Strategies for ultra-low Ag consumption for industrial n-type cells

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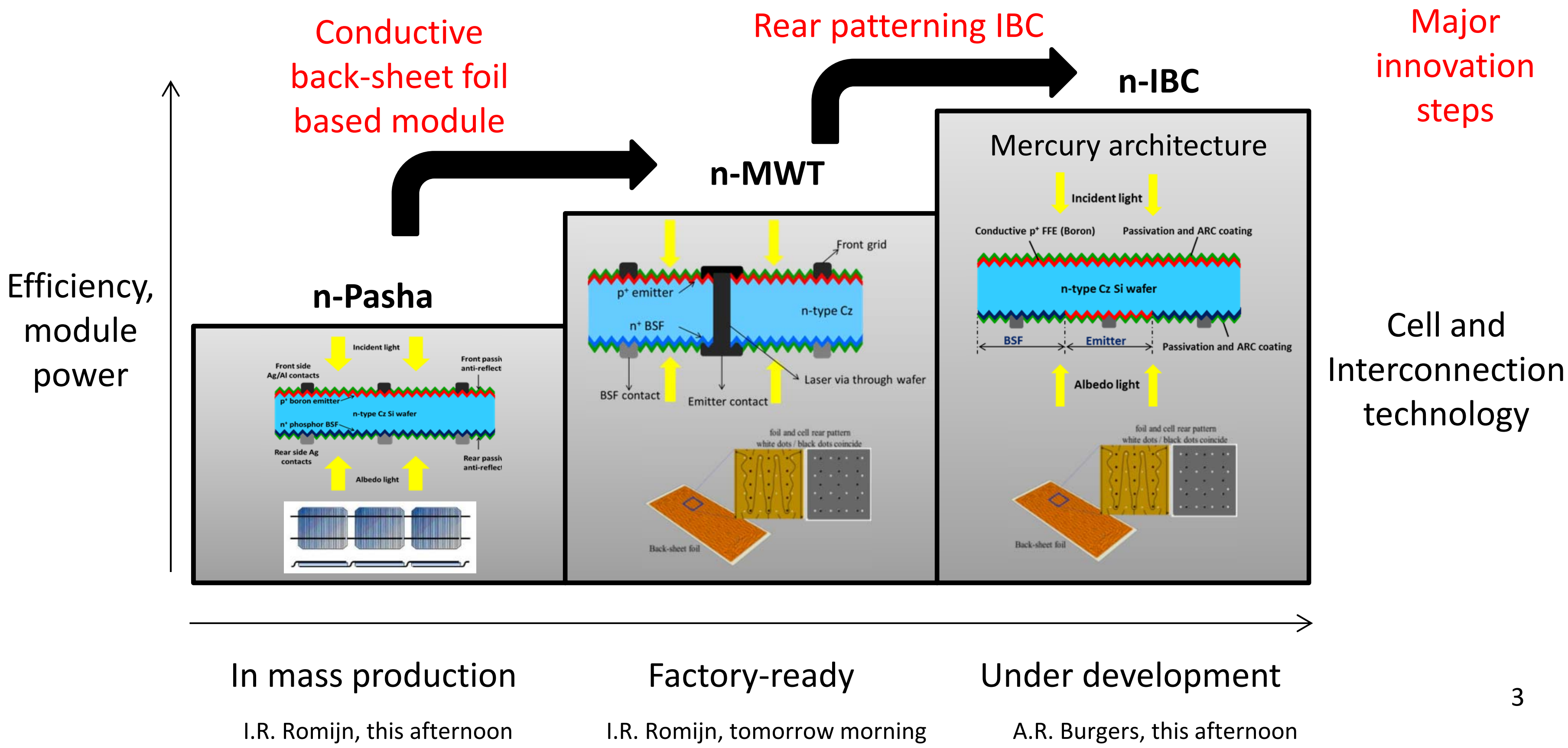
ECN n-type technology platform

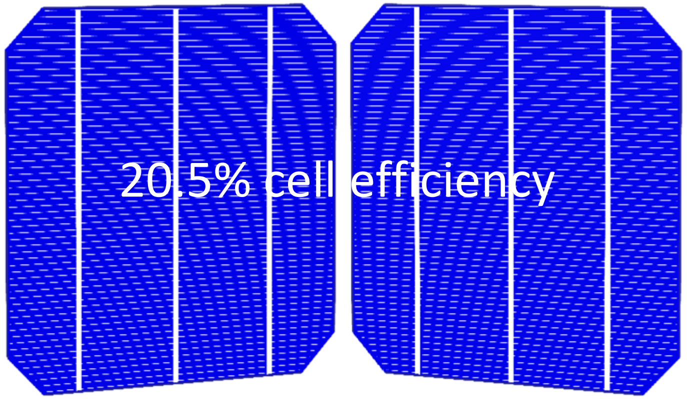


ECN n-type cell technology

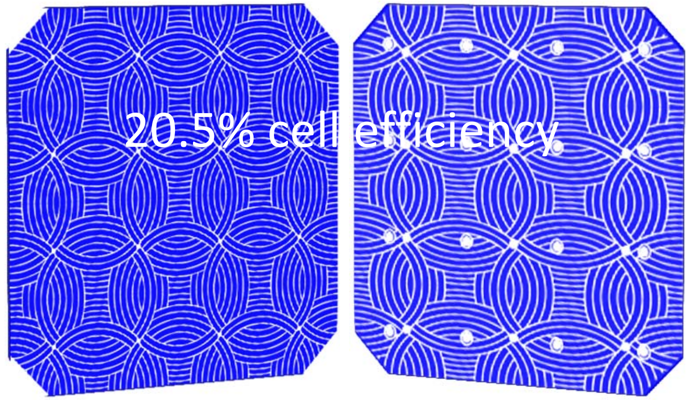
- Rear-passivated bifacial cells
  - Front boron emitter and phosphorus BSF
- n-Pasha[1]
  - Passivated both sides with H-pattern grids
  - Front and rear tabbed interconnection
- n-MWT[2]
  - Metal wrap through of front side grid to rear contacts
  - Module interconnection on the rear

- Simple and industrial process steps

- Both n-Pasha and n-MWT reach 20.5%
  - Presentations: [1]I.G. Romijn et al., We. afternoon
    [2]I.G. Romijn et al., Thu. morning

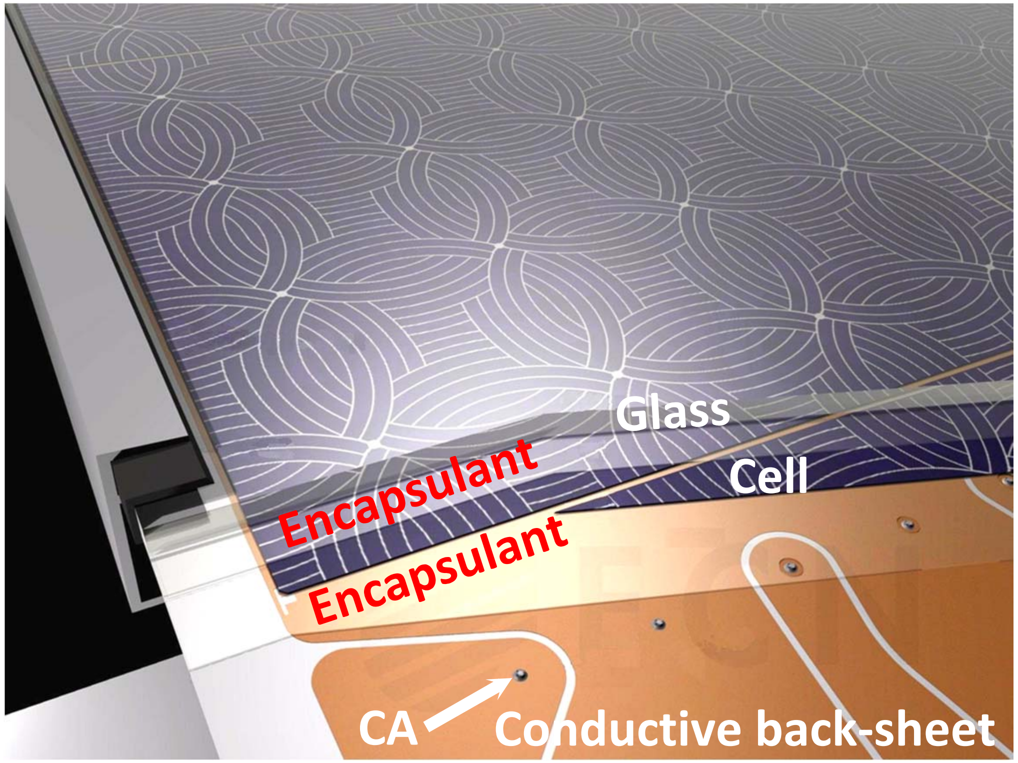


n-Pasha – front side   **n-Pasha** – rear side



n-MWT – front side   **n-MWT** – rear side

ECN back contact module technology*



CA: conductive adhesive

- Low cell-to-module loss
- Low stress on wafers
  - no tabbing, no soldering
  - suitable for very thin wafers
- Higher packing density of cells
- Combined lamination and interconnection

* I.J. Bennett et al., poster session

Sustainability of PV

- Key sustainability parameters of c-Si PV are:
  1. Use of Ag for metallisaton (cost, resource depletion)
  2. Energy for production of silicon wafer (cost, CO_2 footprint)
  3. Recyclability of PV modules (recovery of materials, CO_2 footprint)

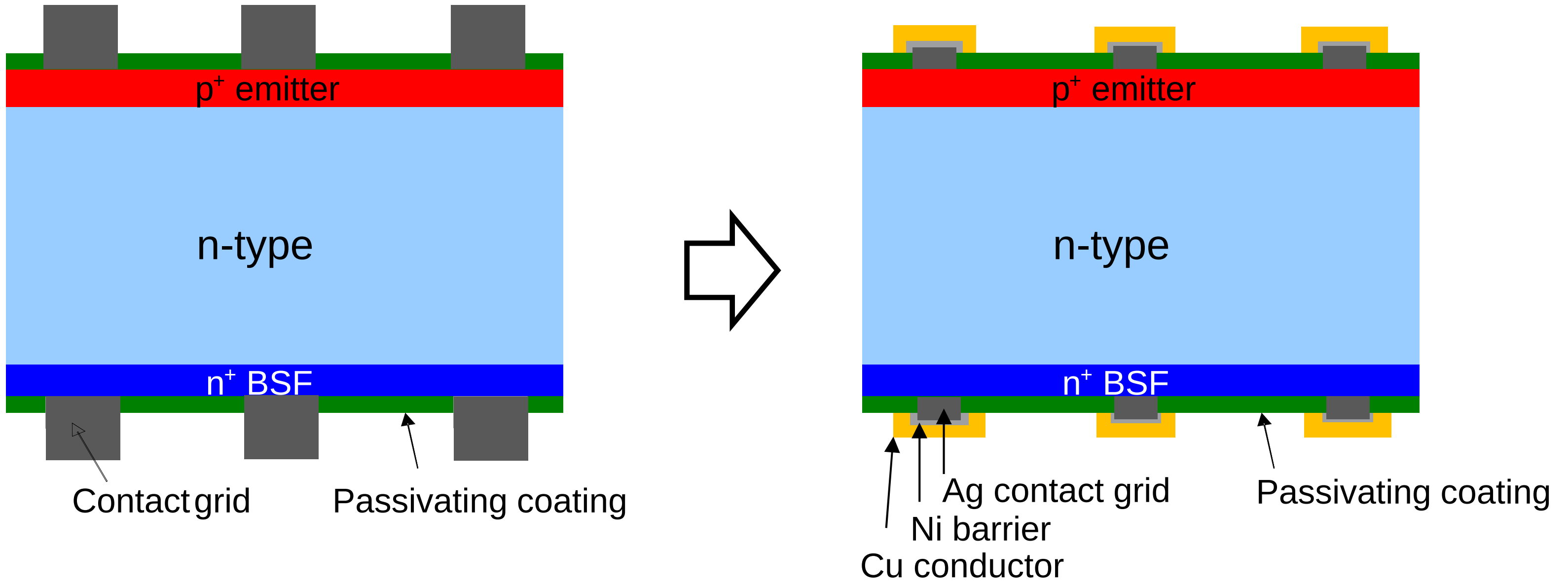
- Efforts in the Cu-PV project:
  1. Ag reduction for metallisation
  2. Very thin cells with all contacts on the rear (MWT, IBC)
  3. Back-contact module technology, designed for recycling

- This presentation covers methods and progress in Ag reduction
  - Demonstrator devices: n-Pasha and n-MWT cells and modules

Cradle-to-cradle sustainable PV modules

Ag reduction by seed & plate

- Based on established firing-through metallisation
- ⇒ *Inkjet* printing of seed grids allows minimal Ag consumption and fine lines
- ⇒ *Electroplating* of Ni barrier, Cu conductor, and capping layer



Seed & plate front side

- 86 fingers, seed Ag consumption between 3.6 and 7.2 mg Ag
- 3 busbars 1.5mm width, 6.2mg Ag

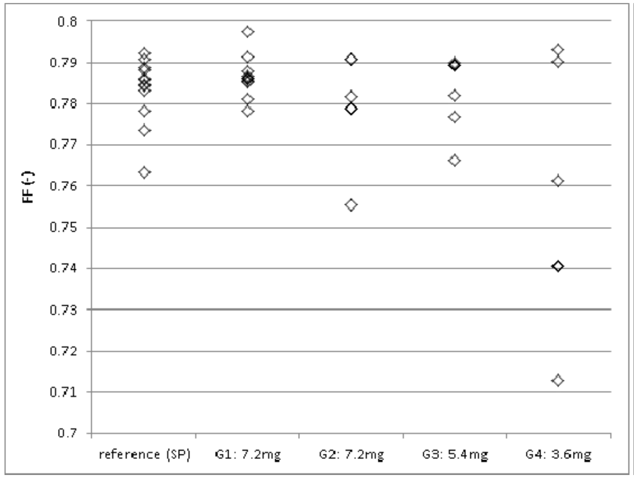
Inkjet printed finger before plating
3.6 mg Ag for 86 fingers

After NiCu plating (2+8 μm):
width 55-60 μm

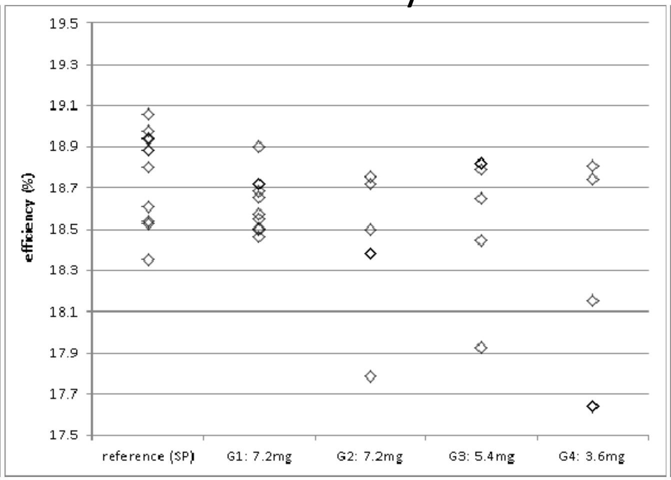
Seed & plate front side

- 86 fingers, seed Ag consumption between 3.6 and 7.2 mg Ag

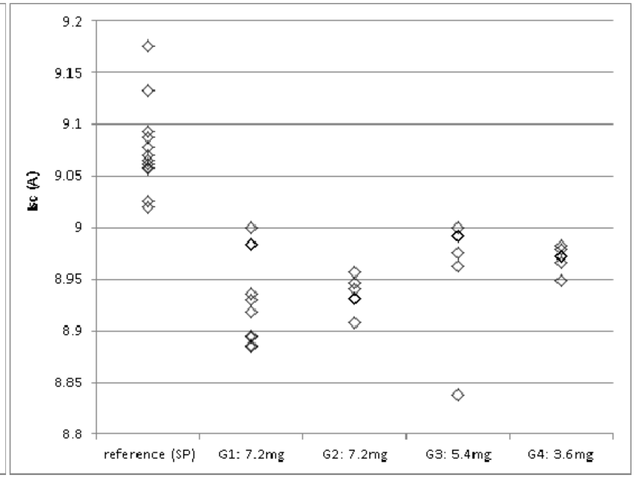
Fill-factor



Efficiency



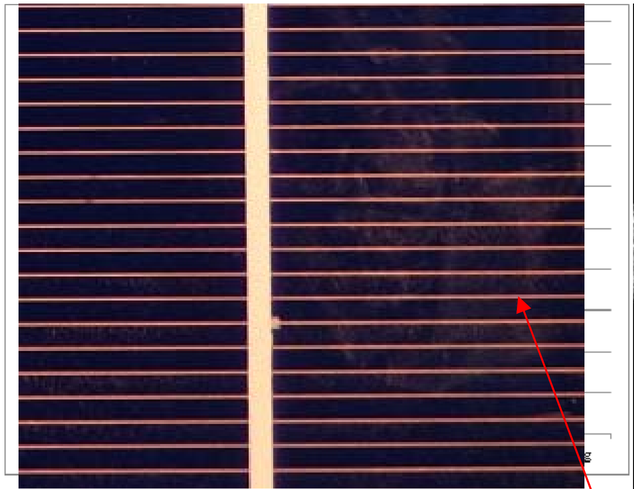
Current

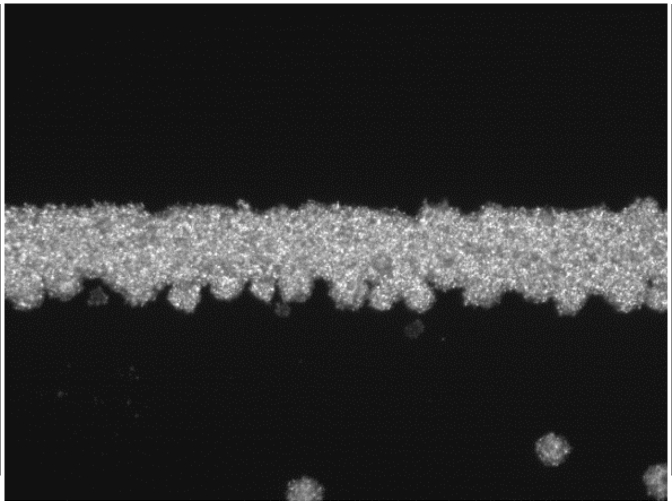


- FF comparable to reference for seed Ag consumption of 7.2 or 5.4 mg
- scatter in FF increases for seed Ag consumption of 3.6mg

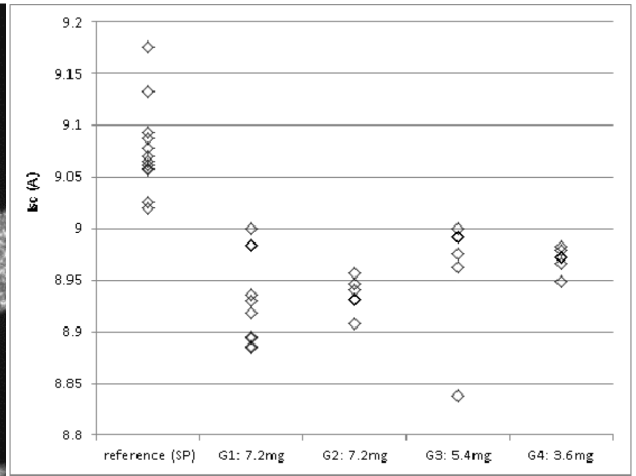
Seed & plate front side

- 86 fingers, seed Ag consumption between 3.6 and 7.2 mg Ag





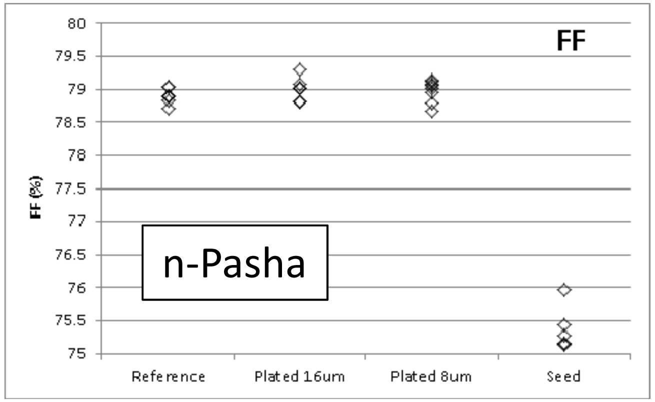
Current

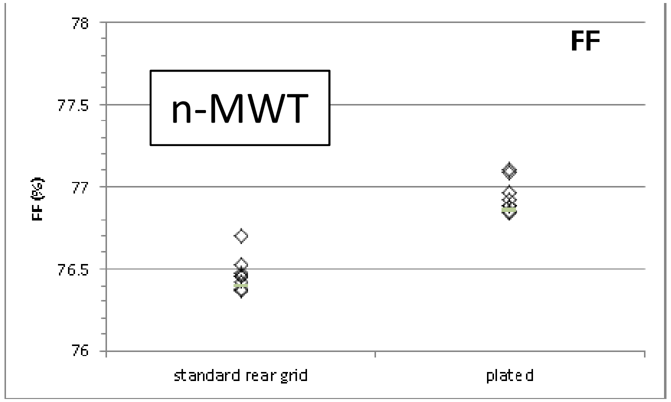


- Isc loss due to ghost plating and stray inkjet droplets;
  will be solved by equipment calibration and cleaner processing

Seed & plate rear side

- Benefits: Ag reduction and FF increase
- No efficiency penalty from wide fingers or ghost plating
- Screen print seed: at least 75% Ag reduction
- FF gain about 0.2-0.4%$_{abs}$, depending on plating thickness

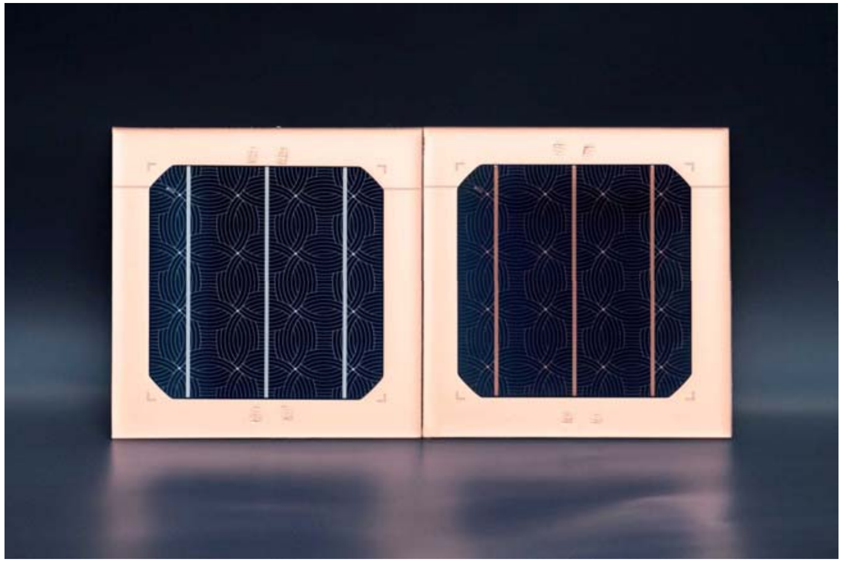




- Inkjet seed: in progress. At least 90% Ag reduction.

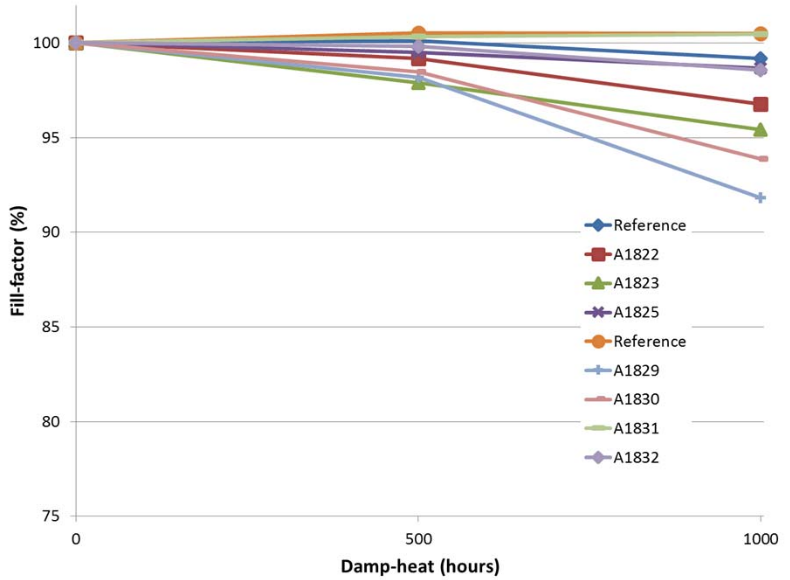
Copper-plated MWT cells in modules

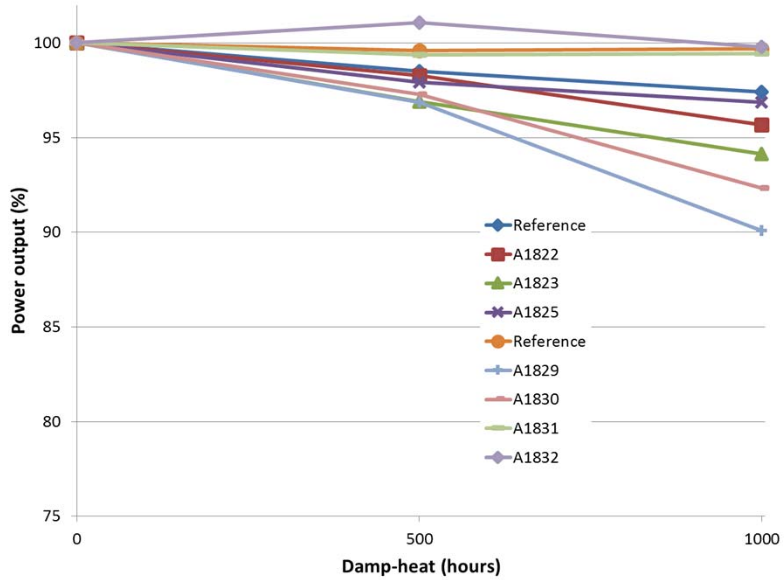
- Single cell modules with copper plated MWT cells
- Initial test with several configurations
  - Front, back and both side plated
  - EVA and alternative encapsulants
  - Qualified conductive adhesive
- Modules characterized and subjected to climate chamber testing



Module with plated cell right, reference module left

Results damp-heat testing





- Degradation within 5% limit for most modules
- No obvious influence of encapsulant on degradation rate
- No significant difference between cell types

Conclusions

- Seed & plate metallisation with copper gives a 70-90% reduction in Ag consumption
- Efficiency similar to fired Ag metallisation
  - Improvement in current will be made through tuning and clean processing
  - Plating of the rear side results in an improved fill-factor
- Cells compatible with back-contact module processing
- Modules show promising performance in accelerated testing

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