Effect of Different Metal Contact on MEH-PPV for Organic Solar Cells Application

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Abstract- **This paper focuses on the characterization of electrical, physical and optical properties of Organic Solar Cells (OSC) depending on the type of metal contact. The active layer of the sample is prepared by dissolving polymerpoly [2-methoxy-5-(2-ethylhexyloxy)-1, 4 phenylene-vinylene](MEH-PPV) with Tetrahydrofuran (THF). The active layer was deposited on top of the substrate using the spin coating technique. Then, the metal contacts were deposited. Type of metal contacts that involved in this experiment are Silver (Ag), Gold (Au) and Platinum (Pt). The samples were characterized on their physical and optical properties. Besides the effect of metal contact on MEH-PPV, this research is also done to investigate whether the thickness of the polymer will affect the optimization of OSC properties. The sample with the number of 5 times (active layer being deposited) has the best optical and physical properties. This sample is then taken into consideration for investigation of electrical properties. Metal contact of Ag, Au and Pt were deposited on these samples and it was observed that Ag portrays good conductivity.**

Keywords*-Organic Solar Cells, metal contacts, MEH-PPV, THF*

I. INTRODUCTION

Organic electronics is a future-oriented green technology involving environmentally-friendly energy generation, economical energy use and the manufacture of electronic components in a way which protects resources, using conducting and semi-conducting plastics. [1]

One of the technologies that have been further developed is Organic Solar Cell (OSC). OSChave a number of potential advantages such as lower production cost and flexibility[2].First significant 1 % efficiency was achieved by introducing the bilayerheterojunction concept between p- and n-type organicsemiconductors [3].So, since the pioneering work of Tang [Tang, Appl.Phys. Lett., 1986] the interest devoted to OSC has been raising very fast, whichhas undergone a gradual evolution of the energy conversion efficiency, η, from less than 1%to more than 5% [Kim et al., Sciences, 2007, Xue et al., J. Appl. Phys., 2005].

These significant progresses demonstrate that OSC are a potential avenue to low cost nextgeneration solar cells[4].In the fabrication of organic electronics poly [2-methoxy-5-(2-ethylhexyloxy)-1, 4 phenylene-vinylene] (MEH-PPV) has been extensively used [5].

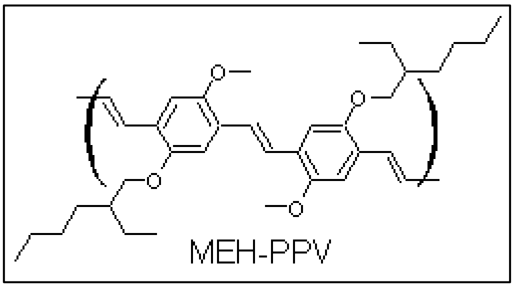

Figure 1: Chemical structure of poly [2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene]

Its asymmetric alkoxy side chains make MEH-PPV soluble in common organic solvents such as tetrahydrofuran (THF), chloroform, xylene, and toluene [6]. The THF-cast gives an increase in excimer emission. It was attributed to the formation of polymer aggregates (MEH-PPV), which yielded that better interaction between polymer chains led to increased excimer emission [7,8]. It is very important to understand the relationship between the morphology and the processing conditions, and their influence on the electronic and photonic properties of polymer thin films. Among the many parameters which can affect the optical properties and surface morphology of the bulk-heterojunctionsolar cells are the composition between donor and acceptor [5,9, 10, 11], the solvent used to make blend solutions [12, 13] and the thickness of the active layer [14, 15].

Despite its low cost in production, organic-based solar cells are not competitive because its power conversion efficiency is still too low, poor long-term environmental stability and its lifetime is too short. Some efforts are still necessary to improve the cell efficiency and lifetime [16].

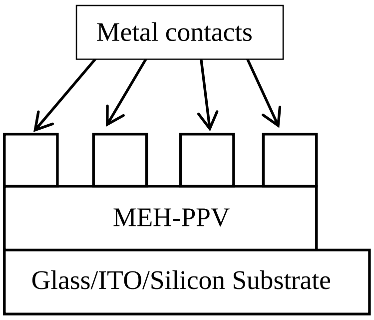

Figure 2: Organic Solar Cell structure

The main purpose is to find out how the OSCefficiency can be improved. There are various methods and materials used in this matter.In this research, the manipulative variable is metal contact. Metal nanoparticles were used to achieve plasmonic enhancement of small molecule OSC [17, 18].The plasmonic effects produced an increase in the optical absorption [19]. The conductivity is different for different type of metal. Silver, gold and copper colloids have been reported to be the major focus of interest because of their unique optical properties determined by the collectiveoscillations of electron density termed plasmons, which give rise to an intense absorption in the near UV-visible [20]. This leads to the investigation of type of metal contact that will be experimented in this research. Hencetype of metal that will be used are Silver (Ag), Gold (Au) and Platinum (Pt).These metals behaved differently according to their properties.The fabrication of the organic solar cell in this study was completed by preparing an active layer (MEH-PPV and THF) and for each experiment the layer was varied. The number of layers that were experimentedwas 1, 3, 5, 7 and 9.The characterizations involved are electrical, physical and optical properties.

II. EXPERIMENTAL PROCEDURES

A. Fabrication Procedures

Glass, Indium Tin Oxide (ITO) and Silicon were used as substrates in this experiment. Glass and ITO were cleaned in the following sequence: firstly they were soaked with Aceton and cleaned ultrasonically in the sonic bath for 10 minutes. Next, they were immersed in Methanol and cleaned ultrasonically in the sonic bath for 10 minutes. Finally, they were cleaned ultrasonically in the sonic bath for 10 minutes with DI water. For these three steps, the substrates were rinsed by using DI water subsequently. For substrate that using Silicon, an additional step is required. After the three steps, Silicon substrate was immersed in a solution of Hydrofluoric Acid (HF) and DI water with a ratio of 1:10. Then, it was cleaned with DI water ultrasonically in the sonic bath for 10 minutes. Finally all the substrates were dried by blowing nitrogen gas.

The next process step was active layer deposition. The active layer was prepared in the following step. First, 40 mg of MEH-PPV is dissolved in 10ml THF. Then, it was let to be stirred at 600rpm for 48 hours. The active layer solution was spin coated on top of theGlass, Silicon and ITO substrate with a spin speed of 2000rpm for 40 seconds.

Finally for metal deposition, the method used is sputtering. To deposit the Gold (Au) and Platinum (Pt) contact, a layer of mask is placed on top of the substrate and was sputtered. For the deposition method of Silver (Ag) as metal contact, it was sputtered in Electron-beam thermal evaporator (E-beam evaporator) at the thickness of 60 nanometer. Ag is deposited by applying this method is due to its low melting point.

The fabricated samples are classified based on the number of times of active layer being deposited. Thus, the sample will be named accordingly.

Table 1:Sample's name

1 time	3 times	5 times	7 times	9 times
Sample A	Sample B	Sample C	Sample D	Sample E

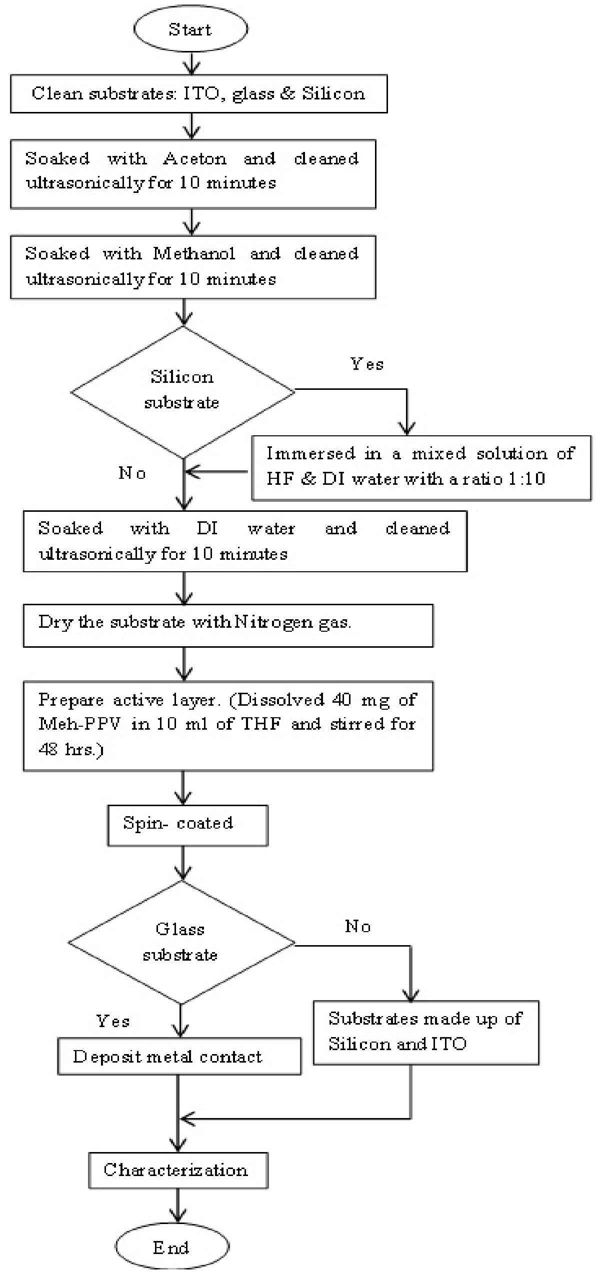

Figure 3: Process Flow

B. Characterization Procedures

There are three properties that were being measured; electrical, physical, and optical.For electrical properties, current in dark and under illumination has been measured by the implementation of solar simulator. Then, the result obtained is then plotted in a graph by using software Origin Pro8. For physical properties, the thickness is measured by using surface profiler, FESEM and AFM. Lastly, in measuring optical properties such as absorbance and transmittance in light is measured by using UV-VIS/NIR Sprectophotometer.

III. RESULTS AND DISCUSSION

A. Physical Properties (Thickness)

Table 2: Thickness of samples

Sample	**ASH (nm)**
A	71.73
B	119.76
C	116.92
D	165.98
E	277.40

Table 2 shows the results of the thickness of the samples. It can be seen that the thickness shows a trend whereby, as the number of times increases, the thickness also increases.The nanostructured layers of thin film allowed effectiveness absorption of the optical path. Light generated electrons and holes travel over a much shorter path [21]. The thickness also affects the resistance of the sample. Thick active layer will results in high resistance. Thus, this will cause a drawback in current value [22].Otherwise, resistance is low. Decrease in layer thickness enhanced the mobility of electrons [23].

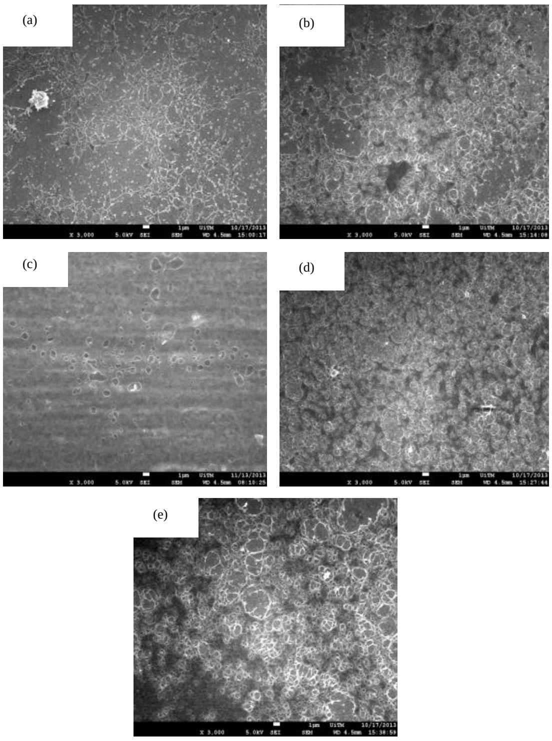

Figure 4: FESEM images (a) sample A (b) sample B (c) sample C (d) sample D (e) sample E

Figure 4 (a) represent FESEM image of sample A. Figure 4 (b) is the results of sample B. Figure 4 (c) is the image of sample C. Figure 4 (d) illustrates the result of sample D. Figure 4 (e) show structure of sample E. Sample B, D and E have dark spots on certain places. This indicates that the sample may have burned. Sample C has the least porous structure and it is the most compact. A compact sample means that it is dense.It allows more photons to be absorbed. Therefore, in optical properties sample C is expected to have a high absorbance.

B. Optical Properties

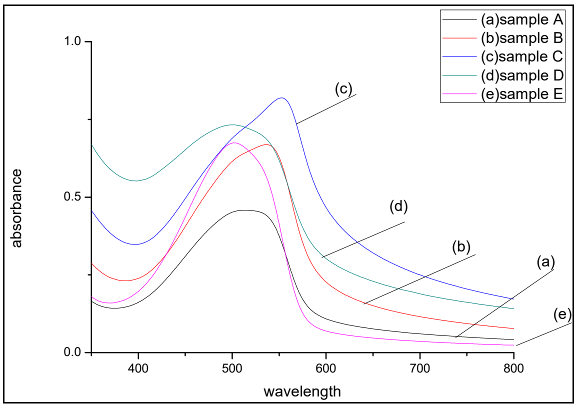

Figure 5: Absorbancespectra of MEH-PPV thin film

Figure 5 show the absorbance spectra of MEH-PPV thin film of all 5 samples. It can be observed that the absorption of light increases as it approaches 500nm and increasing towards 600nm.MEH-PPV has a strong enhancement in the photoinduced charge generation which happened to be observed particularly in the red spectrum[24].The absorption of sample C is the highest compared to the others. The second highest is sample D. For sample B and sample E, the value of absorption is much less the same. However, sample E started to absorb 450nm whereas sample B started to absorb at 500nm. 1 time sample has the least absorption. This is mainly because MEH-PPV polymer acts as the sensitizer in absorbing light at 500nm[9]. Pure MEH-PPV has the absorption peaks located at ~ 507nm [6]. Thus, the absorbance of all the samples is at the same range.

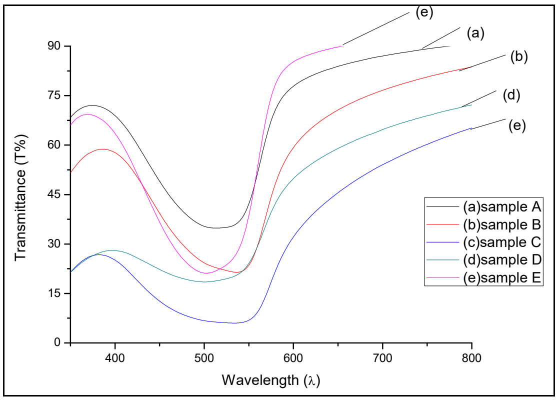

Figure 6: Transmittance spectra of MEH-PPV thin film

Since sample C has the highest absorbance value, thus it has the lowest transmittance value 6T%. Therefore,sample A has the highest transmittance value 37.5T%.From transmittance data, the absorption coefficient (α) can be calculated. $\alpha$was obtained through Lambert's law, which is indicated by the following relation:

$$\propto = \frac{1}{t}\ln\left(\frac{1}{T}\right)$$

t is thickness, T is transmittance [25].

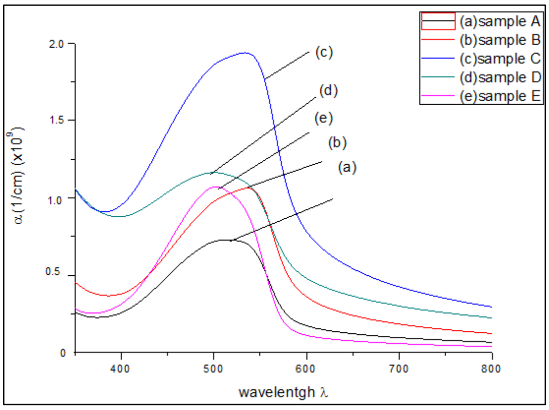

Figure 7: Absorption Coefficient

Figure 7 show absorption coefficient of MEH-PPV thin film. Sample C has the highest absorption coefficient with a value of $1.89x10^{9}$((1/cm). So, a large amount of light can be absorbed.

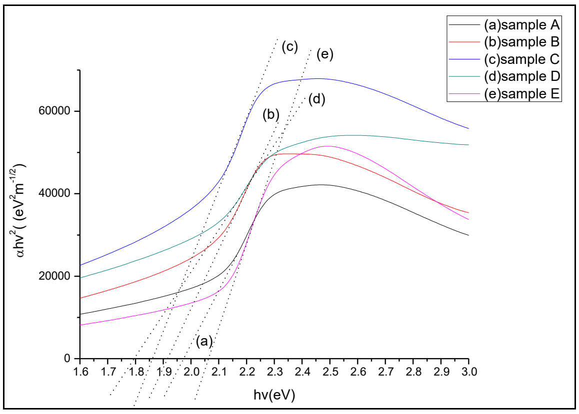

Figure 8: Tauc plot

Table 3. Optical band gap of samples

Sample	**Optical Band Gap (eV)**
A	1.97
B	1.91
C	1.86
D	1.80
E	2.06

The value of optical band gap was determined using Tauc's plot. The results show that there is no fluctuation in the optical band gap according to the number of times of the samples.Sample C has the second lowest optical band gap that 1.83eV. Lower optical band gap allows electron excite to LUMO (lowest unoccupied molecular orbital) easily which causes higher photo absorption. Thus, sample C has the highest absorbance.

C. Electrical Properties

Sample C has shown a trend in physical properties and also optical. It has the least thickness and it is the least porous. Since sample C is compact, it avoids any penetration and the layer will be protected. Therefore, a lot of photons can be absorbed and optical band gap is proven to be low. Subsequently, the behaviour of sample C in electrical measurement is then observed.

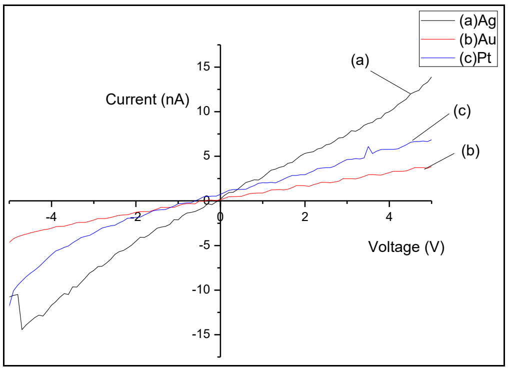

Figure 9: I-V measurement under illumination

Figure 9 shows current measured under illumination for sample C. Under illumination Ag has the highest value of current, whereas Au has the lowest.

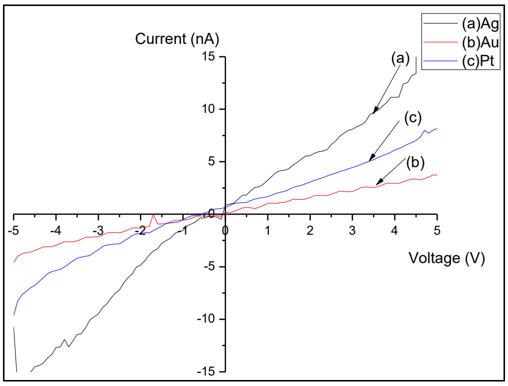

Figure 10: I-V measurement in dark

Figure 10 shows sample C measured in dark. Also in dark, Ag's current is the highest. By comparing figure 9 and 10, it is clearly seen that the resistance under illumination (figure 9) is higher than the resistance in dark (figure 10). The current in dark is also higher than under illumination. Since resistance is inversely proportional to current, it will increases as current decreases. This indicates that sample C has been degraded. Specifically, the material of thin layer which is MEH-PPV is sensitive towards light. The samples were not supposed to be exposed in light.

Based on the current; resistivity, photoconductivity (conductivity under illumination) and conductivity (in dark) can be obtained. Ag has the highest conductivity in dark as well as under illumination which is 9.95$x10^3$(S/cm) and 1.026$x10^{-4}$(S/cm respectively. The conductivity is higher than the photoconductivity. This is due to the value of resistivity of sample C under illumination higher than in dark.

Table 4:Photoconductivity and conductivity of samples

	Ag	Au	Pt
Photoconductivity (S/cm)	1.03 $x10^{-4}$	2.70 $x10^{-5}$	8.25 $x10^{-5}$
Conductivity (S/cm)	9.95 $x10^3$	3.76$x10^4$	1.2$x10^4$
Ratio (photoconductivity/ conductivity)	1.01 $x10^{-8}$	7.08 $x10^{-10}$	6.55 $x10^{-9}$

Based on the results in Table 4, it can be seen that Ag has the highest photoconductivity. It also gives the highest ratio. Theoretically, in the work function of metal, Pt has the highest work function that is 5.63φ/eV. Whereas Au's work function is 5.28φ/eV and Ag has the lowest work function which is 4.29φ/eV [26, 27]. Work function is the energy required to extract an electron[27]. In comparison of sample C to other samples, it has low optical band gap which allows the electron to excite easily. However, in this research Ag gives an unexpected result. This is probably due to the method of metal deposition. Ag is deposited on sample C by using E-beam evaporator while Au and PT were deposited using sputter-coater. The advantage of E-beam evaporator is that it permits direct transfer of energy to source during heating and very efficient in depositing pure evaporated material to substrate. Also, deposition rate in this process can be as low as 1 nm per minute to as high as few micrometers per minute [28]. On the other hand, Sputtering uses a plasma, which produces many high-speed atoms that bombard the substrate and may damage it [29].The purity of the deposited film depends on the quality of the vacuum, and on the purity of the source material [30] which in this case the source is Ag.

IV. CONCLUSION

Under illumination, the resistance and resistivity is too high which causes the photoconductivity to be very low compared to the conductivity in dark. The photoconductivity of Ag is higher than other metal contact which explains that under illumination and in dark it has higher currentthan other type of metal.

ACKNOWLEDGEMENT

The author thanks PuanPuteri Sarah bt Mohamad Saad for her continuous support and helpful advices. Also special thanks to staffs of NANO-ElecTronic Centre, UiTM.

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puttering process involves ejecting material from a “target” that is a source onto a “substrate” (such as a silicon wafer) in a vacuum chamber. This effect is caused by the bombardment of the target by ionized gas which often is an inert gas such as argon. Sputtering is used extensively in the semiconductor industry to deposit thin films of various materials in integrated circuit processing. Anti-reflection coatings on glass for optical applications are also deposited by sputtering. Because of the low substrate temperatures used, sputtering is an ideal method to deposit metals for thin-film transistors. Perhaps the most familiar products of sputtering are low-emissivity coatings on glass, used in double-pane window assemblies. An important advantage of sputtering is that even materials with very high melting points are easily sputtered while evaporation of these materials in a resistance evaporator or Knudsen cell is difficult and problematic

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