

Title: Planar multi-layer perovskite solar cell with graded energy band structure via fast-drying spray deposition

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Abstract

Over the past years, perovskite solar cells (PSCs) have attracted a lot of interest by exhibiting desirable properties like dynamically tunable electronic band structures, suitable electromagnetic waves absorbance, and long charge carrier diffusion length. Moreover, PSCs are also solution-processable, which, when combined with their excellent photovoltaic properties, further heightens the technology's attractiveness. That being said, manufacturing constraints still exist as a major paradigm that has to be overcome in order to commercialize large-scale PSCs. As an alternative to spin coating, recent progress saw spray coating assuming dominance as a promising candidate for scale-up PSCs manufacturing. This research utilizes a proprietary automated spray coating system and leverages its innate characteristic of depositing quickly-dried films to stack multiple perovskite active layers without causing unwanted re-dissolution. By engineering optimum stoichiometric formulas for each of the perovskite layers, a stacked architecture of perovskites absorbers with

spatially graded energy levels can be manufactured. Properly graded energy levels form built-in electric fields within the perovskite layers, which induce preferential drift-diffusion movement of electron-hole pairs to their respective transport layers and reduce carrier back recombination. To achieve graded energy band levels, $\text{Cs}_x(\text{FA}_{0.853}\text{MA}_{0.147})_{(100-x)/100}\text{PbI}_{2.55}\text{Br}_{0.45}$ triple cation mixed halide perovskite system is chosen. By varying the ratio of cesium to the organic cations in the system, shifts in energy band structures can be observed via ultraviolet photoelectron spectroscopy (UPS). First, a series of preliminary testings are done on the relationships between the spray coating system's deposition parameters and the resulting film thickness and morphology. Afterward, cross-section views from scanning electron microscope (SEM) and carrier quenching characteristics from photoluminescence spectroscopy (PL) are used to confirm the existence of multi-layer perovskite films. Finally, planar-NIP structure solar cell devices are fabricated and tested to investigate the effects of graded energy structure in comparison to the non-graded counterparts.