PUBLIC PROJECT SUMMARY (ENGLISH)

Project Aim

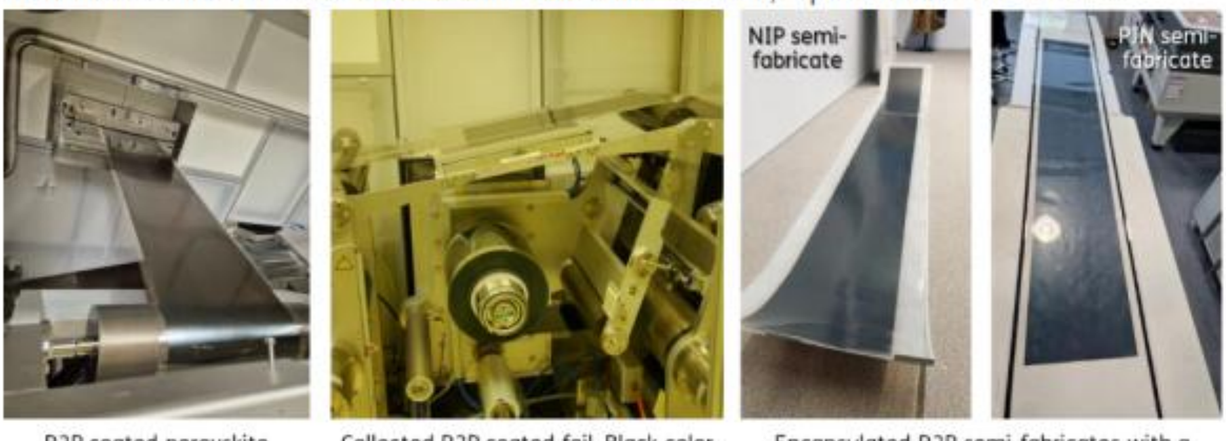
Perovskite solar cells emerge as a new technology enabling efficient and stable modules. Roll-to-roll production of these modules with high-throughput, consumes low amounts of abundant materials at low temperatures leading to low cost modules with an improved environmental profile, while public support for the energy transition requires aesthetic solar solutions. PERSEVERANCE project aims to develop an industrially relevant process for manufacturing perovskite solar modules, develop an encapsulant material and process for roll lamination of perovskite modules and assess at an early stage whether perovskite solar modules could be compatible with Mass Customization.

Main Project Activities

- Processing of flexible perovskite laminates in a continuous process
- Electrical interconnection of these laminates to make functional devices
- Development of a lamination material and equipment, suitable for roll to roll packaging
- Assessment of the prototype to building integrated PV (BIPV) applications

Highlights on efficiency, stability and encapsulation

TNO's roll-to-roll (R2R) and sheet-to-sheet (S2S) coating lines have been used in this project to create flexible perovskite solar cells with an aimed power conversion efficiency of 14% with stability targets. For realizing this, a number of functional layers have been deposited. In the simplest form, a perovskite solar cell stack consists of a perovskite absorber layer that absorbs the light from the sun and generates photocurrent, two selective charge transport layers that are enveloping the perovskite absorber to allow the created photo-induced charges to be extracted, and two electrodes to collect these charges in the form of current. **Figure A** demonstrates the coated perovskite foil in the R2R line before it is collected at the rewinder unit. The coated foils were cut into pieces as demonstrator and laminated via R2R lamination unit of Maan, a partner in Perseverance.



R2R coated perovskite transferred out of furnace | Collected R2R coated foil. Black color is the perovskite layer. | Encapsulated R2R semi-fabricates with a length of ~2 meters.

Figure A: Demonstration of the output of D1.1. R2R coated perovskite semi-fabricates were encapsulated. These semi-fabricates were in NIP and PIN architecture and the processed material has been used to make functional devices, and screen encapsulants in other work packages.

Evaluation of flexible perovskite solar cells produced using R2R and S2S processing tools in Perseverance has led to efficiencies up to 14.5% for champion devices, and an average of 13% from a measurement of a number of devices. In addition, a laser interconnected module has been produced. The process is a conventional laser interconnection process, a so-called, series monolithic interconnection. This enabled collecting the current of the solar cell device over an aperture area of 100 cm^2, and overcoming the limitation of electrode conductivity. In addition, the processed module showed stability under accelerated stress tests. These tests are done to create harsh environmental conditions, that usually does not exist in terrestrial conditions. These conditions help us to simulate long term stability in a relatively shorter time frame and draw conclusions and make improvements in a timely manner. **Figure B** shows the small scale device efficiencies and large are area module efficiencies.

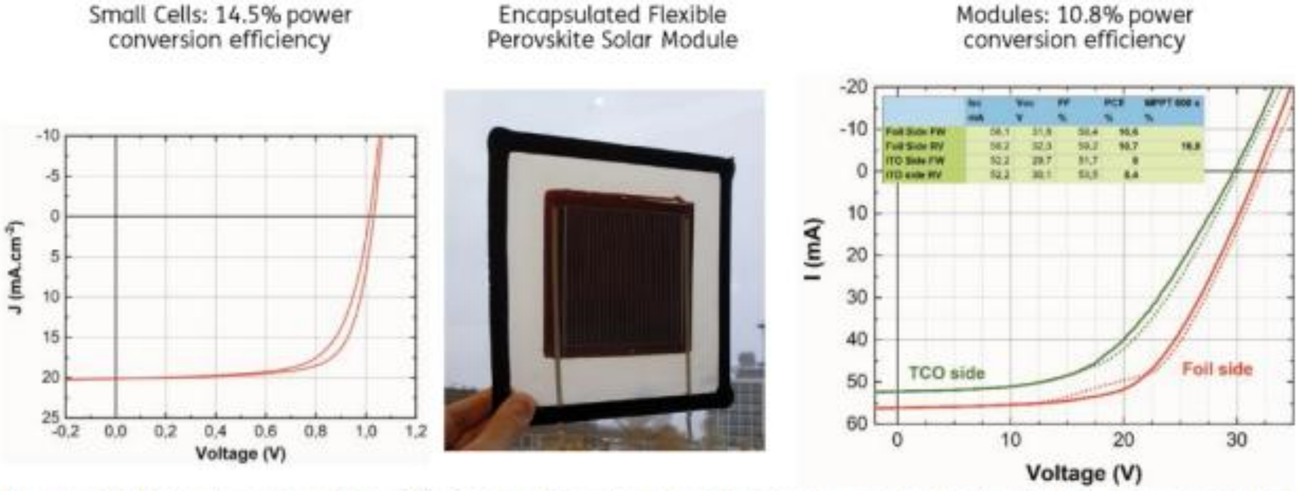


Figure B: Power conversion efficiency of a small scale device goes up to 14.5%. Encapsulated flexible modules reach efficiencies up to 10.8% on an aperture area of 100 cm^2.

The produced semi-fabricate foils were used to showcase a lamination on the building façade element of Rockpanel. To be able to laminate the perovskite foil on the building element, it has to be first packaged. Packaging is used to protect the perovskite foils from the external weather conditions and from UV light. A number of different packaging methods and materials have been used to laminate the packaged foils onto the same building element. Figure C shows three demonstrators laminated on the building elements that are used by Rockpanel.

Figure C: Laminated perovskite foils on Rockpanel building elements.

In conclusion, in Perseverance project, R2R and S2S coated perovskite foils were produced and measured for their solar power conversion efficiency. The highest efficiencies that were reached by R2R coated small cells were 14.5%, while for the modules 10.8%. It is shown that correct packaging of the modules provide good stability. Furthermore, the different packaging materials and methods can be tested to showcase the adhesion to the building elements. The results of Perseverance project is being exploited further in local, national, and European funded projects. From this point of view, the contribution of project into the scheme (sustainable energy management, strengthening knowledge position) is strong.

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Funding

The project was carried out with a PPP program allowance subsidy from the Ministry of Economic Affairs and Climate for TKI Urban Energy, Topsector Energy. www.tki-urbanenergy.nl.