Becquerel Prize Acceptance

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Metal halide perovskites: From curiosity driven research to mainstream PV production

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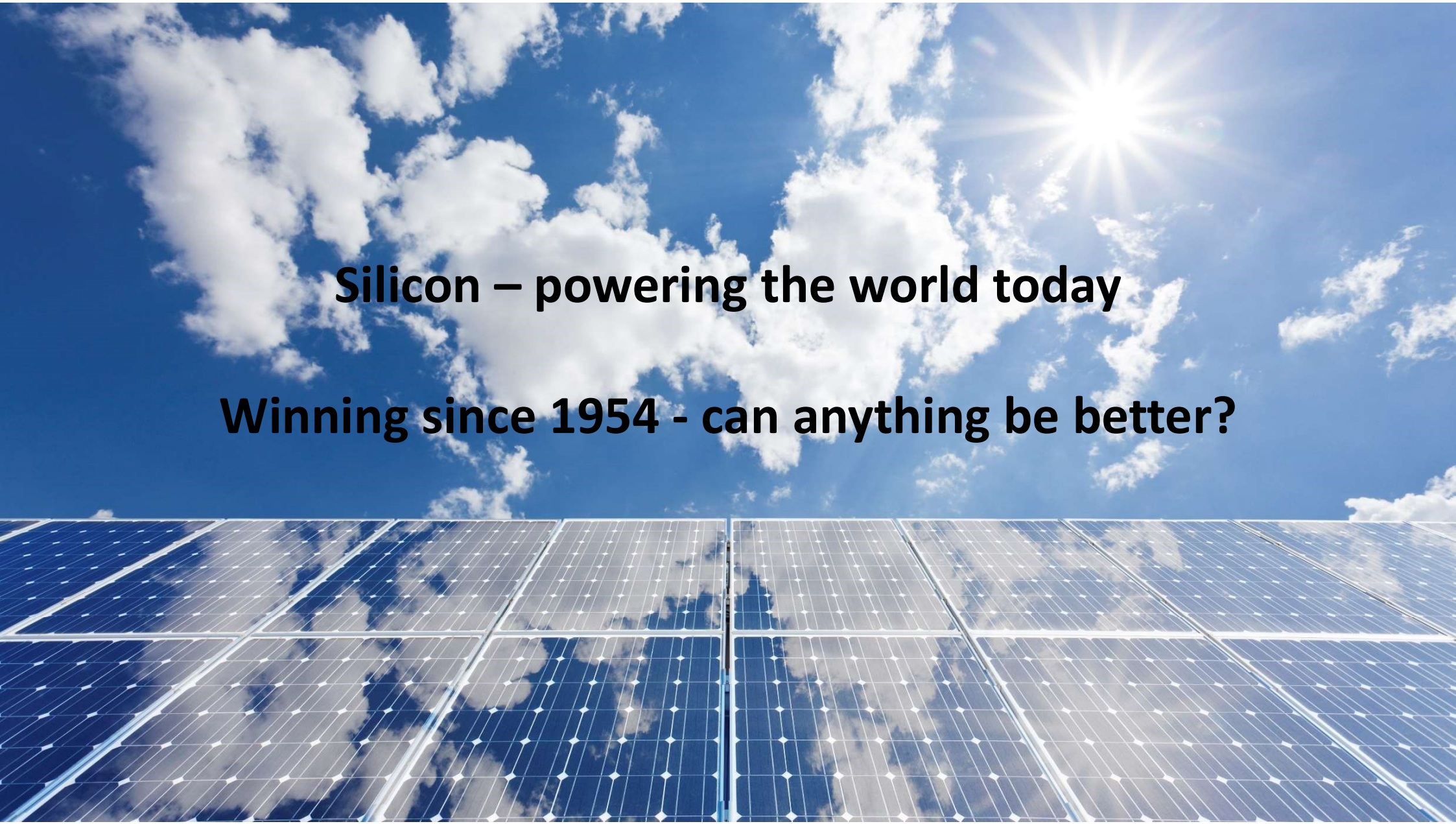
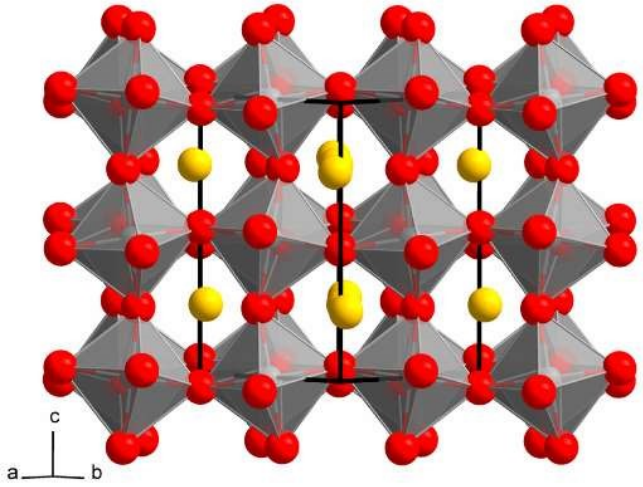
Photovoltaics and
Optoelectronic Devices Group

OXFORD PV™
The Perovskite Company


Silicon – powering the world today
Winning since 1954 - can anything be better?

Perovskites: from 1892 to 2009



ABX_3 Crystal Structure

Über die Cäsium- und Kalium-Bleihalogenide.

Von

H. L. Wells.[1]

Als Fortsetzung der in diesem Laboratorium[2] begonnenen Arbeit über Doppelhalogenide ist von den Herren G. F. Campbell, P. T. Walden und A. P. Wheeler eine Untersuchung über die Cäsium-Bleisalze unternommen worden. Diese Herren haben die Untersuchung mit vielem Eifer und Geschick durchgeführt, und es macht mir Freude, ihnen meinen Dank auszusprechen. Sie haben die Existenz folgender Salze konstatiert:

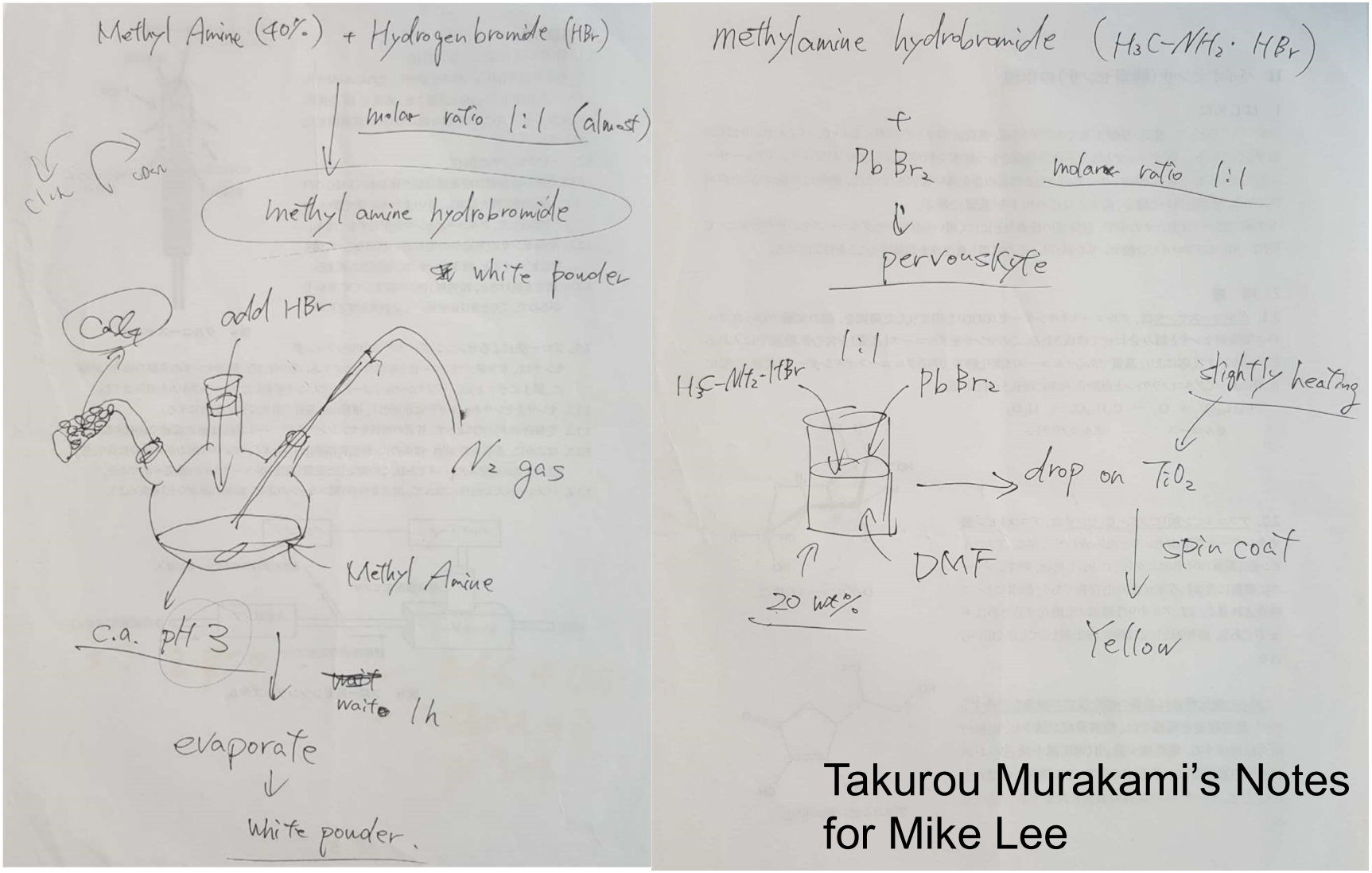
Cs_4PbCl_6	Cs_4PbBr_6	—
$CsPbCl_3$	$CsPbBr_3$[3]	$CsPbJ_3$
$CsPb_2Cl_5$	$CsPb_2Br_5$	—

Sheffield Scientific School, New Haven, Conn., Oktober 1892.

Discovery: *1892*

Solar energy conversion: *2009*

Our starting point in 2010



Takurou Murakami's Notes for Mike Lee

Two disparate “tribal” fields of research (pre-perovskites)

“Traditional” PV:

Silicon and thin-film

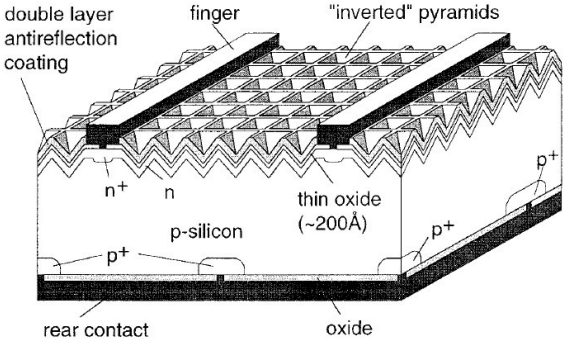
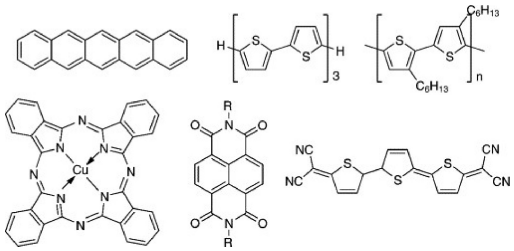


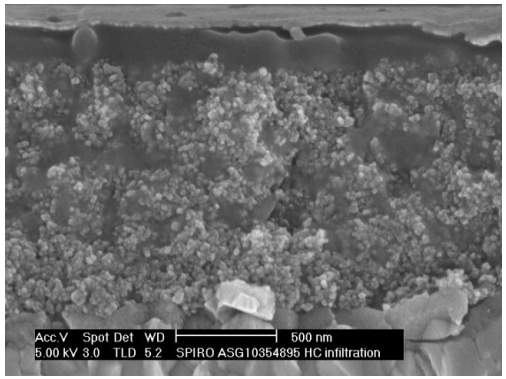
Figure 1. PERL (passivated emitter, rear locally-diffused) cell structure

Solid poly, micro or crystalline absorber layer sandwiched between charge selective contacts

Emerging PV:

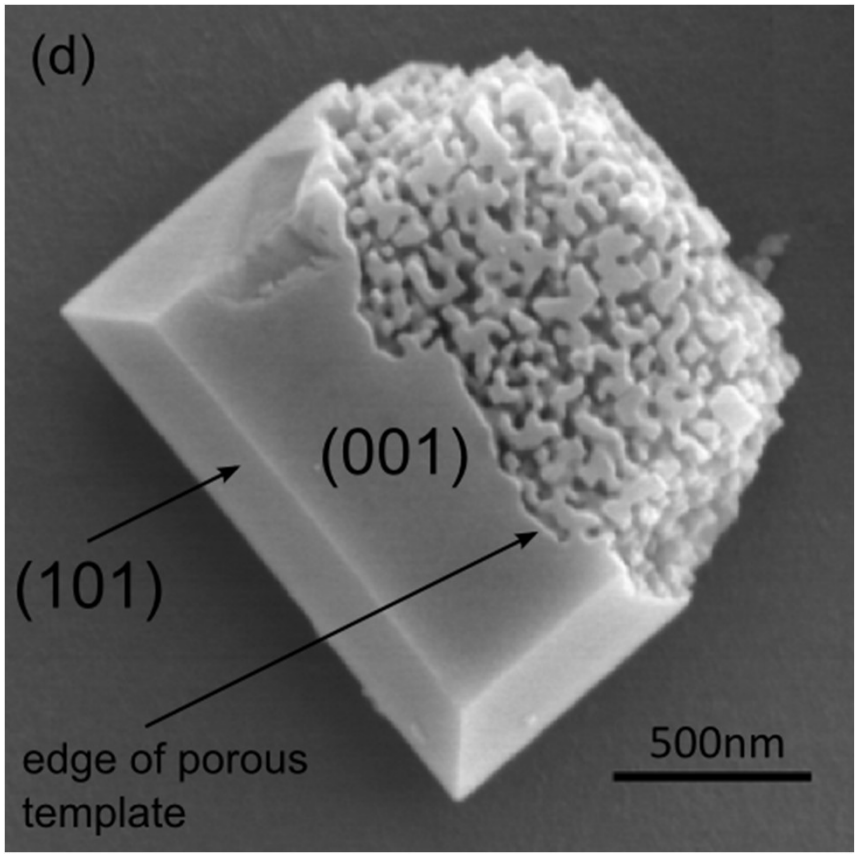
Organic, dye-sensitized and nanostructured PV



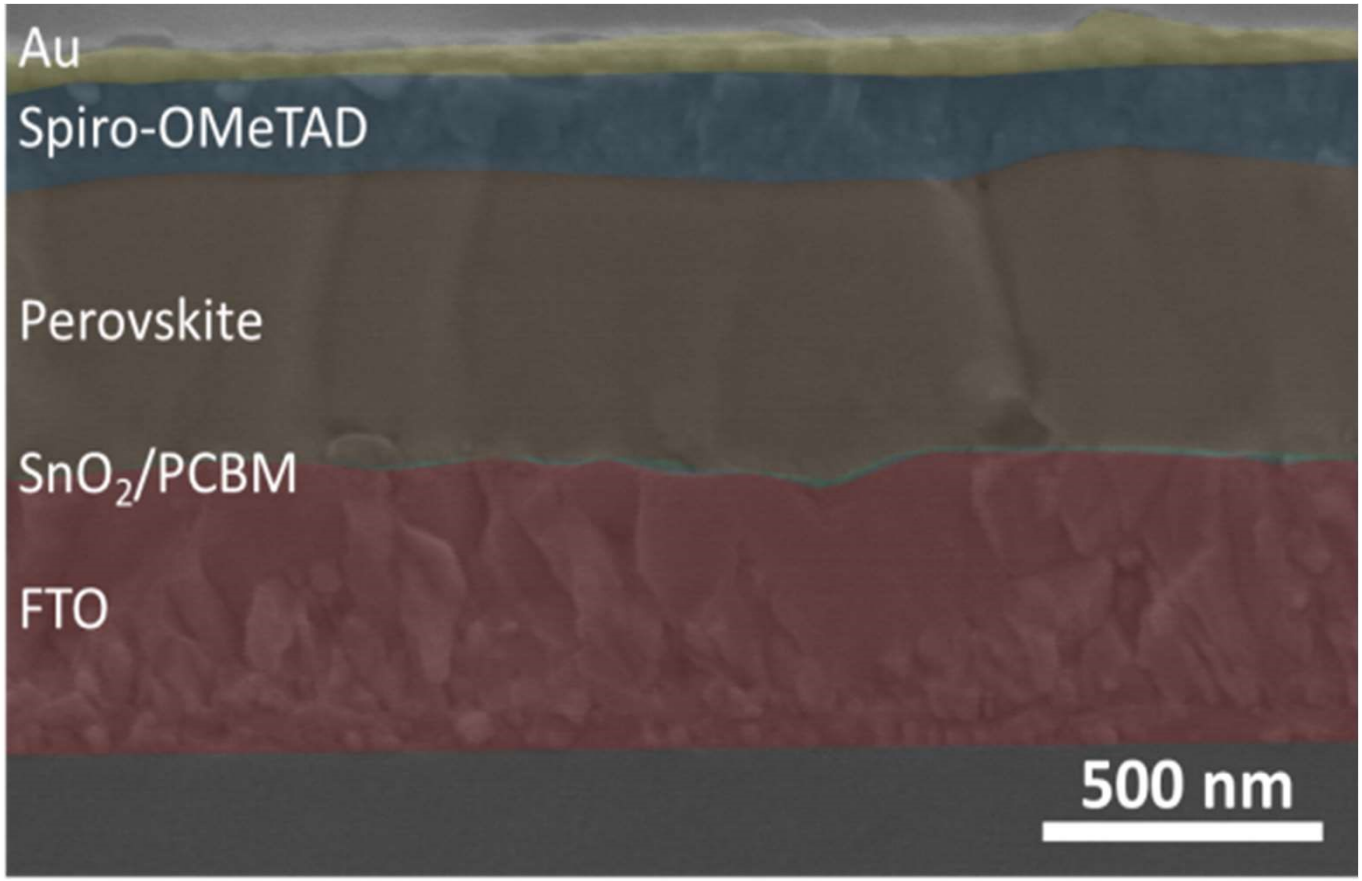


Based on interpenetrating networks on electron and hole conducting materials – required to separate tightly bound excitons and transport electron and holes in highly disordered materials.

Are perovskites best when porous or crystalline?



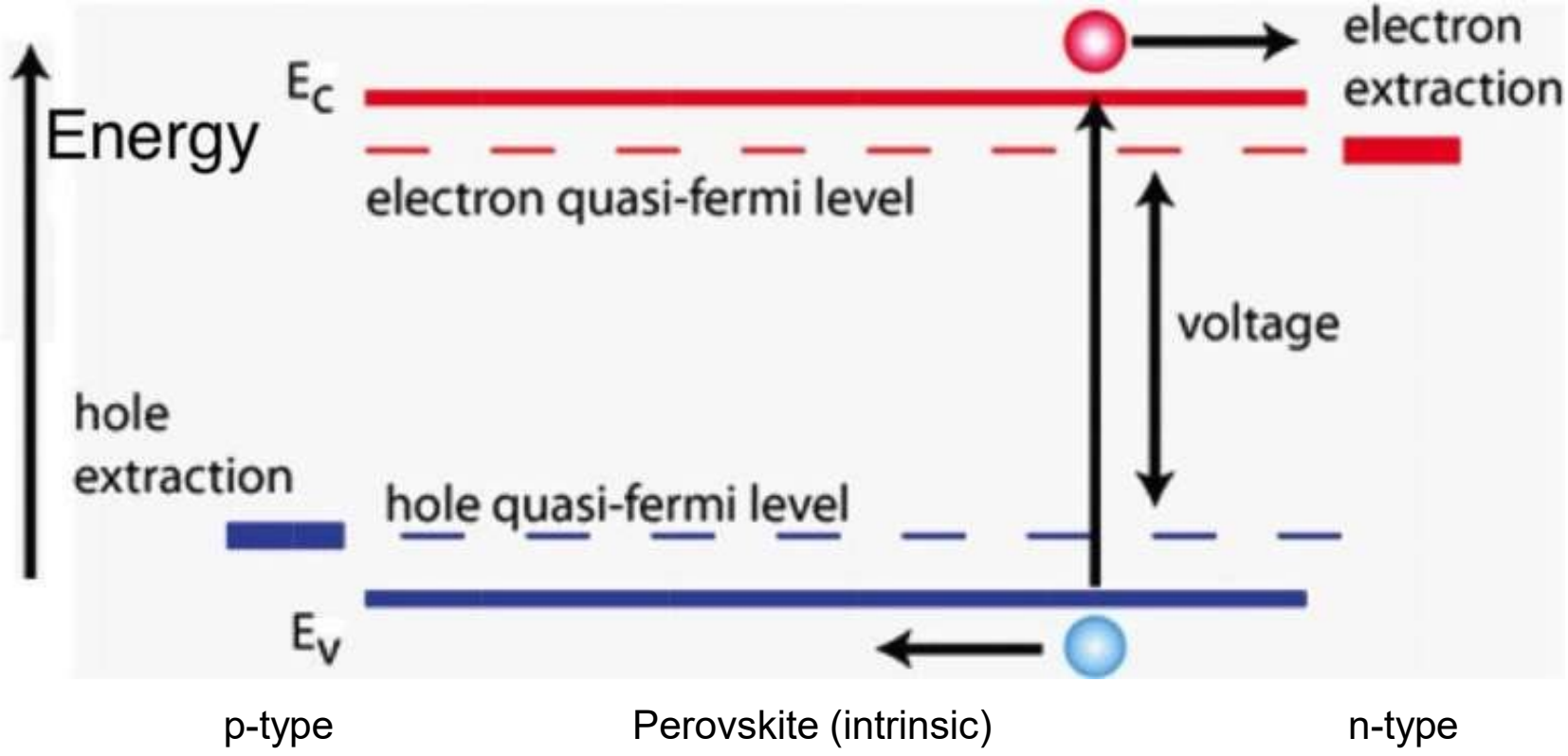
The n-i-p “planar” heterojunction



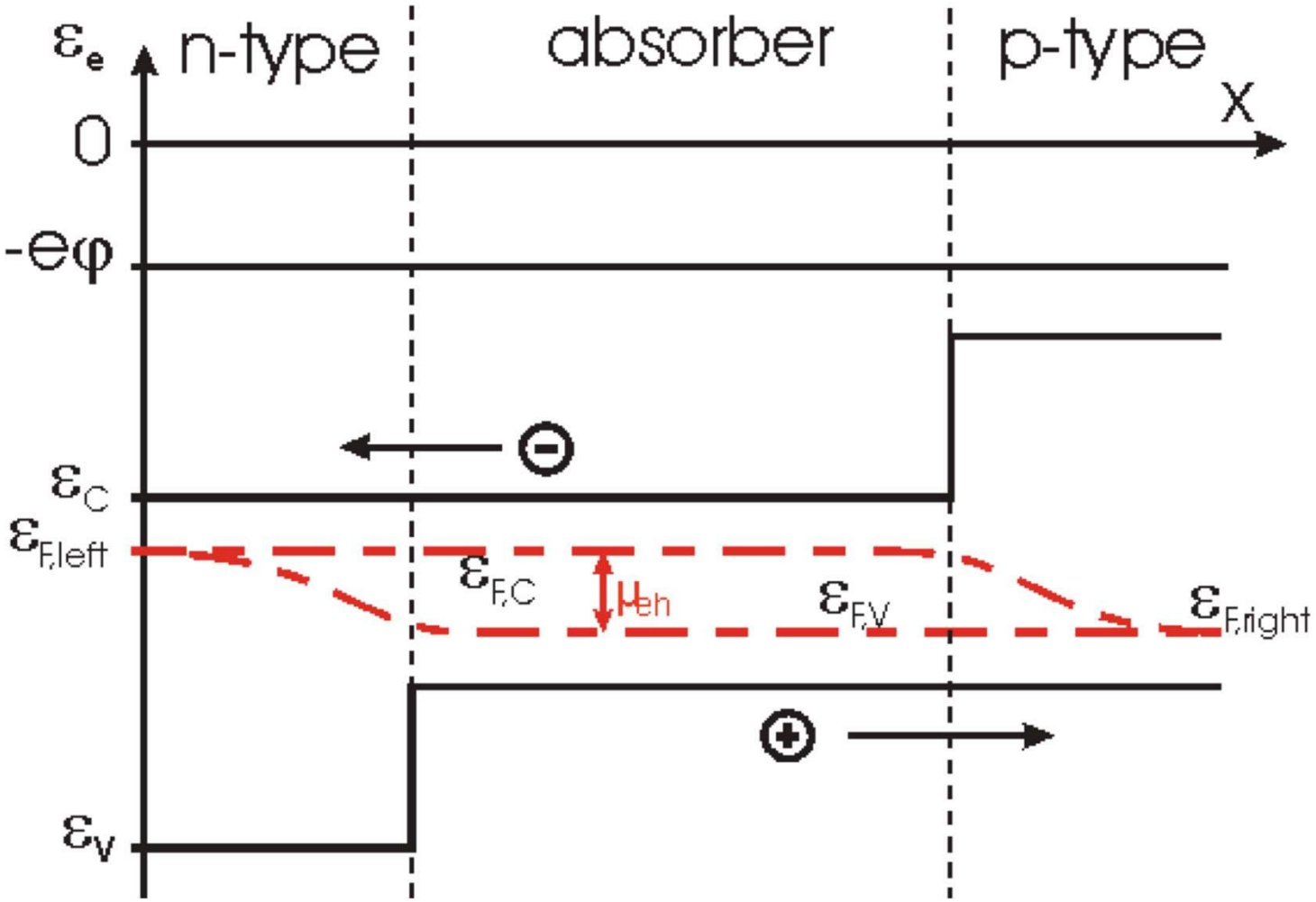
Surprise discovery:

- No efforts for passivation - Benign defects
- Long carrier lifetimes
- High charge carrier mobility
- Very high radiative efficiency

The n-i-p “planar” heterojunction



c.f. the “Würfel cell”



Prof Peter Würfel, Becquerel Prize speech, 2018

Surging Efficiency

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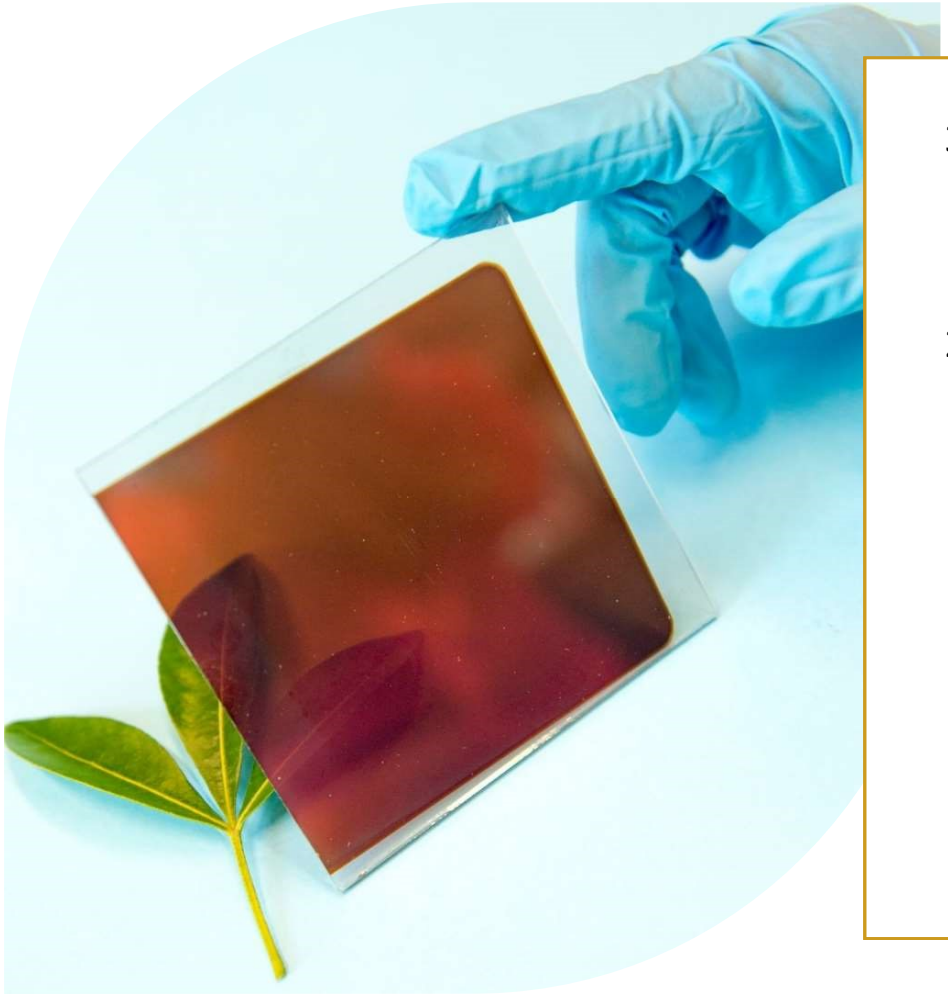
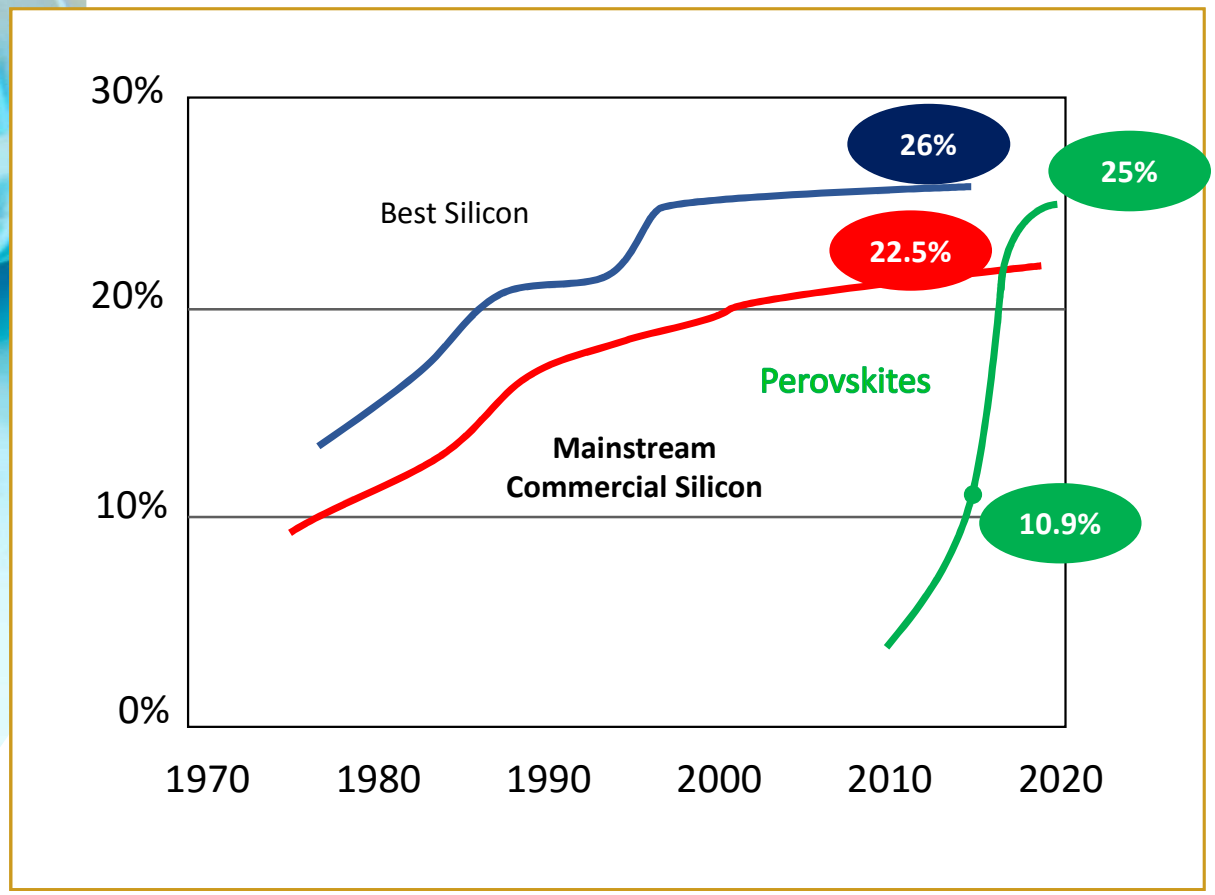
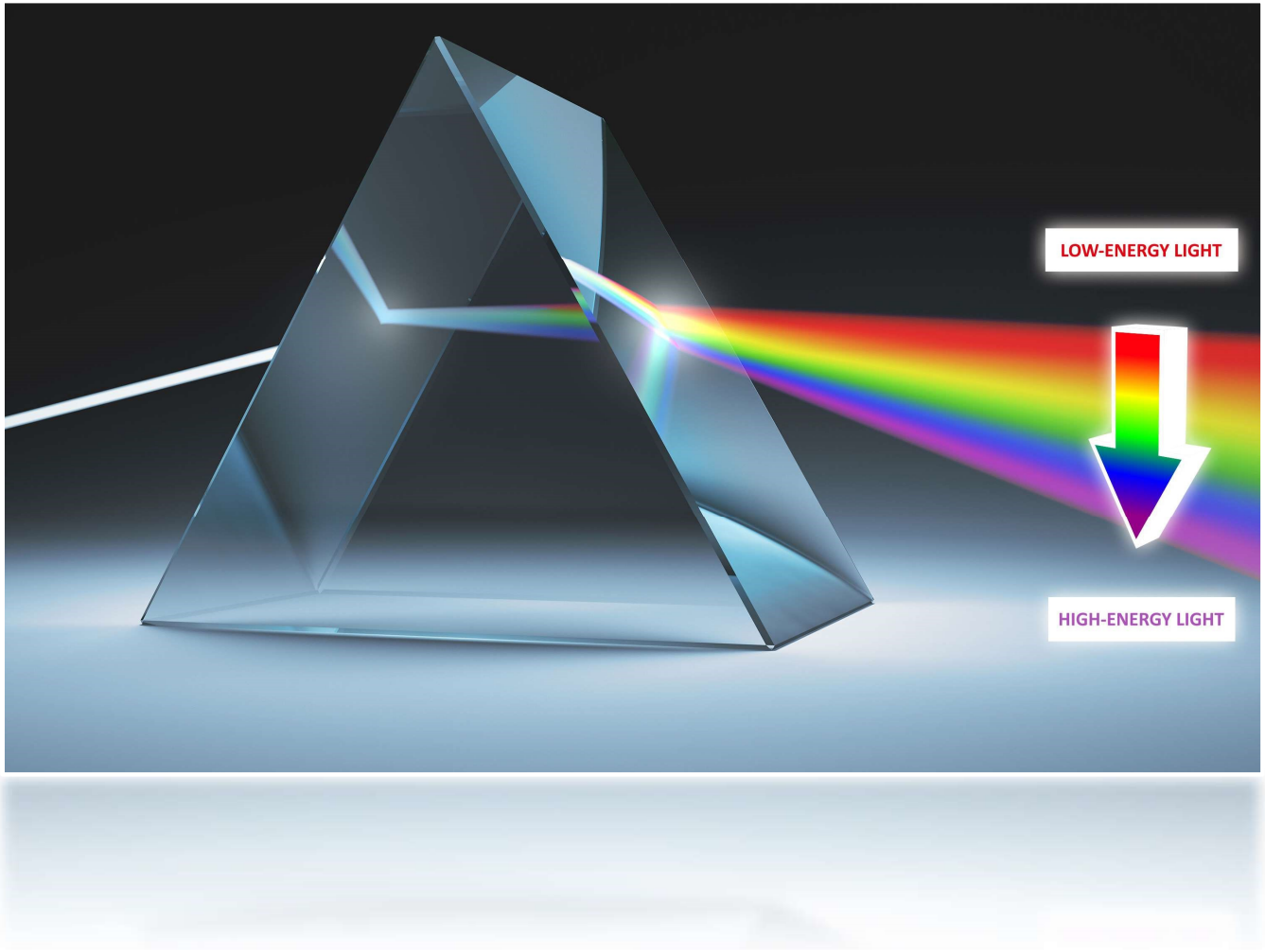




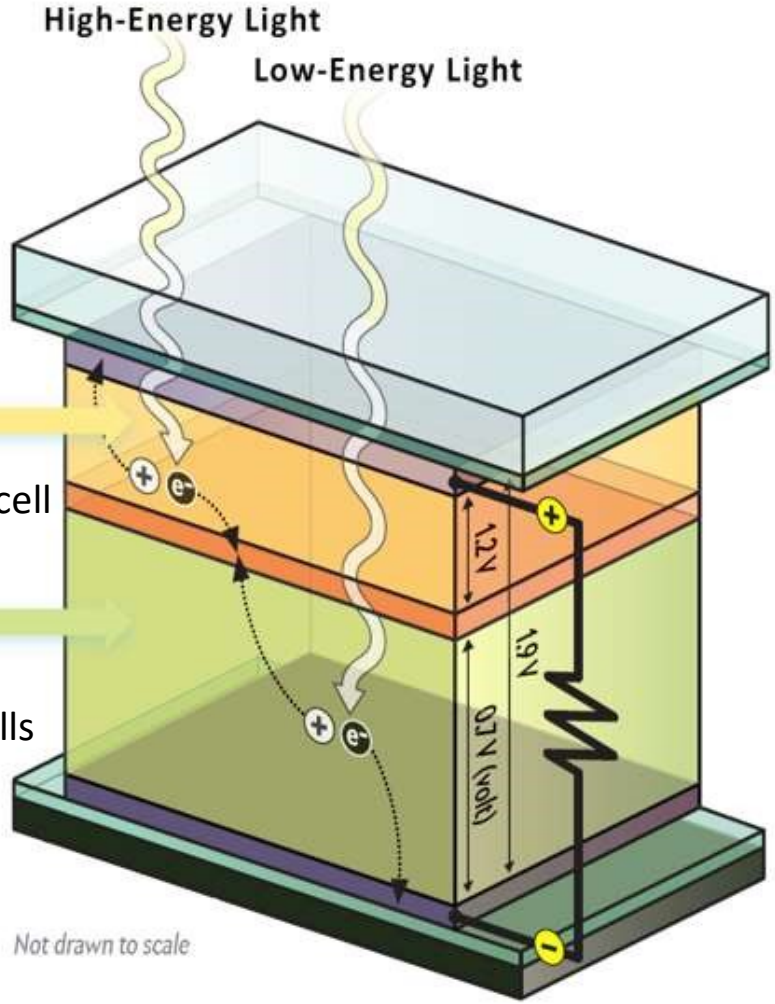
How Can We Extract More Energy From Sun Light?

UNIVERSITY OF OXFORD

The “tandem” concept



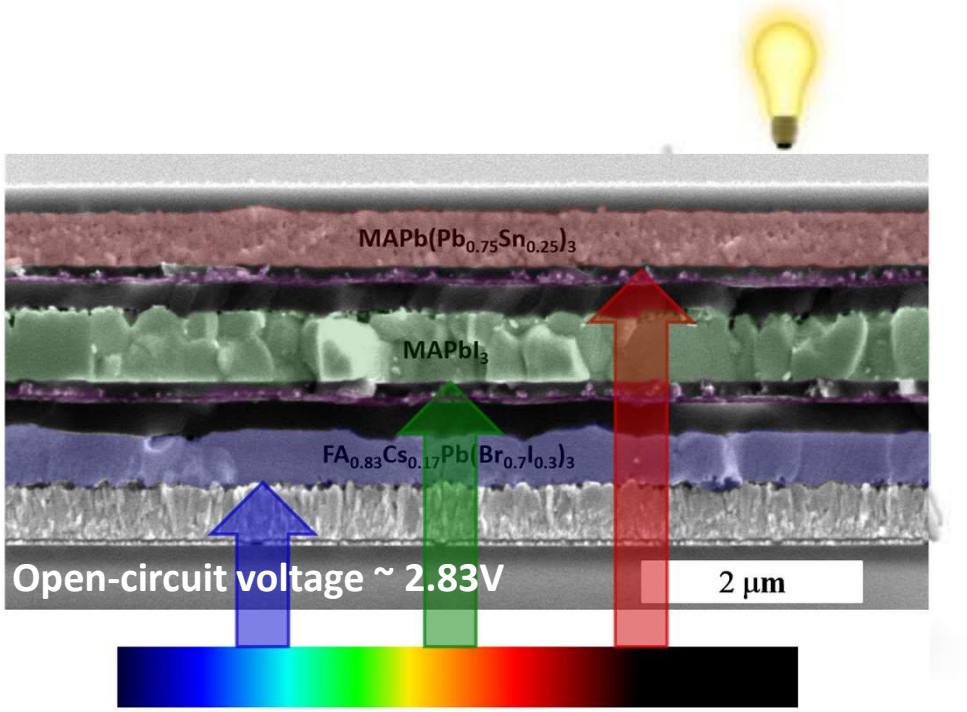
Perovskite-on-silicon tandems



- Efficiency: Presently >29%
- Near Future: 32 to 34%

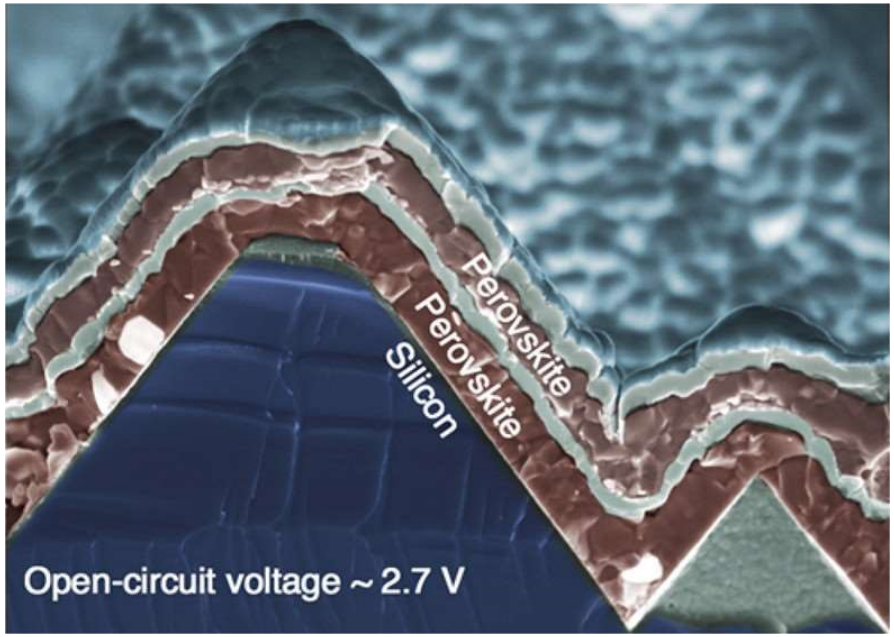
Where to go beyond 2 junctions?

3- Junctions!



D. McMeekin et al. 2019 Joule

Triple Junction “All-perovskite” thin-film
Potential for 37% efficiency

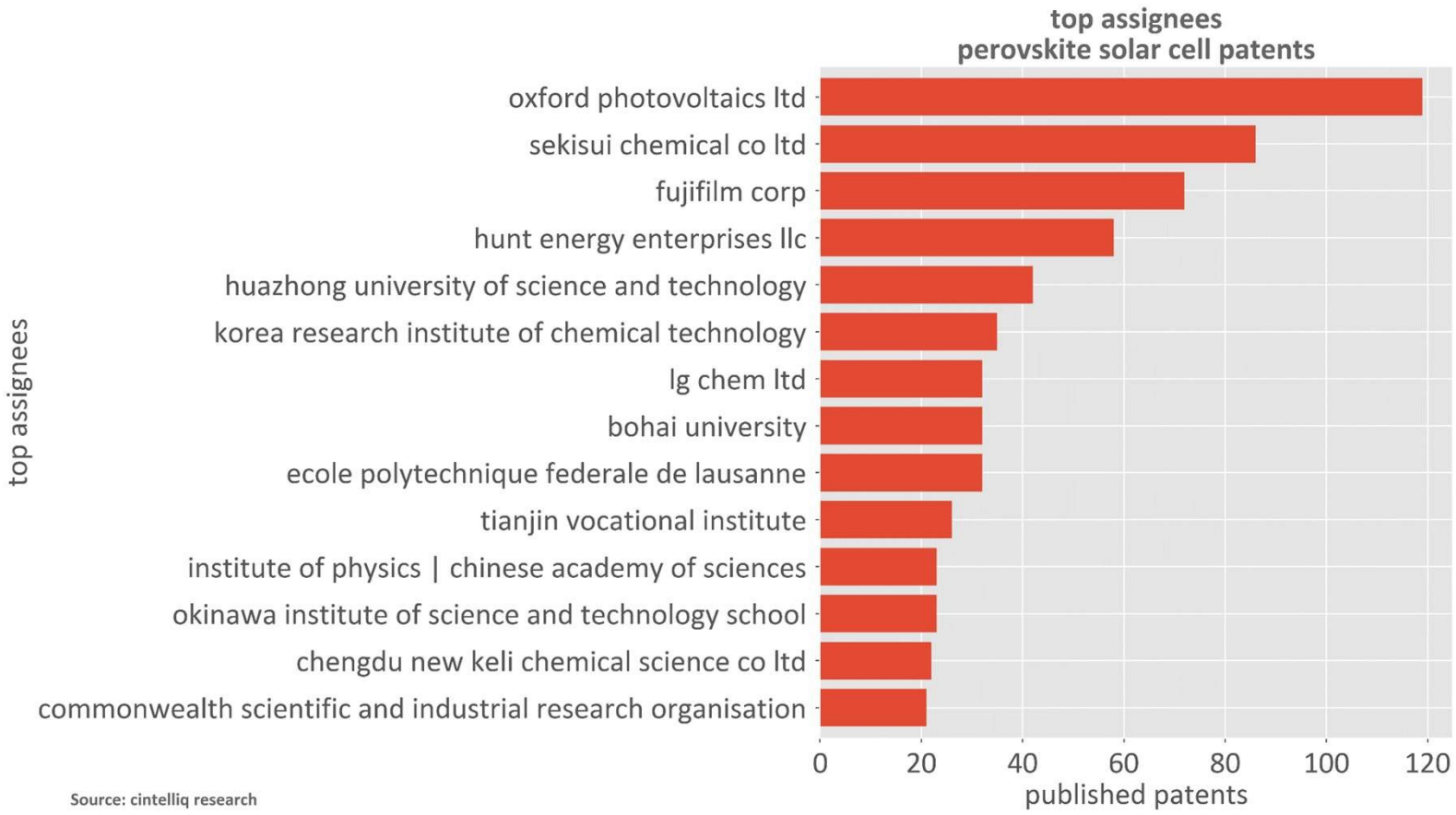


J. Werner et al. 2018 ACS Energy Letters

Triple Junction “perovskite-perovskite-silicon”
Potential for 39% efficiency

Patent landscape….

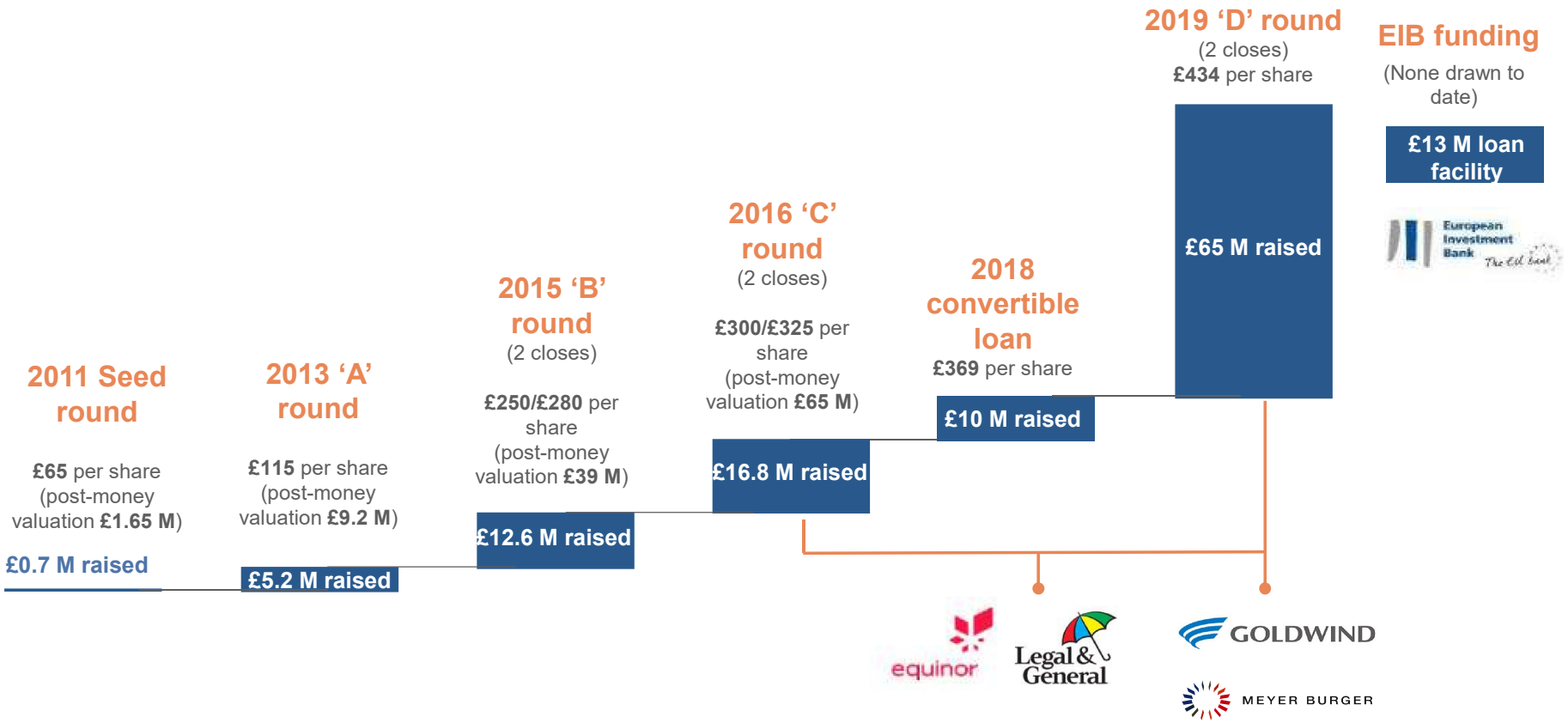
Explosion in academic and industrial activity all over the world



Independent assessment done in early **2018**, total number of **patents trebled by 2020**

Our commercialisation Path

>£110 million raised to date



Oxford PV tandem cell roadmap

To 30% efficiency and beyond….

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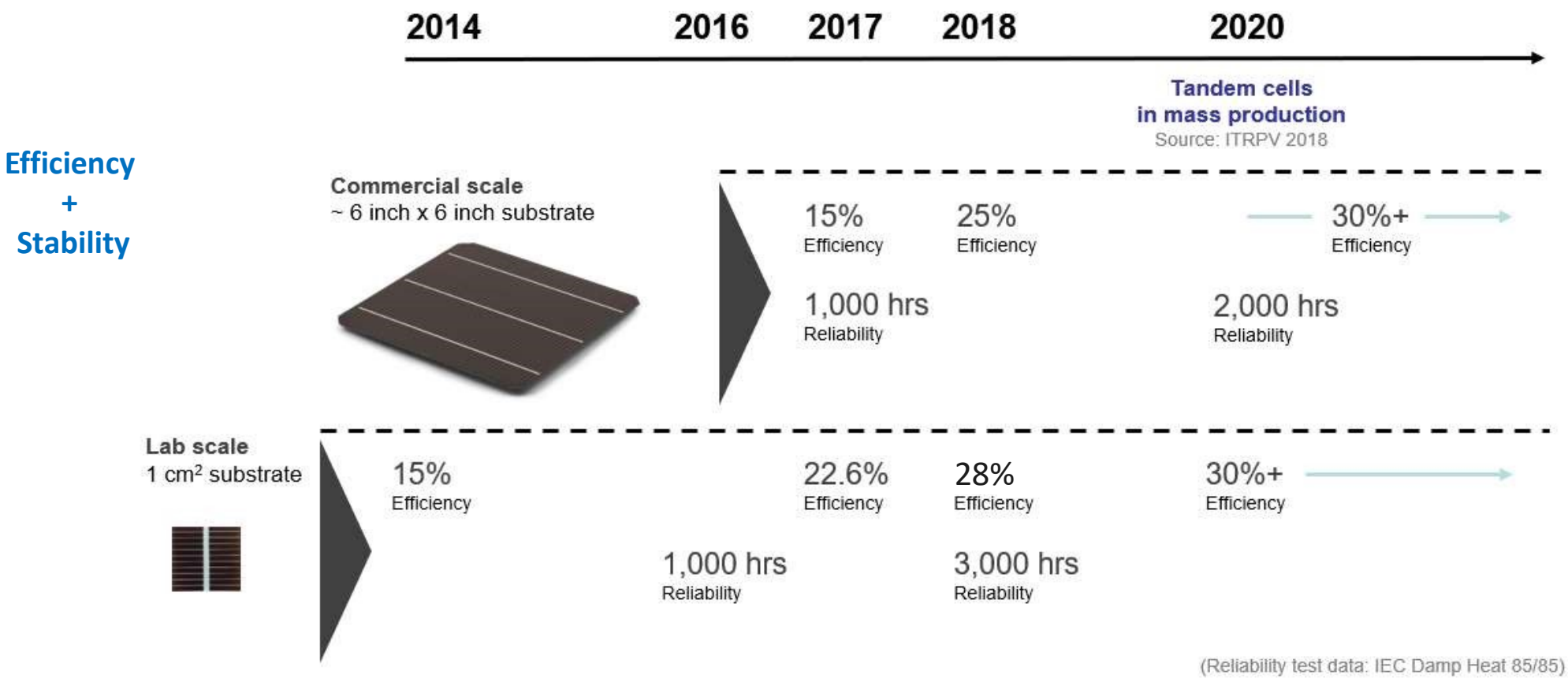

Volume manufacturing

2019
Low volume production

2019 / 2020
Scale up

2021
Volume manufacturing

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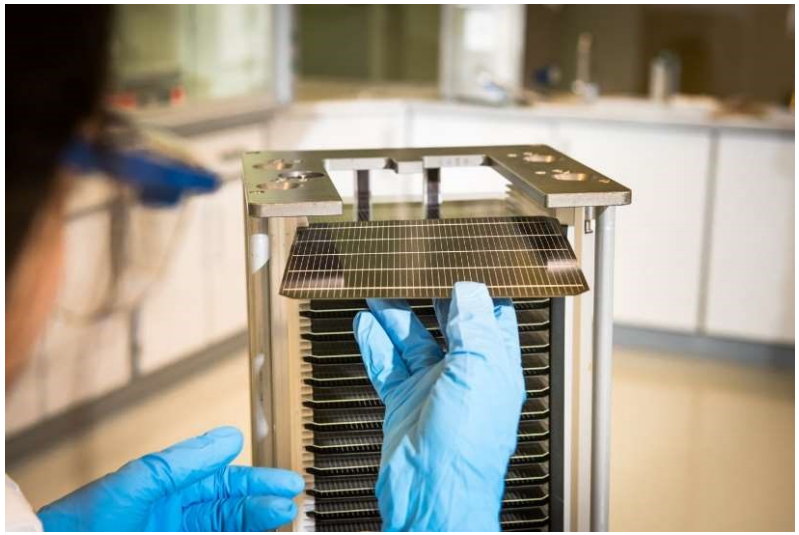
Roadmap to high volume manufacturing

>100 MW production during 2021 then to GW scale and beyond….



Cells to modules*

*the automation is presently being installed….

Thanks to……

EU Projects and **Partners from**: SANS, MESO, CHEOPS, PERTPV, PEROCUBE
And ITN networks, DESTINY, Maestro and PERSEPHONE

Collaborators:

Over 250 collaborators and co-authors, including:

Oxford:
Michael Johnston
Laura Herz
Robin Nicholas
Feliciano Giustino (now U Texas)
Paolo Radaelli
Moritz Reide

IIT Millan:
A. Petrozza et al.

HZB Berlin:
PV ComB team

Cambridge:
RH Friend et al.

Linköping:
Feng Gao & Sai Bai

USA:
S. Marder et al.
D. Ginger et al.
M. McGehee et al.
A-KY Jen et al.
J. Berry et al.

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