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FNSNF

Laser Scribing Patterning for the Production of Organometallic Halide Perovskite Solar Modules

Soo-Jin Moon,[a] Jun-Ho Yum,[a] Linus Löfgren,[a] Arnaud Walter,[b] Laurent Sansonnens,[a] Mustapha Benkhaira,[a] Sylvain Nicolay,[a] Julien Bailat,[a] Christophe Ballif [a,b]

[a]PV-Center, CSEM, Jaquet Droz 1, 2002 Neuchâtel, [b]EPFL, IMT, Photovoltaics and Thin Film Electronics Laboratory

csem

Motivation

What are the advantages of the organometallic halide perovskite?

1. Tunable dimensionality
2. Tunable optical and electronic property
3. Low-cost process-based solution process
4. High molar extinction efficient
5. Steep absorption onset and no optically detected deep states

However, most of high efficiencies have been achieved on laboratory scale area below 0.5 cm^2.

CSEM task is to upscale perovskite solar cell:

CSEM is focusing on optimizing perovskite layer *via* laser scribing for patterning, production-oriented processes such as wet coating, spin-coating or new innovative coating, with the final aim of transferring the high efficiency achieved in the labs to pre-production scale mini-modules.

Laser patterning

- W_d < 300 µm
- Precision tool (focus down to 20 µm)
- Non contact process (use of brittle materials in PV: silicon, glass, TCO)
- Fast positioning and process
- Selectivity

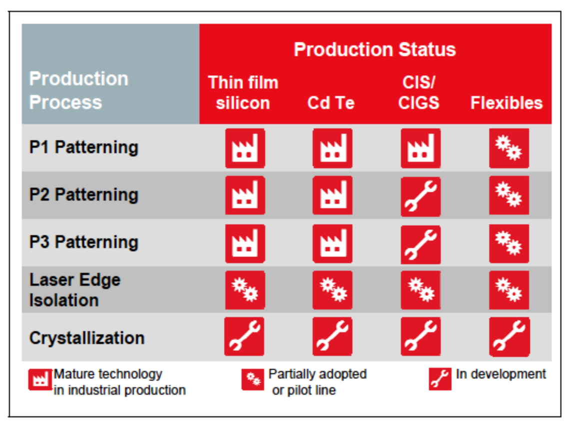
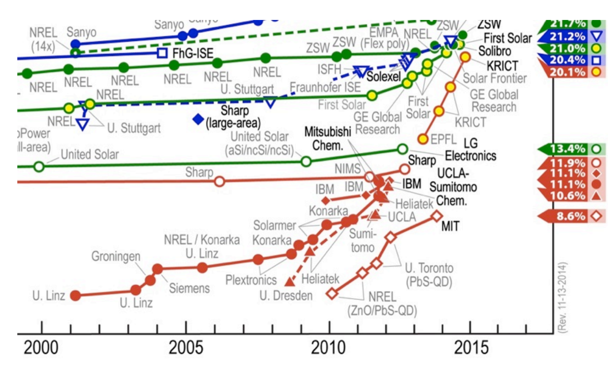
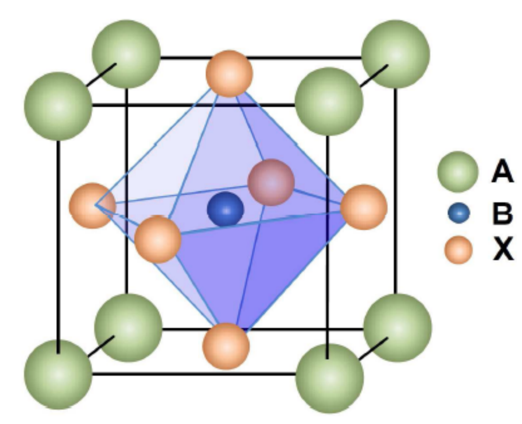


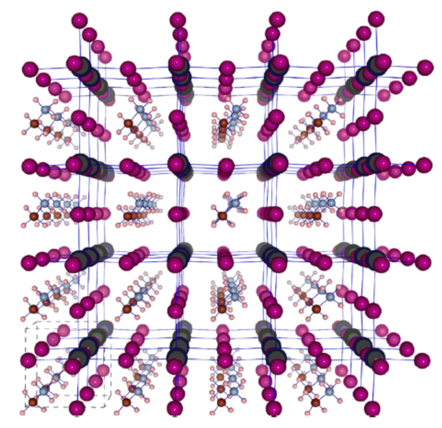
Table 1 Laser processes for thin-film PV and status for industrial production.

H. BOOTH, *J. Laser Micro. Nanoen.* 2010, *5*, 195-203.



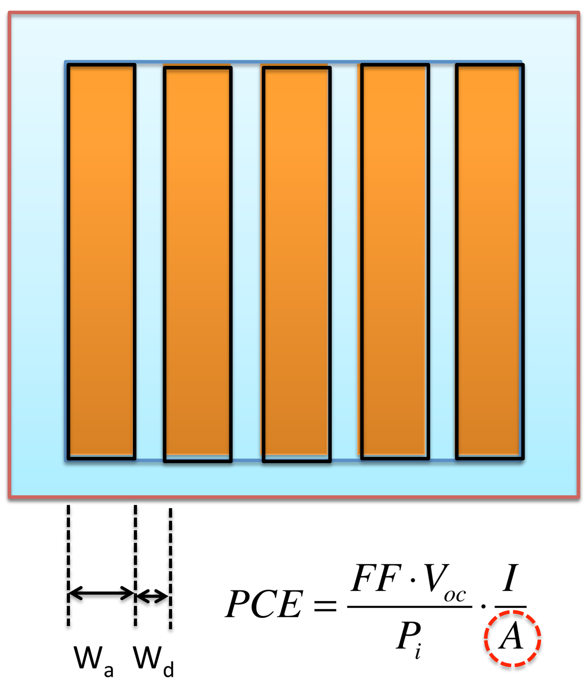
NREL Research Cell Efficieicny Records 2015
http://www.nrel.gov/ncpv/images/efficiency_chart.jpg.



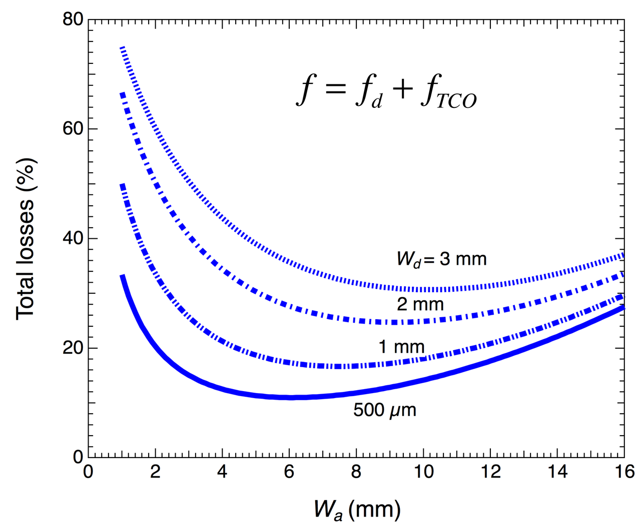


Perovskite structure (H. S. Kim et al., *J. Phys. Chem. C*, 2014, *118*, 5615)

Module performance characterization



$$PCE = \frac{FF \cdot V_{oc}}{P_i} \cdot \frac{I}{A}$$



$$f_d = \frac{W_d}{W_a + W_d}$$

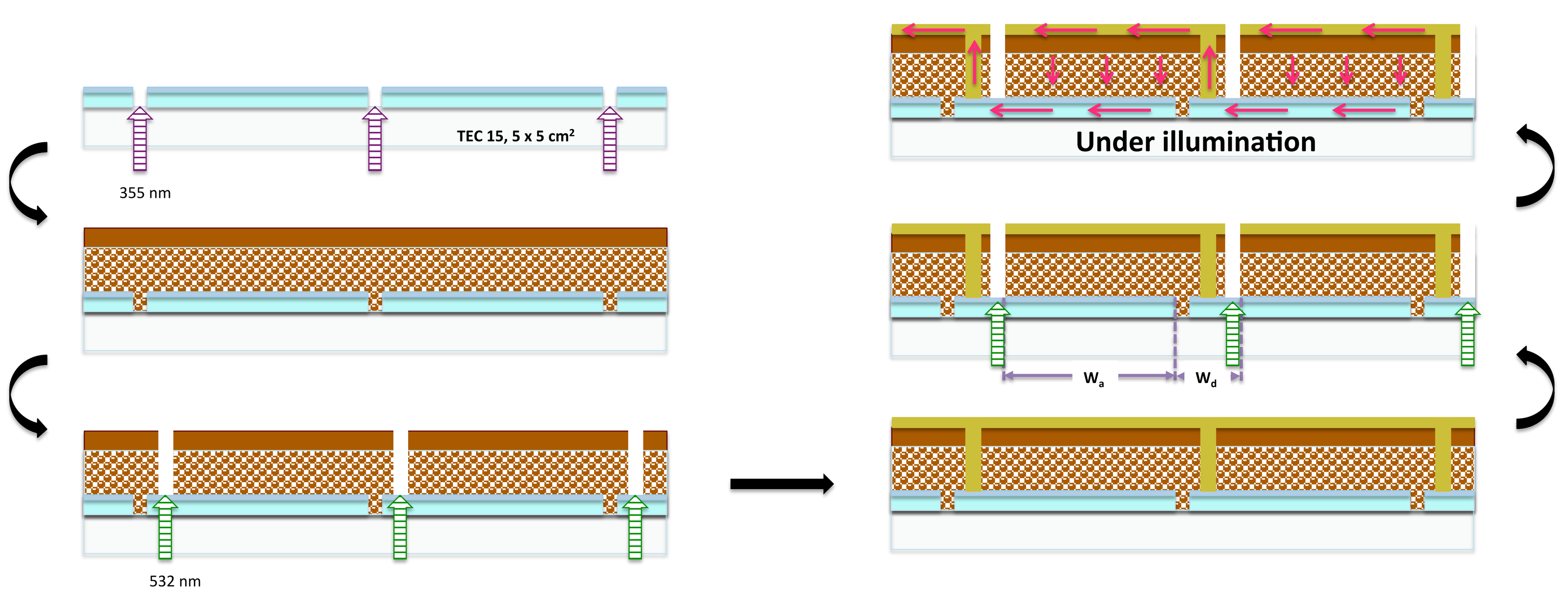
$$f_{TCO} = \frac{1}{3} \cdot R_{sh} \cdot \frac{J_{mpp}}{V_{mpp}} \cdot \frac{W_a^3}{W_a + W_d} \quad (a)$$

Assumption[b]
J_{sc} = 19.6 mA/cm^2
V_{oc} = 1.1 V
FF = 0.74
R_{sh} = 15 Ω/□

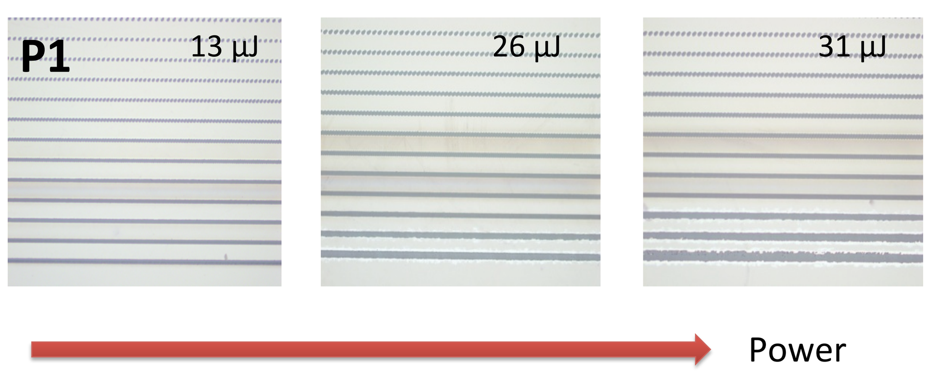
The relative power losses of the module (f) depend on the trade-off between the dead area loss (f_d) and the TCO resistive loss (f_{TCO})

[a] S. Haas et al., *Prog. Photovolt.*, 2008, *16*, 195–203.
[b] N. J. Jeon et al., *Nat. Mater.*, 2014, *13*, 897-903.

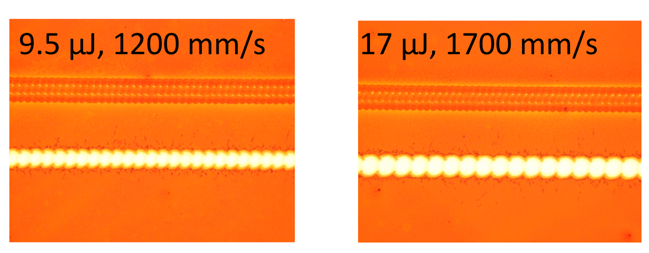
Laser scribing pattering



Pattern optimization by laser pulse energy, scribe speed

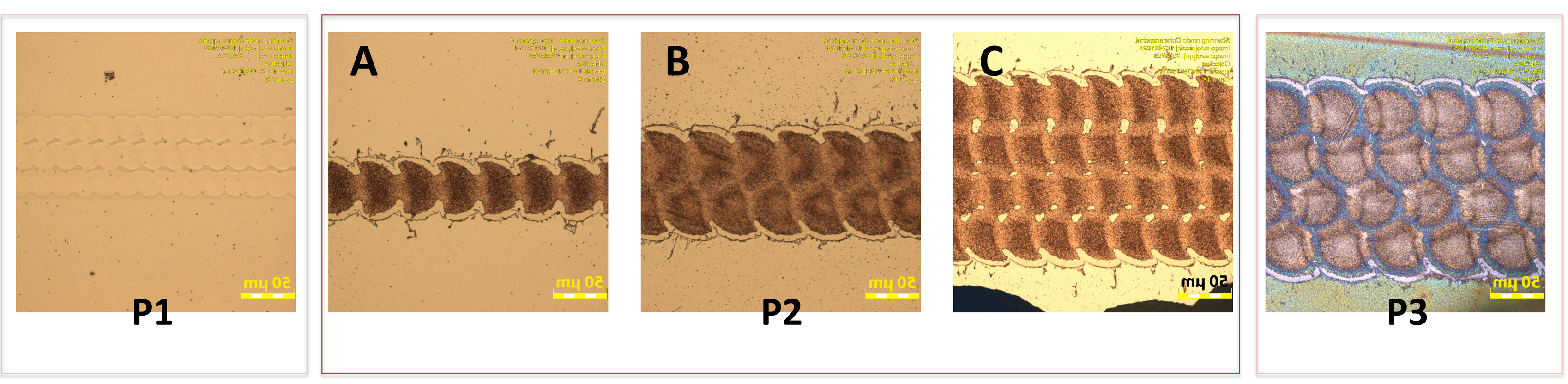


P2 and P3

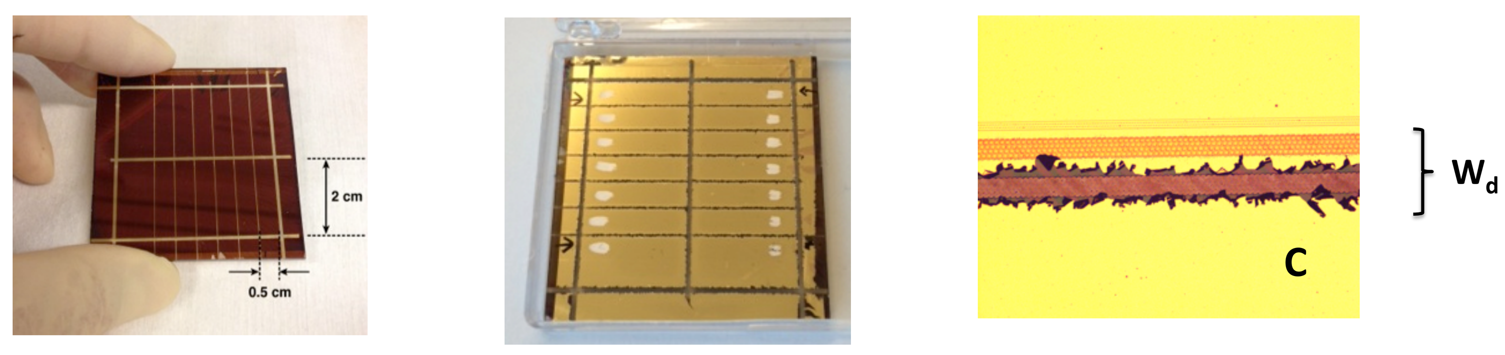


P1 = 20 µm and P2 = 40 µm

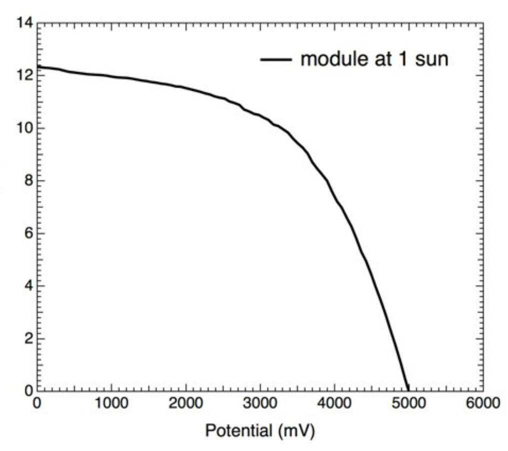
P2 pattern optimization by scribing lines



Results

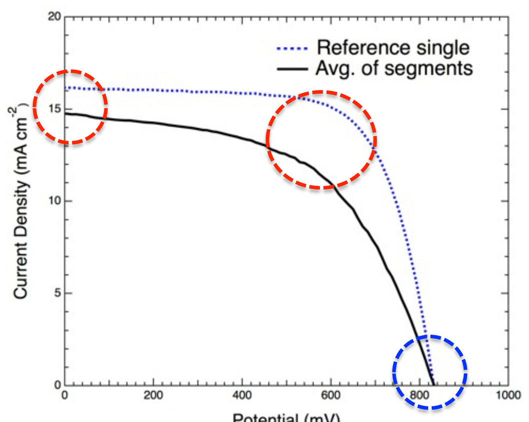


Module	No of P2 lines	W_d (µm)	A_{seg} (cm^2)	F_d (%)
Module A	1	710	0.858	14
Module B	2	750	0.850	15
Module C	4	820	0.836	16



Module	PCE (%)	V_{oc} (mV)/seg	J_{sc} (mA/cm^2)/seg	FF (%)
A	3.60	767	14.2	33.2
B	4.89	785	14.3	43.6
C	6.42	839	14.5	52.9
C	6.60	833	14.8	53.7

Wide P2 improved FF!



Sample	Area (cm^2)	PCE (%)	V_{oc} (mV)	I_{sc} (mA)	J_{sc} (mA/cm^2)	FF (%)
C	5.02	6.60	5000	12.4		53.7
	6.00	5.52				
Segments$_{avg}$	0.84	6.60	833	12.4	14.8	53.7
Ref	0.43	9.38	842	7.10	16.5	67.7

No loss in V_{oc}!

Summary

1. **Perovskite minimodule**: 5 x 5 cm^2 mini-module prepared by 1 step perovskite solution process and laser patterning.
2. **< 16 % dead area**: Laser process can achieve dead width smaller than 820 µm.
3. **V_{oc}**: No loss compared to the reference solar cell.
4. **Efficiency**: 6.6 % based on active area and 5.5 % based on aperture area.
5. **Further work**: P2 process optimization and the dead area to < 300 µm or less that 5 % of the active area of the segment.