POWER: High-performance tandem solar cells with improved stability and cost-competitive manufacturing

info@csem.ch www.csem.ch

BRIDGE

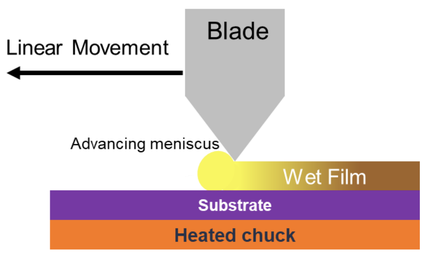
A. Walter,[1] B. A. Kamino,[1] S. Rafizadeh,[1] M. Dussouillez,[1] F. Sahli,[2] P. Fiala,[2] X. Y. Chin,[2] D. Jacobs,[2] Q. Guesnay,[2] C. Wolff,[2] T.Moser,[3] Y. Jiang,[3] B. Paviet-Salomon,[1] F. Fu,[3] Q. Jeangros,[2] S. Nicolay,[1] A. N. Tiwari,[3] C. Ballif,[1,2] M. Despeisse[1]

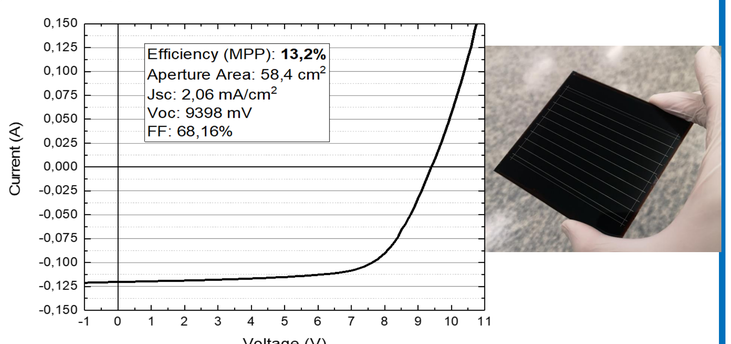
[1]CSEM SA, PV-center [2]EPFL, PV-lab [3]Empa, Thin Films and Photovoltaics

The POWER Project aims to develop a new generation of solar cells by combining emerging perovskite cells with market-proven CIGS and crystalline silicon cells. By combining scientific excellence with innovation and production oriented development, the project will pave the way towards the realization of low cost solar cells with >30% performance, surpassing 25 years lifetime.

Scalable deposition techniques

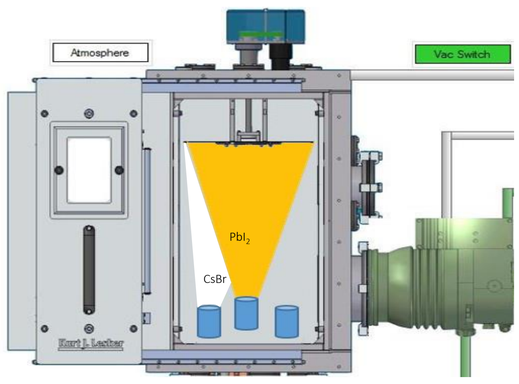
- Spin coating is the technique of choice for deposition of small scall PK devices
- We demonstrate that this can be successfully applied to coating of up to 4” wafer size with no loss of uniformity
- To achieve high throughput, high uniformity on large area substrates, meniscus (blade) coating was applied

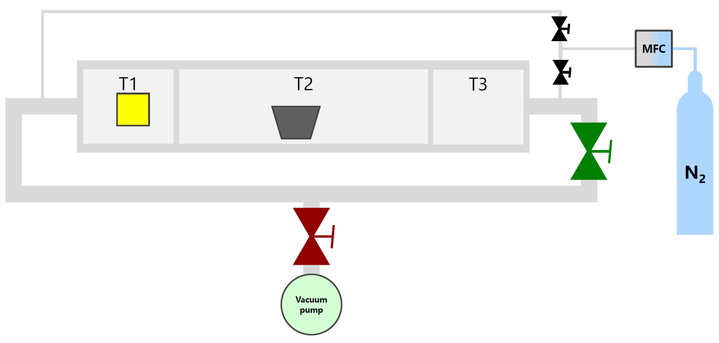




Fully laser interconnection, single junction mini-module on 10x10 cm² substrate by blade coating

- A scalable hybrid evaporation-CVD technique has been developed
- First a CsPb(I,Br) template is evaporated under high vacuum
- An organo-halide component (e.g. FAI) has then to be incorporated to form the photoactive perovskite
- This can be done by either spin-coating from a solution or a CVD-like technique

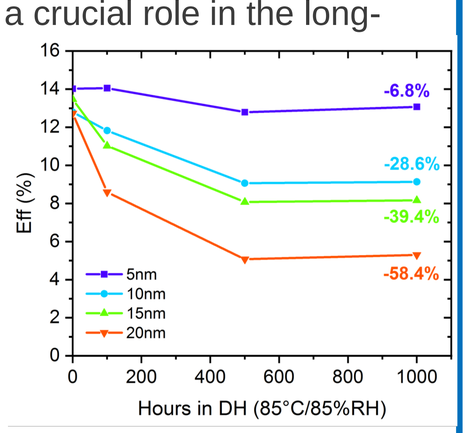


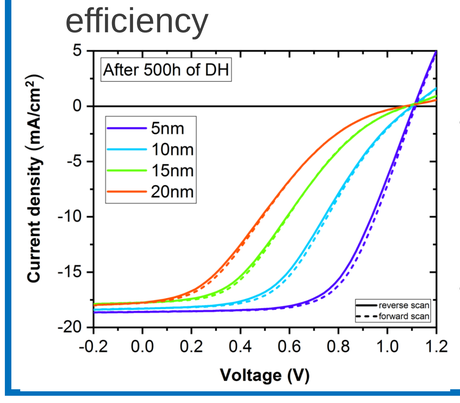


- A custom CVD reactor was developed in the form of a multizone tube furnace with reversible carrier gas flow for a fine control of the heating and deposition steps (see also Poster 6 by S. Siegrist *et al.*)

Accelerated aging of PK cells

- Charge extracting layers are found to play a crucial role in the long-term stability of PK cells
- Here we vary the thickness of the NiO hole transporting layer
- The encapsulated devices are subjected to accelerated aging for 1000h
- A clear trend is observed, with the thinner NiO device losing less than 10% relative efficiency



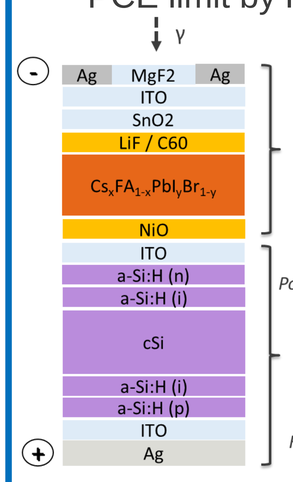


- An extraction barrier is building at the interface between PK and NiO due to a band misalignment, creating an s-shape
- M. Dussouillez *et al.*, Manuscript in preparation

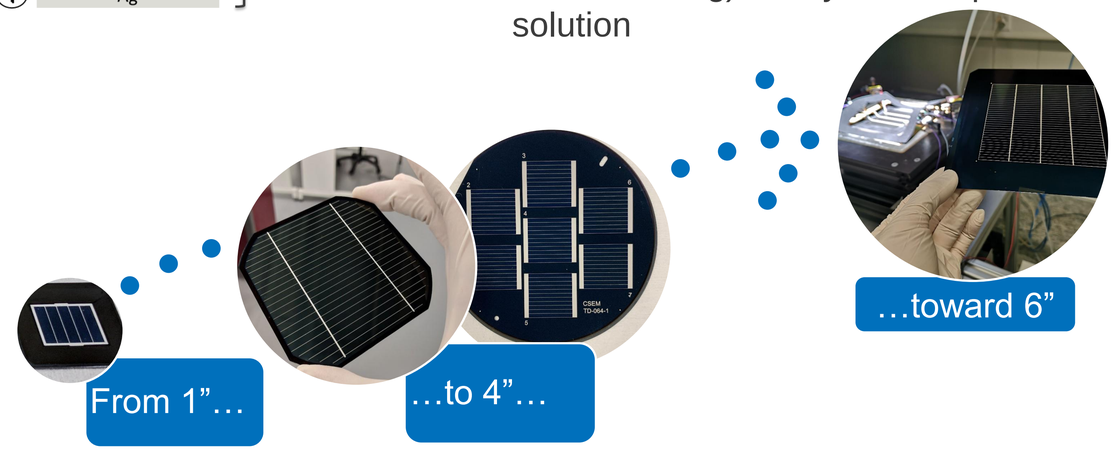
PK/Si tandems: towards industrialization

- Perovskite on low-bandgap absorbers (such as CIGS and Si) tandem devices are seen as a promising way of bringing PV across the 30% PCE limit by limiting thermalization losses

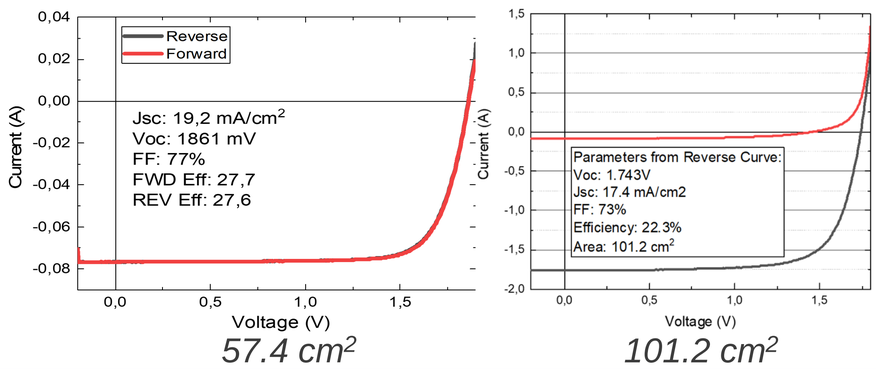
Werner et al. *Adv. Mater. Inter.* 2018



- Si Heterojunction is used as bottom cell
- Excellent passivation of bottom cell provides high V_{OC} and good NIR response
- Top cell absorber is deposited by solution processing (spin-coating or blade coating) or hybrid evaporation + solution

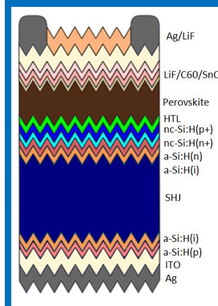


- POWER provides a platform for the development of industry relevant processes for the contacting of tandem devices
- Screen printing of industrial low-temperature silver paste was demonstrated to achieve very high efficiency on record breaking large area

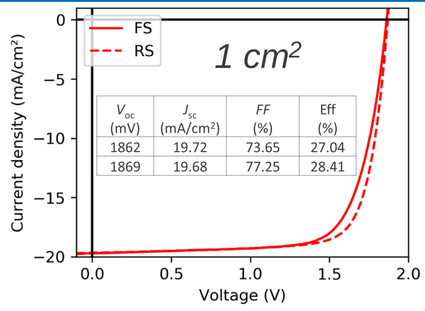


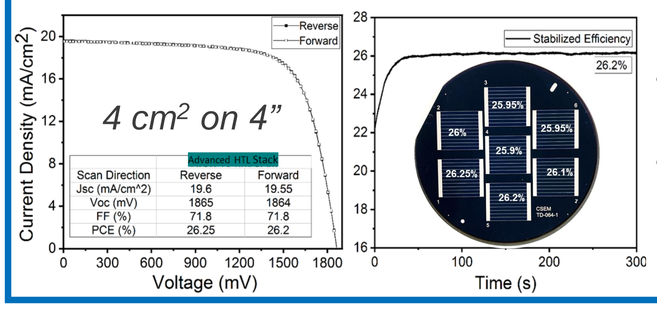
57.4 cm² *101.2 cm²*

Textured tandems: potential unlocked



- To unlock the true potential of tandems, a fully textured bottom cell should be used
- Only a process based on vapor deposition is suitable
- With optimized contacts: record efficiency!





- Ready for scaling: 4 cm² cells show minor efficiency loss
- Outstanding homogeneity over full 4” wafer

This work has received funding from SNF Bridge project POWER (No. 20B2-1_176552)