Towards fully printed larger organic photovoltaic solar cells

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Abstract

Organic photovoltaic (OPV) technologies convert solar energy into electricity with organic semiconductors. OPV solar cells are composed of multiple layers, including two electrodes, charge transport layers (ETL and HTL), and an active layer. This technology offers a low energy payback time of 3 to 4 months [1] compared with 1 to 4 years for silicon solar cells [2] and significant environmental advantages. OPV, based on low-temperature printed processes, eliminates the need for critical materials to manufacture light, flexible and semi-transparent modules. In recent years, OPV made significant advances in materials enabling power conversion efficiencies (PCEs) close to 20% [3] for a single cell with an effective area of 6 mm^2, 14.5% [4] for a module (aperture area: 204 cm^2) and up to 6-7% for a commercial module.

This work investigates the PCE drop during scaling up and the lab-to-fab transition emphasizing the selection of scalable materials and processes. For example, it includes R2R coating, materials soluble in non-halogenated solvents (non-toxic) and low temperature processing in air. A key challenge is to minimize resistive losses while ensuring homogeneous, defect-free layer deposition. In this study, after selecting compatible materials [5] with the above constraints and coating techniques such as Blade coating for interlayer and the active layer, we first analyse the impact of charge transport distance on OPV cell performance. It is shown that the series resistance, and therefore the PCE, increases linearly with the distance travelled by charge carriers within the solar cell. The influence of scaling up from small to larger cells is also studied. While achieving 10.5% PCE for small cells (21 mm^2), efficiency dropped to 8.4% and 5.7% for 57 mm^2 and 166 mm^2 cells, respectively. Optimizing thin-film deposition improved performances to 10.4% and 7.5%. The fill factor (FF) is particularly affected. This is linked to the active layer morphology, affecting charge extraction, mobility, and recombination balance.

Future work will focus on slot-die coating of the ETL and the active layer to improve layer quality and efficiency. It will also involve replacing the vacuum-deposited HTL and top electrode with solution-based deposition (e.g., screen printing).

References

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