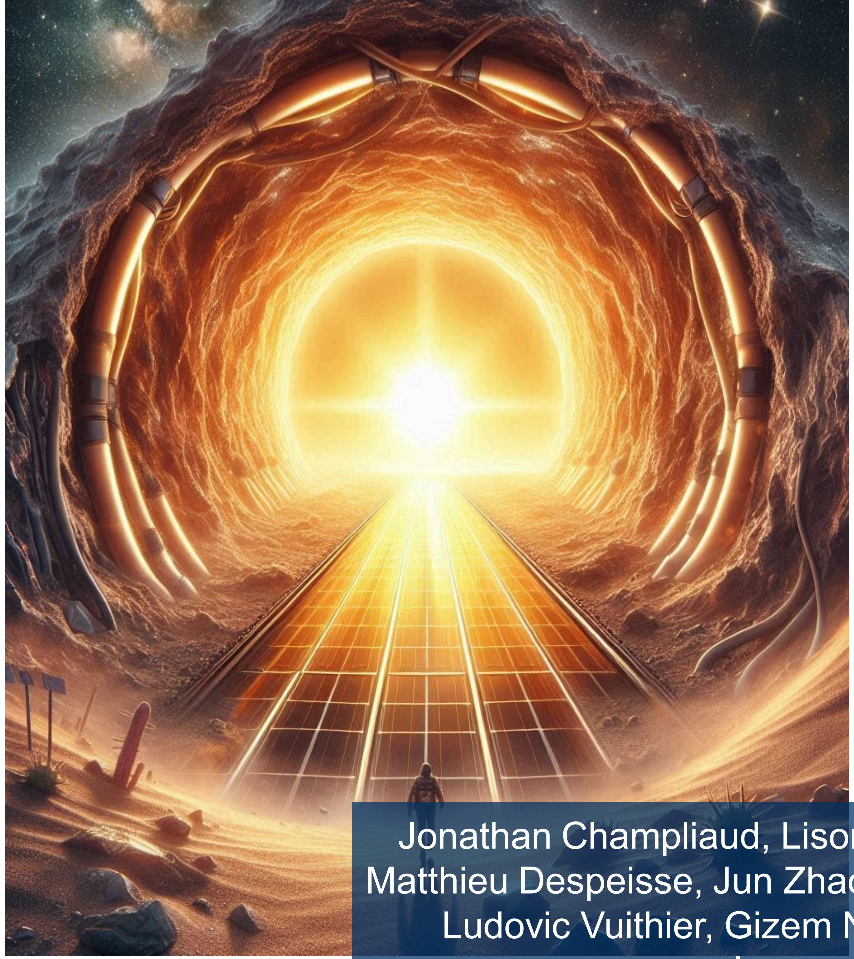

Jonathan Champliaud, Lison Marthey, Loann Baume, Alessandro Virtuani, Matthieu Despeisse, Jun Zhao, Damien Lachenal, Pierre Papet, Till Kössler, Ludovic Vuithier, Gizem Nogay, Rainer Grischke, Florent Sahli, Quentin Jeangros, Bertrand Paviet-Salomon, Christophe Ballif

04.12.2024

TUNNEL IBC HETEROJUNCTION SMARTWIRE MODULES: ILLUMINATING SOLUTIONS

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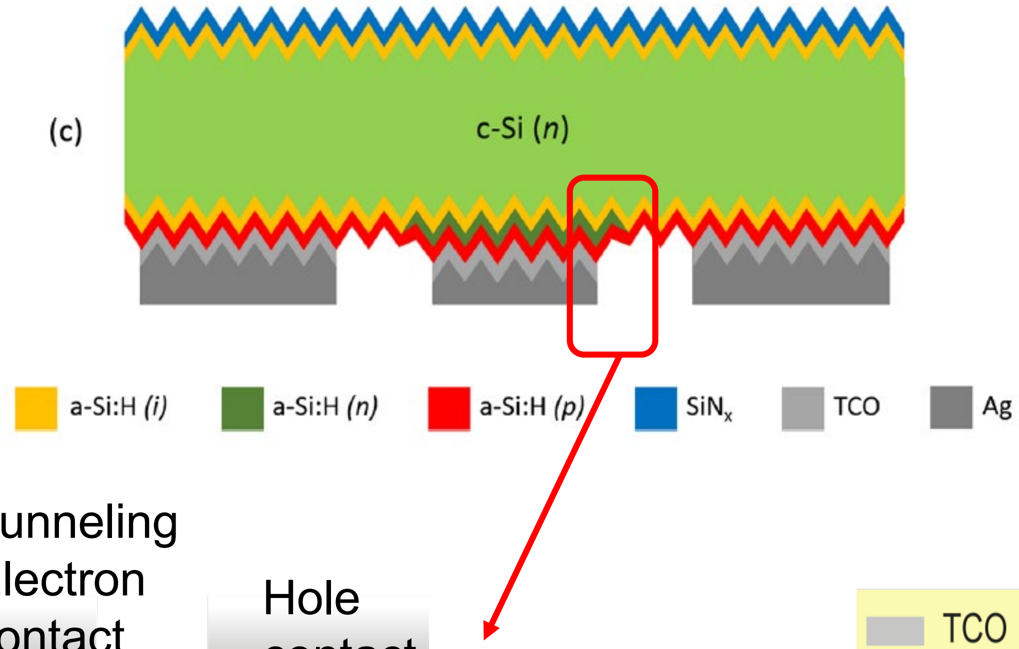
40 YEARS OF INNOVATION

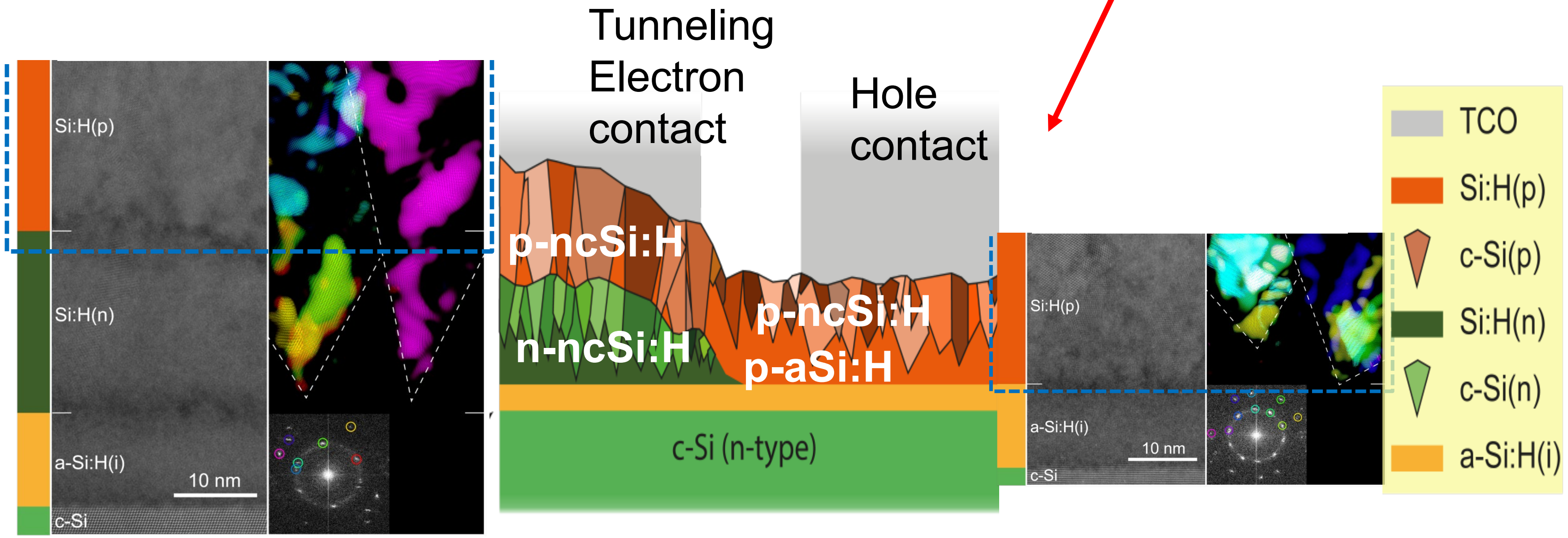
INTRODUCTION

TUNNEL IBC HJT SMARTWIRE TECHNOLOGY

Innovation firstly co-developed at EPFL/CSEM, focus on simple process flow from the development start:

Based on smart engineering of thin film silicon layers properties: no patterning of p-layer, rely on materials different properties depening on substrate on which it grows ! MAGIC ! ☺





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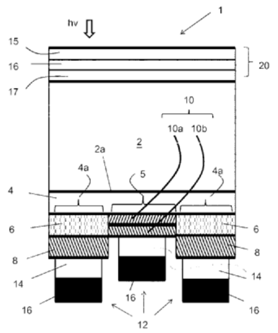
TUNNEL IBC HJT SMARTWIRE TECHNOLOGY

- Performance > 25% demonstrated in 2019 at CSEM, industrial potential > 26%
- Industrial process: 10 process steps only, only 2 patterning steps, 1 alignement (other concepts 2 times more)

Patented (incl. CN)

Title
[EN] PHOTOVOLTAIC DEVICE AND METHOD FOR MANUFACTURING SAME
[ZH] 光伏器件及其制造方法



Abstract

[EN] A photovoltaic device is proposed comprising a silicon-based substrate (2) having a p-type or n-type doping, with an intrinsic buffer layer (4) situated on said substrate. A first silicon layer (6) ofa first doping type is situated on predetermined regions (4a) of the intrinsic buffer layer. The first layer has interstices (5) between said predetermined regions (4a). The first silicon layer comprises at least partially a microcrystalline layer at its side away from the substrate. A microcrystalline silicon layer (8) of a second doping type is situated on said first silicon layer (6). A thirdsilicon layer (10) of the second doping type is situated on said intrinsic buffer layer at the interstices, the third silicon layer being amorphous at its side facing said silicon-based substrate andcomprising an at least partially microcrystalline layer portion to the side away from the intrinsic buffer layer.
[ZH] 提出了一种光伏器件，该光伏器件包括具有p型掺杂或n型掺杂的硅基衬底(2)，其中本征缓冲层(4)位于所述衬底上。第一类型掺杂的第一硅层(6)位于本征缓冲层的预定区域(4a)上。第一硅层具有处于所述预定区域(4a)之间的间隙(5)。第一硅层在其远离衬底的这一侧至少部分地包括微晶层。第二类型掺杂的微晶硅层(8)位于所述第一硅层(6)上。第二类型掺杂的第三硅层(10)在位于所述本征缓冲层上的间隙处，第三硅层在其面对所述硅基衬底的这一侧是非晶的并且在远离本征缓冲层的这一侧至少部分地包括微晶层部分。

Related patent documents
EP3163632 EP3371833 US20180309010 JP2018532273 WO/2017/076832 IN201817014641

Published (incl. Nature Energy - 2017)

nature › nature energy › articles › article

Article | Published: 24 April 2017

Simple processing of back-contacted silicon heterojunction solar cells using selective-area crystalline growth

Andrea Tomasi, Bertrand Paviet-Salomon, Quentin Jeangros, Jan Haschke, Gabriel Christmann, Loris Barraud, Antoine Descoeudres, Johannes Peter Seif, Sylvain Nicolay, Matthieu Despeisse, Stefaan De Wolf & Christophe Ballif

Transferred to Meyer Burger Research

MEYER BURGER

Lot of innovations and improvements brought by MBR in Industrialization :see talk of G. Nogay

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TUNNEL IBC HJT SWCT

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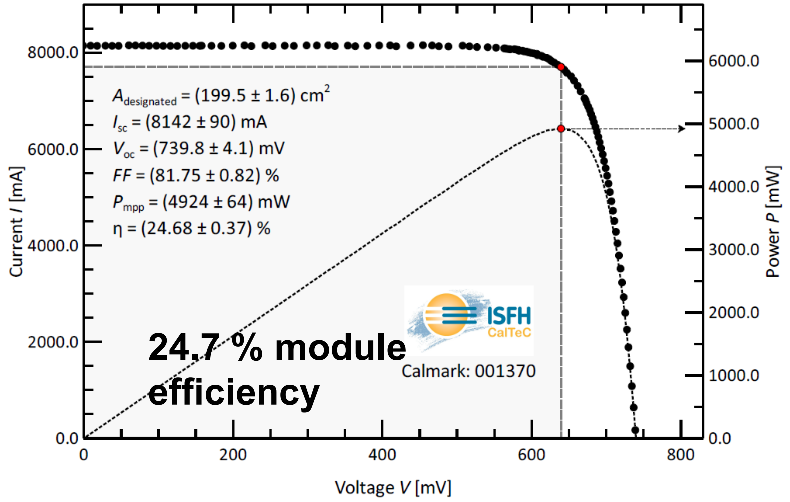
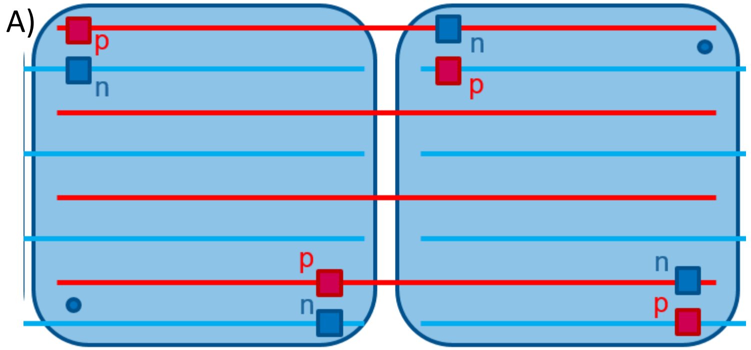
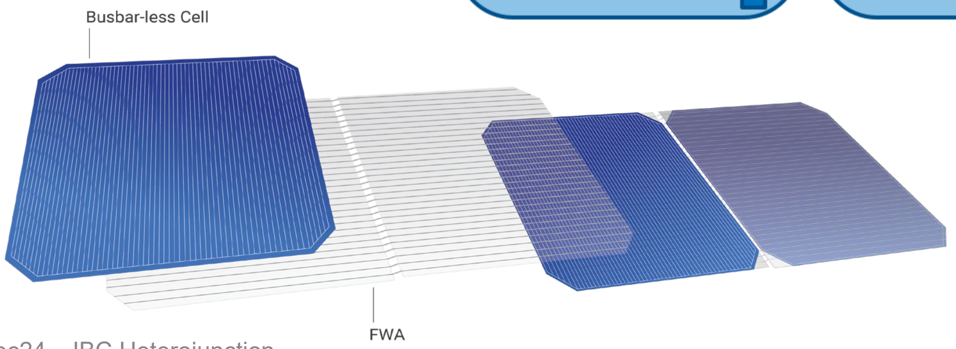
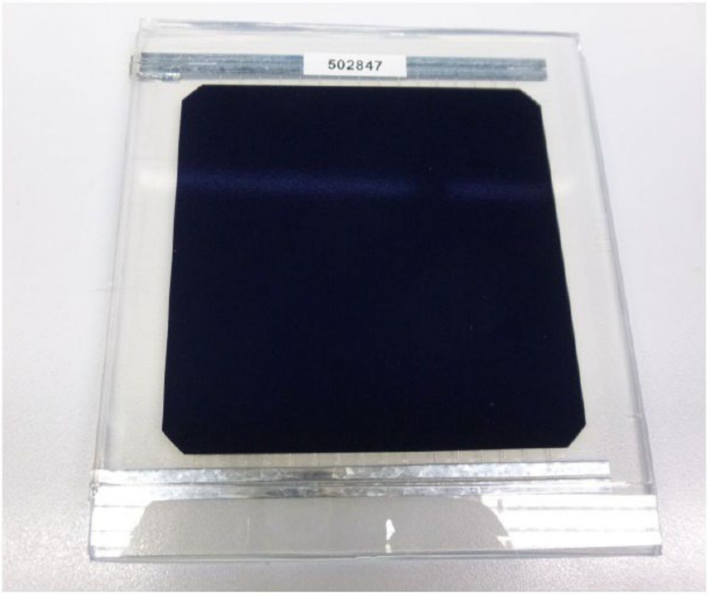
Radically new rear electrode and cell back-end processes developed in past years for SmartWire^{TM} contacting (D. Lachenal / nPV workshop 2023):

- Ultra low Ag consumption / no plating
- Indium free based electrodes
- 5x filled patents









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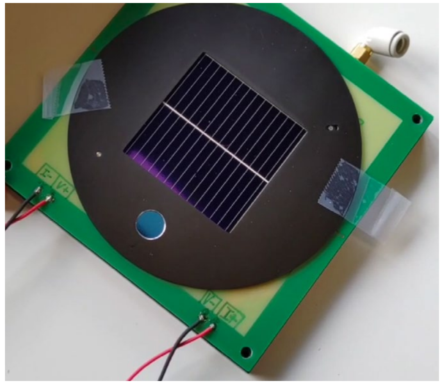
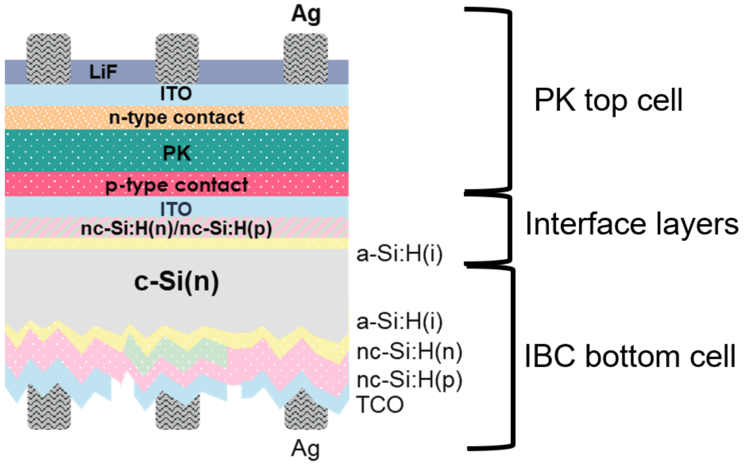
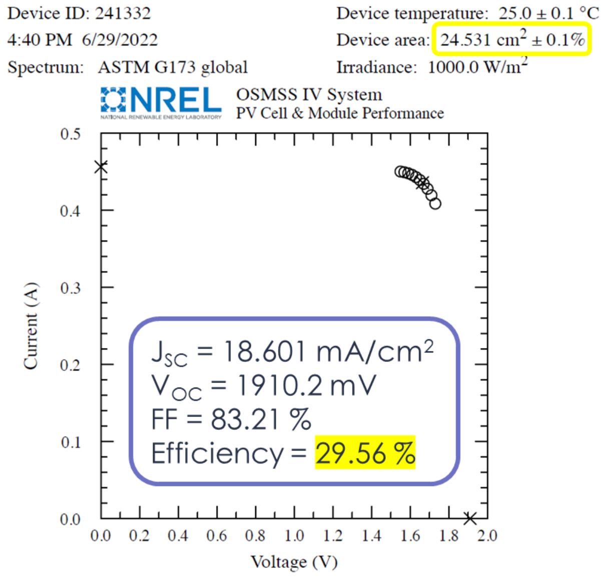
TUNNEL IBC HJT & PK: 3TT IBC/PK

- CSEM new developments:
- 3 Terminals Tandem PK





Highlights:
- 3TT solar cell with a size of 24.5 cm^2 certified at **29.56%** efficiency in 2TT configuration



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OBJECTIVES

OBJECTIVES

- **Combination of tunnel IBC-HJT cell with the SmartWire technology in Glass-Backsheet (GBs) module Bill of Materials (BoM)**

- Goals of tests performed:
  - Achieve high reliability for module design
  - Detection of potential failure modes and understanding
  - Helping support to mass production

- Evaluation of design variation:
  - Reduction of Critical Raw Material (CRM)
  - Reducing silver (Ag) content
  - Integration of solution without aluminum backsheet
  - Reduction of encapsulant consumption in module manufacturing

RELIABILITY: IEC EXTENDED TESTS

IEC EXTENDED TESTS

❑ Extended tests goals:

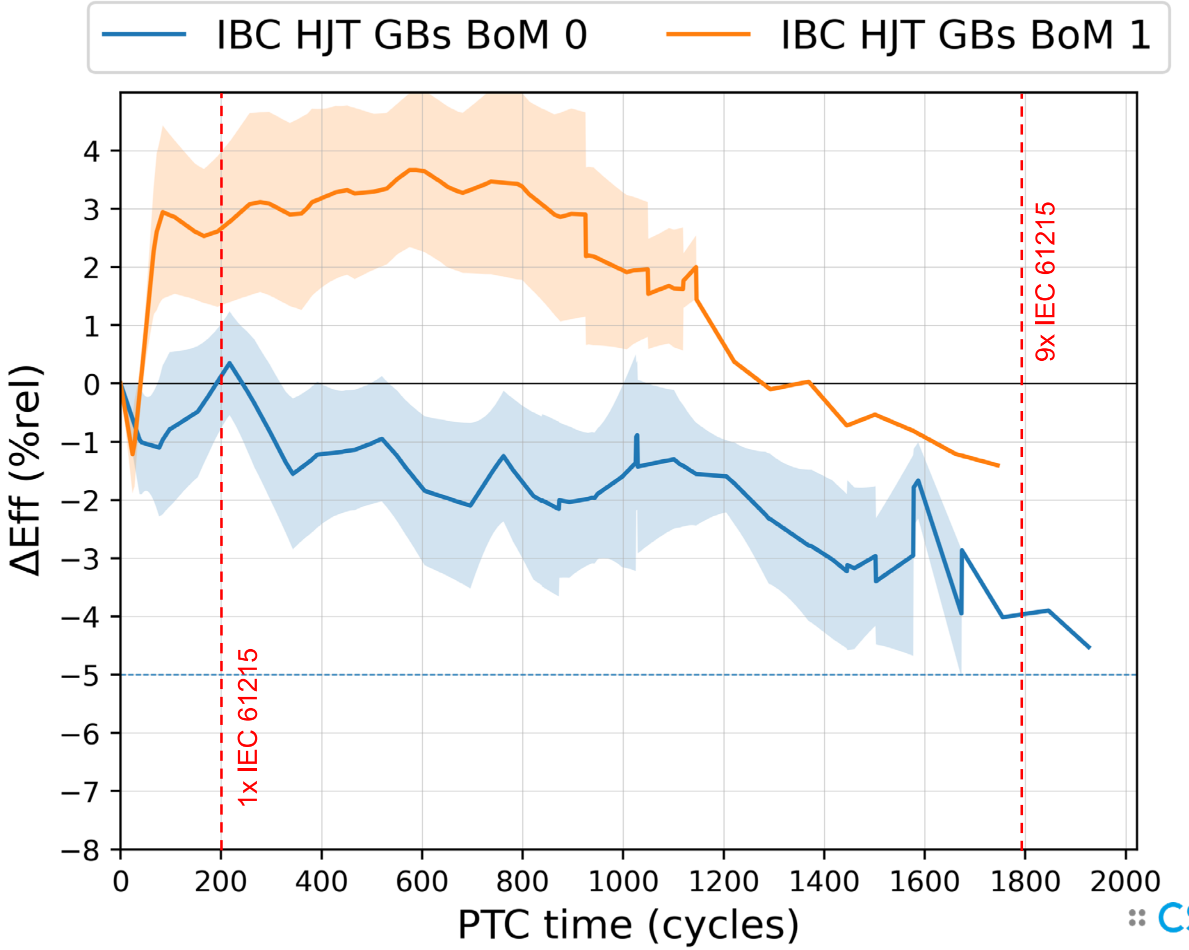
Detect any unforeseen critical failure modes due to the cell and module technologies.

→ Mini-modules of 1 or 2 half cells in Glass-Alu-Backsheet configuration

→ 2 BoMs will be presented

Thermal cycling (TC)

- -40°C → 85°C, + current injection
- Extended TC → **1800 cycles**
- **9x** IEC 61215 required cycles



❑ Conclusion:

- Equivalent to more than 2x 25 years of solder fatigue
- Good resistance to thermal stress

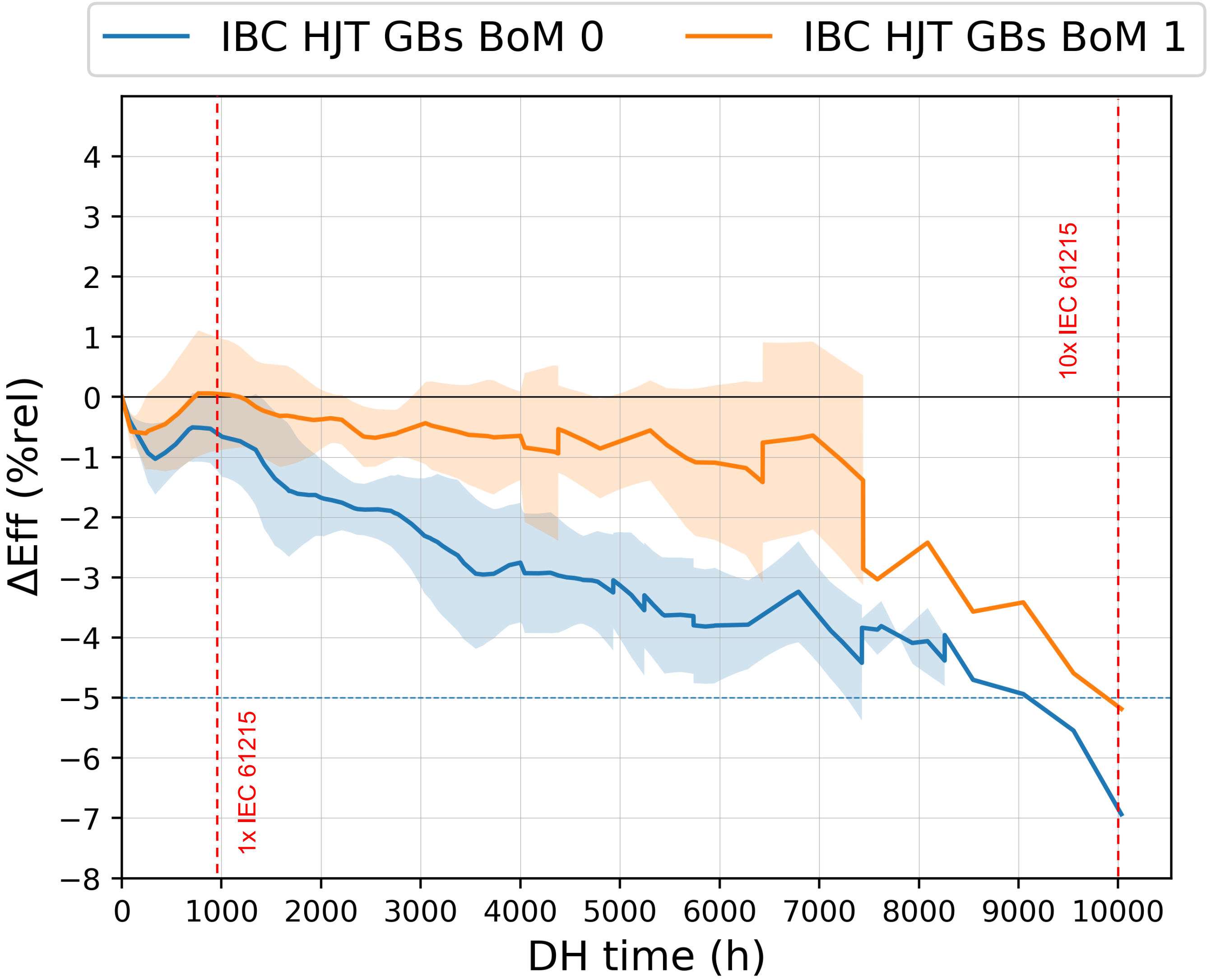
IEC EXTENDED TESTING

Damp heat (DH)

- 85°C, 85% RH
- Extended DH → 10 000 hours
- **10x** IEC 61215 required time

❑ <u>Conclusion</u>:

- No sudden or critical issue observed even by extended DH test
- Not representative of outdoor conditions
- Very low moisture sensitivity



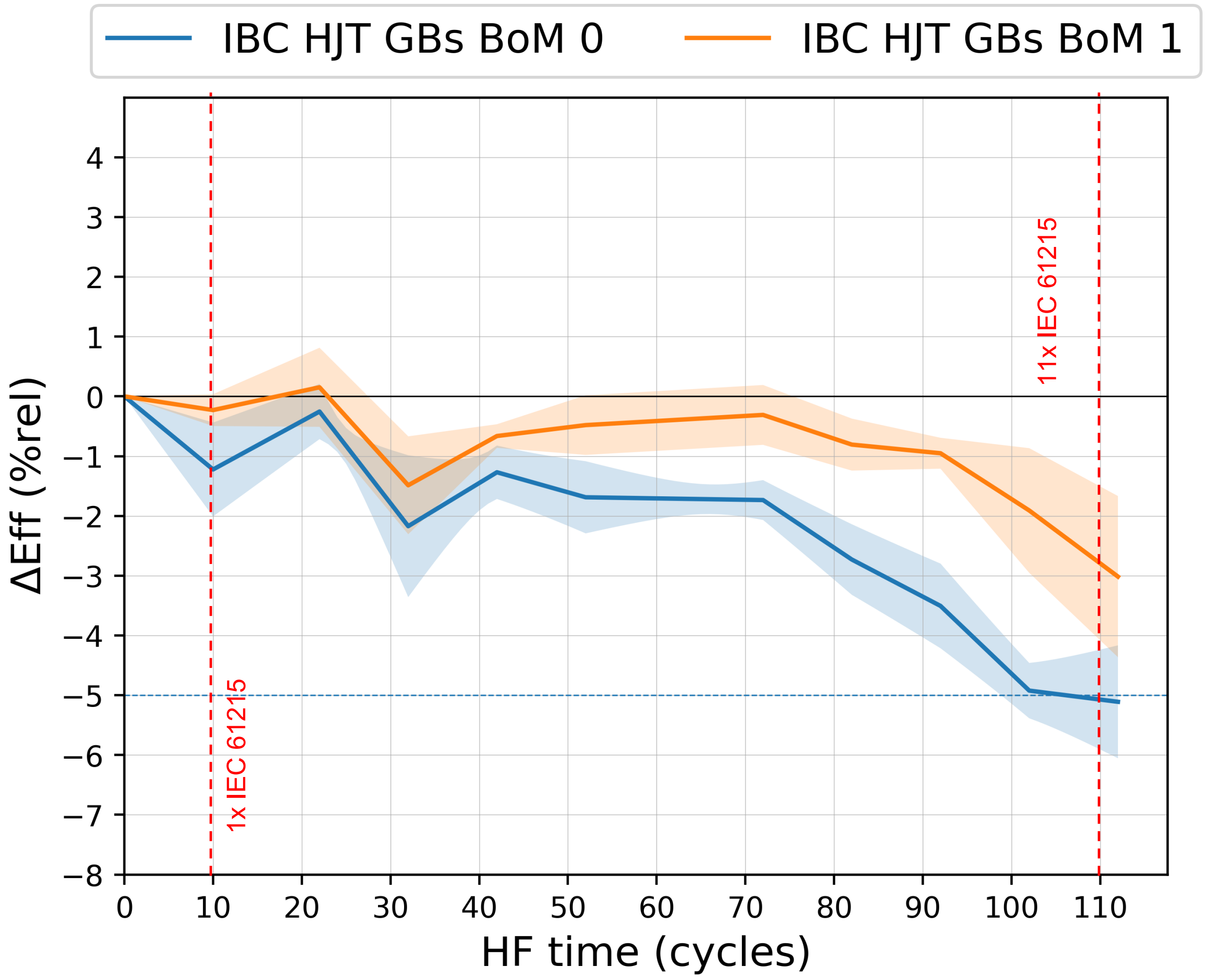
IEC EXTENDED TESTING

Humidity freeze (HF):

- +85°C, 85%RH → -40°C
- Extended HF → **110 cycles**
- **11x** IEC 61215 required cycles

❑ <u>Conclusion</u>:

- Good resistance to Hight T°C combined with high RH followed by negative T°C



SEQUENTIAL TESTS

SEQUENTIAL RELIABILITY TESTS

- Goal:
  - Extended test is not sufficient → apply of sequential tests to detect any unforeseen critical failure modes.
  - Why?
    - New IBC cell technology never tested before
    - SmartWire + IBC is not conventional
- CSEM applied its own sequences based on IEC standards
  - Problem → How to visualize results of such sequential tests?

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SEQUENTIAL RELIABILITY TESTS

❑ <u>Data visualization:</u>

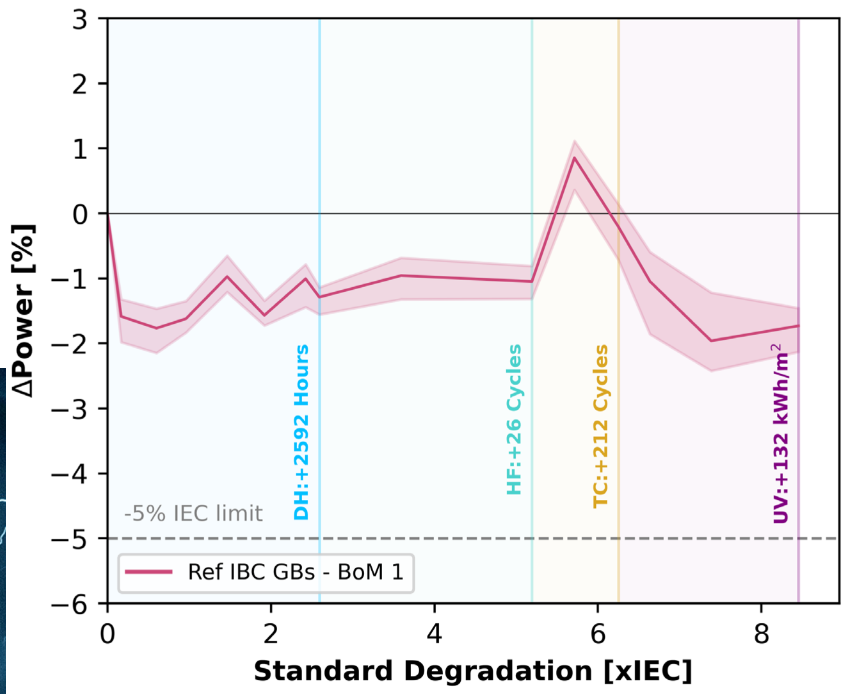
- Normalization of all degradation in “IEC scale”
  - → be cautious with interpretation, every test has its own degradation time ⚠️
- For better visualization, a color scale is used

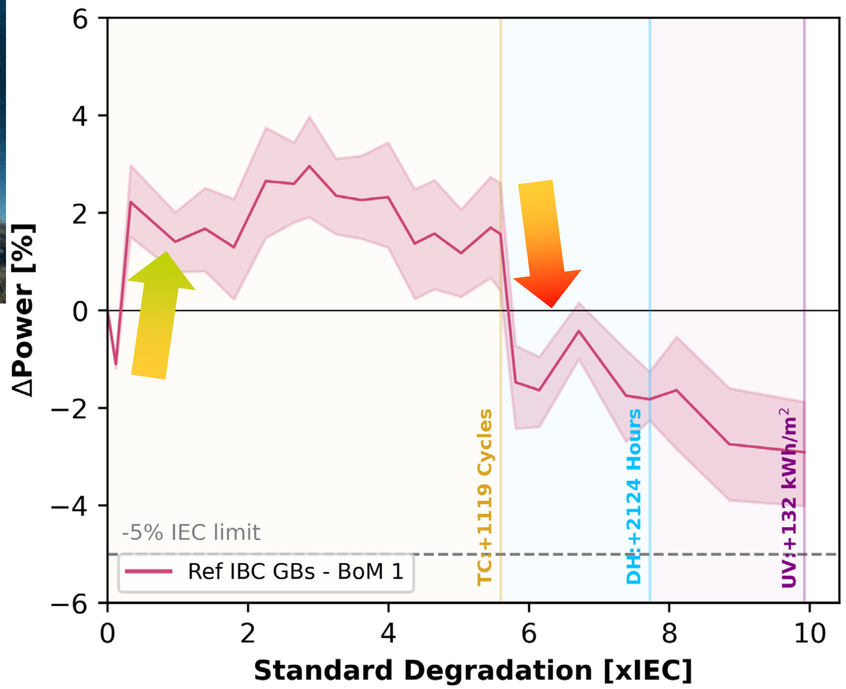
STD IEC 61215:
- TC = 200 cycles
- DH = 1000H
- UV = 60kwh/m2
- HF= 10 cycles

- In each sequence the real degradation time is written

- Tests performed on Ref BoM 1

❖ **Very low degradation! → Highlander Modules**

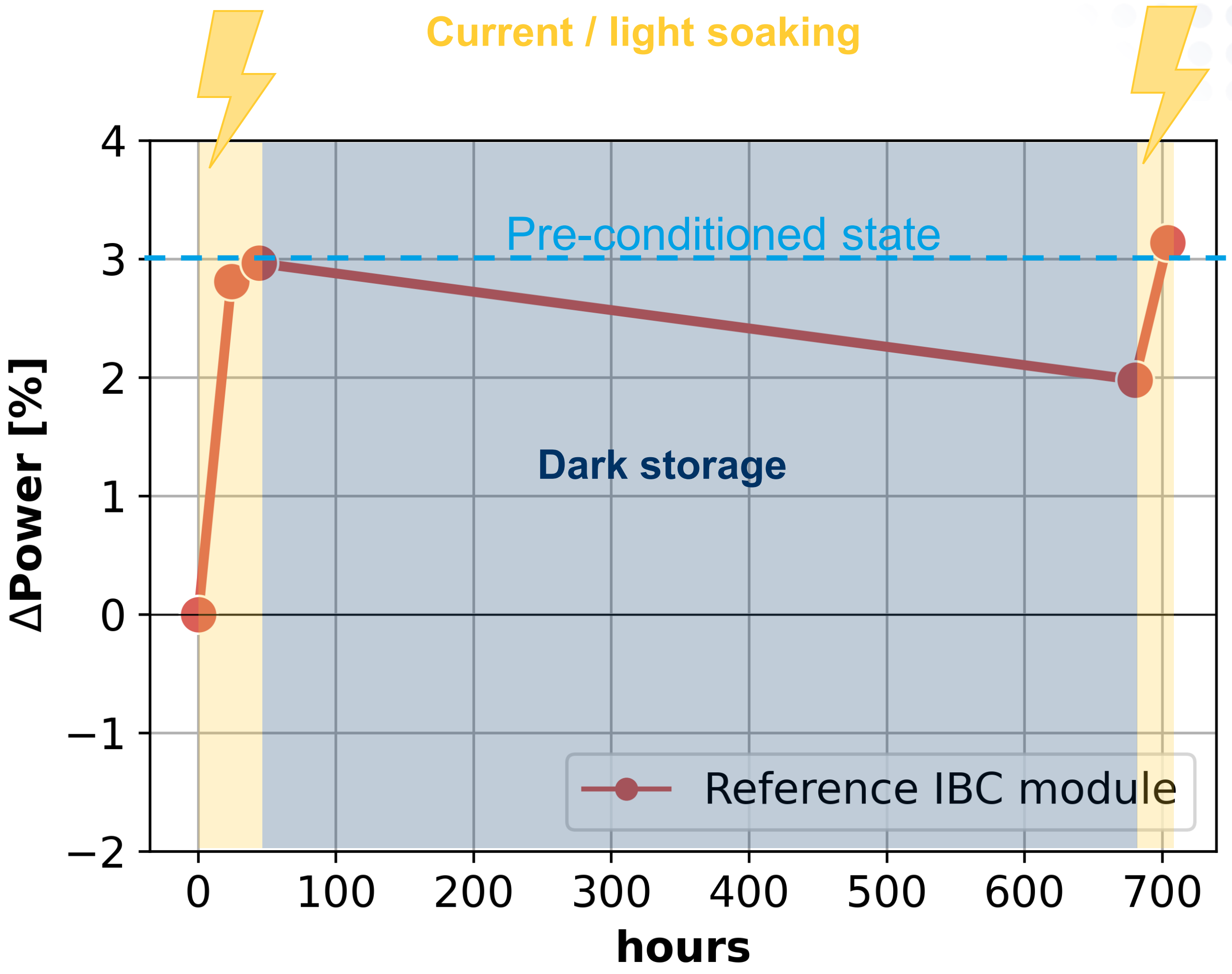




IBC TECHNOLOGY METASTABILITY

- Metastability of the technology:
  - Rapid gain in performance with light or current soaking (as seen in TC)
  - Loss of this gain after prolongated storage in the dark

- Need to perform pre-conditioning



NEW DESIGNS

DESIGN VARIATION

Cell innovation

- Goals:
  - Reducing cost at cell level
  - Increase cells throughput
- Approaches:
  - Low Ag metallization paste
    - **3.3mg/Wp**
    - lower than TopCon
  - Higher print speed

Module innovation:

- Goals:
  - Reducing module cost
  - Reducing module environmental impact
- Approaches:
  - Critical Raw Materials (CRM) consumption reduction
  - No aluminum backsheet
  - Encapsulant reduction

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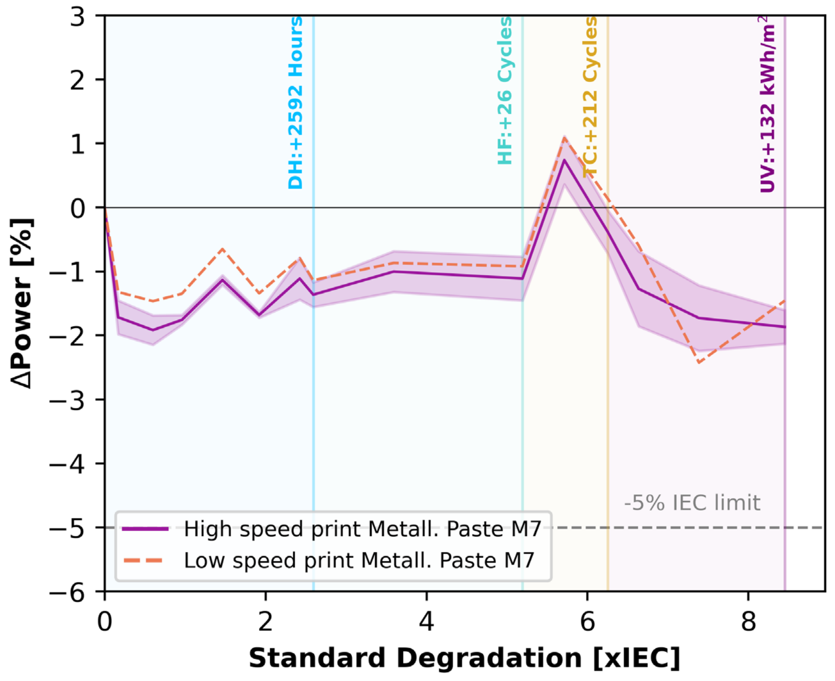
CELL DESIGN INNOVATION

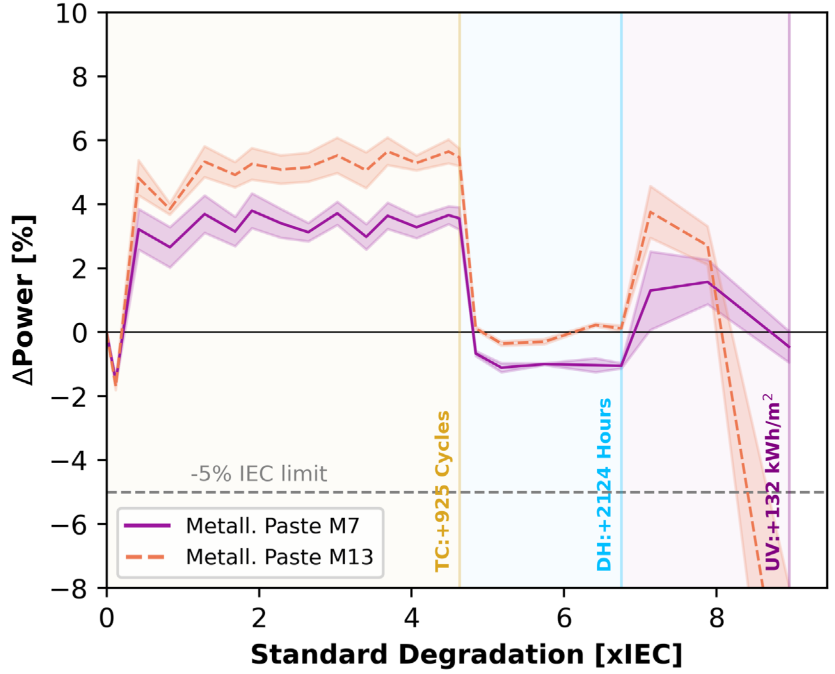


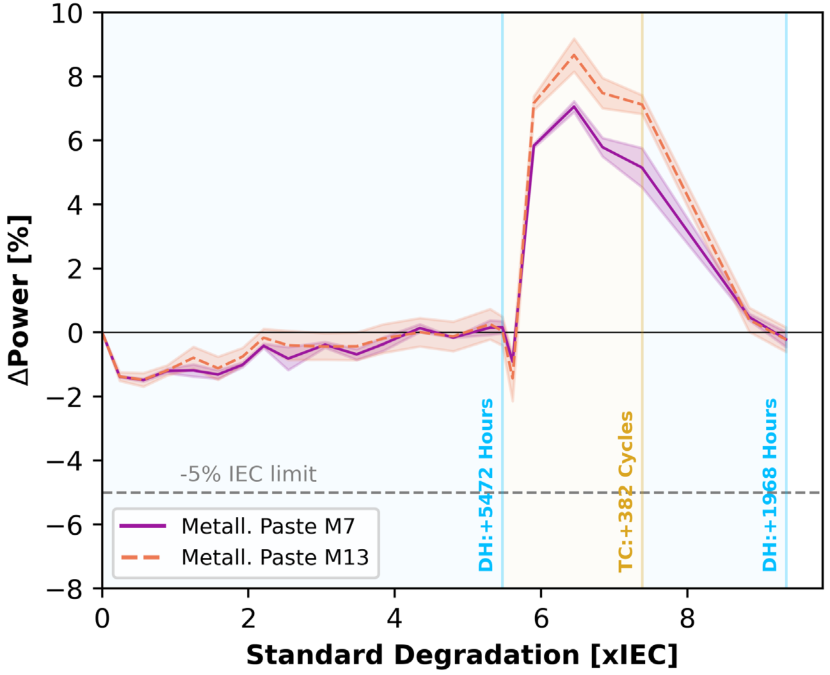
- Validation of higher print speed process
- Validation of lower silver content in tunnel IBC HJT

- Not all metallization pastes can pass sequential tests

❑ Cell processes and materials can have a high impact on module reliability

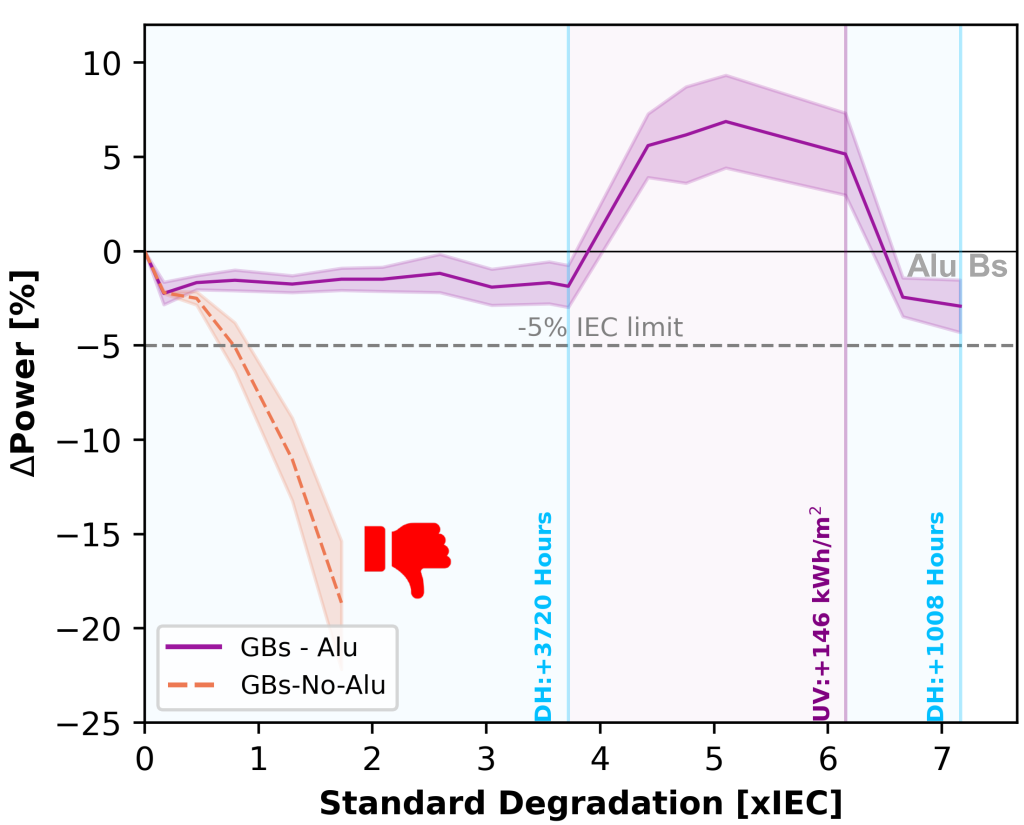
Paste name	Ag-%
Ref	95
M7	47
M13	46

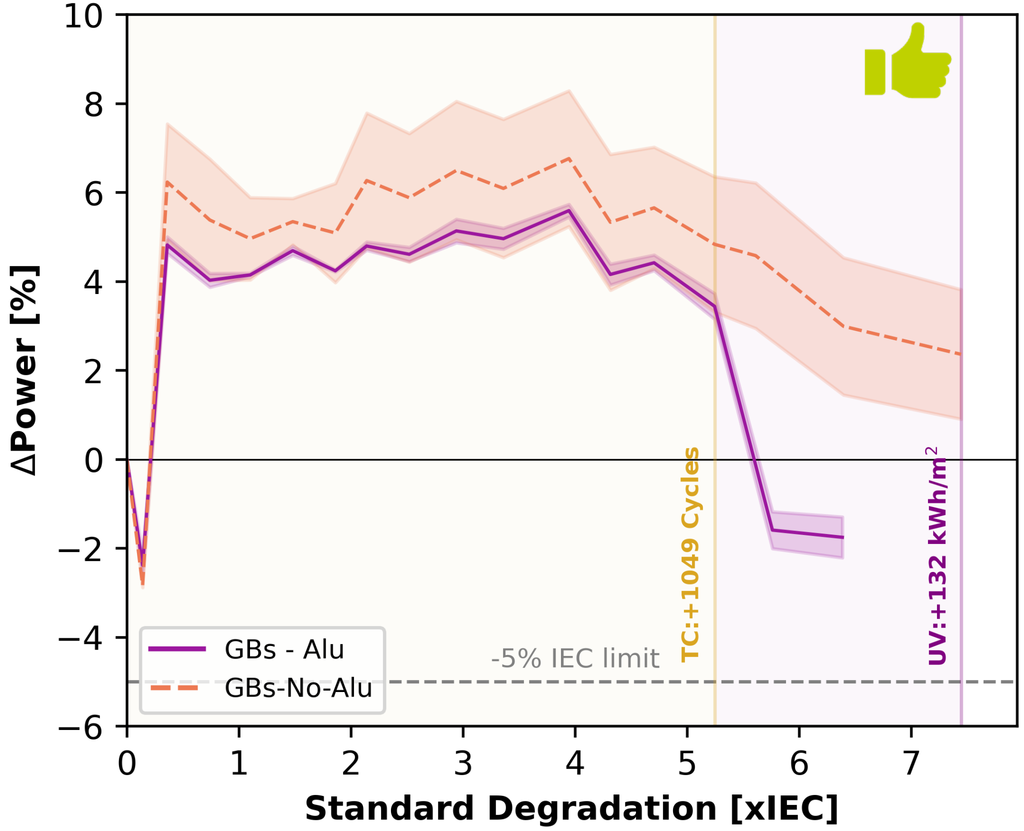




MODULES INNOVATION: BACKSHEET

- Conclusions:
  - No-aluminum backsheet combined with low Ag metallization paste:
    - DH: not OK
      - Metallization / interconnection humidity sensitivity
    - TC + UV: OK





CONCLUSION

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- Back-contact technology:
  - More efficient
  - Integrated bypass (low breakdown voltage)
  - Better aesthetics
- Tunnel IBC HJT:
  - Higher reliability than conventional technologies (coming from device and SW interconnection)
  - Fewer process steps
  - Low silver content
  - Good potential for industrialization

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AKNOLEDGEMENTS

MEYER BURGER

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Federal Office of Energy SFOE

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  - https://pilatus-project.eu/
- **Meyer Burger:**
  - **Meyer Burger Reseach:**
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    - Pierre Papet
    - Kill Kössler
    - Ludovic Vuithier
  - **Meyer Burger Switzerland:**
    - Gizem Nogay
    - Rainer Grischke
- **CSEM:**
  - Jonathan Champliaud
  - Lison Marthey
  - Loann Baume
  - Alessandro Virtuani
  - Matthieu Despeisse
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  - Quentin Jeangros
  - Christophe Ballif

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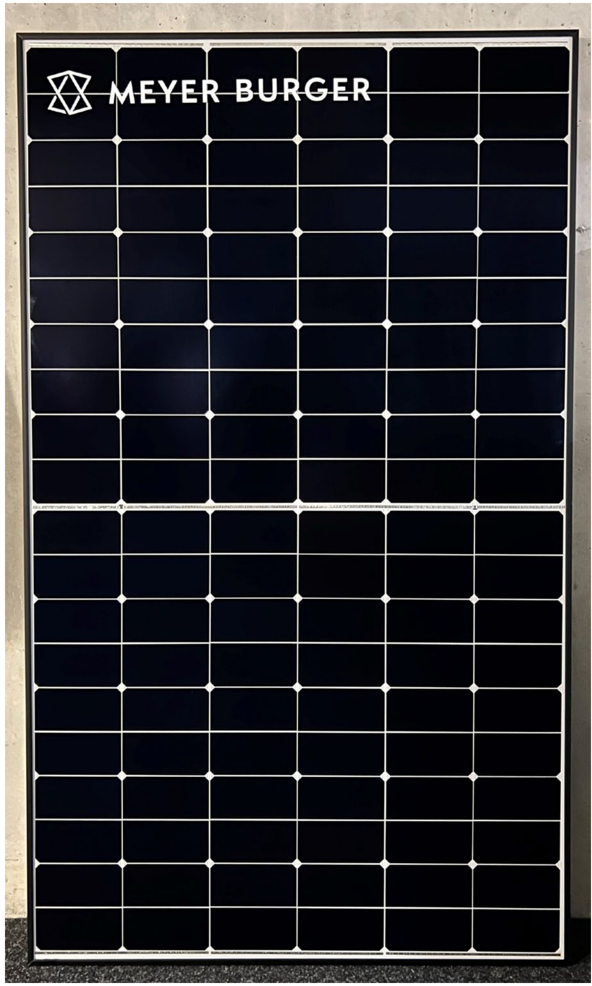

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