Conductivity and Work function Study of PEDOT:PSS with Different Shaking Times

Charity Diamonon, Sebastian Valbuena, Dr. Weining Wang

Department of Physics, Seton Hall University, South Orange, NJ 07079 U. S. A.

Abstract

Conducting polymers are recognized because of their ability to replace expensive and often heavy metals and semiconductors on solar cells because of their high conductivities and high work functions. They have shown much potential because they are transparent, inexpensive, and easy to create as well as work with. Conducting polymers and the research towards improving them also improves the fields of optoelectronics and renewable energies.

The purpose of this research is to discover two relationships: the relationships between the shaking time, the conductivity of the polymer solution, and the polymer solution's work function. The properties concerning conductivity and work function are especially important factors when creating solar cells. Studying these relationships between the polymer and its resulting conductivity and work function will help to create more efficient, new generation solar cells.

Introduction

The purpose of this research is to study two relationships between the PEDOT:PSS/DMSO polymer solution's shaking time and its resulting conductivity and work function. The conducting polymer at the focus of this research is poly(3,4 -ethylenedioxythiophene):poly(styrenesulfate) (PEDOT:PSS), which is mixed with dimethyl sulfoxide (DMSO) to create the polymer solution (PEDOT:PSS/DMSO). The addition of DMSO is known to increase the conductivity of the PEDOT:PSS polymer.

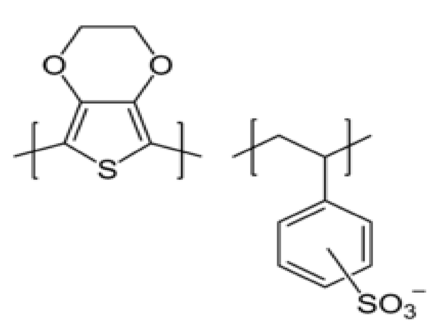

Fig. 1 The Structure of PEDOT:PSS. This is prepared by mixing an aqueous solution of PSS with EDOT monomer. This results in a solution of sodium persulfate and iron (III) sulfate.

The polymer solution was shaken for a total of four hours; a sample of the solution was taken at one-hour intervals and spin-coated onto glass slides. Gold electrodes were deposited onto each slide—this was done in order to measure the resulting resistance and calculate the conductivity of each sample. The work function for each sample was calculated using the data from Kelvin Probe measurements.

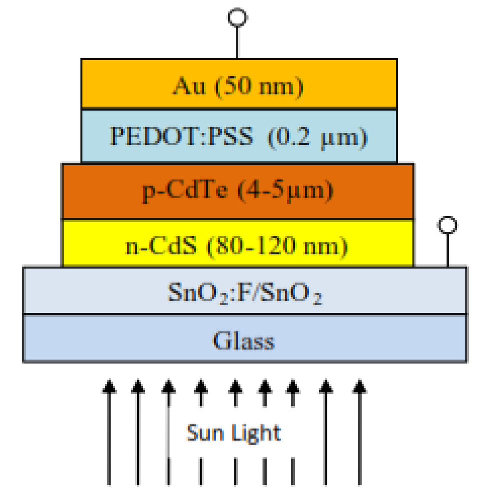

Fig. 2 Device structure for glass/SnO2:F/SnO2/CdS/CdTe with PEDOT:PSS back contact.

Both the conductivity and work function of the polymer solution affect the overall efficiency of the solar cell. The PEDOT:PSS/DMSO acts as a back contact for a solar cell.

In a previous study done with CdTe (Cadmium telluride) solar cells, it was discovered that as the conductivity of the PEDOT solution increased, the more efficient the device became. This can be seen as the polymer's conductivity rose from 0.03 S/cm to 0.24 S/cm, the solar cell's efficiency rose from 2.7% to 5.1%. In addition, the PEDOT:PSS/DMSO solution acts as an ohmic contact with the CdTe. CdTe has a high work function, meaning that if the ohmic contact does not have a compatible work function, a Schottky barrier is created. This barrier is responsible for the loss of electrons, lowering the efficiency of the solar cell by reducing its fill factor.

Equipment Used

Fig. 3 Vortex Mixer is used to shake the polymer solution for the desired amount of time and speed (rpm).

Fig. 4 Spin Coater spin-coats each solution sample onto glass microslides at a certain speed (rpm).

Fig. 5 Cary 60 UV-Vis is used as a Spectrophotometer. The laser in the machine measures absorbance at different wavelengths. This can be used to calculate the thickness of the sample.

Fig. 6 Thermal Vacuum Evaporator evaporates gold (used as electrodes) onto the sample slides.

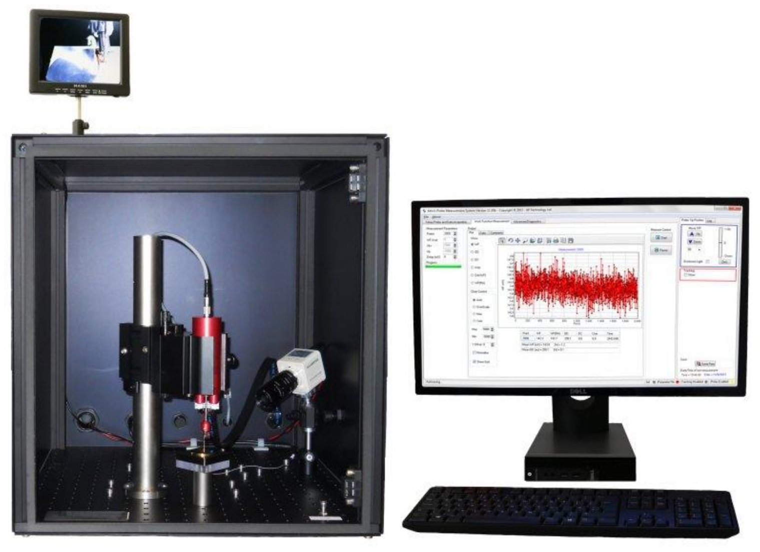

Fig. 7 Kelvin probe technique relies on the detection of an electric field (gradient in ϕ) between a sample material and probe material. The electric field can be varied by the voltage that is applied to the probe relative to the sample. If the voltage is chosen such that the electric field is eliminated, then then we can vary the voltage by a known amount and calculate the difference in work function.

Results

Shaking Time	Resistance (Ω)	Conductivity (S/cm)	Work Function (eV)	Work Function Std. Deviation
1 hour	37.6	217.37	5.22	2.3
2 hours	40.2	320.64	5.25	2.2
3 hours	30.3	372.31	5.31	28.1
4 hours	32.5	305.81	5.32	1.5

Table 3 Displays the results for the conductivity with the PEDOT:PSS and is calculated with:

Thickness: $d = -\frac{\ln(T)}{\alpha}$ Conductivity: $\sigma = \frac{1}{5Rd}$

WF of Tip: $\Phi_T = \Phi_{Au} - CPD_{Au+P}$

WF of Solution: $\Phi_s = \Phi_T + CPD_s$

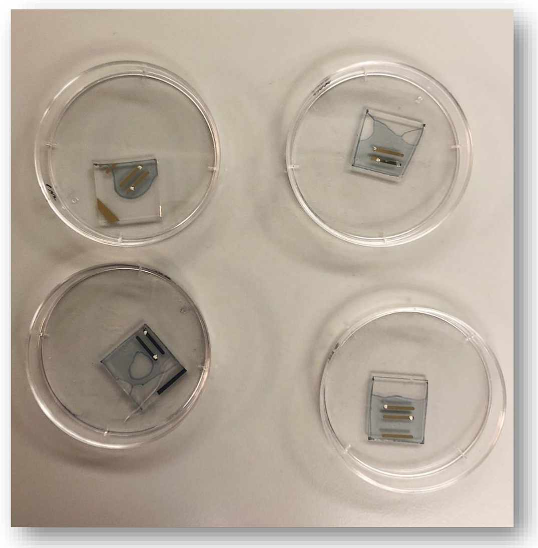

Fig. 8 The slides coated with each hour sample and deposited with gold electrodes

Conclusion

Each sample was successfully made and tested. Based on the results, as the total shaking time increased, both the conductivity and work function of the polymer solution increased. The conductivity of the solution is directly related to the overall efficiency of the solar cell. Although it may seem that a higher work function would be detrimental to the efficiency of the solar cell, with respect to CDTE solar cells, which have a high work function, being able to control and increase the work function of the PEDOT in order to match that of the CDTE is beneficial. Therefore, the 3 hour sample gave the best conductivity and the best work function results. Due to the small sample size tested, however, it is difficult to determine the exact relationship that exists between the shaking, conductivity, and work function. Further testing will be done to make a more firm conclusion.

References

[1] Weining Wang, Naba Raj Paudel, Yanfa Yan, Fernanda Duarte, Michael Mount, Journal of Materials Science: Materials in Electronics, 27(2), 1057-1061 (2016)

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