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A Review on Perovskite Solar Cell for High Efficiency Future Applications

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Abstract— *Perovskite is the material which has shown lot of potential in fabrication of new generation solar cell. In this study we have reviewed the recent and ongoing development of perovskite solar cells (PSCs) in context of its efficiency and stability.*

Here we have reviewed various processes for formation of solution processed perovskite film with enhanced quality by controlling the parameters like dipping time, temperature, concentration of precursor for pinhole free thick uniform film deposition. The power conversion efficiency (PCE) can be increased due to the better quality of PSC films. Further, a comparison of organic and inorganic perovskite structure is performed based on available database, to address stability issues. Lastly a few new strategies are proposed to enhance the efficiency of optimised PSCs.

Keywords— *perovskite, solar cells, High efficiency and stable perovskite structure.*

1. INTRODUCTION

Halide perovskites are materials promising for low cost and high efficiency solar cell. The efficiency of perovskite based solar cell has increased rapidly from 3.8% in 2009 to 22.1% in 2016 by using all solid state thin film architecture.[1] A perovskite is any material with the same type of crystal structure as calcium titanium oxide. A perovskite solar cell (PSCs) is a type of solar cell which includes a perovskite structure compound, most commonly a hybrid organic inorganic lead or tin halide based material, as the light harvesting active layer in basic formula ABX3. Perovskites are sensitive to oxygen and water vapour. Instability is a big issue in perovskite materials. The perovskite solar cells with high efficiencies, low cost and high stability are our final goal in pursue.

In order to understand the basis for degradation of PSCs and solve it, three factors have been investigated:

Air Stability (Moisture and Oxygen), Photo stability and Thermal Stability. For the Perovskite film construction different methods have been developed such as solution process, vapour deposition process and vapour assisted solution process. Compared to vapour deposition process, solution process provides simple and easy procedures, low cost and adjustable components in the films. During the solution preparation component from the solvent, solutes, additives and impurities may destroy the crystal structure. So it is necessary to control the morphology of thin film in solution technique. In this paper we have reviewed the developments of PSCs till date and suggested to further develop the parameters of Perovskite thin film like dipping time, concentration of precursor and temperature.

In PSCs the main two issues which create problems in the high performance are stability and quality of film.

1.1 Comparision of Various Generation Perovskite Solar Cell

The first organic inorganic hybrid PSCs with efficiency of 3.8%was made in 2009. Since then it has made a remarkable progress with efficiency reaching to record level of 22.1% in early 2016. Refer to table 1 below the timeline of development of PSCs.

Table 1 shows the marked efficiency improvement from 3.8% to 6.5% though the compositions of PSCs are same. It is evident the improvement in efficiency can be attributed to various parameters like, modifications in the process of fabrication, nature of electrodes used, using mixed halides in organic perovskites, modifications in the charge transporting layers. Further it is clear that mixed halide perovskites shows better efficiency than monohalide perovskites. However the prevalence of issues like stability and higher efficiencies still exist. One of the major paradigm shift was observed when the organic perovskites were replaced by inorganic ones. These structures show lower efficiency, but it gives better stability. Till now there are a few reports of all inorganic PSCs [15].

Figure1 shows the stability comparison of $CsPbBr_3$/carbon based inorganic PSCs with $MAPbI_3$ based hybrid PSCs.

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Table 1: Development trends in perovskite solar cells with detail of device structure[2]

Year	*Device Structure*	*Efficiency*	*Ref.*
2009	FTO/bl-TiO_2/mp-TiO_2/$CH_3NH_3PbI_3$/Redox liquid electrolyte/Pt	3.8%	[3]
2011	FTO/bl-TiO_2/mp-TiO_2/$CH_3NH_3PbI_3$/Redox liquid electrolyte/Pt	6.5%	[4]
2012	FTO/bl-TiO_2/mp-TiO_2/$CH_3NH_3PbI_3$/Spiro-OMETAD/Ag	9.0%	[5]
March 2013	FTO/bl-TiO_2/mp-Al_2O_3/CH3NH3PbI_3-xClx/Spiro-OMETAD/Ag	12.3%	[6]
July 2013	FTO/bl-TiO_2/mp-TiO_2/$CH_3NH_3PbI_3$/Spiro-OMeTAD/Au	15%	[7]
2013	FTO/graphene-TiO_2/mp-Al_2O_3/ $CH_3NH_3PbI_{3-X}Cl_x$/ Spiro-OMeTAD/Au	15.6%	[8]
December 2013	ITO/np-ZnO//$CH_3NH_3PbI_3$/ Spiro-OMeTAD/Ag	15.7%	[9]
August 2014	ITO-PEIE/Y-TiO_2/ $CH_3NH_3PbI_{3-X}Cl_x$// Spiro-OMeTAD/Au	19.3%	[10]
June 2015	FTO/bl-TiO_2/mp-TiO_2/(($FAPbI_3$)$_{1-X}$($MAPbBr_2$)$_x$/PTAA/Au	20.1%	[11]
March 2016	FTO/bl-TiO_2/mp-TiO_2/$Cs_x(MA_{0.17}/FA_{0.83})_{1-X}Pb(I_{0.83}Br_{0.17})_3$/ Spiro-OMeTAD/Au	21.1%	[12]
March 2016	NA	22.1%	[13]
October 2016	$CsPbI_3$ (Inorganic perovskite)	10.77%	[14]

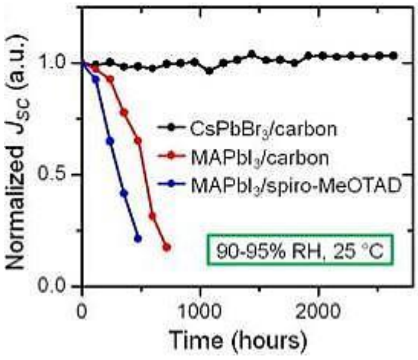

Fig. 1: Normalized J_{sc} of $CsPbBr_3$/carbonbased all inorganic PSCs, $MAPbI_3$/carbon and $MAPbI_3$/spiro-MeOTAD based hybrid PSCs as function of storage time in humid air (90-95%RH,25^{0}C) without encapsulation [15].

1.2 Analysis of Possible Causes for Lower Efficiency and Stability

To increase the efficiency of PSCs it is necessary to deposit thin pinhole free smooth layer. We are studied solution process method which is simpler and applicable. When we use additive in solution which increases the solubility of precursor and heating the solution leads to rapid formation of crystal nuclei which results in homogeneous crystalline size distribution therefore the homogeneous thin film form. In solution process annealing play an important role to stabilize perovskite film. After depositions of solvent residues are there in perovskite film. To remove them annealing is perform but maintaining suitable temperature is very important during annealing process. A very high annealing temperature though helps in faster evaporation of residue but also results in decrease of surface coverage due to aggregation of perovskite crystal. So it is very important to maintain suitable and low temperature during fabrication. Dipping time is another factor which affects the perovskite film. According to the studies excessive exposure to the solution may cause the dissolution of perovskite layer resulting in decrease of coverage area. So the lower dipping time is preferred. In comparison to simple dip process the spin dip process is better because it given thicker perovskite film with better absorption of wide range of wave length of light. In this process different parameters which affect the quality of perovskite film are shown below in Table2

We can also increase efficiency by band gap engineering. High J_{sc} is typically the result of a dense and uniform perovskite film with appropriate thickness good crystallinity and large grain size. High V_{oc} is enabled by inter-grain, inter-grain-defect densities, and by good interface properties between the perovskite and selective charge collection. Fill factors (FF_S) are typically very high

Table 2: Parameters affecting the efficiency of perovskite film

Parameter	*Controlling process*	*Effect*
Slow rate of crystallisation	Use suitable precursor like $Pb(OAc)_2$ in place of (PbI_2,$PbCl_2$)	Large continuous crystal structure with large surface coverage and get high quality film
Annealing temperature	Using suitable low temperature[17]	Form homogeneous film
Antisolvent use during last few second of spin process	Using toluene, xylene, benzene, dimethylether etc.[16]	Prevent to dissolve perovskite film and find extremely uniform and dense perovskite film
Dipping time	Lower dipping time preferred	Form uniform smooth film

with many devices. FF_s in the range of 0.75-0.80 has been reported [16]. Additionally compositional engineering of the perovskite absorber contributes to wave length longer than 800nm hence enhancing the J_{sc}.

1.3 Proposed Model for All Inorganic Perovskite Solar Cells

Previous studies in the all inorganic halide perovskites have revealed that these materials have great potential in optoelectrical application. $CsGeX_3$ are known for their nonlinear optical properties and are potentially useful for nonlinear optics in the mid infrared and infrared region. Optical measurements show that both $CsPbI_3$ and $CsPbBr_3$ are photoluminescence active with $CsPbBr_3$ showing strong photoluminescence and $CsPbI_3$ exhibiting a self trapping effect.

We hereby propose the following modifications in order to develop all inorganic stable high efficiency PSCs:

1. *To introduce Nano crystalline Perovskite structures*— The bigger size crystal (in bulk form) the $CsPbI_3$ absorbs sunlight only up to 400nm. So it does not have much application as a photovoltaic material. But by reducing the size of crystal to nm range, the material in ambient temperature is able to absorb visible sunlight till 700nm this is because the material retains the desirable crystal structure(cubic phase) even at the room temperature.
2. *Device engineering strategies*— Device engineering strategies lead to smooth and pinhole free perovskite thin film with good crystallinity. The combination of these advances engineering method will improve the optoelectronic properties of the perovskite films and consequently the device performance as well.
3. *Band Gap Engineering*— To improve the efficiency of PSCs it is important to understand about the electronic properties and how they can be tuned by changing the compositional and structural properties. The research about key ingredients affecting the electrical, optical and transport properties of perovskite will lead to design of improved PSCs through band gap engineering.

2. CONCLUSIONS

The present review addresses the stability and efficiency issues in organic- inorganic hetero structure. This study was focussed to solve the issues by proposing suitable modifications paving a way towards a new generation of all inorganic PSCs. These modifications include introduction of nanocrystalline structures, device engineering strategies and band gap engineering through incorporation of suitable materials. The conclusions drawn after the review will be quite useful in the field of research on comparatively less studied all inorganic PSCs with high efficiency.

REFERENCES

[1] W.-J. Yin, J.-H. Yang, J. Kang, Y. Yan, S.-H. Wei, T. Heumuller, M.G. Christoforo, M.D. McGehee, M.B. Johnston, A.M. Petrozza, L.M. Herz, H.J. Snaith, R. Mosca, R.H. Friend, Halide perovskite materials for solar cells: a theoretical review, J. Mater. Chem. A. 3 (2015) 8926–8942. doi:10.1039/C4TA05033A.

[2] N.K. Elumalai, M.A. Mahmud, D. Wang, A. Uddin, Perovskite solar cells: Progress and advancements, Energies. 9 (2016). doi:10.3390/en9110861.

[3] A. Kojima, K. Teshima, Y. Shirai, T. Miyasaka, Organometal halide perovskites as visible-light sensitizers for photovoltaic cells. TL - 131, J. Am. Chem. Soc. 131 VN- (2009) 6050–6051. doi:10.1021/ja809598r.

[4] J.H. Im, C.R. Lee, J.W. Lee, S.W. Park, N.G. Park, 6.5% Efficient Perovskite Quantum-Dot-Sensitized Solar Cell, Nanoscale. 3 (2011) 4088–4093. doi:10.1039/c1nr10867k.

[5] H.-S. Kim, C.-R. Lee, J.-H. Im, K.-B. Lee, T. Moehl, A. Marchioro, S.-J. Moon, R. Humphry-Baker, J.-H. Yum, J.E. Moser, M. Grätzel, N.-G. Park, Lead iodide perovskite sensitized all-solid-state submicron thin film mesoscopic solar cell with efficiency exceeding 9%., Sci. Rep. (2012). doi:110.1038/srep00591.

[6] J.M. Ball, M.M. Lee, A. Hey, H.J. Snaith, Low-temperature processed meso-superstructured to thin-film perovskite solar cells, Energy Environ. Sci. 6 (2013) 1739. doi:10.1039/c3ee40810h.

[7] J. Burschka, N. Pellet, S.-J. Moon, R. Humphry-Baker, P. Gao, M.K. Nazeeruddin, M. Grätzel, Sequential deposition as a route to high-performance perovskite-sensitized solar cells., Nature. 499 (2013) 316–320. doi:10.1038/nature12340.

[8] J.T.-W. Wang, J.M. Ball, E.M. Barea, A. Abate, J.A. Alexander-Webber, J. Huang, M. Saliba, I. Mora-Sero, J. Bisquert, H.J. Snaith, R.J. Nicholas, Low-Temperature Processed Electron Collection Layers of Graphene/TiO_2 Nanocomposites in Thin Film Perovskite Solar Cells, Nano Lett. 14 (2014) 724–730. doi:10.1021/nl403997a.

[9] D. Liu, T.L. Kelly, Perovskite solar cells with a planar heterojunction structure prepared using room-temperature solution processing techniques - supporting infomation, Nat. Photonics. 8 (2013) 133–138. doi:10.1038/nphoton.2013.342.

[10] H. Zhou, Q. Chen, G. Li, S. Luo, T. -b. Song, H.-S. Duan, Z. Hong, J. You, Y. Liu, Y. Yang, Interface engineering of highly efficient perovskite solar cells, Science (80-.). 345 (2014) 542–546. doi:10.1126/science.1254050.

[11] W.S. Yang, J.H. Noh, N.J. Jeon, Y.C. Kim, S. Ryu, J. Seo, S. Il Seok, High-performance photovoltaic perovskite layers fabricated through intramolecular exchange, Science (80-.). 348 (2015) science.aaa9272-. doi:10.1126/science.aaa9272.

[12] M. Saliba, T. Matsui, J.-Y. Seo, K. Domanski, J.-P. Correa-Baena, M.K. Nazeeruddin, S.M. Zakeeruddin, W. Tress, A. Abate, A. Hagfeldt, M. Grätzel, Cesium-containing triple cation perovskite solar cells: improved stability, reproducibility and high efficiency, Energy Environ. Sci. 9 (2016) 1989–1997. doi:10.1039/C5EE03874J.

[13] M.A. Green, K. Emery, Y. Hishikawa, W. Warta, E.D. Dunlop, D.H. Levi, A.W.Y. Ho-Baillie, Solar cell efficiency tables (version 49), Prog. Photovoltaics Res. Appl. 15 (2016) 659–676. doi:10.1002/pip.2855.

[14] 5 Joseph M. Luther1* Abhishek Swarnkar, 1, 2 Ashley R. Marshall, 1, 3 Erin M. Sanehira, 1, 4 Boris D. Chernomordik, 1 David T. Moore, 1 Jeffrey A. Christians, 1 Tamoghna Chakrabarti, Quantum dot–induced phase stabilization of a-CsPbI3 perovskite for high-efficiency photovoltaics Abhishek, Sci. Downloaded. 354 (2016) 92–95. doi:10.1126/science.aag2700.

[15] J. Liang, C. Wang, Y. Wang, Z. Xu, Z. Lu, Y. Ma, H. Zhu, Y. Hu, C. Xiao, X. Yi, G. Zhu, H. Lv, L. Ma, T. Chen, Z. Tie, Z. Jin, J. Liu, All-Inorganic Perovskite Solar Cells, J. Am. Chem. Soc. (2016) jacs.6b10227. doi:10.1021/jacs.6b10227.

[16] Z. Song, S.C. Watthage, A.B. Phillips, M.J. Heben, Pathways toward high-performance perovskite solar cells: review of recent advances in organo-metal halide perovskites for photovoltaic applications, J. Photonics Energy. 6 (2016) 22001. doi:10.1117/1.JPE.6.022001.

[17] H. Hu, K.K. Wong, T. Kollek, F. Hanusch, S. Polarz, P. Docampo, L. Schmidt-Mende, Highly efficient reproducible perovskite solar cells prepared by low-temperature processing, Molecules. 21 (2016). doi:10.3390/molecules21040542.