Recycling Friendly Design

the CU-PV Project for sustainable photovoltaics

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Outlook

- Introduction – problem definition
- Possibilities to improve recyclability of PV modules
- Preliminary tests and results within Cu-PV project
- Conclusions

Cu-PV EU project

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

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

- This presentation covers progress in Design for recycling of back-contact modules

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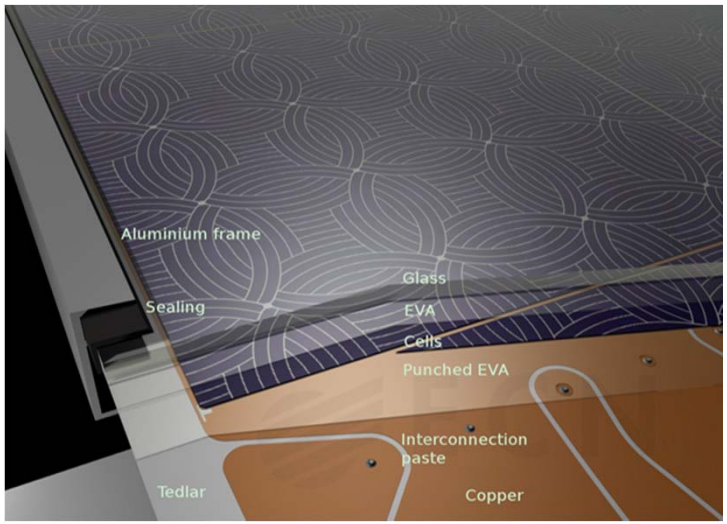
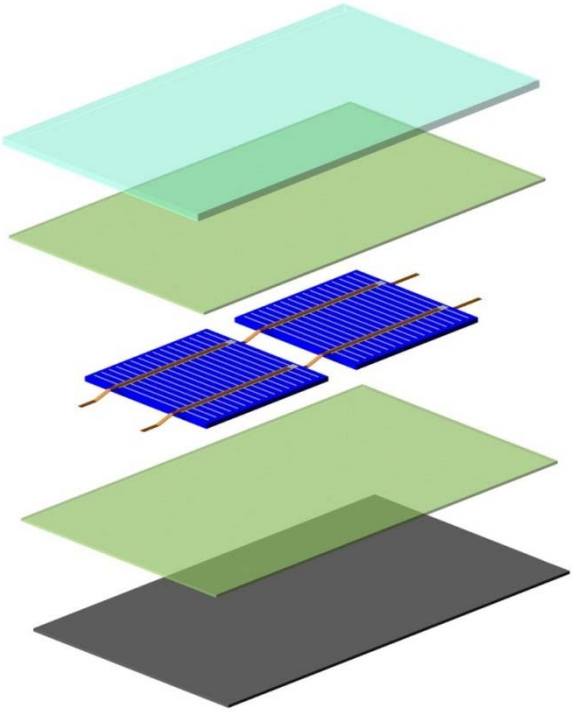
Module concept used in experiments



Back-contact module

H-pattern module



State of the art c-Si PV recycling method

- Remove Al-frame and J-box (manually)
- Shredding of the remaining sandwich (glass-EVA-solar cell-EVA-backsheet)
- Separation of the clean glass fraction and tabbing material
- Collect contaminated glass, solar cell grit and backsheet (store in big bags or sell as low quality material)

Main disadvantage of this recycling method:

- Low yield of high value material
- A negative business case for the recycler (recycling method costs more than the revenue from the sold components)
- To compensate for this, PV module collector needs to pay a gate fee to the recycler

Valuable components in module

- The components in module which are valuable for recyclers/suppliers are
  - Aluminium
  - J-box (plastics, copper wires)
  - Glass (Low Iron, super white)
  - Silver
  - Silicon Solar cell
  - Copper (foil or tabbing material)
  - PVF

- These components needs to be provided in the smallest possible volume and as clean as possible

What makes recycling difficult?

- The module is designed and manufactured for long lifetime (>25 years)
  - Al-frames are glued to the module to avoid moisture penetration
  - EVA encapsulant (thermoset)

Suggestions to improve recyclability

- Use thermoplastics as encapsulant (melts, easier to separate)
- Use release layers (intermediate layers with specific properties)
- Use no encapsulant (e.g. the Nice module concept)
- Use different kind of sealants in the Al-frame (easier to remove from module)

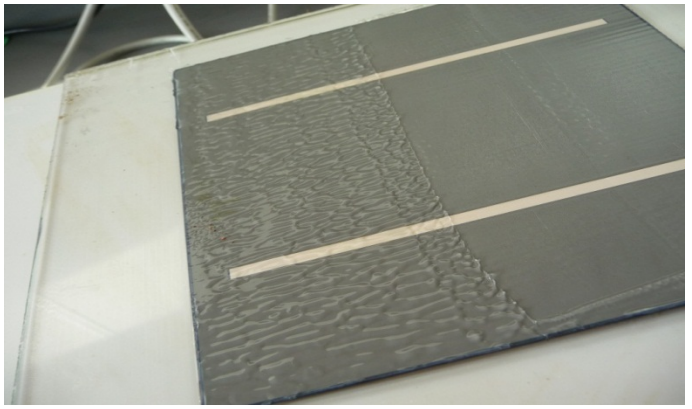
- Within the Cu-PV project ECN performed experiments using
  - different TPO's (polyolefin) and PVB
  - Different designs and materials for sealants in the frames

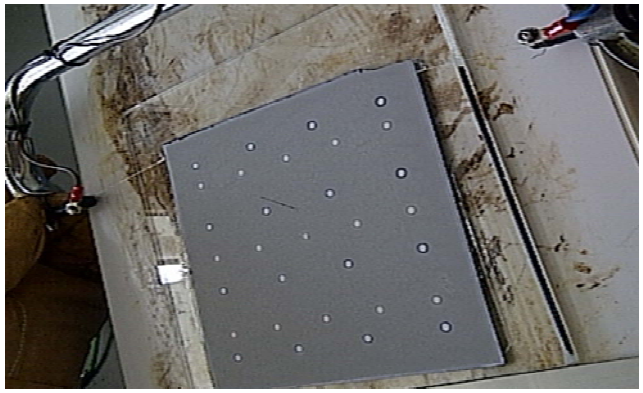
Recycling of modules with thermoplastics

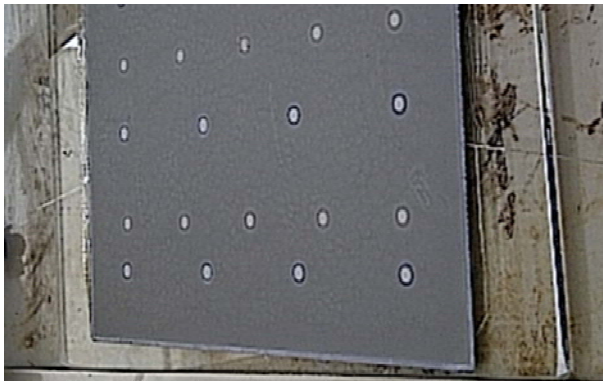
- Concept of recycling process
  - Heat module to soften encapsulant
  - Remove back-contact foil
  - Remove as much as possible encapsulant from solar cell and glass with putty knife
  - Separate cell from glass with e.g. wire cutter

- Resulting materials
  - Glass and undamaged solar cells with encapsulant residue
  - Encapsulant
  - Back-contact foil containing copper - PET - PVF

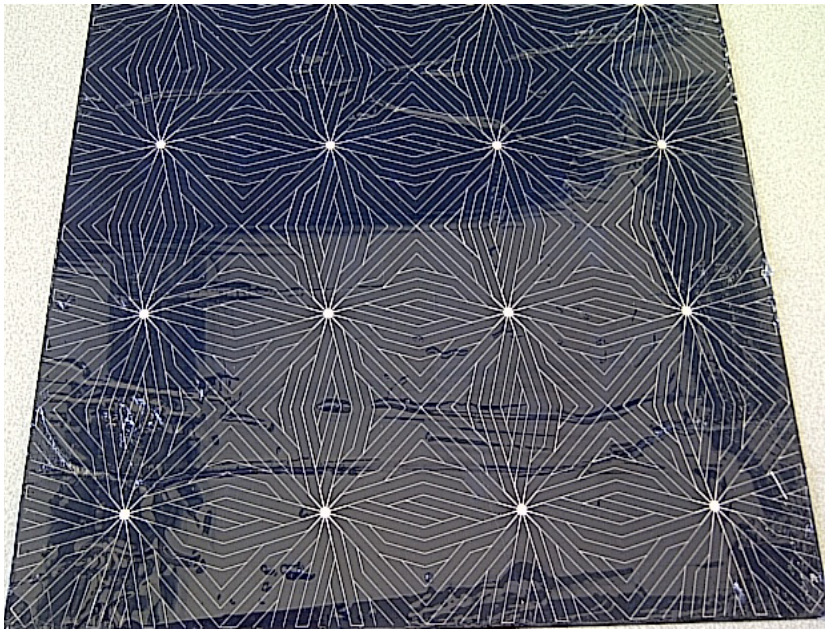
Concept of recycling



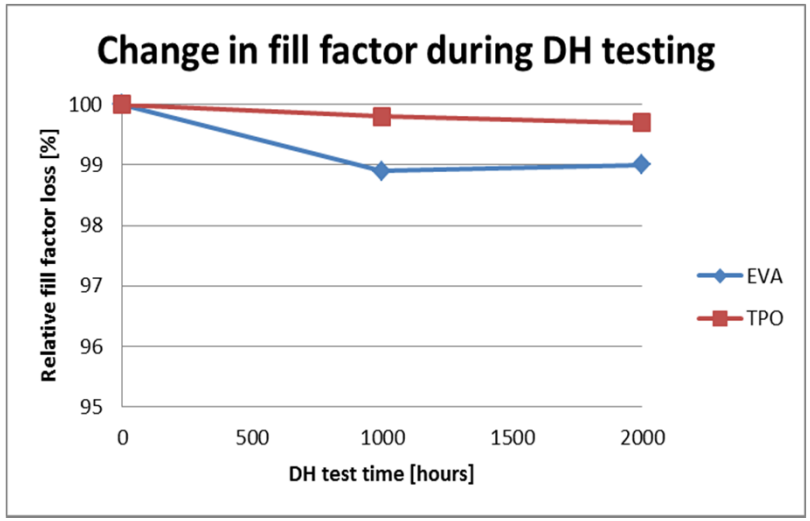


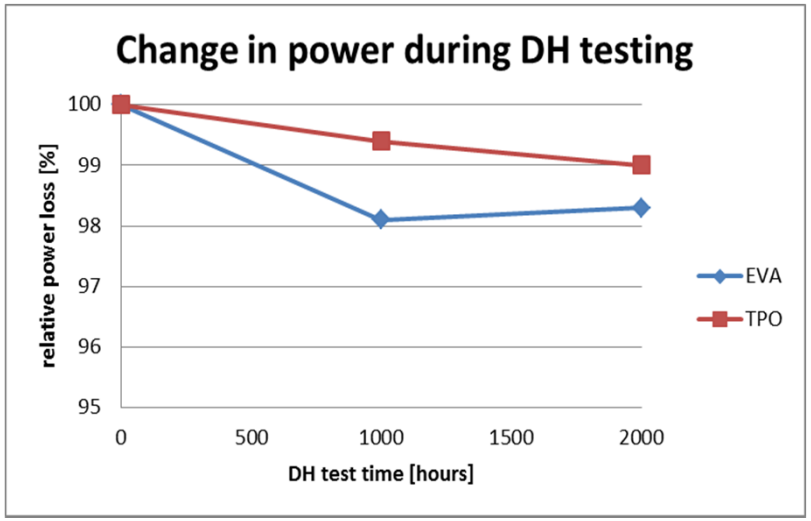


Resulting material



Reliability (DH) test of modules with TPO





Reliability of modules with TPO is comparable to modules with EVA, tested on full size module level

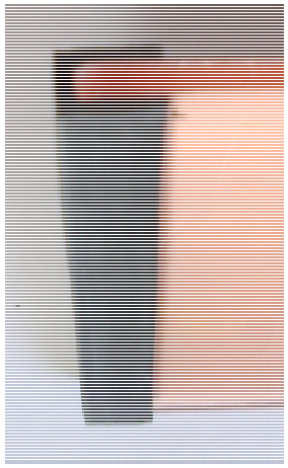
Alternative frame sealants

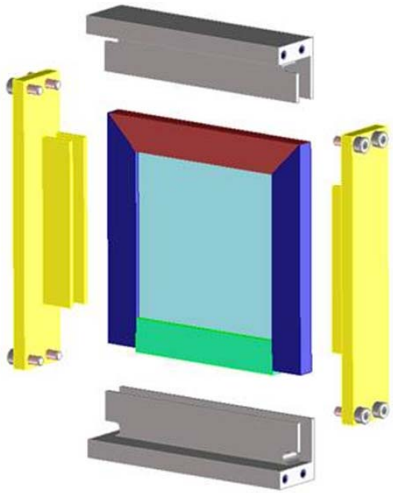
- State of the art module manufacturers use DOW Corning PV-804 or double sided adhesive tape (e.g. Duplomont) as edge sealant.

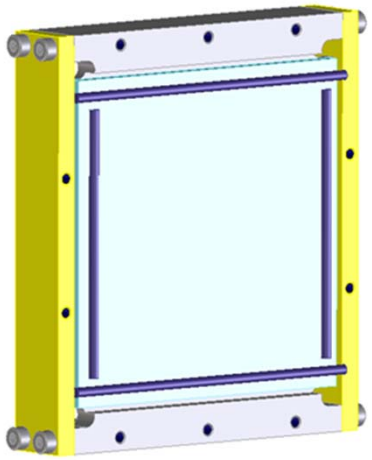
- Disadvantage: frame is difficult to remove and distortion of aluminium frame during manual removal

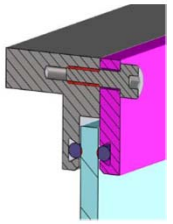
- Alternative frame sealants
  - O-ring
  - U-profile
  - Sponge rubber
  - Single sided adhesive tape (no adhesion in frame)

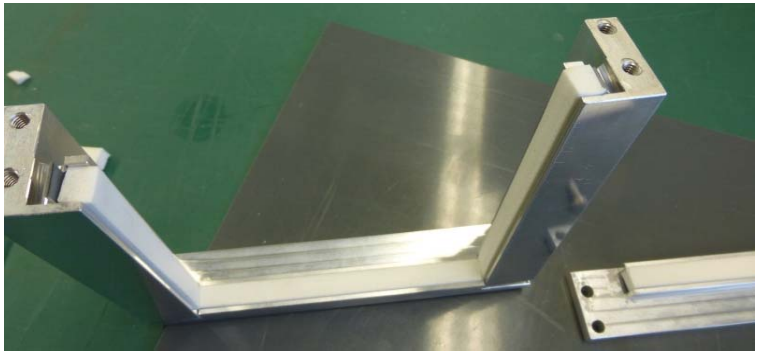
Test samples for alternative frame sealants

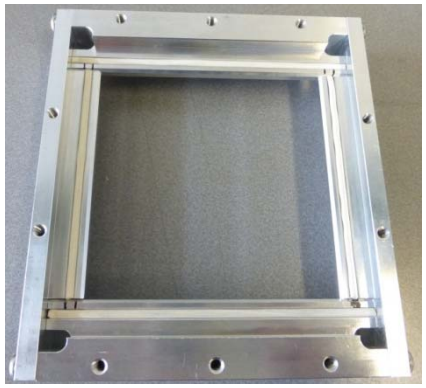












Results

- After 500 hours of DH tests (85°C, 85% rel. humidity) no discoloration of copper in back-contact foil observed for modules with O-ring, U-profile and single side adhesive tape.
- Reference sample (without any edge sealant) and with sponge rubber shows discoloring of the copper around the edges

Conclusions

- Improving recyclability of PV modules is required to receive rest materials with higher value (positive business case)
- Preliminary tests shows that there are possibilities in changing the encapsulant to improve the recyclability of PV modules
- Changing the encapsulant shows no decrease of the reliability on module level (tested for 2000 hours in DH)
- There are alternative edge sealant available which show good sealant properties.

Recommendation

For improving the economical output of recycling process, cost reduction of module and lower the CO_2 footprint, bring together

- module manufacturers,
- recyclers
- companies who can upgrade and use the recycled components
- research institutes.

The aim is to develop a closed loop of applied materials in module, recycling of the modules, and re-use of all of the components in the solar industry or other industries. We have to think about solutions which are profitable after more than 25 years.

Thanks for your attention

Questions ?

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