INTERNATIONAL JOURNAL OF ENGINEERING
AND APPLIED SCIENCE
ISSN 2709-8117
MAR. 2021 VOL. 2, NO. 1

Comparison of TiO_2 Blocking Layers Prepared by Spray Coating and Spray Pyrolysis Of Perovskite Solar Cells

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ABSTRACT

In this study, the optical and photovoltaic properties of the active layer of PSCs prepared by rotary spraying and spray pyrolysis were studied and compared. Diffusion transmission spectroscopy (DTS) was used to study the optical properties of the active layer, and the photovoltaic performance and efficiency of JSC, VOC and FF solar cells were measured. Because of the importance of barrier layer and mesoporous TiO_2 layer to transmission, the scattering spectra of these layers and the importance of light absorption spectra in perovskite are studied. Diffuse transmission spectrum of active layer is studied from optical point of view. Titanium and, finally, it can conclude that the bill of lading in spin coating and spray pyrolysis method does not block the sunlight reaches the perovskite absorbent and perovskite materials absorption rate, the bill of lading was built in the spin coating method, higher than the cells of the bill of lading is by spray pyrolysis, which is why the first condition of Jsc content is higher, this led to a higher efficiency than the second mode.

KEYWORDS

Terms-Perovskite Solar Cell; Blocking Layer TiO_2; Spin-coating; Spray pyrolysis.

1. Introduction

The organic-inorganic perovskites used for photovoltaics (PV) have an ABX_3 formula that is comprised of a monovalent cation, A = [methylammonium (MA) $CH_3NH_3^+$; formamidinium (FA) $CH_3(NH_2)_2^+$; ethylammonium (EA) $CH_3CH_2NH_3^+$]; a divalent metal B= (Pb^{2+}; Sn^{2+}); and an anion X = (Cl^-, Br^-; I^-) [1]. Low-cost perovskite solar cells (PSCs) have achieved certified power conversion efficiencies (PCEs) of 22.1%. This highest efficiency are Pb-based with mixed MA/FA cations and Br/I halides. In this paper, the structure of $MAPbI_2$ has been used. PSCs consist of n-type electron transport layer (ETL), perovskite layer, and p-type hole transport layer (HTL) similar to a p–i–n structures [2].

ETL involves blocking layer (BL) and mesoporous TiO_2 (mp-TiO_2) layer. In highly efficient PSCs, those exceeding a power conversion efficiency of 20%, TiO_2 is used as ETL, although the use of other oxide materials, such as SnO_2, ZnO, and Zn_2SnO_4, has been reported. The compact TiO_2 layer can be produced either by electrochemical deposition, thermal oxidation, dip-coating, atomic layer deposition, spin-coating, and spray pyrolysis [3]. MAPbI3 has a combination of desirable properties, including large absorption coefficient in the visible spectrum, favourable direct band gap, high carrier mobilities, and long carrier-diffusion lengths for both electrons and holes. Typically, deposition of MAPbI3 perovskite thin films is done using the one-step or the two-step solution-processing methods. HTLs are mainly based on organic semiconductors such as 2,20,7,70-tetrakis(N,N-di-p-methoxyphenylamine)-9,90-spirobifluorene (spiro-OMeTAD); poly(3,4 ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS); poly-triarylamine (PTAA) and NiO. Usually, the last layer is a metallic layer of high-conductivity made of gold (Au) or silver (Ag); with the thickness of more than 50 nm [3]. This layer was deposited using thermal evaporator or sputtering and a shadow mask. This layer can also be replaced with carbon.

In this work, the blocking layers were made using spin-coating and spray pyrolysis methods. The optical properties of these two different active layers were studied. Then, PSCs were fabricated using these active layers to investigate the effect of spin-coating and spray pyrolysis method on the performance of cells.

2. Materials and Method

The commercial materials used are listed as follow: titanium di-isopropoxide (TTIP); Hydrochloric acid (HCl); TiO2 past (18NRT,Dyesol); PbI2; Methyl Ammonium (MA); 2,20,7,70-tetrakis(N,N-dip-methoxyphenylamine)-9, 90-spirobifluorene (spiro-OMeTAD); FTO substrate. In this research, transparent conductive oxide, Fluorine-doped Tin Oxide (FTO) used as substrates. FTO glass substrates were selectively etched with Zn powder and 0.1 M HCl in deionized water, followed by mechanical attrition with a toothbrush. After that, the FTO substrates were cleaned in an ultrasonic bath with Soapy water, 0.1M HCl in isopropanol, Acetone, and ethanol for 10 minutes at 60°C, respectively, and were annealed at 500°C for 30 minutes. A solution consisting of TTIP and HCl in Ethanol was utilized to deposit BL on the substrates using the spin-coating technique. They were annealed at 500°C for 30 minutes. In spray pyrolysis method, a solution consisting of 0.1M of titanium di-isopropoxidebis (acetylacetonate, 75%vol.2-propanol) inabsolute ethanol (1:39, v/v ratio) was sprayed at 380°C to made BL. Then, the layers were annealed at 500°C for 30 minutes. Subsequently, a TiO2 solution (18NR-T, Dyesol) in ethanol was spin-coated on TiO2 BL at 4000 rpm for 30s to fabricate the mp-TiO2 layers. They were annealed at 500°C for 30 minutes. PbI2 solution in N, N′-dimethylformamide (DMF) was spin-coated on mp-TiO2 layer at 6500 rpm for 5s. As-prepared PbI2 layer was immediately dipcoated in fresh 10 mM MAI solution in anhydrous isopropanol. Then, they were annealed at 70°C for 30 minutes to obtain a dark-colored perovskite layer. This was followed by spin-coating a solution of Spiro-MeOTAD as a HTM. Finally, 80 nm Au layer was deposited using thermal evaporation technique.

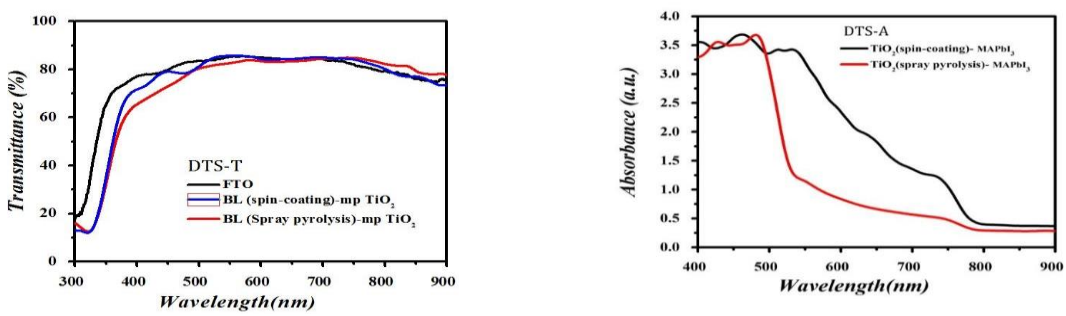

Figure 1. The transmittance spectra of FTO, blocking layer that these layers prepared by spin-coating and spray pyrolysis methods on mpTiO2

3. Results and Discussion

The diffuse transmittance spectra of FTO, BL (spin-coating) and mp-TiO2 on FTO, as well as BL (spray pyrolysis) and mp-TiO2 on FTO are observed in Figure 1. They have transmittance of about 80% in a wide range of visible wavelengths from 500 to 750 nm. This means that the addition of the BL and the mp-TiO2 layer do not reduce the amount of light, which is absorbed by the perovskite. Since the TiO2 band gap is around 3.2 eV [2], there are no absorbance at the wavelengths higher than 400 nm due to electron transitions. In this range of wavelengths, since their transmittances are similar, it could be found that light do not lost in the TiO2 layers when they are deposited on FTO. Therefore, no considerable scattering centres inside TiO2 layer are observed. Reduction in transmitted light occurs at lower wavelengths, where transmitted light strongly comes down. FTO glasses with BL and mp- TiO2 have similar trend, which occur at higher wavelength rather than FTO glass. This confirms that the TiO2 band gap is less than the FTO band gap. In the range of 300 to 500 nm, the light transmission rate with the BL and the mp-TiO2 layer on the FTO decreases about 6% to 59% ratio to the FTO. At wavelengths of 750 nm, there is not an Impressive difference in the transmission of light from the FTO and The layers on the FTO which deposited with BLs not seen. However, an increase in the passage of about 5% is observed for a sample which BL is prepared by the spray pyrolysis method, which indicates that in this range of layers have acted as anti-reflection layers and increased the light transmission rate.

TheabsorbancespectraofBL(spin-coating),mp-TiO2 andMAPbI3 on FTO; as well as BL (spray pyrolysis), mp-TiO2 and MAPbI3 on FTO are shown in Figure 2. Hybrid perovskites exhibit strong optical absorbance, allowing for a much-reduced thickness necessary to efficiently facilitate the collection of charge carriers. Absorption

The absorption spectra of the BL/mp-TiO2/Perovskite that BL is prepared by spin-coating and spray pyrolysis methods. across the entire visible spectrum is achievable with an only 500 nm thick perovskite film, far less than the 2μm limitations typically required by solar cell active layers. The absorption peak for both samples are sharp, indicating a direct band gap. In the absorption spectra of two selles, an absorption onset at about 790 nm is found, corresponding to an optical bandgap of about 1.57 eV, in good agreement with the trend reported by Byung-wook Park et al [4]. In comparison to the MAPbI3 film that BL prepared by spin-coating, the MAPbI3 film that BL prepared by spray pyrolysis an increasing absorption can be seen at wavelengths below 720 nm and further below 540 nm, which can be attributed to absorption in the PbI2 and MAPbI3 fractions in this material, respectively. The other word, it could be said that the PbI2 cannot be converted completely to CH3NH3PbI3 unless the layer is quite dense and thick.

Table 1. Best values for Voc, Jsc, FF, and PCE, for Perovskite solar cell, that blocking layer is prepared with spin-coating and spray pyrolysis methods

Cell	J_{sc} (mA/cm^2)	V_{oc} (V)	FF	PCE (%)
BL(spin-coating)	14.81	0.72	0.35	3.76
BL(spray pyrolysis)	5.1	0.82	0.38	1.61

Both of cells are built, achieve absorption up to the tail end of the red region of the spectrum, approximately 800 nm. This means that the conduction band and the valence band in the Perovskite structure have not been shifted. In other words, the better performance of solar cells which BL were prepared by spin-coating, attributed to the absorbing properties. It is clear that the light absorption properties of in the two samples are completely different, which confirms that perovskite is sensitive to construction. Figure 1 showstheJ–Vcharacteristicsofthecellswiththestructure: FTO/TiO2 BL/mp-TiO2/CH3NH3PbI3 /Spiro-OMeTAD/Au. Table 1 shows the summary of the photovoltaic parameters of the cells.

The best photovoltaic performance with Jsc of 14.81 mA.cm−2, Voc of 0.72 V, FF of 0.35, and an overall power conversion efficiency of 3.76% was obtained for the cell consisting of BL, which made using spin-coating. Since the amount of absorbed light in the visible range is higher, the higher current density was obtained for this cell.

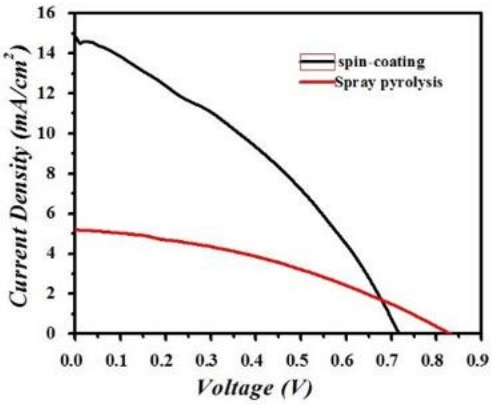

Figure 2. J-V curves of the PSCs is, which blocking layer was prepared

4. Conclusions

In this study, the optical properties of the active layer and the photovoltaic properties of PSCs which BLs were made using the spincoating and spray pyrolysis methods were investigated and compared. Finally, it can be concluded that the titanium BL in both spin-coating and spray pyrolysis methods don't prevent sunlight from reaching the perovskite absorbent material and The perovskite absorption rate, which The BL was built in a spin-coating manner, is higher than that of the cell which BL was built with spray pyrolysis, which is why the amount of Jsc in the first state is higher, which results in higher efficiency than the second mode has been.

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