Improving Stability of Organic-Inorganic Hybrid Perovksite PV absorber layer

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by

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Conclusion and Outlook

In this chapter, an overview of the findings of this thesis is summarized. The major conclusions drawn from the work are enumerated, and the scope of future work in this area has been suggested, indicating possible refinement and modifications.

6.1 Brief summary and conclusion

In this thesis, strategies have been developed to overcome some of the challenges faced by the practical implementation of perovskite solar cells (PSC). The effort is geared towards devising strategies to improve the stability and efficiency of PSC.

Chapter 1 gives a brief idea of the energy crisis in the world and the implementation or importance of solar cells in contributing to the fulfilment of energy demand. This chapter is dedicated to the introduction, principles and classification of solar cells. A detailed discussion of the architecture of PSCs, major challenges and ways to improve the stability and performance of PSCs were also discussed.

Chapter 2 is devoted to the methodology i.e. processing and characterization techniques utilized in this work. Starting from the cleaning and etching of the substrate, the preparation of solution from the precursor for the different layers of the PSC, deposition of the films, and the post-deposition annealing strategy, along with processing parameters used in this thesis are presented. The various characterization techniques, including the structural, electrical, and optical characterization and the analysis method, were mentioned in detail.

Chapter 3 studied the role of various parameters controlling the microstructure of Pb and Sn-based perovskite including additives, solvent, co-solvent antisolvent and annealing time and temperature were studied. Co-solvent DMSO: DMF (1:4) and dripping of antisolvent (chlorobenzene, CB) is found to help in improving the microstructure of Pb-based perovskite absorber layer. A highly stable and large-grained perovskite film $FAMAPb(I,Br)_3$ was obtained using radiative annealing in vacuum (RAV) at a relatively low temperature of 120 ºC for just 60 seconds, which showed the major XRD peaks of $FA_{0.75}MA_{0.25}Pb(BrI)_3$ perovskite albeit with lower intensity even after 60 days in ambient conditions (RH 60%) confirms relatively better stability of RAV films. The PSC based on $FAMAPb(I,Br)_3$ has realized a PCE of 12.24%. Similarly, for Sn-based perovskite, introducing the additives SnX_2 (X=F, Cl) and CB dripping during the last stage of spin coating is found helpful in improving the stability of $FASnI_3$ by restricting the oxidation of Sn^{2+} to Sn^{4+} and making the film stable for up to 10 hours.

Chapter 4 describes the study of stability and charge transfer abilities of $FAMAPbI_3$ perovskite film on TiO_2, SnO_2, and bilayer TiO_2-SnO_2 ETL processed via a spray coating technique. Various factors, such as wettability and roughness of the substrate decide the morphology and uniformity of the perovskite film. The higher wettability of bilayer TiO_2-SnO_2 assisted in achieving better compactness and film morphology. The absence of defects and discontinuities has improved the stability of perovskite films on bilayer ETL which showed stability up to 60 days in ambient air (RH = 70%). At the same time, the PL peaks revealed greater quenching and more efficient electron extraction at the bilayer-ETL/perovskite interface. PSCs on bilayer ETL have realized a higher PCE of 13% as compared to 10% with TiO_2 and SnO_2 alone.

C**hapter 5** highlights the contribution of mixing three cations (MA, FA, and Cs) at A-site to form triple-cation $CsFAMAPbI_3$ perovskite in improving the stability and performance of

PSCs. The triple-cation perovskite layer remained stable up to 1000 h without any hint of decomposition or phase change from XRD. The triple cation perovskite absorber film, along with spray-deposited TiO_2 (ETL), results in an efficient device having an efficiency close to 18.60%, while the 1000 h stored perovskite could still deliver a 12.2% efficiency.

6.2 Suggestion for future work

The thesis provides an understanding and possible ways to improve the stability and efficiency of the solution-processed PSC. As mentioned earlier stability of PSC is challenging and the biggest concern for the commercialization of the same. Based on the insight from this work, a few suggestions for future efforts in this area are as follows:

1. As mentioned in Chapter 1 several factors are responsible for poor stability and efficiency and strategies to balance the stability and efficiency of PSC. Incorporating hydrophobic large cations into 3D perovskite materials results in mixed 2D/3D perovskite material which is more robust to humidity. Large cations such as phenyl ethylene ammonium (PEA), butyl amine (BA) and guanidinium (GA^+) controls the growth orientation, act as a spacer and make the layers more hydrophobic, which improves the stability of PSCs. To increase the PCE of photovoltaic devices (PV), a technical strategy including precursor preparation engineering such as co-solvent, anti-solvent and additives, spin coating parameters and annealing conditions and temperature utilized in Chapters 1,3 and 4 should be optimized.
2. This thesis investigated the stability of perovskite film under humidity and heat in chapters 3, 4 and 5. For realistic research, PV devices should be studied in environments that apply moisture, heat, and UV light simultaneously. Before testing realistic operation conditions, it would be advisable to perform tests involving two factors, such as moisture and heat, moisture and UV light, or heat and UV light.

3. As demonstrated in Chapter 5, PSCs were fabricated on large 2.5 x2.5cm^2 substrates by using the spray-coated TiO_2. Spray coating of perovskite layer for device fabrication could be an interesting study for large and flexible substrates. However, it could be a viable approach for scaling up PSC.
4. The toxicity of Pb is the bottleneck for the commercialization of PSC. Exploring a suitable, less toxic alternative material such as germanium, bismuth, and tin could be the beneficial approach. Although Sn-based perovskite emerges as a replacement for lead, it suffers from rapid oxidation, poor stability and efficiency as compared to Pb based counterparts. Unravelling the properties of less toxic alternative materials and utilizing them as PV absorbers without compromising efficiency could be a fruitful study.