Overview: bifacial module concepts

Dr. Hartmut Nussbaumer, Zurich University of Applied Sciences

Requirements on a bifacial module

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

Lowest LCOE when used in a PV System

- Maximum energy harvest (NOC, bifacialiaty factor,…)
- Long lifetime (Partial shading behaviour, encapsulant & structure, interconnection…)
- Cost for mounting and installation comparable to standard

What is state of the art of commercial available bifacial PV modules?

Examples of bifacial modules
Trina Solar

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

DUOMAX twin

Trinasolar

Features:
G/G; 2.5mm /2.5 mm
Frameless
P-type PERC technology, mono –Si
Efficiency range 17.2 – 18% at STC
Encapsulant: EVA
Junction box on the edge
3? Bypass diodes
Bifaciality factor: ?

Examples of bifacial modules
Meyer Burger

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

MEYER BURGER

Features:

G/G; 2.5mm /2.5 mm

Frameless

n-type HJT technology, mono –Si

Smart Wire interconnection technology

Efficiency range 17.8 - 19% at STC

Encapsulant: TPO

Junction box on the edge

3 Bypass diodes

Bifaciality factor: 93%

Examples of bifacial modules
LG

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

LG NeON™ 2 BiFacial

LG
Life's Good

Features:
G/ transparent BS
Aluminium frame
n-type technology, mono –Si
Multibusbar technology
Efficiency ~ 18.3% at STC

Examples of bifacial modules
Yingli

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

panda BIFACIAL 144HCF

YINGLI SOLAR

Features:

G/G; 2.5mm /2.5 mm

5 Bus-bar half cells, n-type mono –Si

Efficiency range 16.6 – 17.6% at STC

Examples of bifacial modules Solarworld

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

SolarWorld
REAL VALUE

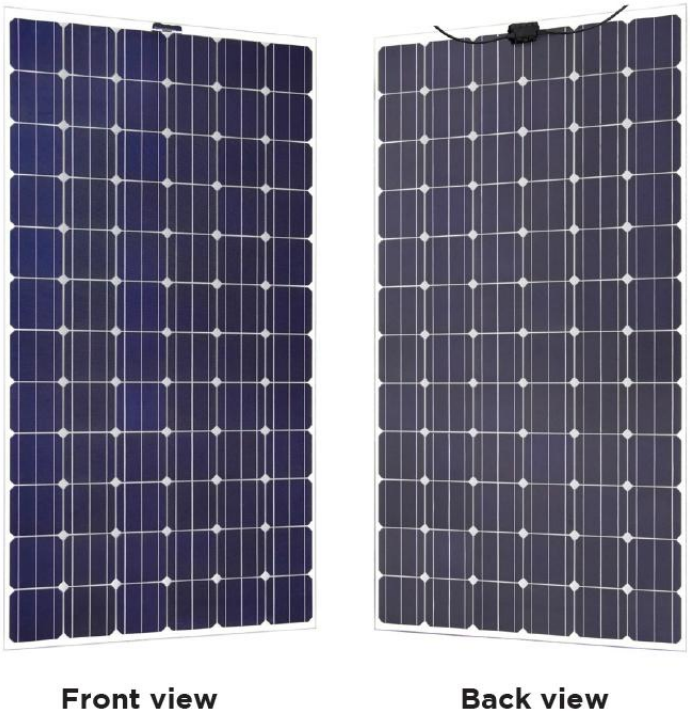
Features:
G/G
p-type, mono –Si
Efficiency 17.3% at STC
Junction box on the edge
Lattice-like white reflecting coating at the inside of the rear glass

Examples of bifacial modules
Prism solar

Zurich University of Applied Sciences
zh aw School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

GxB and HxB Series

SUNPREME® Premium Bifacial Thin Film Solar



Front view Back view

Features:
HJ cell technology,
Efficiency ~19.1% at STC
60 – 96 cell modules

Comparison

Zurich University of Applied Sciences
zh aw School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

Company	Technology	Rated Module Efficiency STC	Speciality
Trina Solar	p-type Mono PERC, G/G	18%	
Meyer Burger	HJT, Mono, G/G	19.1%	Smart Wire, TPO encapsulant
LG Electronics	n-type Mono, G/BS	18.3%	Multiwire, Transparent BS
Yingli Green Energy	n-type Mono PERT, G/G	17.6%	Half cells 5BB
SolarWorld	p-type Mono PERC G/G	17.3%	Reflecting coating
Sunpreme	HJT Mono, G/G	19.1%	Large 96 cell modules

List incomplete!

Current «industrial standard» for bifacial modules:
Glas/Glas: 2.5/2.5 mm, 60 cells, EVA encapsulant, 5BB technology, *p-type PERC*,
3 Bypass diodes, JB at the edge not shading the cell area, Efficiency 17-18% at STC

Possible future trends and optimizations

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

- Interconnection technologies: SmartWire, Multibusbar, Half or even smaller cells?
- Reflective & antireflective coatings?
- New encapsulants and technologies?
- Glass/BS instead of Glass/glass?

Interconnection technologies

Interconnection technologies SmartWire, Multibusbar

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

Main advantages:

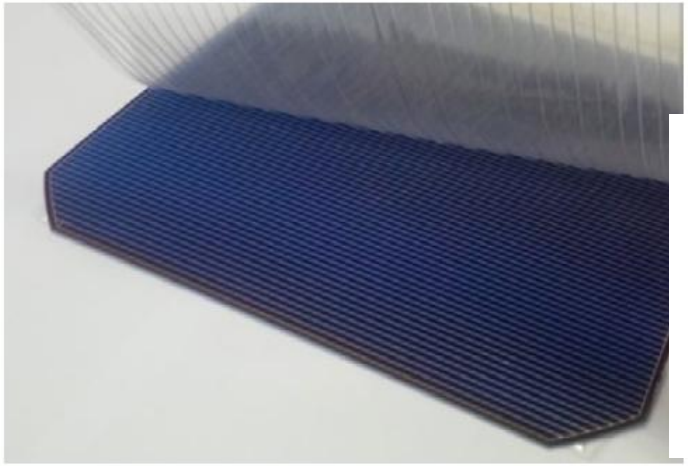
No busbars needed, reduced finger cross section needed

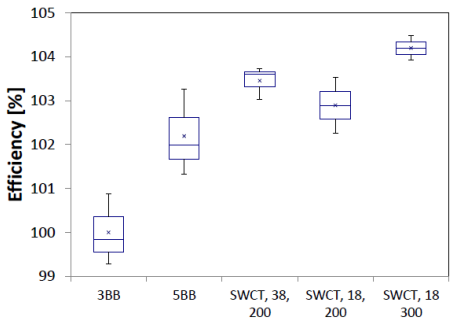
⇒ Reduced silver consumption

⇒ Reduced impact of cell breakage by increased number of current collection paths

⇒ Efficiency enhancement

MEYER BURGER Smartwire





18-38 Wires

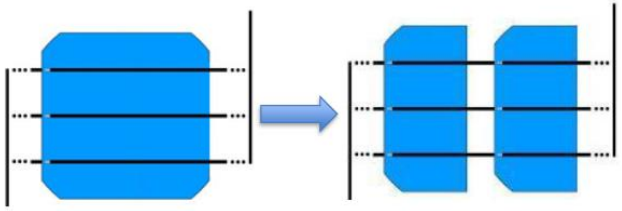
SCHMID Expect Solutions Multibusbar

12 Busbars

Source: T. Söderström et. al. ; SMARTWIRE CONNECTION TECHNOLOGY

Interconnection technologies
Half or smaller cells

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

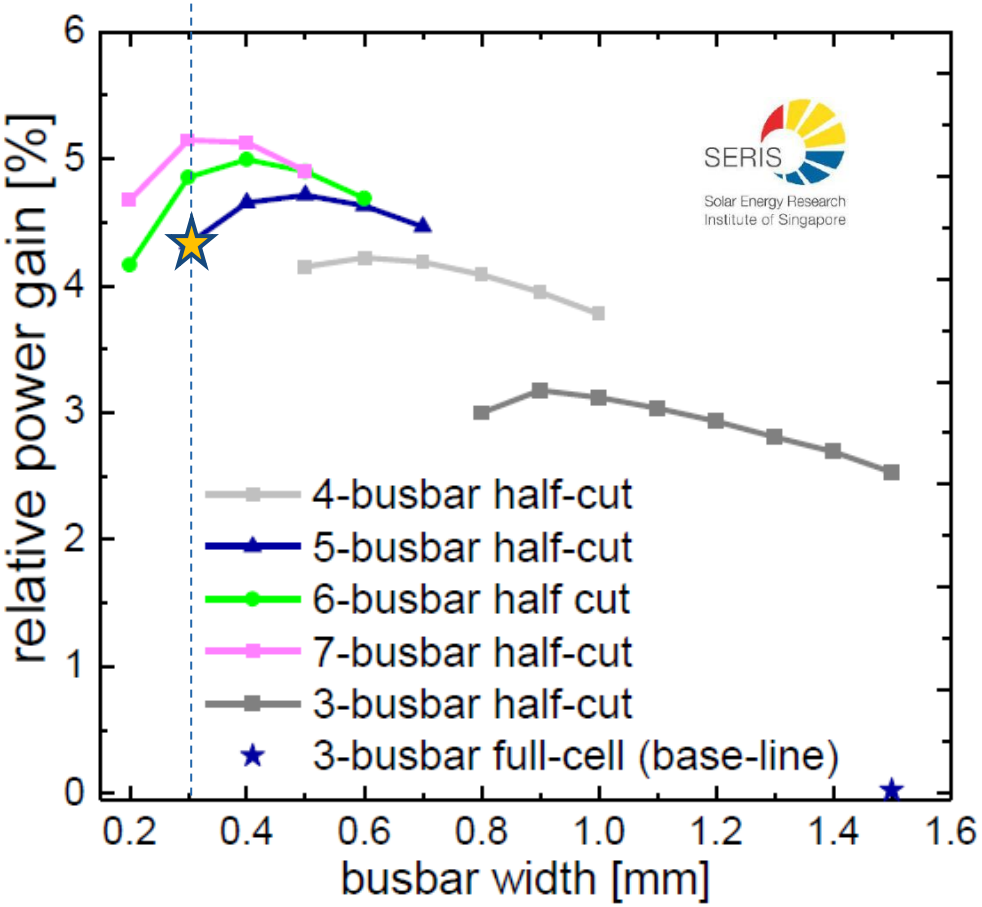


Source: Yong Sheng Khoo, Jai Prakash Singh, Min Hsian Saw
Solar Energy Research Institute of Singapore
National University of Singapore, bifi Workshop 2016, Miyazaki,

*Source: T. Söderström et. al. ; SMARTWIRE CONNECTION TECHNOLOGY

SMCT*

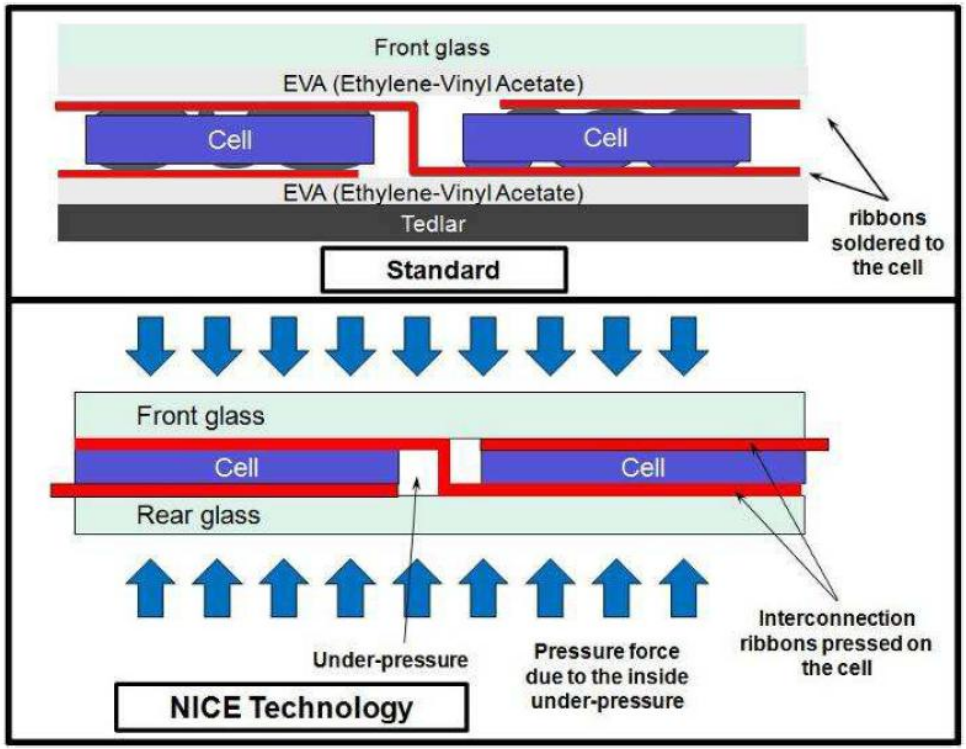
In combination with HJT



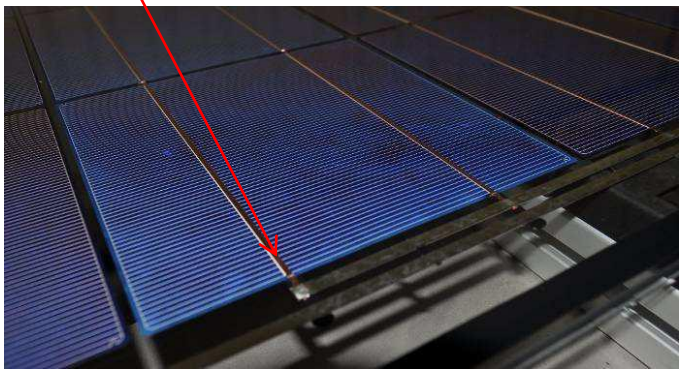
Smaller cells have been proposed by Soria et. al. in order to reduce losses by inhomogenious illumination of the rear

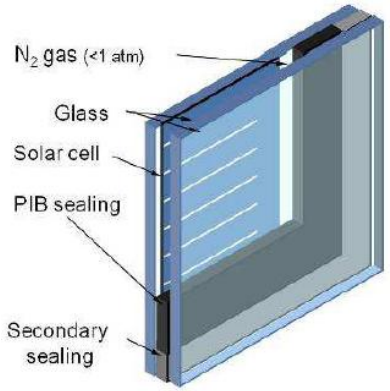
Interconnection technologies NICE

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering



Copper ribbons





NICE module

<u>Main advantages:</u>

No encapsulants needed => cost reduction

No busbars needed => reduced silver consumption

Thicker Copper ribbons without tin can be used => efficiency gain

No UV cut off from EVA

Multibusbar possible? Minimum width of busbars?

Interconnection technologies

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

Subjective rating*

	5BB	5BB HC	Conductive BS	Multi-busbar	SmartWire	NICE
PERC, PERT	+	++	In comb. with MWT	++	++	Combined with 5BB /HC ++
HJT	0	0	In comb. with MWT or IBC	0	++	++
IBC (Zebra, Mercury,…)	(√)	(√)	++ (bifacial?)	(√)	(√)	(√)

0 = suitable, + good fit, ++ special advantages, (√) suitable, but adaptions needed (isolating layers…)

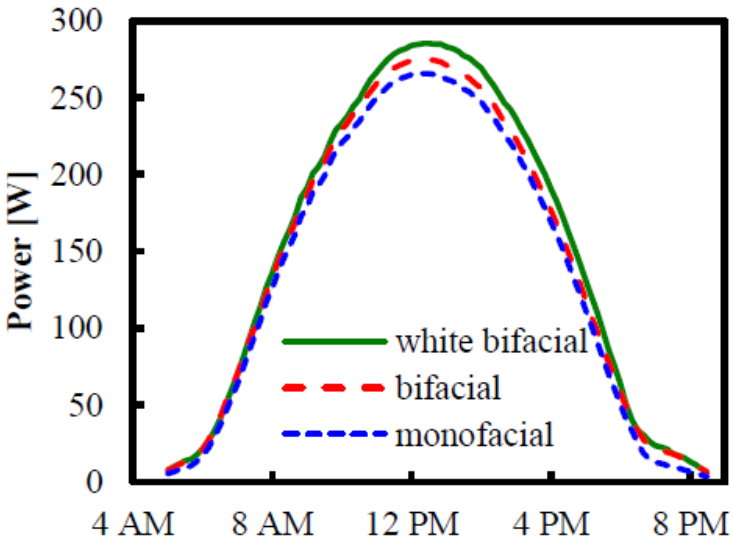
*Shingled/overlapping cells not included

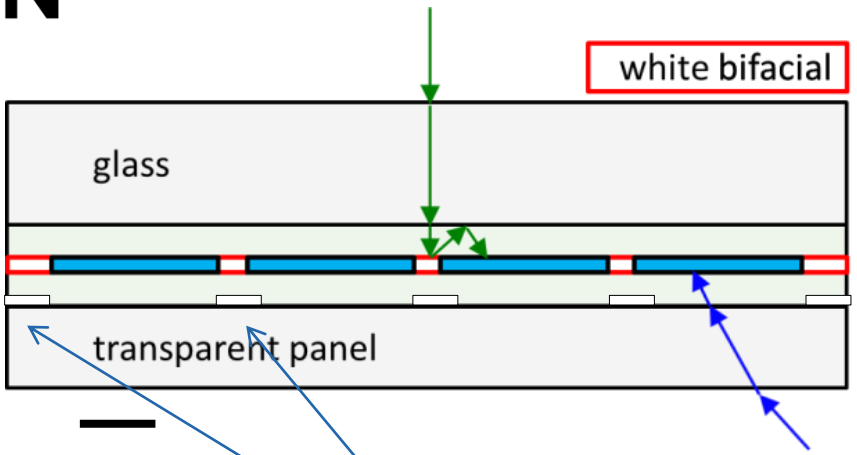
Reflective coatings/layers

White bifacial module

ECN

+5% energy yield vs standard bifacial





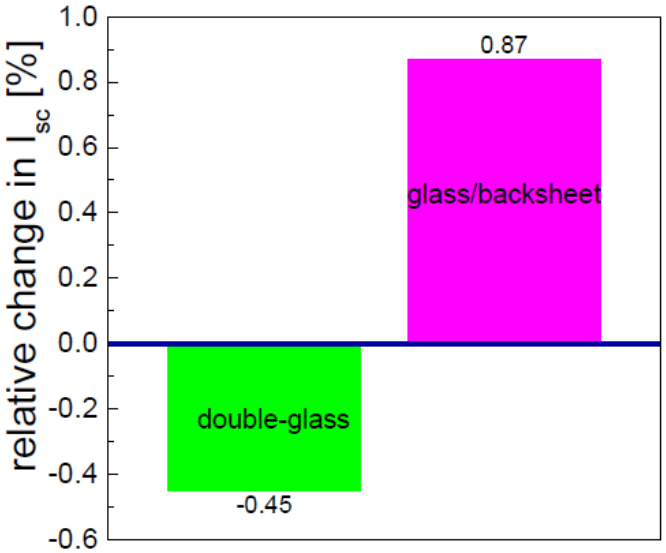
B. van Aken EUPVSEC, Munich, Germany, 2016, Proceedings p. 43

Similar approach Solarworld

SolarWorld
REAL VALUE

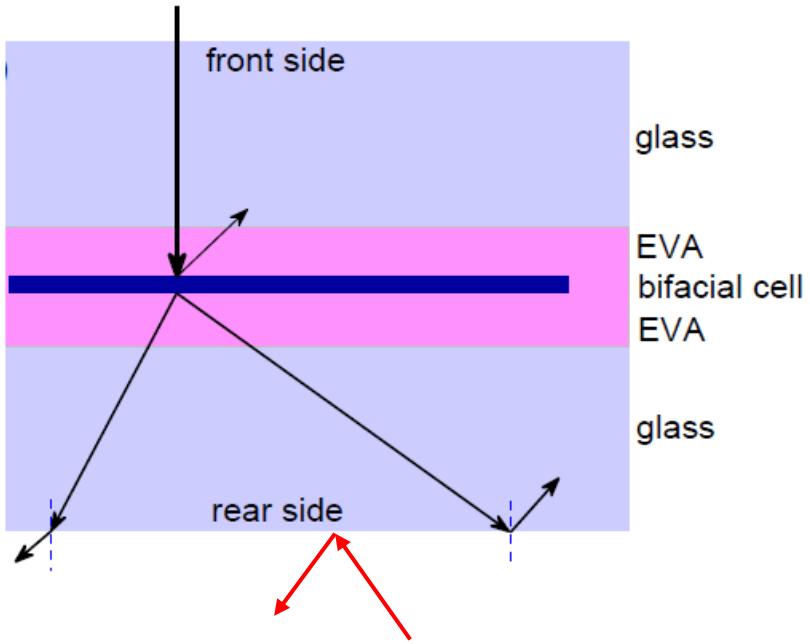
Reflective coatings/layers

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering



Source: Yong Sheng Khoo, Jai Prakash Singh, Min Hsian Saw
Solar Energy Research Institute of Singapore
National University of Singapore, bifi Workshop 2016, Miyazaki,

SERIS
Solar Energy Research Institute of Singapore



Solution: Using IR reflective coating on the rear side glass

=>Reflective coating only reflects IR
=>Bifacial performance is maintained

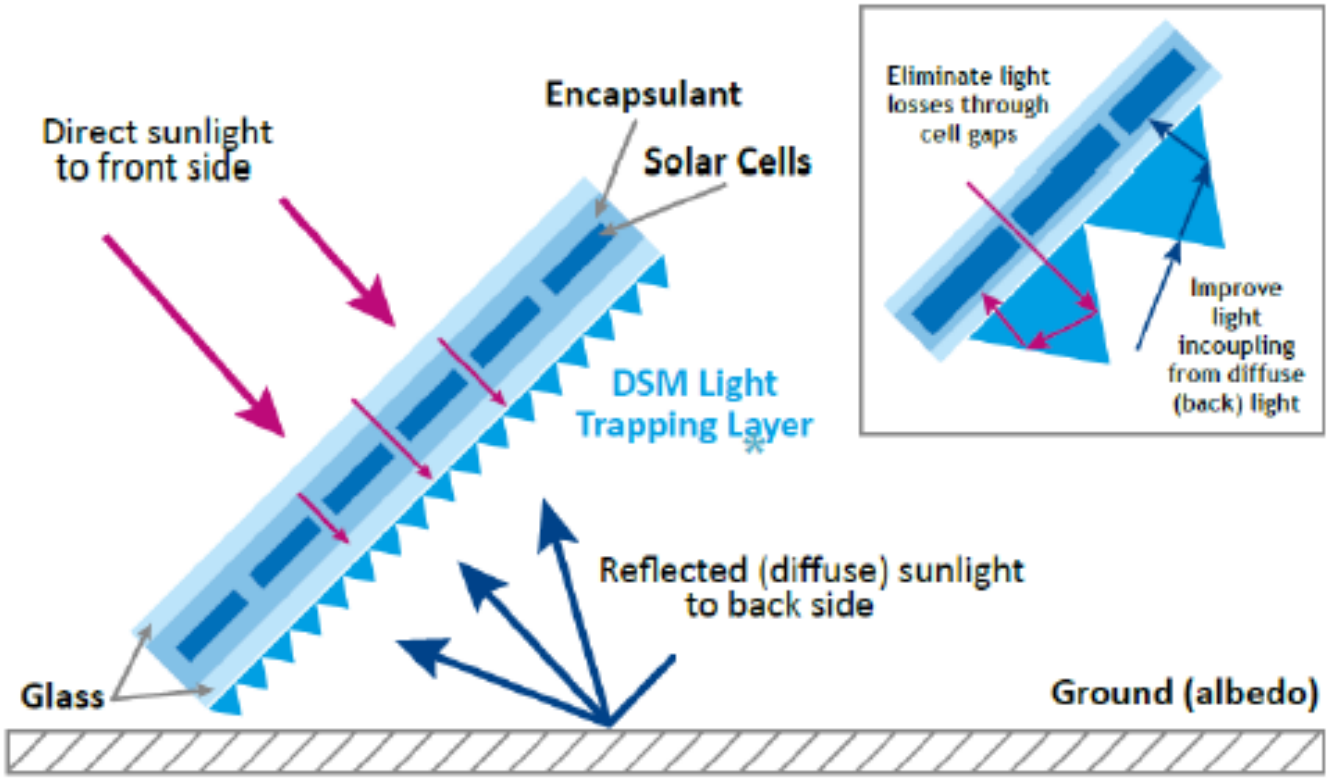
Reflection of IR Photons from the back?

Combine with ECN approach?

Reflective coatings/layers

Light-trapping technology Bi-facials

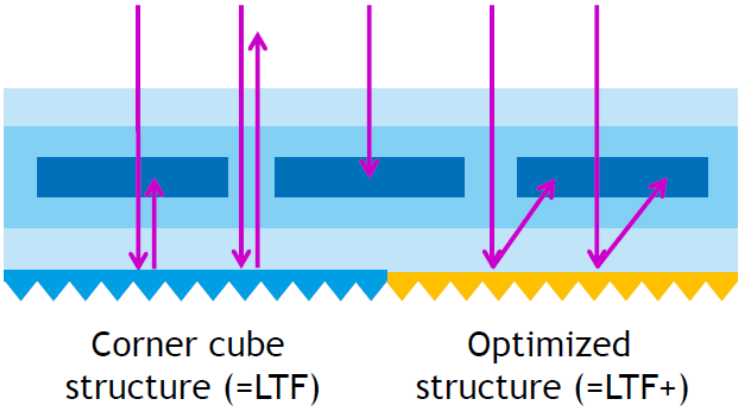
DSM BRIGHT SCIENCE. BRIGHTER LIVING.

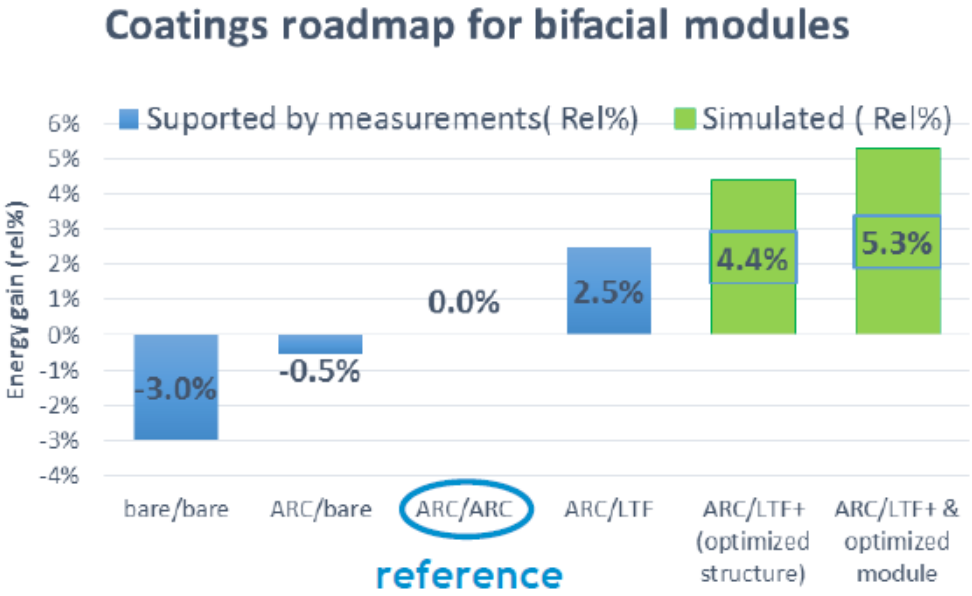


Source: Milica Mrcarica et. al., bifi Workshop 2016, Miyazaki,

Reflective coatings/layers

Light trapping film LTF





Source: Milica Mrcarica et. al., bifi Workshop 2016, Miyazaki,

=> Substantial gains in energy yield can be achieved by using appropriate light trapping concepts

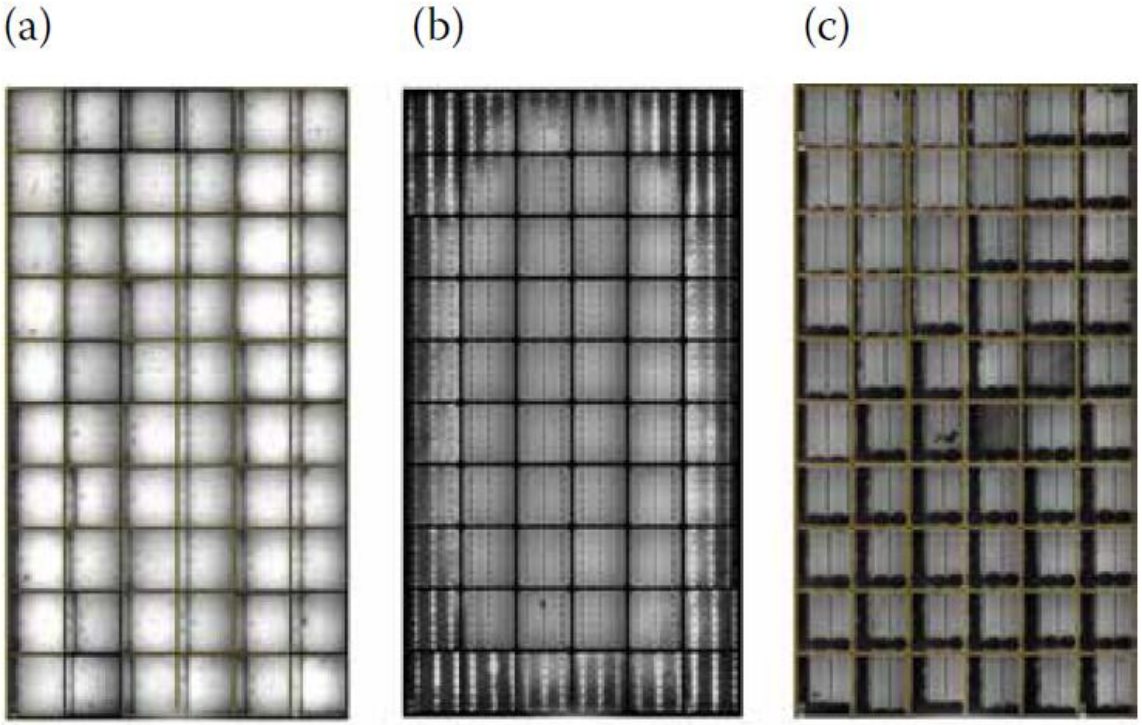
Zurich University
of Applied Sciences
School of
Engineering
IEFE Institute of Energy Systems
and Fluid Engineering

Encapsulants & structure for bifacial modules

Encapsulants & structure for bifacial modules

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

Ethylene vinyl acetate (EVA) is still the predominate encapsulant material



ΔP_{max} = -0.4% -19.5% -42%

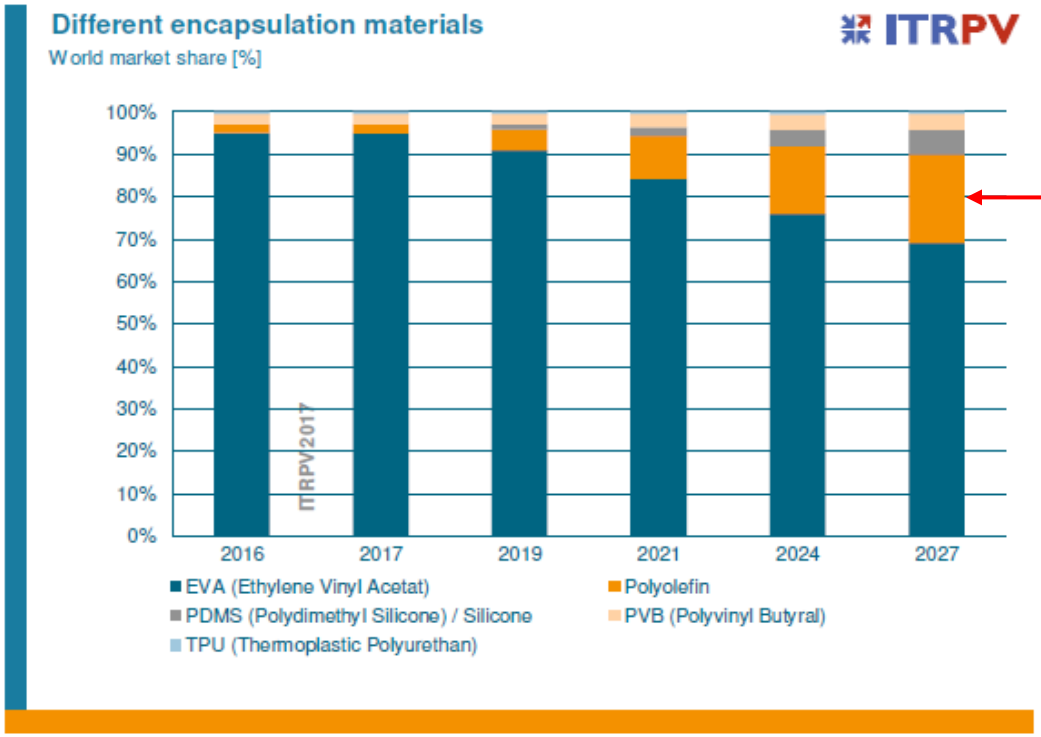
Source: Gianluca Cattaneo et. al.; “Lamination process and encapsulation materials for glass–glass PV moduledesign”, Photovoltaics International Vol. 27, 2015

Electroluminescence analysis after DH: 85°C, 85% RH 7000h: (a) GG module (SWCT) laminated with TPO; (b) GG module with ribbon connection technology laminated with EVA; (c) GBS module with ribbon connection technology laminated with EVA.

Encapsulants & structure for bifacial modules

Zurich University of Applied Sciences
School of Engineering
IEFE Institute of Energy Systems and Fluid Engineering

Belongs the future to thermoplastic polyolefines (TPO)?



Polyolefin

Source: ITRPV 2017

Summary

- Major PV module manufacturers have a bifacial PV module in their product portfolio
- The current «industrial standard» for bifacial modules is a G/G: 2.5/2.5 mm, 60 cells, EVA, 5BB, p-type PERC, 3 Bypass diodes, efficiency 17-18% at STC, no shading JB box
- Several options for improvements of bifi modules are available such as
  - specialized reflecting & antireflective coatings,
  - advanced interconnection technologies,
  - optimized encapsulants