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THE INFLUENCE OF TRANSITION METALS ON THE SOLAR CELL EFFICIENCY

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ABSTRACT

In this work the nano solar cell were successfully designed by using a conducting polymer MEH-PPV as a positive electrode and transition metals Al, Ag and Au as a negative electrode, the different dyes were concerned as a sensitizer. The efficiency of the nano solar cell was studied using the current – voltage characteristic. The results show a good improvement in the efficiency which increasing from Al to Au gradually and this may due to the atomic size and Fermi energy for that elements.

Keywords: *Solar cell, Efficiency, Dyes, Conducting polymer.*

I. INTRODUCTION

Solar cells based on conjugated polymers [1, 2] are attractive due to their potential for low-cost manufacture. Power conversion efficiencies are currently approaching the values required for commercial viability, with a considerable amount of research being carried out to further improve the efficiencies. One of the main areas highlighted for improvement is the role of charge generation and transport in such devices. The mechanism of charge generation in organic solar cells differs from that in conventional inorganic devices. In the former light absorption results in the production of exactions, as opposed to the free electron-hole pairs which are formed in the latter [3, 4]. For more efficiencies of the organic photovoltaic (OPV) response, the photo generated exactions must dissociate at the interfaces between electrons conducting and holes conducting materials. The typical diffusion length of exactions, however, is only around 20 nm [5], and thus important to maximize the interface area for a given device so as to increase the chances of exactions encountering the interface. This fact, has investigated the development of bulk hetrojunction organic solar cells containing blends of electrons and holes conducting materials, in which the fine detail of the structure creates the large interface area required [6].Experiments performed on these so called bulk hetrojunction devices have shown that the large interface area created does indeed lead to efficient exactions dissociation, with evidence to suggest that complex composite morphologies can effect charge dissociation efficiencies [7,8]. Despite this, the overall power conversion efficiencies, while much improvements, are not as high as would be expected. This means that poor transport in the device is allowing the photo-generated charge to recombine before reaching the respective electrodes. Polymers have been used previously in photovoltaic cells, but the low electrons mobility's of most conjugated polymers only allows them for use as the hole conducting components in a blend with other materials, such as fullerene [7], organic dyes [9] or in the present work with carbon nanotubes (CNTs). In these composite materials, the photocurrent is typically increased by several orders of magnitudes with comparison to polymer only devices. This work deals with the transport of charges in crystalline organic semiconductors.

II.   METHODOLOGY

Four samples of solar cells were made by depositing the solution of dye (Ecrchrom Black T, DDTTC) on ITO by Spin Coating technique, and another layer was deposited from dye on a layer of (MEH-PPV). Aluminum (Al), Silver (Ag) and Au electrodes were fabricated on the layers to acts anode and ITO Cathode. The fabrication process started by preparing the MEH-PPV and the dye of interest then spin coated it on indium tin oxide glass. The formed cells were characterized by Ultra violet-visible spectroscopy. Electrical circuit containing the voltmeter and Ammeter and a light source Lamp was needed to study the performance. The solar cell was exposed to light and the current and voltages of the cell were recorded. The UV spectrometer was needed to display absorption spectrum. For the purpose of the present study Electronic transport in the four samples of solar cells were made by depositing the solution of dye (Ecrchrom Black T, DDTTC) and another layer was deposited from dye on a layer of (MEH-PPV)) .The electrical characteristics is studied via current density voltage (*J-V*) curves, taken using a 2400 Keithley source meter by sourcing voltage across the ITO (positive) and aluminum (negative) electrodes and measuring the resulting current density. Due to the reversed internal field, measurements on the ITO/PEDT/MEHPPV/ Al devices are taken by sourcing ITO positive and the transition metal is negative.

The STE solar cell into the plug-in board was plugged and the upper negative poles to the lower positive pole were connected using two bridging plugs (series connection of four solar cells).

Then the STE potentiometer as a variable resistor was plugged, and connected to the solar battery using bridging plugs. The ammeter was connected in series with the solar battery and the variable resistor. The measuring range was selected from 100 to 10^{-11}A DC.
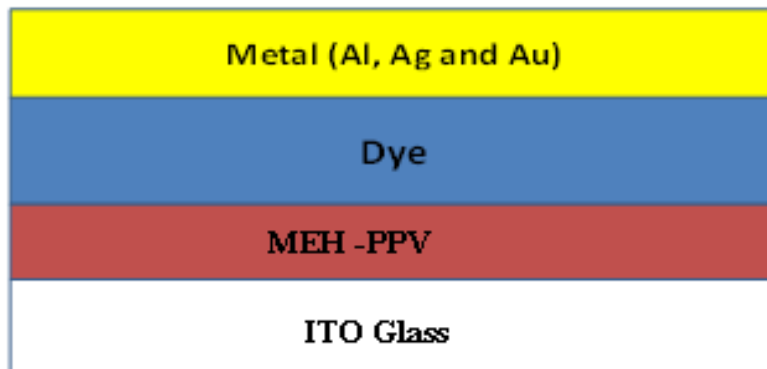

Fig (1) samples of solar cells were made by depositing the solution of dye (Ecrchrom Black T, DDTTC) on ITO and Aluminum (Al) is electrodes), and another layer was deposited from dye on a layer of (MEH-PPV))
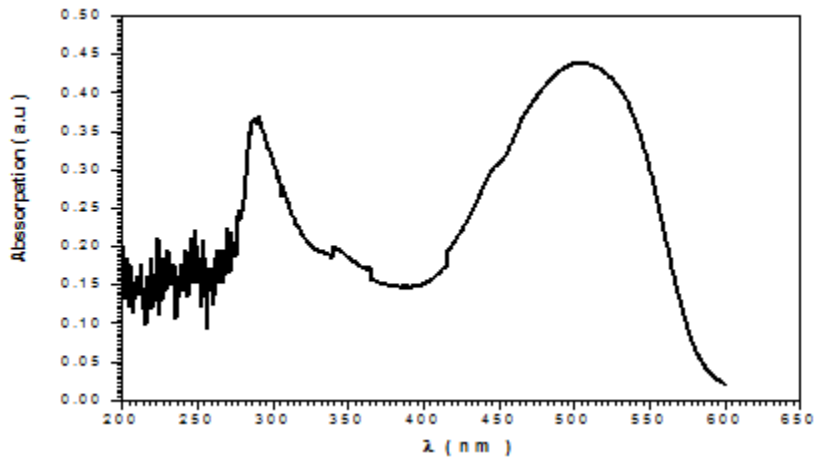
III.   RESULTS

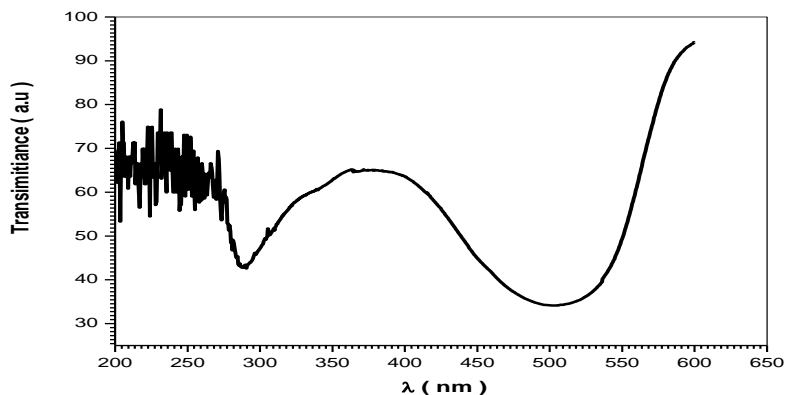*Fig (2): the relation between absorbance and wavelength of MEH-PPV + Ecrchrom Black*

Fig (3): the relation between transparent and wavelength of MEH-PPV + Ecrchrom Black
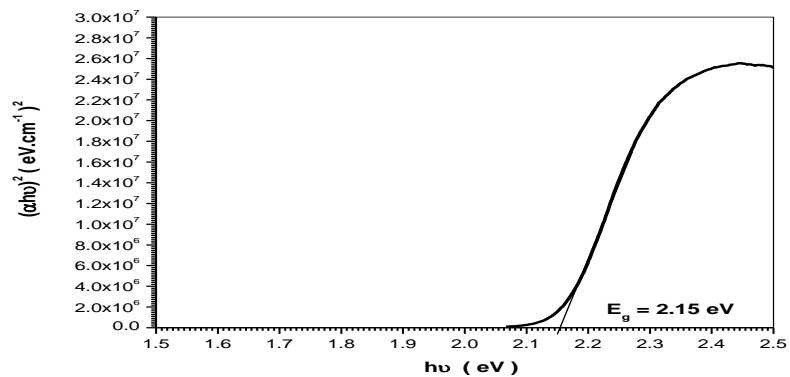

Fig (4): the optical energy gap (E_g) value of MEH-PPV + Ecrchrom Black T thin film
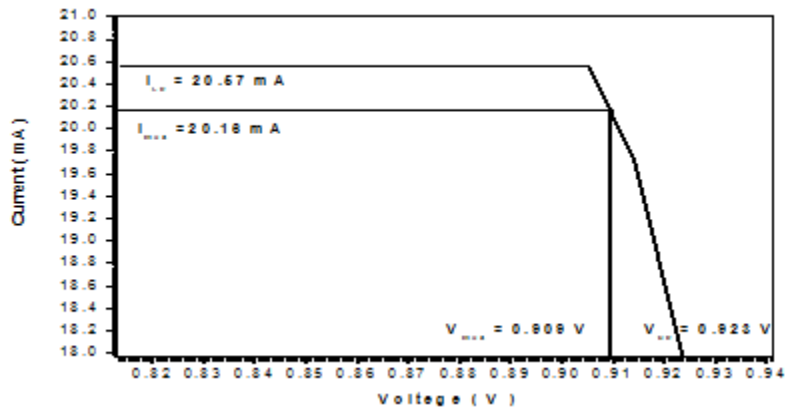
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Fig (5): Typical I-V curve of the cell of MEH-PPV + Ecrchrom Black T thin films for Al electrode
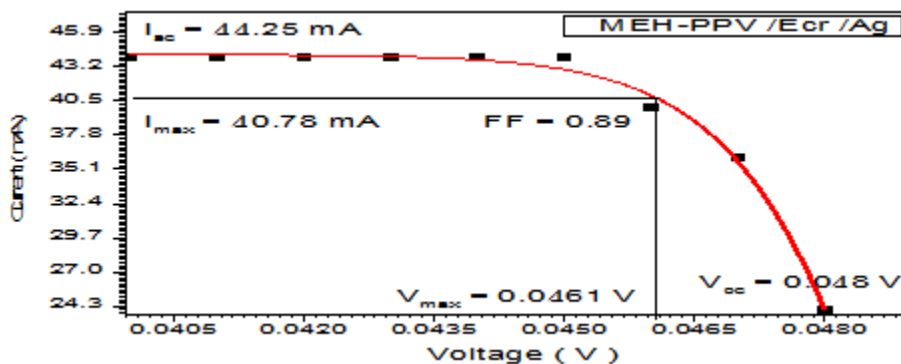

Fig (6): Typical I-V curve of the cell of MEH-PPV + Ecrchrom Black T thin films for Ag electrode
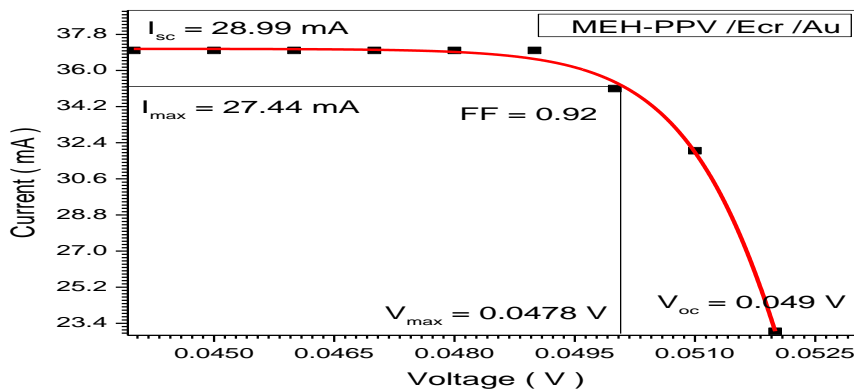

Fig (7): Typical I-V curve of the cell of MEH-PPV + Ecrchrom Black T thin films for Au electrode
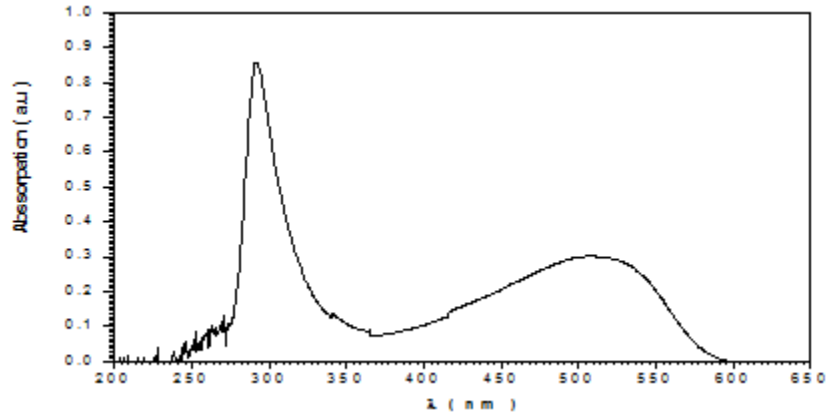
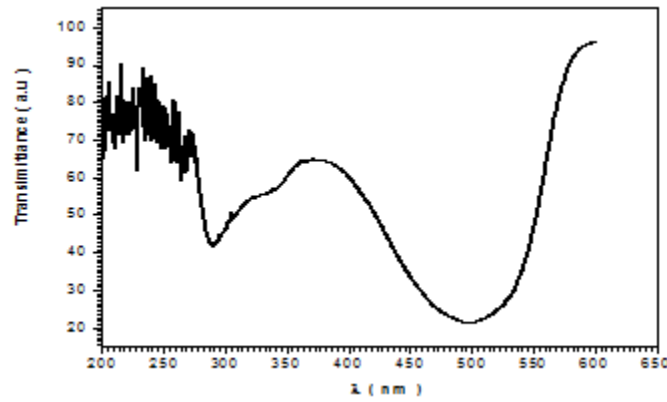*Fig (8): the relation between absorbance and wavelength of DDTTC + MEH-PPV*

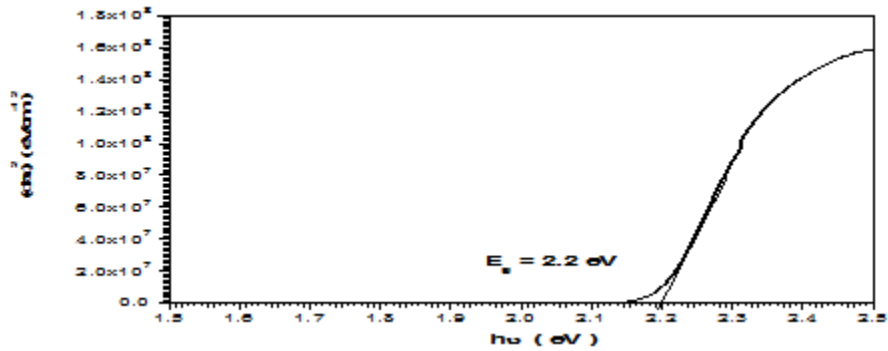*Fig (9): the relation between transparent and wavelength of DDTTC + MEH-PPV*

Fig (10): the optical energy gap (E_g) value of DDTTC + MEH-PPV thin films
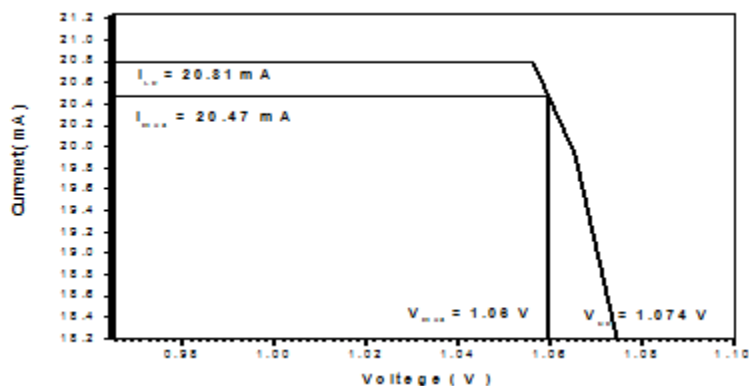
Fig (11): Typical I-V curve of the cell of DDTTC + MEH-PPV thin films for Al electrode
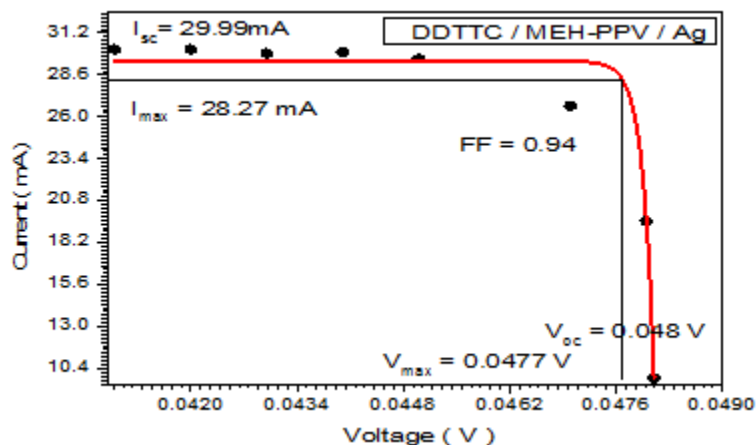
Fig (12): Typical I-V curve of the cell of DDTTC + MEH-PPV thin films for Ag electrode

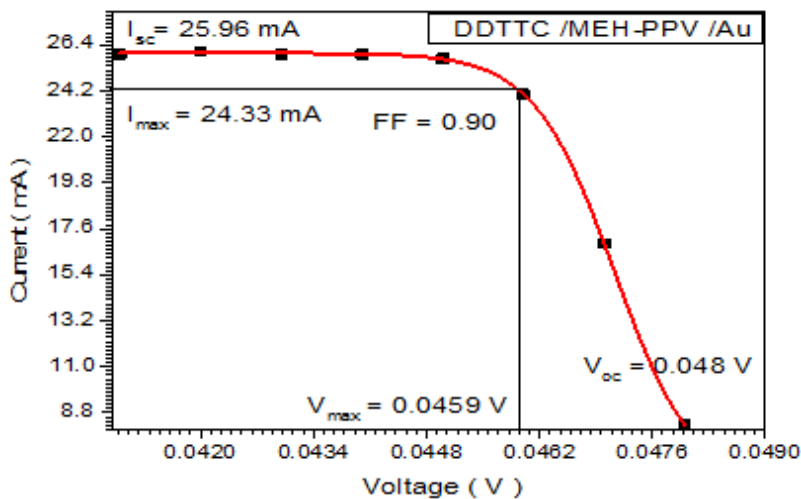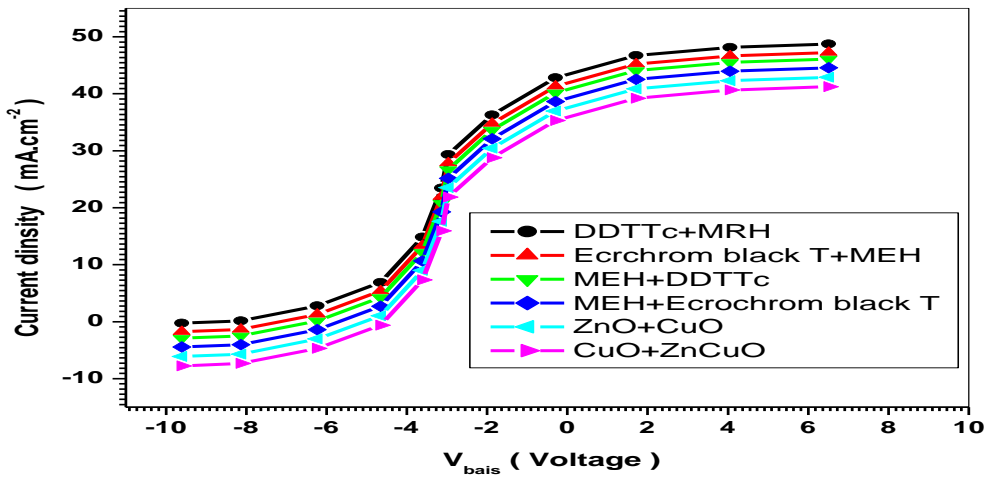*Fig (13): Typical I-V curve of the cell of DDTTC + MEH-PPV thin films for Au electrode*

Fig(14): Current density as a function of applied voltage for devices of the type ITO/ Dyes /MEH-PPV/Al. Polymer
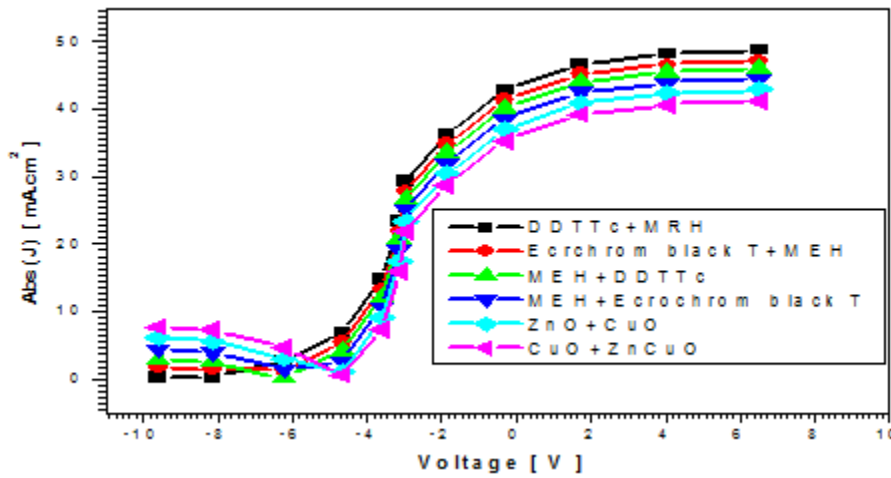

Fig (15): The absolute value of the current density as a function of applied voltage at various light intensities for an ITO/ Dyes / MEH-PPV/Al device. Light intensities are approximately 220 mW/cm²
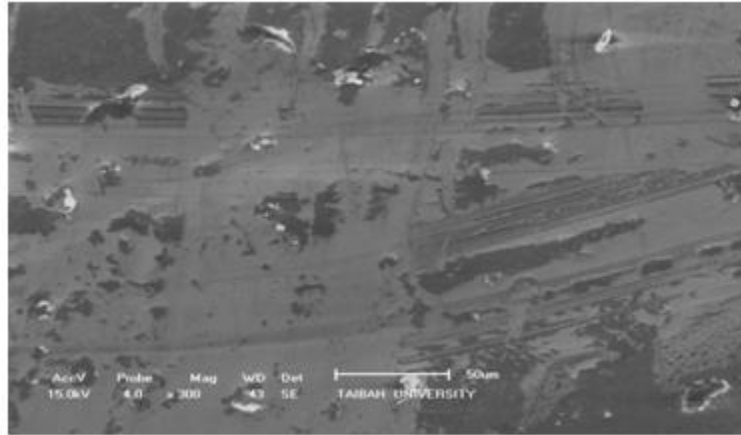
Fig (16) side view of the layered structure for the ITO/DDTTC /MEH- PPV/Al devices. By AFM image of nanoparticles layer
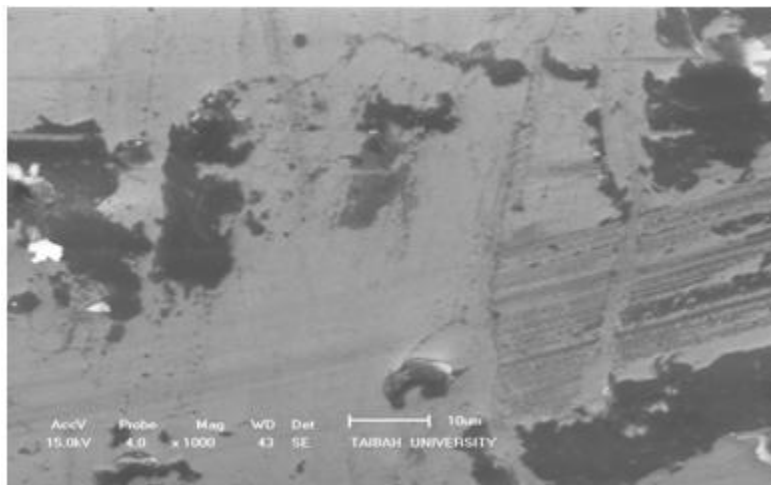

Fig (17) side view of the layered structure for the ITO/ Ecrchrom black T /MEH- PPV/Al devices. By AFM image of nanoparticles layer

Table (1) Result of the samples measurement for Al electrode:

s a m p l e	I_{sc}	V_{oc}	I_{max}	V_{max}	J_{sc}	F F	η %
MEH-PPV EcrchromBlack T	20.57	0.923	20.16	0.909	3.29	0.965	0.00378
MEH-PPV + DDTTC	20.21	0.891	19.73	0.88	3.23	0.964	0.00347

Table (2) Result of the samples measurement for Ag electrode:

s a m p l e	I_{sc}	V_{oc}	I_{max}	V_{max}	J_{sc}	F F	η %
MEH-PPV EcrchromBlack T	28.99	0.049	27.44	0.0478	4.638	0.923	0.381
MEH-PPV + DDTTC	36.04	0.048	33.75	0.0461	5.766	0.897	0.451

Table (3) Result of the samples measurement for Au electrode:

s a m p l e	I_{sc}	V_{oc}	I_{max}	V_{max}	J_{sc}	F F	η %
MEH-PPV EcrchromBlack T	44.25	0.048	40.78	0.0461	7.080	0.885	0.547
MEH-PPV + DDTTC	44.96	0.048	43.39	0.0465	7.194	0.935	0.587

IV.   DISCUSSION

In this work active layers are sandwiched between ITO which acts as positive electrode and Al, Ag and Au were act as a negative electrode where the active layers are MEH/Dye.

The energy gap represents a good indicator for designing a solar cell, which play as a classifier for the materials, which was found to be 2.16 eV. This means that in the former (MEH/Dye) cell electrons can easily reach the conduction band (cb), since E_g is narrow. Thus much more electrons can contribute to the cell current, which increases cell efficiency. More over since MEH/Dye atoms are smaller in size (z=small), thus their density is expected to be more. This means that the MEH/Dye atoms give more electrons per unit volume to the cb, which increases electric current and efficiency.

The dyes here can improve the solar cell efficiency which is very interesting to observe that the efficiency of ITO/MEH / Dye /Al for Ecrch. B and DDTTC dyes

(table (1)) is equal to 0.00293 and 0.00277 respectively is lower than ITO/MEH / Dye /Al efficiency which are 0.00378 and 0.00347 respectively. This may be attributed to the fact that existence of MEH layer between ITO and the dye decreases the light intensity which decreases photo generated electrons which in turn decreases efficiency.
The effect of changing negative metallic electrode on the solar cells ITO/MEH/METAL and efficiencies shows interesting results. When changing Al by Ag electrode the efficiency was increases (table (2)). This may be related to the fact that Al has small atomic number (z=13) compared to Ag (z=47). Thus The Al size is small compared by Ag. Thus one expects Al to be denser than Ag for the same volume. Since both Al and Ag have only one electron in the outer most shell thus one expects that; the free electrons to have more concentrations for Al. Moreover the less positive charges in Al nucleus enables electrons to have more chance to escape and become free compared to Ag. This means that the concentration gradient of free electrons between Al and the nearby layer (acceptor) is very small. Thus one expects small diffusion current to flow to Al and this decreases the solar cell efficiency. However, for Ag the concentration gradient is large; as for as it has less free electrons. This enables large diffusion current to flow, which in turn increases the solar cell efficiency.

The replacement of Ag electrode with Au one decreases the efficiency in general. This may be attributed to the effect of Fermi energy E_F which is related to the concentration of atomic electrons (not free electrons), according to the relation:

$$E_F = \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3} \sim n^{2/3}$$

(1)

Thus the Fermi level for Ag is small (n ~ 47) compared to Au (n ~ 49), i.e:
$E_F(Ag)$=small
$E_F(Au)$=large

Thus the Ag LUMO is considerably below Au LUMO. Since electrons prefer to occupy the lower orbit, thus more electrons prefer to be in Ag lower orbit. This means that the number of electrons occupying Ag LUMO is more than that of Au. This increases current and efficiency for Ag compared to Au. Another explanation is also possible by using energy conservation principle. It is known that the potential energy decreases the kinetic energy increasing. The larger the potential difference, the larger the kinetic energy gain. For Ag the potential difference is large. Thus the kinetic energy gain is large. This increases the current since
(J= nev).

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V.   CONCLUSIONS

The nano solar cells were successfully synthesized using a conducting polymer namely MEH-PPV as a positive electrode, the transition metal as Al, Ag and Au were used as a negative electrode. Two different dyes were used so as to play as sensitizer. The efficiency of the nano solar cell is affected by the metallic electrode due to the effect of atoms concentration and Fermi energy. The energy gap and atoms concentration of active layer affect also the efficiency. The results show improving in the efficiency from Al to Au and this may due to the atomic size which increases the number of electrons passing to the conduction band.

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