Low-breakdown-voltage solar cells for shading-tolerant photovoltaic modules

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PVMD
Delft University of Technology

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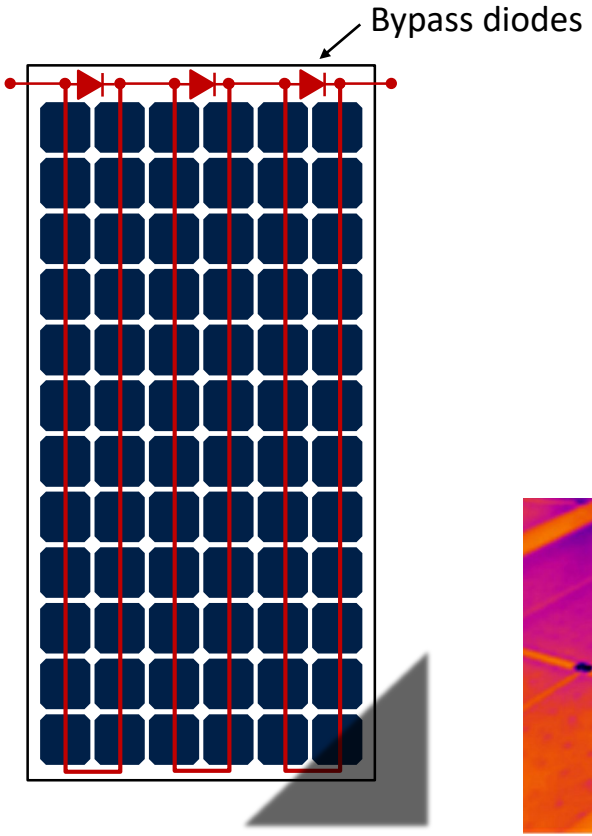
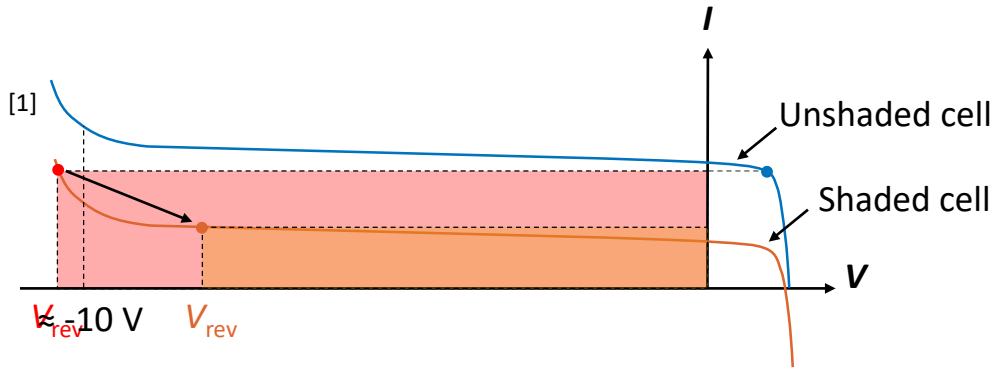
BCworkshop 2024

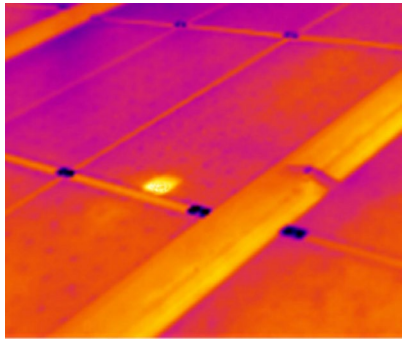
TU Delft

Partial shading

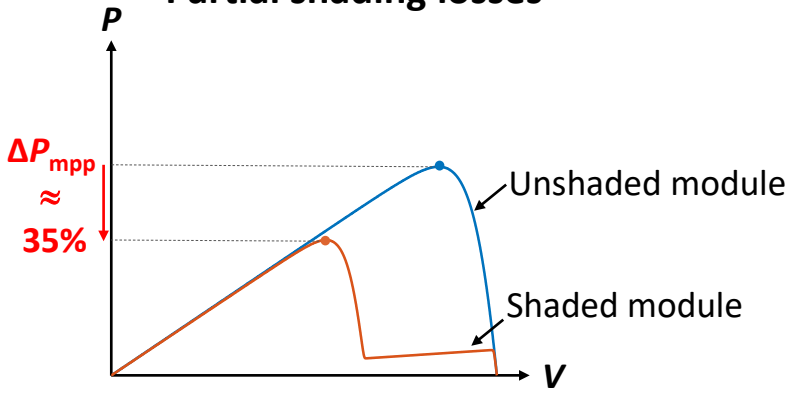




Hot-spots

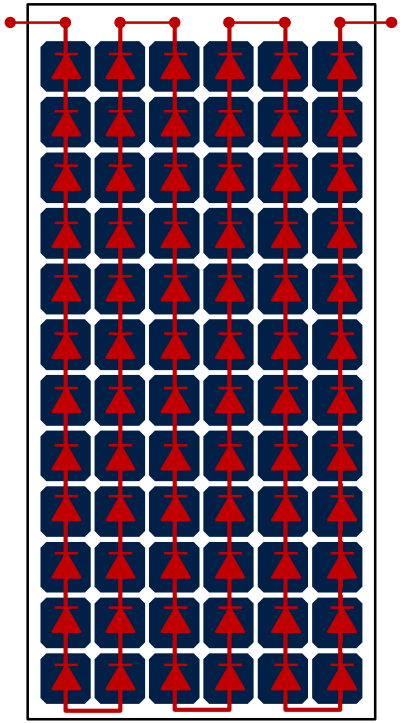


Partial shading losses

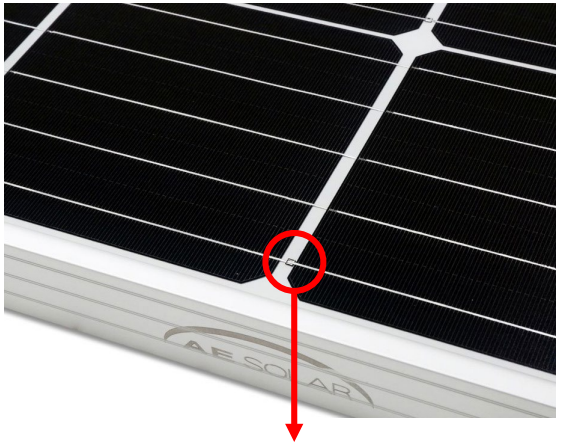


[1] F. Fertig, et al., *Ener Proc* **38**, 32-42 (2013)

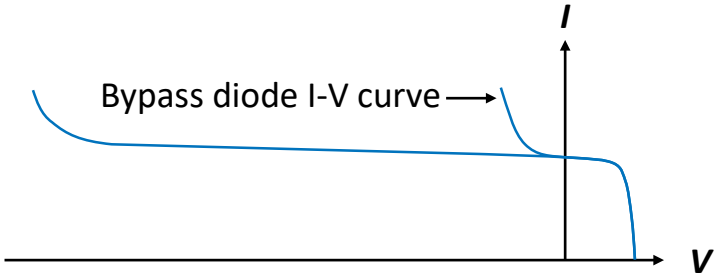
One bypass diode per cell



[1]



Integrated bypass diode [2]



\+ Reduced hot-spot probability

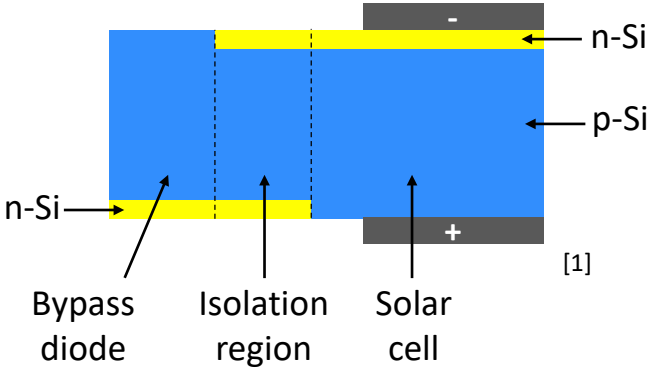
\+ Reduced partial shading losses

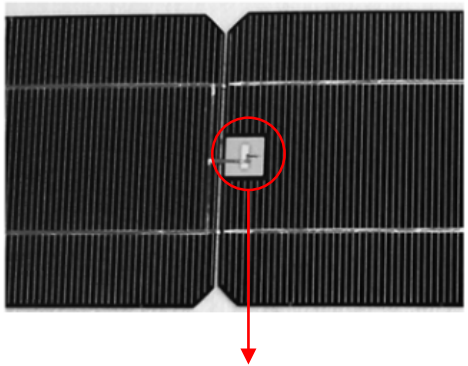
\− Higher cost and complexity

[1] B. B. Pannebakker, et al., *PiP* **25**, 836-849 (2017)
[2] H. Hanifi, et al., *Sol. Ener*. **193**, 814-819 (2019)

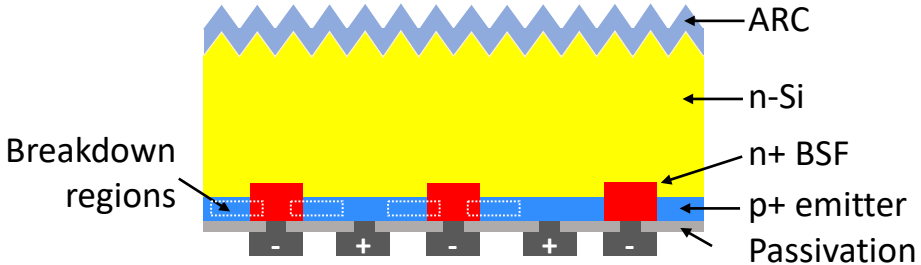
Integral bypass diodes

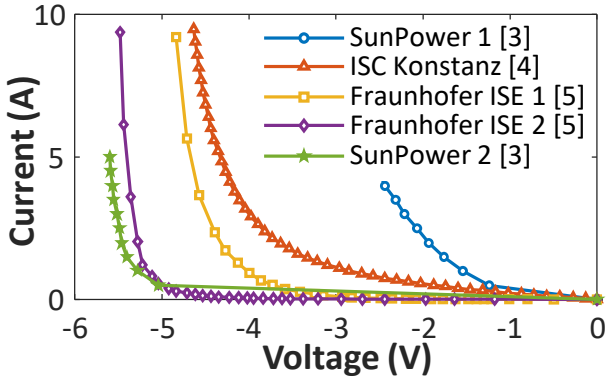
Front/Back Contacted (FBC)





Interdigitated Back Contact (IBC)





[1] M. A. Green, et al, *Solar Cells* **3**, 233-284 (1981)
[2] K. Chen, et al, *Science China Tech. Sciences* **55**, 594-599 (2012)
[3]D.D. Smith, et al, *IEEE PVSC* **38**, (2012)
[4] H. Chu, et al, *Ener. Proc.* **77**, (2015)
[5] R. Müller, et al, *Sol. Mat.* **142**, (2015)

Objectives

1. Analyze breakdown mechanism in IBC solar cells

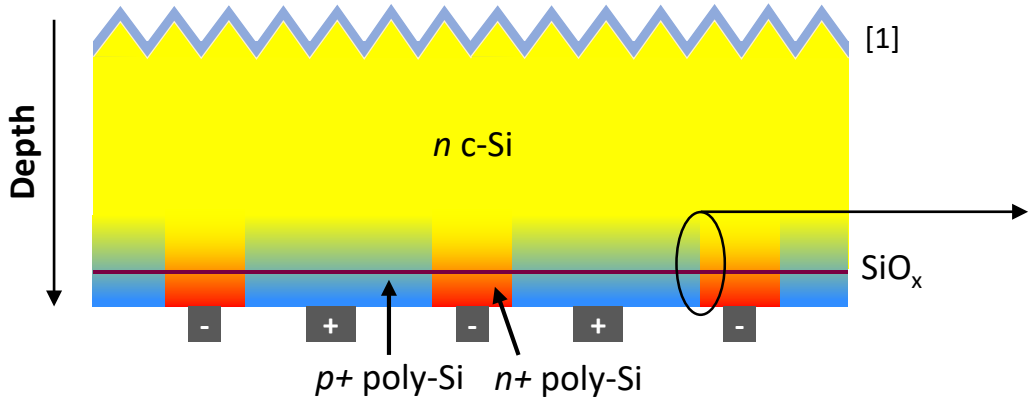
2. Simulation of PV modules with low breakdown voltage solar cells

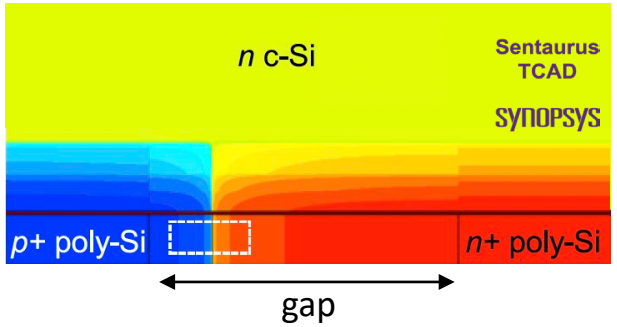
3. Results from outdoors experiments

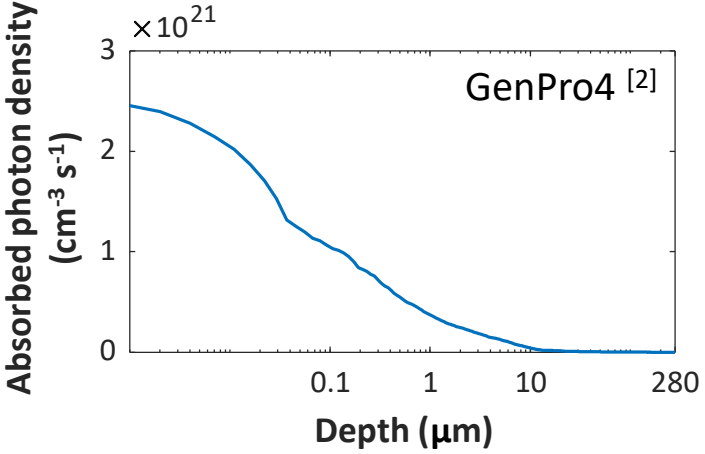
Objectives

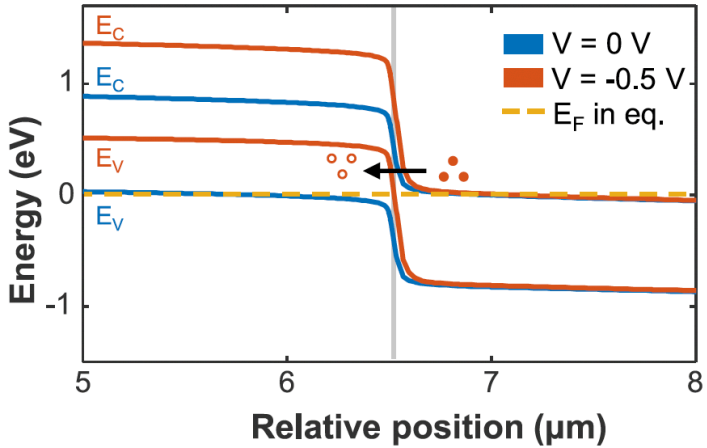
1. **Analyze breakdown mechanism in IBC solar cells**
2. Simulation of PV modules with low breakdown voltage solar cells
3. Results from outdoors experiments

Low breakdown IBC solar cells



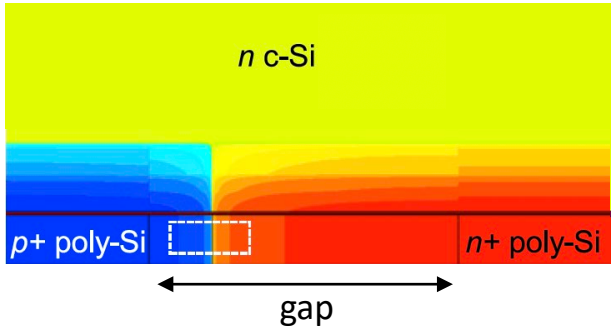


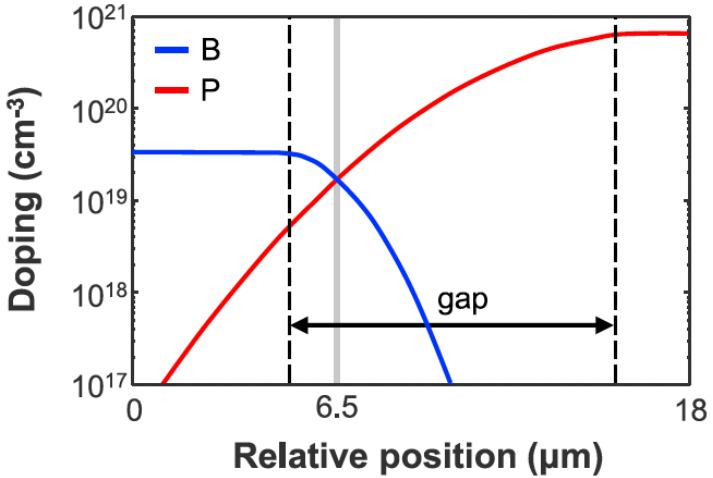




[1] C. Hollemann, et al, *Scien. Rep.* **10**, 1-15 (2020)
[2] R. Santbergen, et al, *IEEE JPV* **7**, 919-926 (2017)

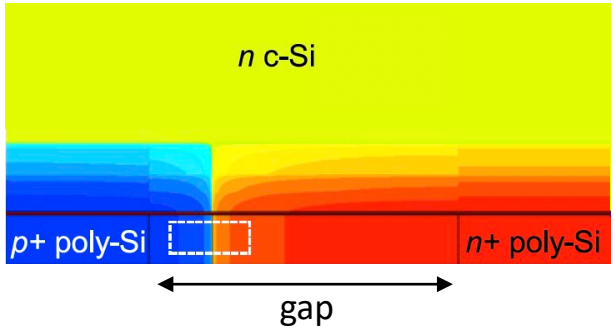
Dopant diffusion and effect of varying gap

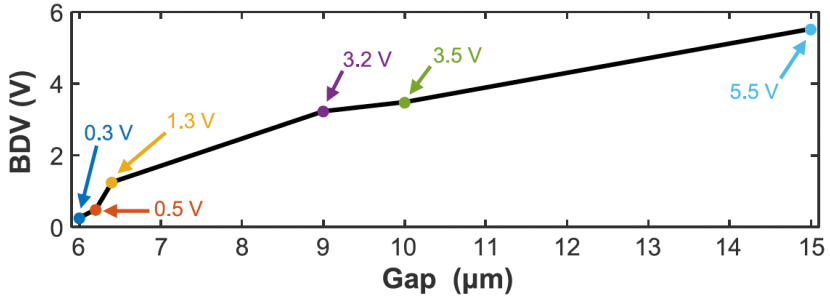


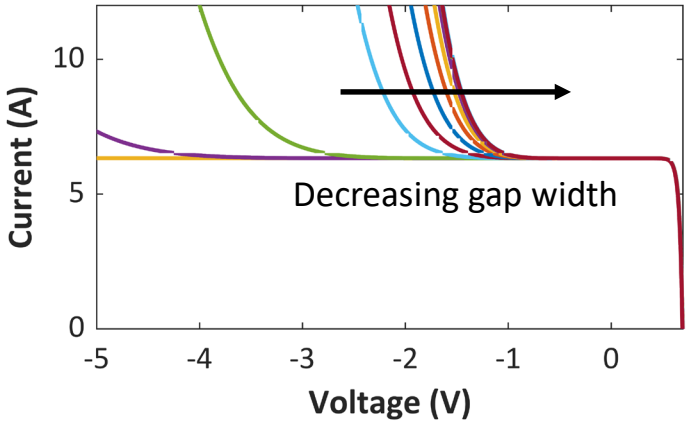


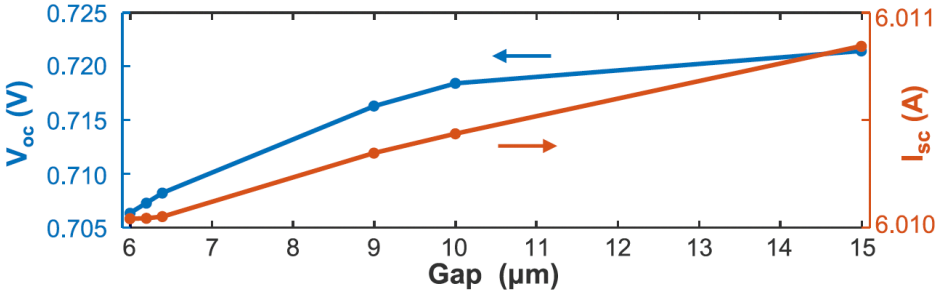
P. Procel, et al, *IEEE JPV* **9**, 374-384 (2019)

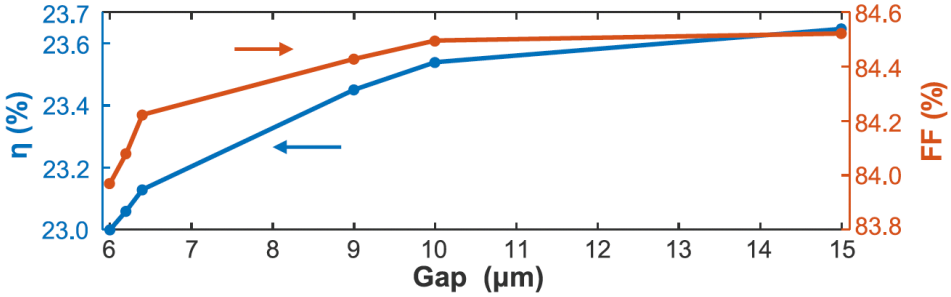
Dopant diffusion and effect of varying gap











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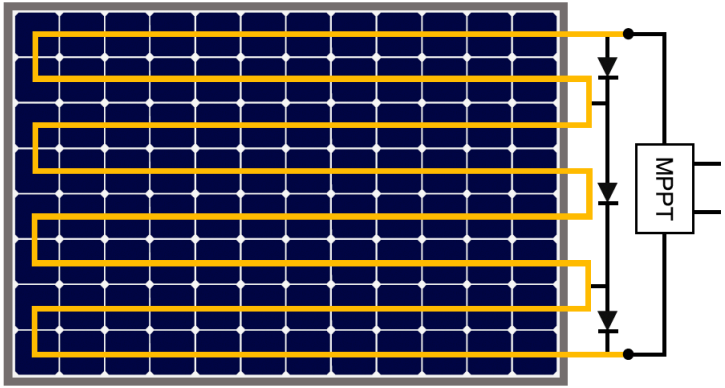
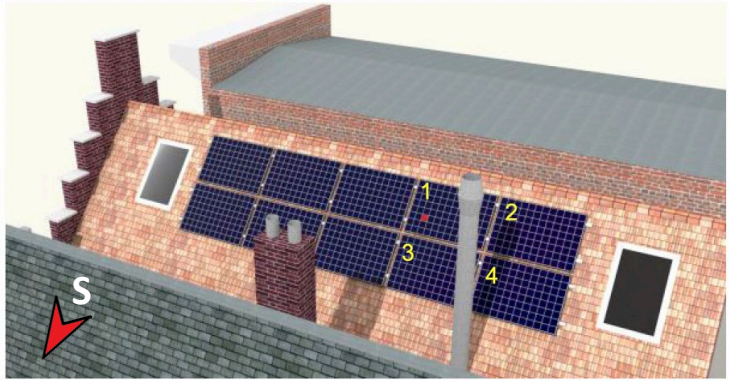
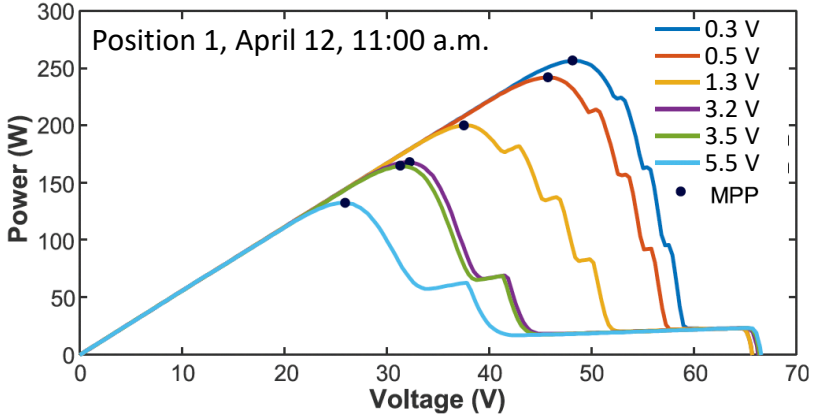
3. Results from outdoors experiments

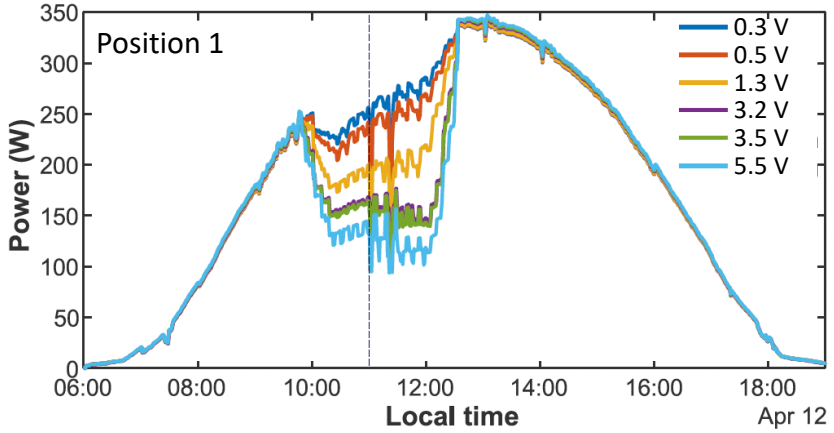
Simulation scenario



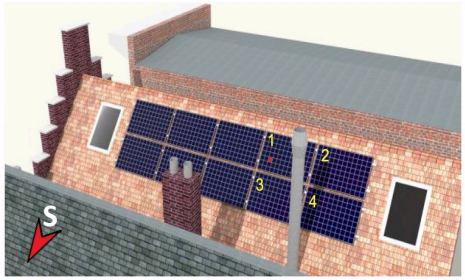


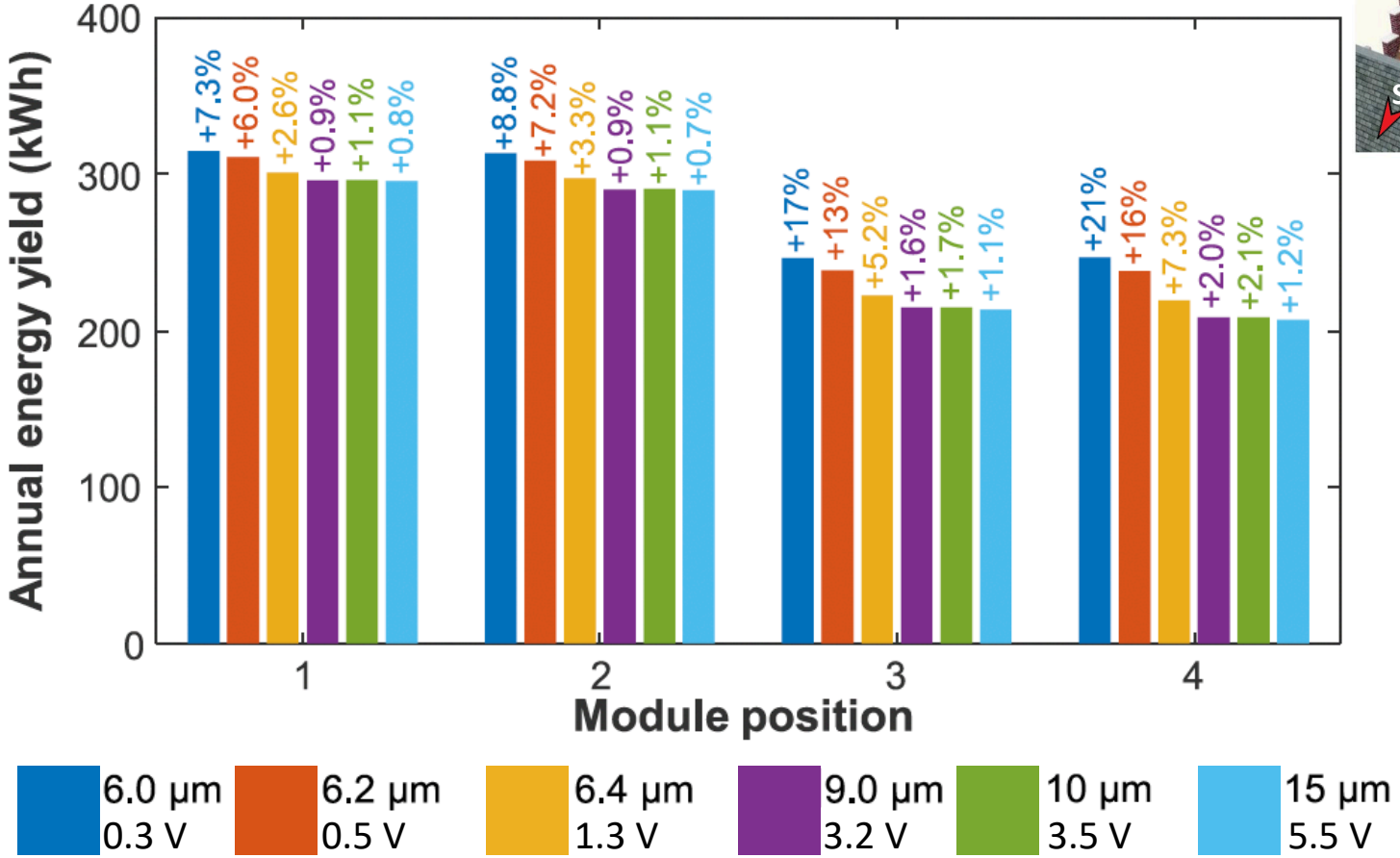
Delft, Netherlands



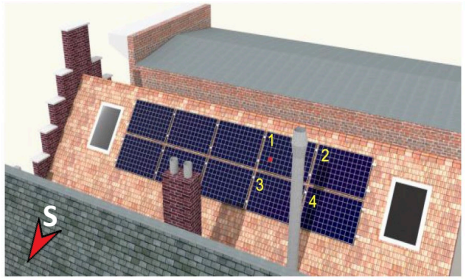


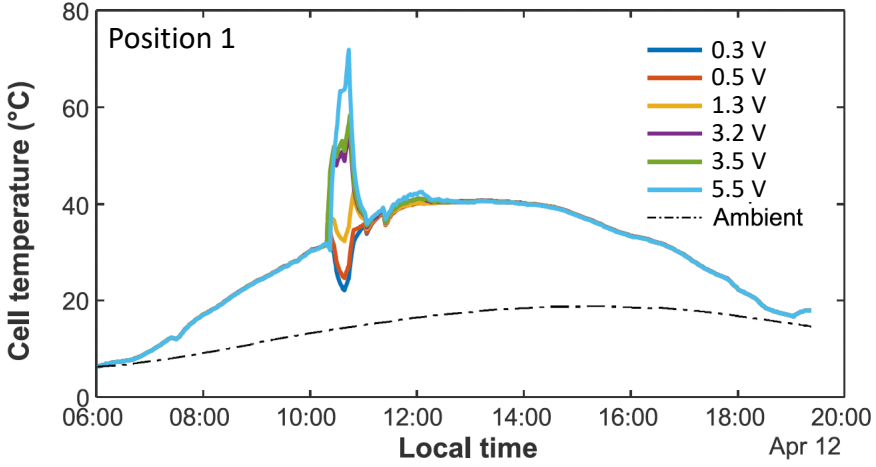
Annual DC energy yield

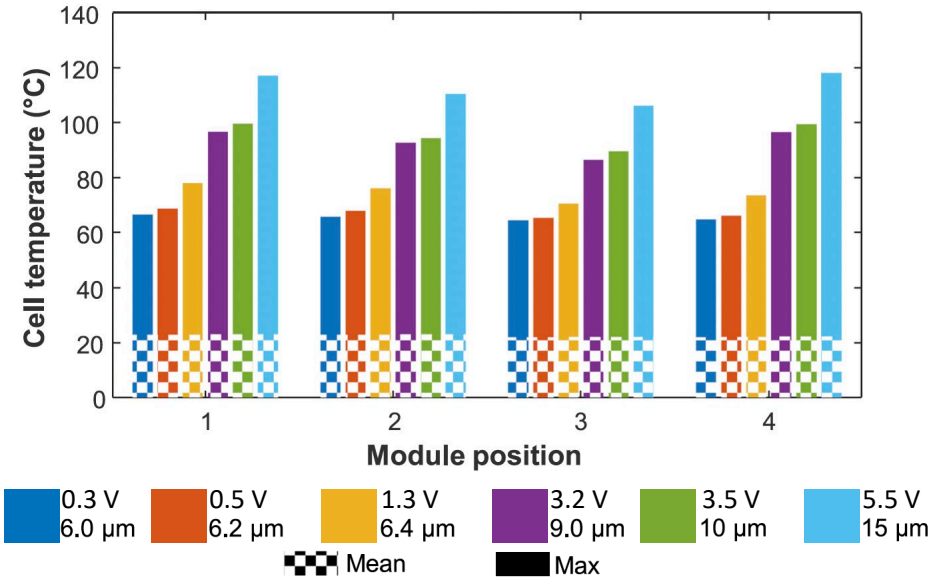




Simulated temperature







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Monitored PV modules

IBC

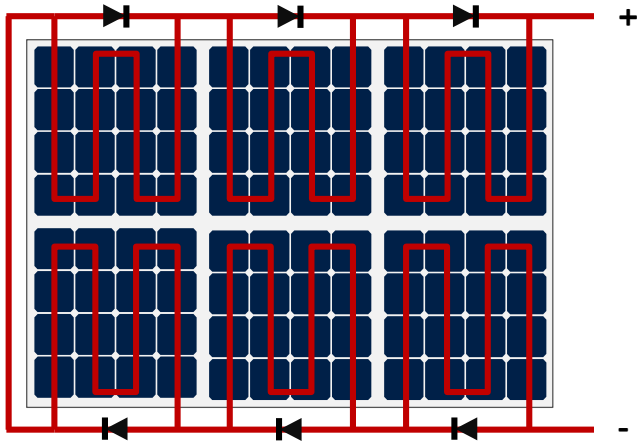
η_{IBC} = 24.8%

$\kappa_{\eta\text{ - IBC}}$ = -0.29%/K

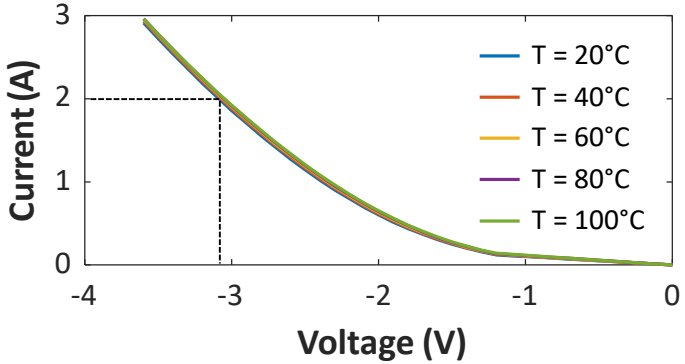
FBC

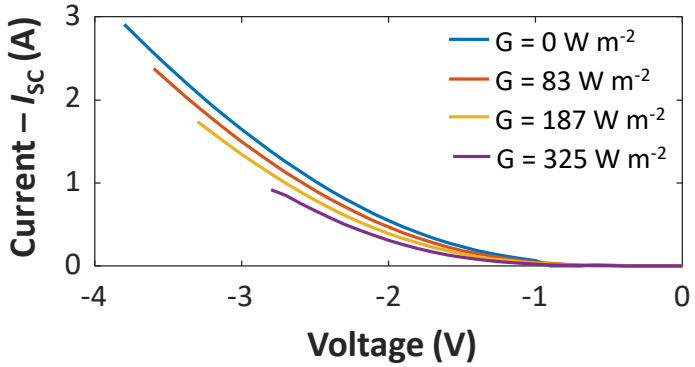
η_{FBC} = 18.1%

$\kappa_{\eta\text{ - FBC}}$ = -0.45%/K

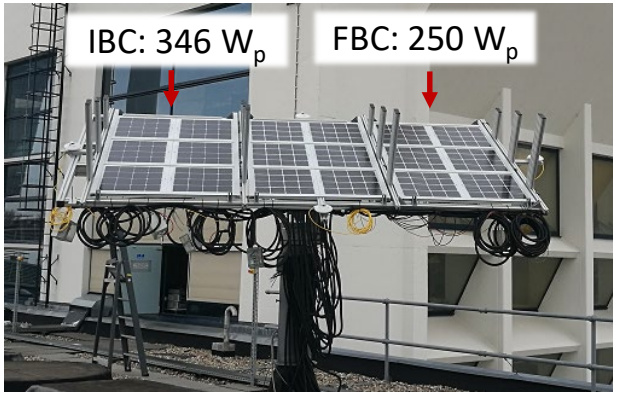


IBC under reverse bias

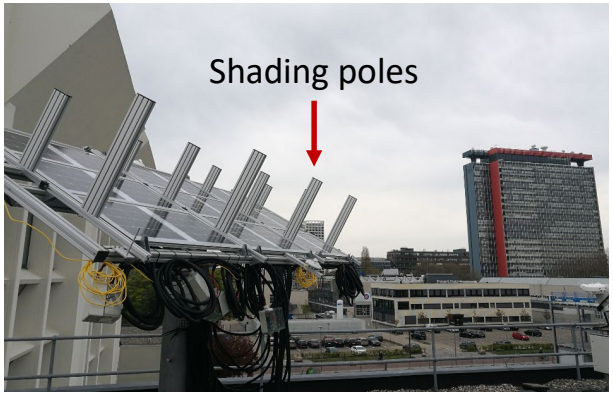


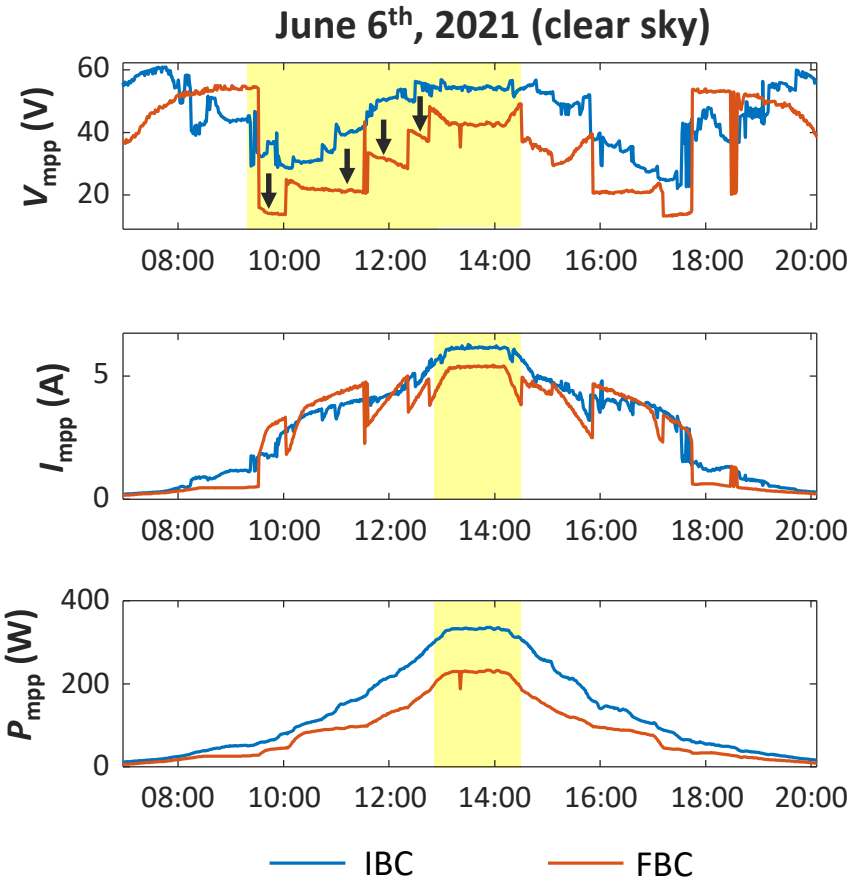


Experimental setup

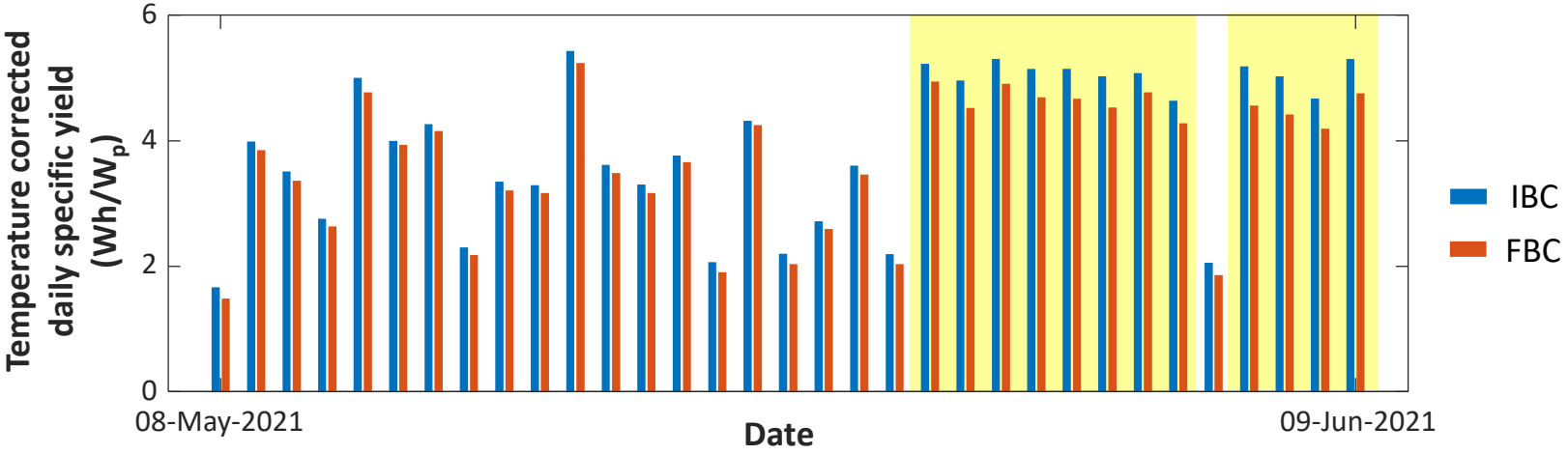


Delft, the Netherlands





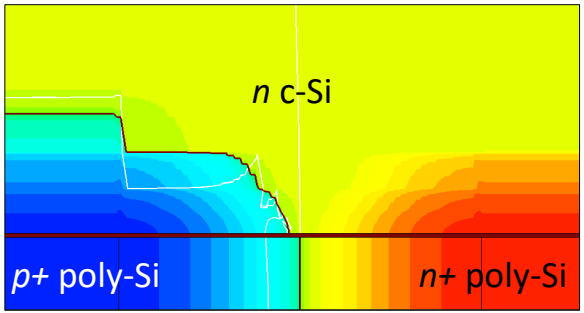
Daily specific yields



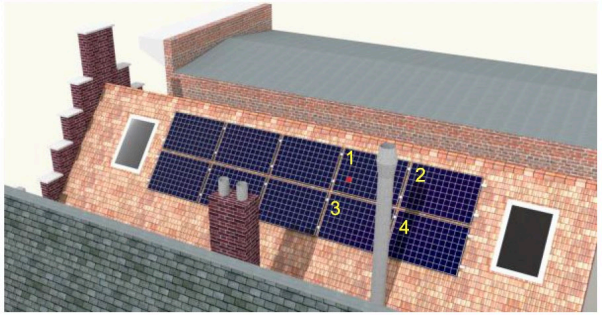
$E_{y\text{ - IBC}}$ = 139.9 Wh/W_p $E_{y\text{ - FBC}}$ = 129.7 Wh/W_p

ΔE_y = + 7.9%

Conclusions



Band-to-band tunneling between BSF and emitter in IBC solar cells



20% energy yield gain with cells with -0.3 V breakdown voltage and partially shaded for 20% of the time

Measured 7.9% increase in specific yield with IBC cells with -3 V breakdown

A. Calcabrini, et al., *Cell Rep. Phys. Sci.* **3**, 101155 (2022)

Thank you for your attention!

TU Delft Institutes

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e-Refinery

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TU Delft Climate Action Programme

PVMD funding

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