Active-layer evolution and efficiency improvement of $(CH_3NH_3)_3Bi_2I_9$-based solar cell on TiO_2-deposited ITO substrate

Xinqian Zhang, Gang Wu*, Zhuowei Gu, Hongzheng Chen*

MOE Key Laboratory of Macromolecular Synthesis and Functionalization, State Key Laboratory of Silicon Materials, & Department of Polymer Science and Engineering, Zhejiang University, Hangzhou 310027, P. R. China

E-mails: wmang@zju.edu.cn, hzchen@zju.edu.cn

Introduction

Recently, the hetero-valent substitution of Pb^{2+} with Bi^{3+} and Sb^{3+} was reported to achieve lead-free organic–inorganic hybrids, with the advantages of stability under humid environments, and low temperature solution processability. However, the reported PCE value of the $MA_3Bi_2I_9$-based organic–inorganic hybrid solar cell is far lower than expected. Here, we report a modification of the $MA_3Bi_2I_9$-based solar cell. By studying the development of the morphology and crystallinity of the one-step spin-coated $MA_3Bi_2I_9$ film on different substrates, we enhanced the PCE of $MA_3Bi_2I_9$-based solar cells by 2-3 times, with the device structure of glass/ITO/compact-TiO_2/$MA_3Bi_2I_9$ sensitized mesoscopic-TiO_2/spiro-MeOTAD/MoO_3/Ag, when 0.45 M precursor was applied.

Results and discussion

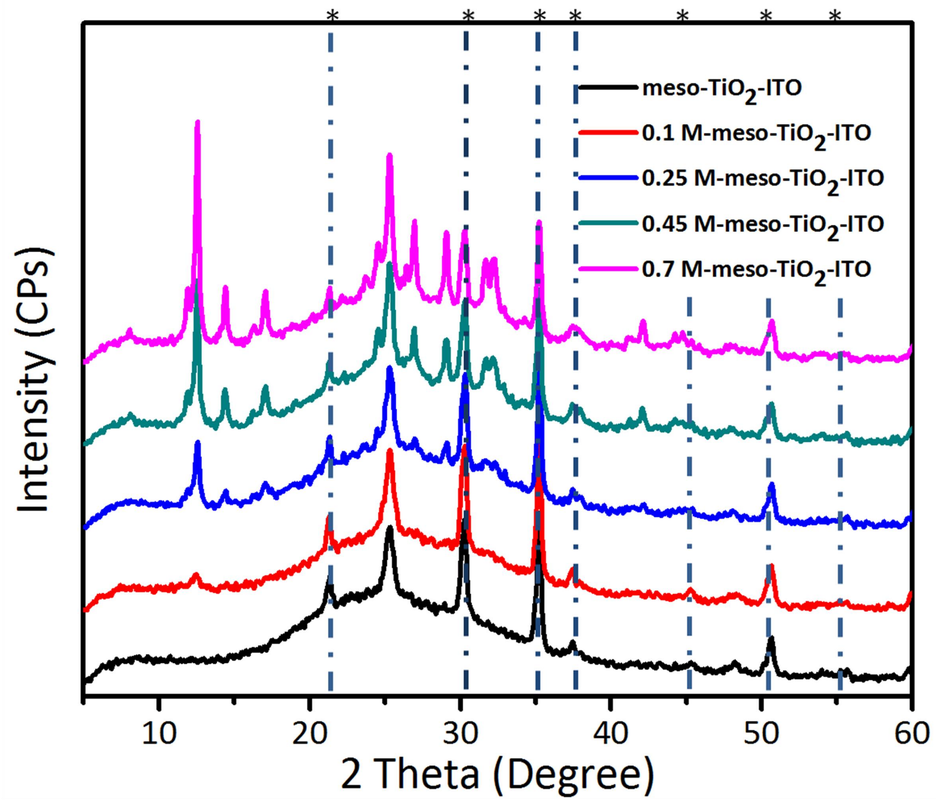

Fig. 1 XRD patterns of $MA_3Bi_2I_9$ films on meso-TiO_2/ITO substrates (* labels diffraction peaks of substrate).

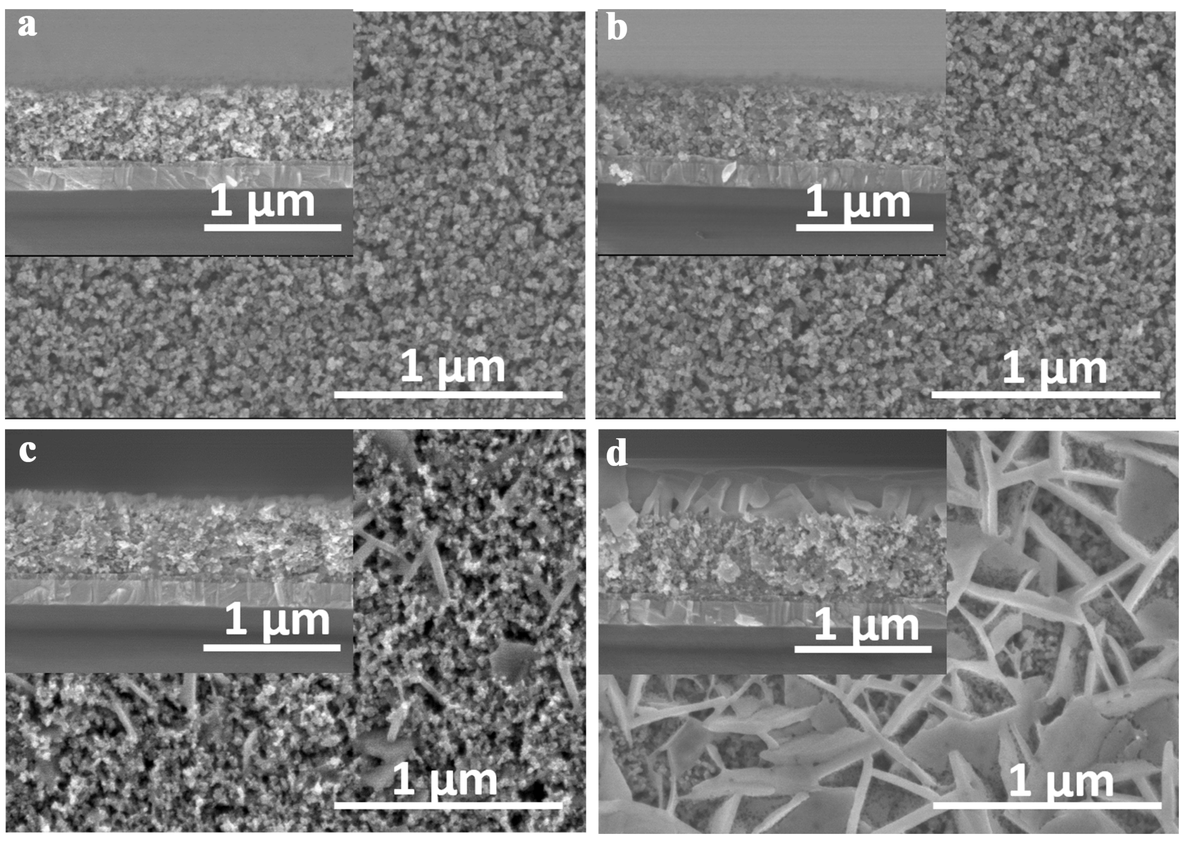

Fig. 2 SEM images of $MA_3Bi_2I_9$ films on meso-TiO_2/ITO substrates with various precursor concentrations of 0.1 (a), 0.25 (b), 0.45 (c), and 0.7 M (d)

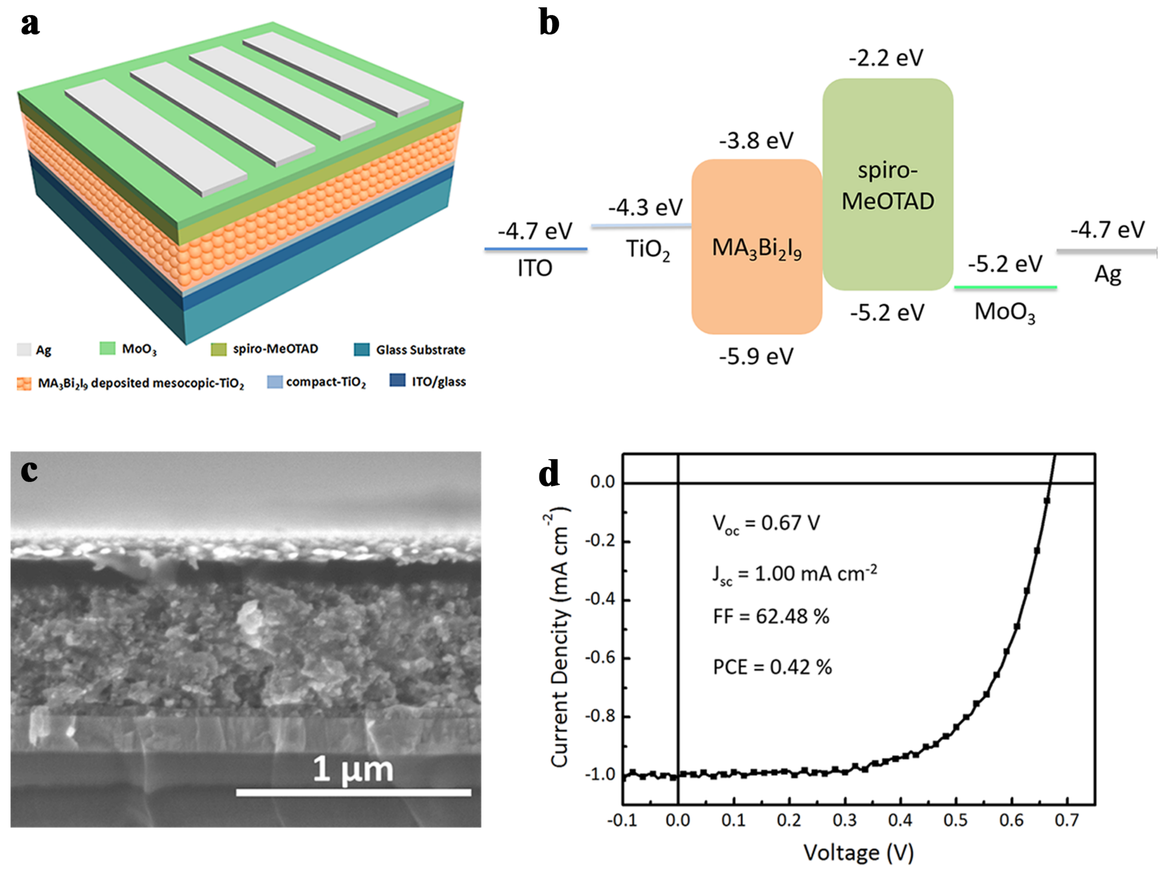

Fig. 3 Photovoltaic property of solar cell based on $MA_3Bi_2I_9$, with corresponding device structure: (a) overall device structure, (b) energy-band alignment, (c) cross section of solar-cell device, (d) *J*–*V* curve of the best device under 1 sun condition (100 mW/cm^2).

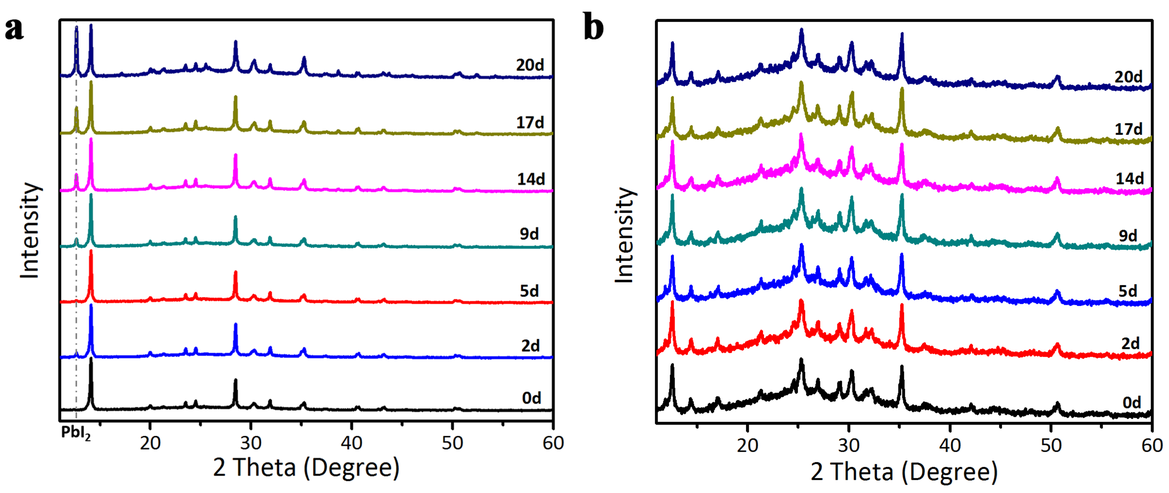

Fig. 4 XRD patterns of $MAPbI_3$ (a) and $MA_3Bi_2I_9$ (b) films kept in humidity environment (Hr = 55% ± 5%) for different time.

Conclusions

We have successfully improved the efficiency of a $MA_3Bi_2I_9$-based solar cell to 0.42% with the mesoscopic architecture on a TiO_2/ITO substrate through one-step spin-coating, with a relatively high *V*oc of 0.66 V, and an obviously enhanced fill factor of 62.48%. The precursor concentration is the most critical element that will significantly affect the morphology and crystallinity of the solution-processed $MA_3Bi_2I_9$ film, further the photovoltaic properties of solar cells.

Notes and references

1. X. Zhang, G. Wu, Z. Gu, H. Chen, *Nano Res.* **2016**, *9*, 2921-2930.
2. B.-W. Park, B. Philippe, G. Boschloo, E. M. J. Johansson, *Adv. Mater.* **2015**, *27*, 6806-6813.
3. M. Lyu, J.-H. Yun, L. Wang, *Nano Res.* **2016**, *9*, 692-702.
4. S. Öz, J.-C. Hebig, E. Jung, Sol. *Energy Mater. Sol. Cells* **2016**, *158*, 195–201.
5. R. L. Z. Hoye, R. E. Brandt, T. Buonassisi, Chem.-Eur. J. **2016**, *22*, 2605–2610.