Article

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Study of spin coating variables for deposition of hole transport nanolayer used in hybrid perovskite solar cells

Estudio de variables de spin recubrimiento para deposición de nano capa transportadora de agujeros utilizada en celdas solares híbridas de perovskita

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Abstract

PEDOT:PSS (poly(3,4-ethylenedioxythiophene):poly (styrene sulfonate)) is a conductive polymer, which has among its properties a high transmittance to visible light, and has a relatively high electrical conductivity for an organic polymer. This polymer is widely used as one of the key materials in the structure of a perovskite organometallic solar cell (POSC). The main function of PEDOT:PSS is to act as a carrier layer for the positive charges or holes generated by sunlight and direct them to the output electrode of the device. This layer has a thickness of approximately 10 to 50 nanometers. In this research, the spin coating technique is exposed to deposit PEDOT:PSS films with different thicknesses. To achieve this purpose, three variables must be taken into account: the rotation speed, which varies between 1000 and 6000 revolutions per minute. The amount of solution that ranges from 40 to 100 microliters of solution, and the method of deposit on the substrate, which can be with the spin coater off or on when the solution is poured. It was found that depositing the PEDOT:PSS solution with the spin coater turned on at 5000 RPM and 100 microliters of solution yielded nano films that exhibit greater homogeneity and adherence. Leading to the conclusion that this is the best combination for producing uniform and homogeneous hole-transporting films, which should translate into an improved solar cell efficiency.

PEDOT:PSS, spin coating technique, perovskite solar cell

Resumen

PEDOT:PSS (poli(3,4-etilendioxitiofeno):poli(sulfonato de estireno)) es un polímero conductor, que tiene entre sus propiedades una alta transmitancia a la luz visible, y tiene una conductividad eléctrica relativamente alta para un polímero orgánico. Este polímero se utiliza ampliamente como uno de los materiales clave en la estructura de una celda solar organometálica de perovskita (CSOP). La función principal de PEDOT:PSS es actuar como capa portadora de las cargas positivas o agujeros generados por la luz solar y dirigirlas al electrodo de salida del dispositivo. Esta capa tiene un espesor de aproximadamente 10 a 50 nanómetros. En esta investigación, se expone la técnica de spincoating para depositar películas de PEDOT:PSS con diferentes espesores. Para lograr este propósito se deben tener en cuenta tres variables: la velocidad de rotación, que varía entre 1000 y 6000 revoluciones por minuto. La cantidad de solución que oscila entre 40 y 100 microlitros de solución, y el método de depósito sobre el sustrato, que puede ser con el equipo spin coating apagado o encendido cuando se vierte la solución. Se descubrió que depositar la solución PEDOT:PSS con el spin coating encendido a 5000 RPM y 100 microlitros de solución produjo nanopelículas que exhiben mayor homogeneidad y adherencia. Lo que lleva a la conclusión de que esta es la mejor combinación para producir películas transportadoras de agujeros uniformes y homogéneas, lo que debería traducirse en una mejora de la eficiencia de las células solares.

PEDOT:PSS, Spin coating, Celdas solares perovskite

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Introduction

PEDOT:PSS(poly(3,4ethylenedioxythiophene): poly(styrene sulfonate)) is a polymer widely used in electronic and photovoltaic applications. One of its most prominent uses is as a key material in the structure of perovskite-based organometallic solar cells (PSCs). PSCs exhibit promising efficiency due to the combination of perovskite-structured materials as a light-absorbing layer and PEDOT:PSS as a hole-transporting layer [1]. PEDOT:PSS offers high visible light transmittance and a relatively high electrical conductivity for an organic polymer, having reached 6259 S cm−1 for thin films and 8797 S cm−1 for single crystals [2], making it an attractive option for improving the efficiency and stability of solar cells.

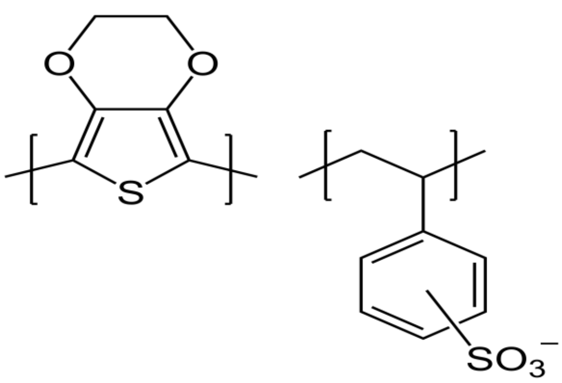

Figure 1 PEDOT:PSS molecule

Methodology

Spin coating technique was explored to deposit PEDOT:PSS thin films with different thicknesses. Spin coating is a method widely used in the electronic device industry to produce uniform and controlled films [3]. Experiments were carried out by modifying three main variables: the rotation speed, the amount of solution and the deposition method on the substrate. For this, a spin coater brand/ model VTC-50 A was used.

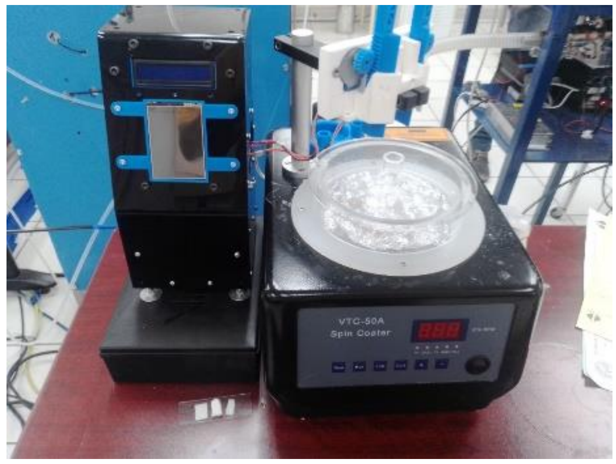

Figure 2 Spin Coater VTC-50 A

First, the rotation speed of the spin coater was varied in the range of 1000 to 6000 revolutions per minute (RPM). Different rotation speeds were selected to investigate their influence on the thickness and uniformity of the deposited films. A higher rotation speed was expected to provide thinner and more uniform films due to greater dispersion of the solution over the substrate surface.

Secondly, the amount of PEDOT:PSS solution used during the spin coating process was evaluated . Different volumes of solution were tested, varying from 40 to 100 microliters. The objective was to determine the optimal amount of solution necessary to obtain uniform and adherent films, avoiding excess solution that could generate defects or lack of adhesion.

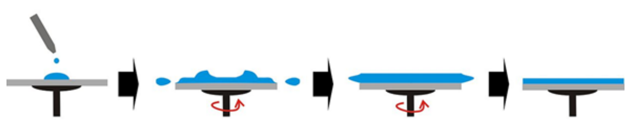

Figure 3 40/100 µl of PEDOT:PSS were deposited varying the speed from 1000 to 6000 RPM

Third, the deposition method on the substrate was investigated. Two different approaches were compared: the spin coater turned off during solution deposition and the spin coater turned on when pouring the solution onto the substrate. It was analyzed whether the activation of the spin coater during deposition had any effect on the uniformity and adhesion of the films.

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Figure 4 Deposition with the spin coating: a) OFF and b) ON.

The depositions were carried out on 22 by 22 mm D 263® borosilicate glass substrates with a thickness of 0.13 to 0.17 mm, which have a high transmittance of 92% [4].

Results and discussion

After performing 18 experiments and measurements, promising results were obtained regarding the quality of the deposited PEDOT:PSS films. It was observed that the combination of a rotation speed of 5000 RPM, 100 microliters of solution and the spin coater turned on during deposition produced films with greater homogeneity and adhesion.

The films deposited with this configuration presented an adequate thickness and a uniform distribution on the substrate. Furthermore, good adhesion was observed between the PEDOT:PSS film and the substrate, which is essential to ensure efficient charge transfer through the device.

UV-Vis characterization studies were carried out in the range of 200 to 800 nm in the electromagnetic spectrum. Transmittance results are shown in Figure 4, because perovskite (CH3NH3PbI3) has an approximate absorption range of 400 to 800 nm and its maxima are approximately between 400 nm and 560 nm. To highlight the absorption range of the perovskite in the transmittance response of the samples, a script was made in MicroPhyton.

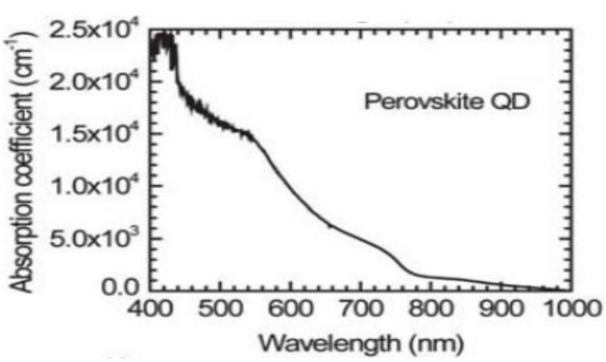

Figure 6 Absorption coefficient of CH3NH3PbI3 Perovskite
Source: [8]

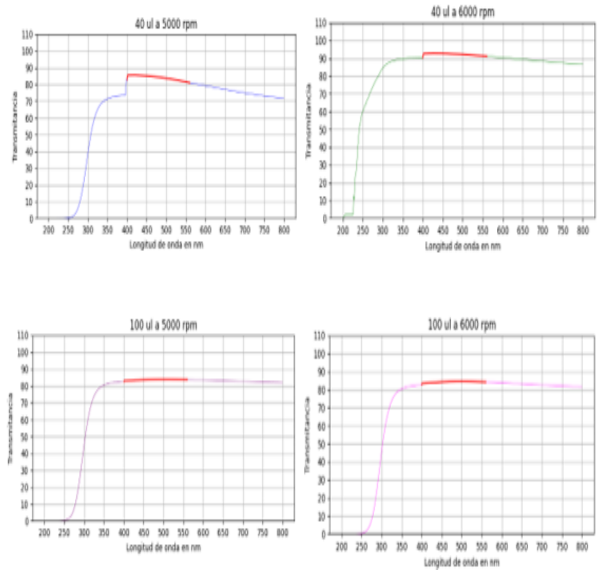

Figure 7 Transmittance graphs

Using the Scanning Electron Microscopy (SEM) technique, you can observe the formation of the layer and determine its thickness in the samples, as shown in Figure 5.

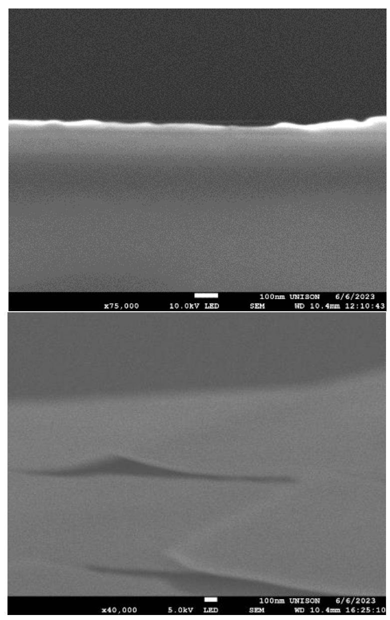

Figure 8 SEM characterization

Multiple thickness measurements were carried out during PEDOT:PSS deposition using ImageJ. It was observed that nanolayers were obtained an average of 27 nm.

The most successful combinations were obtained with volumes of 40 microliters at 6000/5000 RPM and 100 microliters at 6000/5000 RPM, both using the spin coater in operation. For volumes of 40 microliters, high transmittances were observed, while for those of 100 microliters, the curves showed a more uniform behavior. In addition, better coverage in the area was seen when 5000 RPM was used.

With which the formation of thin nanolayers with an average thickness of approximately 27 nm was obtained.

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Conclusions

In summary, the results obtained in this research demonstrate that the spin coating technique is effective for depositing PEDOT:PSS nanofilms with desired properties in terms of thickness, uniformity and adhesion. Additionally, the optimal combination of process parameters was identified, including a rotation speed of 5000 RPM, 100 microliters of solution, and the use of the spin coater on during deposition.

The use of this combination allowed to obtain PEDOT:PSS nanofilms with greater homogeneity and adhesion, which translates into a potential improvement in the efficiency of solar cells. These findings contribute to the advancement in the development of PEDOT:PSS-based photovoltaic technologies and offer opportunities to further improve the efficiency and stability of perovskite organometallic solar cells.

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