**Air-Processed Stable Perovskite Active Layers Fabricated Through Controlled Layer-by-Layer Deposition**

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Abstract  
The development of cost-effective, scalable, and efficient photovoltaic technology is essential to the improvement of global energy sustainability. Perovskite solar cells (PSCs), have emerged as a competitive alternative to traditional single-junction silicon-based solar cells due to their high-power conversion efficiency (PCE) and solution-processable active materials. However, standard fabrication processes typically need complex anti-solvent procedures and inert conditions, which limit scalability and increase production costs. Layer-by-layer (LBL) deposition offers a good substitute for anti-solvent techniques by separating the crystallization and solidification processes. Despite these advantages, it is still exceedingly challenging to produce high-quality mixed-cation perovskite layers in air, mostly due to the sensitivity of perovskite materials to moisture, which disrupts perovskite phase formation and phase stability. In our work, we used a LBL deposition method to make an air-processable perovskite layer that could help us solve these problems. To fix problems with moisture, the substrate was heated up before the film was applied. This lowered the surface tension and made the film cover better. Hexamethylenetetramine (HMT) was doped to the MAI precursor to passivate the both MA and Pb sites, keep moisture from interfering, and help the transition to the α-phase of methylamonium lead iodide (MAPbI3) without any PbI2 left in the air. These strategies made it possible to make PSCs in the air with a PCE of 12.7%. The open circuit voltage (Voc), short circuit current density (Jsc), and fill factor (FF) of the device are 0.93V, 23.96 mA/cm2, 57% respectively. Perovskite behaviour during annealing process in high humidity conditions can be guid for the commercialization of perovskite solar cells. According to stability tests, PSCs with HMT had device lifetime of more than 100 hours.

**Keywords.** *Air processable; additive; layer-by-layer deposition; halide perovskite; stability. Solar cell*