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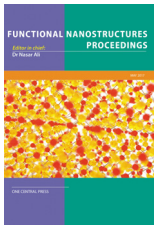

Study of Carbon-based Hole Transport Material (HTM)-free Perovskite Solar Cells

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ABSTRACT

In this paper, the perovskite solar cells（PSCs）with structure of FTO glass /TiO_2 blocking layer/ mesoporous TiO_2 / $CH_3NH_3PbI_3$ /carbon (C) electrode were designed and fabricated. The perovskite $CH_3NH_3PbI_3$ layers were prepared using one-step solvent-engineering method. The effect of molar ratios of PbI_2 to CH_3NH_3I (MAI)and volume ratios dimethyl sulfoxide (DMSO) to N,N-dimethylformamide (DMF) on structure and morphology of perovskite layers $CH_3NH_3PbI_3$, as well as photovoltaic performance of PSCs were studied. The results show that the PSCs based on a specific ratio of PbI_2:MAI=1:1.4 and DMSO:DMF=1:3 exhibited an optimal photovoltaic performance, yielding an open circuit voltage (V_{oc}) of 0.72V, short-circuit current density (J_{sc}) of 25.98 mA/cm^2, fill factor (FF) of 0.46, and power conversion efficiency (PCE) of 8.45%. And the photo-to-current efficiency (IPCE) is close to 85% between 400 and 600nm visible region.

I. INTRODUCTION

Hybrid organic/inorganic perovskit solar cells (PSCs) have recently emerged as attractive solar cell [1, 2]. A typical PSCs consists of electron transport materials, perovskite layer, hole transport materials (HTMs), and noble metal electrode. However, the conventional organic HTMs (e.g. spiro-OMeTAD) and noble metal (Au) are usually expensive and unstable. Carbon-based HTM-free PSCs have shown much promise for practical applications because of their high stability and low cost [3]. However, the efficiencies of this kind of PSCs are still relatively low. In this paper, the PSCs with structure of FTOglass/TiO_2 blocking layer/ mesoporous TiO_2/$CH_3NH_3PbI_3$ /carbon (C) electrode were prepared and its photovoltaic performance was studied.

II. EXPERIMENTAL SECTION

In the PSCs fabrication process, the TiO_2 blocking layers and mesoporous layers were prepared using spin-coating. The carbon electrode was fabricated by blade-coating. The $CH_3NH_3PbI_3$ layers were prepared by one-step solvent-engineering method in the air. In a typical synthesis process, the $MAPbI_3$ precursor solutions were prepared by using 576mg PbI_2 and 199mg MAI as solute, 200ul DMSO and 800ul DMF as solvent. And the anti-solvent was ethyl acetate. To study the effect of molar ratios of solute and volume ratios of solvent on structure and morphology of $CH_3NH_3PbI_3$ layers, as well as photovoltaic performance of PSCs, two series samples were prepared by varying the molar ratios of PbI_2 to MAI and volume ratios of DMSO to DMF while keeping the concentrations of precursor solutions as constant. The deposition process parameters of different PSCs were listed in Table 1. The $CH_3NH_3PbI_3$ layers were obtained by spin-coating and then annealing at 100 °C for 30 min. The structure of $CH_3NH_3PbI_3$ absorption layers were characterized via the X-ray diffractometer (XRD, D/MAX Ultima IV, Rigaku). The surface morphology was analyzed using scanning electron microscopy (FE-SEM, SU8010). The J-V curves of PSCs were recorded under standard AM 1.5 solar illuminations with an intensity of 100mW cm^{-2} using a Keithley Model 2400 digital source meter.

III. RESULTS AND DISCUSSION

Fig.1 (a) and (b) show the X-ray diffraction patterns of $CH_3NH_3PbI_3$ absorption layers prepared using different molar ratios of solute and volume ratios of solvent, respectively. The major XRD diffraction peaks appeared at 2θ=14.04°, 19.94°, 23.46°, 24.48°, 28.32°, 31.86°, 34.92°, 40.52° and 43.04° can be indexed as (110), (112), (211), (202), (220), (310), (312), (224) and (314) of the tetragonal-type perovskite crystal structure [4]. Results indicate that the molar ratios of solute and volume ratios of solvent affect the phase purity of $CH_3NH_3PbI_3$ absorption layers.

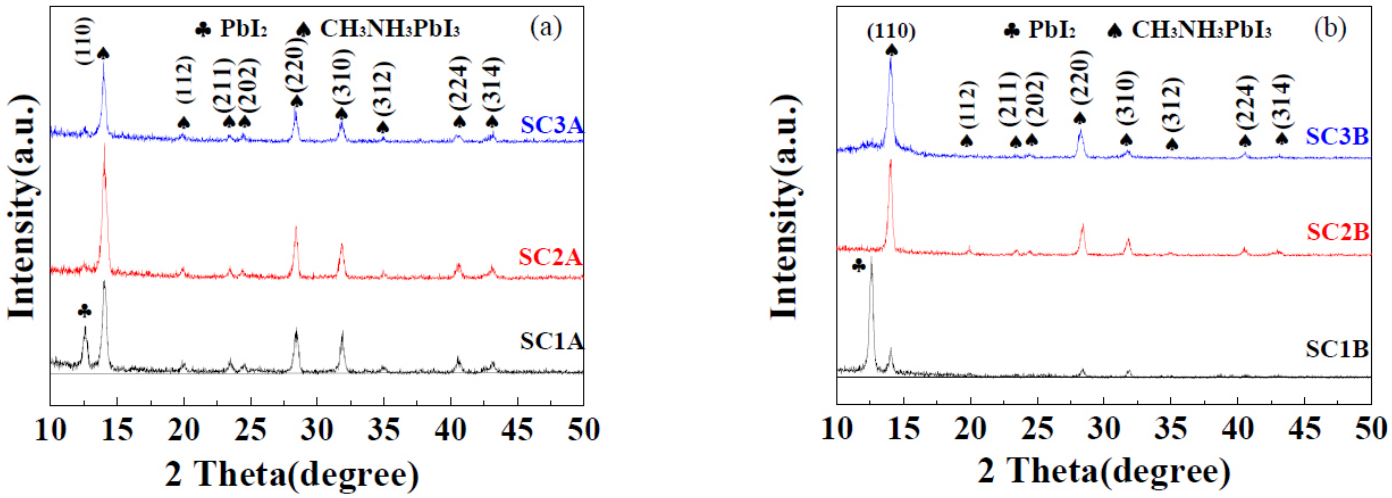

Figure 1 X-ray diffraction pattern of $CH_3NH_3PbI_3$ absorption layers.

Fig.2 shows the SEM images of the $CH_3NH_3PbI_3$ layers prepared using different molar ratios of PbI_2 to MAI and volume ratios of DMSO to DMF. The results indicate that $CH_3NH_3PbI_3$ layers have good coverage on TiO_2 films for all samples, however, the grain size increases gradually with decreasing of PbI_2 or DMSO in precursor solutions.

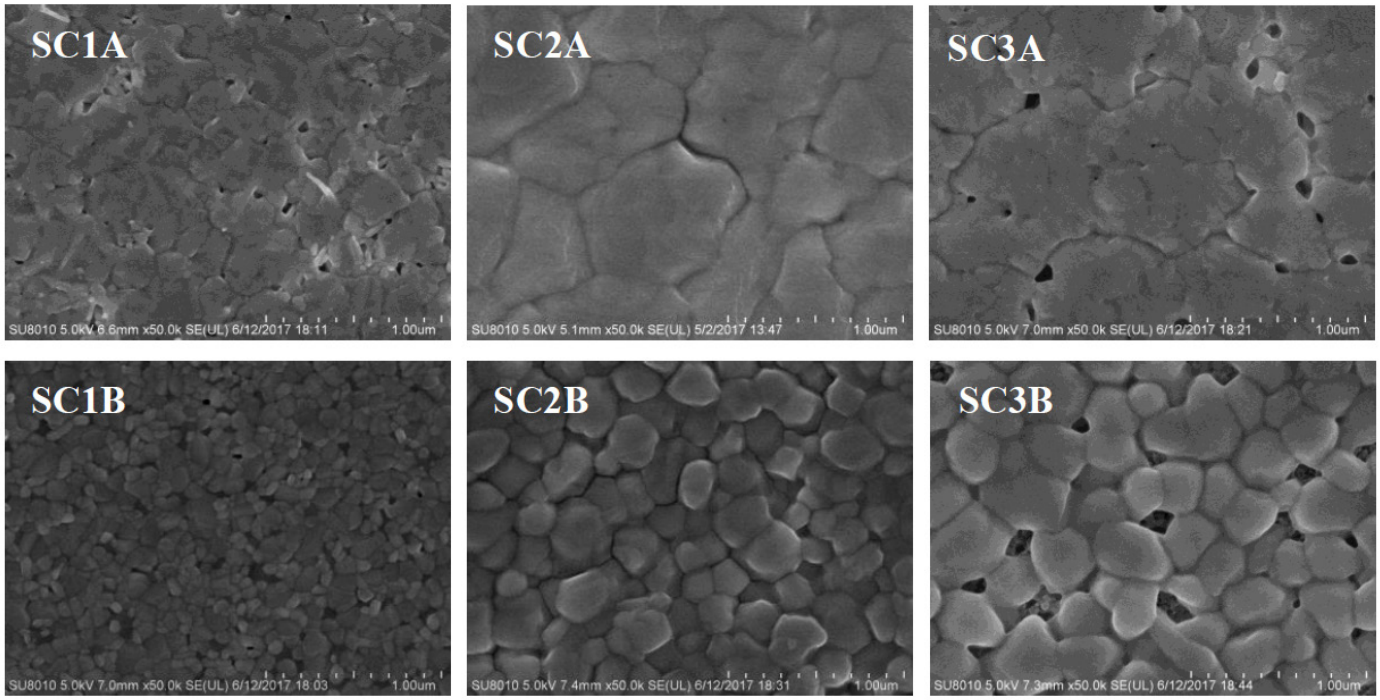

Figure 2 SEM images of $CH_3NH_3PbI_3$ absorption layers.

The photocurrent density-voltage characteristic curves of PSCs fabricated were measured under standard AM 1.5 solar illuminations with an intensity of 100 $mWcm^{-2}$, as indicated in Fig. 3. The short-circuit current density J_{sc}, open circuit voltage V_{oc}, fill factor *FF* and power conversion efficiency η of these solar cells are listed in Table 1. The results show that the PSCs based on a specific ratio of PbI_2:MAI=1:1.4 and DMSO:DMF=1:3 exhibited an optimal photovoltaic performance, yielding an open circuit voltage (V_{oc}) of 0.72V, short-circuit current density (J_{sc}) of 25.98 mA/cm^2, fill factor (FF) of 0.46, and power conversion efficiency (PCE) of 8.45%. The photo-to-current efficiency (IPCE) is close to 85% in visible region. The photovoltaic performance could be further improved by

precisely controlling the quality of every layer and the preparation process of solar cells. However, lower fill factor due to high series resistance causes lower performance of the present device. Further work is needed to fabricate a high performance photovoltaic device.

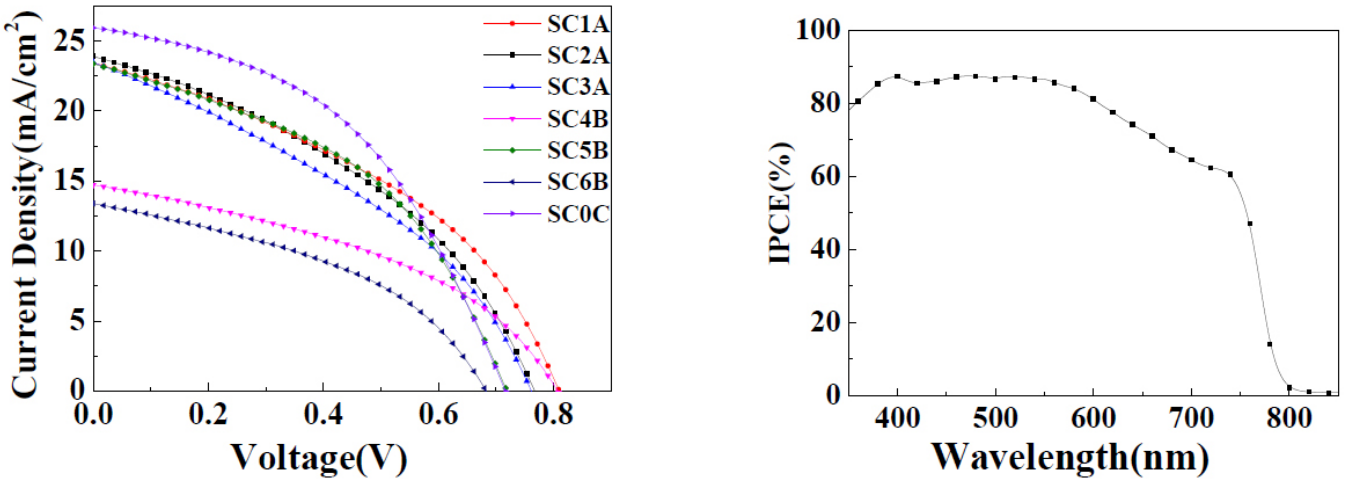

Figure 3 J-V characteristic curve and (b) IPCE spectra of PCSs.

Table 1 Parameters of preparation process and photovoltaic characteristic parameters of PSCs.

	Parameters of preparation process		photovoltaic parameters			
Sample No	DMSO : DMF	PbI_2 : CH_3NH_3I	V_{oc}(V)	J_{sc}(mA/cm²)	FF	η(%)
SC1A	1.3	1.1	0.881	23.43	0.40	7.62
SC2A	1.4	1.1	0.766	23.93	0.39	7.17
SC3A	1.5	1.1	0.763	23.48	0.36	6.50
SC1B	1.4	1:0.6	0.807	14.76	0.41	4.87
SC2B	1.4	1:1.4	0.719	23.25	0.44	7.39
SC3B	1.4	1:1.8	0.682	13.36	0.42	3.85
SC0B	1.3	1:1.4	0.715	25.98	0.46	8.45

IV. REFERENCES

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