Investigation of Multi-Wire Interconnected Lightweight PV modules Using Micro-Computed Tomography

Bin Luo, Rik Van Dyck, Jonathan Govaerts, Tom Borgers, Bart Ruttens, Jan D’Haen, Hariharsudan Sivaramakrishnan Radhakrishnan, Michael Daenen, Aart Willem Van Vuure, Jef Poortmans
Contents

- Introduction
  - Motivation for lightweight modules
- Experimental Setup
  - Sample preparation and experimental matrix
- Results and Discussion
- Conclusions
Motivation for lightweight modules

Next-generation VIPV
Sample fabrication

Module exploded view

- Polymer front sheet
- Front encapsulant (PO)
- Cell strings
- Back encapsulant (PO)
- Composite back sheet
Sample fabrication
Fiber reinforced polypropylene backsheet

- Lamination of 8 plies
  - [0/90] unidirectional fibers
  - 60 w% glass fibers and 50 w% carbon fibers
- Glass and carbon fiber reinforcements

Fiber reinforced polymer backsheet $[0/90]_s$

GFPP backsheet

CFPP backsheet
Sample fabrication

Cell interconnection

- Bifacial SHJ cells
- Cell interconnection foil
  - 18 Cu wires with SnBiAg-coating
  - Polyolefin-based carrier foil
Module fabrication

- Module layup and lamination
- During lamination:
  - Encapsulation
  - Soldering
Experimental matrix

- Thermal cycling according to IEC61215
Reliability assessment
Thermal cycling (-40 to 85 °C, IEC 61215)

Before TC  |  After TC 200

![Graph showing normalized FF over thermal cycling cycles for GFPP and CFPP before and after thermal cycling.](image)

MWI before TC | MWI after TC 200

![Images showing MWI before and after thermal cycling.](image)
Reliability assessment
Thermal cycling (-40 to 85 °C, IEC 61215)
3D Micro-computed tomography

- Non-destructive analyzing technique
- Multiple X-ray scans of rotating sample, followed by reconstruction to create 3D volume rendering
- Voxel (3D Pixel) sized as low as 1-3 µm
- Resolution depends on sample size
Reliability assessment and characterization
Micro-computed tomography (µ-CT) imaging

- Wire deformation between cells due to thermal strain
Reduced thermal strain

Coefficient of Thermal Expansion (μm/m°C)

\[ \Delta G = L \cdot \alpha_{\text{backsheets}} - C \cdot \alpha_{\text{Si}} \]

GFPP: \( \Delta G = 7.5 \, \mu m/°C \)

CFPP: \( \Delta G = 0.2 \, \mu m/°C \)
Conclusions

- Lightweight modules using a multi-wire interconnection are prone to degradation due to thermo-mechanical stress.
- Decreasing the backsheet CTE improves the reliability.
- 3D micro-computed tomography can be used to visually inspect interconnections.
- Further investigation using FEM is ongoing.
Thank you for your attention

ACKNOWLEDGEMENTS:
EU H2020 project “HighLite” under Grant Agreement no. 857793
SNRoof icon research project funded by imec and Agentschap innoveren & ondernemen

For more information:
Lightweight modules at imec: bin.luo@imec.be
3D computed tomography: rik.vandyck@imec.be