Conductive substrate BC module technology for new applications

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12th workshop on BC cell and module technology, Delft, 2024

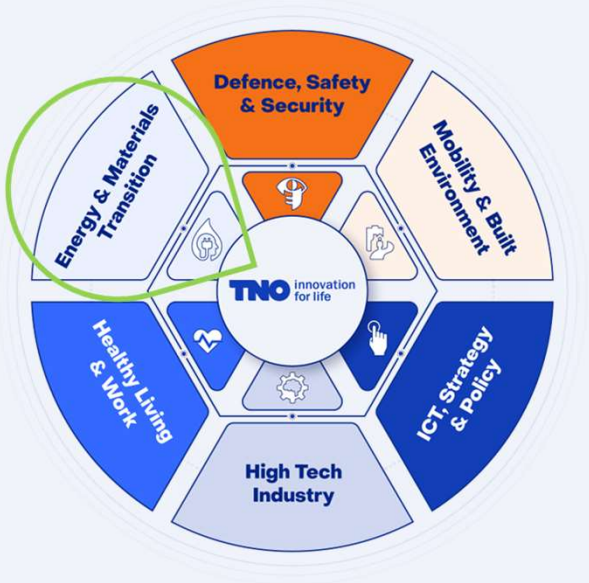
Outline

- Introduction TNO Solar R&D program
- Outline BC module technology based on conductive back foil (CBF)
- New PV applications and PV integration
- Potential of the conductive substrate BC technology for IPV

TNO Solar

TNO Energy & Materials Transition Unit

TNO develops technologies and concepts that drastically reduce the costs of generating **renewable electricity** thus accelerating the energy transition and promoting the circular economy



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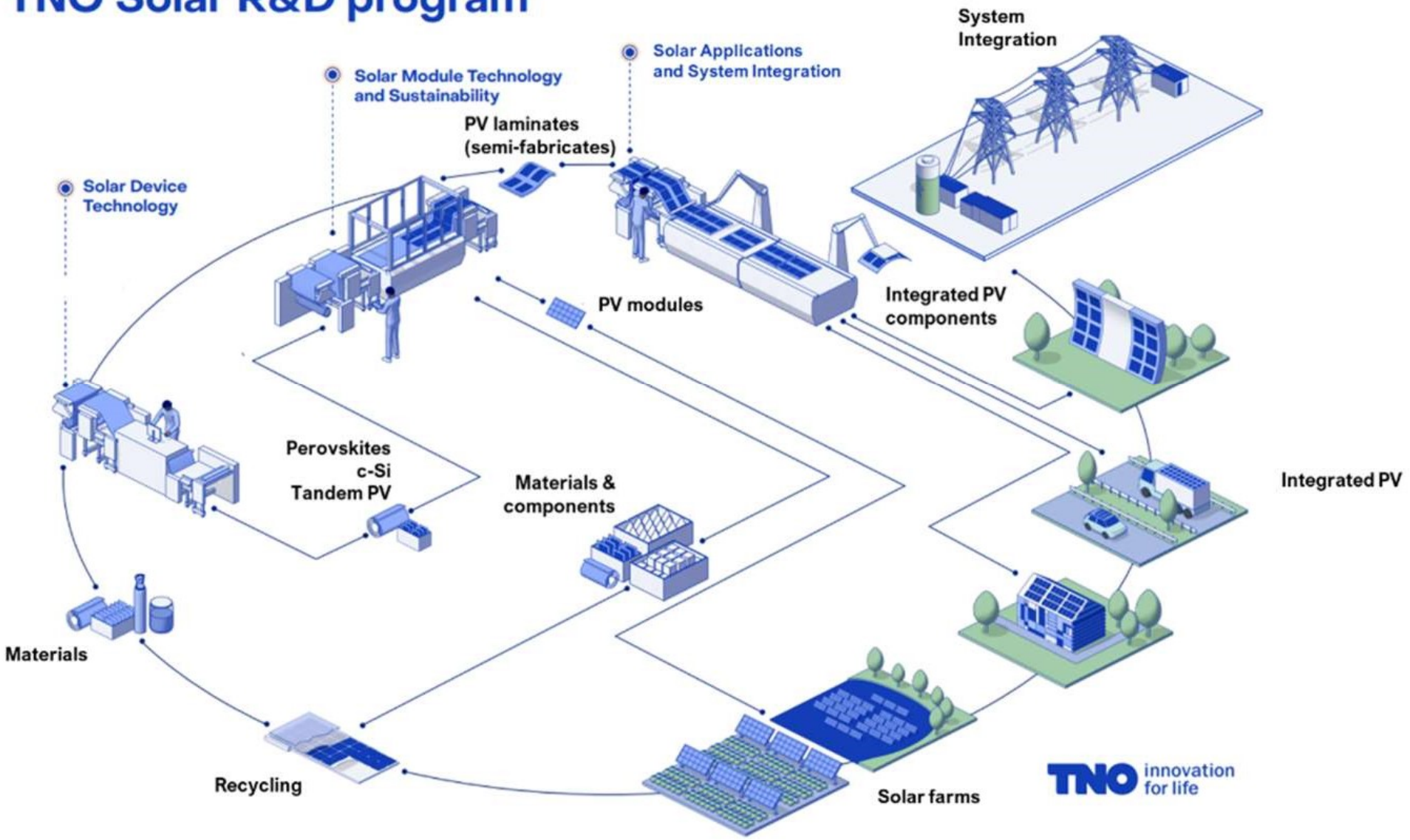
TNO Solar R&D program



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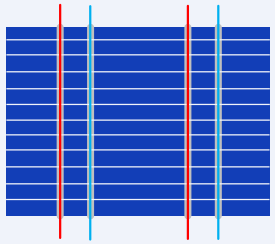
Industrial BC interconnection technologies

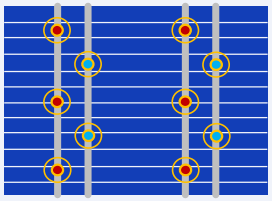
Back-contact module interconnection technologies

- **Tabbing stringing**
- **Conductive substrate**



- Module-level (ML) conductive grid: solder coated Cu ribbon or wires
- Continuous (linear) mechanical & electrical coupling between cell and ML grid
- Industrial method (more cost-efficient)
- Limited design flexibility

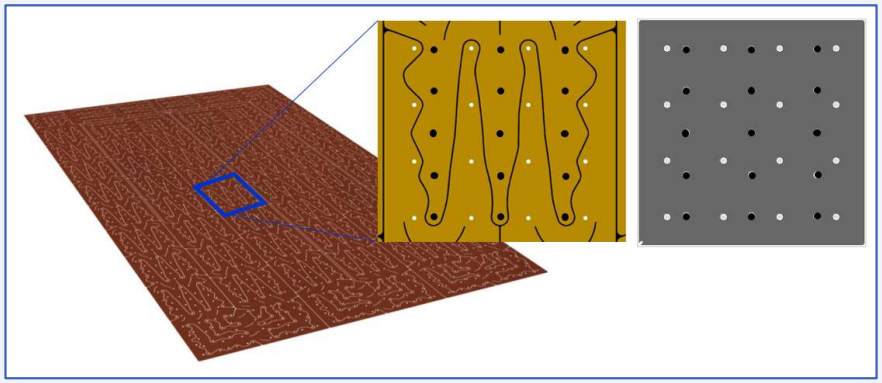
- Module-level (ML) conductive grid: PCB-like conductive substrate + interconnection material
- Discrete (contact dots) electrical coupling between cell and ML grid
- Industrial method
- High design flexibility

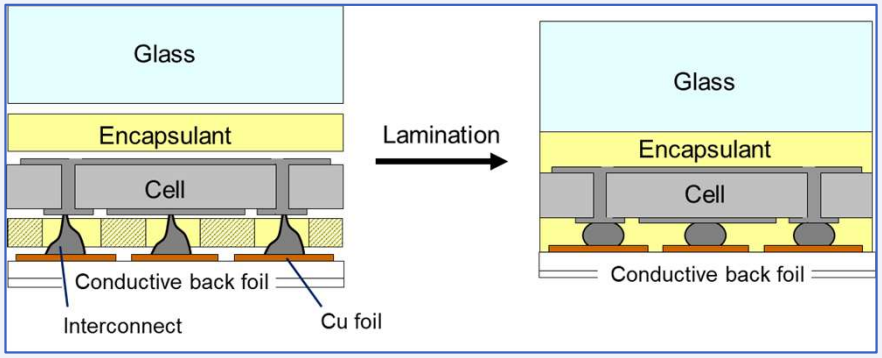


CBF BC module technology

Proven on the industrial scale module interconnection technology compatible with any BC cell (PERC-, HJT-) MWT, IBC

1. Higher cell and module efficiency
2. Higher production speed and yield
   - Suitable for larger and thinner wafers (handling of wafers down to 100um tested and validated)
   - Single-step interconnection and encapsulation
   - Higher level of automation
3. Low-T low-stress processing & interconnection (<150C)
4. Ultimate (electrical) design flexibility (PCB-like)
5. Improved esthetics





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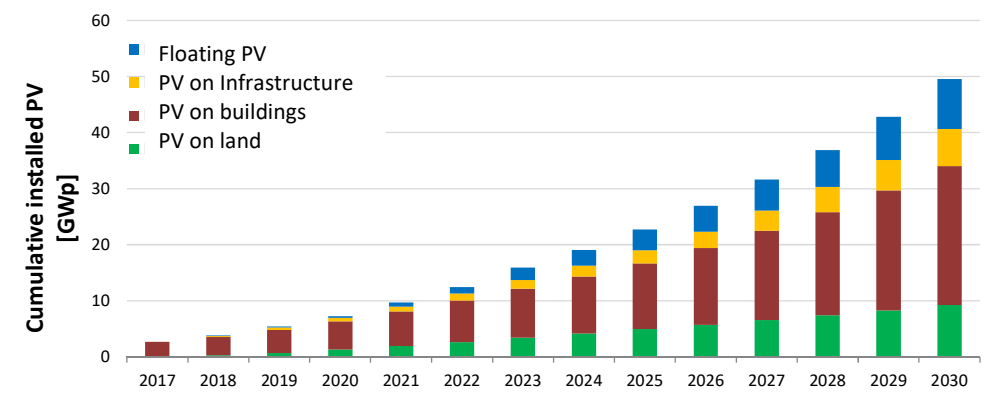
New PV application areas

Added cost & complexity, but highest value!

- Electricity generated close to / in urban areas
  - Dual-use of space; no competition for agricultural land
  - Little or even positive effect on the environment
  - Functional and aesthetic integration
- New business opportunities (NL, EU)

Applications Roadmap (Netherlands)



1. Land

2. Water

3. Infrastructure

4. Buildings

5. Vehicles

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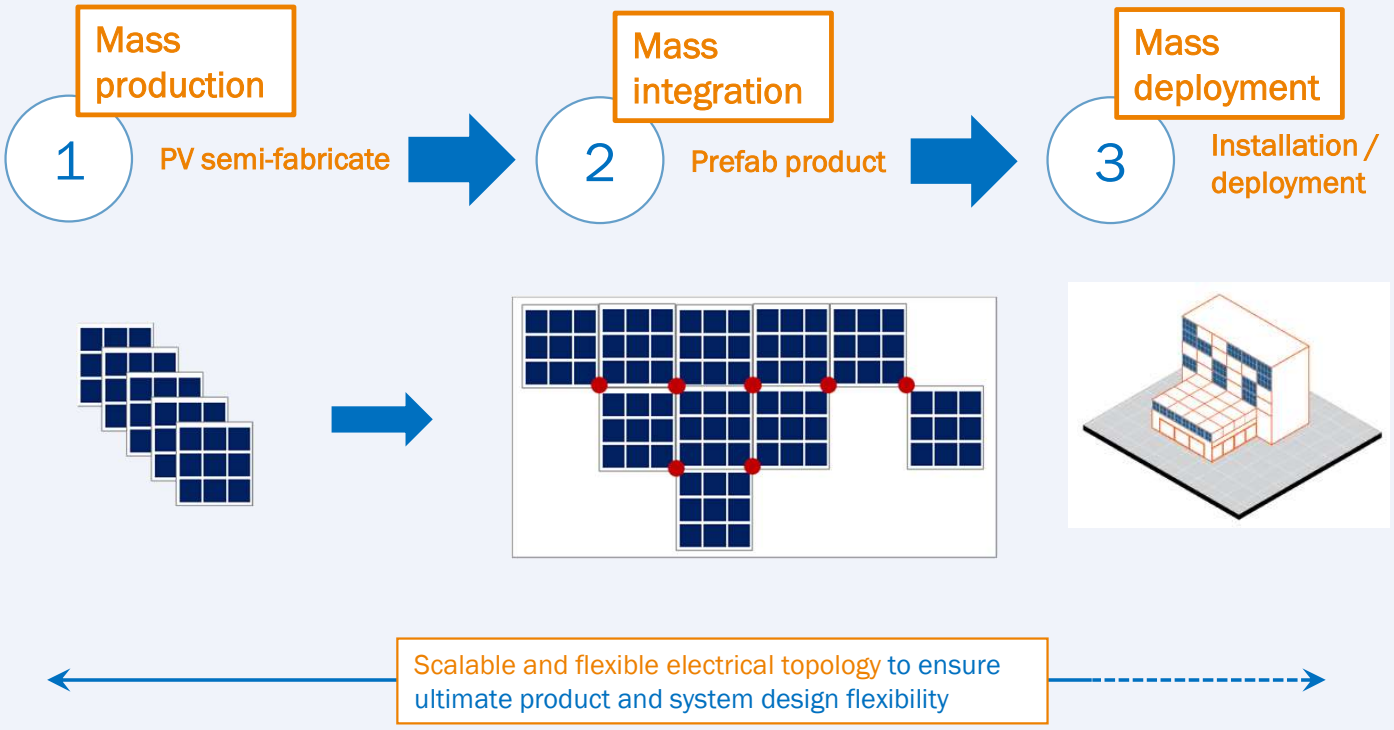
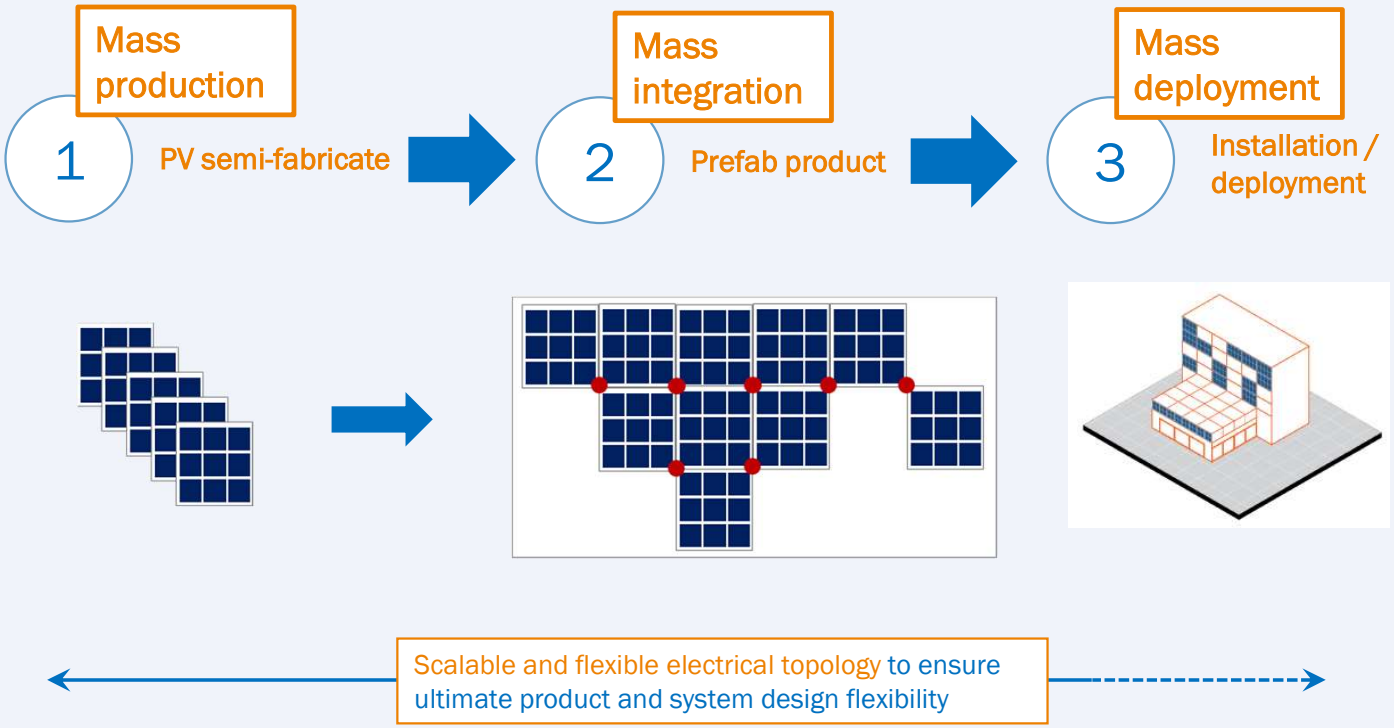
Mass customization of IPV products



Mass deployment of IPV products enabled by:

1. PV semi-fabricate produced *en masse* using state-of-the-art PV module assembly processes and materials
2. Prefab production as main route to cost reduction and quality

Mass customization of IPV products



Conductive substrate BC module technology as platform for PV integration technologies

- Use of high-efficiency industrial BC cells
- Unique (electrical) design flexibility
- Highly flexible manufacturing

Outline

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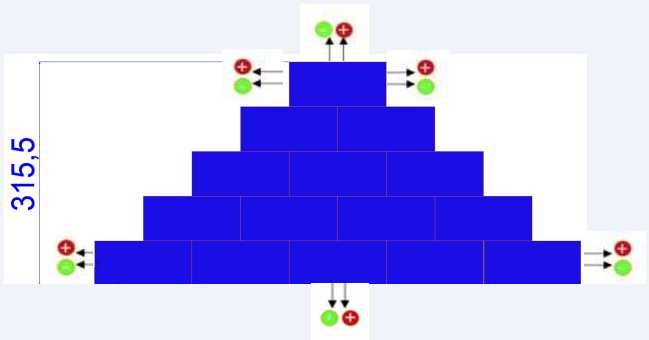
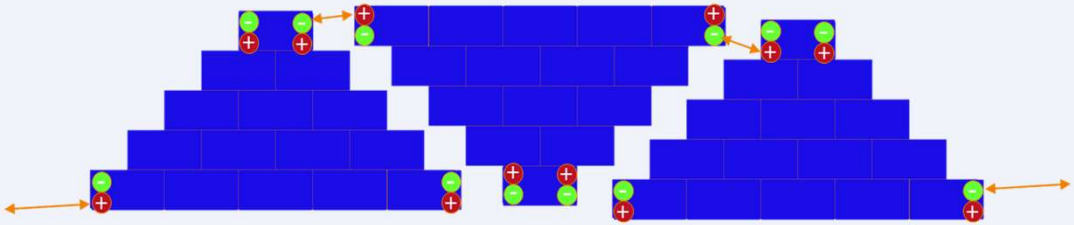
- New PV applications and PV integration
- Potential of the conductive substrate BC technology for IPV
  - Pixel module concept
  - Light-Transmitting Conductive substrate

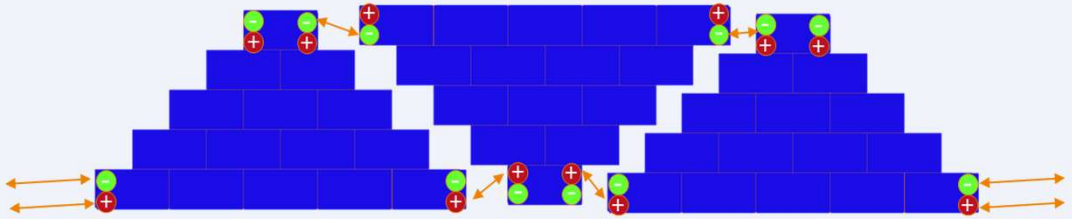
Pixel module concept (1)

- Pixel (PV semi-fabricate) made of 15 cut cells connected in series (631×315.5 mm)
- Output terminals at every corner, along the triangle base, and rear side thanks to dedicated interconnection pattern
- Cell size, cell number, pixel size optimized to ensure desired power output
  - Impp: 3A
  - Vmpp: 9.3 V





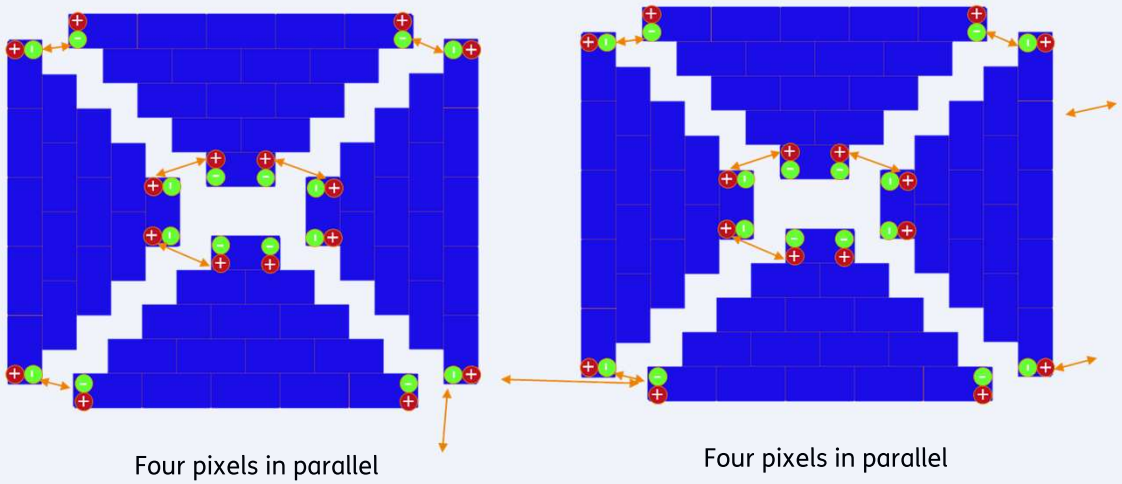
Series



Parallel

Pixel module concept (2)

- From triangular to square:
  - clusters of four pixels in parallel
  - 0.757m x 0.631m
  - Vmpp: 9.3V
  - Impp: 12A
- I-V characteristics of a 4-pixel cluster compatible with typical power optimiser
- Four-pixel clusters could then be connected in series to build a larger system

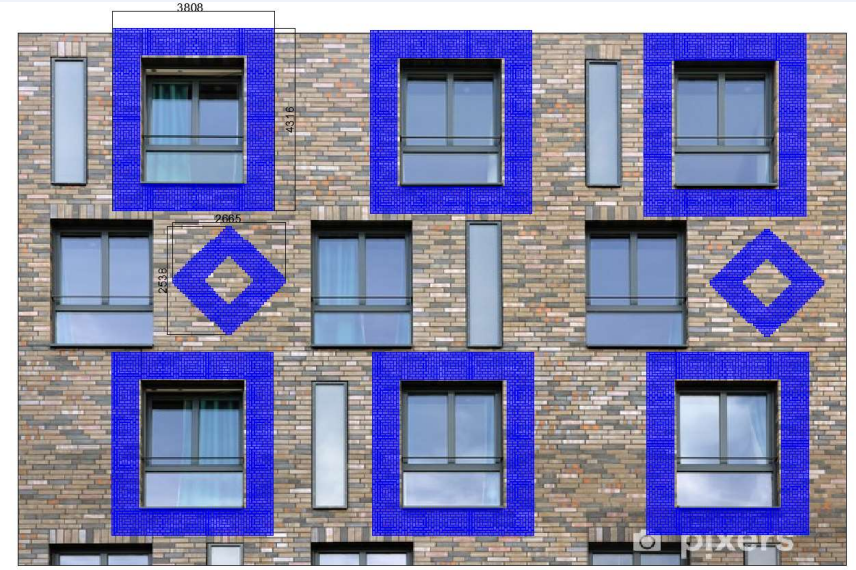


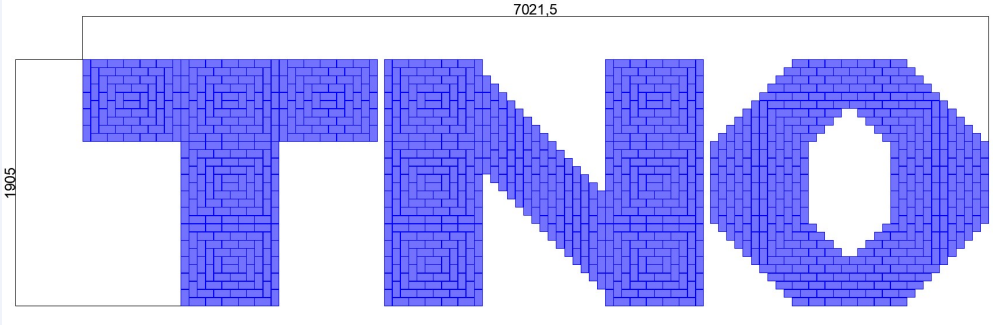
Four pixels in parallel

Four pixels in parallel

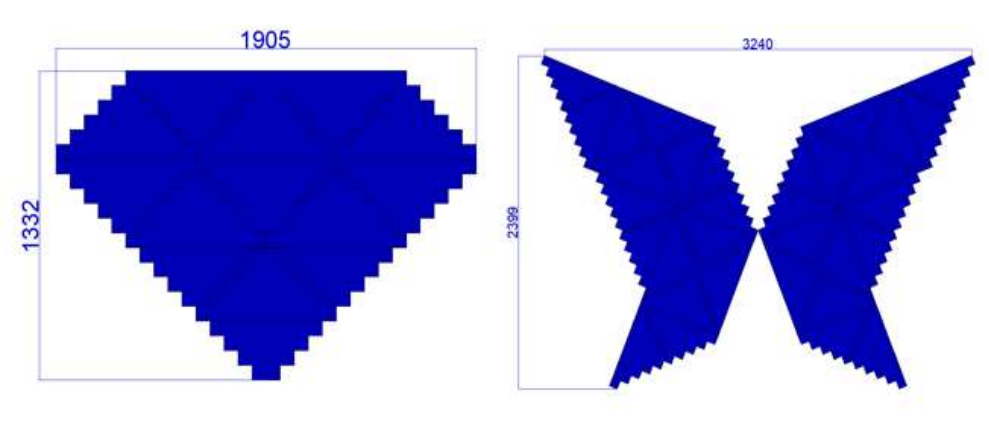
Pixel module concept (4)

- The concept is being applied for development of BIPV and VIPV products together with our industrial partners





TNO logo: x72 pixels, 9.3V, 12A

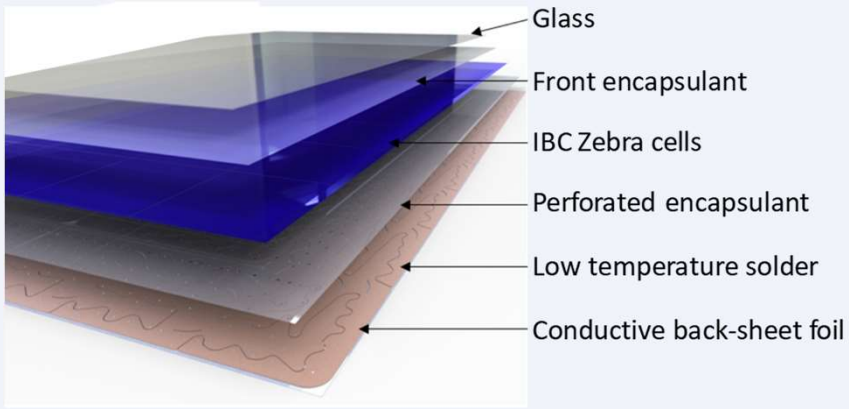


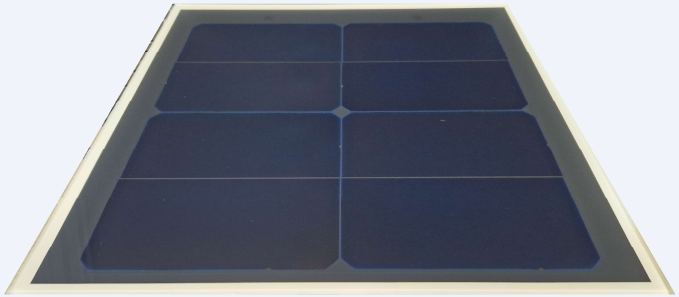
Diamond 1: x14 pixels, 65V, 6A

Butterfly: x32 pixels, 74.4V, 12A

Light-transmitting conductive substrate (1)

- TNO's mono-facial CBF-based IBC module





- TNO's Bi-facial module technology (under development)
  - Light Transmitting Conductive Substrate (LTCS) technology
  - Based on the standard industrial BC module assembly process (pilot line at TNO)
  - >80% bi-faciality demonstrated so far

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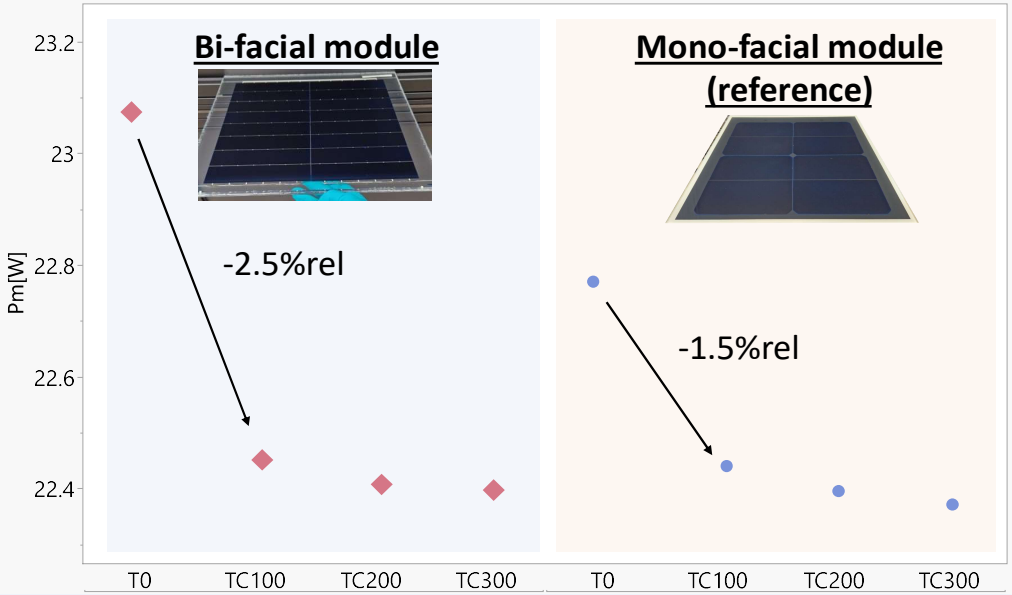
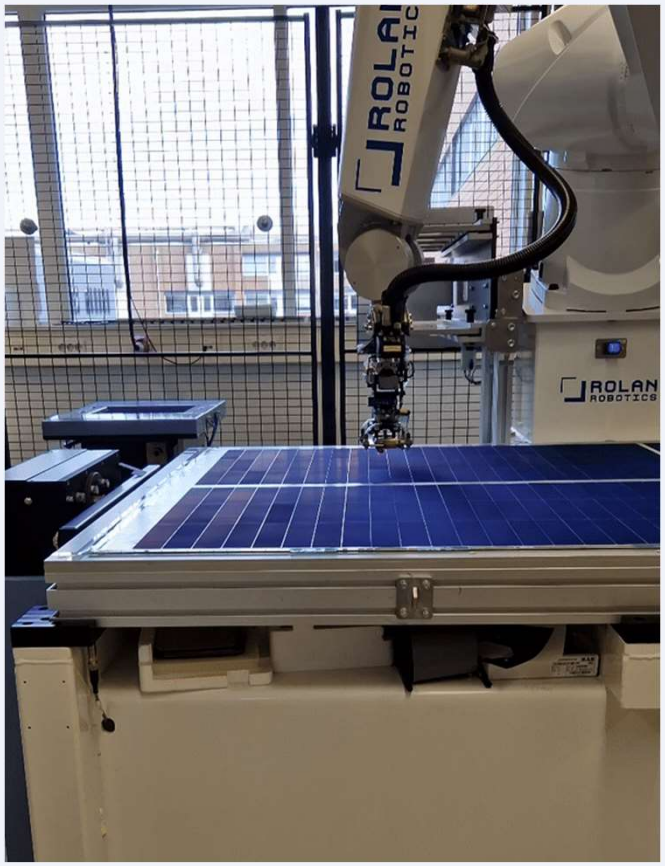
Light-transmitting conductive substrate (2)

- First 1x2m prototype built with IBC Zebra cells with >370Wp
- Good Isc and Voc, but suboptimal FF (process quality control)
- TC300 test passed on 40cmx40cm laminates
- Cost and performance optimisation in progress





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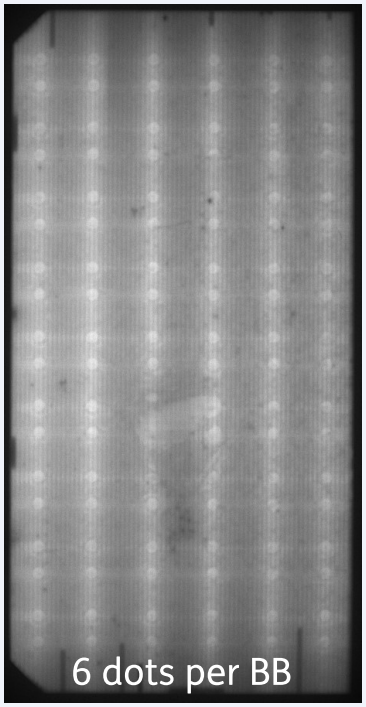
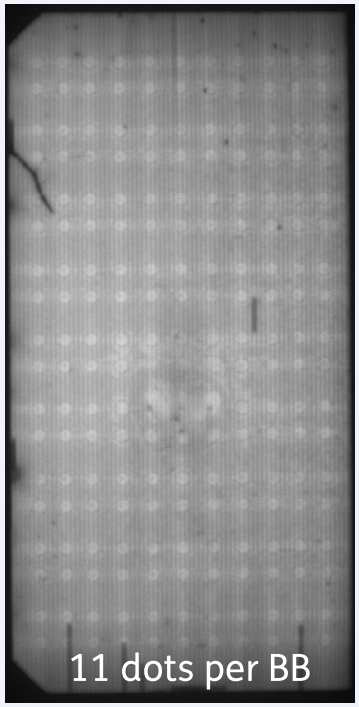
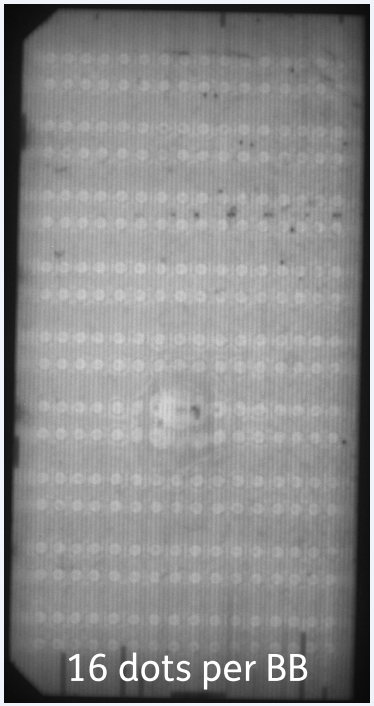
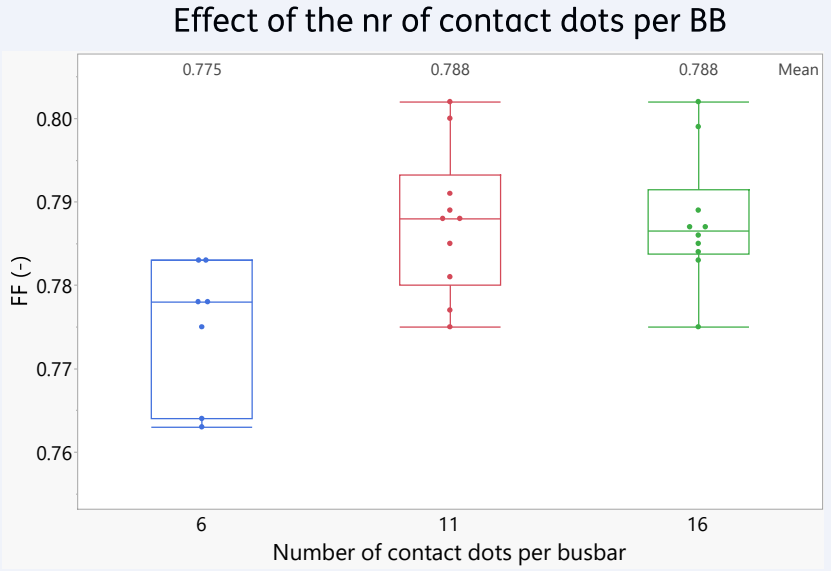
Light-transmitting conductive substrate (3)

- Interconnection design and process optimization (IBC4EU project)



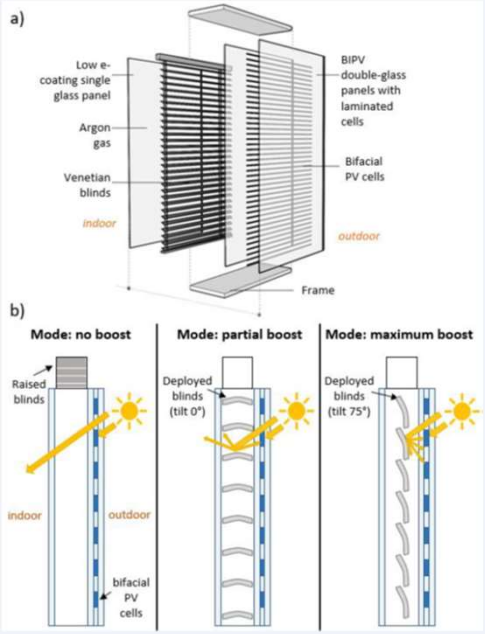






Light-transmitting conductive substrate (4)

- LTCS technology already implemented for BiPV application: (smart) PV windows
- Design flexibility and manufacturability demonstrated (ZIEZO project)




De Telegraaf NIEUWS SPORT ENTERTAINMENT FINANCIEEL VROUW LIFESTYLE WAT U ZEGT

Lees voor

TNO maakt dubbelzijdig zonneraam: opwek stroom aan binnen- en buitenkant woning

Door THEO BESTEMAN
14 nov. 2024 in FINANCIEEL

AMSTERDAM - Onderzoekers hebben een raam ontwikkeld dat stroom opwekt als een zonnecel en tegelijkertijd de warmte en lichtinval regelt. Het kent dubbelzijdige zonnecellen en wekt aan binnen- en buitenkant stroom op.

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Het ontwikkelde raam van de onderzoeksgroep onder leiding van TNO.

Outdoor Performance Analysis of Semitransparent Photovoltaic Windows with Bifacial Cells and Integrated Blinds - Villa - 2024 - Solar RRL
https://onlinelibrary.wiley.com/doi/full/10.1002/solr.202400515

Takeaways

- New PV application areas require advanced level of customization, both on the module and system level
- Conductive substrate back-contact module technology offers unique opportunities in terms of design freedom and manufacturability of IPV products
- TNO is committed to development of technically and economically feasible PV integration technologies together with industrial partners

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