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Effect of Surfactants to The Electrical Properties of The Hole Transporting Layer of Organic Solar Cells

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Abstract

Nowadays, Organic Solar Cells (OSC) become one of the alternatives to replace inorganic solar cells towards roll-to-roll process. For OSC, hole transporting layer (HTL) plays an important role as this layer also contributes to the increase in efficiency of OSCs. The conductivity of HTL increases the efficiency of charge collection at anode. In this study, the effect of different surfactants which are dimethyl sulfoxide (DMSO) and Triton X-100, covering different concentrations and temperatures toward the HTL conductivity are studied and analyzed by using two-probe method. It is found that the conductivity of HTL increases by concentration as well as higher temperature, meanwhile DMSO shows higher conductivity than Triton X-100.

Keywords: *Hole transporting layer, surfactants, conductivity.*

1. Introduction

Inorganic solar cells have some limitations in terms of processing methods and moving towards flexible substrates. One of the alternatives to overcome the limitations is by using Organic Solar Cells (OSC). In OSC, it is possible to fabricate the cells by using solution process which is also suitable for roll-to-roll (R2R) process [1]. OSC consists of several functioning layers such as indium tin oxide (ITO), hole transporting layer (HTL), active layer (AL) and metal electrode which is usually either gold (Au) or silver (Ag). It is important to have high conductive HTL in order to improve the efficiency of the OSC. One of the most widely used HTL is poly(3,4-ethylenedioxythiophene): poly (styrene sulfonate) (PEDOT: PSS) [2]. Although it has disadvantages such as degrading the metal electrode in inverted structure [3], it is still widely used as a HTL. Sorbitol dimethyl sulfoxide (DMSO) and ethylene glycol (EG) are commonly used surfactants to increase the conductivity of the PEDOT: PSS [4-6]. Triton X-100 is another surfactant that is used to improve the wettability of PEDOT: PSS on other polymer layers [6-7]. Still very few researches have been conducted to investigate the effect of Triton X-100 to the conductivity of the PEDOT: PSS film. To further investigate the effect of surfactant to the HTL conductivity, in this study we add Triton X-100 and DMSO at different concentration to the PEDOT: PSS Clevios PH1000. Two probe method is used to measure the resistivity before converting to the conductivity [8].

2. Materials and Methodology

The glass substrates are cleaned by sonicating them for 10 minutes in acetone, deionized water and isopropanol, respectively. PEDOT: PSS CLEVOIS PH 1000 is purchased from Heraeus, meanwhile DMSO and Triton X-100 are purchased from Sigma Aldrich. PEDOT: PSS solutions are prepared with different conditions which are PEDOT: PSS only, PEDOT: PSS with 1.0 wt% and 2.0 wt% of DMSO, and PEDOT: PSS with 1.0 wt% and 2.0 wt% of Triton X-100. The solutions are stirred for 5 hours before spin coated on the substrates at 1000 rpm for 60 seconds. Then, the substrates are heated at 200°C for 10 minutes. The resistivity of the substrates is measured by using two probe system with a Keithley 2450 source meter and calculated using Eq.1 before converted to the conductivity by using Eq.2. The surface morphologies are characterized by using Scanning Electron Microscope (SEM).

$$\rho = \frac{VA}{IL} \qquad (1)$$

$$\sigma = \frac{1}{\rho} \qquad (2)$$

where,
$\rho = resistivity\ (\Omega m)$;
$V = voltage\ (V)$;
$A = cross\ sectional\ area\ \left(m^2\right)$;
$I = current\ (A)$;
$L = length\ (m)$;
$\sigma = conductivity\ (S/m)$.

3. Results and Discussion

3.1 Effect of Temperatures to The PEDOT: PSS Conductivity

Table 1 summarizes the effect of heating the PEDOT: PSS without any surfactant from 0°C to 200°C. At 0˚C, the conductivity of the substrate is 2.77 $\times 10^{-4}$ S/m. After heated to 200˚C, the conductivity increases to 1.67 $\times 10^{-3}$ S/m which is an increase about 6 times higher than the substrate without heating. These results show that, by heating the pristine PEDOT: PSS alone can improve its conductivity.

Table 1: Effect of temperatures to the conductivity of pristine PEDOT: PSS.

Temperature of	Conductivity, σ (S/m)
0	2.77×10^{-4}
200	1.67×10^{-3}

3.2 Influence of Surfactants to The Conductivity of PEDOT: PSS

In this work, DMSO and Triton X-100 are chosen as the surfactants. PEDOT: PSS solutions are added with 1.0 wt% and 2.0 wt% of DMSO or Triton X-100 and heated at 200°C for 10 minutes before being measured for the conductivity. It can be observed that by adding 1.0 wt% DMSO into PEDOT: PSS, the conductivity increases from 1.67×10^{-3} S/m to 4.61×10^{-3} S/m. When higher concentration of DMSO 2.0 wt% is added, the conductivity is further increased about 10 times as compared to that of the pristine PEDOT: PSS substrate. The trend is depicted in Figure 1.

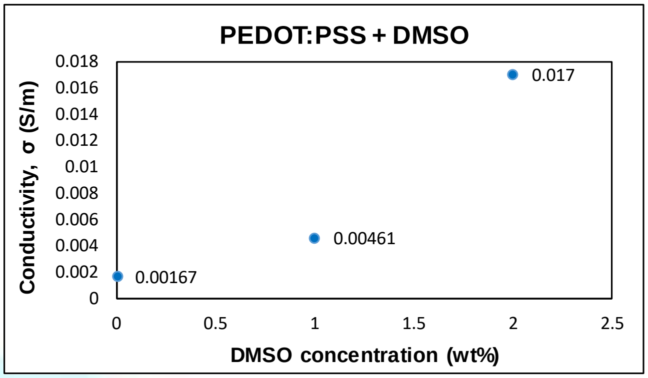

Fig. 1: Conductivity of PEDOT: PSS films at different DMSO concentrations.

Compared to DMSO which is widely used as a surfactant to increase the conductivity of PEDOT: PSS PH1000, Triton X-100 on the other hand is usually added to PEDOT: PSS to reduce the contact angle of PEDOT: PSS on the active layer such as P3HT: PCBM rather than to improve the conductivity [6-7]. The conductivity of pristine PEDOT: PSS is compared to that of the PEDOT: PSS added with 1 wt% and 2 wt% of Triton X-100.

Pristine PEDOT: PSS records a conductivity of 1.67×10-3 S/m. By adding 1.0 wt% of Triton X-100, the conductivity increases significantly to 8.45×10-3 S/m. The conductivity slowly improves about 5 times compares to the pristine PEDOT: PSS, when 2.0 wt% of Triton X-100 is added. Figure 2 shows the trend of conductivity at different concentrations. Although the conductivity of the Triton X-100 is lower than the DMSO, it proves that Triton X-100 not only could be used to reduce the contact angle of PEDOT: PSS on the active layer but also to improve the PEDOT: PSS conductivity.

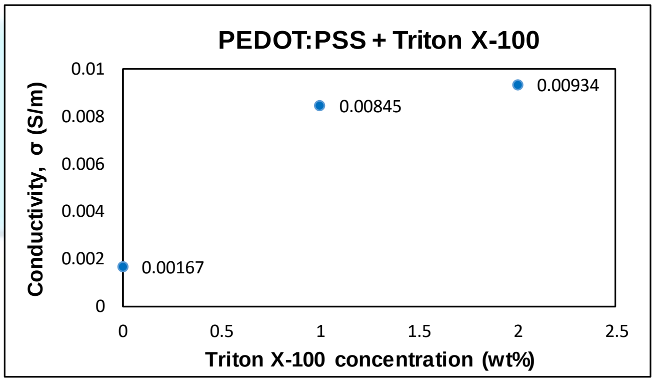

Fig. 2: Conductivity of PEDOT: PSS films at different Triton X-100 concentrations.

3.3 Effect of DMSO to The Surface Morphology Of PEDOT: PSS

The surface morphologies of pristine PEDOT: PSS and PEDOT: PSS added with 2.0 wt% of DMSO which are characterized by using SEM (not shown here) does not show any significant difference, which means that the small amount of concentration of the surfactant added to the PEDOT: PSS solution does not change the surface quality of the PEDOT: PSS films.

5. Conclusion

Based on the findings, it can be concluded that temperature is one of the parameters that can improve the conductivity of pristine PEDOT: PSS PH1000. Apart from that, by increasing the surfactant concentration such as DMSO and Triton X-100, it leads to higher conductivity. Although DMSO shows higher concentration than Triton X-100, but Triton proves that it can act as both wetting surfactant and improving the PEDOT: PSS conductivity which could lead to a higher power conversion efficiency of OSC. Finally, the low concentration of the surfactant does not affect the surface morphologies of the PEDOT: PSS films.

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