Development of Elevation Machine for Thin Film Production in Self Assembling, Suitable for Die Sensitized Solar Cell.

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Abstract

Solar Cell is used to convert radiation energy to electrical energy. Still they are in very primitive stage and a lot of research is needed to be done to improve efficiency. Although the efficiency and durability of organic solar cell (OSC) is to be greatly improved, the potential in that area has increased due to low cost, flexibility and light weight. Further, Dye Sensitized Solar Cell (DSSC) is popular in research studies due to the cost factor in the manufacturing process and there are lots of ongoing researches in this scenario in the world including Sri Lanka. Further, DSSCs are referred to as thin film solar cells and it is important to emphasize the thickness of the depletion layer of a cell is prominent in improving its efficiency. The optimum level of the thickness of depletion layer of solar cell is found as 20nm for better operation. There are different techniques which can be used for thin film production such as the doctor blade method, photolithography or screen print method, spin coating method, and Ionically self-assembled method. The self-assembling process has more potential as it can deposit thin film in the form of monolayer with high morphology without using complex and expensive equipment. However, the constraint is how to reduce vibration and it is required to find a proper mechanism to immerse sample of ITO glass and removing. That cannot be done directly by hand and the current practice is to immerse sample using an elevator lab jack available in the laboratory. This method is not convenient because the vibration may arise due to elevation and as a result, morphology will be reduced. In this research, the main objective is to develop a vibration free elevation method which is suitable for the film production of self-assembling process. It is difficult to use a motor controlled system because the monolayer may crack or break due to the vibrations of motor armature. Therefore , in this research a hydraulic elevation system is introduced as a novel technique so that it can have a vibration free system. The required speed is 8.33 x 10-5 ms-1 and the proposed system can easily vary its speed between 2.78 x 10-6 ms-1 and 1.67 x 10-4 ms-1, which provides ideal conditions suitable for ISAM technique. UV-Visible Absorption Spectroscopy was used to observe the growing of the monolayer because it gives an indication about absorption with the thickness of formed layer according to Beer–$_{Lam}$bert law.

Keywords – Dye Sensitized Solar Cell, Ironically Self-Assembled Method, UV-Visible Absorption Spectroscopy.

1 Introduction

1.1 Solar Energy and Solar Cell

Solar energy is an abundant and renewable energy source. The sun functions as a source of energy from nuclear fusion reaction. Every second, $6x10^{11}$ kg of H2 is converted in to Through that nuclear reaction the mass loss is $4x10^{3}$kg, converted to energy using Einstein Relation (E $=mc^2$). The intensity of the solar radiation on the earth surface is 1353 Wm^{-2}. That much of energy is absorbed to atmosphere, Infra red attenuates by the water vapor, and Ultraviolet attenuates by the Ozone Layer. The existence of nearly all the life on the earth surface is nearly fueled by sun. The rest of that energy is absorbed by the dust and aerosols. But the way that collecting energy is important. There are many methods but two of them are popular in the world.

1) The solar energy can be converted in to heat and converted energy is stored in a water body as heat energy.
2) Solar energy can be converted in to electrical energy and that converted energy is stored in Batteries as electrical energy.

The first method is very cheap but that is taken a very large space and the efficiency is low. The device by using second method is taken very small space therefore most of the scientist are interring in that method. Solar cell is one of the devices which is designed by using second method. Most of the solar cells available in market are composed using inorganic specimens. They are very expensive. In this research work, it is stud ied, how to designed a chap solar cell with high efficiency. Actually there are two types of solar cells

1) Organic Solar Cell (OSC)
2) Non Organic Solar Cell

The OSC is high efficient and very hard. The OSC composed by using Group IV elements in periodic table, especially silicon. Since the purification process of Silicon is very expensive, the price o f solar cell goes up. Even though the pure silicon existed in Sri Lanka, It is not possible to manufacture semiconductor device I Sri Lanka. Because, the purity of quarts which is found in Sri Lanka is 99.98%. That is a considerable purity as compared with the others. But to manufacture a good semiconductor device, it is needed to have 99.9999% of purity. Since quarts are melted to perform the purification process for long time, a huge amount of energy is consumed, and large amount of money is needed to be invested. It is a good sign of turning the Electricity Board in Sri Lanka to the Nuclear Power. The maximum conversion power of present Silicon Solar Cell may be 18%.

Ionically self assembled monolayer (ISAM) films are a revolutionary class of materials that allows detailed structural and thickness control at the molecular level, combined with ease of manufacturing and low cost. A relatively new deposition technique that has been shown to bypass many of the problems of these other methods was first demonstrated by Decher and co-workers in 1991.The technique, referred to here as Ionically self-assembled monolayer (ISAM),utilizes the Coloumbic attraction between oppositely charged polymers to form ultra thin layers of organic polymers in a precisely controlled fashion. The advantage of using ISAM technique for solar cell is to control the thickness of the absorber and donor layers on ITO Glass. The thickness of monolayer is dependent on the PH value of polymer solution and dipping timing. The rate of change of time for immersing and rising of ITO glass is required to be uniform. Otherwise the assembled monolayer on ITO glass is not uniform. The current practice for this purpose is to use a lab jack to raise the beaker up and down relatively with the fixed mounted ITO Glass.

1.2 Electronically Conducting Glass - ITO glass

Indium Oxide, although a semiconductor, is not a particularly conducting material. This is because it lacks any free electrons. Electrons are normally added by doping with a similar element but one that has one more electron that the basic material. So in the case of Indium Oxide we add Tin. At low concentration this fits neatly into the Indium Oxide structure and adds the required electrons as shown in figure 2.

There is an upper limit to the amount of Tin that can be added, as the Tin not onlyadds electrons but reducesthe mobility of these electrons The optimum dopi ng levelis about 5 - 10% of Tin. This Tin doped Indium Oxide is known as Indium Tin Oxide or ITO.

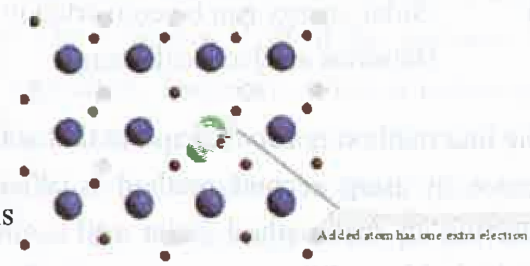

Figure 1: The lattice of Indium oxide doped with Tin.

There is an upper limit on the speed with which electrons can respond to electric or magnetic fields. The electron density in ITO is not as high as it would be in a metal. This means that this response limit is in the infra-red for ITO (whereas it is above the visible limit for a metal). The consequence is that ITO is transparent in the visible but becomes conducting (and therefore reflecting/absorbing) in the infra-red (3 micron wavelength or 1×10^{14} Hz). So at all frequencies below 10^{14} Hz we can use ITO as a shielding material. So to summarize: Indium Tin Oxide (ITO) is a semiconductor material, it is conducting at frequencies in the infra-red and below, and insulating at the frequencies of visible light. So at the frequencies of visible light ITO is insulating and therefore transparent. This means that ITO is transparent to visible light but still electrically conducting at the frequencies of interest for EMC shielding and anti-static applications (GHz to DC).

1.4 Ionically Self-Assembled Monolayer (ISAM) techniques

Ionically self assembled monolayer (ISAM) films are a revolutionary class of materials that allows detailed structural and thickness control at the molecular level, combined with ease of manufacturing and low cost.

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reverses the surface charge. This process can be repeated in the $(AB)_n$ fashion. Until the desired film thickness is obtained. Since deposition requires only that successive layers have opposite ion charge (anion/cation), it is possible to construct films whose structure is more complicated than the $(AB)_n$ bilayer repeat unit. Films with $(ABAC)_n$ structures, for example, have been fabricated and other structure is also possible. This allows polymer layers with different functionality to be easily incorporated into a single film with precise structural control.

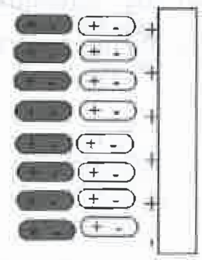

Figure 2: The diagram of two monolayers fabricated on TIO glass

At the beginning the material has complete bonds but in the outer surface, its bond is incomplete. Due to this incompletement, surface of the material has very little spontaneous charges. Some opposite polar material can be attached on the surface of the material due to the presence of these charges. Therefore we use this technique to fabricate poled po lymer on the ITO glasses. ITO glass is used to do this. Since the ITO surface is electronically negat ive surface poled polymer can be attached on it.

Since this outer surface of ITO glass has incomplete bonds, some coulomb charge may exist on those points. Then if we dip this glass in a solution which has polarity, the molecule's opposite polar points will attract to that point and make a bond with the glass surface. Now the other pole of the molecule is opened to the outer surface and again it will act as a charged point. Then the other layer can be fabricated on the ITO glass. This monolayer is known as the self assembled monolayer.

1.4 Characterization techniques (UV-Visible Absorption Spectroscopy)

Ultra violet-Visible spectroscopy (UV/VIS) involves the spectroscopy of photons in the UV Visible region. It uses light in the visible and adjacent near ultraviolet (UV) and near infrared (IR) ranges. In this region of the electromagnetic spectrum, molecules undergo electronic transitions. The technique is complementary to fluorescence spectroscopy. UV-Visible spectroscopy is routinely used in the quantitative determination of solutions of transition metal ions and highly conjugated organic compounds. Solutions of transition metal ions can be colored (i.e. absorbs visible light) because the electrons within the metal atoms can be excited from one electronic state to another. The color of metal ion solution is strongly affected by the presence of other species, such as certain anion or legends. For instance, the color of dilute solution of the copper sulphate is light blue, Adding ammonia intensified the color and changes the wavelength of maximum absorption (λ) Organic compound, specially those with a high degree of

max

conjugation, also absorbs light in the UV or visible regions of the electromagnetic spectrum. The solutions for these determinations are for water soluble components, or ethanol for organic-soluble compounds. (Organic solvents may have significant UV absorption; not all solvents are suitable for use in UV Spectroscopy. Ethanol absorbs very weakly at most wave lengths) Solvent polarity and pH can affect the absorption spectrum of an organic compound. While charge transfer complexes also give rise to color, the colors are often too intense to be used for quantitative measurement. The Beers-Lambert law states that there is a logarithmic ratio of incident light intensity and transmitted light intensity depend on the product of the absorption coefficient of the substance, α,and the distance the light travels through the material, ℓ, and concentration of the material, *d*.

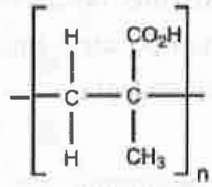

Figure 3: Chemical Structure of PMA

2. Materials

PMA solution is used as the Electron Accepter material and IUPAC name of PMA is Poly (methacrylic acid,Sodium salt),40wt% solution in water (PMA-5000 gmol-1). The chemical structure is given in the figure 3.

MEH-PPV solution (Dye) is used as Electron Donor material and IUPAC name of MEH-PPV is Poly [2- methoxy-5-(2'-ethyl-hexyloxy)-1, 4- Phenylene vinylene] (MEH-PPV- 85000gmol-1). The chemical structure of MEH-PPV is given in the figure 4.

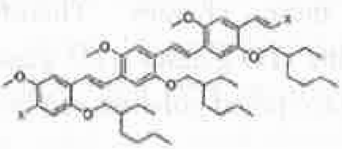
Figure 4: Chemical Structure of MEH-PPV

3. Experimental

4.1 Preparation of PMA solution

Since the molar weight of PMA is $5000 gmol^{-1}$ 12.5grams of pure PMA should be solved ml of 0.1M NaCl solution (pH=2.5) to prepare 10mM of PMA solution. Since the pur solution is 40% 3.125grams of PMA solution was measured and it was dissolved with NaCl solution (pH=2.5) till the whole volume gets 25ml

4.2 Preparation of MEH-PPV solution

Since the molar weight of PMA is $5000 gmol^{1}$, 3.25grams of MEH-PPV was measured : was dissolved with Toluene till the whole volume gets 5ml.

4.3 Arrangement of ITO Glass

First 2x1cm^2 size ITO glass pieces were cut down. All the impurities were removed, having washed with Tepol and again the samples were thoroughly washed using distilled water to remove Tepol on ITO glass. After that, the washed ITO Glasses were dried using hot air flows. They were laid on the flat Pyrex vessel (keeping the conducting side is top) and kept in the desicator under vacuum to prevent growing of fungus on the conducting side and the dust. Those ITO glasses were taken to fabricate the polymer films on it.

4.4 Preparation of Elevation Machine

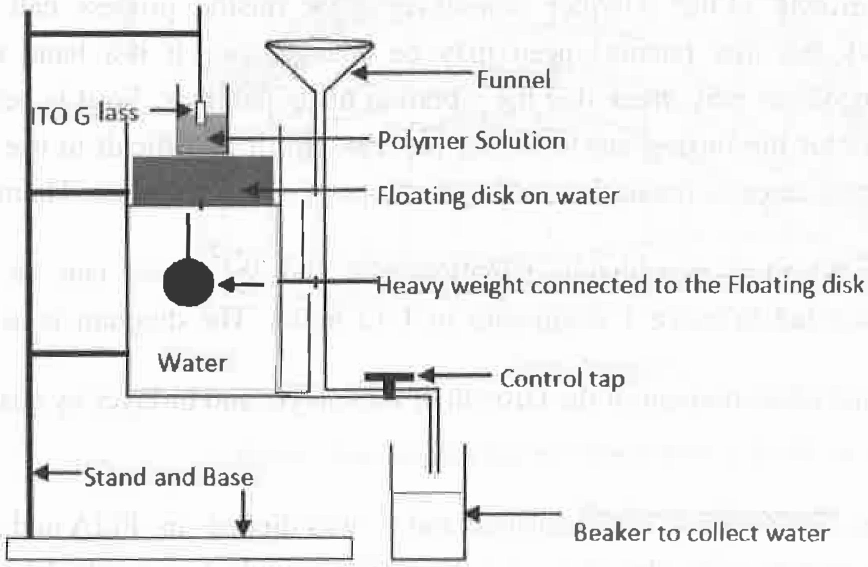

Figure 5: The apparatus used for polymer fabrication

When water poured is into the funnel the water it slowly fills a large tank and the floating disk moves up with the beaker of polymer solution. So automatically ITO glass is dipped into the polymer solution. After the control tap was opened and slowly a monolayer of polymer sample was fabricated on the ITO Glass. The control tap can be used to adjust flow rate and then the removing speed of ITO glass from the polymer sample can be changed. Here the floating media is rigid foam; the beaker cannot be kept on the rigid foam media at once. Therefore heavy weight was connected to the bottom of the rigid foam disk to lower the center of gravity of the system and to get it from meta-stable position to stable position. The fabrication behavior of the solution during the dipping and removal process of the sample is shown in the figure below.

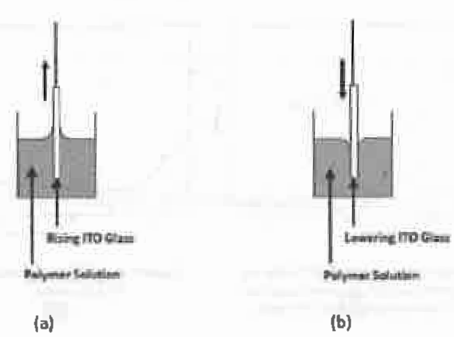

Figure 6: The side view of the beaker with solution (a) when the sample was removing, (b) when the sample was dipping

The polymer sample should be completely wet on the conducting side of the ITO glass. Otherwise it is difficult to fabricate the solution on the conducting side. Since the fabrication of non conducting side is not necessary, a thin adhesive sheet was stick on that side to prevent fabrication.

4.5 Fabrication of PMA and MEH-PPV by ISAM technique

For this technique the ITO sample was mounted using a crocodile clip. Then instead o f dipping the sample into the solution, the beaker was raised up and lowered down. The raising speed strongly influences the growth of the polymer monolayer. That raising process can be done manually using a lab jack but that raising speed may be change since it is a hand operating process. And also the monolayer may break due the vibration of the lab jack. So it is better if we use an automated process for the raising and lowering process. But it is difficult to use a motor, because the monolayer may crack or break due to the vibrations of motor armature. Therefore I

designed a new device which is completely vibration free and the speed can be adjusted deliberately. It can be adjusted to move 1 centimeter in 1-12 hours. The diagram is as follows.

4.6 Sample Preparation and Measurement of the Growth of monolayer and bi-layer by absorption spectra

First the light absorption of ITO glass was measured and it was dipped in PMA and after ten minutes it was removed slowly using the above machine. The sample was washed by distilled water to remove other non fabricated polymer molecules. The cleaned sample was dried by using hot air flow. After that light absorption was measured. Again the sample was dipped in MEH-PPV solution for ten minutes in order to prepare a bilayer, the light absorption was measured of it. This process was done alternatively more than ten times.

5. Results

5.1 Optical Properties of PMA and MEH-PPV.

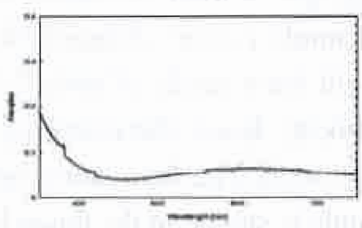

Figure 7: The Absorption Spectrum of Pure ITO Glass

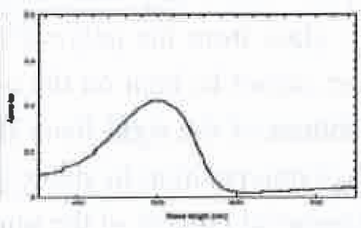

Figure 8 The Absorption Spectrum ITO with MEH-PPV Monolayer

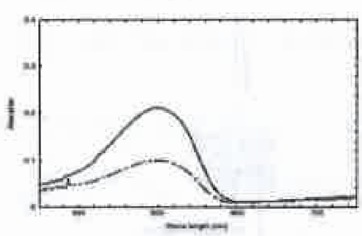

Figure 9: The absorption spectrum of MEH-PPV; Solid line Is the absorption spectrum just after fabrication and dashed line represents the absorption spectrum after 120 seconds

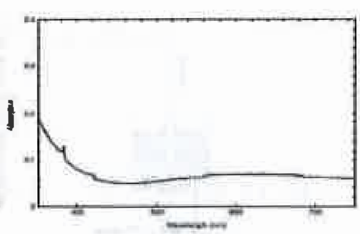

Figure10: the Absorption Spectrum of ITO with PMA Monolayer

5.2 Growth of Monolayer by Absorption Spectrum

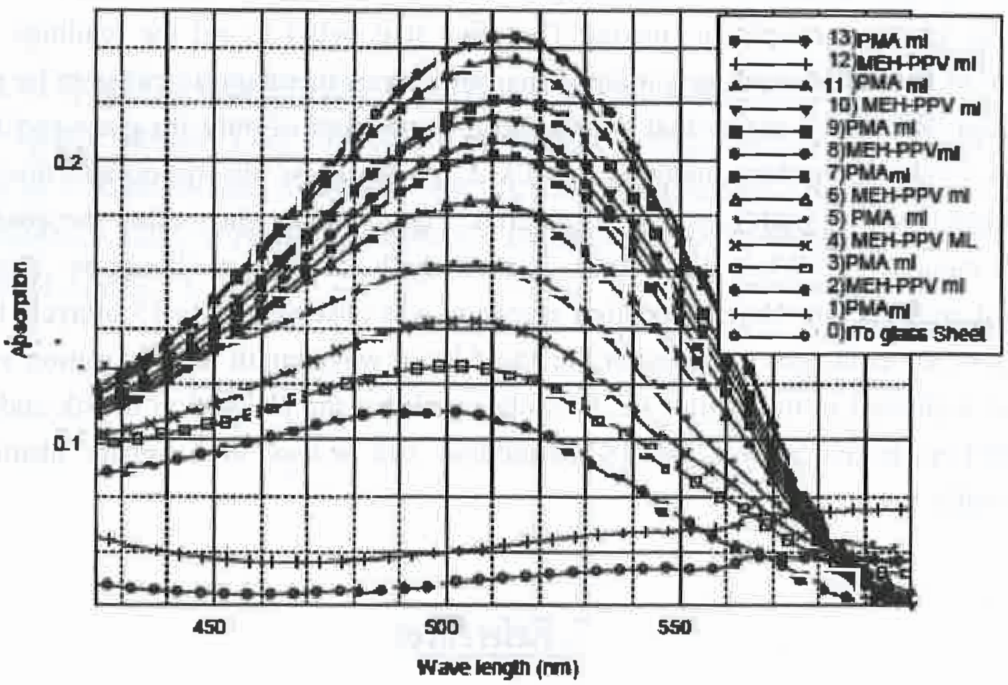

Figure11: The Absorption Spectrums of each PMA/MEH-PPV bilayers

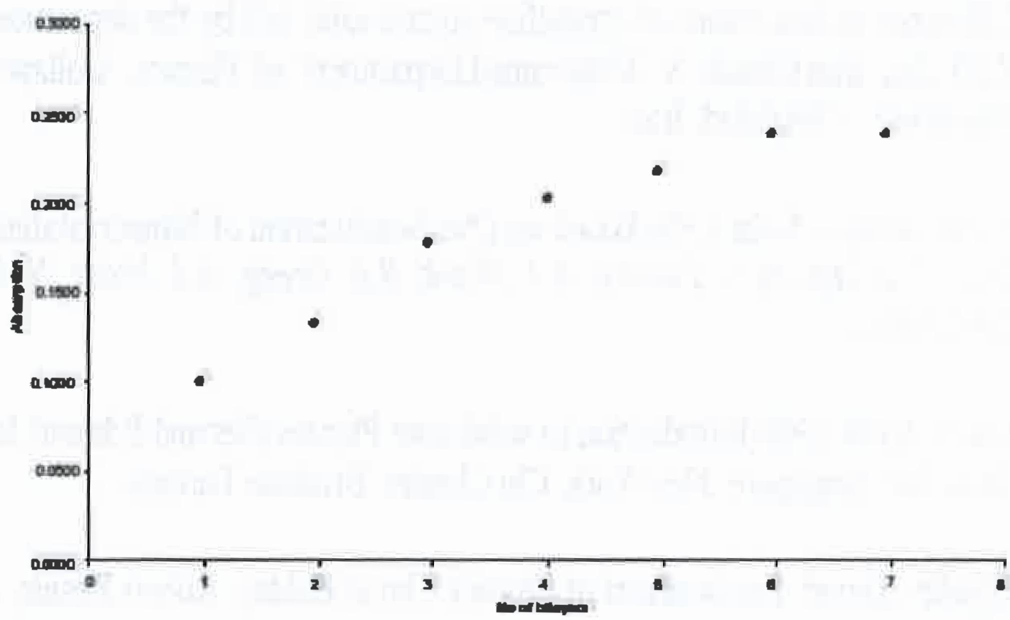

Figure 12: The Absorption value of each monolayer at 520nm.

6. Conclusion

Here figure seven shows that the absorption spectrum above 300nm is very less .Therefore this type of glasses can be used as the UV filter media. Figure eight shows that it gives the maximum absorption at around 500nm.Therefore MEH PPV is a light good absorber and MEH-PPV can be used as the electron donor material. Figure nine shows that the absorption of material decreases with time in the atmospheric media. Therefore it is better to get the readings as much as it is possible to get rid of the degrigation of the polymer or this experiment is to be done in the inert gas media. Figure ten shows that the absorption spectrum of pure Ito glass and PMA is coincide together. Then it can be concluded that PMA has very low absorption and this type of material can be used as very high transparent material. Figure eleven shows that the absorption spectrum of each monolayers. When the bilayer is growing the absorption should be increased according to Beer-Lamberts law. Here absorption spectrum was observed up to 15 bilayers but 13th14th15th monlayers are coincides all together.For the 520nm wavelength the absorption versus number of bilayers is plotted in the Figure 12. It is observed that the absorption of 6th and 7th bilayers are same and up to five bilayers this ISAM method can be used to fabricate absorbers and donors successfully.

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