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Evaluation the Electrical Conductivity of PEDOT: PSS as a Function of an Electrode Metal Type Under the Impact of a Neodymium Magnet

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ABSTRACT: The Poly (3,4-ethylene dioxythiophene): polystyrene sulfonate (PEDOT:PSS) thin films were coasted after dilution with a distilled water, then applying it on different metal substrates by the casting method. An annular neodymium magnet (with 5 cm in diameter and 70 milli Tesla) was used in this study. All substrates are positioned in the center of a magnet during the coasting prosses. The intrinsic electrical conductivity of this semiconductor polymer is 9×10^{-4} $S.cm^{-1}$. We used a range of substrates to cast several thin films onto various copper, aluminum, and ITO electrodes, each substrate dimensions are (2x2) centimeters.

The 25, 50, and 100 milliliters were taken since we used distilled water as a dilution solvent, the findings indicated that 50 milliliters of solvent were the optimal amount to apply to the aluminum electrode. As indicated earlier, one aspect of this effort is the use of many electrodes. Using varying amounts of solvent is the second dimension. The results explain the magnet affact the electrical conductivity of PEDOT:PSS up to 5×10^{-2} $S.cm^{-1}$, after which the conductivity only increased by 100 times. The electrical conductivity of PEDOT:PSS is influenced by the type of electrode metal.

KEYWORDS: PEDOT:PSS, Conductivity, Electrical, Polymer, Electrode, and Magnet.

INTRODUCTION

Through the previous literature that has appeared since the discovery of the electrical properties of polyacetylene, a new type of materials has emerged known as conductive polymers, which is a special category that combines good mechanical properties, or rather a wide range of mechanical properties of varying degrees, with the electrical conductivity of metals, passing through the semiconductor characteristic. [1]

The improvement in electrical conductivity and mobility can be in one direction, thus making it a one-way conductor, we do not mean the absence of bilateral conductivity in the lateral direction, or triple conductivity in the lateral direction, or the direction of the chains of the polymer. Rather, the predominance here is in conductivity in the direction of the length of the polymer chain. [2]

Recently, a new way to improving of conductivity has emerged, there is a trend toward by applying a magnetic field to crystalline materials, or by monomers that polymerize to form oligomers and then form polymer chains with large molecular weights. The applying of a magnetic field effect on the movement of charge carriers within the polymer and causes a Lawrence force affecting charges movement. This application can lead to a change in the movement paths of the electric charge along the polymer chains or by jumping from one polymer chain to another, whether this chain is sideways, above, or below, i.e., a transition to three-dimensional conductivity. Therefore, this improvement in electrical conductivity in a specific direction is known as anisotropy, resulting from the application of an external magnetic field to conductive polymers during the coasting or the polymerization process. [3-5]

The process of applying a magnetic field to polymer chains, specifically during the coasting process, which we have addressed in this research, in a new way that differs from other research or the literature on conductive polymers leads to a change in the directionality of polymer chains, as if they tend to elongate more and become unidirectional. To illustrate the idea, there was a paved road, but it was very twisted. The process of sweeping of the magnetic field along these twisted paved roads will reduce or eliminate these twists over a long distance, leading to the convergence of these paved roads, or rather, the polymer chains. This convergence reduces the energy gap between the polymer chains on the one hand and increases mobility and speed along the road, or rather along the polymer chain, and thus a general change in the crystalline properties of these polymers, which increases the percentage of crystallinity in the polymers. [6-10]

Therefore, this change in crystallinity necessarily leads to a change in the optical properties and directional light emission or selective light absorption of crystalline polymers under the influence of the magnetic field, which in turn affects the polarization of polymer molecules and their dielectric properties has led to a new trend in the polymerization, called magnetic field-directed polymerization. This leads to the reorientation of molecules and the reconstruction of the polymer structure or polymer network to generate better electron mobility and a more balanced distribution of electrical charges, which leads to improved optical properties and modifies or reduces dielectric properties. Consequently, this change and diversity in new properties we can creation and new characteristics-with characteristics that distinguish them from the parent polymers that produced them, which were isolated from the magnetic field, has created numerous opportunities for innovation and new generations of electronics. [11-17]

Studies have continued in this regard, or the new trend in preparing new polymers, and they have used this magnetic field to manufacture new polymers characterized by increased efficiency in their use as active materials in the manufacture of solar cells. [18-19]

The experimental procedure:

An Indium Tin Oxide (ITO), copper, and aluminum electrodes were used to discover the effect of changing electrode metal type in the presence of a magnet of electrical conductivity of PEDOT:PSS. The electrode surface, (2x2) cm^2, was chosen as the substrate to coasting a thin film.

The electrical conductivity of the used PEDOT:PSS was 9×10^{-4} $S.cm^{-1}$. Its water-soluble characteristic led to its selection for the preparation process.

The PEDOT:PSS was diluted independently in 25 milliliters of distilled water. Then, electrodes composed of copper, aluminum, and ITO were coated thinly with PEDOT:PSS.

The balance system was used in the casting process to achieve the highest level of homogeneity, as shown in figure 1. After that, the cast samples were left on the bases shown in figure 1 for a full day to complete the solidification process and remove any remaining solvent residues from the polymer matrix. 25, 50, and 100 milliliters of solvent were used to replicate the identical processes, every process mentioned above was repeated for the three substrates metal type on which the polymer was casted. The top circular electrode, which 0.25 cm in diameter, is deposited using the evaporation technique by the aluminum with 99% purity.

The resulting current-voltage characteristics (I-V) was measured using the Keithley instrument, after dryness in room temperature and treatment in 50ºC in oven for an hour, model Keithley Series 2400 Source Meter, manufactured in the United States, which is connected to a computer to receive and display results on the screen

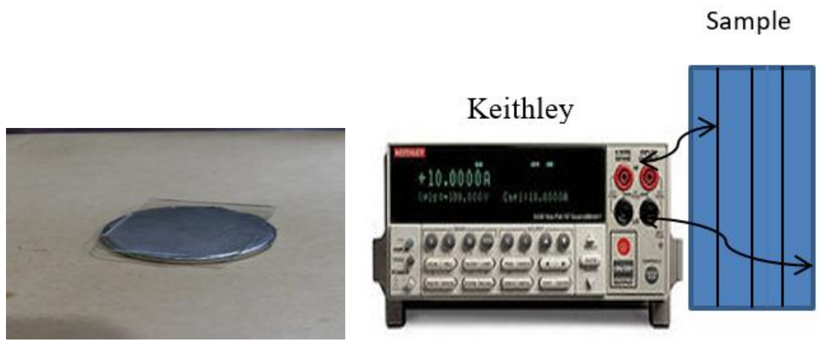

Figure 1: the electrodes (ITO) on top of the used magnet and the Keithley instrument.

RESULTS AND DISCUSSION

The figures (2) to (7) illustrates the current-voltage characteristic of the poly(3,4-ethylenediox-dioxythiophene):polystyrene sulfonate (PEDOT:PSS) polymer prepared with a solvent volume of 25 ml to 50 ml of distilled water on the substrate type (Copper, Aluminum, or ITO) on a solid magnet. The purpose of choosing this polymer as a conductive polymer was to determine the duration of the effect of this technique on conductive polymers, whether it has the same effect as on insulating polymers. This polymer is among the most widely used conductive polymers in electronics, especially in the field of solar cell and photovoltaic. This is due to the high percentage of crystallinity it possesses.[6] The electrical conductivity of this polymer in its pure state is shown in table 1. In the aforementioned figures demonstrates that the electrical conductivity of the polymer when cast on a solid magnet is not significantly affected and remains the same as in the pure state, except when using an aluminum electrode. This is a slight increase in electrical conductivity compared to the pure state of PEDOT:PSS, where the increase was significant and clear. Tables (2) and (3) show the conductivity of the PEDOT: PSS polymer when using a solid magnet and at solvent volumes of 25 ml and 50 ml of distilled water, respectively. The electrical conductivity was also measured at a solvent volume of 100 ml and for an aluminum electrode. The electrical conductivity of the PEDOT:PSS was $2x10^{-2}$ $S.cm^{-1}$, reflecting the lack of influence of the solvent volume on the electrical conductivity of this polymer, even with increased solvent volume. We note that the change in electrical conductivity of the PEDOT: PSS cast on different electrodes has no significant effect on this property. The increase of solvent volume to 100 ml, the conductivity remains within the above range mentioned in Tables 2 and 3. Discussing the above figures clearly shows that the electrical conductivity of these polymers when cast on a solid magnet is not significantly affected and remains the same as the pure state, except when using an aluminum electrode, where we notice an increase of 100 times over the pure state, which is a slight increase.The use of other solvents was tried in the preparation process, such as the organic solvents DMF or DMSO. The electrical conductivity changed slightly, which indicates the specificity of water as a solvent in the preparation process of this type of polymer semiconductor

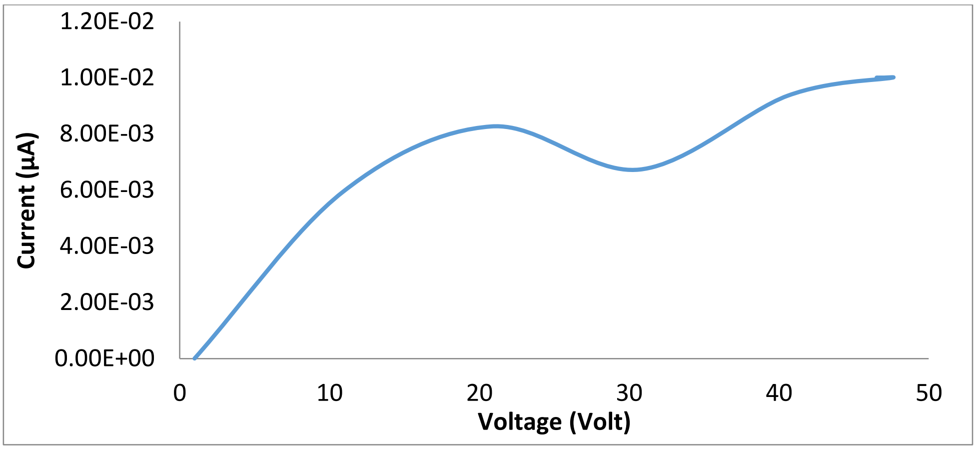

Figure 2: The (I-V) characteristic of PEDOT:PSS at 25 ml. on ITO substrate, lying on a solid neodymium magnet

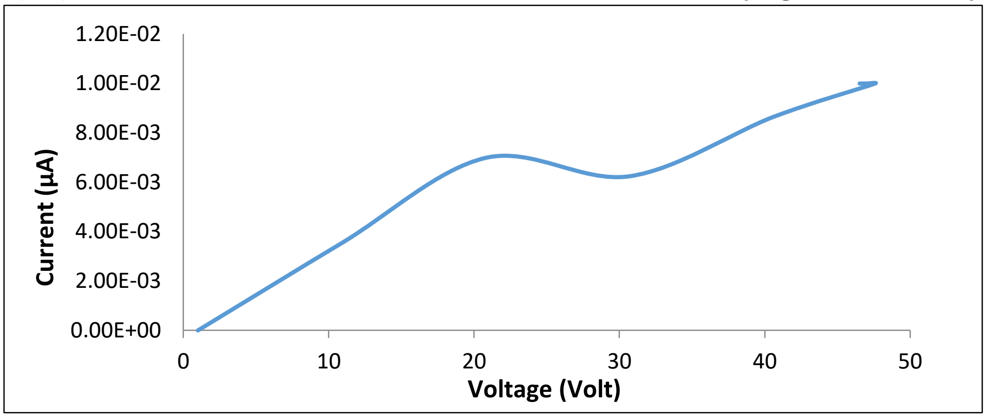

Figure 3: The (I-V) characteristic of PEDOT:PSS at 25 ml. on an Aluminum substrate, lying on a solid neodymium magnet.

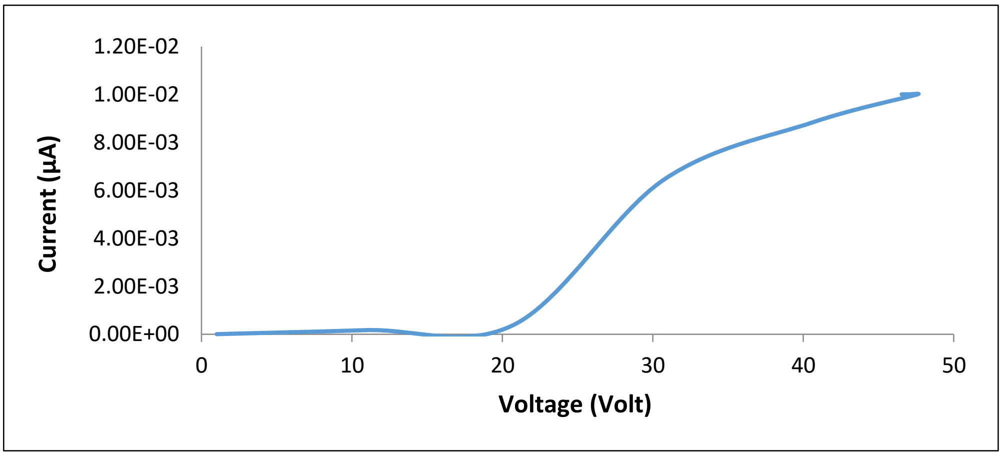

Figure 4: The (I-V) characteristic of PEDOT:PSS at 25 ml. on copper substrate, lying on a solid neodymium magnet.

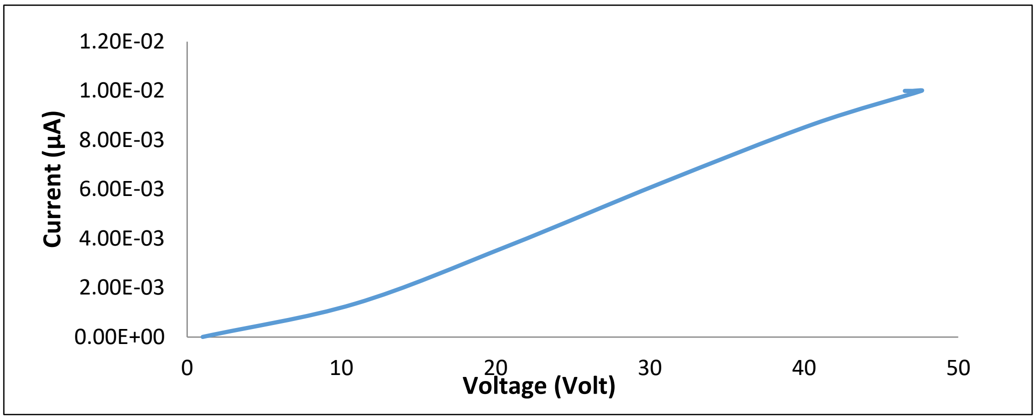

Figure 5: The (I-V) characteristic of PEDOT:PSS at 50 ml. on ITO substrate, lying on a solid neodymium magnet

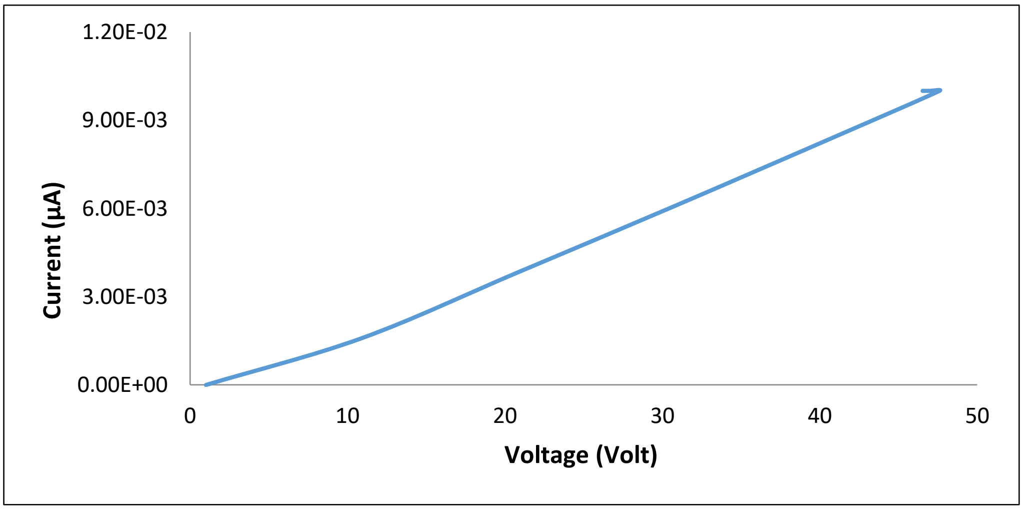

Figure 6: The (I-V) characteristic of PEDOT:PSS at 50 ml. on an Aluminum substrate, lying on a solid neodymium magnet

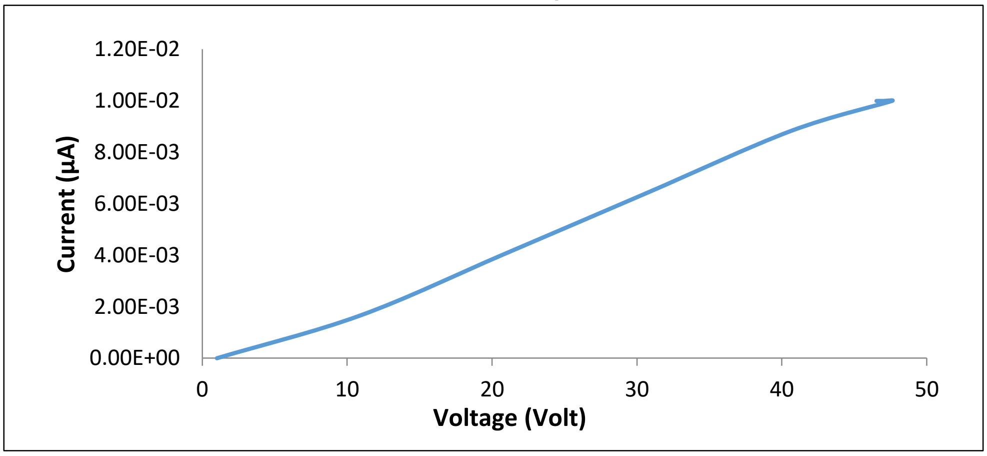

Figure 4: The (I-V) characteristic of PEDOT:PSS at 50 ml. on copper substrate, lying on a solid neodymium magnet

Table (1) shows the conductivity values of the pure state of the PEDOT:PSS polymer as a function of the type of casting electrode.

Electrode Type	**Conductivity σ ($S.cm^{-1}$)**
ITO coated glass	$8.4x10^{-4}$
Copper	$1.9x10^{-4}$
Aluminum	$0.014x10^{-3}$

Table (2) Conductivity values of PEDOT:PSS polymer diluted in 25 ml of solid magnet as a function of casting electrode.

Electrode Type	Conductivity σ ($S.cm^{-1}$)
ITO coated glass	$6x10^{-4}$
Copper	$2.81x10^{-4}$
Aluminum	$2x10^{-2}$

Table (3) Conductivity values of PEDOT:PSS polymer diluted in 50 ml of solid magnet as a function of casting electrode.

Electrode Type	Conductivity σ ($S.cm^{-1}$)
ITO coated glass	$11x10^{4}$
Copper	$12.5x10^{4}$
Aluminum	$2x10^{2}$

CONCLUSION

From the results obtained, we can conclude that the casting mechanism of the conductive polymer is by placing the casting base or electrode directly on a solid magnet, and with the difference in substrate, we notice that there is a difference in electrical conductivity from one substrate metal to another, which indicates the effect of the magnetic field on dilution concentration or the substrate type of polymer through the impact on first, and through the effect on the PEDOT:PSS chains secondly, because it works, as we explained in the text of the study, to change the alignment of the polymer chains, whether this change is convergence or divergence, and thus this affects the crystallinity or the crystallization rate in PEDOT:PSS network and the change of properties as a result of this crystallization, then the greater permissibility of the wave function to pass longer without the presence of potential barriers, or let's say 10 loose, and as there is another effect of the type of solvent, it became clear that water is more effective than DMF. Also the dilution concentration of water that used in this research, the dilution of PEDOT:PSS affects the electrical conductivity, this effect was explained based on the freedom of movement of the PEDOT:PSS chains with the increase in volume from 25 ml to 50 ml. Also, increasing the volume to 100 ml did not have a clear effect on this electrical conductivity. Therefore, the conclusion can be summarized that the electrical conductivity is not an intrinsic property of PEDOT:PSS, but rather a property affected by the surrounding conditions.

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