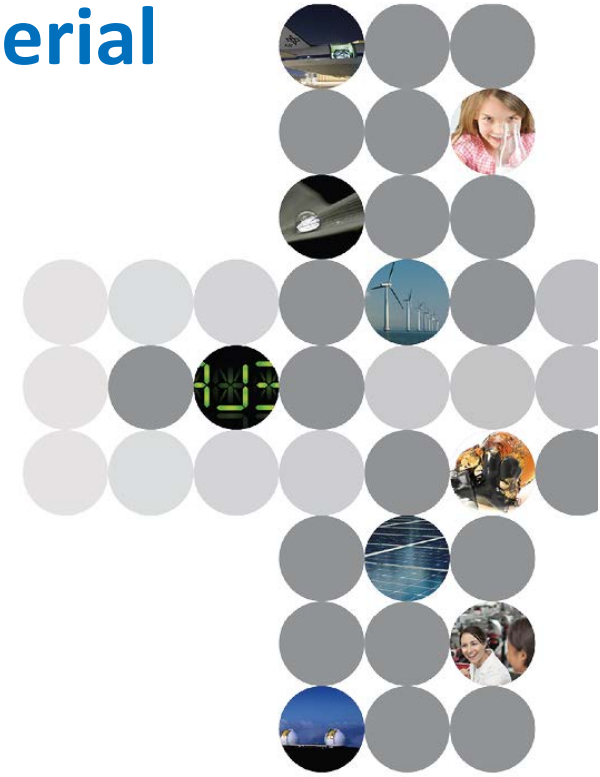
A bottom up approach for customized and highly reliable encapsulation material

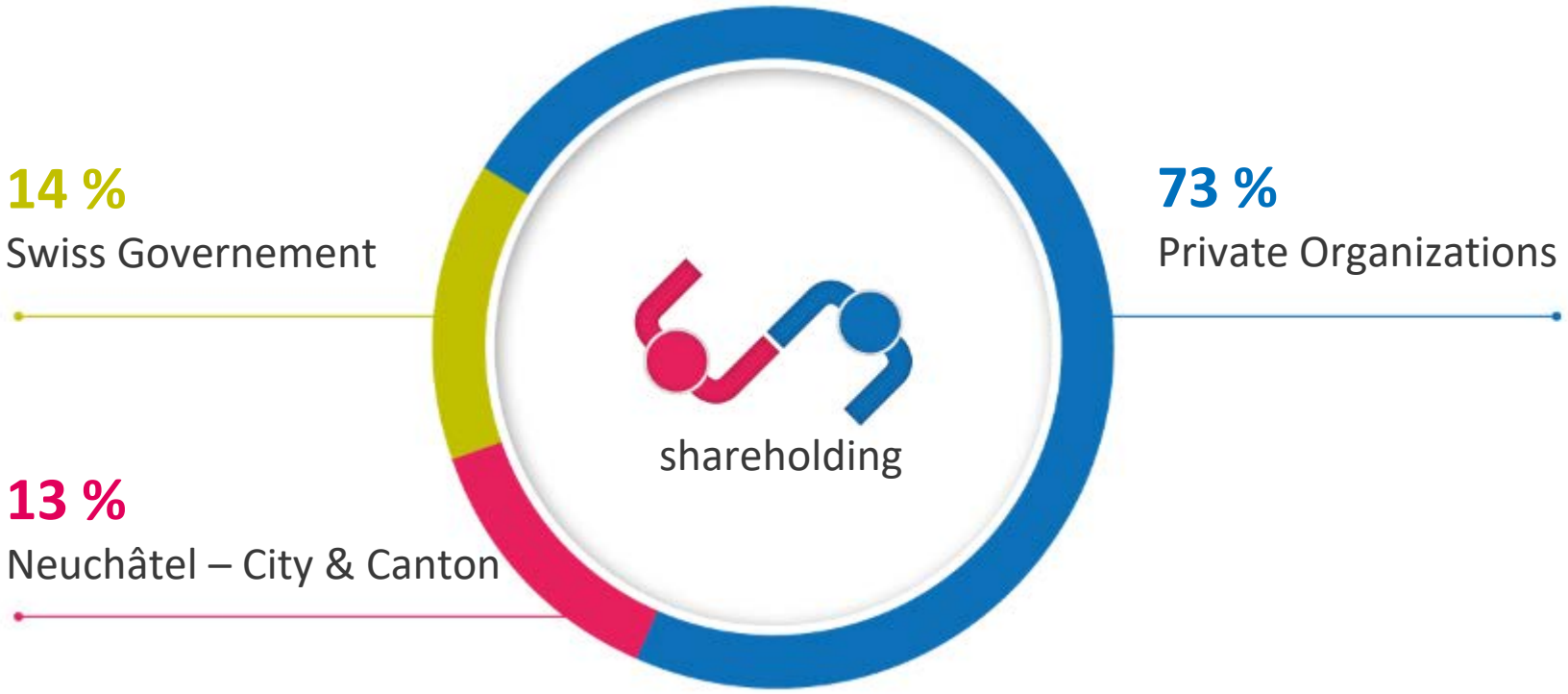
G. Cattaneo



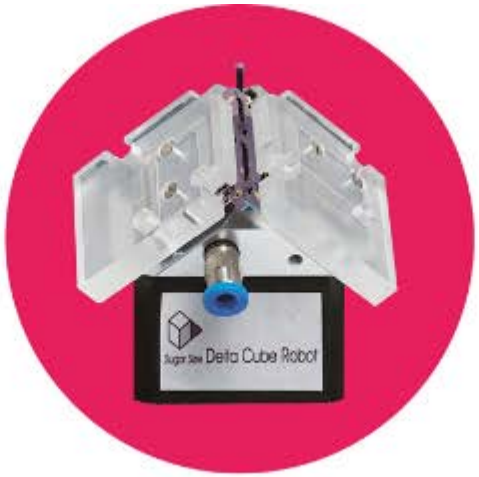
SUPSI Industry Day 2017 6th October 2017

A public-private partnership

- Not-for-profit ***Research and Technology Organization (RTO)*** supported by the Swiss Government.



Our mission



Development and transfer of microtechnologies to the industrial sector – in Switzerland, as a priority – in order to reinforce its competitive advantage.

- Cooperation agreements with established companies
- Encouraging the creation of start-ups

Close to industry, leveraging Swiss academic research

CSEM Zürich

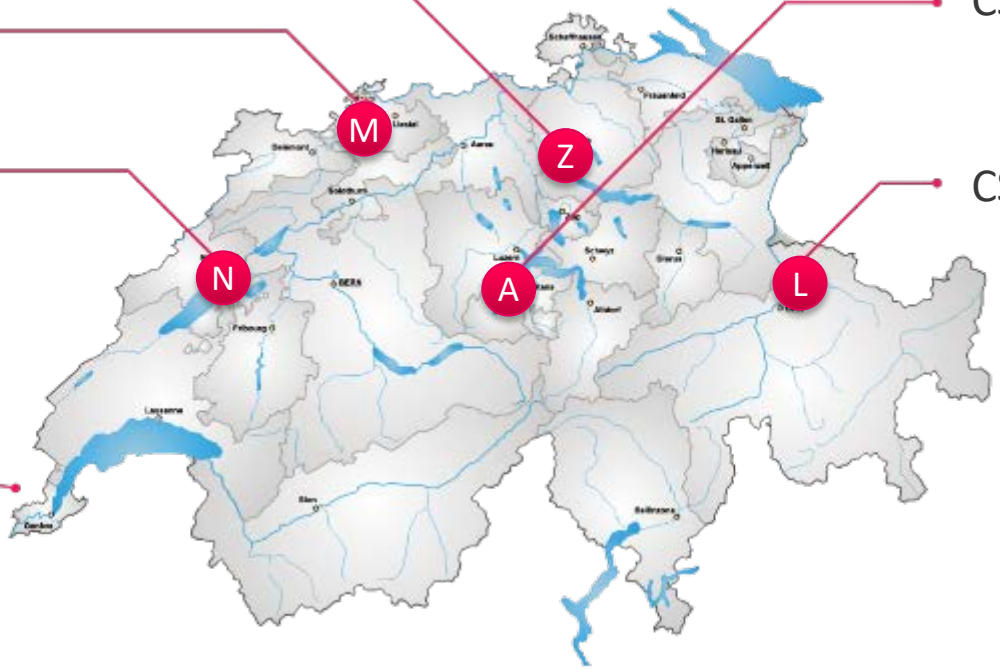
CSEM Muttenz

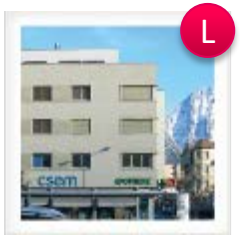
CSEM Neuchâtel

CSEM Brasil

CSEM Alpnach

CSEM Landquart





CSEM at a glance

79.3

Turnover (mio CHF)

40

Nationalities

437

Persons

43

New ventures

190

Industrial clients

196

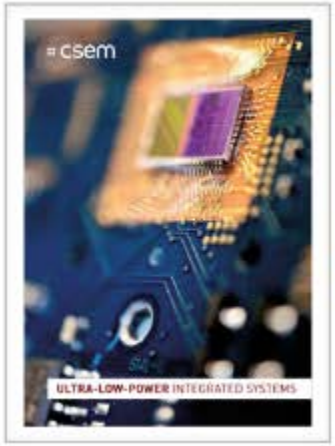
Patent families

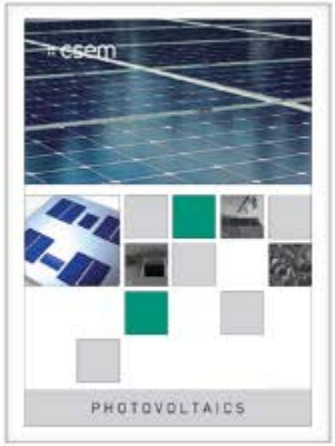
62

European projects

Technology platforms to foster innovation

- Microsystems
- Surface Engineering
- Systems
- Ultra-low-power integrated systems
- PV-center & energy management

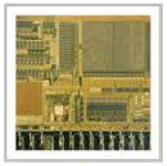




Disruptive developments – a story of "*firsts*"

1967 – The first electronic watch in the world: B1

1982 – The first watch micro-processor



1991 – The first commercial standalone AFM in Europe

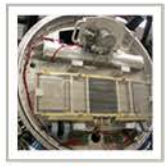
1993 – The first optical mouse in the world

1997 – The first UMTS (3G) demonstrator in the world

2003 – The first 3D TOF camera in the world

2007 – The first "Invar" out of silicon

2012 – Obser-vation of the oldest galaxy



And since 2014?

2014 — A revolution in the mechanical watch industry, a completely new movement principle

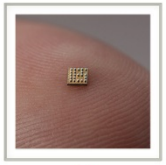
2014 — Colored photovoltaics panels

2014 — Landing of Philae on P67 the eyes of the scientists

2015 — Architectural integration of PV solar panels

2016 — First commercial solution for GPS-free geolocation of connected devices

2017 — Smallest Bluetooth 5.0 chip of the market



...

PV-centre & energy management

Powerpure
technologies for lowest cost solar electricity

2020>20%, < 0.4€/Wp, > 30 years
2026 >23% <0.3€/Wp, > 40 years
high energy yield

Elegance and architecture
transforming building and cities with solar

All shapes, all colors, and/or active construction material

Smart
intelligent E-management, efficiency in building, storage, renewable

Algorithms and electronics/
IT services
managing light, heat, electricity

Explore
customized PV products from the water to the air

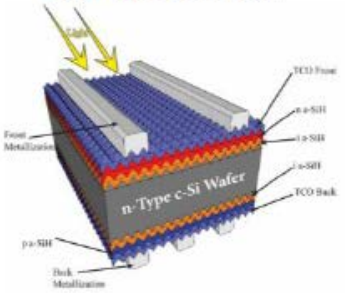
Lightweight modules and power solutions for planes, drones, cars and more

E-tonomy
energy scavengers and ubiquitous power sources

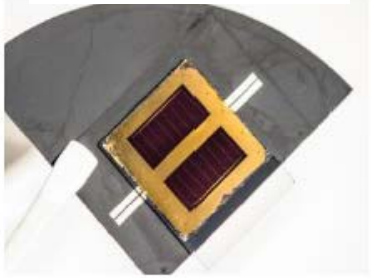
20% indoor autonomous harvesters, connected

Results

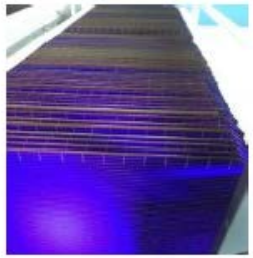
23.9% Si HJT cell



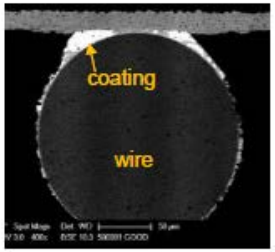
III-V/Si tandem
32.8% 2 junctions
35.9% 3 junctions



Low Ag Si HJT cells
(< 60 mg for bifacial cells)



Reliable wire contacting
w. Indium free coating

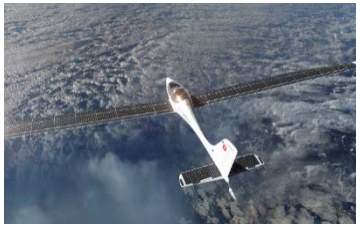


Terra-cotta PV tiles

White PV module

kaleo

solarstratos



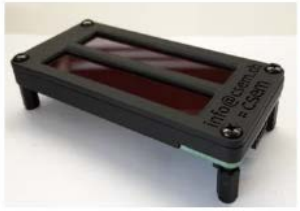
SolarArticPassage

PV cars

Watches

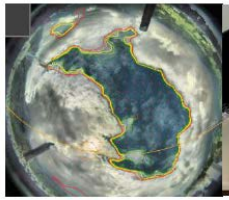
Heidi.com PV patch

Ultra-high efficiency low illumination harvester



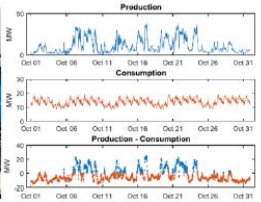
Indoor printable PV

Cloud recognition to future prediction

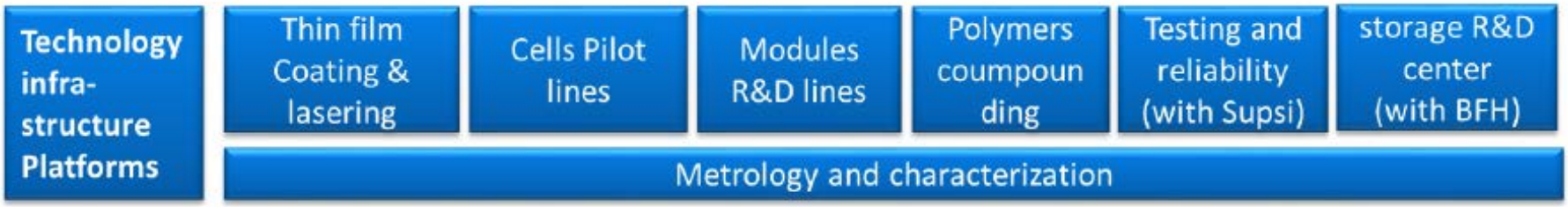


Micro-DC grid

Optimization consumption



Technologies infrastructures



- 500m^2 cleanroom infrastructure: thin film coating, wet-chemical processing, high-T processes, metallization, laser platforms (picoseconds laser processing) , materials and cells characterization.
- 600m^2 technology lab for module fabrication (cells interconnection and module lamination), module characterization and reliability testing.
- Compounding and extrusion of polymer foils facilities: polymer characterization.
- Batteries and cells testing: ESREC BFH-CSEM storage research centre in Biel.

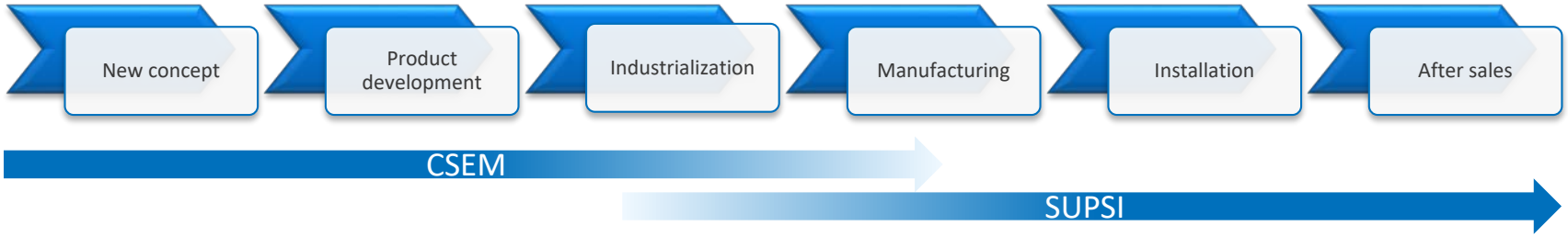
CSEM and SUPSI collaboration

Motivations

- Increasing demand for innovative (BIPV) solar products
- Need for testing and accreditation of commercial solar system

Solution

- Offer to industries, PV installer, architects a ***unique solution*** along the value chain of solar modules and systems



Services

- Development of cutting edge products: new polymeric materials, new module design, lamination process optimization (CSEM)
- Development of new testing procedures of innovative products: characterization, accelerating aging test, test quality (CSEM/SUPSI)
- Product performance verification, analysis of PV power plant, performance and failures (SUPSI)

Customized encapsulant formulation

- Purpose of encapsulant materials in **standard** PV modules
  - Resist to heat, humidity, UV radiation and thermal cycling
  - Provide good adhesion
  - Electrically isolate components
  - Optically couple glass to cells
  - Control, reduce or eliminate moisture ingress
  - Easy to be processed

For **innovative** PV modules different or additional requirements are needed !

Compounding platform

- Extrusion

- *Cast film extrusion line:*
  - *Output: 10 kg/h*
  - *Film thickness: ~ 50 um to 1 mm*
  - *Film width: up to 18-19 cm*
  - *Non-textured chill roll and winding system*

- *Compounding line:*
  - *Compounder output: 4 kg/h*
  - *Film thickness: ~ 50 um to 1 mm*
  - *Film width: up to 10 cm*
  - *Textured cooling belt*
  - *Pelletizing system output: 4 kg/h*

- *Material preparation work bench*

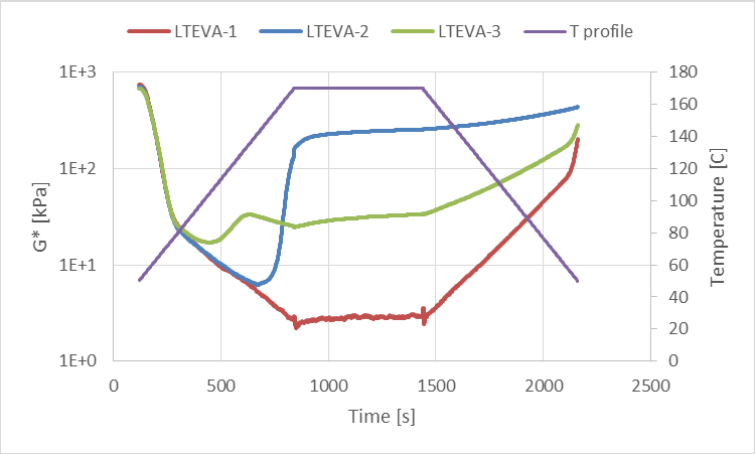
- *Dry with automatic material loading*

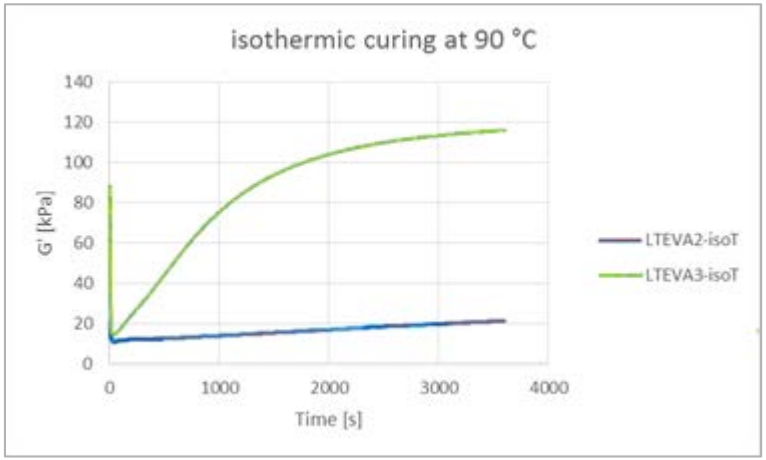
Compounding platform

- Analysis facilities
  - *Adhesion strength and mechanical properties at temperature from -70 to 200 ° [peeling test, compressive shear test with universal tester]*
  - *Gel content analysis [soxhlet extraction]*
  - *Thermal transitions from -20 to 500 °C [Differential scanning calorimetry DSC]*
  - *Viscosity profile and curing kinetics [Dynamic moving-die rheometer DMDR, DSC]*
  - *Volume resistivity [Keithley electrometer+resistivity test fixture]*
  - *Water vapour transmission rate [MOCON at partner lab]*
  - *Water intake percentage [Karl Fischer titration]*
  - *Simulation on moisture ingress rate [FEM using COMSOL]*
  - *Optical property [UV/Vis/NIR spectrometer]*
  - *vinyl acetate contents [thermogravimetric analysis TGA at partner lab]*
  - *Outgassing analysis during encapsulant lamination [thermal desorption gas chromatography/mass spectrometry GC/MS at partner lab]*
  - *Composition analysis [(ATR-)FTIR, confocal Raman spectrometry*
- Accelerating lifetime testing facilities
  - Climate chambers (DH, TC, HF)
  - UV chambers
  - Ovens
  - High-pressure cooker

Low-temperature lamination process

- Standard lamination process temperature 150-165°C (curing time 6-12min)
- New PV materials (DSSC, perovskite…) need lower lamination temperature
  - EVA formulation cured at 90°C (curing time < 60min)
  - Peroxide selection

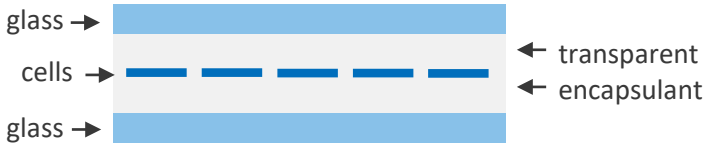




BIPV modules

- Glass/glass PV modules to meet building requirements.

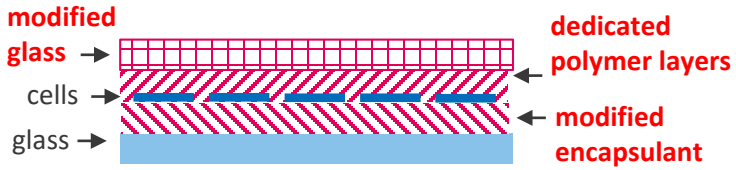
Transparent solutions



With bifacial cells higher energy productions compared to mono-facial cells

- Engineered and designed solutions to make novel generation of PV modules for an easier integration in buildings.

Opaque solutions



IR-reflective black encapsulant

Black pigments:

Common black pigments:
- BkP1: Carbon black (Most used black pigment)
- BkP2; BkP3: Inorganic oxide black pigments
- BkP4: IR-reflective pigment

BkP4 advantages:
- Highest IR reflectance
  - Cooler surface temperatures
  - Black back reflector for bifacial solar cells
- Black color:
  - Ideal for some BIPV applications (glass / glass configuration)

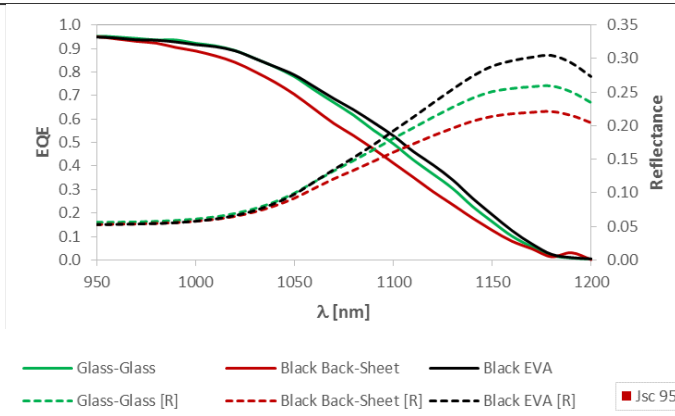
Absorbing back encapsulant doesn't allow to exploit bifacial cells gain

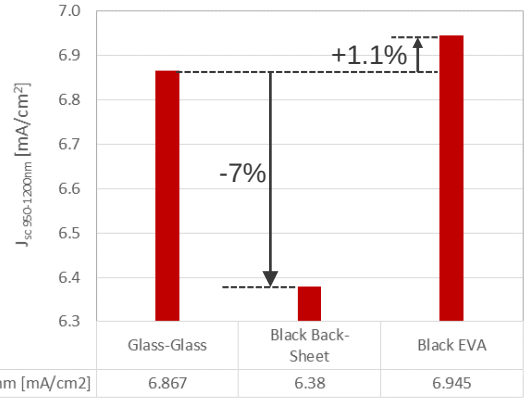
Results on Jsc gain:

Visual aspect:

Module configuration:

Glass 3mm	Glass 3mm	Glass 3mm
EVA	EVA	EVA
Bison cell	Bison cell	Bison cell
EVA	EVA	Black EVA
Glass 3mm	Black BS	Glass 3mm

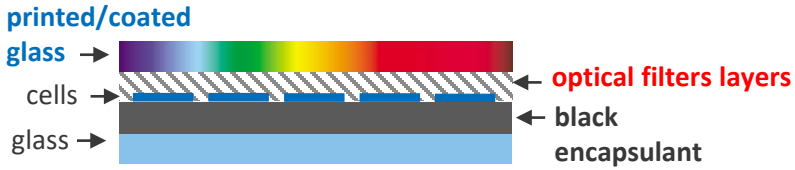




- Bifacial solar module: BkP4 preliminary gain in J_{sc} of 8.8% comparing with black-black back-sheet

Diffuser encapsulant

- Opaque BIPV modules:
  - printed/coated front glass
  - (non)-selective optical filters

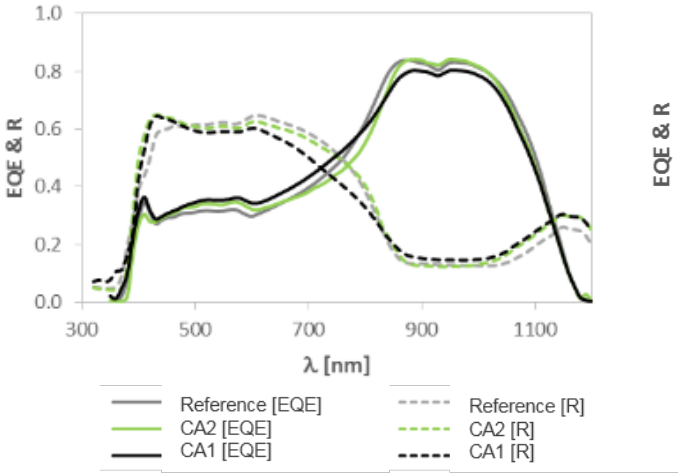


Selective optical filters
to reflect the visible range of the sun spectrum (to hide the PV cells), while allowing the infrared energy to pass for high PV module performance.

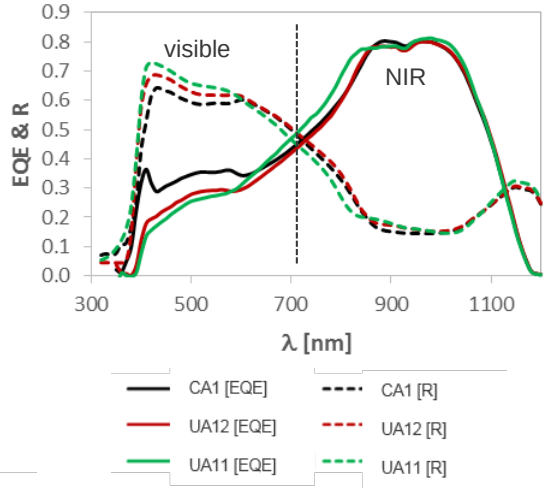
+

Diffuser layers
to scatter the reflected light.

Diffuser encapsulant



Improved spectral selectivity

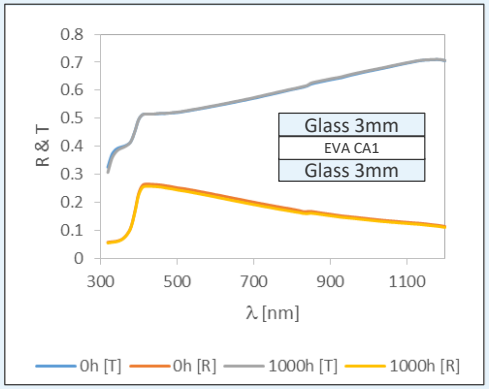


Reliability testing

UV light testing:

Test conditions:

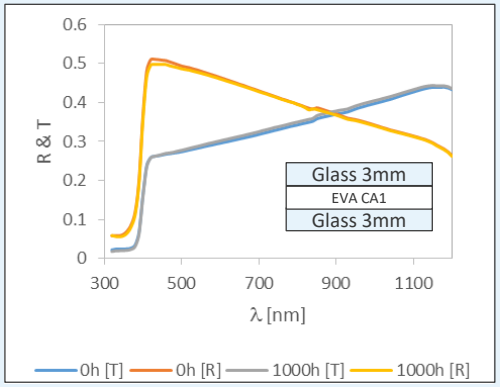
- QUV chamber
- Lamps: UVA – 340 nm
- Temperature: 60°C
- Irradiance: 0.8 W/m^2 @ 340 nm



DH testing:

Test conditions:

- Weiss chamber
- Temperature: 85°C
- Humidity: 85%

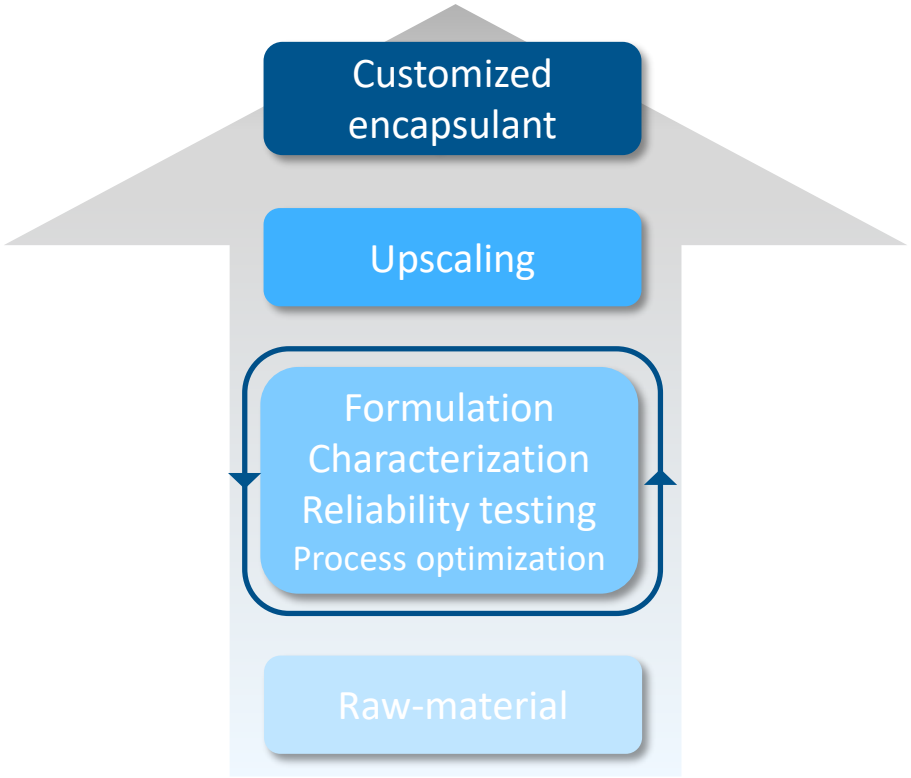


- No reliability problems for diffuser EVA with CA1 after 1000h of QUV and DH for glass/glass laminate samples.

Bottom up approach…

- …from the individual elements to the whole.

Certified test of modules manufactured with customized encapsulant done at SUPSI



CSEM-SUPSI

- Roof tiles (2017)
  - Client: Freesuns
  - CSEM: development of module design scheme for roof tiles
  - SUPSI: certified HF, Mechanical Load, Hail test, Fire test

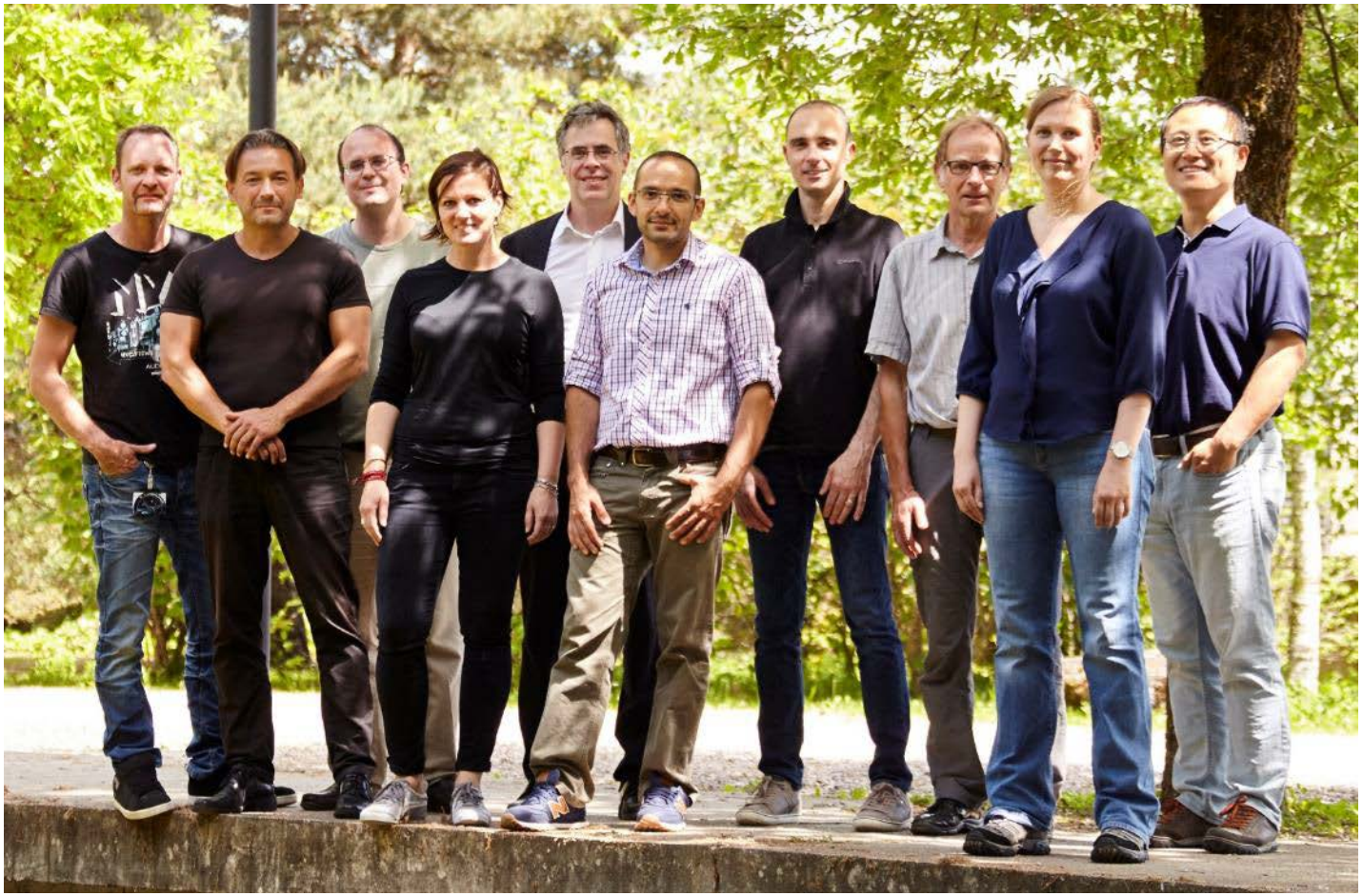
- White Solar module (2016)
  - Client: Solaxess
  - CSEM: development of nanostructured foil for white module manufacturing
  - SUPSI: certified UV,HF,TC test

- Brutten (2015)
  - Client: ÜserHuus
  - CSEM: development of textured front glass technique for thin film modules
  - SUPSI: certified UV, TC, HF, Mechanical load, Hail test, Breakage test

- Terracotta (2015)
  - Client: ÜserHuus
  - CSEM: development of terracotta thin film module
  - SUPSI: certified Hail test, Mechanical load.

PV module team

G. Bugnon, G. Cattaneo, P. Duvoisin, J. E. Palou, U. Fuerholz, P. Heinstein, H. Li, K. Söderström, L.E. Perret-Aebi, C. Ballif



pv-support@csem.ch

Thank you for your attention!

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