Flexible Synthetic Semiconductor Applied in Optoelectronic Organic Sensor

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ABSTRACT

The synthesis and application of new nanostructured organic materials, for the development of technology based on organic devices, have taken great interest from the scientific community. The greatest interest in studying organic semiconductor materials has been connected to its already known potential applications, such as: batteries, organic solar cells, flexible organic solar cells, organic light emitting diodes, organic sensors and others. Phototherapy makes use of different radiation sources, and the treatment of hyperbilirubinemia the most common therapeutic intervention occurs in the neonatal period. In this work we developed an organic optoelectronic sensor capable of detecting and determining the radiation dose rate emitted by the radiation source of neonatal phototherapy equipment. The sensors were developed using optically transparent substrate with Nanostructured thin film layers of Poly(9-Vinylcarbazole) covered by a layer of Poly(P-Phenylene Vinylene). The samples were characterized by UV-Vis Spectroscopy, Electrical Measurements and SEM. With the results obtained from this study can be developed dosimeters organics to the neonatal phototherapy equipment

Keywords: Phototherapy; PVK; PPV; Organic Sensor.

1. INTRODUCTION

In 1977, a new chapter in the evolution of organic semiconductor materials began, when Hideki Shirakawa, from the University of Tsukuba (Japan), Alan Macdiarmird, from the University of Pennsylvania, and Alan J. Heeger from the University of Santa Barbara (The U.S.), demonstrated the existence of conductive properties for doped Polyacetylene (intrinsically an insulator), which assured them the Nobel Prize in Chemistry, in 2000 [1][2]. Research studies, realized to synthesize and characterize the components of this new class of materials, have been currently passing through a continuous process of technological advance in search of new conductive polymers. In addition, the greatest interest in studying organic semiconductor materials has been present in its potential applications, among which are: lightweight batteries, organic sensors, gas sensors, electrochromic devices, capacitors, electrochemical cells, organic solar cells, organic light emitting diodes, shielding of electromagnetic radiation, artificial muscles, passivation of integrated circuits MOSFET, pn junction, satellites weighing less than 0.2 kg, and others [3][4].

The insulating properties of most available industrial plastics come from the formation of σ bonds among the constituent carbon atoms. However, in conjugated polymers, as the polyacetylene, for example, the situation is different: In these polymers, the bonds among the carbon atoms, which make up the backbone, are alternatingly single or double, and this property is called conjugation. In the backbone of a conjugated polymer, each carbon atom binds to only three adjacent atoms, leaving one electron per carbon atom in a p_z orbital [5].

The overlap between these pz orbitals results, when forming π bonds along the conjugated backbone, thereby delocalize the π electrons along the entire conjugation path. These delocalized π electrons fill up the whole band, and, therefore, conjugated polymers are considered intrinsic semiconductors. Still, the filled π band is called the highest occupied molecular orbital and the empty π^* band is called the lowest unoccupied molecular orbital [5-6].

This π system can be excited without the chain, held together by σ bonds, then, falling apart. Thus, it is possible to promote an electron from the highest occupied molecular orbital to the lowest unoccupied

molecular orbital level, for instance, upon the light absorption [6].

As the band gap (the energy difference between the highest occupied molecular orbital and the lowest unoccupied molecular orbital) of a conjugated system depends on its size, any disturbance of the conjugation along the backbone of the polymer will change the highest local occupied molecular orbital and the lowest unoccupied molecular orbital positions [6-7].

In this research paper, we have presented the an organic optoelectronic sensor capable of detecting and determining the radiation dose rate emitted by the radiation source of neonatal phototherapy equipment. Furthermore, we have presented the results obtained by characterizing the layers and devices, utilizing UV-Vis Spectroscopy**,** Electrical Measurements and Scanning Electron Microscopy (SEM) techniques.

2. EXPERIMENTAL DETAILS

The Organic Sensors, developed in this research, has been manufactured by utilizing optically transparent material, covered by a layer of ITO, with 200 nm thick. The ITO has high conductivity and transmittance in the visible region of the electromagnetic spectrum, which enables their utilization, for instance, in organic sensors, organic gas sensors, organic transistors and electrochromic devices [8-9].

The Poly(9-Vinylcarbazole), PVK, layer was deposited through the spin-coating technique, adding from 120 to 120 µL at 500 rpm for five seconds in each deposition. On these layers, a conjugated polymer, corresponding to the active layer, has been deposited. This layer deposited through the Poly(P-Phenylene Vinylene), PPV, spin-coating technique, was prepared with Chloroform and Toluene (10^{-6}mol/L), utilizing 120 to 120 µL at 500 rpm for five seconds in each deposition. The spin-coating system utilized in this experiment has been presented in figure 1.

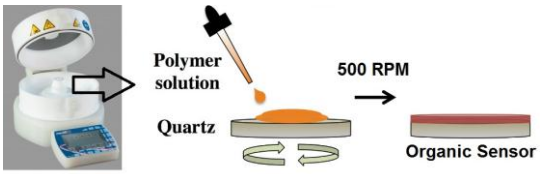

Figure 1. The Spin-coating System.

The developed Organic Sensor Device has presented a PET/ITO/PVK/PPV configuration layered, as represented schematically in figure 2.

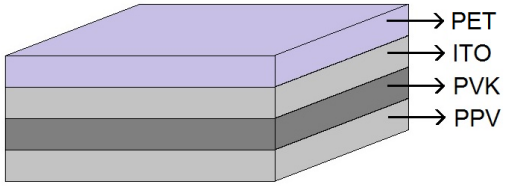

Figure 2. The Configuration of the Organic Sensor Device.

3. DISCUSSION

The spectrum absorption in the spectral region of 200-1100 nm of the non-irradiated Organic Sensor Device is shown in figure 3.

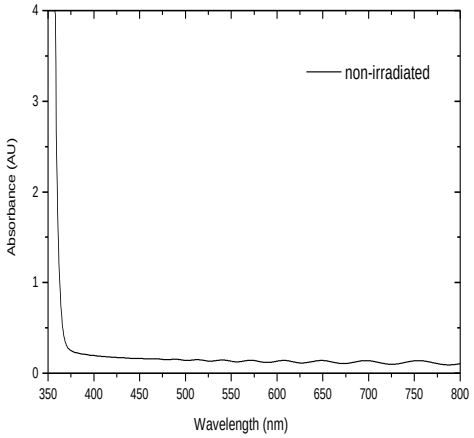

Figure 3. UV-Vis Spectroscopy of the non-irradiated Organic Sensor Device.

In figure 4 for Organic Sensor is shown the optical absorption spectra between 200 and 400 nm. It can be seen that optical absorption increases as a function of ultraviolet dose. The dosimetric band wavelengths are 250 and 350 nm for PVK and PPV films,respectively.

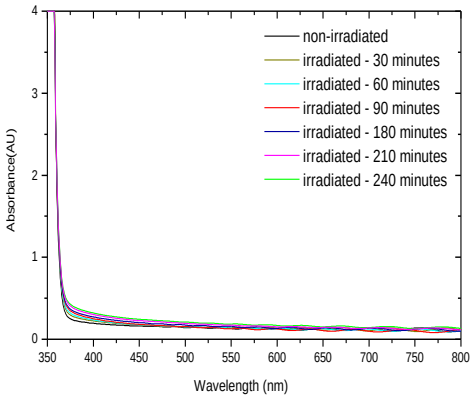

Figure 4. UV-Vis Spectroscopy of the irradiated Organic Sensor Device.

Figure 5 shows the dose–response curves for PVK and PPV, using exposure time equivalent radiation exposure dose. A linear dose–response correlation was established. The relationship can be described by the following equation: Absorbance = A + (B x Dose).

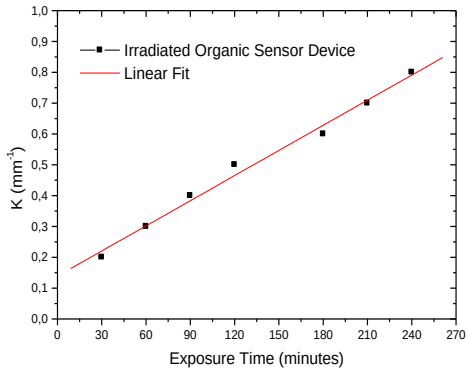

Figure 5. Dose-response curves UV-Vis Spectroscopy of the irradiated Organic Sensor Device.

The electrical characterization of PVK/PPV layers was made at room temperature utilizing an Electrometer Keithley 6517A semiconductor parameter analyzer. All measurements were made without vacuuming and no precautions were taken to prevent the degradation of PPV films during these measurements. Thus, the results obtained in the electrical measurements for PVK/PPV layers have been presented in figure 6. Note that there is an increasing in the electrical resistance, Rs, and electrical resistivity, ρ, after the deposition of thin film layers. The electrical resistivity was calculated from the equation 1, where V is the voltage in volts, I is the electric current, ρ is the electrical resistivity and Δx is the thickness of the deposited material [10-11]. See equation 1.

$$R_S = \frac{\rho}{\Delta x} = \left(\frac{\pi}{\ell n 2}\right).\frac{V}{I} \qquad (1)$$

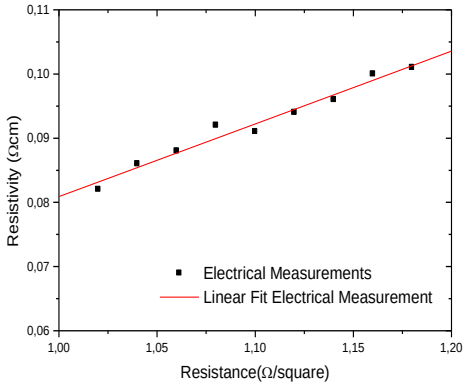

Figure 6. The Electrical resistivity of the PVK/PPV layers in function of sheet resistance.

This graph presented in figure 6 has indicated that the electrical resistivity is related to the sheet resistance and thickness, Δx, of the deposited thin film. Counting on the linear fit of experimental results from equation 2, one has obtained the conductive layer of thin film deposited, α, and the lowest resistivity, Bres, associated with the gap between the valence and the conduction band. See equation 2.

$$\rho = \alpha.R_s + B_{res} \qquad (2)$$

The microscopic analysis performed in Organic Sensor by Scanning Electron Microscopy, has allowed us to observe the induction on the surface of the samples before and after the application of voltage. Figure 7 has shown the micrograph of Organic Sensor before applying voltage. It may be observed that the surface of the sample has some homogeneous aspect, plane and without changes.

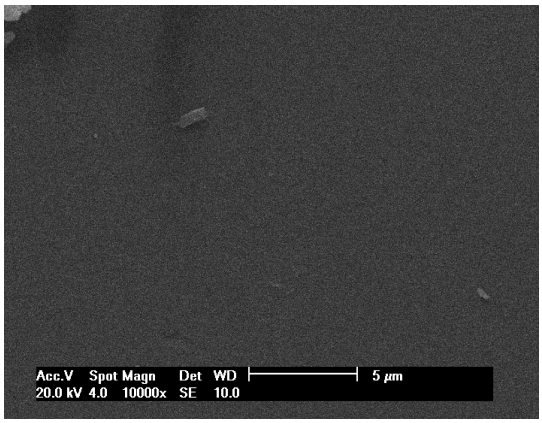

Figure 7. The Scanning Electron Microscopy (SEM) of the Organic Sensor surface.

Figure 8 has shown the micrograph of Organic Sensor after 10 hours exposure time. In this micrograph, it may be observed the surface of the sample in some irregular aspect, with holes and cracks.

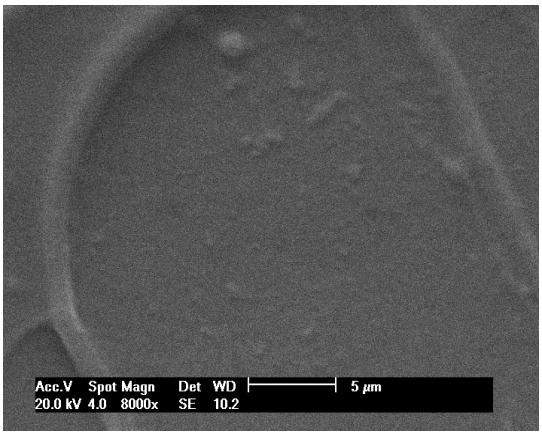

Figure 8. The Scanning Electron Microscopy (SEM) of the Organic Sensor surface after exposure time.

4. CONCLUSIONS

The Radiation induced changes in the optical absorption spectra of the studied PVK-PPV polymer films can be correlated to absorbed dose. The use full dose range is large and probably this can be extended to time exposure higher than 10 hours. The UV–Vis spectra present a linear correlation between the 250nm and 330nm peak intensities, which were chosen as being wavelength dosimetric interest for the time equivalent radiation exposure dose. The Organic Sensor films present excellent dosimetric characteristics and are promising materials alternatives to quality control in neonatal phototherapy equipment..

5. ACKNOWLEDGMENTS

MCTI-BRAZIL, CNPq, FINEP, GPETA/ University ESTACIO of RS and LabNANO/ INTELLECTOS.

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