Mol2Net-04, **2018**, BIOCHEMPHYS-01 (pages 1- x, *type of paper*, *doi: xxx-xxxx*
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Mol2Net-04

Electrical study of new anthracene derivatives for electronics applications

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Received: / Accepted: / Published:

Abstract: Due to the holes high transport mobility, anthracene derivates are widely used for the elaboration of OLEDs and other organic thin-layer-based electronic, such as transistors and photovoltaic cells. This study aims to investigate the electric properties of two new anthracene derivatives: 9-{[4-({[4-(9 anthrylmethoxy)phenyl]sulfanyl}methyl)] methyl]anthracene (TDP-AN) and 4-(9-anthrylmethoxy) benzyl[4-(9-anthrylmethoxy)phenyl]sulfone (BPS-AN). The main difference between them is related to the functional group between the two central phenyls. Conductance measurements results show a frequency-independent behaviour, for low frequencies ranging between 0.1 and 100 KHz, while they exhibit a power law model for higher ones. BPS-AN was found more conductive than the TDP-AN. Impedance spectroscopy (IS) was then investigated to understand the charge carrier mechanisms in both TDP-AN and BPS-AN molecules. Measurements were carried out in the frequency range 100 Hz – 10 MHz at different bias voltages (from 0 V to 3 V). The obtained results agree with conductivity measurement ones.

Keywords: Anthracene derivates; Conductance, Impedance spectroscopy, Charge carrier.

1. Introduction

Organic semiconducting materials are very attractive for electronic applications such as organic thin-film transistors (OTFTs), organic photovoltaic cells [1, 2] and organic light-emitting diodes (OLEDs).

Several organic monolayers have been investigated for electronics applications. Our work concerns anthracene derivatives because of their multiple advantages, such as improved electrical conduction making them good materials for elaboration of organic diodes.

In this study we have chosen to investigate the electric properties of two new anthracene derivatives: 9-{[4-({[4-(9 anthrylmethoxy)phenyl]sulfanyl}methyl)]methy] anthracene(TDP-AN) and 4-(9-anthrylmethoxy) benzyl[4-(9-anthrylmethoxy)phenyl]sulfone (BPS-AN).

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2. Results and Discussion

For conductance and impedance measurements, each anthracene derivative was placed between an aluminum (Al) cathode and a tin oxide (ITO) anode (Figure. 1). The realized structures were then characterized by impedance spectroscopy, a powerful technique for exploring the charge carrier mechanisms in organic semiconductors.

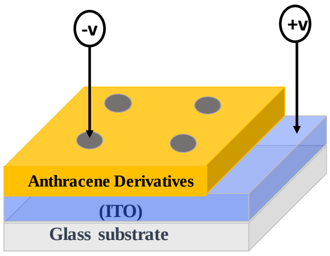

Figure. 1. [ITO/ anthracene derivative/Al] diode structure

2.1 The conductance measurements:

The variation of conductance versus frequency at different bias voltages for the two realized devices is presented in Figures. 2a and 2b. These spectra present the steps performed in the frequency range 100 Hz – 10 MHz. Results indicate the presence of two parts, a quasi-constant conductance at low frequencies and an increase, according a power-law, for high ones. Besides, the conductance increases with the applied bias voltage.

In general, the variation of conductance *G* according to frequency in disordered materials obeys the relation:

$$G(\omega) = G_{dc} + G_{ac}(\omega)$$

The dc conductance (G_{dc}) remains constant at low frequencies (0.1-100 kHz). Thus, a charge carrier jumps from one position to its neighbouring vacant one [3]. Beyond a critical frequency of order of 100 kHz, the conductance starts to increase. Consequently, a charge carrier will hop from a site to another one [3].

According to the conductance at 0V, obtained in Results gathered in Figure. 2c indicate that BPS-AN is more conductive than TDP-AN.

2.2 Parameters obtained by modeling the impedance spectra

Cole-Cole representation for both devices at different bias voltages are shown in Figures.3a. and 3b. The application of a voltage to the device, results in a single semicircle whose radius decreases with increasing the bias from 0V to 3V. The minimum value of Re (Z) (high frequency) indicates the existence of voltage-independent series resistance R_s which corresponds to the ohmic contact with the interface holes-injecting ITO/organic material. The maximum value of Re (Z) (low frequency) represents the sum of R_p parallel resistance with R_s contact resistance. For the both structures, the bulk resistance R_p decreases with increasing bias.

The obtained values, gathered in Figure 3c., indicate that ITO/BPS-AN/Al structure has a lower resistance than that of ITO/TDP-AN/Al one, in concordance with the conductivity measurement results.

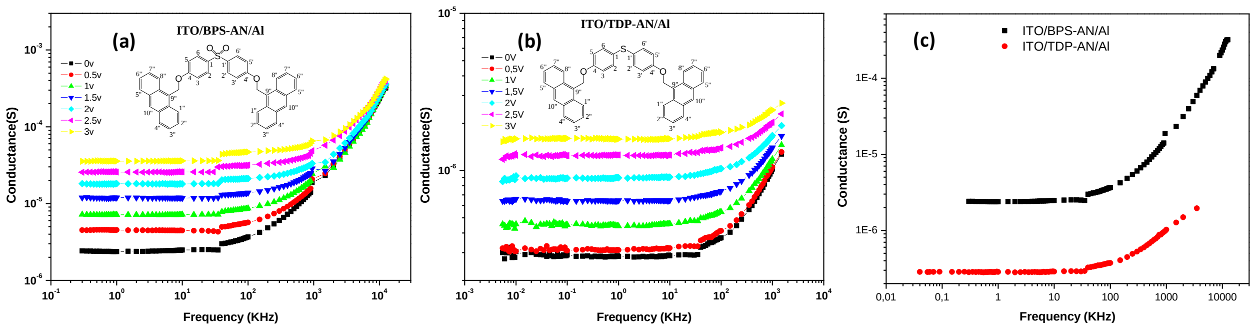

Figure 2. Conductance versus frequency at different applied bias voltages for (a) ITO/BPS-AN/Al, (b) ITO/TDP-AN/Al, (c) Superposition conductance versus frequency for the two devices at 0V.

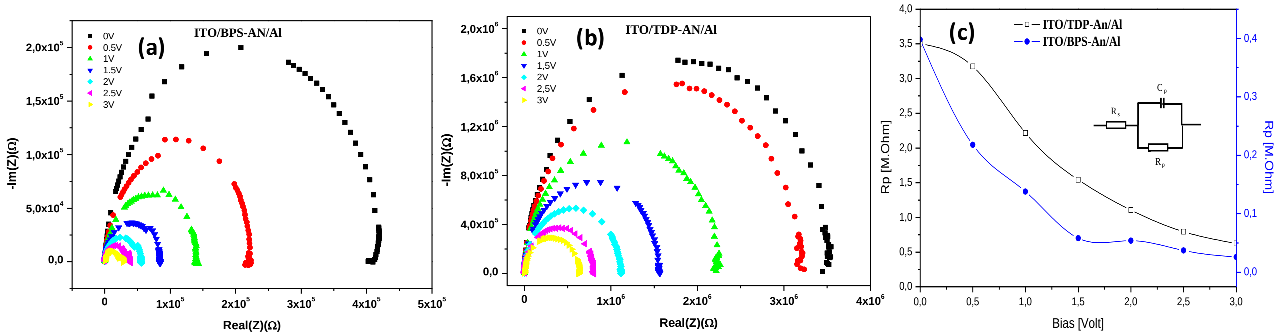

Figure 3. Cole–Cole plots of complex impedance with variation of the bias voltage for

(a) ITO/BPS-AN/Al, (b) ITO/TDP-AN/Al

(c) Superposition of the bulk resistance R_p at bias voltage for the both structures

3. Materials and Methods

The anthracene-based organic materials were synthesized via the Williamson reaction through the condensation of AnCl (9-(Chloromethyl) anthracene) with two different bisphenols. Thus, the reaction of AnCl with BPS (4,4′ Sulfonyldiphenol) led to BPS-AN whereas TDP-AN was obtained from AnCl with TDP (4,4'-thiodiphenol). These anthracene-based semi-conducting materials were found to have good solubility in common organic solvents such as tetrahydrofuran, chloroform, DMF and DMSO.

Single-layer device was fabricated as sandwich structures between an aluminum (Al) cathode and an ITO anode (Fig 1.). ITO devices were cleaned for 20 min in an ultrasonic bath in acetone and isopropanol successively and finally dried by a nitrogen gas flow. After this treatment, a 50 µl of an anthracene molecule was used to form a thin film on the ITO substrate by the spin-coating technique with a controlled speed of 2000 rpm. Finally, the obtained film was dried at 60 °C for 20 min to improve the adhesion between ITO and the anthracene layer.

Impedance spectroscopy (IS) measurements, a powerful technique for exploring the charge carrier mechanisms in materials and mainly in organic semiconductors, have been recorded using HP 4192 LF impedance analyzer.

4. Conclusions

Two anthracene derivatives were synthesized and presented in this work: TDP-AN and BPS-AN. Conductance measurements show the existence of two regimes: constant conduction at low-frequencies, and a power-law behaviour at high ones. Also, conductance results indicate that BPS-AN is more conductive than TDP-AN. Cole–Cole plots were modelled to extract the suitable equivalent circuit: resistance in series with capacitance and resistance in parallel. From the fitted parameters, it appears that the bulk resistance decreases with the applied bias, and that BPS-AN molecule is more conductive than the TDP-An one.

Conflicts of Interest: "The authors declare no conflicts of interest"

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