STUDY OF PEDOT:PSS THIN FILMS DEPOSITED BY SPINNER MOUNTED WITH HARD DISK MOTOR

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ABSTRACT

In this work, a spinner using hard disk motor with low cost was developed. This equipment has been frequently used for deposition of polymeric thin films applied in the construction of P/OLEDs (polymer or organic light emitting diodes) devices [1].

Commercial equipments of spin-coating have robust size and vacuum pump, in contrast, the apparatus here described has compact size and no vacuum pump to hold the sample [2].

During the experiments, a range of rotation rate was applied to study the polymeric films of PEDOT:PSS formed on glass and also Indium Tin Oxide (ITO) films, as substrates [3]. It was possible to observe the formation of uniform PEDOT:PSS films, as pointed by thickness and transmittance measurements.

A discussion about the best processes parameters for PEDOT:PSS deposition is not found in the literature as: rotation rate, heating time and heating temperature. Additionally, in this work, some results of electrical measurements and storage method are presented.

It was verified that the storage condition and heating temperature have direct influence on the electrical resistance of the PEDOT:PSS films.

1. INTRODUCTION

In the assembly of P/OLEDs devices, some thin films have been used, as follows:

(1) an inorganic Transparent Conductive Oxide (TCO) deposited on glass or plastic substrates (as anode electrode),
(2) oxidative treatment on the surface of TCO to remove contaminants,
(3) polymeric layer deposited by spin-coating (as hole transport layer),
(4) organic polymeric layer also deposited by spin-coating (as light emitting),
(5) organic film deposited by thermal evaporation (as electron transport layer),
(6) metallic film also deposited by thermal evaporation (as electrode cathode) and
(7) encapsulation of the devices inside the glove box system under inert atmosphere [4].

The polymers used in these devices degrade with the presence of the moisture and oxygen, then the spin-coating deposition should be accomplished inside the glove box system, but these processes do not occur frequently, due to the different geometric size of the glove box and the common spinner [5]. In this case, this work suggests the spinner assembly as alternative method.

1.1. SPINNER ASSEMBLY

The homemade spinner was built from a hard disk motor, manufactured by Quantum, model 3.5 Trailblazer Series, a power supply, manufactured by Casetek of 300 Watts, a magnet, and a metallic disk, all mounted on a metallic base, while the substrate was hold by a double-sided adhesive tape [6].

Metallic disk was screwed on the motor shaft and this motor was used as originally manufactured fixed on the metallic base.

Acceleration of metallic disk was controlled by the action of the magnetic field using the magnet that was screwed (by one side only) on the same metallic base.

This magnet was used to approach or repel the metallic disk, then different outlines of the magnet were marked and numbered on the metallic base.

For example, the position 1 let the magnet farther (increasing the rotation) and the position 5 let the magnet closer of the metallic disk (decreasing the rotation).

Figure 1 shows the spinner mounted using the hard disk motor.

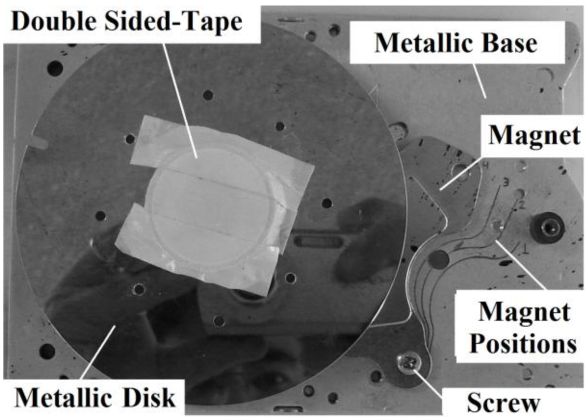

Figure 1 – Complete spinner using hard disk motor.

Five different rotation rates were measured in rpm, using a tachometer manufactured by Tako, model TD-303. The tachometer shaft was placed on the motor shaft (by physical contact) and ten measurements were collected for each different position of the magnet.

The rotation time was controlled by electronic circuit board automatically set at 35 seconds.

1.2. Samples preparation, PEDOT:PSS films deposition and analyses

Polymeric films using PEDOT:PSS or poly(styrenesulfonate)/poly(2,3-dihydrothieno[3,4-b]-1,4-dioxin) with 1.3 wt. % dispersed in water was provided by Sigma-Aldrich.

Substrates (glass and glass/ITO) presented size of 2.5 x 2.5 cm were used. First, they were cleaned with water and common detergent, rubbing the surfaces with gloves and then rinsed. The samples were immersed sequentially into the alcohol and acetone (both for 20 minutes in an ultrasonic bath) [7]. For all experiments, one substrate was used as reference.

The surface of the ITO films (used in the thickness and transmittance results) were exposed to UV-Ozone treatment during 5 minutes using an apparatus previously developed [8]. In the deposition of the polymer solution, a 500 µL syringe was used.

Thicknesses of PEDOT:PSS films were obtained by profilemeter technique using a equipment manufactured by Alfa Step, model 500 Surface.

Transmittances of the films were obtained by UV-Vis. spectroscopy with equipment manufactured by Shimadzu, model UV-1650 PC. The electrical resistances were obtained by Resistivity Test Rig manufactured by A. & M. Fell LTD, model B connected with a multimeter manufactured by Minipa, model ET 2082A using the resistance method. For all electrical resistance measurements, the distance of the two point probes was the same.

2. RESULTS

In the first experiment, ten rotations were collected for each different position of the magnet. In Table I, the positions of the magnet with the respective rotation rate (and standard deviation) are shown. The deposition was carried out few minutes after the bottle of PEDOT:PSS had been removed from refrigerator.

Table I shows the direct influence of the magnetic field on the metallic disk to obtain a range of different rotation rates. The measurements presented a small standard deviation for each condition.

Table I – Different positions of magnet and the rotation rate (and sd - standard deviation).

Magnet position	rpm (± sd)
Pos. 1 (farthest from the disk)	5095 (± 157)
Pos. 2	3957 (± 73)
Pos. 3	2606 (± 60)
Pos. 4	1503 (± 73)
Pos. 5 (closest from the disk)	1284 (± 40)

The range of thicknesses for any polymeric material is not only dependent on the spinner rate, but also on its viscosity (composition of the polymer + solvent).

Therefore, different rates can generate very similar thicknesses or completely distinct for the same material analyzed.

In Figure 2, PEDOT:PSS films thicknesses measurements on the ITO/glass were obtained at five conditions of deposition. In this case, it was found ≈70 nm for the lowest rate at 1284 rpm (pos. 5) and ≈35 nm for the highest rate at 5095 rpm (pos.1).

The different rates presented similar thicknesses of PEDOT:PSS films for assembly of P/OLEDs devices, as reported by some authors [9-15].

In Figure 3, the transmittances results for all five conditions are presented. It was verified for all samples with PEDOT:PSS films on the ITO/glass values above of 80 % in the range of visible light wavelengths (400-700 nm).

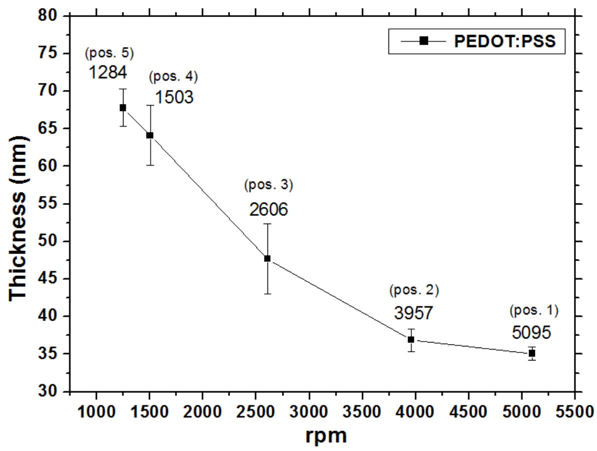

Figure 2 – Thickness vs. rpm for PEDOT:PSS films (deposited on ITO/glass) using five conditions.

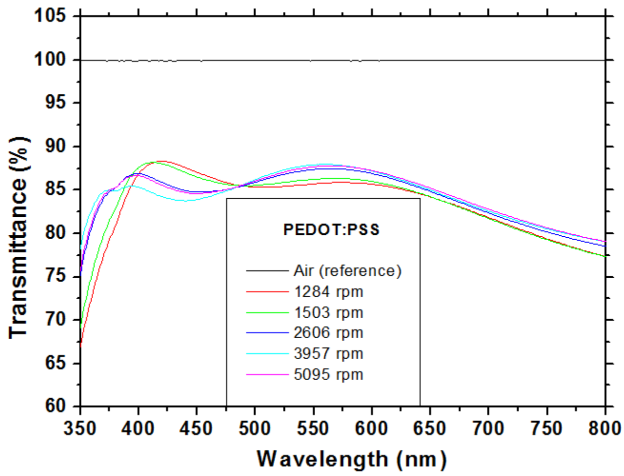

Figure 3 - Transmittance vs. wavelength for PEDOT:PSS films (deposited on ITO/glass) using five conditions.

In recent years, in the literature, thicknesses of PEDOT:PSS films in the order from 30 to 35 nm have been reported to present good results in different devices, thus, in this work, a rate of 5095 rpm (pos. 1) was chosen as the standard condition [16-18].

In Figure 4, the electrical resistance determined for different heating time is shown, which allows the study of the influence of heating time at 100°C on the PEDOT:PSS films.

The increase of the electrical resistance with the heating time increased until 120 minutes.

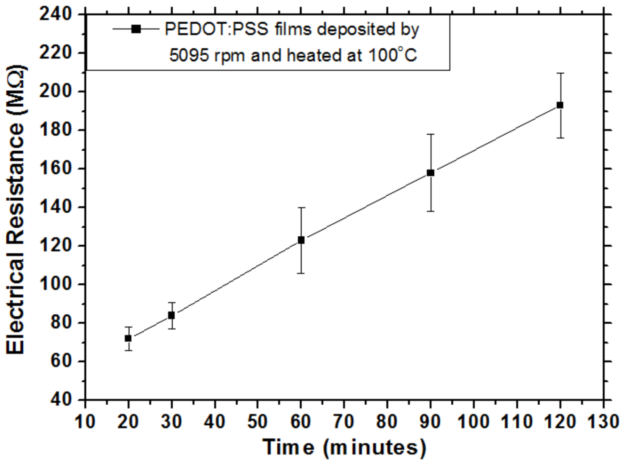

Figure 4 - Electrical resistance of PEDOT:PSS films vs. heating time.

According to the results (Figure 4), a lowest electrical resistance of PEDOT:PSS films deposited at 5095 rpm is observed, when it was heated at 100°C for 20 minutes.

The increase of the electrical resistance happens along the time.

As 20 min. heating presented the lowest electrical resistance, it was used in the investigation of the PEDOT:PSS films heated at different temperatures in two distinct situations, soon after the bottle of PEDOT:PSS was removed from the refrigerator (cold) and after three days at room temperature.

Figure 5(a) shows the behavior of the electrical resistance vs. heating temperature for the PEDOT:PSS films with the cold bottle and Figure 5(b) shows the electrical resistance vs. heating temperature with the PEDOT:PSS bottle left at room temperature.

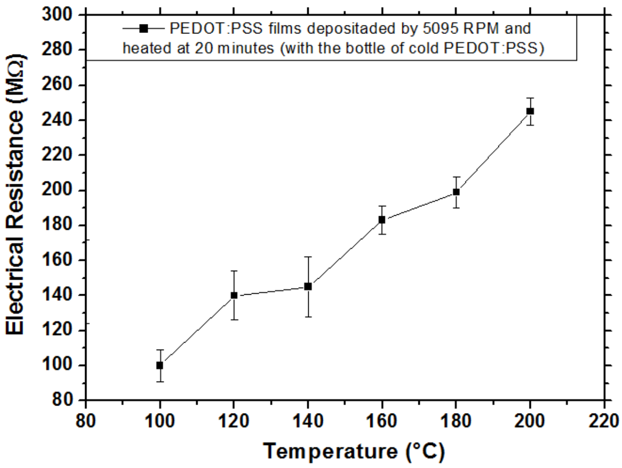

Figure 5 (a) - Electrical resistances vs. heating temperature for PEDOT:PSS films (with the bottle of cold PEDOT:PSS).

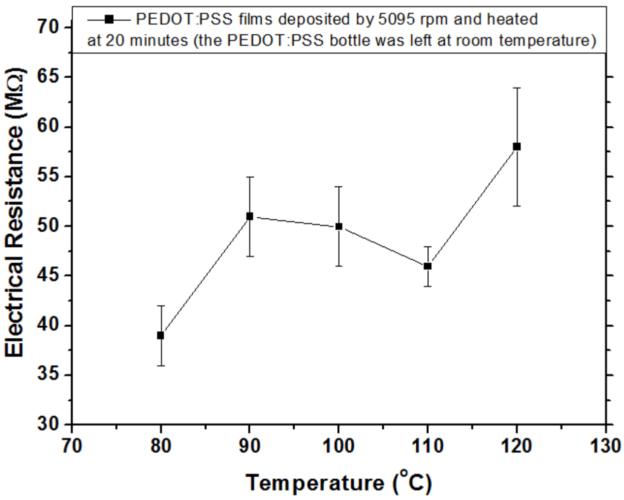

Figure 5 (b) - Electrical resistance vs. heating temperature for PEDOT:PSS films (the PEDOT:PSS bottle was left at room temperature).

The results shown in Figs. 5(a) and (b) revealed the strong influence caused by the storage condition of PEDOT:PSS. Lower electrical resistance of the films was observed for PEDOT:PSS left at room temperature for three days.

3. CONCLUSIONS

The mounted spinner using a hard disk motor showed good results in the spin-coating deposition of polymeric films (PEDOT:PSS), observed by thickness and transmittance measurements. It also presented three different advantages (if compared with a commercial spinner) as: low cost, no need of a vacuum pump and compact size.

In general terms, in the construction of P/OLEDs devices, deposition of PEDOT:PSS films is suggested to set at 5095 rpm for 35 seconds, and heating treated at 100°C for 20 minutes. These process parameters generated the lowest electrical resistance for the PEDOT:PSS stored at room temperature.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

[1] T. Munters; Philips, 2011, p. 28.
[2] L. Hu; J. Li; J. Liu; G. Grüner; T. Marks; Nanoterch., 2010, 21, 1.
[3] E. Yuki; E. R. Santos; E. C. Burini; F. C. Correia; G. Santos; W. S. Hui; F. J. Fonseca; A. M. de Andrade; Latindisplay, 2010, p.1.
[4] T. Clausen; C. Dabruzzi, 3M DOE Solid-State Ligh. Manufac. Workshop, 2009, p. 24.
[5] A. Benor; S. Takizawa; C. Pérez-Bolívar; P. A. Junior; Org. Electr., 2010, 11, 938.
[6] R. F. Bianchi; M. F. Panssiera; J. P. H. Lima; L. Yagura; A. M. Andrade; R. M. Faria; Prog. in Org. Coat., 2006, 57, 33–36.
[7] E. R. Santos; F. C. Correia; S. H. Wang; P. Hidalgo; F. J. Fonseca; E. C. B. Júnior; A. M. de Andrade; Quim. Nova, 2010, 33, 8, 1779.
[8] E. R. Santos; F. C. Correia; E. C. B. Júnior; S. H. Wang; M. A. Yamasoe; P. Hidalgo; F. J. Fonseca; A. M. de Andrade; Sens. & Trans. J., 2009, 101, 2, 12.
[9] J. Hwang; F. Amy; A. Kahn; Org. Elec., 2006, 7, 387.
[10] C. K. Chan; F. Amy; Q. Zhang; S. Barlow; S. Marder; A. Kahn; Chem. Phys. Lett., 2006, 431, 67–71.
[11] G. Ge; X. Yu; H. Guo; F. Wang; D. Zou; Synth. Met., 2009, 159, 1178.
[12] C.-Y. Lin; Y-M. Chen; H.-F. Chen; F.-C. Fang; Y.-C. Lin; W.-Y. Hung; K.-T. Wong; R. C. Kwong; S. C. Xia; Org. Electr., 2009, 10, 181.
[13] S.-Y. Kim; J.-J. Kim; Org. Electr., 2010, 11, 6, 1010.
[14] K. H. Kim; J. Y. Lee; T. J. Park; W. S. Jeon; G. P. Kennedy; J. H. Kwon; Synth. Met.; 2010, 160, 631.
[15] M. de Kok; W. Sarfert; R. Paetzold; Thin Solid Films, 2010, 18, 518, 5265.
[16] K.-R. Lin; C.-H. Kuo; L.-C. Kuo; K.-H. Yang; M.-K. Leung; K.-H. Hsieh; Eur. Pol. J. 2007, 43, 4279.
[17] T. Tsuboi; FNMA L'Aquila-Sulmona, 2009, p. 47.
[18] W. ZhiQiang; Z. CaiJun; L. Heng; O. XueMei1; Z. XiaoHong; Scie. China Press and Spring.-Verlag Berlin, 2011, 54, 4, 666.