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Post-Lamination Treatment of Solvent-free Carbon Back-Electrodes for Fabrication of Efficient Perovskite Solar Cells

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Abstract

While substituting carbon for metals as the electrode material in perovskite solar cells (PSCs) enhances stability, reduces CO_2 footprint, and lowers production costs, carbon-based PSCs (C-PSCs) have struggled to surpass an efficiency record of 21% as of February 2024, trailing behind the overall PSC efficiency of 26%. The primary limiting factor often lies in the solvents present in the carbon paste commonly used for deposition, which can wash out the underlying charge transport layer (CTL), such as Spiro-OMeTAD in the *n-i-p* structure, thereby constraining CTL options. Another factor contributing to lower efficiency is the lack of back-reflection of escaped photons from the carbon layer. In addressing the first issue, we explored the press-transfer method for applying dried carbon films as an alternative to carbon paste to mitigate solvent-related damage. Laminated carbon films (CLam) were employed in an *n-i-p* architecture, revealing an excessively rough surface and uneven thickness. This resulted in a suboptimal connection between the carbon layer and the underlying surface during plate-to-plate pressing, leading to higher series resistance compared to blade coating or printing. To investigate this phenomenon, we utilized 3D laser scanning microscopy, mathematical modeling, and electro-optical characterizations. Through process optimization, we achieved an 83% efficiency compared to gold-based cells on a triple cation perovskite with a bandgap of 1.53 eV. However, even after optimization, concerns persisted regarding the roughness of the carbon layer potentially limiting device performance. To enhance electrode adhesion and interconnection quality, we employed solvents as post-lamination treatment. Employing the solvent treatment approach significantly reduced sheet and interface resistances, resulting in an efficiency exceeding 90% of gold-based reference cells. The reduction of sheet and interface resistances can be seen from *I-V* measurement and DLIT results.

Keywords

Carbon-based Perovskite Solar Cell, CPSC, Carbon Lamination, Solvent-free Carbon, Interface Resistance