Gas assisted Crystallization of MA free Slot die coated perovskite films towards module fabrication.

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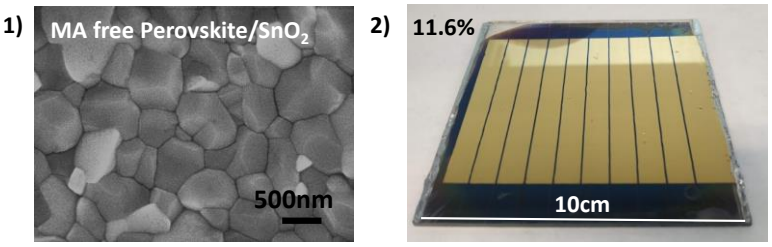
Slot-die coating is a promising scalable deposition method for perovskite films. It enables fast coating (~ 0.2 m^2/min), in continuous or batch-to-batch configurations, and is compatible with rigid glass or flexible plastic substrates. Today, perovskite crystallization control from the deposited wet film without anti-solvent is the key bottleneck for scalable processing. Most researches focus on $MAPbI_3$ perovskite crystallization and/or use numerous additives in the precursor ink to control the crystallization[1–3]. In this work, we developed a continuous coating and crystallization process via an embedded gas blading system to deposit MA free perovskite.

First, the crystallization of perovskite using the embedded gas blading will be explained with its key parameters: substrate temperature, wet film thickness and gas flowrate. Optical and Scanning Electron Microscopy images show the formation of a compact layer in the optimized process conditions. The conversion into alpha phase of $FA_{1-x}Cs_xPb(I_{1-y}Br_y)_3$ perovskite is confirmed by X-Ray diffraction.

The crystallization of perovskite can vary depending on the underlying substrate. Thus, we compared the perovskite material slot die coated on compact SnO_2 and compact TiO_2 layers. While the morphology and thickness of perovskite is similar on SnO_2 and TiO_2, we noticed slight orientation variation of perovskite plans. Time Resolved Photoluminescence (TRPL) measurement indicates long bulk lifetime over 200 ns in both cases. High efficient devices (>16%, active area 0.09 cm^2) are fabricated on both ETLs, reinforcing the versatility of this printing method.

In order to scale up this deposition process, we assessed the homogeneity of the perovskite layer by thickness and absorbance mappings on 100cm^2 SnO_2 coated FTO substrates. Device efficiency mapping show efficiency ~ 16.9 ± 1 % (unit cells active area 0.09 cm^2). Lastly, large-scale module of 55 cm^2 active area was fabricated resulting in 11.6 % PCE. This is the first MA free perovskite module fabricated in open air with continuous coating and crystallization process (< 3 minutes).



1) *Morphology of perovskite film via Scanning Electron Microscopy (SEM),* ***2)*** *Picture of Champion module.*

1. Deng, Y. *et al.* Tailoring solvent coordination for high-speed, room-temperature blading of perovskite photovoltaic films. *Sci. Adv.* **5**, eaax7537 (2019).
2. Tang, S. *et al.* Composition Engineering in Doctor-Blading of Perovskite Solar Cells. *Adv. Energy Mater.* **7**, 1700302 (2017).
3. Deng, Y. *et al.* Surfactant-controlled ink drying enables high-speed deposition of perovskite films for efficient photovoltaic modules. *Nat. Energy* **3**, 560–566 (2018).