Thin Film and Advanced light management

Martina Schmid, Helmholtz – Berlin

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration

Objectives

Higher efficiencies of thin-film solar cells (TF-Si, Cu(In,Ga)(S,Se)$_2$ and Kesterites) with less solar cell base materials

→ Enhance todays maximum efficiencies
→ Cost reduction of 20% envisaged

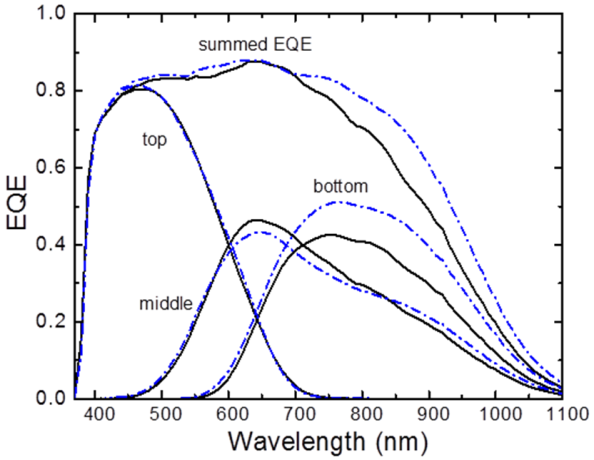
- Thin-film Si
  nano-patterning/-structuring of the cell itself or by introducing grating structures, to improve the optical absorption of the solar cell absorber without any electrical losses of the device
  → Efficiency goal: ≥ 15%
- For CIGSSe (+ CZTSSe)
  development of monolithic microconcentrator solar cells with low and medium concentration enhancement; starting from top-down to bottom-up device fabrication
  → Efficiency goal: ≥ 22% (≥ 24% combined)

Current results

Light management in thin-film silicon solar cells

Multijunction solar cells with textured interfaces

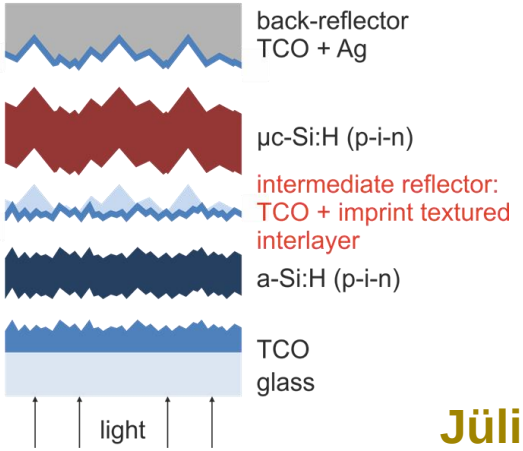
p-i-n triple (a-Si/µc-Si:H/µc-Si:H)



12.8% stable (13.7% initial) on LPCVD ZnO, 14.1% initial on multi texture TCO

EPFL

Nano-imprint textured intermediate reflectors

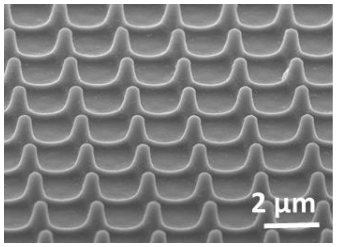


Results will be presented: Thursday, Session **3DO.13.2**

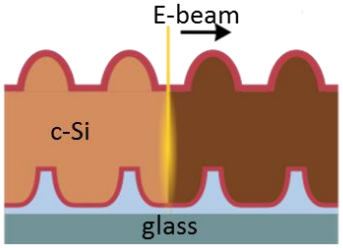
Jülich

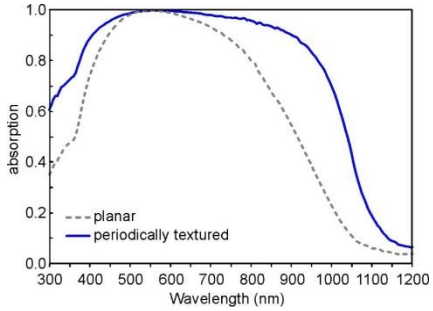
Liquid phase crystallized Si solar cells on nanoimprinted glass

Nanoimprinted glass



Si LP-crystallization





Absorption increase, η = 8.1%

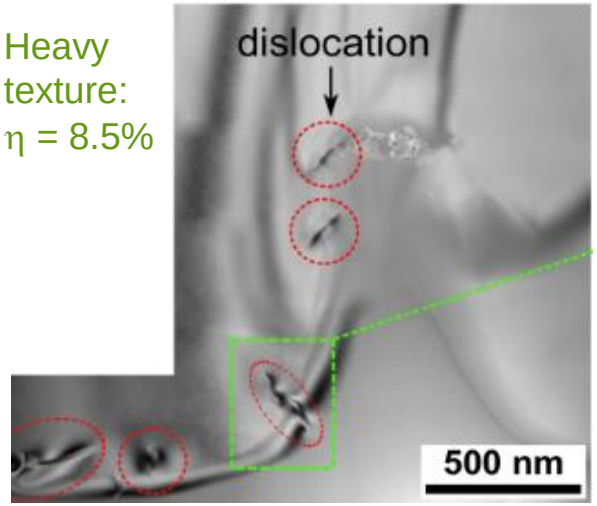
Becker et al., Solar Energy Materials and Solar Cells **135** 2 (2015)

HZB

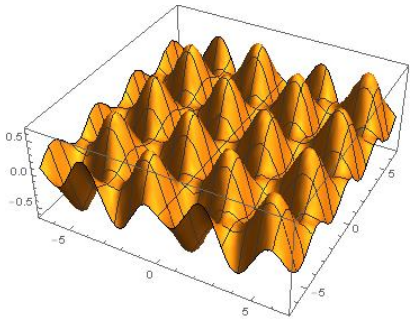
Upcoming challenges
Light trapping schemes for LPC-Si

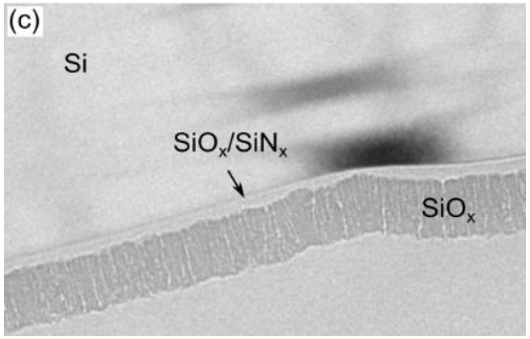
Shape of textured substrate crucial
→ Texture enabling high material quality & broadband absorption

Heavy texture: η = 8.5%



→ Sinusoidal





Gentle texture: η = 13.2%

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Activities on µc-Si finished → focus on liquid phase crystallized Si

Individual texturing of front, intermediate and back side textures
→ Maintain device performance throughout processing steps

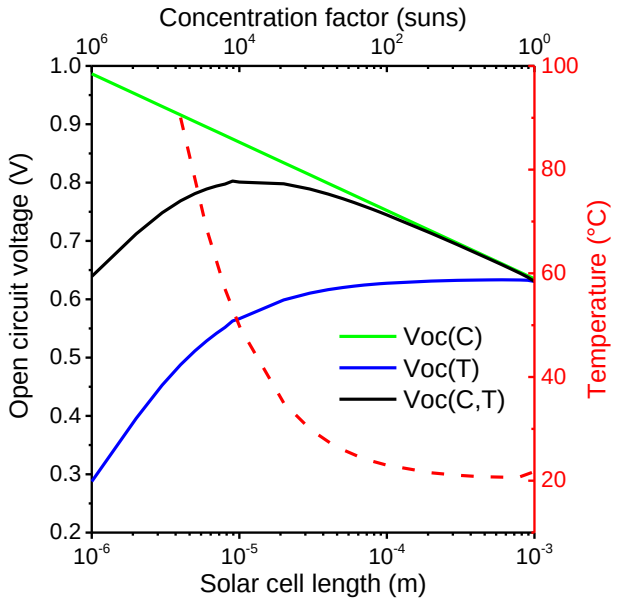
Jülich, EPFL

Current results

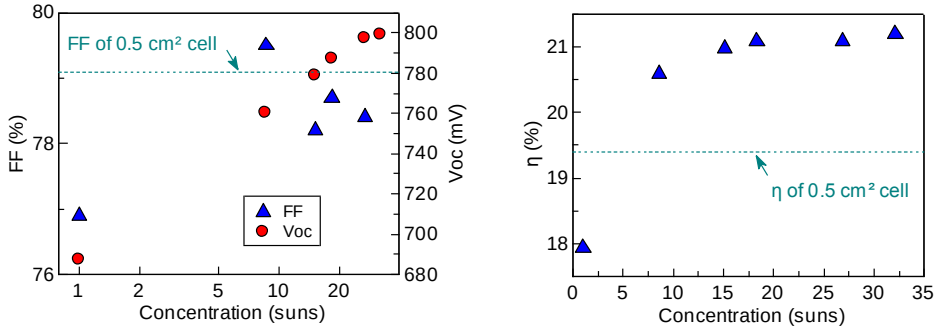
Top-down approach for CIGSe microconcentrators

Potential and first achievements

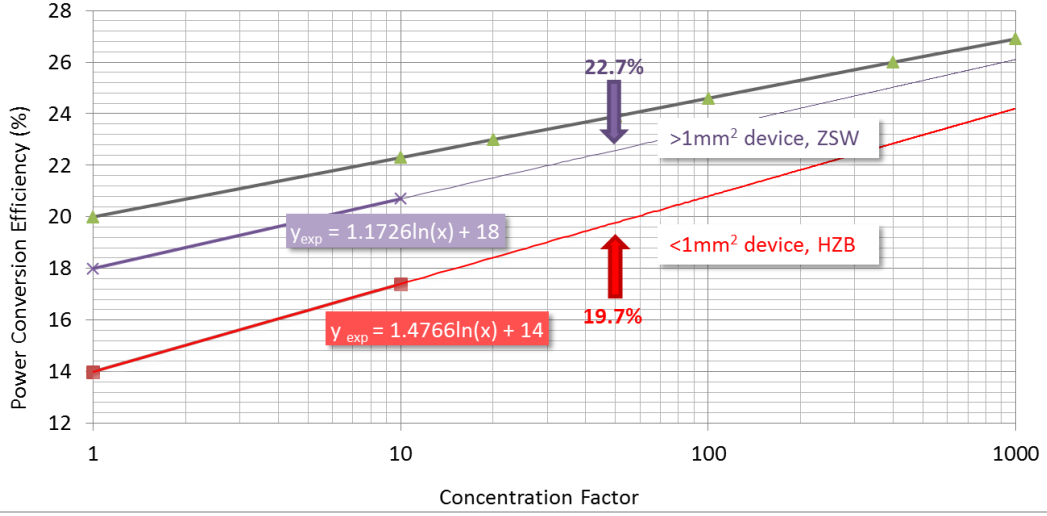
Calculated Voc **HZB**

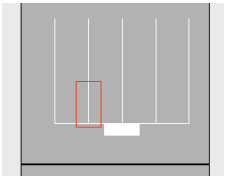


2.5 mm² cells show η > 21% under concentration **ZSW**



Measured and extrapolated efficiencies





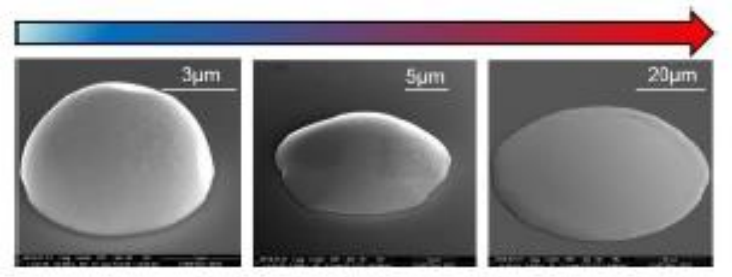
Micro cells cut from high efficiency cells

Current results

Bottom-up approach for chalcopyrite growth

CISe absorbers based on In islands

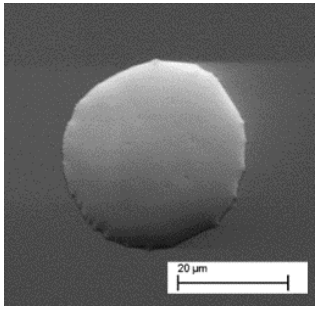
In islands: influence of temperature



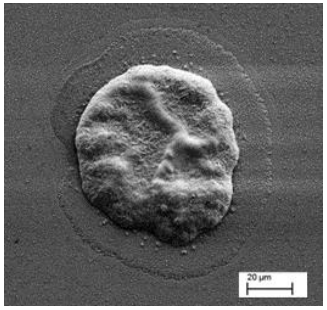
Preferential nucleation on laser patterned substrate

IKZ

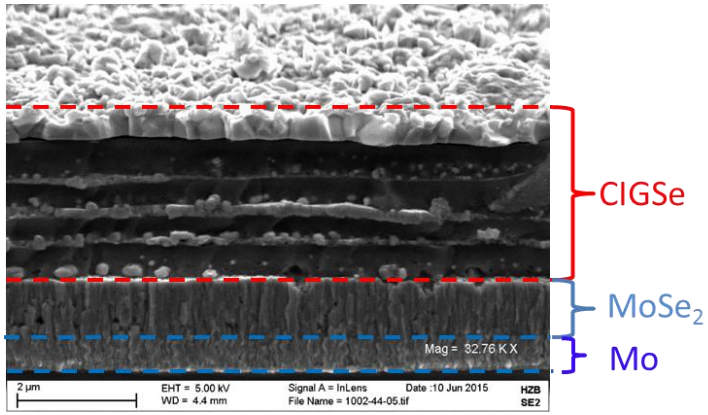
In island + Cu

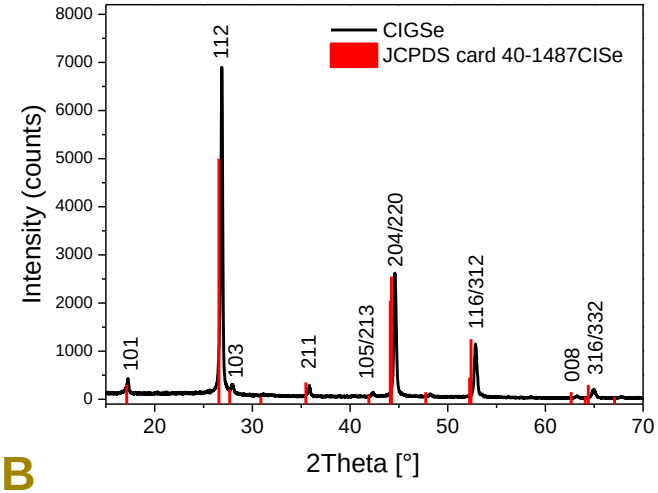


after selenization and KCN



Injekt printing of CIGSe





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Upcoming challenges

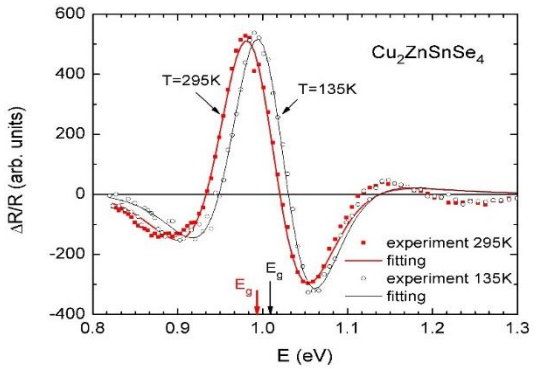
Novel routes for microconcentrator devices

High defect phases in CZTS

→ not suitable for concentration

→ novel device architecture

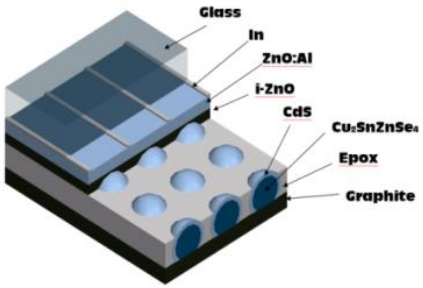
T-dependent electroreflectance



J.Krustok, T. Raadik, M. Grossberg, et al., Materials Science in Semiconductor Processing **39** 251 (2015)

Solar cell structure for diffuse and direct light usage

HZB



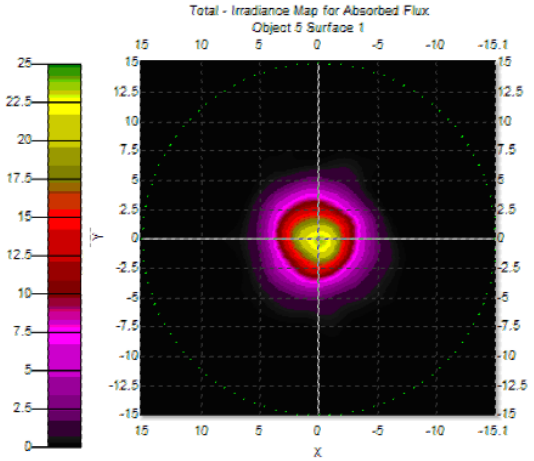
Adding CZTS to concentrator device

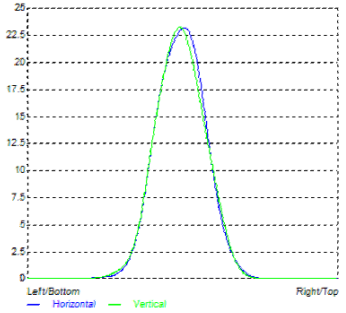
TUT

Concentrator optics for µ-cells

Optical characterization and optimization of microconcentrator optics

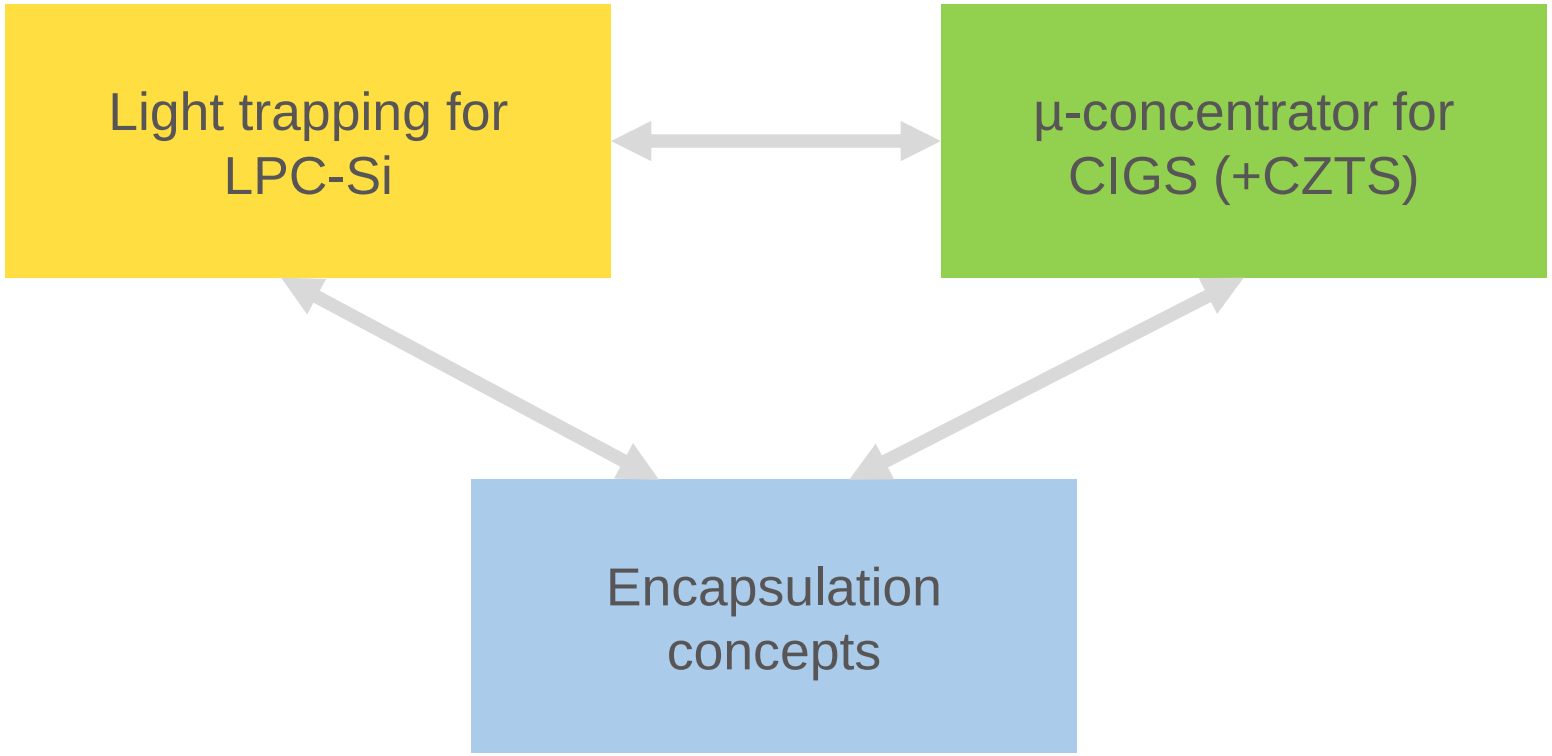
Impact of concentration profiles on device





ENEA

Outlook
Combination of concepts



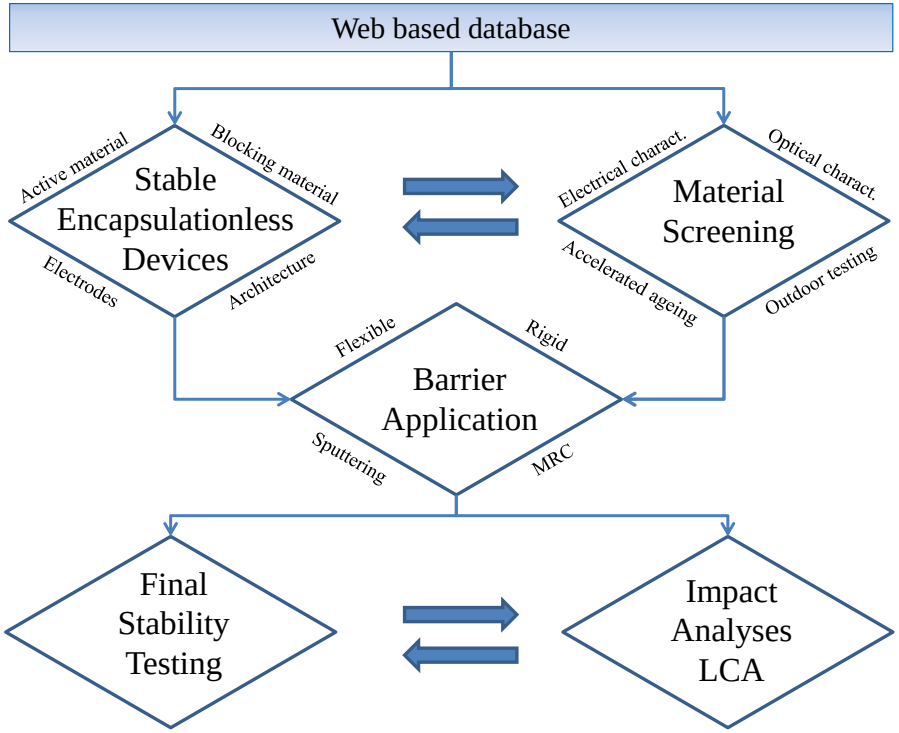
Very low cost-OPV

Suren Gevorgyan

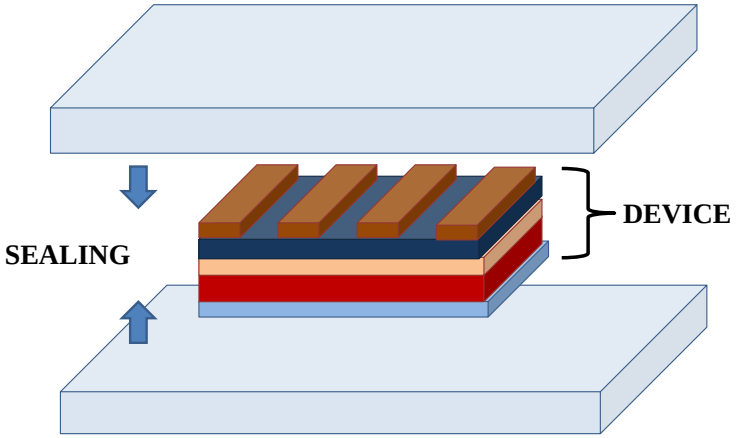
This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration

Objectives

- *To develop an "encapsulationless" organic solar cell*
- *To build the methodology to screen materials and layers combinations for enhanced stability*
- *To use that innovation as platform for an encapsulated long-lived organic solar cell*



Objectives

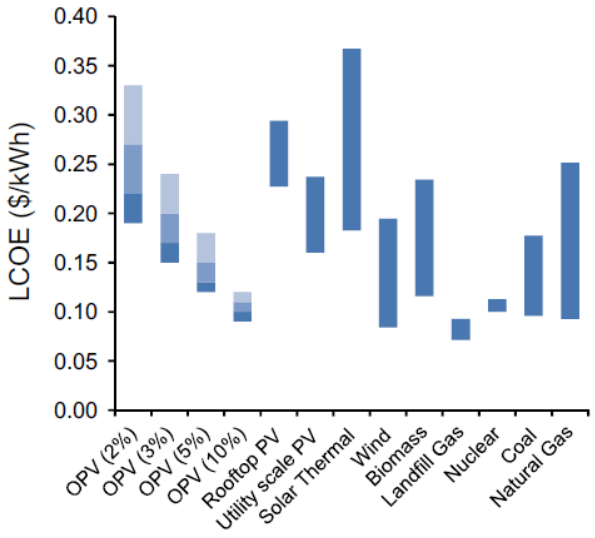


40 - 60 % of Cost

With PET
Module cost ~$8/m2

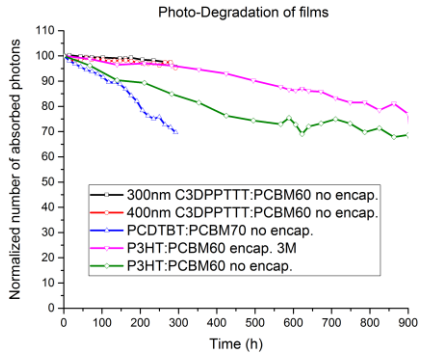
Solar Energy Materials & Solar Cells 120 (2014) 9–17
SolarEnergyMaterials&SolarCells133(2015)26–31

Lifetime (Yrs) \ Efficiency (%)	1	2	3	4	5	10
1	0.95	0.51	0.37	0.29	0.25	0.16
2	0.59	0.33	0.24	0.20	0.18	0.12
3	0.47	0.27	0.20	0.17	0.15	0.11
4	0.41	0.24	0.18	0.16	0.14	0.11
5	0.37	0.22	0.17	0.15	0.13	0.10
10	0.30	0.19	0.15	0.13	0.12	0.09



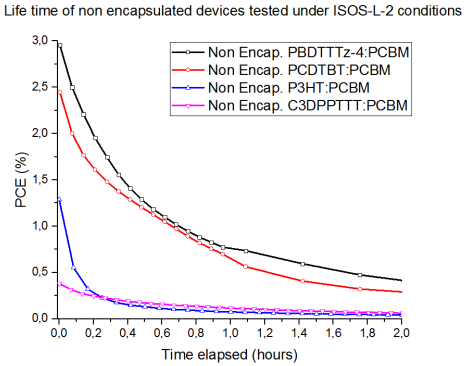
Current results

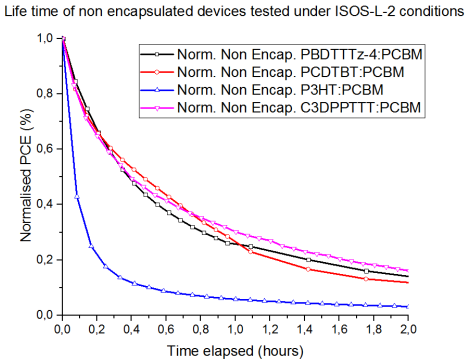
Film photoageing under light



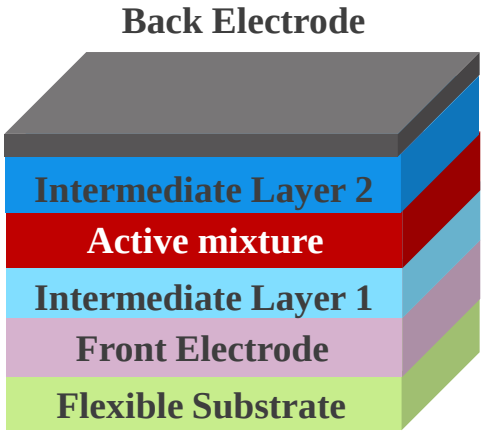
Polymer films can last hundreds of hours

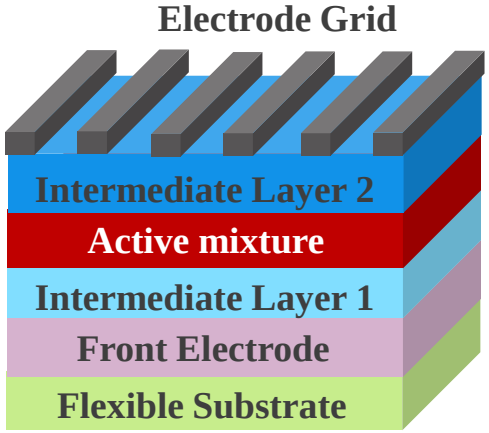
Ageing of unprotected device with grid electrode





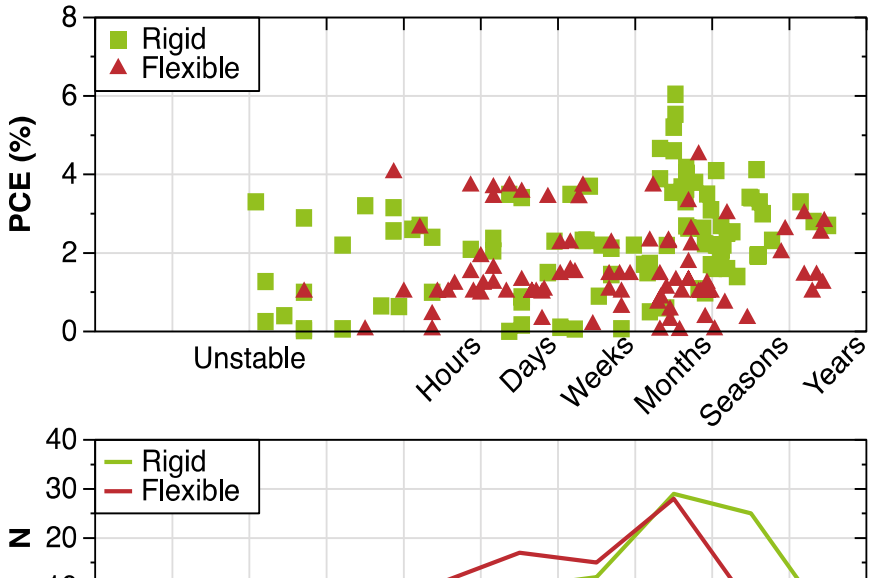
Unprotected devices degrade in an hour



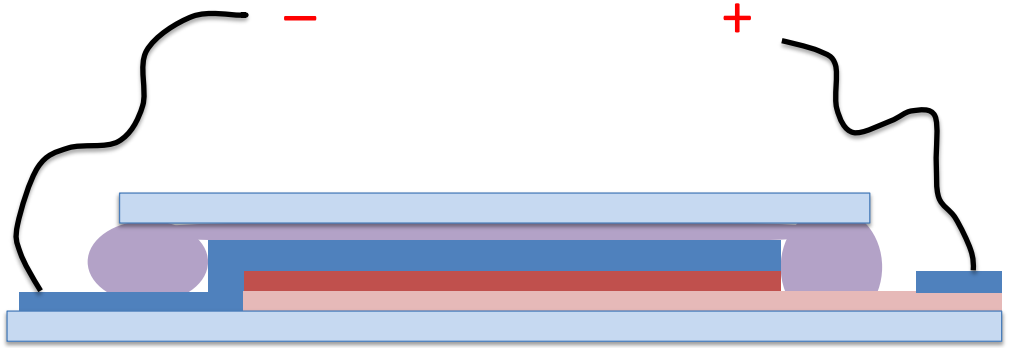


Current results

plasticphotovoltaics.org



- Edge diffusion
- Electrode deterioration



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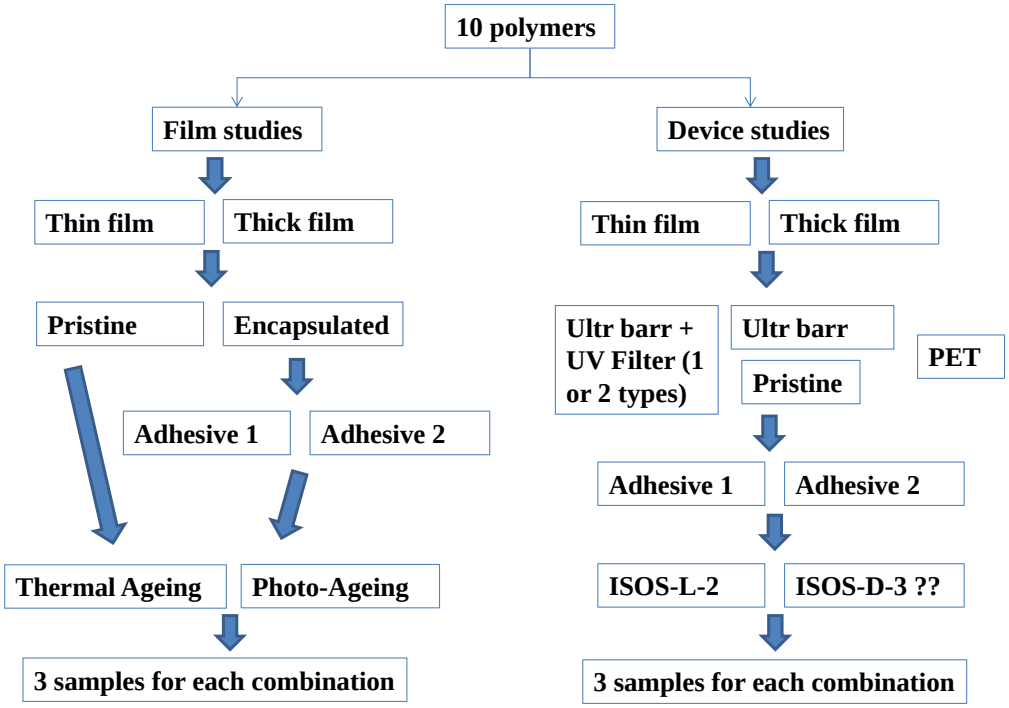

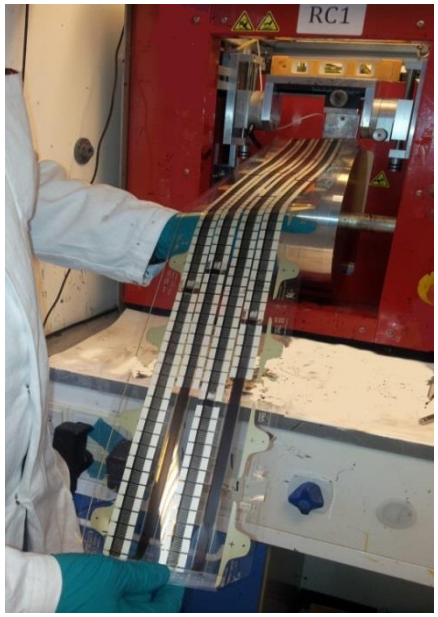

Upcoming challenges

- Substitution of PEDOT:PSS
- Better electrode isolation
- Better edge sealing
- Life cycle analyses
- Stability metrics
- ALD of barriers

Challenge: Samples with 10.000h under accelerated tests

CHEETAH

Thank you very much!!!

Any questions for our experts?

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration