



INDTECH2018

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Vienna, Austria

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PILLAR 1

Session 1.2

Ink-jet printed, flexible, perovskite solar cells – status & perspectives

Olga MALINKIEWICZ

SAULE TECHNOLOGIES

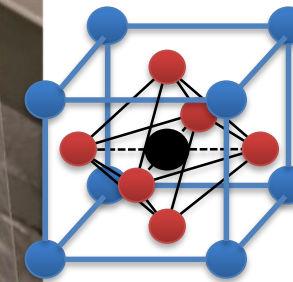
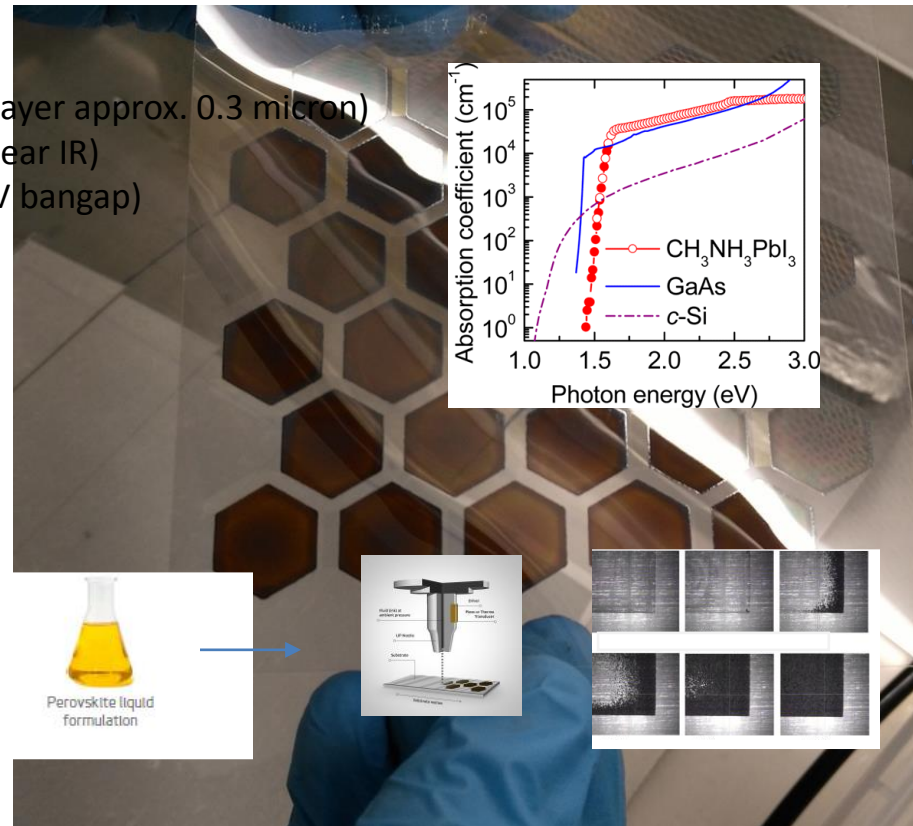
30 October 2018


PEROVSKITE MATERIAL

Perovskite in solar cells:

1. High absorption coefficient (active layer approx. 0.3 micron)
2. Low bandgap (cover all visible and near IR)
3. Low qV_{oc} losses (exp. 1.1 V for 1.5 eV bandgap)
4. Diffusion length > 1micron
5. Soluble in many solvents

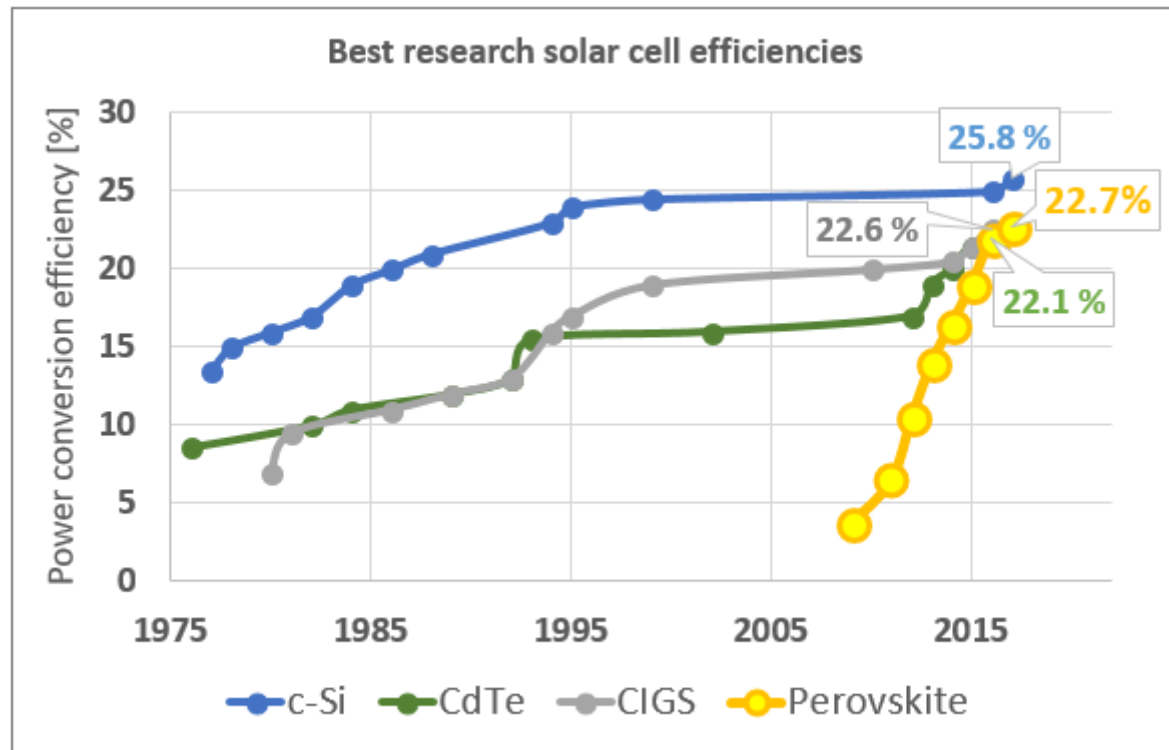
Easy processing:



A B X

A – ORGANIC = low cost
B – METAL = high efficiency
X – HALOGEN = bandgap tuning



EFFICIENCY



Theoretical maximum efficiency of ANY single junction solar cell: 33.7%

Shockley, W. & Queisser, H. J. Detailed balance limit of efficiency of p-n junction solar cells. *J. Appl. Phys.* 32, 510–519 (1961).

Theoretical maximum efficiency of SILICON solar cells: 29.8%

Tiedje, T., Yablonovitch, E., Cody, G. D. & Brooks, B. G. Limiting efficiency of silicon solar cells. *IEEE Trans. Electron Devices* 31, 711–716 (1984).

Theoretical maximum efficiency of PEROVSKITE solar cells: 31 %

Sha, W. E. I., Ren, X., Chen, L. & Choy, W. C. H. The efficiency limit of CH₃NH₃PbI₃ perovskite solar cells. *Appl. Phys. Lett.* 106, 221104 (2015).



STABILITY & LEAD CONTENT



2009

A few minutes:

Kojima, a, Teshima, K., Shirai, Y. & Miyasaka, T. Organo Metal Halide Perovskites as Visible-Light Sensitizer for Photovoltaic Cells. *Priv. Commun.* 1, 1 (2009).



2016

1000 hours:

Saliba, M. *et al.* Cesium-containing triple cation perovskite solar cells: improved stability, reproducibility and high efficiency. *Energy Environ. Sci.* 9, 1989–1997 (2016).



2017

Over 10000 hours:

Grancini, G. *et al.* One-Year stable perovskite solar cells by 2D/3D interface engineering. *Nat. Commun.* 8, 15684 (2017).

Legislative issues:

EU Directive on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment do not apply to a range of applications (see (Art. 2(4)(i))). Examples include:

- photovoltaic panels (for public, commercial, industrial or residential use)
- transport for people or goods
- equipment designed to be sent into space
- Etc...

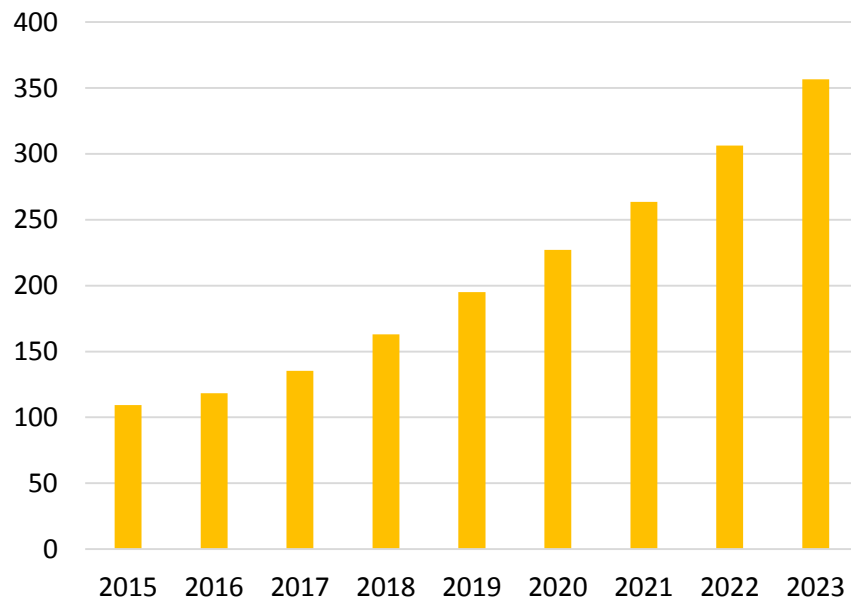


Environmental issues:

- Initial internal tests on examining water contamination passed with great results
- Published life cycle assessment of perovskites show positive prospects
- Internal life cycle assessments are performed in the scope of a European project

MARKET & POTENTIAL APPLICATIONS

Global crystalline silicon solar PV installation market value | B USD



Source: report „Solar Photovoltaic (PV) Installations Market“; Allied Market Research

Until now, the most significant solar cells were silicon cells. However, there are a number of alternatives for them, the most promising of which are perovskite cells.

*“Perovskites have the potential to outshine silicon in solar panels.”
„Saule Technologies (...) is close to bringing the first commercial perovskite solar cells to market.”*

03 Feb 2018

**The
Economist**

“Perovskite currently has taken the lead among emerging photovoltaic (PV) technologies, [...] a material that could enable manufacture of cheap, highly efficient solar coatings that could be unspooled from a printer much as newspaper is printed.”

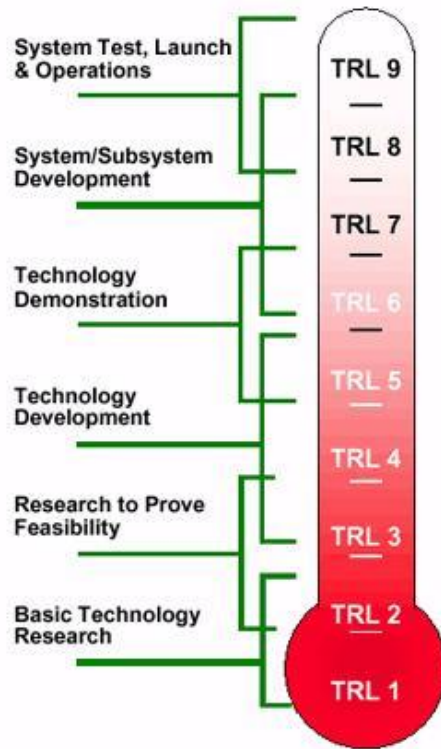
Author: Varun Sivaram, fellow for science and technology at the think tank CFR (Council on Foreign Relations)

28 Feb 2018

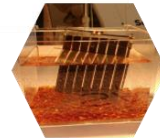
**The
Guardian**



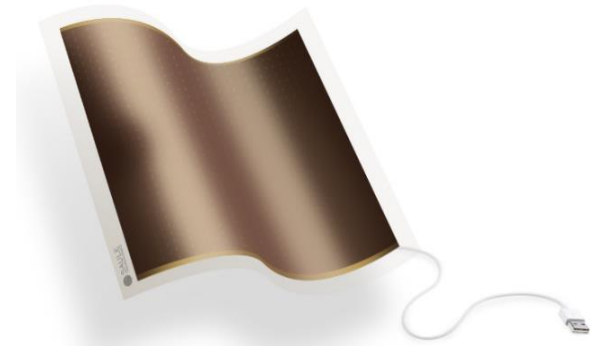
TRL LEVEL



First large format modules (1m²) are being released for contractors in urban construction implementation.

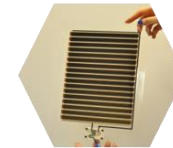


Stable performance of perovskite module validated under water, Saule presented the stability of a module and underwater operation for the first time at the Conference on Perovskite Solar Cells and Optoelectronics (PSCO-2017) in Oxford



2017

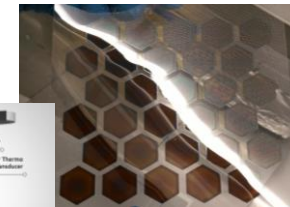
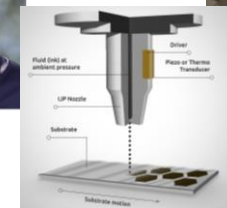
First documented flexible, perovskite module the size of A4, Saule presenting an operating module printed on an ultra-thin plastic foil able to charge personal electronic devices at the IDTechEx Show! in Santa Clara, California.



2014



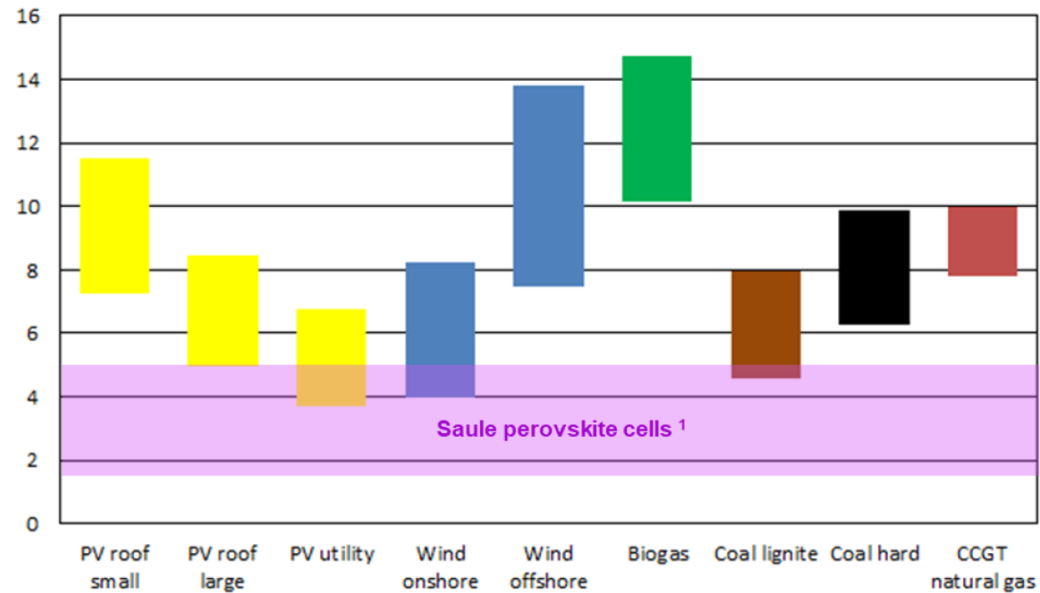
First ink-jet printed perovskite cells





LCOE

Levelized cost of electricity (LCOE) for Germany | EuroCent/kWh



The minimum LCOE of perovskite cells can be as low as 1.5 EuroCent/kWh. This is much lower compared to minimum LCOE for other sources of energy such as gas or coal

The perovskite cells require low temperature processing. This makes production less expensive compared to traditional silicon PV

A relatively simple infrastructure in comparison with traditional cells. The synthesis of perovskites is a rather straightforward process and the materials required are commercially available.

- ¹ LCOE of Saule perovskite cells is in a range between:
- 1.5 EuroCent/kWh for 15% efficiency and 25-year lifetime
 - 5.0 EuroCent/kWh for 10% efficiency and 10-year lifetime

Sources:
Fraunhofer Research, March 2018
Cost-Performance Analysis of Perovskite Solar Modules, September 2016
(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5238749>)