference in flatness in the layers [30]. Figure 5 (a) shows that the polystyrene layer formed is uneven so that the surface of the ITO glass has not been completely coated, this shows that the process of forming the layer is less than perfect. Formation of layers that are less than perfect can be caused by several factors, one of which is uneven heating when removing solvents (toluene) so that the formation of layers occurs not simultaneously. This situation also occurs in the layer formed at MMA as shown in Figure 5 (b).

The polystyrene layer and MMA besides the SEM test were also characterized using a UV-Vis spectrometer to determine the transmission and absorption values. The transmission test results for the polystyrene layer are shown in Figure 6. From Figure 6 shows that light transmission at a wavelength of 400-475 nm has the highest transmission value in a polystyrene solution when rotated at 1000 rpm and produces a thickness of 9.554 μm. The test results show that by adding a 3% polystyrene layer with a thickness of 9.554 μm in an ITO glass it can transmit light at 89.85% at a wavelength of 430 nm. But at a wavelength of 475-675 nm, higher light transmission or can increase light transmission by 1.14% when ITO glass is coated with polystyrene and rotated at a

speed of 2,000 rpm or produces a thickness of 7,547 μm.

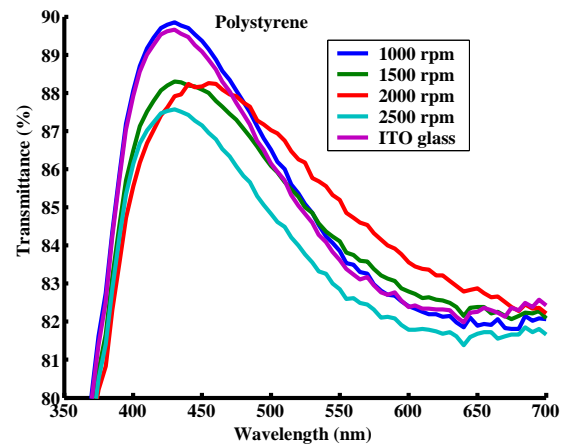


Figure 6 The transmission spectra of polystyrene layer

Based on the results of the polystyrene coating transmission test in this study it can be recommended to be used as an electrode in Chlorophyll Sensitized Solar Cells (CSCCs). This is consistent with research on high efficiency in CSCCs where chlorophyll experiences absorption peaks at wavelengths of 437 nm [18]. While in the fabrication layer the fabrication results with a rotation speed of 2000 rpm can be utilized in DSSC using red bougainvillea dyes, because these dyes have a peak chlorophyll absorption at 475, 550 and 675 nm [10].

The results of the transmission test in the MMA layer are shown in Figure 7. Based on the results of the transmission test shown in Figure 7, it shows that the transmittance value on the ITO glass that has been coated with MMA has increased at a wavelength of 400-500 nm with spin speeds of 1000, 2000 and 2500 rpm. In this study, the highest light transmission occurs at the MMA layer when the MMA solution is rotated at a speed of 2000 rpm or at a thickness of 6.987 μm with a value of 90.11% at wavelength 420 nm.

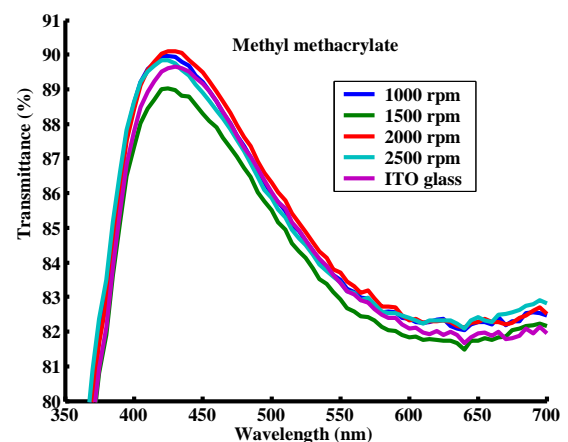


Figure 7 The transmission spectra of MMA layer

From the results of this study about anti-reflection with material MMA, it can be recommended as a working electrode in DSSC that uses chlorophyll as a dye because chlorophyll absorbs light in the visible light region with the highest absorption peak at a wavelength of 420 nm[17].

The test results using a UV-Vis spectrometer in addition to the transmission value obtained also obtained the value of light absorption by the layer. The light absorption value by ITO glass after being coated with polystyrene material is shown in Figure 8, while the absorption value of ITO glass after coated with MMA material is shown in Figure 9. Based on the test results show that the absorption value is the opposite of the transmission value, where when it reaches the maximum transmission the minimum absorption value. This situation occurs in both the polystyrene layer and the MMA layer as shown in Figure 8 and Figure 9.

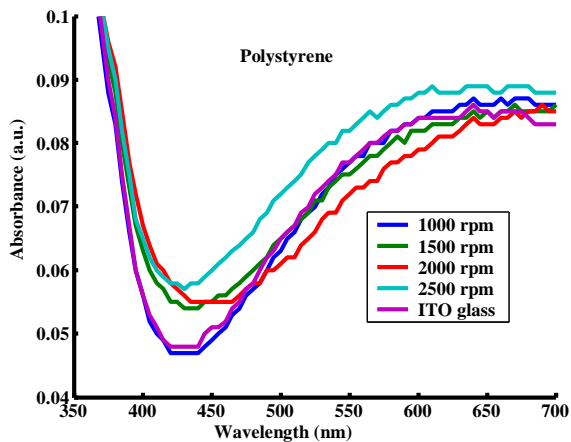


Figure 8 The absorbance spectra of polystyrene layer

Figure 8 shows that the absorption value of ITO glass after being coated with polystyrene material occurs at a wavelength of 430 nm. This shows that adding a thin layer of polystyrene can reduce light absorption in the ITO glass, so that when applied to DSSCs it is expected to increase its efficiency.

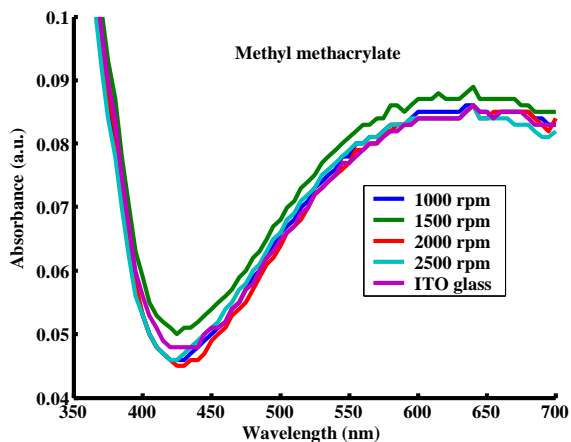


Figure 9 The absorbance spectra of MMA layer

The polystyrene layer in this study can be applied as an anti-reflection layer applied to ITO glass as working electrode in the manufacture of DSSC[16, 31]. Figure 9 shows that the smallest absorption in ITO glass that has been coated with MMA material occurs at a wavelength of 420 nm.

From the results of this study it can be seen that the material suitable for increasing the value of light transmission at a wavelength of 400-475 nm is methyl methacrylate with a thickness of 6,987 μm . However, for wavelengths of 475-700 nm, it uses polystyrene material with a thickness of 7,547 μm .

4.0 CONCLUSION

In summary, this study shows that polystyrene and methyl methacrylate materials can be used as an anti-reflection coating on the ITO substrate by spin coating method. The methyl methacrylate material is good for anti-reflection coating at 400-475 nm wavelength region, while the polystyrene material is good for 475-700 nm wavelength. The addition of a 3% polystyrene coating on ITO glass can increase light transmission at a wavelength of 475-700 nm by 1.14% when compared to ITO glass without a polystyrene coating. The highest light transmission of 90.11% occurs at a wavelength of 420 nm when the ITO glass is coated with methyl methacrylate.

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