Tandem solar cells activities at CSEM and EPFL in Neuchâtel

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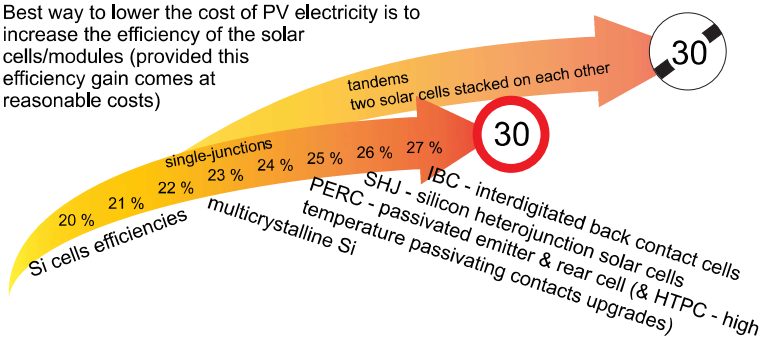
Silicon solar cell technologies approach their efficiency limit

Solar cells using a single light absorber are limited in efficiency to about 30% or less

With a record at 26.7%, best-in-class silicon solar cells are close to their practical efficiency limit (about 27%)

Problematic on the longer term due to the cost distribution of a PV system dominated by balance of system components

Best way to lower the cost of PV electricity is to increase the efficiency of the solar cells/modules (provided this efficiency gain comes at reasonable costs)



Tandem solar cells promise higher efficiencies

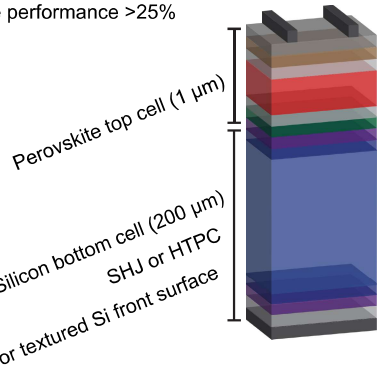
Reduction of losses by adding a second cell on a conventional silicon cell

Silicon, due to its intrinsic optical properties, is an ideal bottom cell

Record efficiency of 32.8% for a III-V-on-silicon tandem solar cell

Metal halide perovskite materials as cheaper alternatives to III-V materials

- Soft deposition conditions (<150°C), tunable bandgap, sharp absorption edge
- High single-junction perovskite performance >25%



Objectives of the research on tandems at CSEM & EPFL PVLAB

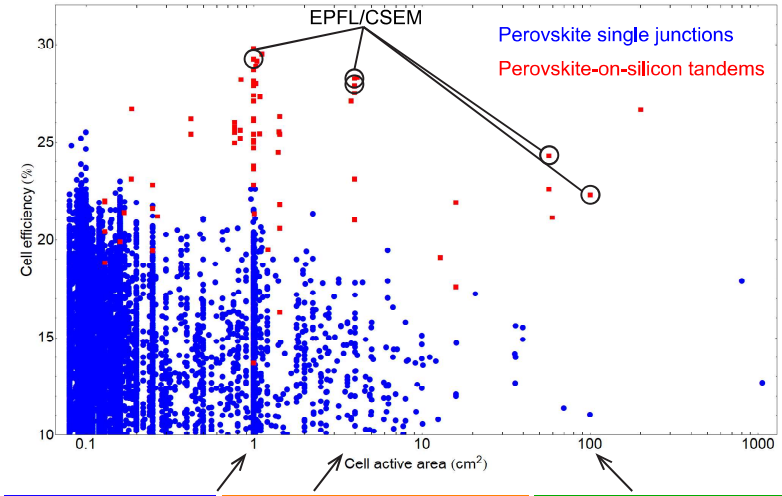
Increase the efficiency of perovskite-on-silicon tandem solar cells by developing materials, processes & device stacks

Scale-up the device dimensions from the 1 cm² of today to full-area >M6 wafers (silicon industry standard)

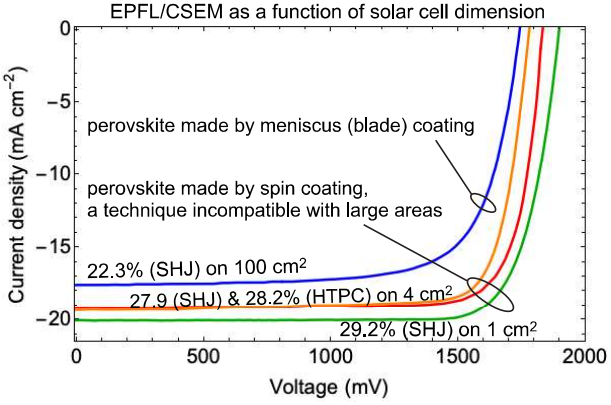
Develop **cell interconnection & encapsulation processes** leading to minimal cell-to-module losses

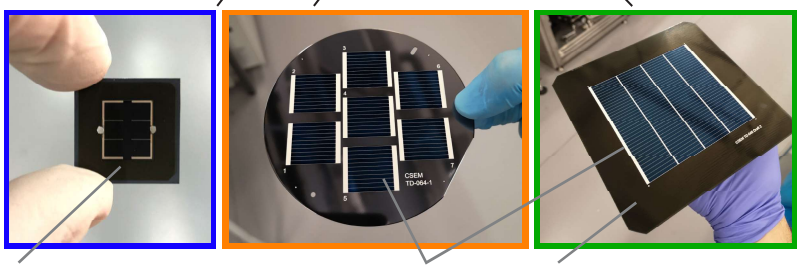
Extend the operational stability of perovskite solar cells, ideally to match the standards of silicon-based PV

Literature review of the efficiency of perovskite single junctions & perovskite-on-silicon tandem solar cells as function of device dimension



Current-voltage properties of tandem cells made at EPFL/CSEM as a function of solar cell dimension

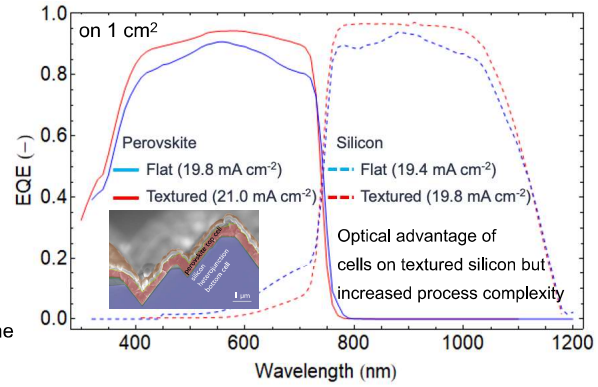




Development of materials & processes on small dimensions

Industrial metallisation method - screen-printing of Ag paste at low temperature

Chemical etching of silicon wafer for compatibility with the deposition of the perovskite by meniscus coating



Summary of our results on perovskite-on-silicon tandem solar cells

Demonstration of **state-of-the-art perovskite-on-silicon tandem efficiencies from 1 cm² (29.2%), 4 cm² (28.2%) to 100 cm² (22.3%)**

Perovskite materials & deposition processes compatible with silicon cells that are either **textured (the industry standard) or chemically polished (to simplify the perovskite deposition process) on their front side**

High-efficiencies demonstrated on different types of bottom cells made in-house, **silicon heterojunction & cells based on high temperature passivating contacts** (PERC upgrades)

Demonstration of **processing techniques compatible with mass-manufacturing constraints** (meniscus coating to deposit the perovskite absorber, screen-printing for the front-side metallisation of the tandem)

Tandem solar cells made at EPFL/CSEM pass some of the IEC stability tests (damp heat, thermal cycling), the light soaking stability at elevated temperature needs to be improved (tests & improvements in progress)

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