Study On The Effect of Doping Time of MEH-PPV:I-MWNT Nanocomposite for Organic Solar Cell Application

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Abstract- **In this paper, the properties of nanocomposited MEH-PPV:I-MWNT thin film are reported by varying the time of deposition of Iodine doped multiwall carbon nanotubes (I-MWNT) in CVD (Chemical Vapor Deposition) to 15, 30, 60, 90 and 120 minutes. The I-MWNT is then mixed with MEH-PPV solution then being sonicated for 1 hour. The yielded MEH-PPV:I-MWNT is being deposited on substrates by using spin coating technique. The characterization is to be done to investigate the optical, electrical and physical properties of the thin films.**

Keywords— **Nanocomposited, MEH-PPV:I-MWNT, CVD, Absorbance Coefficient, Organic Solar cell**

I. INTRODUCTION

Several studies shown that CNTs are the promising nanoelectric elements and are widely used [1]. Carbon nanotubes are a form of conjugated carbon system and currently famous as it has the best potential since it is lower in cost, weight and greater versatility. It is also known to help improve solar cells' efficiency, it has great optical arbsorbance and high conductivity [2]. They exhibit high mechanical strength, wide range of conductivities from insulating to conducting [3]. They are two types of CNT present, which are Single-walled carbon nanotubes (SWNT) and multi-walled carbon nanotubes (MWCNT). MWCNT is chosen for this particular project because its lower absorption energy results in an easier conduction and dispersion and it is affordable compared to the SWCNT. MWCNT are made of a number of concentric coiled carbon sheets while SWCNT is where the tubes are formed by only one carbon. Both have different electrical and mechanical properties [4]. MWNT comes in powder form and is commercially available worldwide [5].

The doping of CNT can be carried out with either acceptor or donor material. CNT can be p-type or n-type in different state. Iodine doping MWNT is to ensure CNT to be highly p-type material before it is being doped with MEH-PPV. The doping of iodine to MWNT is known to change its electronic properties. CNT interacts with a weak Van Der Waals force, so it is difficult to decrease in stability of the composite. This will lead to separation of phase due to strong surface interaction between the tubes itself when CNT fails to disperse. That's why we propose doping the MWNT so that it will be compatible to the MEH-PPV structure[6]. MEH-PPV is a polymer chosen for its widespread usage in polymer community and its certain sensitivity of its photophysics to solid-state morphology. MEH-PPV has high sensitivity in light [7].

II. METHODOLOGY

A. Materials

MEH-PPV (red orange powder) is being stirred in THF (tetrahydrofuran) solution for 48 hours. The CNT powder first being annealed in oven for 30minutes under 450 degree celcius to remove undesired residuals and improve the graphite structures[8]. Then it is being doped with iodine is carried out in thermal chemical vapour deposition (CVD) chamber. The first furnace that contains boat of iodine is set to 100 degree celcius, while the second furnace is set to 800 degree celcius that contain CNT boat. Then the I-MWNT is mixed in MEH-PPV solution and sonicated for 1 hour to ensure that the solution is being dispersed well. It was then being deposited on substrates by spin coating technique [9].

B. Characterization

The optical properties of the glass substrate were measured by UV-Vis-NIR spectrophotometer (Jasco). The thicknesses of the samples were measured by Veeco Dektak 750 Surface Profiler. The surface morphology is by using AFM & FE-SEM. The electrical properties were measured by using two point probes CEP-2000 Spectral Sensitivity Analyzing System Solar Simulator, to observe the current of the samples under illumination and dark, IPCE (Incident Photon Conversion Efficiency) to obtain EQE (external quantum efficiency).

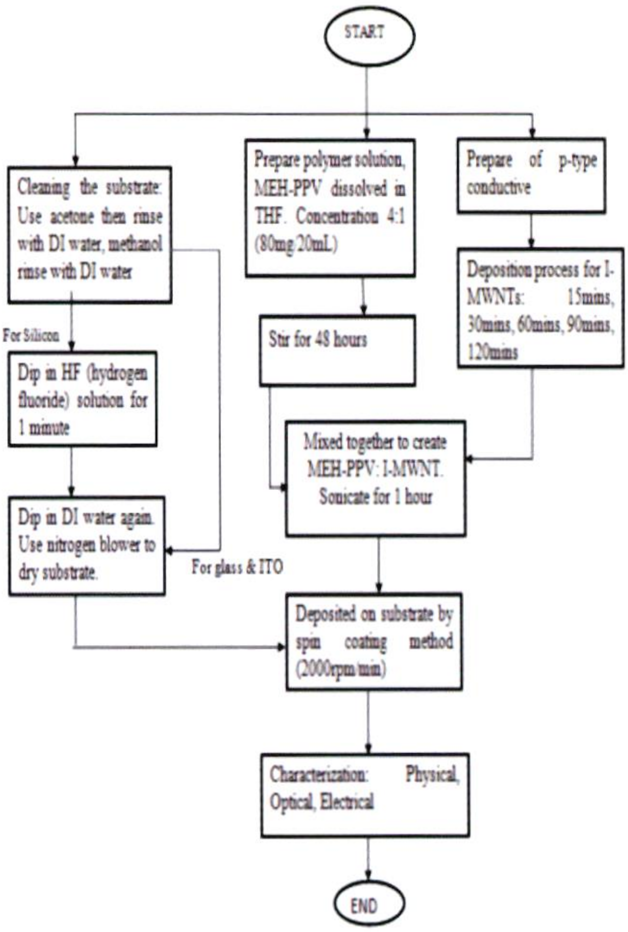

Fig.1: The flow chart of the experimental process

III. RESULT AND DISCUSSION

1. Electrical Properties

Fig.2 show the IV curve of the nanocomposited thin films at different deposition time, which are under dark and illumination condition in the range from -0.2V to 0.8V. From the figure 2, for both under a) dark and b) illumination, it can be seen that all 30, 60, 90, 120 minutes of time doping show no continuous current increment or decrement while 15 minutes parameter shows the highest current gain in both dark and illumination. However it can be observed that the current in illumination for all 5 parameters is higher than their respective current in dark. It means that the nanocomposite thin films show a response to illumination.

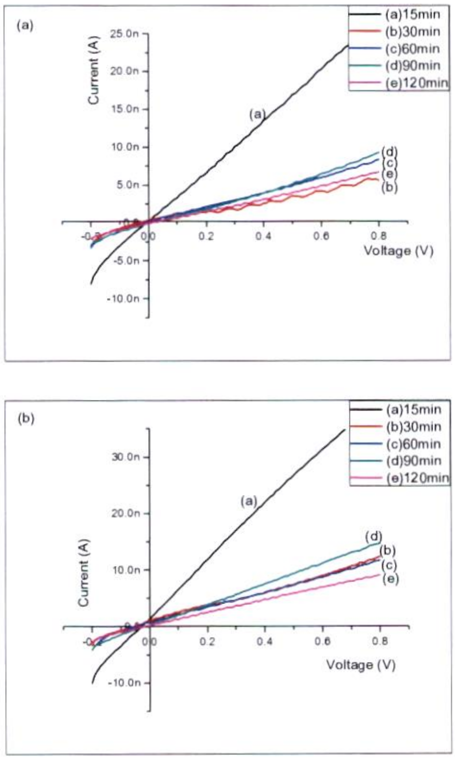

Fig.2: Current-Voltage (I-V) measurement of nanocomposited MEH-PPV:I-MWNT thin film under (a) dark and in (b) illumination

By the Ohm's Law, this is the basic concept of resistance. The Ohm's Law states that voltage is directly proportional to current and resistance. The slope will give the value of resistance value of the thin films. By using the sputter coater EMITECH K550X, gold (Au) are being deposited on thin film as electrode. Using Gold as top electrode is beneficial as it provides ohmic contact to HOMO (highest occupied molecular orbital) [10]. The average thicknesses for different deposition time as shown in Table 1. From this table, it can be seen that the thicknesses of the thin film change with time of deposition. However, there are no trends of continuous decreasing or increasing in the thicknesses as the time of deposition. Optimum thickness usually lies around <100nm. The total active layer thickness must be limited to enable the separated charges to reach their respective electrodes [11].

Doping Time	Thickness (nm)
15 minutes	82.51
30 minutes	102.65
60 minutes	97.91
90 minutes	108.97
120 minutes	85.21

Table 1: The thickness of MEH-PPV: I-MWNT at different doping time.

From the IV curve, the resistivity, ρ and conductivity, σ of the MEH-PPV: I-MWNT can be obtained from these Equations (1) and (2). V is the voltage supplied, I is measured current, t is the thickness of the film, w is the electrode width and l is the length between the metal contacts [12].

$$\rho = (V/I)(wt/l) \qquad (1)$$

$$\sigma = 1/\rho \qquad (2)$$

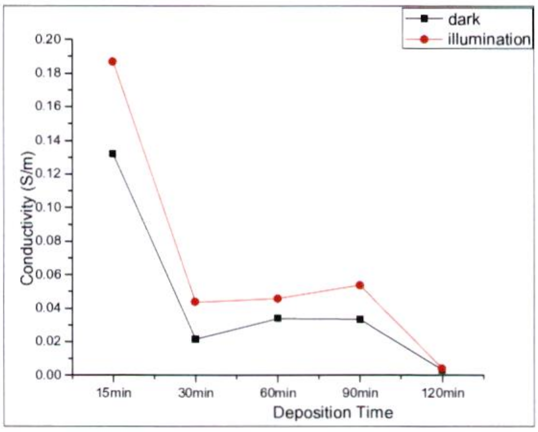

Fig. 3: Conductivity of nanocomposited MEH-PPV: I-MWNT thin films with different doping time.

From the conductivity graph obtained above, it can be seen that 15 minutes time of deposition parameter exhibits the highest conductivity. The 120 minutes parameter seems to exhibit the lowest conductivity amongst all. So we concluded that 15 minute time of deposition is the best parameter out of the others.

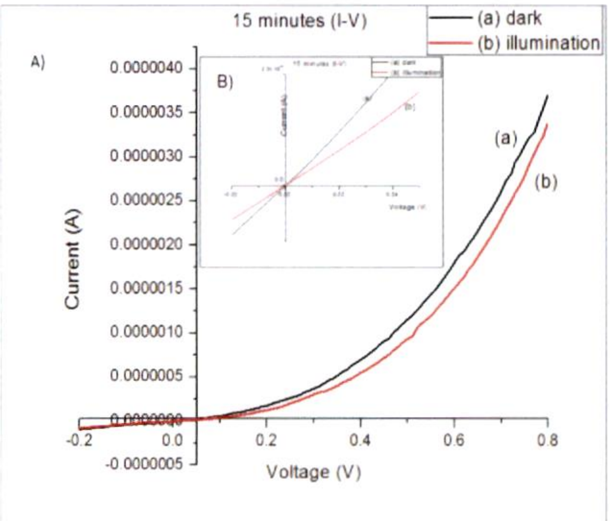

Fig 4 A) and B): IV solar curve for 15 minutes time of doping

The figure 4 A) above shows the IV characteristic curve of the 15 minutes time deposition. Figure 4 B) is the same graph in a closer range at the origin axis. The 15 minute time deposition is the only sample that shows the characteristic curve while the IV graphs of other thin films seem to be straight line graphs and short-circuited.

2. Optical Properties

The optical properties are measured by using UV-VIS NIR and the absorption measurement wavelength range from 800nm to 300nm.

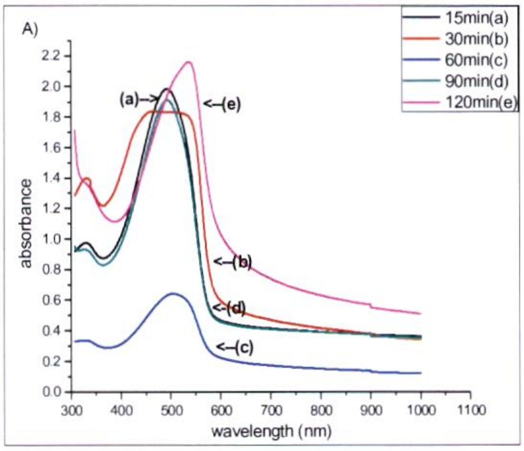

Fig. 5: A) Absorbance Spectra of MEH-PPV:I-MWNT nancomposited thin film at different time of doping

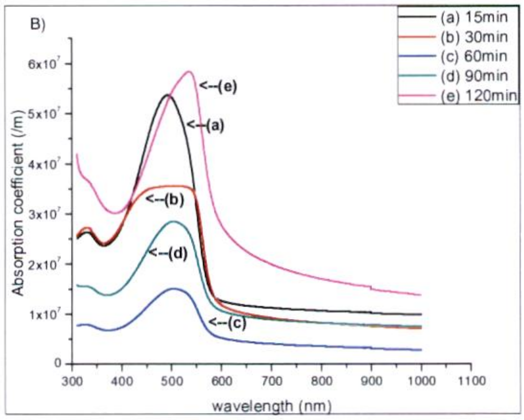

Fig. 5 B) Absorption coefficient of MEH-PPV:I-MWNT nanocomposited thin film at different time of doping

Figure 5 A) shown the absorption measurement. It can be seen that all curves peak at 500nm wavelength, except for 120 minutes time doping, it shift slightly to the right. This condition can be referred to red shift effect, it happened when there is a change in absorbance to a longer wavelength. It is inconvenient

since it involved energy loss as photons cross the solar chromosphere caused by acceleration of an electric charge rather than by a quantum or a relativistic effect [13]. Some authors have objected the interpretation to the Compton Effect (red shift) as it would cause blurring.
The figure 5 B) shows the absorption coefficient of thin film with optimum value located in the range from 450nm to 600nm and it is almost resembles the range peak of absorption spectrum of range peak from 500nm to 600nm of the source or line broadening [14]. The line blurring is not necessary when there is existent of large number of scatterings [15].

The transmittances also show no trend of constant increment or decrement as the time of deposition increased. The absorbance value of the nanocomposite seems to be connected with the values of the transmittance. Both absorbance and transmittance are measured as a simple ratio so they vary exponentially with thickness and concentration of the material. It can be obtained from the relation: Absorbance: -log (Transmittance) [16].
From the transmittance spectra, the absorption coefficient as in Figure 5 B) can be calculated by using the Lambert equation as shown in Equation (3). α is the absorption coefficient, t is the thickness of the film and T is the transmittance of the film.

$$\alpha = (1/t)\ln(100/T) \qquad (3)$$

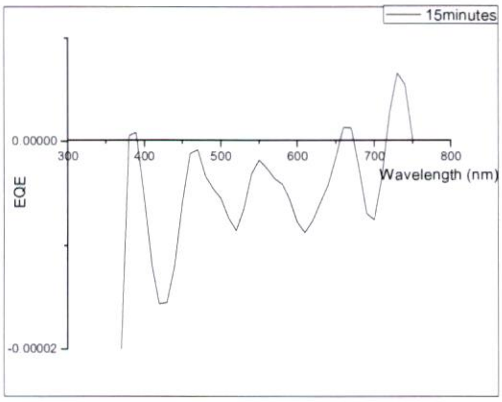

Fig. 6: External Quantum Efficiency for the 15 minutes of time doping

External Quantum Efficiency (EQE) is the ratio of the number of charge carriers collected by the solar cell to the number of photons of a given energy shining on the solar cell from outside (incident photons). External Quantum Efficiency for 15 minutes of time deposition as shown as Fig. 6 above gives more insight into the internal performance of the solar cell itself. This is the most improved EQE among all the other samples, it leads to a better enhance of conversion efficiency of the solar cell. The EQE fitting actually provides information on layer thickness, surface recombination, velocities key interfaces and also the parameters of minority carrier transport like diffusion length, lifetime and mobility [17].

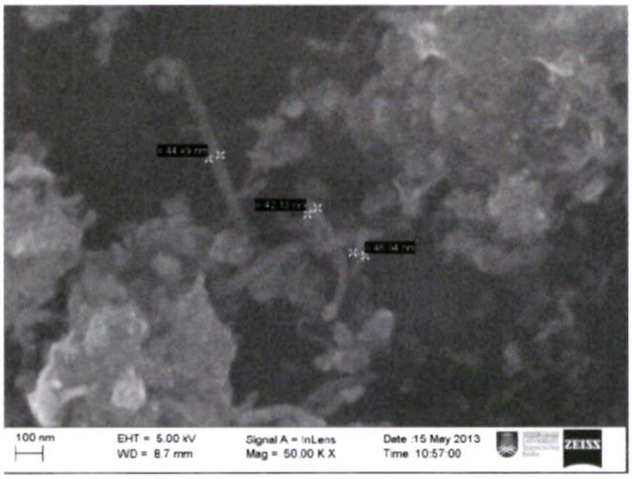

Figure 7 (a) FE-SEM image of nanocomposited MEH-PPV: I-MWNT for 15 minutes time of doping

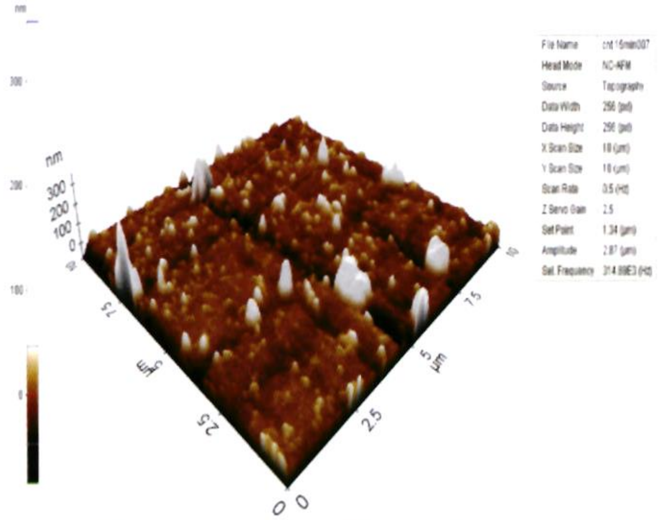

Fig. 7 (b): AFM image in 3D of nanocomposited MEH-PPV: I-MWNT for 15 minutes time of doping

The Fig. 7 a) shows the FESEM image and b) shows the AFM image of MEH-PPV blends with CNTs for 15 minutes parameter. It can be seen from the figure that CNTs tend to get agglomerated instead of filling the matrix of MEH-PPV. Normally Van der Waals forces contribute to agglomeration of the CNT. Although CNT seems to disperse well in naked eyes, but under AFM observation, CNTs are easily agglomerated, so obtaining homogeneous dispersion is not the case. [18]

IV. CONCLUSION

From this work, the electrical, optical and physical properties of nanocomposited MEH-PPV:I-MWNT are being investigated. From the electrical properties it can be proved that doping time of 15 minutes has the highest photoconductivity. Meanwhile for optical properties, it shows better absorbance in the visible range of 500nm. The conductivity also proved that the 15 minutes of time doping exhibits the highest value. From these, it can be concluded that varying the doping time will affect the the thicknesses of the thin films thus affecting the properties of the nanocomposited mentioned earlier.

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