Module and Interconnection Technology for Zebra IBC Cells

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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No.101084259

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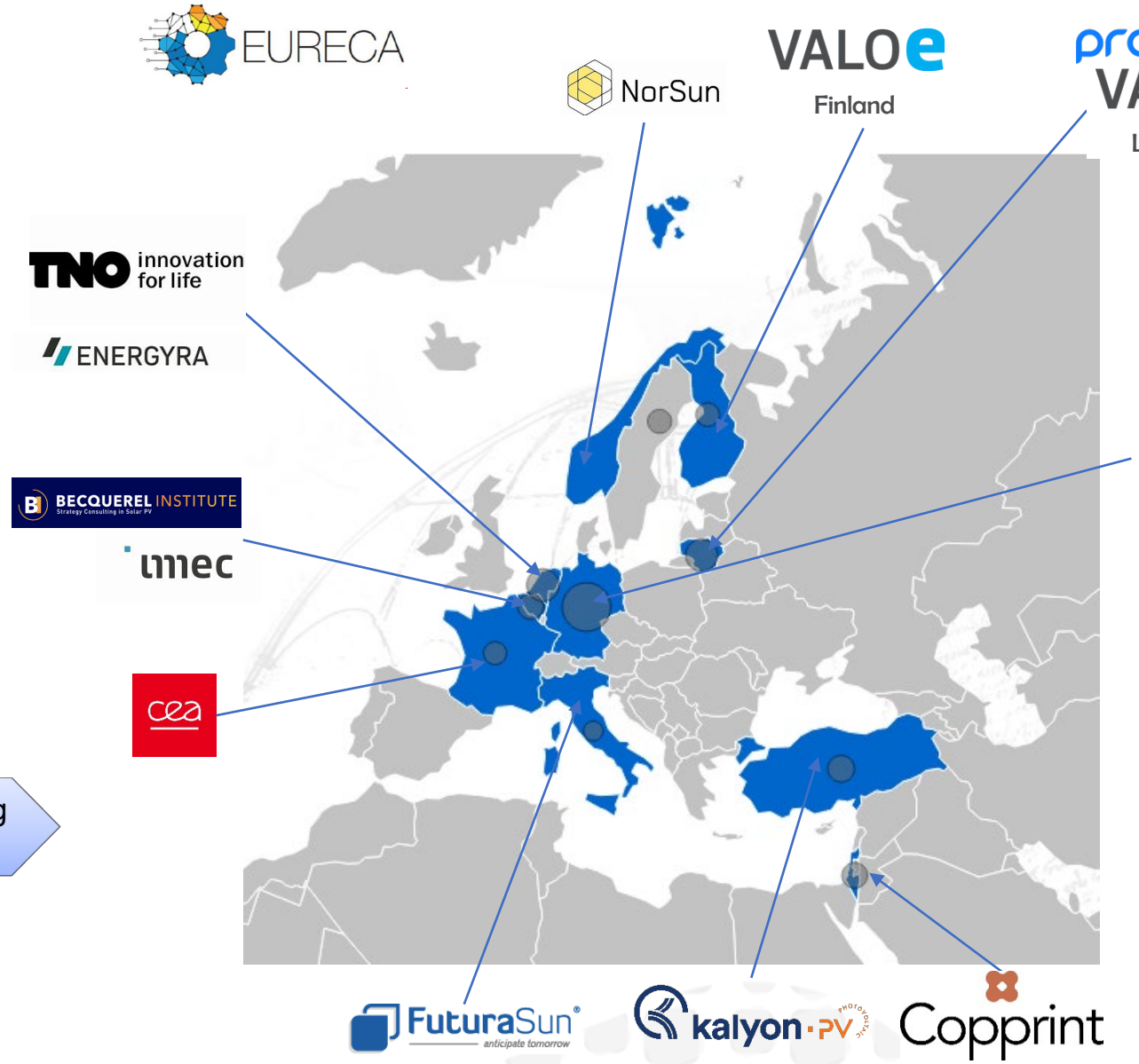
Horizon Europe project

Nov 2022 – Nov 2025
17 funded and 4 associated partners
EU funding: ~14 m €

Research and industrialization along the whole value chain:

Ingot wafers → Cells → **Modules** → Recycling LCA



Associated:

R|E|N|A
Toyal
LPKF Laser & Electronics

Outline

1. Module technologies for IBC cells
2. Study and selection of encapsulation material
3. Module reliability testing
4. Technology evaluation
5. Industrial implementation
6. Conclusions

1. Module technology description

Three technologies evaluated:

As benchmark:

- Tabbing stringing

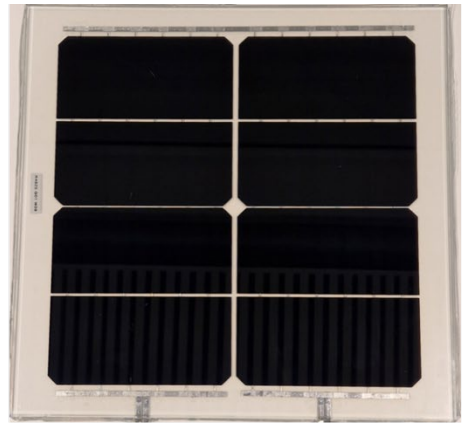
Modular foil-based interconnections:

- Conductive backsheet approach
- 3D Multi-Ribbon interconnection

1. Module technology description

Tabbing and stringing interconnection

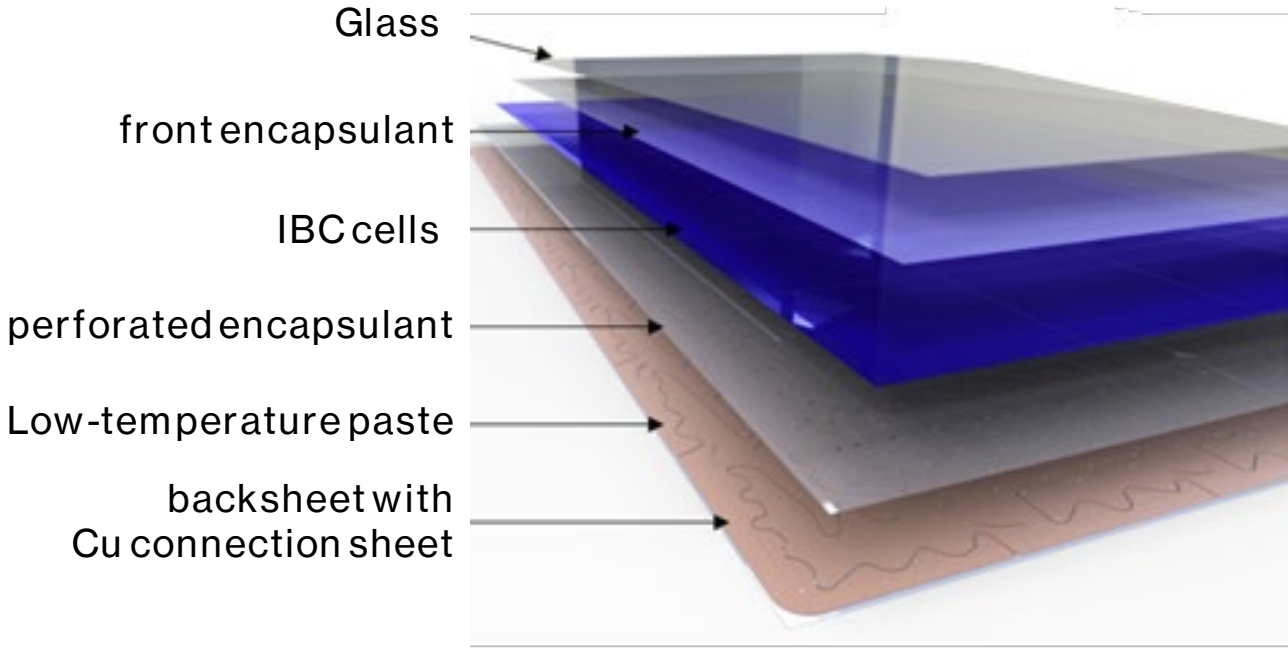
- Mature technology (TRL 9) used as a benchmark
- Multi-busbar connections using SnPb solder
- Can achieve high bifaciality
- Busbarless and negative gap connections are areas of development



1. Module technology description

Conductive backsheet

- Initially developed for MWT cells, now also used for IBC
- Patterned Cu sheet as conductor
- Cu sheet is connected using conductive paste on cell busbars
- Rear perforated encapsulant as selective insulator



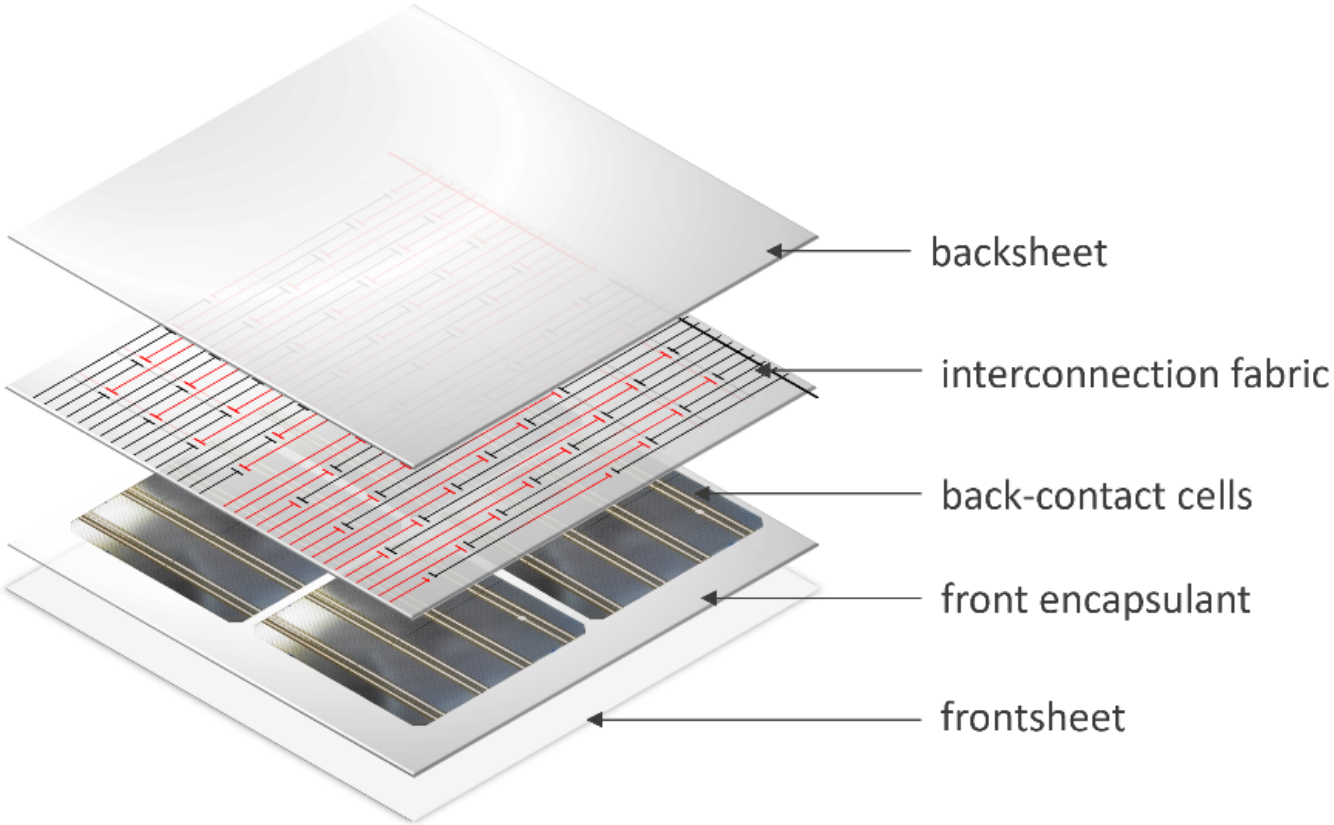
1. Module technology description

3D Multi-Ribbon interconnection

- 3D multi-ribbon foil as conductor

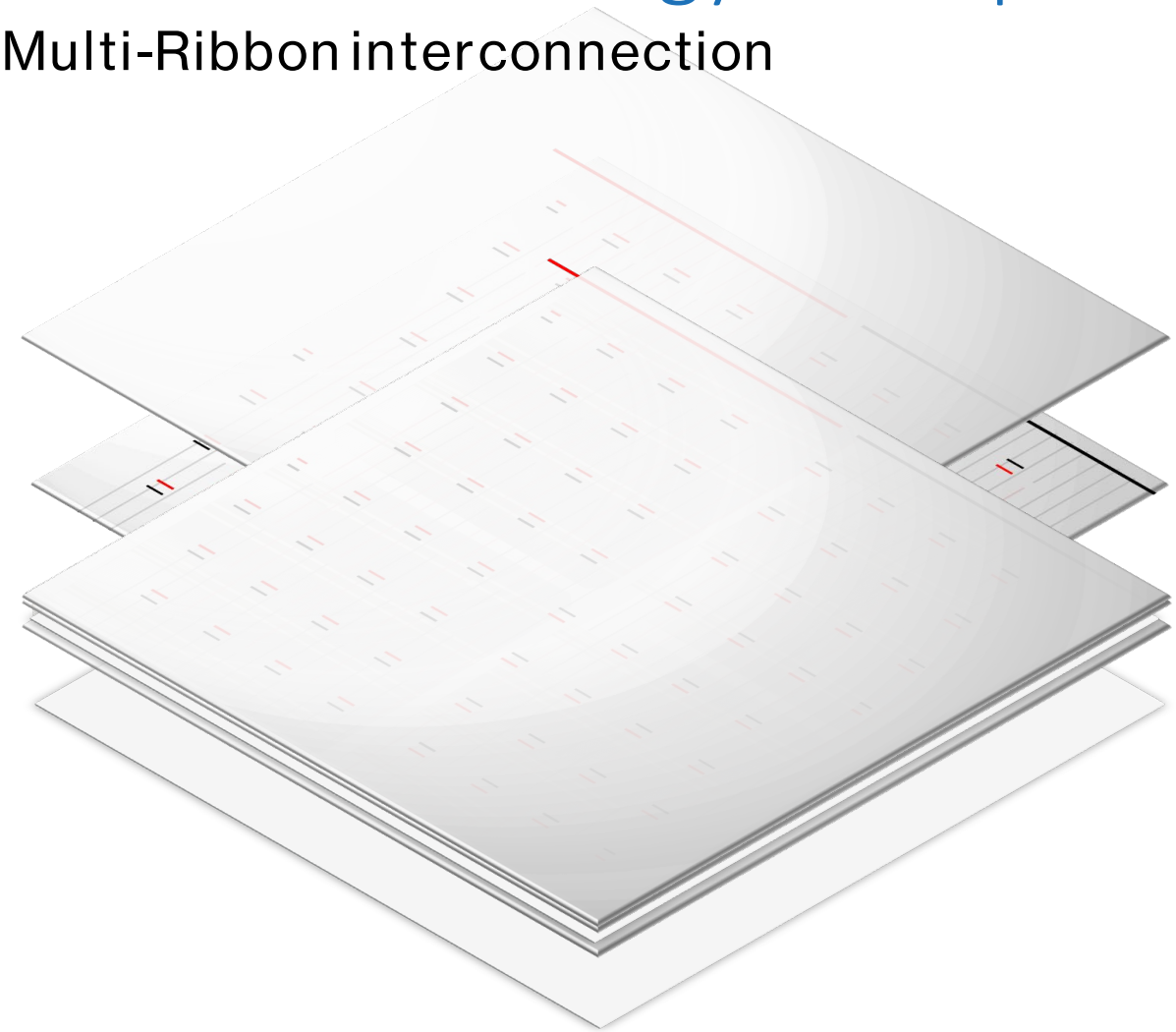
Module fabrication:

- Lay-up phase
- Lamination cycle



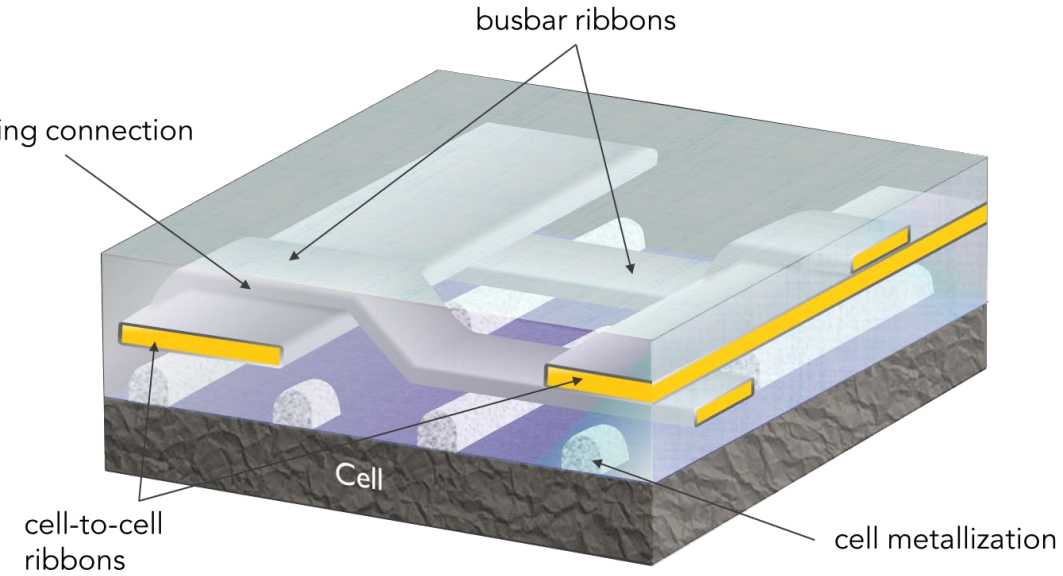
1. Module technology description

3D Multi-Ribbon interconnection



During the lamination cycle:

- Solder coating reflows
- Polymer encapsulant melts



2. Study and selection of encapsulation material

- Materials
  - Thermoplastic polyolefins (TPO 1-3)
  - Polyolefin elastomer (POE 1-3)
  - EVA as benchmark

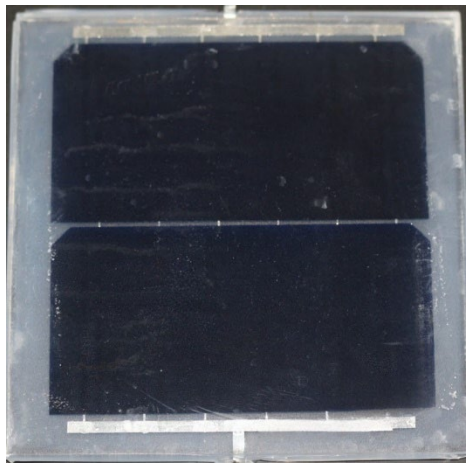
- Characterisation of
  - Adhesion strength
  - Coefficient of thermal expansion
  - Optical performance
  - Calorimetric behaviour (DSC)

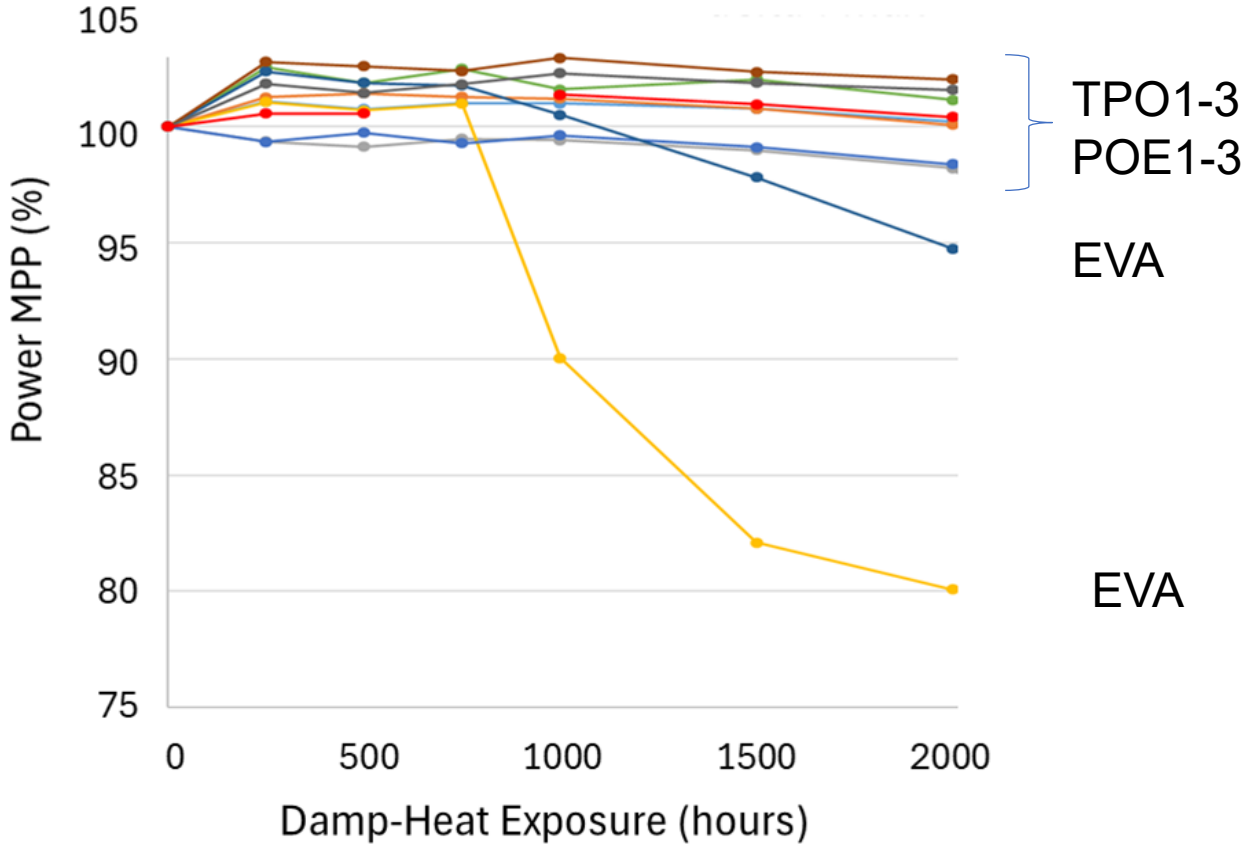
Results suggest each encapsulant can be considered for further testing

2. Study and selection of encapsulation material

Mini-modules during damp-heat exposure

- Mini-modules with tabbing-stringing interconnection to test encapsulant





➡ EU-sourced TPO is selected for further testing

3. Module reliability testing

Design of Experiments: common BOM

	Conductive backsheet (TNO)	Tabbing and stringing (ISC)	3D multi-ribbon (imec)
Front cover	Glass		
Front encapsulant	TPO		
Cells	8 half-cells, 6BB ½ M6 Zebra IBC Cell		
Interconnection	Low-temperature paste	SnPb-solder	Low-temperature solder
Rear encapsulant	Rear perforated insulator	TPO	Custom TPO
Back cover	White backsheet	Transparent Backsheet/Glass	Glass

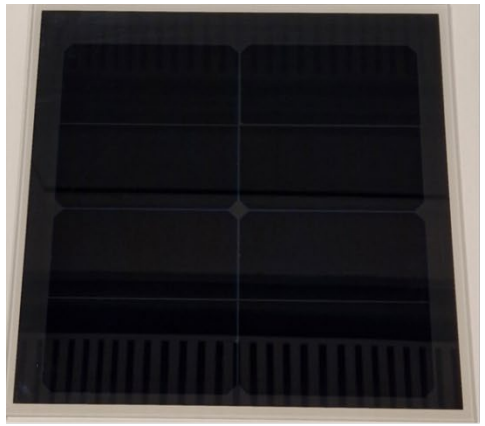
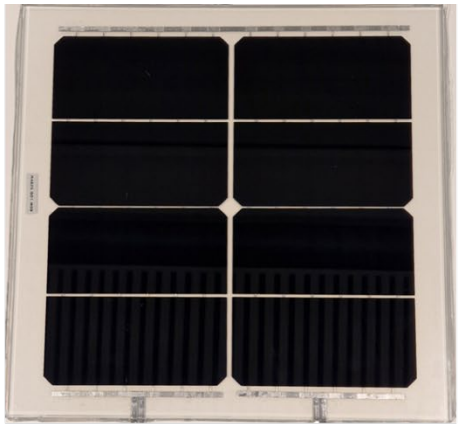
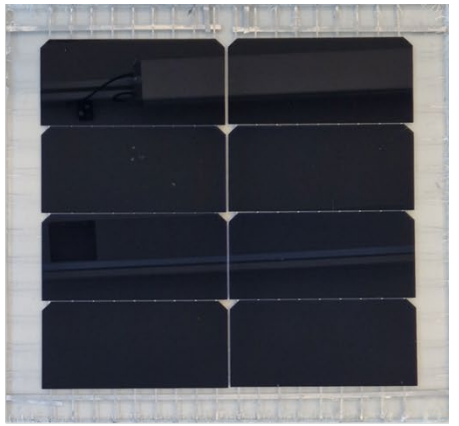
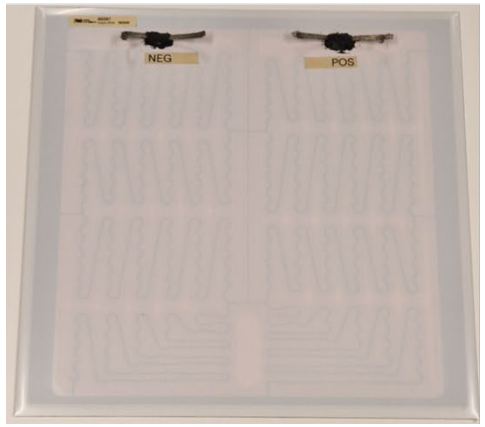
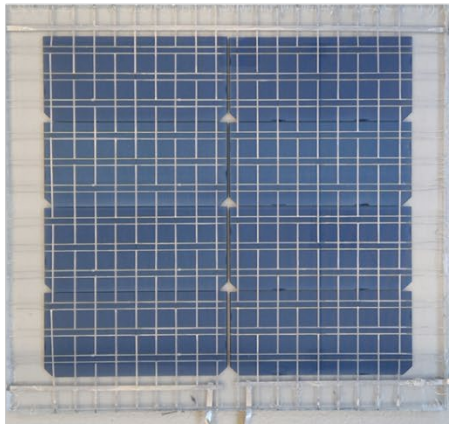
Modules were characterised and underwent damp-heat exposure and thermal cycling tests

3. Module reliability testing

Design of Experiments

- Bifaciality (P_{mpp}):
  - Tabbing-stringing 84%
  - 3D Multi-Ribbon 79%
  - CBS 0%

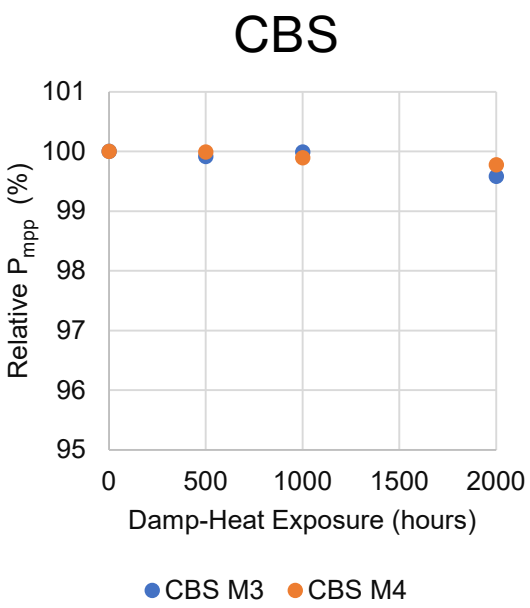
- Half-cut cell orientation was different for 3D Multi-Ribbon*

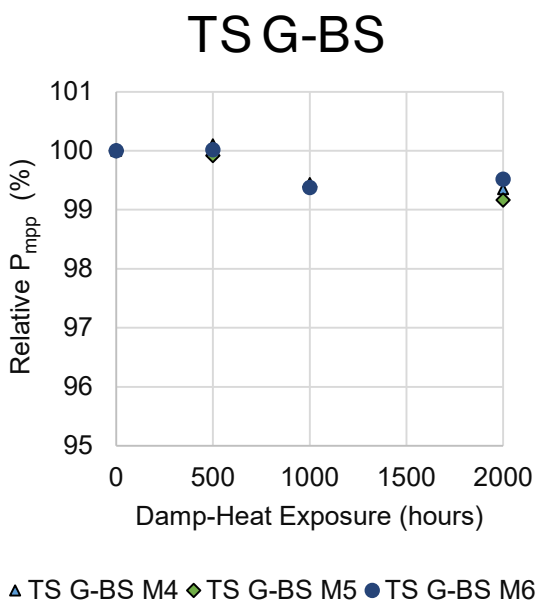
Conductive backsheet	Tabbing and stringing	3D multi-ribbon
		
		

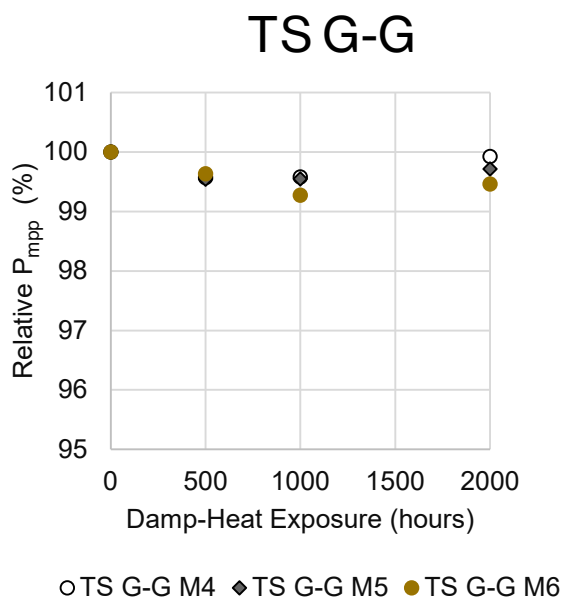
N. Chen et all. (2022) Mitigating cut losses in IBC solar cells

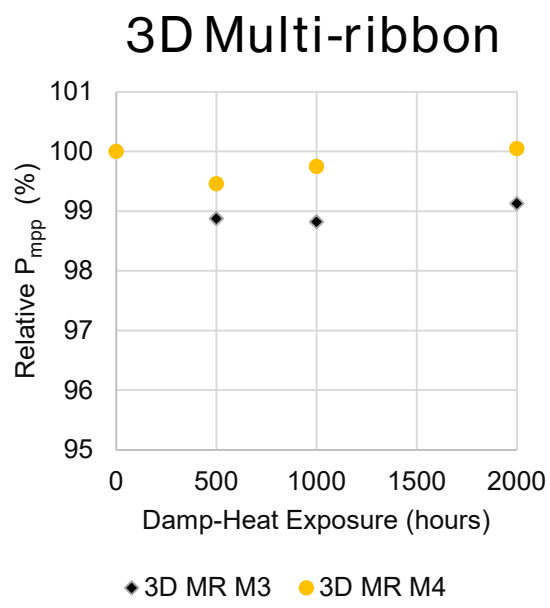
3. Module reliability testing

Damp-heat exposure



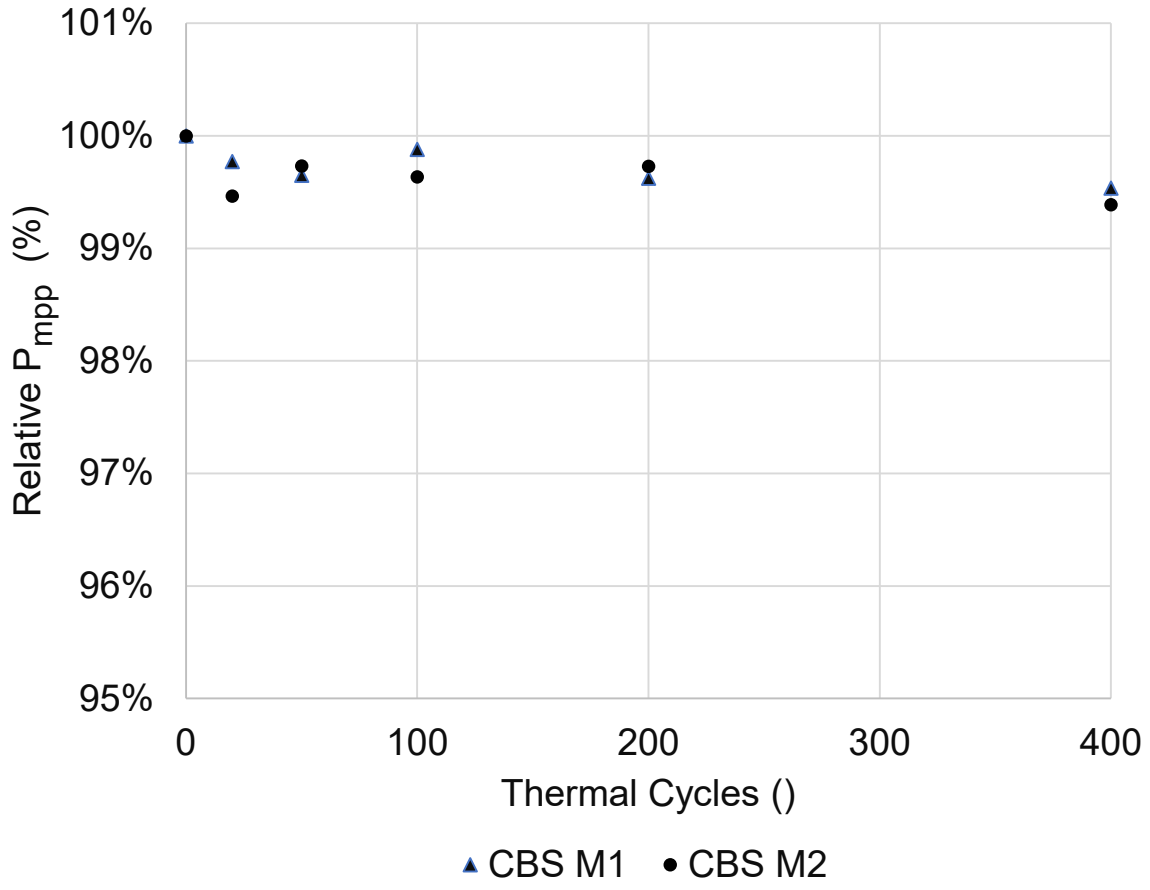


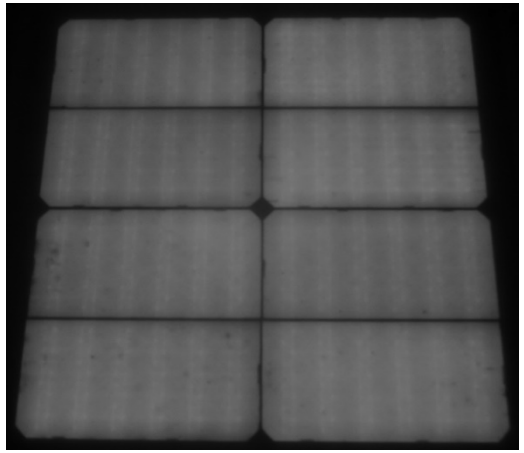




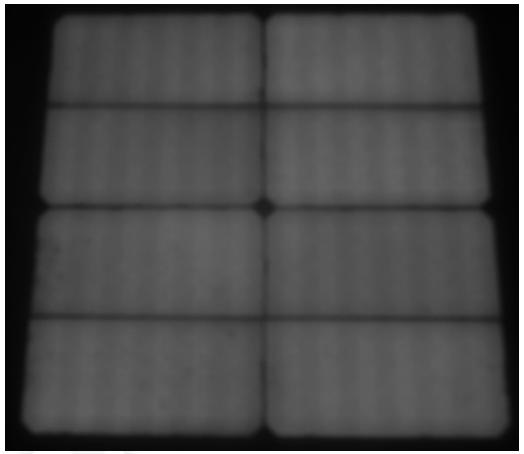
3. Module reliability testing

Thermal Cycling CBS





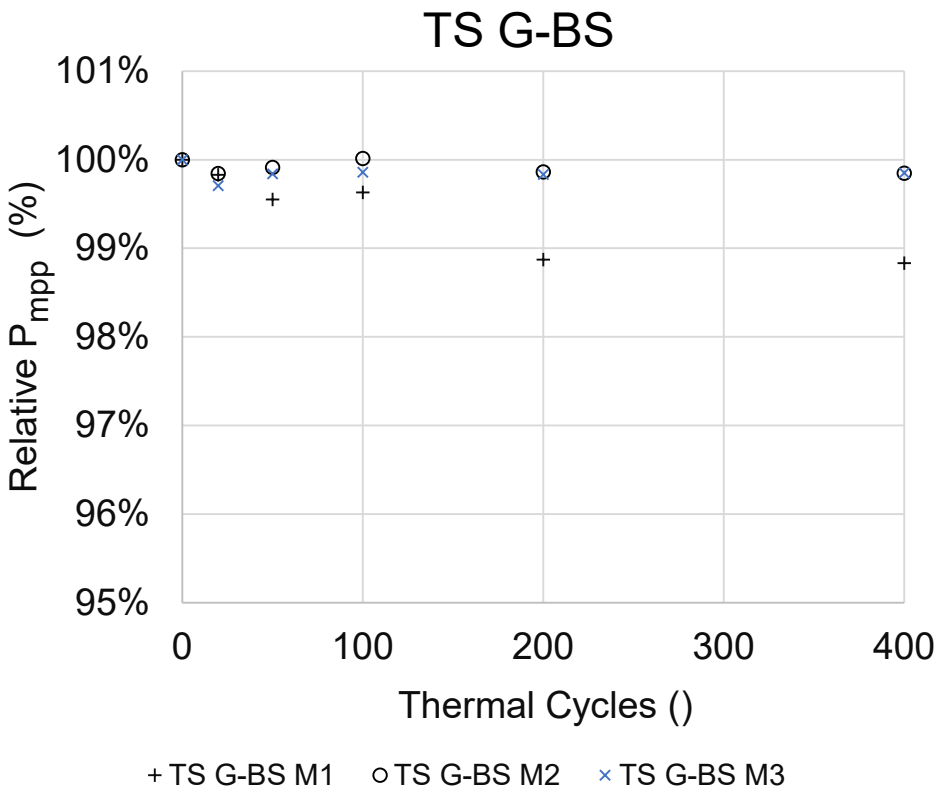
TC0

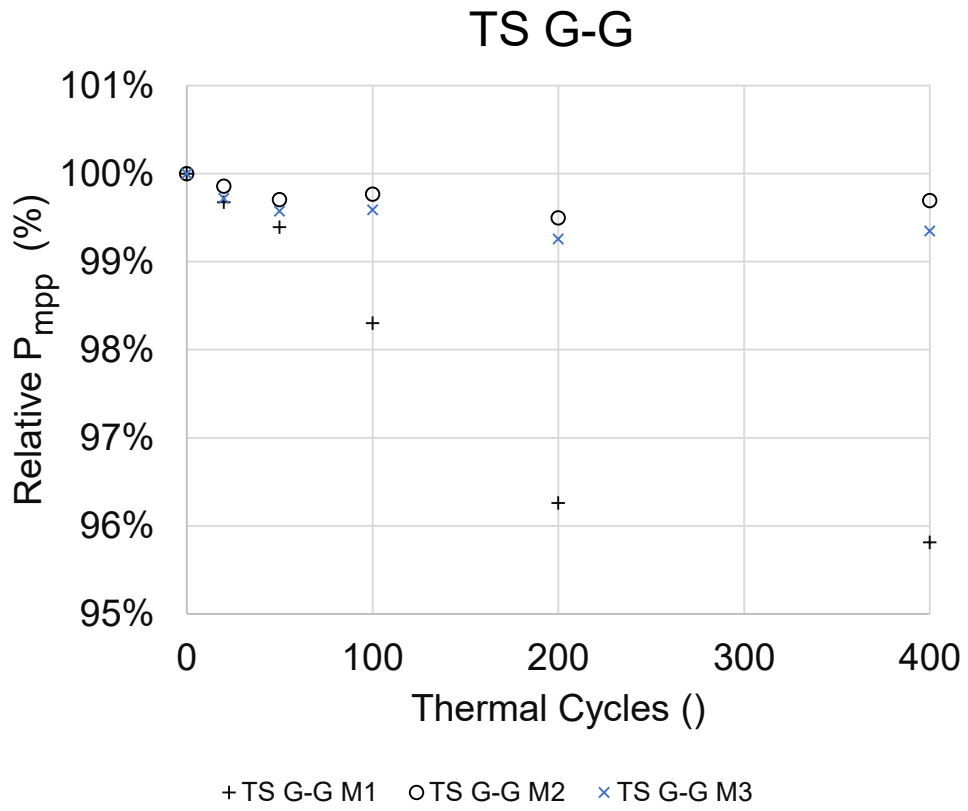


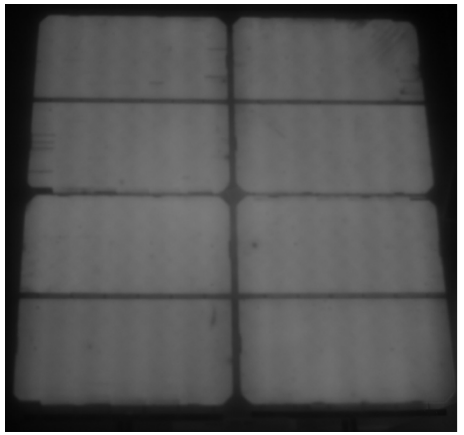
TC400

3. Module reliability testing

Thermal Cycling tabbing and stringing







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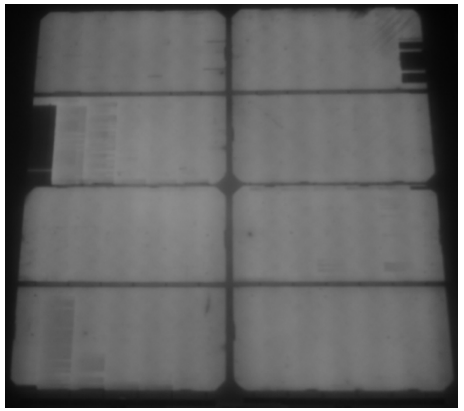
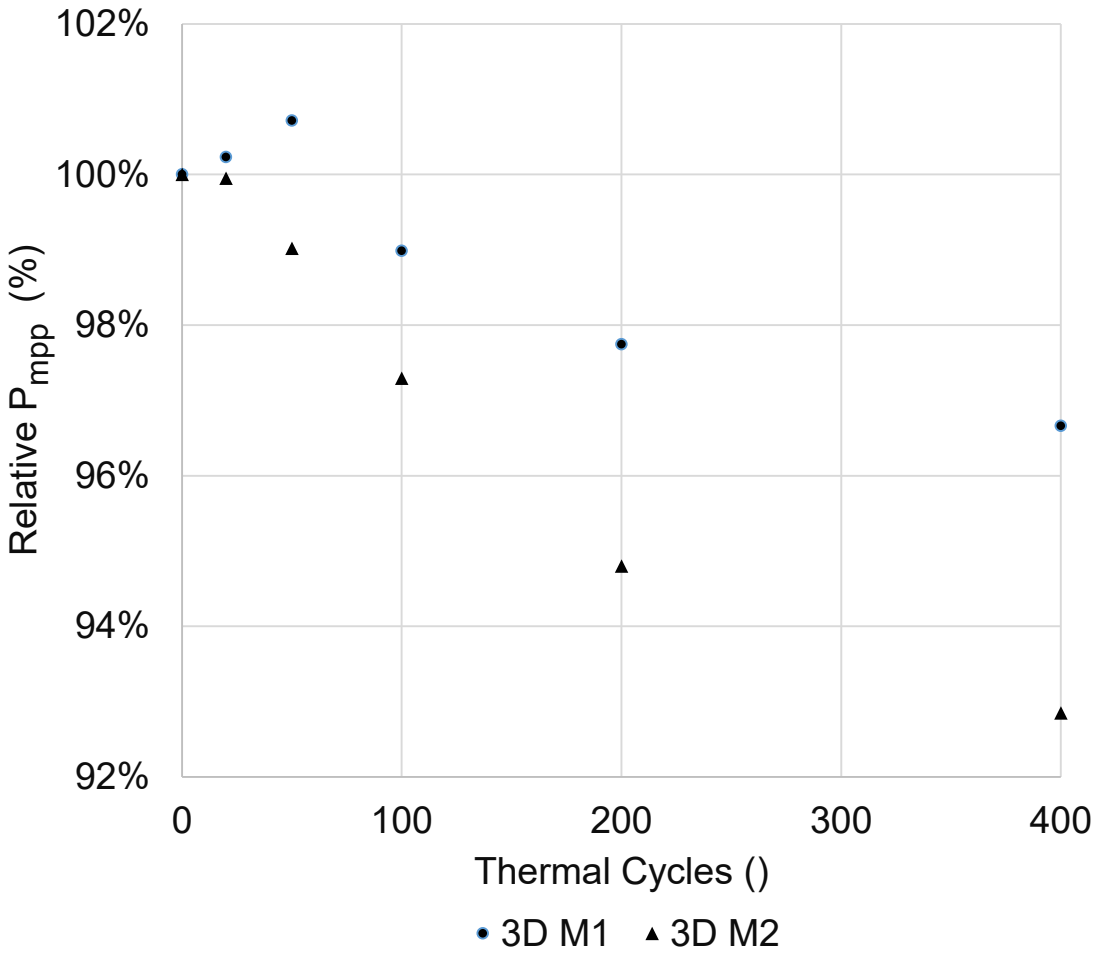


TC400

Process optimisation solves improperly soldered ribbons

3. Module reliability testing

Thermal Cycling 3D multi-ribbon



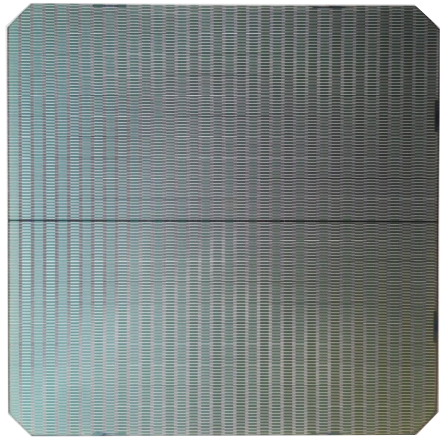
- Different cell orientations caused cleaving issues (lasering through both junctions)
- Initial cell micro-cracks propagated during lamination and TC
- Use of thinner solder-coating proven not to be reliable
- Previous tests on full-cell modules passed 600 TC and 15 HF cycles

TC0 TC200 TC400

3. Module reliability testing

3D multi-ribbon busbarless connections

- First tests on direct finger soldering busbarless connection
- No degradation after 200 Thermaland 10 Humidity-freeze cycles




4. Technology evaluation

Technology	Applicability (mono- and/or bifacial)	Multi-BB or BBless	Performance	Bifaciality	Sustainability	Reliability	Design freedom	Cost effectiveness	TRL
TS	Mono- and bifacial	Multi-BB	reference level (0)						9
		Busbarless	0	+	+	0	0	+	7-9
CBS	Monofacial	Multi-BB	+	NA	0	0	+	-	6
LTCS*	Bifacial	Multi-BB	0	0	0	0	+	0	5
3D	Mono- and bifacial	Multi-BB	+	-	0	0	+	0	4-5
		Busbarless	+	-	+	0	+	+	4

*LTCS = TNO's light-transmitting conductive substrate solution

- Utility scale PV: tabbing-stringing
- Integrated and agri PV: CBS and 3D Multi-Ribbon

5. Industrial implementation

Industrial implementation of low-stress tabbing-stringing by FuturaSun

Today at 14:00 -14:20 by G. Coletti:
Opportunities and challenges of back-contact PV technology

Industrial implementation of CBS for light-weight modules by Energyra

Today at 15:00 -15:20 by M. Kalden:
Advantages of back contact technology in North-West Europe

6. Conclusions

EU-sourced TPO can be implemented to yield modules with high reliability (damp-heat and thermal cycling)

No difference in reliability for glass-glass and glass-backsheet was observed

Three module technologies are being developed in IBC4EU:

- IBC Tabbing-stringing (TRL 9)
  - Industrial implementation of low-stress TS by FuturaSun
  - Test with Cu metallisation, negative gap and busbarless connections are ongoing

- Conductive backsheet (TRL 6)
  - Industrial Implementation in lightweight modules by Energyra
  - Bifacial solutions under development by TNO (see V. Rosca)

- 3D multi-ribbon (TRL 4-5)
  - Under development by imec
  - Cell metallisation design should be customised
  - First results on BBless connections are shown

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Thank you

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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No.101084259