Abstract Book of the 2024 International PhD School on Perovskite PV
http://www.sciencepublishinggroup.com/ISBN/979-8-88599-107-0/001

Two-Step Sequential Vapor-Solution Hybrid Deposition of Uniform and Stable Perovskite Films Assisted by Slot-Die Coating Intended for Commercial Large-Area Photovoltaic Applications

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Abstract

The deposition of perovskite films by slot-die coating (SDC) offers various advantages over the ubiquitously used spin coating techniques, including faster processing, compatibility with large-area substrates, less chemical consumption, cost-effectiveness, and high throughput. Moving beyond a lab-oriented spin coating technique, this research opens gates for large-area deposition of perovskite films mainly focused on commercial and industrial avenues. In this research, we have used a hybrid deposition process for the perovskite film on a 12×12 cm^2 ITO-coated glass substrate which includes both the vacuum-based and solution-based processing. A hybrid deposition of organic-inorganic mixed halide perovskite films (MA, FA, Cs) Pb (I, Br, Cl)$_3$ is achieved by thermally co-evaporating PbI_2 and CsBr followed by an SDC procedure of a mixture containing formamidinium iodide (FAI) and methylammonium chloride (MACl) dissolved in ethanol/isopropanol and butanol. The coating parameters including chuck temperature, coating speed, and pump rate were optimized on the SDC unit while the solution concentration was adjusted to form a uniform and homogenous perovskite film. The X-ray diffraction (XRD) and photoluminescence (PL) spectroscopy results confirm the existence of the α-black perovskite phase (2θ=14.2°) and a bandgap of ~1.6 eV. Moreover, the uniformity of the deposited perovskite layer is depicted by a very low variance in the FWHM of both XRD and PL peaks taken throughout the large area. Furthermore, a surface compositional analysis done by X-ray photoelectron spectroscopy (XPS) featured all the characteristic elemental peaks of the perovskite composition while the absence of residual metallic Pb peak (Pb^0) showed the viability of our technique to avoid undesired decomposition of perovskite. With the power conversion efficiency of the PIN-configured SDC-processed solar cell (ITO/NiOx/Perovskite/LiF/C_{60}/BCP/Cu) comparable to the conventional spin coating technique (~18%), this industrially favorable approach can lead to a pathway toward the commercialization of perovskite solar cells.

Keywords

Perovskite, Hybrid Deposition, Slot-die Coating, Large-Area Substrates