TOWARD R2R-READY AMBIENT PROCESSED FLEXIBLE PEROVSKITE SOLAR MODULES

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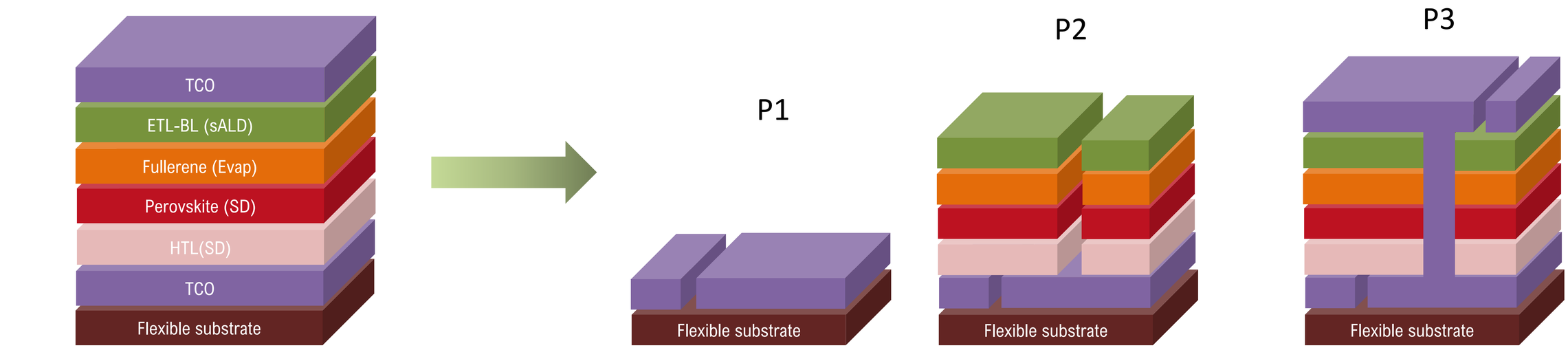
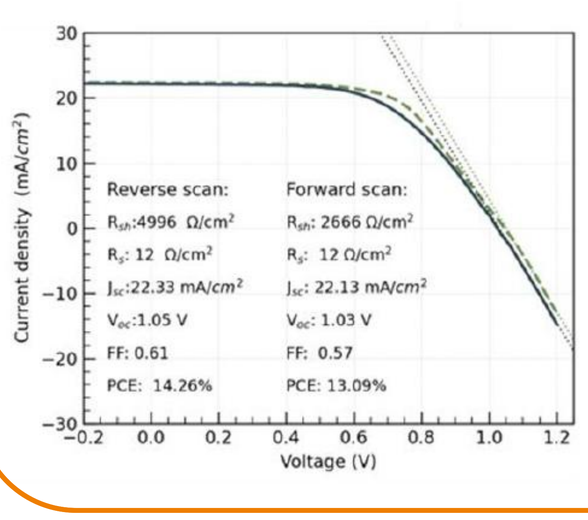
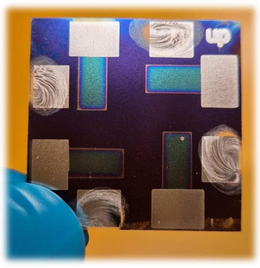
This work advances the scalable fabrication of flexible perovskite solar modules by addressing three key areas: upscaling charge transport layers, enabling ambient-compatible coating of the perovskite absorber, and optimizing laser scribing for module interconnection.
Lab-scale processes were successfully translated into R2R compatible methods on flexible PET/ITO substrates using DMSO-based inks, producing uniform, high-quality films.
A 10 × 10 cm² flexible module achieved up to 13.8% active-area efficiency, closely matching small-area devices, while encapsulated modules showed no performance loss, confirming durability and mechanical robustness. Additionally, integration onto a curved composite roof tile demonstrated a functional efficiency of 12.4%, highlighting real-world applicability.



Small scale flexible device

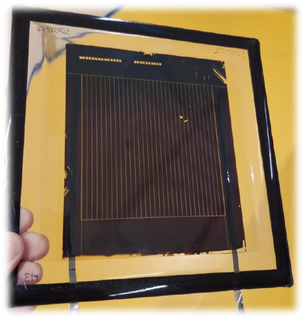


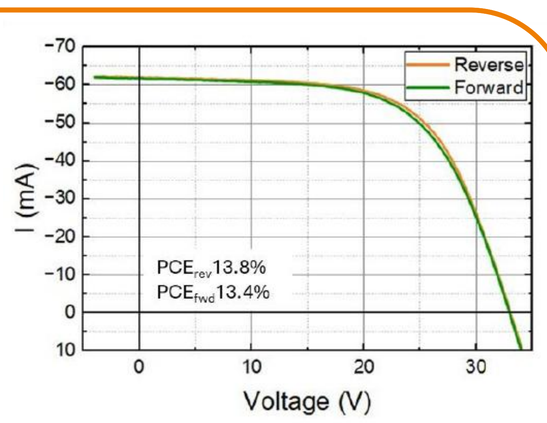


- Inks are R2R compatible
- Perovskite is based on scalable solvents
- Processed in ambient conditions
- Active area <1 cm²
- Efficiency of 14.2%

Large scale flexible module

- Inks are R2R compatible
- Perovskite is based on scalable solvents
- Processed in ambient conditions
- Active area 93 cm²
- PCE of 13.8% on active area





Direction	I_{sc} (mA)	V_{oc}(V)	FF (%)	PCE_{ap} (%)	PCE_{ac} (%)
Reverse	62,0	33,1	62,6	12,8	13,8
Forward	61,7	33,0	61,7	12,5	13,4

Roof tile

Flexible perovskite solar module onto a curved composite roof tile with aperture area 400cm².

- PCE 12.4% despite the tile's non-planar geometry.
- Individual flexible modules achieved efficiencies of up to 13.8%.

Conclusions

- Lab-scale processes were successfully transferred to roll-to-roll-compatible fabrication on PET/ITO substrates using DMSO-based perovskite inks.
- 10 × 10 cm² flexible module achieved a peak active-area efficiency of 13.8% comparable to small-area devices (14.2%).
- Encapsulated modules show no measurable performance loss, highlighting mechanical robustness, durability and marking a key milestone toward industrial flexible perovskite photovoltaics.
- A flexible perovskite solar module was successfully developed and applied onto a curved composite roof tile with an aperture area of 400 cm², achieving an energy efficiency of 12.4% despite the tile's non flat geometry.

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