Back-contact cSi-PSK tandem technology

Melvin ten Kate | BCworkshop 2025

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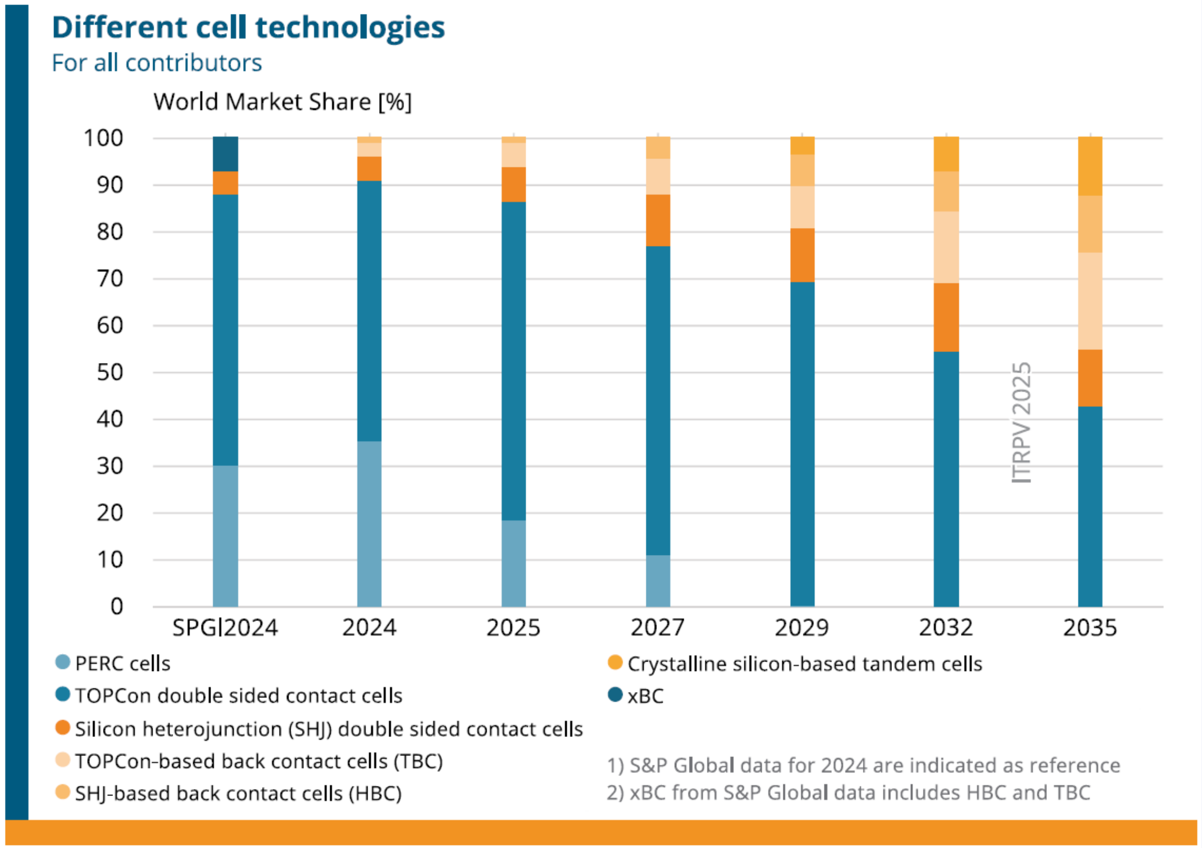
Outline

- Introduction
  - Motivation
  - Metal wrap-through (MWT) technology
- MWT perovskite on ohmic substrate cells
- MWT tandem cells
- Module integration
- Conclusions

Motivation



Market shares for different technologies. S&P Global (PGI) data for 2024 are indicated as reference.
Source: International Technology Roadmap for PV (ITRPV) 2024 results.

Back-contact (BC) solar cells

- Growth in back-contact technology
- Improved energy performance
- Flexibility in module design
- Improved aesthetics

cSi-PSK tandem solar cells

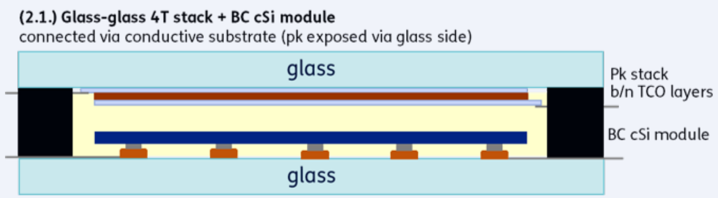
- Emerging technology
- Enabling efficiencies over 40%

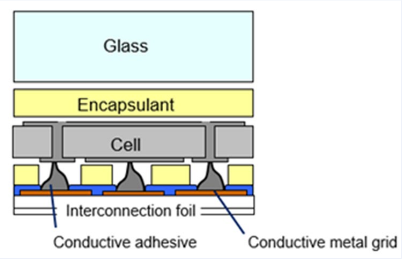
Bring the advantages of back-contact technology to tandem

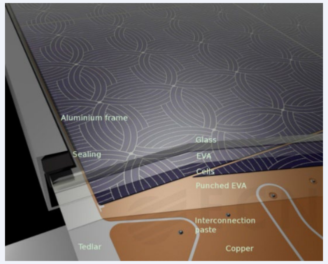
Back - contact technology for tandem

4T tandem

- 4T tandem consisting of perovskite cell and BC cell (e.g. IBC)
- TNO explores advantages of 4T BC tandem modules based on use of light transmitting conductive substrate



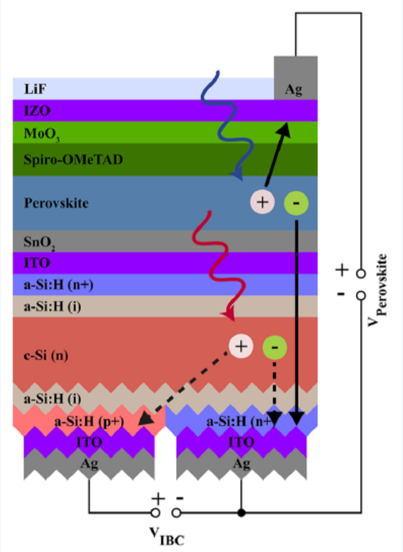


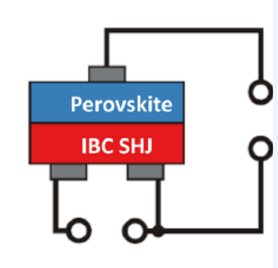


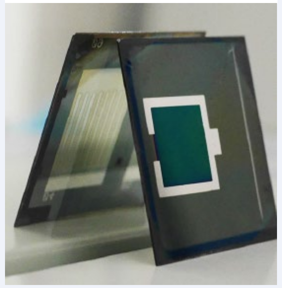
V. Rosca; Hybrid Tandem Module Technology; Sunchain 2025 (Den Bosch).

3T tandem

- 3T tandem consisting of perovskite top cell and BC bottom cell (e.g. IBC)



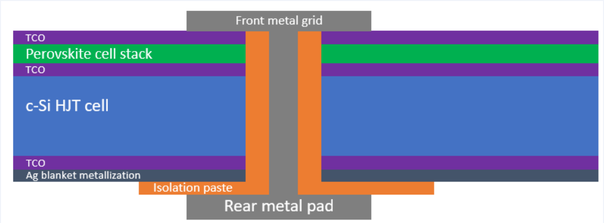


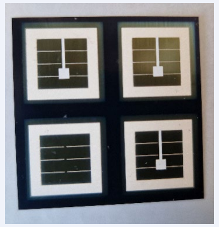


P. Tockhorn et al.; ACS Appl. Energy Mater. 2020, 3, 1381-1392.

2T tandem (MWT)

- 2T tandem consisting of perovskite top cell and c-Si bottom cell
- Application of metal wrap-through (MWT) technology to obtain a BC device with all terminals at the rear side

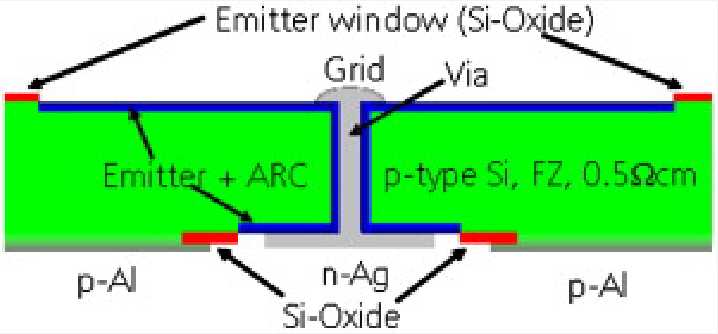




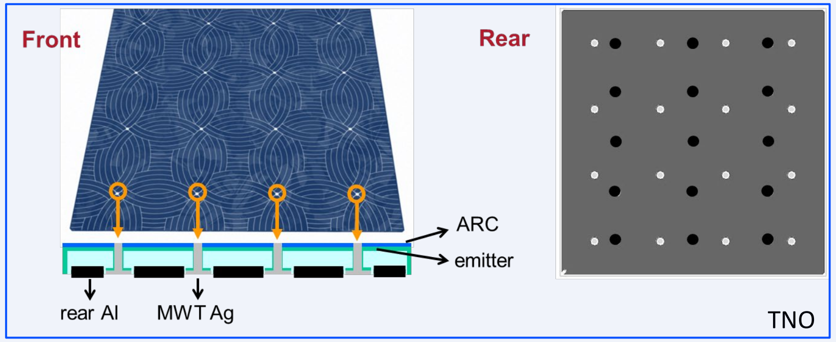
Focus of this presentation

Metal wrap -through (MWT) technology

- MWT is a known back-contact technology that has been applied for various c-Si cell technologies, like SHJ and PERC.
- A through-hole is made in the wafer, allowing to wrap the front metallization through the wafer to a contact pad at the rear side of the device.
- Depending on the architecture, some form of isolation at the via may be required to prevent a shunt.



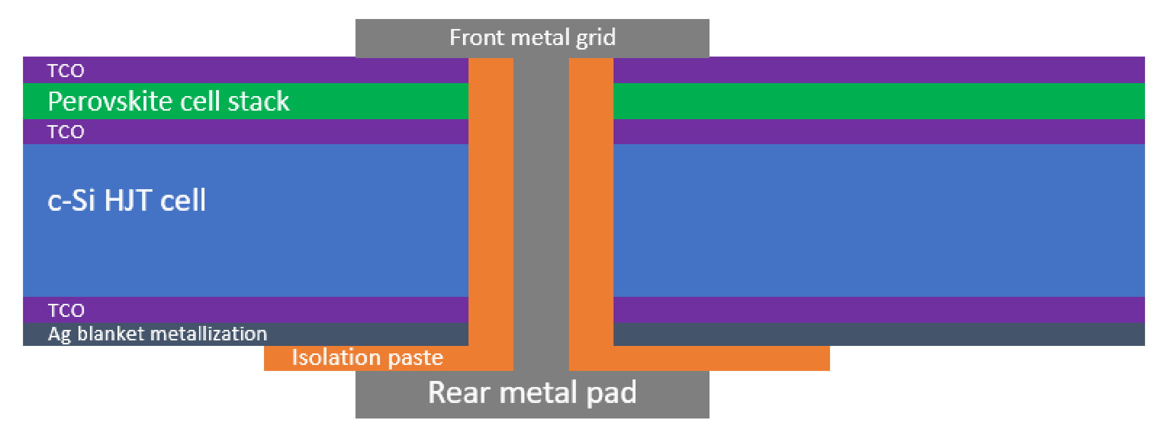
T. Fellmeth et al. Solar energy materials and solar cells 94.12 (2010): 1996-2001.



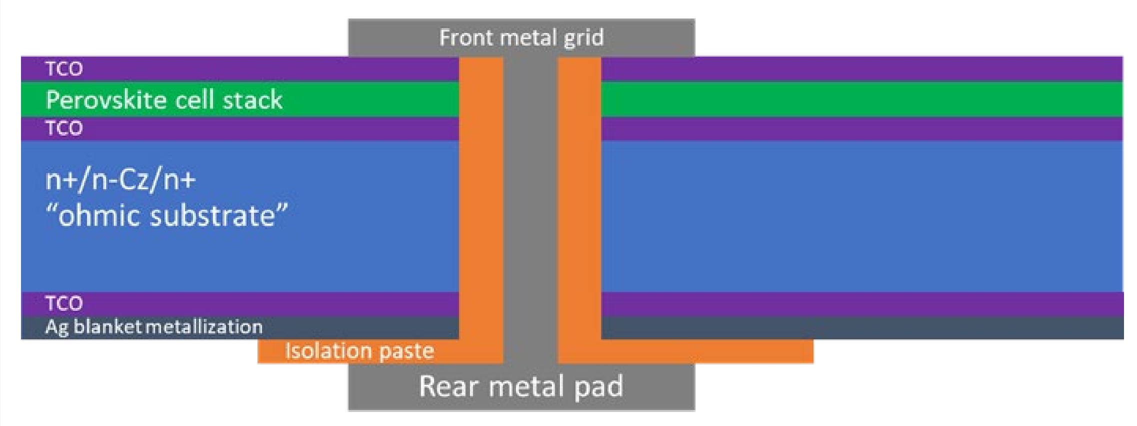
Investigate the potential of MWT technology as a back-contact technology for cSi-PVK 2T tandem cells

MWT architecture

cSi-PSK 2T tandem



Perovskite on ohmic substrate (PSK/OS)



- Through-holes are drilled and filled with metallization paste print, forming a conductive channel (via) from the front electrode towards the rear side.
- An isolation layer is applied to the inside of the through-holes to prevent a shunt.
- MWT perovskite on ohmic substrate (PSK/OS) cells, with a similar architecture as the tandem, are studied first, as a simplified case.

MWT PEROVSKITE ON OHMIC SUBSTRATE CELLS

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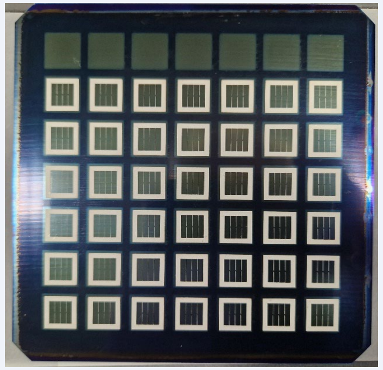
Processing steps

Cell active area = 1 cm^2

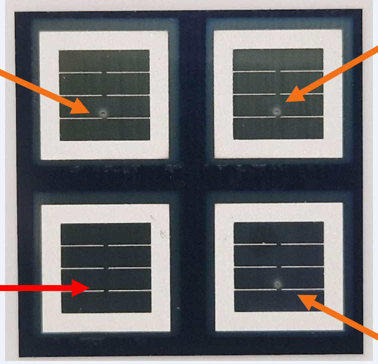


Front view (M2 wafer with individual front-back contact PSK/OS cells)

Laser cutting and drilling →

Through-hole

Reference without via



Through-hole

Through-hole

Front view

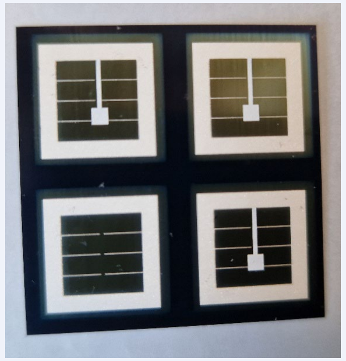
Isolation pad printing →

Rear view

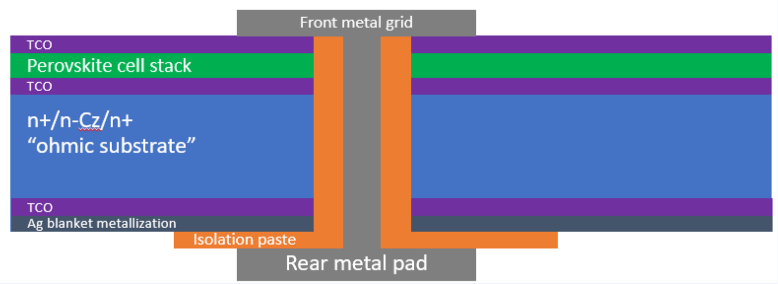
Rear metallization pad printing →

Rear view

Front metallization printing and annealing →



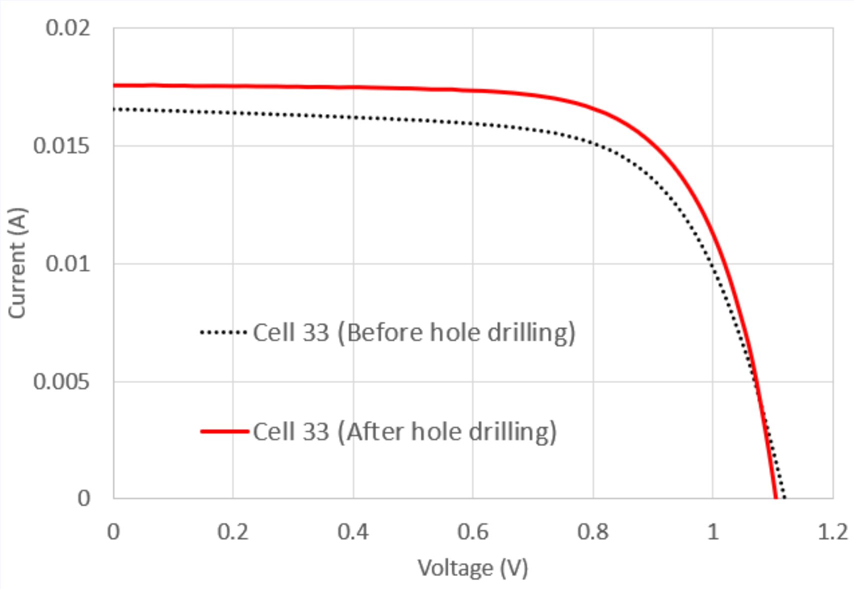
Front view



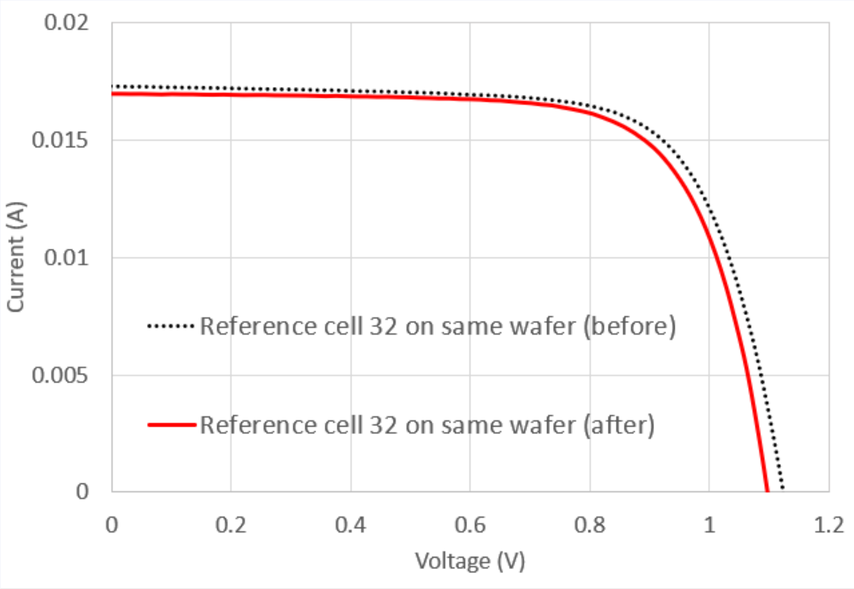
Front-back contact PSK/OS cells are converted into MWT cells by a combination of laser drilling, isolation paste printing and front/rear metallization.

Through -hole drilling

Cell with via



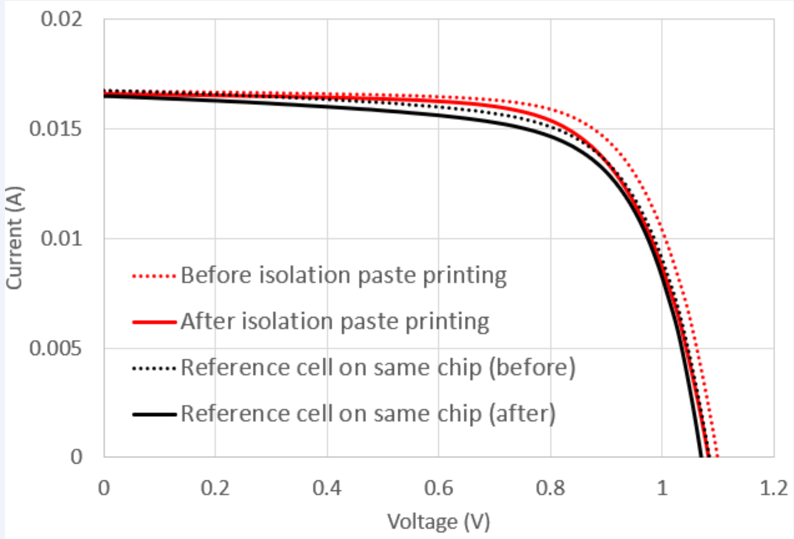
Reference cell without via



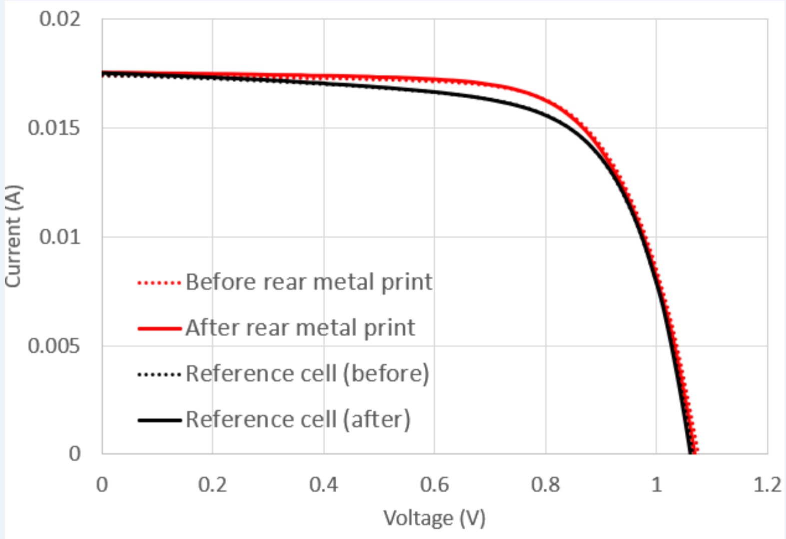
- Through-holes are drilled in the PSK/OS cells by laser.
- Variations in IV are observed after via drilling, presumably related to transport and handling in air.
- The via drilling does not have a negative effect on the cell performance.

Printing

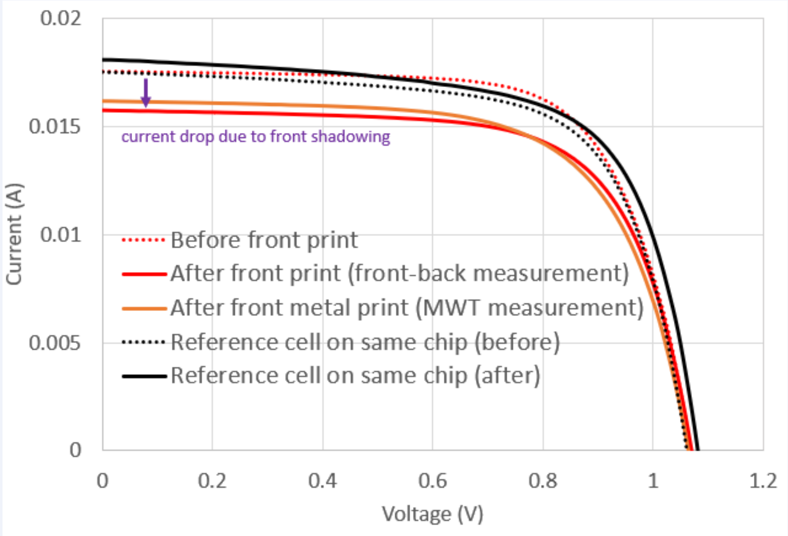
Isolation pad printing



Rear metallization printing



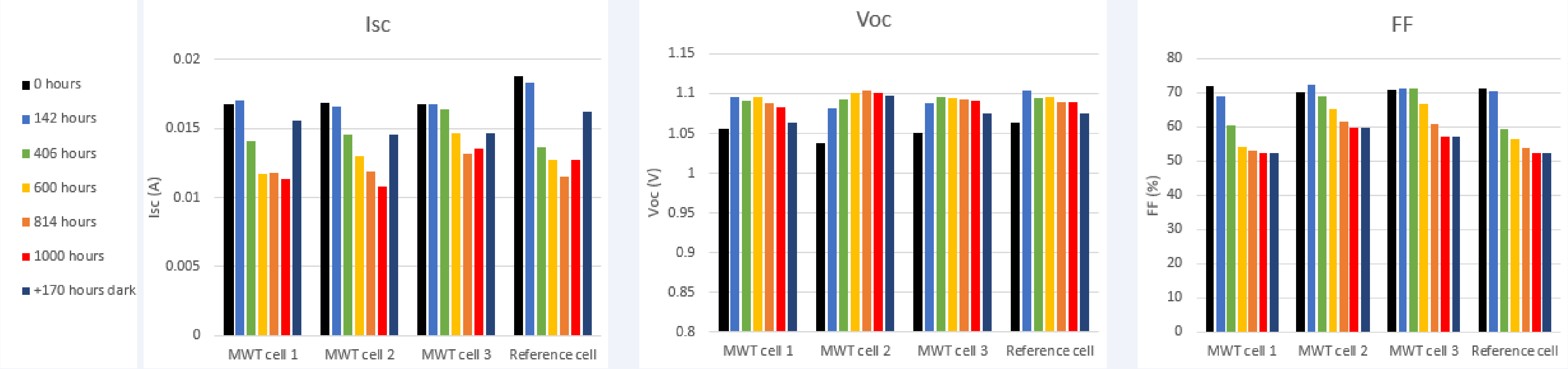
Front metallization printing



- MWT PSK/OS cells were succesfully made.
- Printing steps have no significant effect on the IV characteristics of the cells.
- Current drop for the MWT cells after front metallization print is due to shadowing.

Light stability

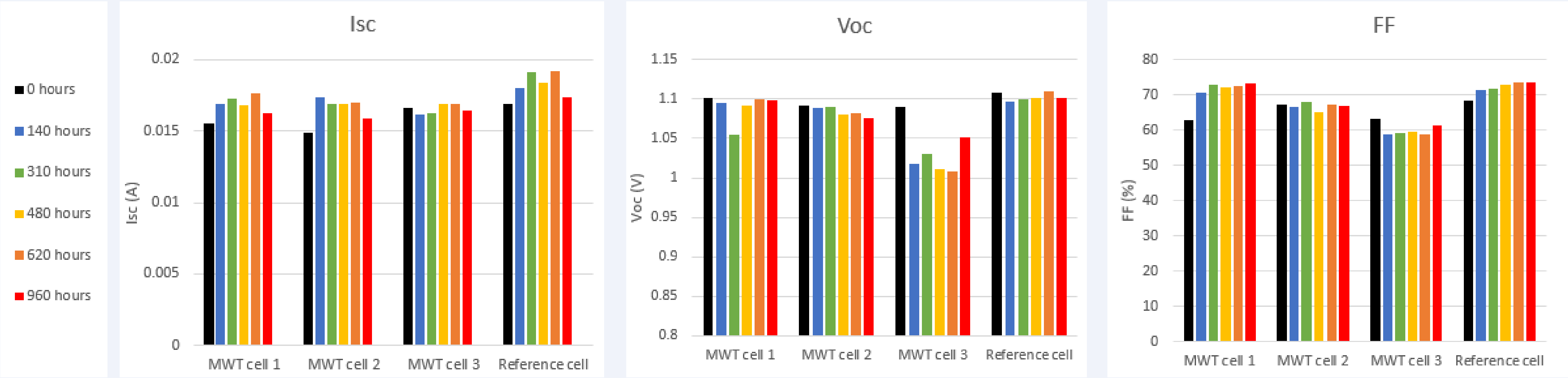
Light stability tests (1000 h, green light at 1 sun intensity, under N_2, at RT) with the MWT PSK/OS cells and front-back contact reference cells.



- The MWT cells and reference cells show a similar light degradation and dark recovery behavior.
- The MWT via does not have a negative effect on the cell stability under light.

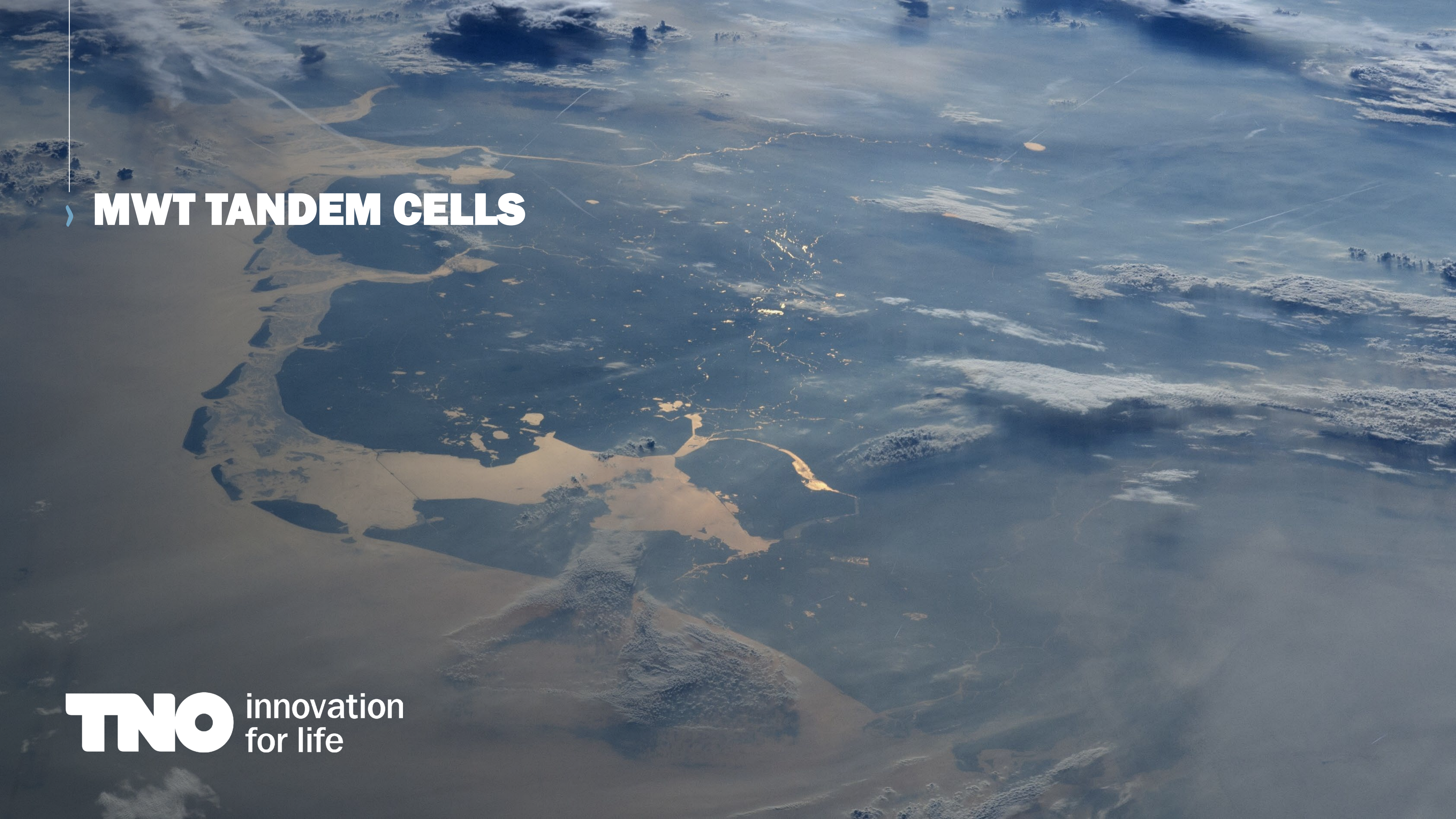
Temperature stability

Temperature stability tests (in dark, under N_2, at 65 °C) with the MWT PSK/OS cells and front-back reference cells.



- The MWT cells and reference cells show a similar behavior.
- Initial Isc increase can be attributed to recovery from the previous light stability test.
- The MWT via does not have a negative effect on the thermal stability.

MWT TANDEM CELLS



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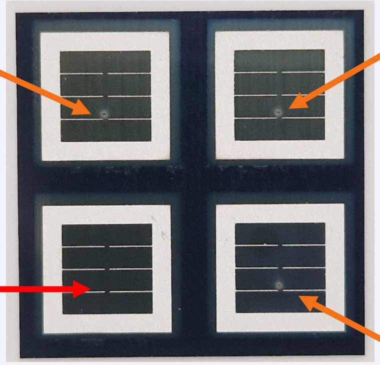
Processing steps

Front view (M2 wafer with individual front-back contact tandem cells)

Laser cutting and drilling →

Through-hole

Reference without via



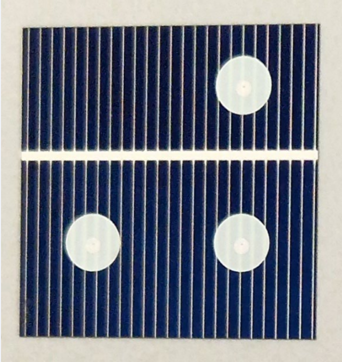
Through-hole

Through-hole

Front view

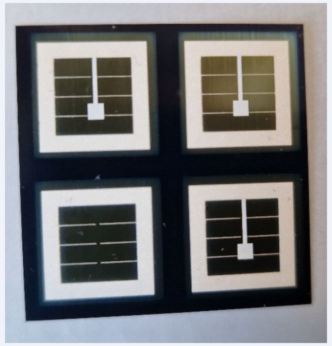
Isolation pad printing →

Rear metallization pad printing →

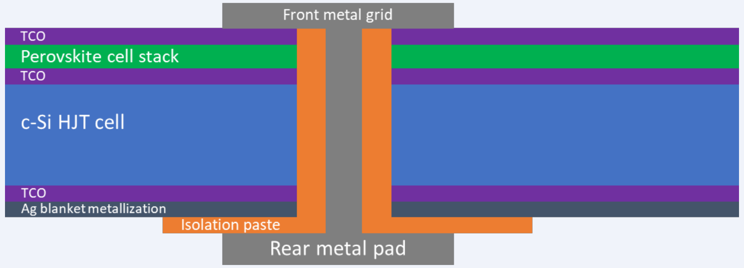


Rear view

Front metallization printing and annealing →



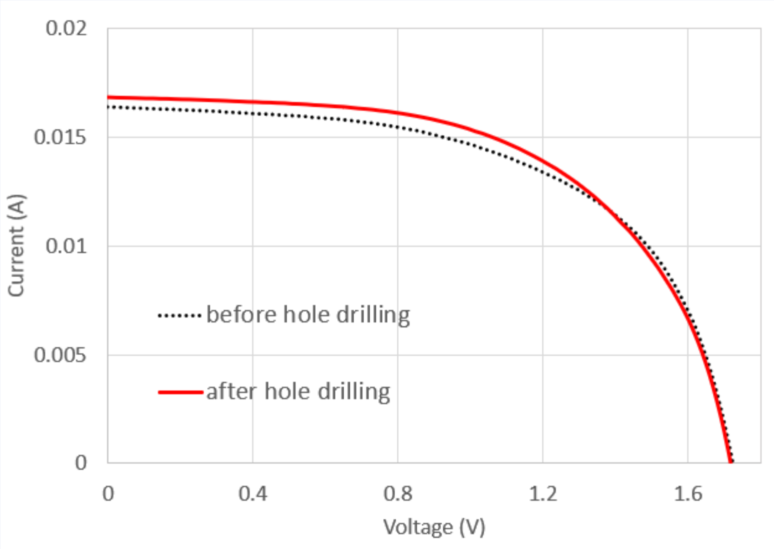
Front view



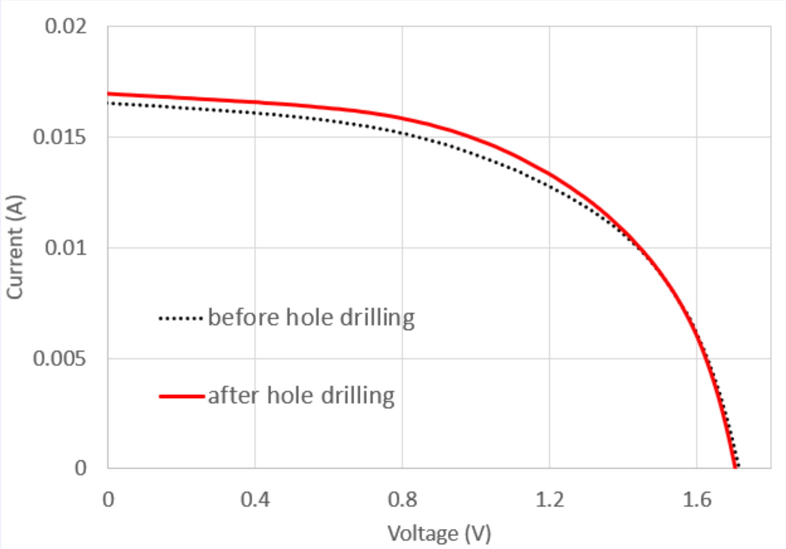
To obtain MWT tandem cells, the same processing steps are followed as for the MWT PSK/OS cells

Through -hole drilling

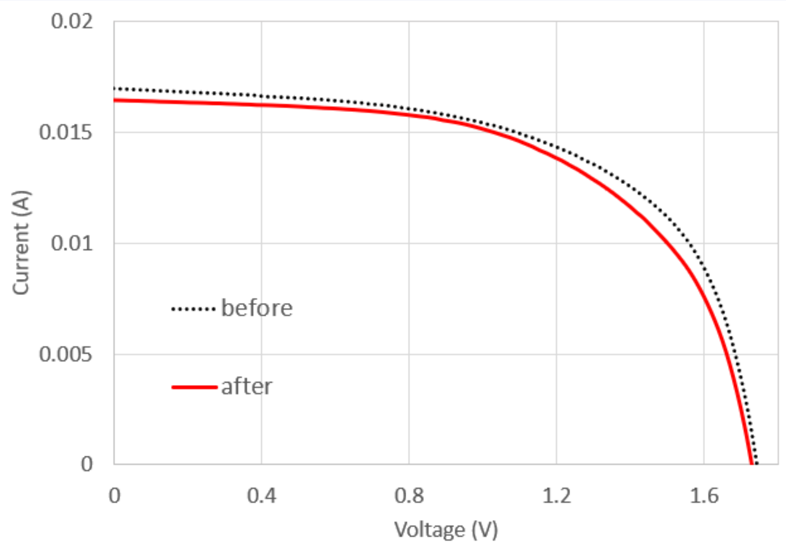
Cell with via



Cell with via



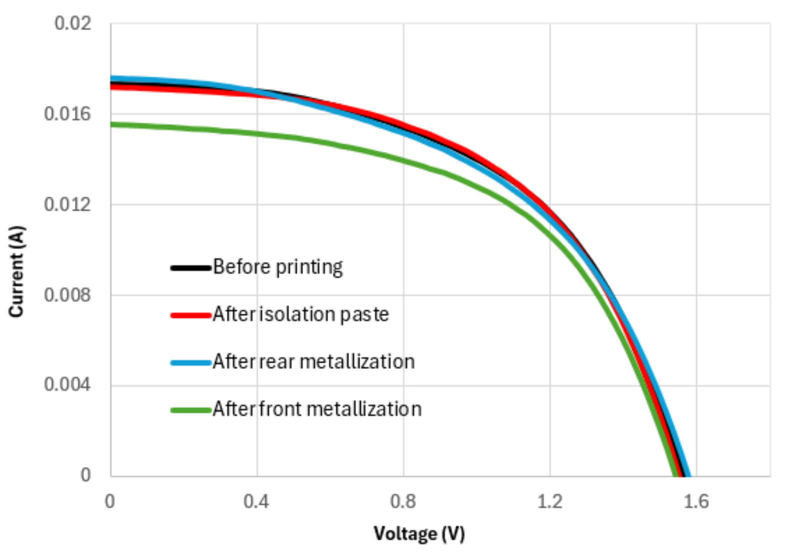
Reference cell without via



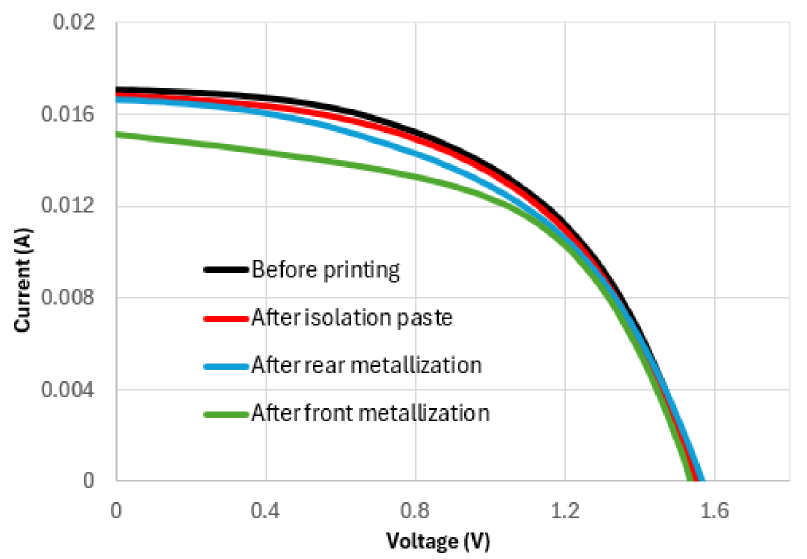
- The low FF of the tandem cells is partly attributed to the shadowed neighbouring cells during measurement, which act as a shunting pathway.
- Laser through-hole drilling does not have a significant effect on the IV characteristics of the tandem cells.

Printing

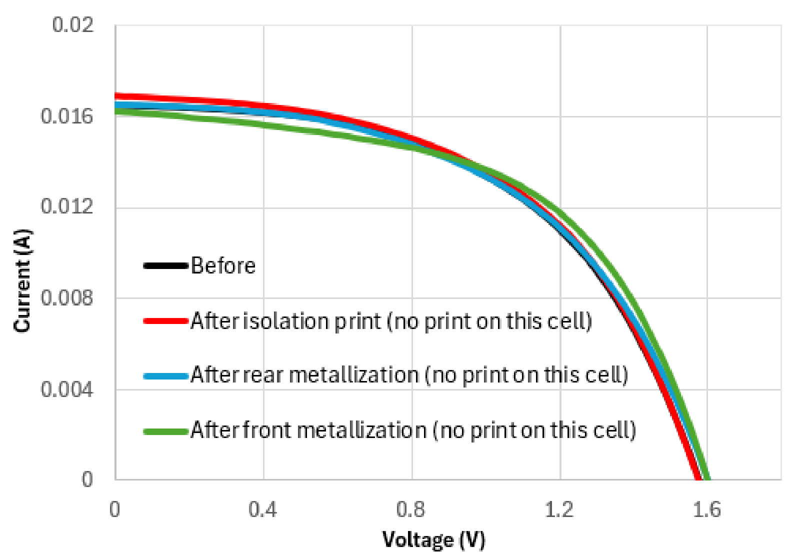
Cell with via



Cell with via



Reference cell without via



- MWT tandem cells were made successfully.
- Current drop for the MWT cells after front metallization printing is due to shadowing.
- Printing steps do not have a detrimental effect on the IV characteristics of the cell.

Main challenge is obtaining a good and stable via isolation.

› MODULE INTEGRATION

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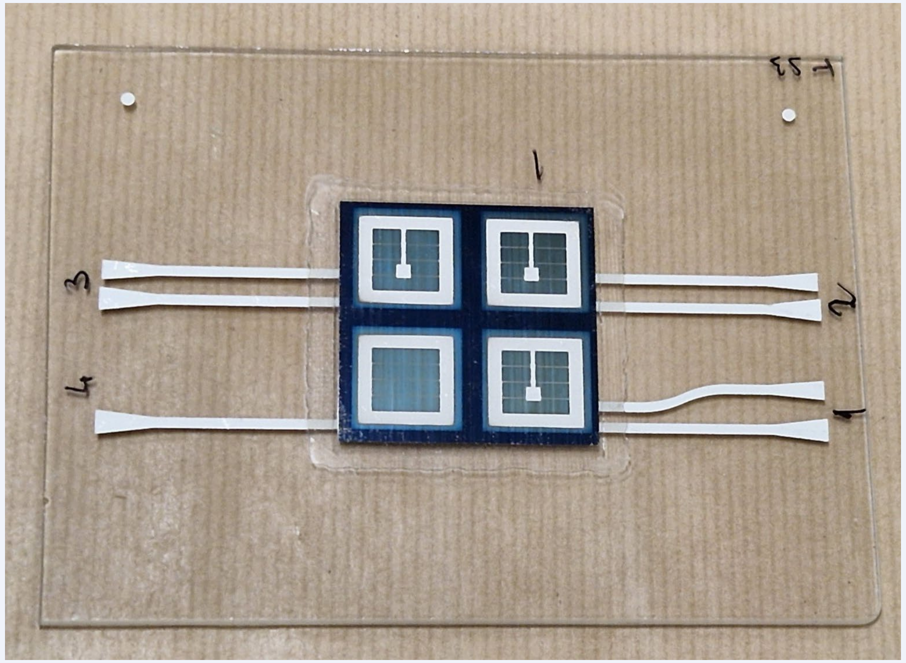
Module integration

- Mini-module integration from the small 4-cell chips, allowing to contact all cells individually, both as back-contact, as well as front-to-back.

- Main challenges:
    - Ensure good packaging/sealing of the laminate having multiple terminals.
    - Optimization of the lamination step (at low temperature).
    - Preventing stress (cracking at the vias).

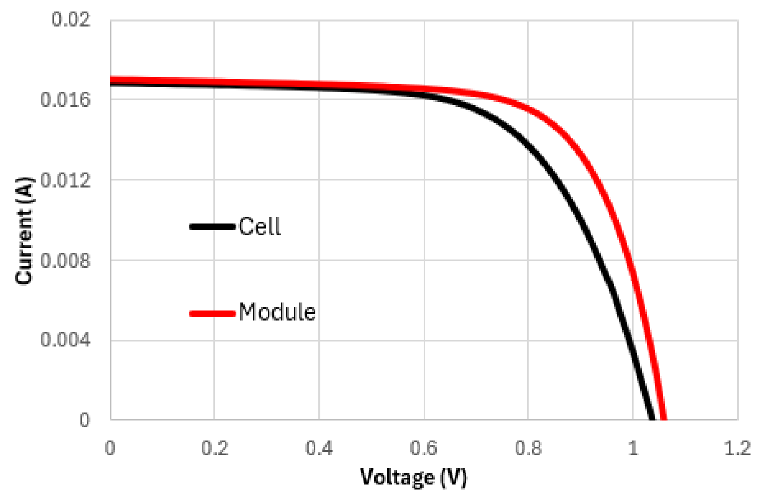
- First mini-modules with the MWT PSK/OS cells.



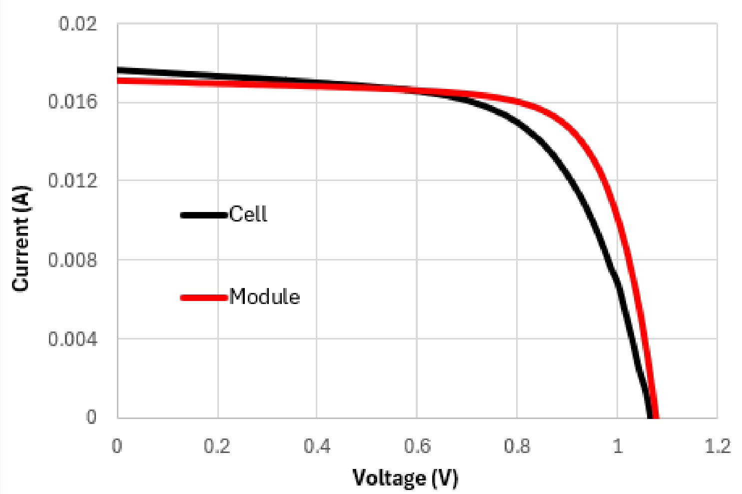
Laminated PSK/OS cells on a rear glass with silver tracks, using ECA for interconnection.

Module integration

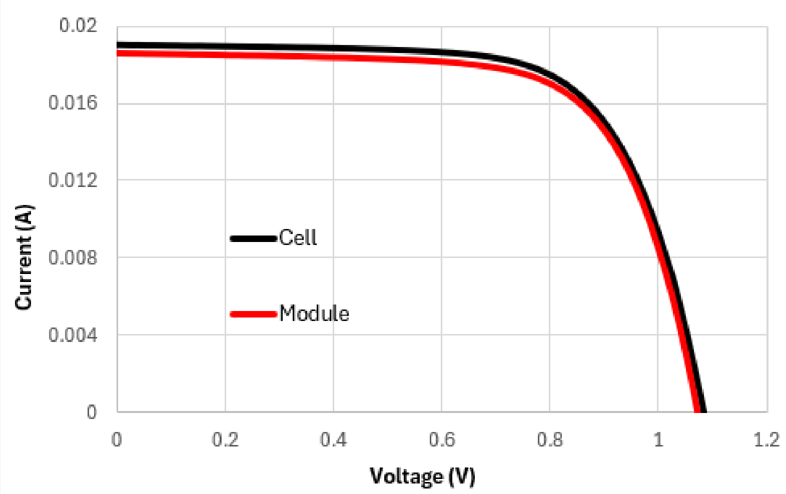
MWT



MWT



Front-back contact (reference)



- The MWT PSK/OS cells still perform well after rear side lamination and interconnection.

Conclusions

- MWT PSK/OS cells were successfully made.
- MWT vias do not have a negative effect on the light and temperature stability of the cells.
- MWT cSi-PSK 2T tandem cells have been made. Current aim is to improve the reliability of the via isolation process.
- Initial results on module integration of the MWT cells, demonstrating interconnection and lamination of the cells.
- An industrially viable process to obtain MWT tandem cells.

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topsector energie

Partners:

Lightyear 3SUN

THANK YOU FOR YOUR TIME

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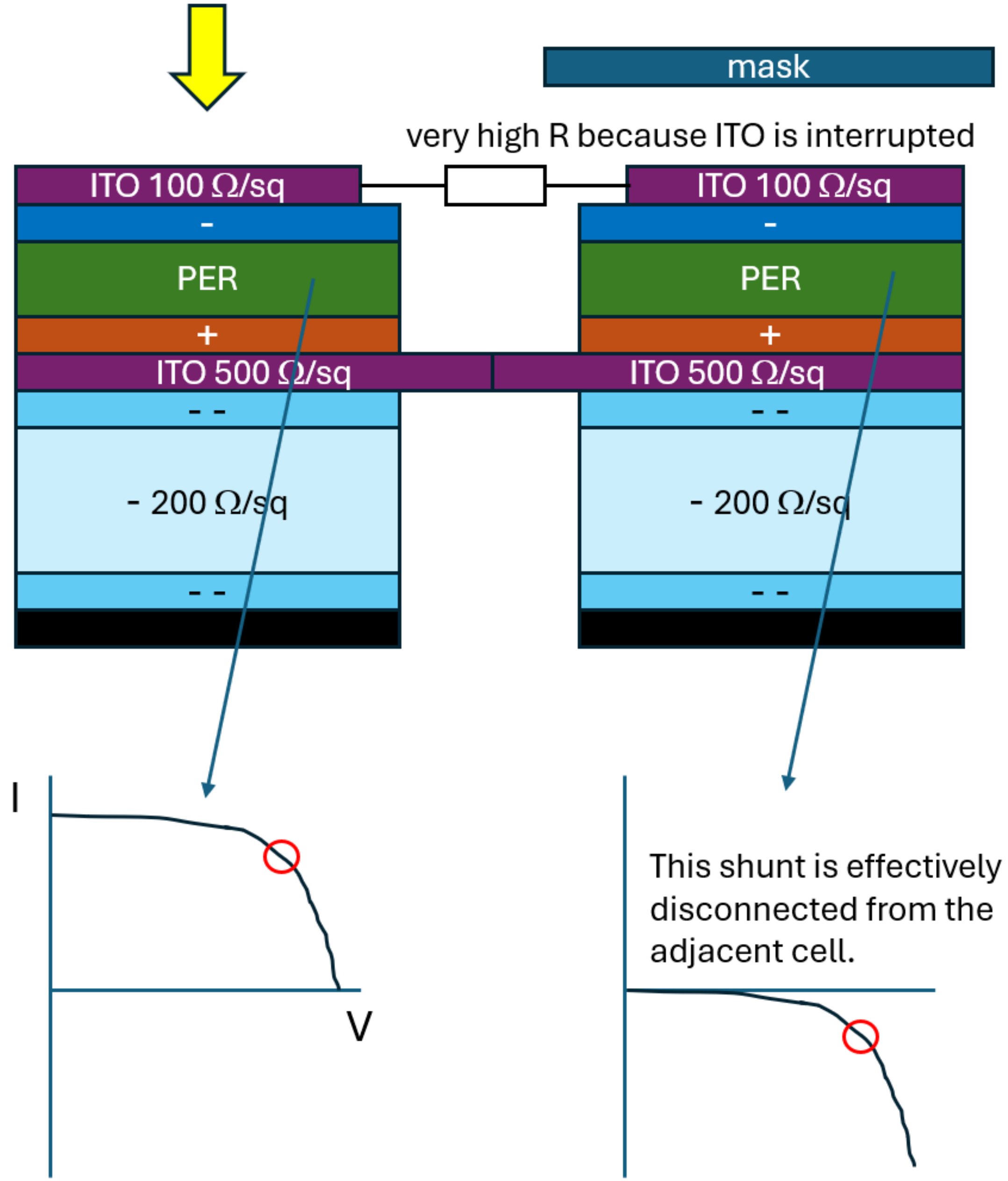
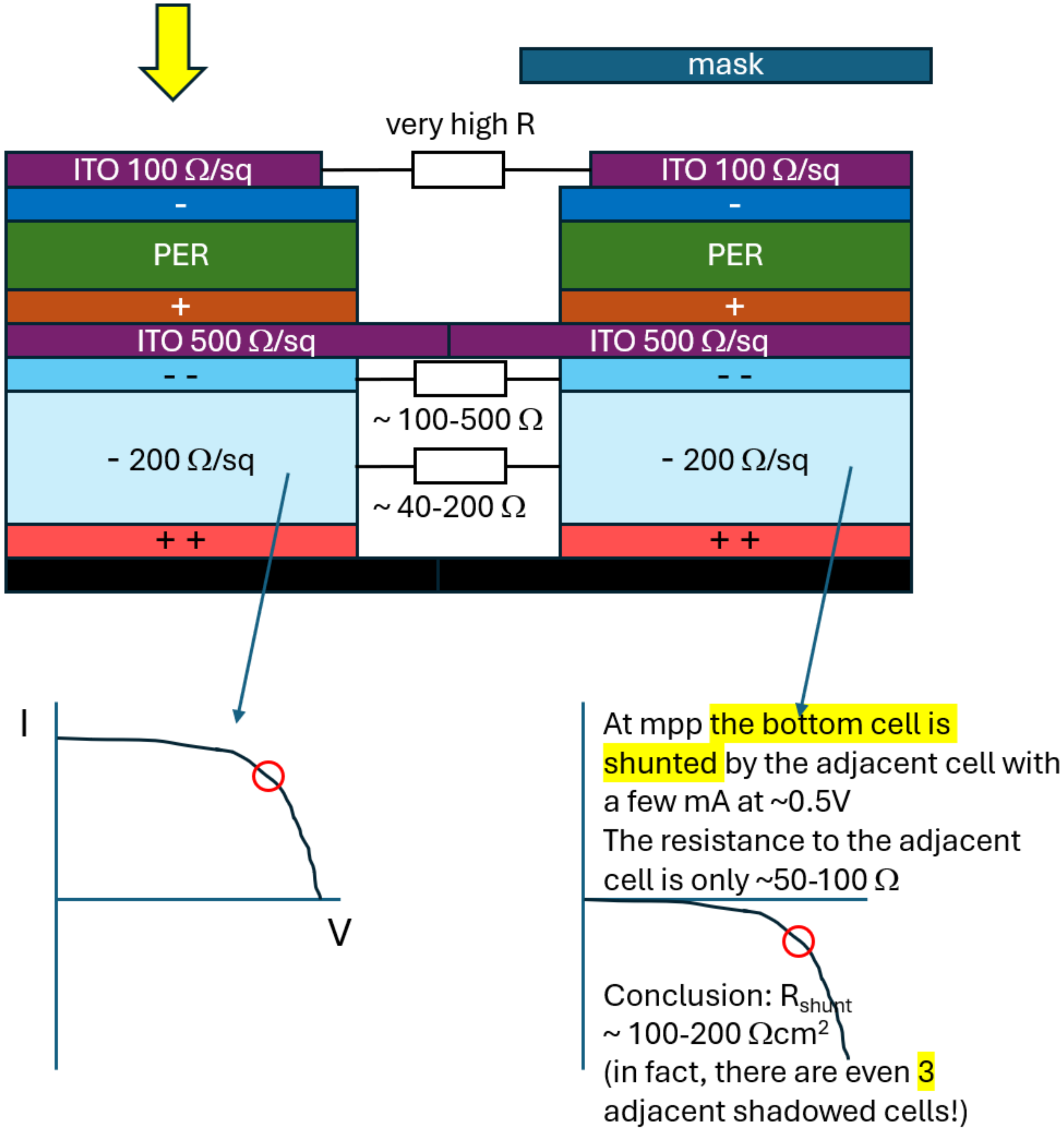


PSC on ohmic substrate



Tandem cell with adjacent shadowed tandem cells