RECENT ADVANCES IN X-SI SOLAR MODULE TECHNOLOGY

WHY SOLAR MODULES ARE STARTING TO LOOK DIFFERENT NOW!

JAN KROON

SUNDAY, 7 NOVEMBER 2018

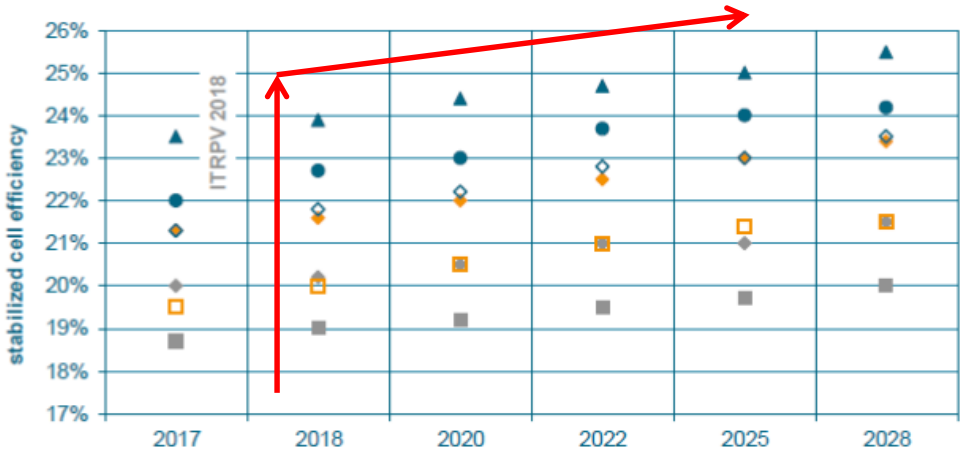
ECN › TNO innovation for life

CONTENT

- International roadmaps for cells and modules
- From Cell to Module
  - Overview on cell interconnection technologies
- Module developments at ECN
- Summary and Outlook

FROM STANDARD TO HIGH EFFICIENCY SI CELLS

- From multi to mono
- From p- to n-type front to rear contact (PERT, Heterojunction)
- From front to rear contact to back contact (MWT, IBC)
- From monofacial to bifacial (> kWh/kWp)

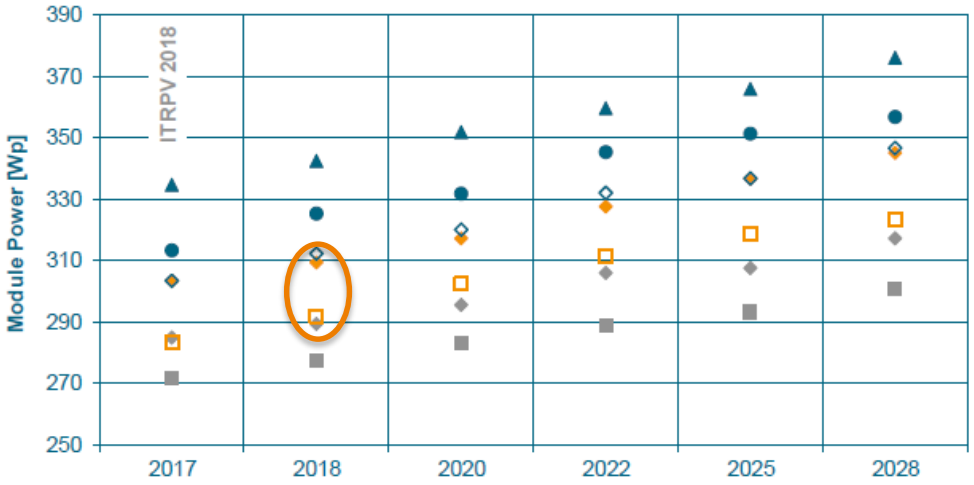


N mono IBC
N mono HJ
N mono PERC/PERT
P mono PERC/PERT
P multi PERC
P mono BSF
P multi BSF

ITRPV roadmap ed. 2018

TO BE TRANSLATED TO HIGH POWER MODULES

- Trend module power of 60 cells 156 x 156 mm
  - 2018 Mono p-type Perc 310 W
  - 2018 Multi p-type Perc 290 W



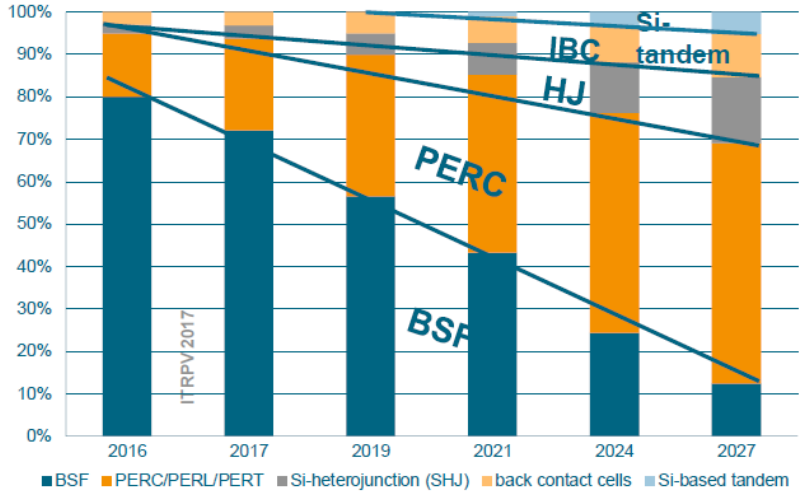
380

270

N mono IBC
N mono HJ
N mono PERC/PERT
P mono PERC/PERT
P multi PERC
P mono BSF
P multi BSF

ITRPV roadmap ed. 2018

EXPECTED MARKET SHARES



Potentially bifacial

- Trends according to ITRPV roadmap:
  - PERC concepts gaining market share (~30 % in 2018)
  - Back Contact and HJ concepts slow increasing share
  - Si-Tandem under development

FROM CELL TO MODULE

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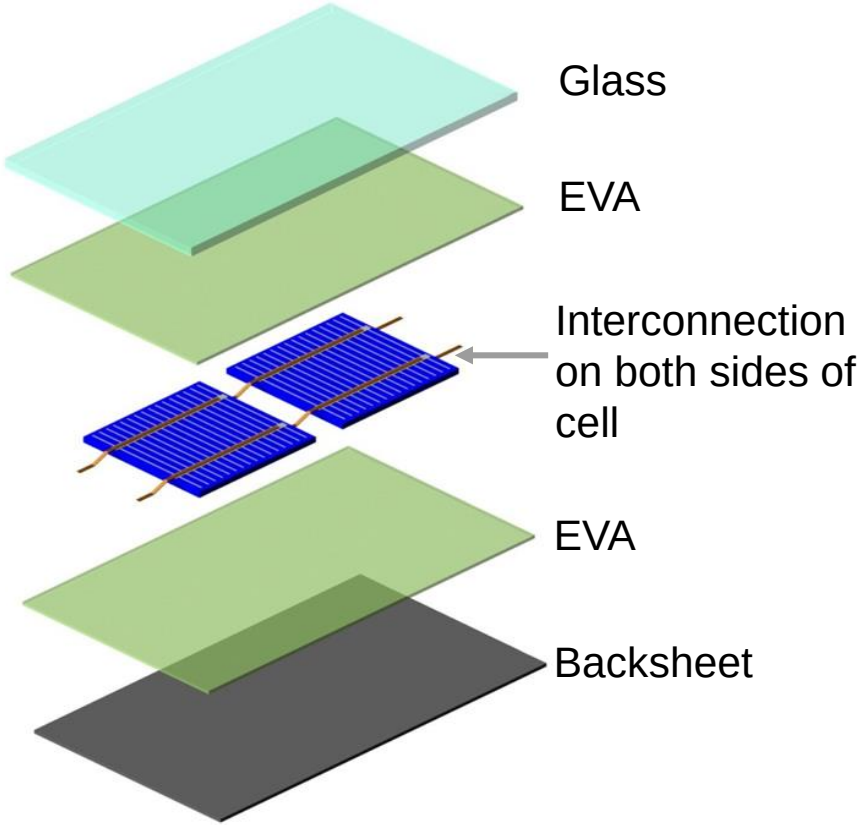
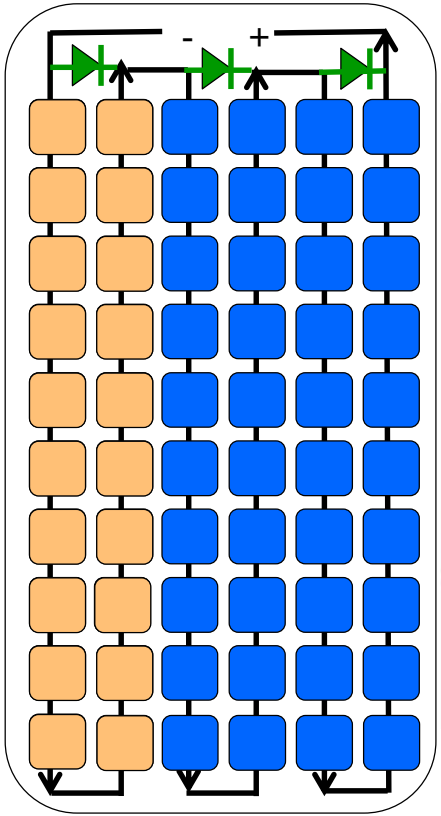
Each cell concept has to be individually evaluated for the best module concept in terms of:

- Lowest cell to module losses → CtM value → > Wp/m^2
- Optimized BoM and production costs → high yields, low investment costs → < €/m^2
- Best energy yield → temperature, low light, incident angle, bifaciality → > kWh/kWp
- Long term stability → < degradation rate → > 25, 30, 40 years product lifetime → < €/kWh

$$LCOE = \frac{(CAPEX + \sum\left[\frac{OPEX(t)}{(1+WACC_{nom})^t}\right]}{\sum\left[\frac{YIELD(0)(1-Degr)^t}{(1+WACC_{real})^t}\right]}$$

STANDARD MODULE MANUFACTURING





ALTERNATIVE APPROACHES FOR INTERCONNECTION

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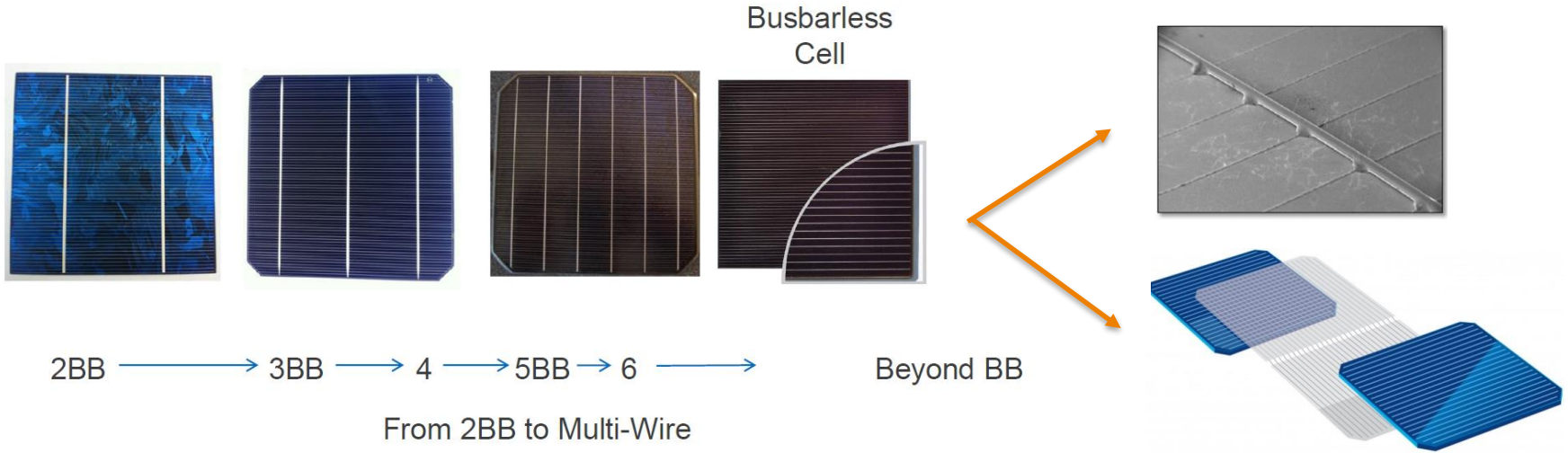
› Front to rear contact (Standard, PERC, Heterojunction)

- Move to more busbars: 2,3,4,5,…, 12, busbarless
- Low silver consumption, lower Rc, less optical shading
- From standard soldering to low stress Multi Wire interconnection technology
  - **Smart Wire** (Meyer Burger) and **Multi Busbar** (SCHMIDT)



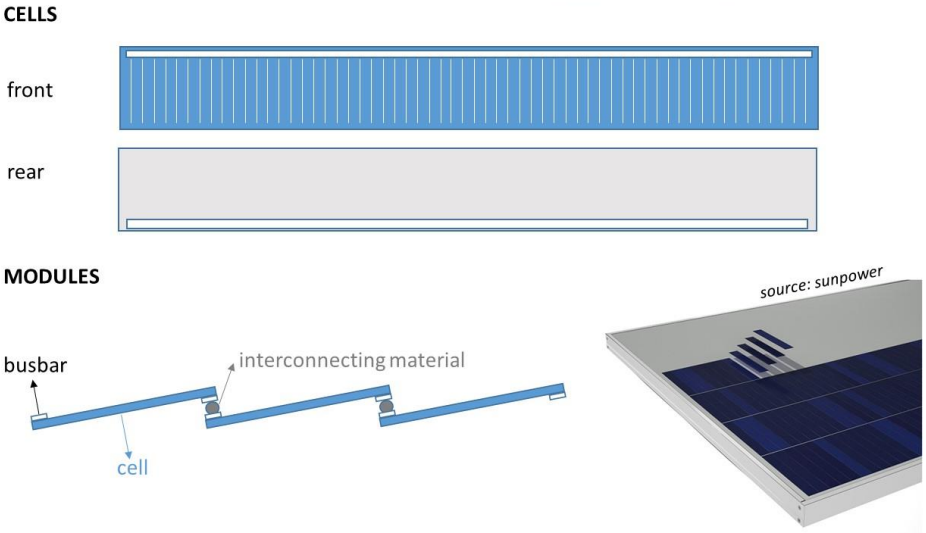
ALTERNATIVE APPROACHES FOR INTERCONNECTION

Front to rear contact

- **Half cells**: reduce resistance loss, standard soldering
- **Shingles**: cascading: dense packing, high power

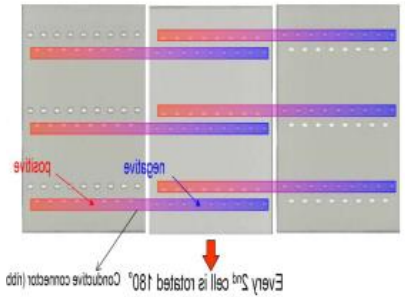
JA Solar
Half cells module

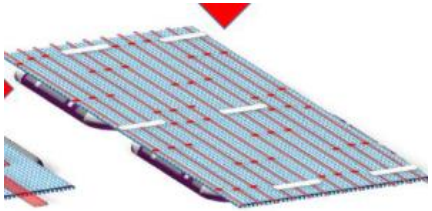
- Requires cell cuttting
- ECA for interconnection
- Improved aesthetics
- Reduced shading losses
- Reliability?
- Costs?

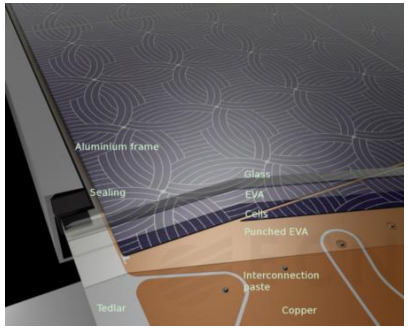


ALTERNATIVE APPROACHES FOR INTERCONNECTION

- **Back Contact (MWT, IBC)**
- no standard metallization lay out → different interconnection technologies
  - Rear soldering
    - Busbar soldering *(ISC, Soltech, ISE,..)*
    - woven interconnect fabric concept *(imec)*
    - Multi/smart wire: Bifacial Back Contact *(MB, CSEM,..)*
  - Smart tab edge interconnection *(SUNPOWER)*
  - Foil interconnection technology *(ECN.TNO)*







FOIL INTERCONNECTION TECHNOLOGY

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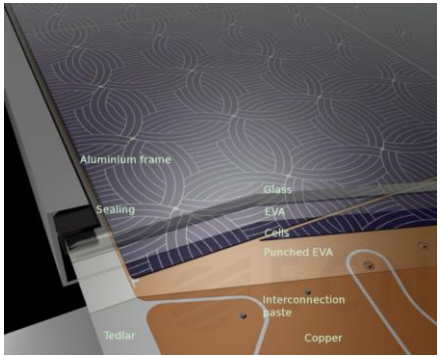
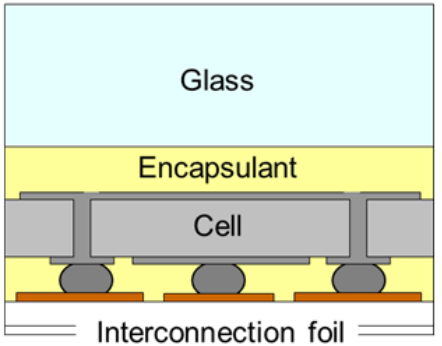
Generic platform for several types of Back Contact (BC) cells

- Conductive back-sheet foil
  - Copper as conductive layer
  - Patterning by chemical etching or milling
- Contact cell to foil through conductive adhesive
  - Printed on foil or on cell
- Isolation cell from foil by encapsulant
  - Holes at contacts
- Lower CtM resistive losses compared to soldering





CELL-TO-MODULE (CTM) CHANGE

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Positive cell-to-module change: Getting more power out of back-contact modules

Bas B. van Aken & **Lenneke H. Slooff-Hoek**, ECN – Solar Energy, Petten, The Netherlands

ABSTRACT

Cell-to-module (CtM) loss is the loss in power when a number of cells are interconnected and laminated in the creation of a PV module. These losses can be differentiated into *optical losses*, leading to a lower photogenerated current, and *resistive losses*, leading to a decrease in fill factor. However, since the application of anti-reflection (AR) coatings and other optical 'tricks' can sometimes increase the I_{sc} of the module with respect to the average cell I_{sc}, the CtM loss in such cases needs to be expressed as a negative value, which gives rise to confusion. It is proposed to use the CtM change, where a negative value corresponds to a loss in current or power, and a positive value to a gain. In this paper, the CtM changes for back-contact modules utilizing a conductive foil are described and compared with other mature module technologies. A detailed analysis of the CtM change for a full-size metal-wrap-through (MWT) module is presented.

Fab & Facilities

Materials

Cell Processing

Thin Film

PV Modules

Market Watch

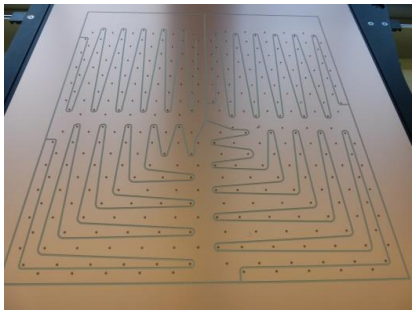
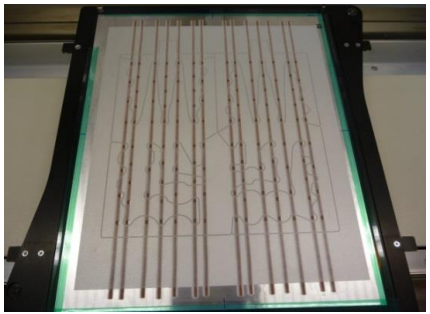
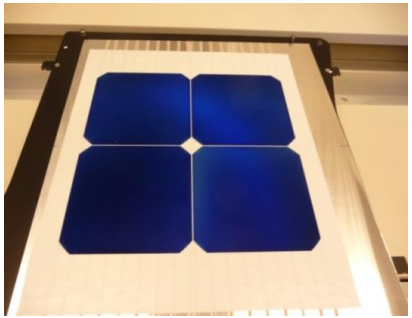
PV international October 2016, edition 33, Page 97

RECENT INNOVATIONS ON BC TECHNOLOGY

- ***Low cost Aluminium Conductive Backsheet***
- ***Cell-to-Module gains for high-efficiency BC cells***
- ***High Yield with thin BC Cells***
- ***View towards applications***

LOW COST AL BASED CONDUCTIVE BACKSHEET

- Replace **Copper** by **Aluminium**
- Local application of **Copper** powder by **Cold-Spray on Al foil**
- BC mini modules pass **> 3 x IEC (Damp Heat, Temperature Cycling)**
- Potential cost saving **~3 Euro per full size backsheet**


CTM GAINS FOR HIGH-EFFICIENCY BC CELLS

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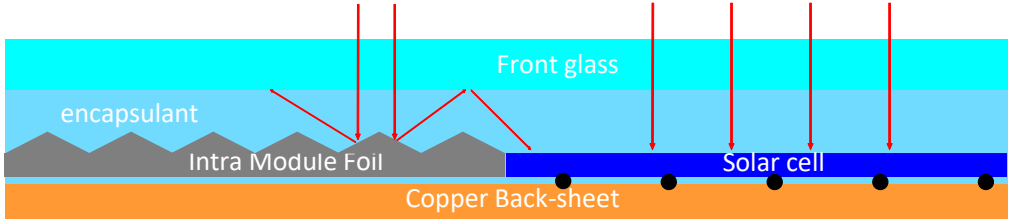
- Use of **highly reflective Intra Module Foil** (IMF) between the cells



Modules	Isc [A]	Voc [V]	FF [%]	Pm [W]	Rel. Isc Gain (%)	Rel. Pm Gain (%)
Ref. (no IMF)	9.8	39.7	76.8	**300**	-	-
With IMF	10.5	40.0	76.5	**322**	+6.9	**+7.2**

@ Tempress test field

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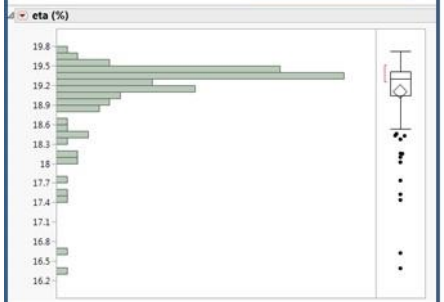
EXASUN

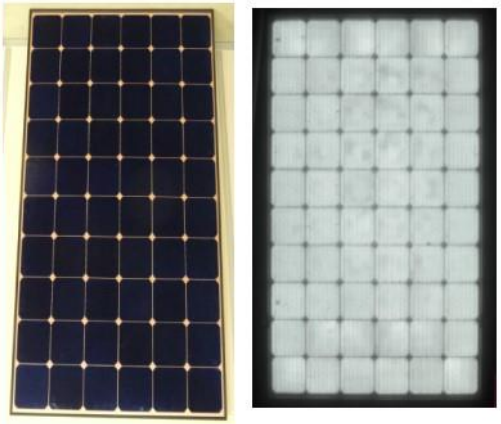
DSM BRIGHT SCIENCE. BRIGHTER LIVING.

HIGH YIELD WITH THIN BC CELLS



95 µm IBC cells

60 cells IBC module manufactured at Eurolab



- No cell breakage
- CtM Power loss < 1 %

TOOLBOX FOR APPLICATIONS

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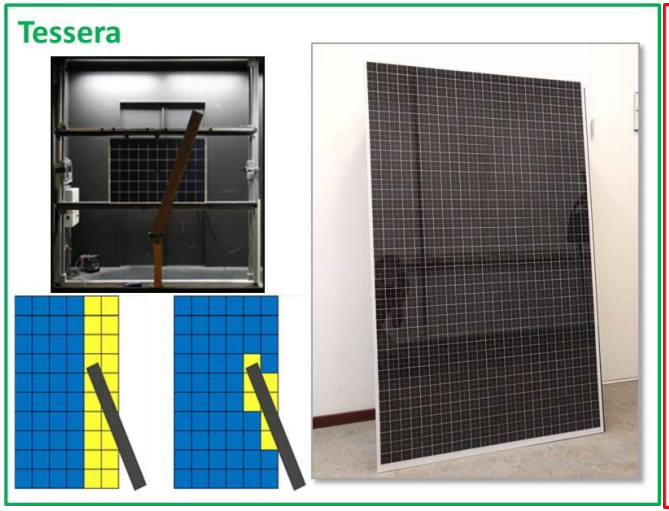
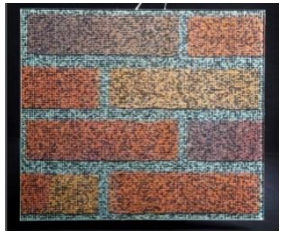
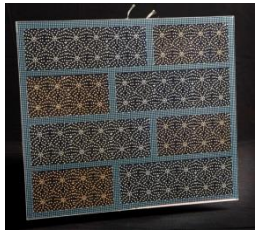
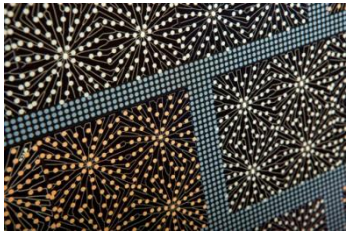
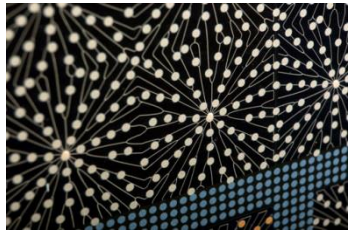
- ✓ High power, uniform appearance
- ✓ Flexible, shade tolerance
- ✓ Freedom of design
- ✓ Aesthetics for BIPV











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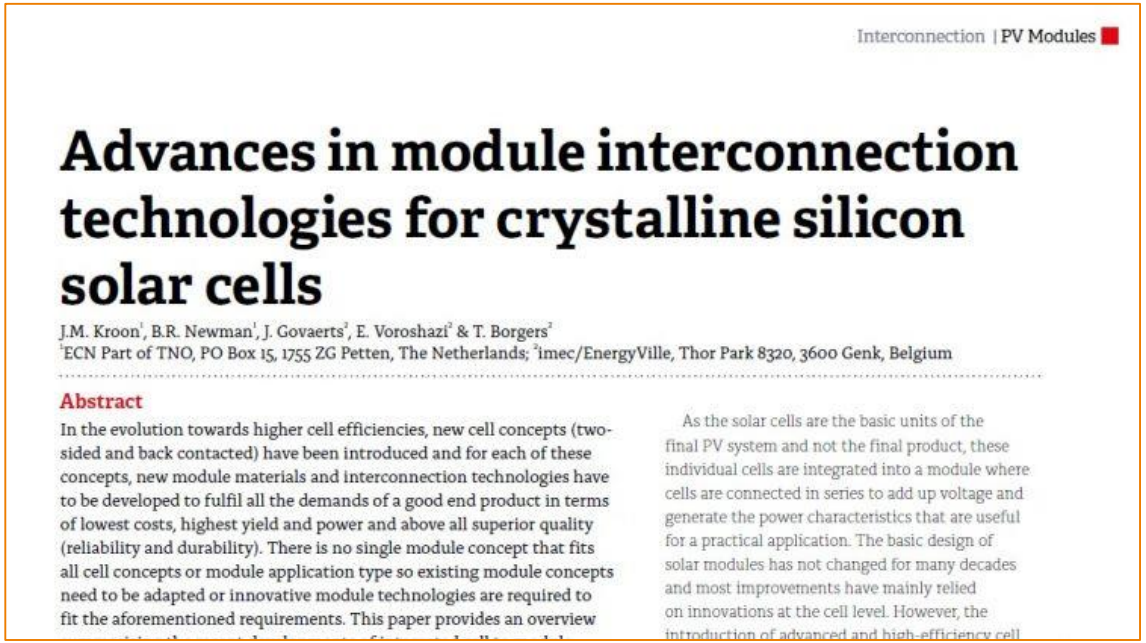
From Dutch Solar Design: ECN, TS Visuals, UN studios

SUMMARY

- There is not one module concept that fits all cell concepts
- Selected interconnection technology and materials must fulfill all the demands:
  - CtM change, highest yield, low costs & QUALITY
- Market adoption of new cell and module concepts is not straightforward

- Broaden applicability via customized module designs
  - **BIPV**: Aesthetics, transparency, colours, flexibility of shape & size, shade tolerance
  - **I2PV**: Bifaciality: PV on water, noise barriers,..
  - **VIPV**: Semi-flexible, 3D shaped, shadow tolerant

FOR MORE INFORMATION SEE:



Interconnection | PV Modules

Advances in module interconnection technologies for crystalline silicon solar cells

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Abstract

In the evolution towards higher cell efficiencies, new cell concepts (two-sided and back contacted) have been introduced and for each of these concepts, new module materials and interconnection technologies have to be developed to fulfil all the demands of a good end product in terms of lowest costs, highest yield and power and above all superior quality (reliability and durability). There is no single module concept that fits all cell concepts or module application type so existing module concepts need to be adapted or innovative module technologies are required to fit the aforementioned requirements. This paper provides an overview

As the solar cells are the basic units of the final PV system and not the final product, these individual cells are integrated into a module where cells are connected in series to add up voltage and generate the power characteristics that are useful for a practical application. The basic design of solar modules has not changed for many decades and most improvements have mainly relied on innovations at the cell level. However, the introduction of advanced and high-efficiency cell

PV International, edition 41, September 2018, page 93
www.pv-tech.org


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CELL-TO-MODULE (CTM) CHANGE

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CtM change of the fill factor for various interconnection schemes

- Only resistive losses in interconnection material: tabs, wires, foil
- Calculated power loss is inversely proportional to the total cross-section of the interconnection material