ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

Developing High Performance Lead-Free Double Perovskite $Cs_2AgBiBr_6$ in a Low Cost Planar Structure

Mehri Ghasemi[1], Miaoqiang Lyu[1], Lianzhou Wang[1]
[1] *School of Chemical Engineering and Australian Institute for Bioengineering and Nanotechnology, The University of Queensland, Brisbane, QLD, 4072, Australia*
E-mail: m.ghasemi@uq.edu.au

Regardless of the high performance reported for hybrid lead halide perovskites, toxicity issue imposes significant circumscriptions toward their market acceptance. In this way, developing low toxic environmentally benign perovskites has become vital important. Recently all-inorganic double perovskite materials have been suggested as a promising alternative due to some of their encouraging properties such as three dimensional (3D) structure, long lifetime and diffusion length, potential tunable band gap and non-toxicity. Among all the reported double perovskite materials, $Cs_2AgBiBr_6$ possesses the proper bandgap for suitable light absorption as an active layer in solar cell. However, attaining high quality thin film of this material using solution process is still an utmost challenge. In this work, we develop a simple and facile solution method to produce high quality smooth $Cs_2AgBiBr_6$ thin film with low root-mean-square (RMS) and grain size in the range of 300-700 nm can obtain (Figure 1. a). The next focus of this work was developing a cost-effective structure to fabricate high efficiency solar cell based on this lead-free material. As matter of fact, in the most common HTLs to fabricate highly efficient and reproducible perovskite solar cells such as Poly(triarylamine) (PTAA), triarylamine-based HTMs and 2,2′,7,7′-tetrakis-(N,N-di-4 methoxyphenylamino)-9,9′-spirobifluorene (spiro-OMeTAD), low hole mobility enforces them to be doped by some dopants such as tert-butylpyridine (tBP) and bis(trifluoromethane)sulfonimide lithium salt [1]. However hydrophilic nature of such dopants compromise stability of the total structure in humidity by accelerating perovskite layer decomposition [2, 3]. Solving the problem numerous works focused on developing dopant free HTL options [4-6]. As mentioned before, thiophene-based polymers conjugated polymers achieved more interest due to their easy processability and solubility [7, 8], in which, P3HT with the highest hole mobility of 0.1 $cm^2V^{-1}S^{-1}$ and an adoptable band alignment is capable to work as an efficient dopant-free HTL [9]. Another favourable features specified to P3HT is its high stability due to hydrophobic nature of this material. In addition, in a comparable scale to the attached alkyl chain, P3HT tends to have a disordered semicrystalline microstructure[10], which with accompany of its low surface energy, this material mainly displays a full coverage upon the substrate[11]. In this way, employing high quality $Cs_2AgBiBr_6$ thin film in device with planar structure contains low cost dopant-free hole transport layer (HTL) of P3HT and non-noble metal contact of Cu, high power conversion efficiency (PCE) of around 2% achieved (Figure 2. b). To make a better comparison, functionality of spiro-OMeTAD also was examined, where the best working devcie showed inferior power convenrsion effcincy of 1.38%. This observation confirms ability of P3HT to work as a appropraite HTL with good charge transport ability.

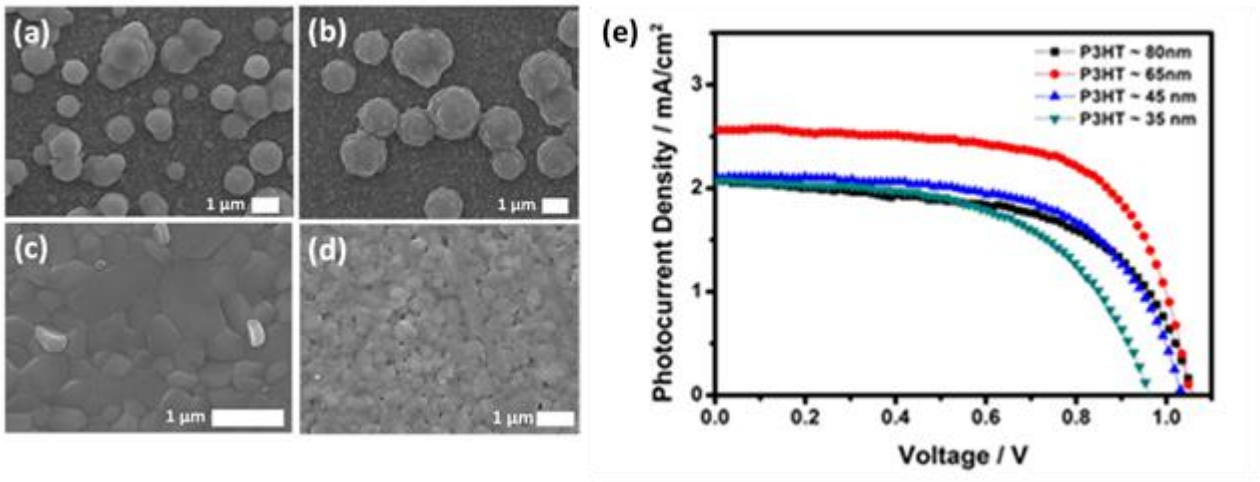

Figure 3. Scanning electron microscope (SEM) images of $Cs_2AgBiBr_6$ on FTO at different spin coating rate (a) 2000 rpm, (b) 3000 rpm, (c) 4000 rpm, (d) 5000 rpm. (e) J-V curve of devices based on planar structure of FTO / C-TiO_2 / $Cs_2AgBiBr_6$ / P3HT / Cu under 1 SUN illumination with different P3HT thickness

References

1. Guo, Y., et al., *Enhancement in the efficiency of an organic–inorganic hybrid solar cell with a doped P3HT hole-transporting layer on a void-free perovskite active layer.* Journal of Materials Chemistry A, 2014. **2**(34): p. 13827-13830.
2. Zhou, P., et al., *Efficient and stable mixed perovskite solar cells using P3HT as a hole transporting layer.* Journal of Materials Chemistry C, 2018. **6**(21): p. 5733-5737.
3. Wang, Q., et al., *Thin Insulating Tunneling Contacts for Efficient and Water‐Resistant Perovskite Solar Cells.* Advanced Materials, 2016. **28**(31): p. 6734-6739.
4. Zhang, Y., et al., *The essential role of the poly (3-hexylthiophene) hole transport layer in perovskite solar cells.* Journal of Power Sources, 2015. **274**: p. 1224-1230.
5. Li, G., et al., *"Solvent annealing" effect in polymer solar cells based on poly (3‐hexylthiophene) and methanofullerenes.* Advanced Functional Materials, 2007. **17**(10): p. 1636-1644.
6. Chen, C., et al., *Cu (II) Complexes as p-Type Dopants in Efficient Perovskite Solar Cells.* ACS Energy Letters, 2017. **2**(2): p. 497-503.
7. Winokur, M., et al., *Structural and absorption studies of the thermochromic transition in poly (3-hexylthiophene).* Synthetic Metals, 1989. **28**(1-2): p. 419-426.
8. Yang, H., et al., *Effect of mesoscale crystalline structure on the field‐effect mobility of regioregular poly (3‐hexyl thiophene) in thin‐film transistors.* Advanced Functional Materials, 2005. **15**(4): p. 671-676.
9. Sirringhaus, H., N. Tessler, and R.H. Friend, *Integrated optoelectronic devices based on conjugated polymers.* Science, 1998. **280**(5370): p. 1741-1744.
10. Colle, R., et al., *Structure and X‐ray spectrum of crystalline poly (3‐hexylthiophene) from DFT‐van der Waals calculations.* physica status solidi (b), 2011. **248**(6): p. 1360-1368.
11. Moon, B.J., et al., *In situ modulation of the vertical distribution in a blend of P3HT and PC 60 BM via the addition of a composition gradient inducer.* Nanoscale, 2014. **6**(4): p. 2440-2446.