
INTERACTION BETWEEN WEATHERING OF SOLAR MODULES AND IN-LAMINATE STRENGTH OF SOLAR CELLS

Dr. Sascha Dietrich, Dr. Martin Sander, Frank Wenger, Dr. Matthias Ebert

2nd WORKSHOP – Impact of mechanical and thermal load on the long term stability of PV modules

Date: 03.02.2015

Venue: Leibniz University Hannover

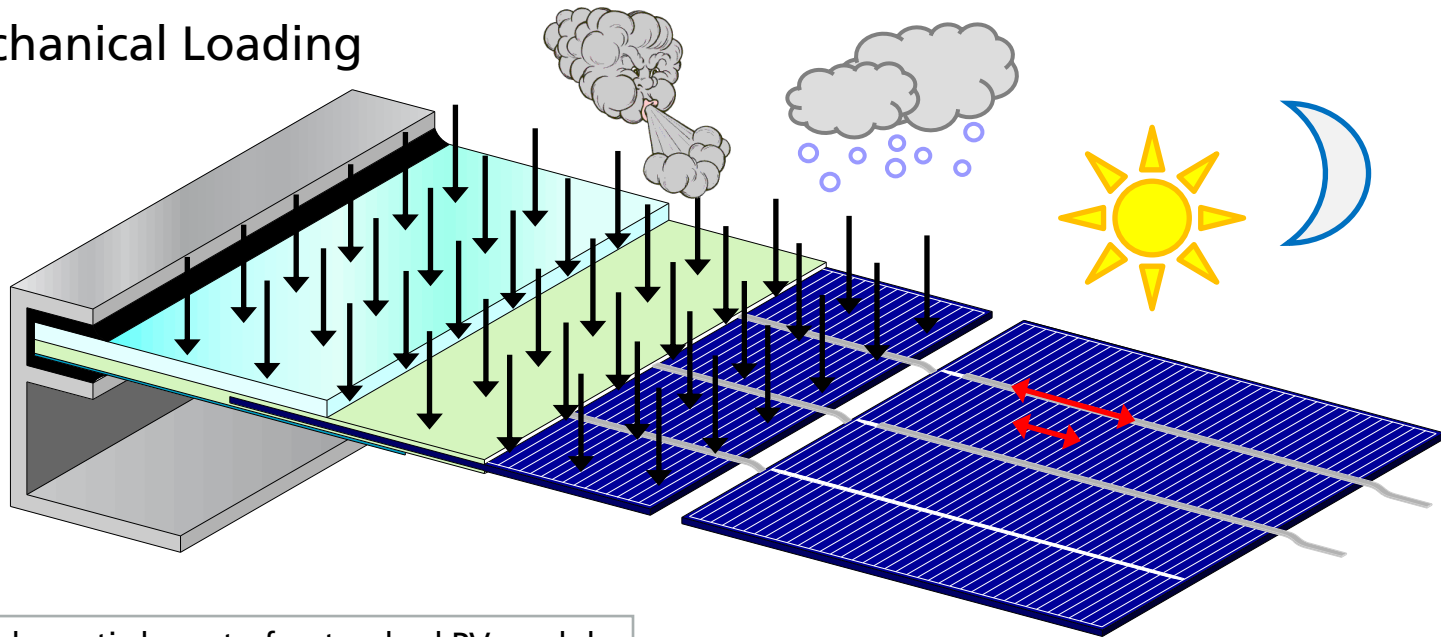


Agenda

- Motivation
- Methods
- Results
- Conclusions

Motivation

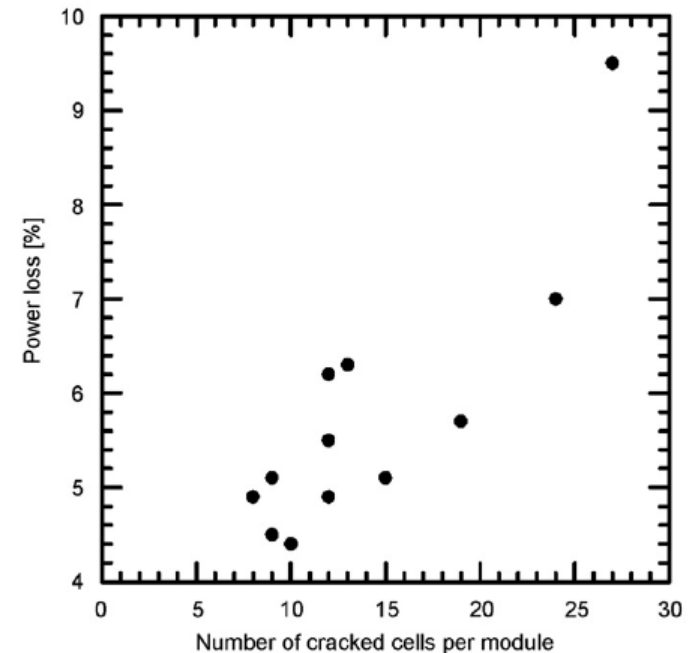
- Loads on PV modules can cause defects
 - During operation and during manufacturing
 - Temperature changes
 - Mechanical Loading



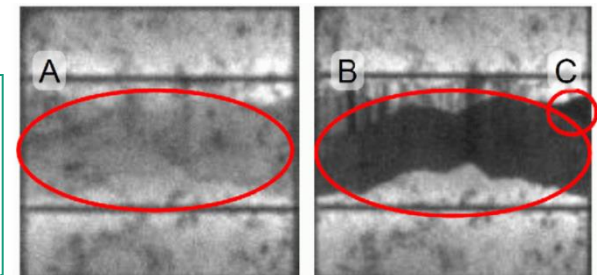
Schematic layout of a standard PV module

Motivation

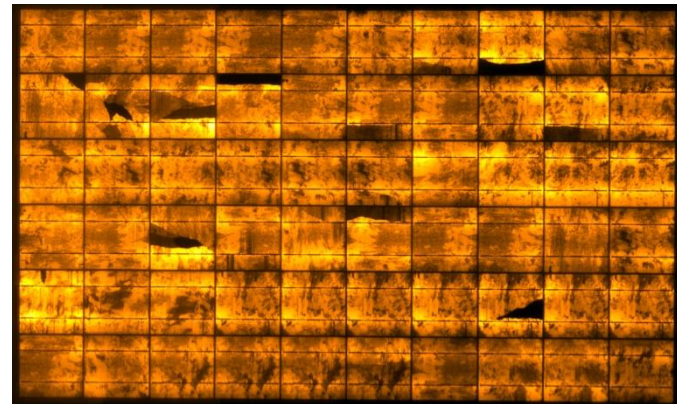
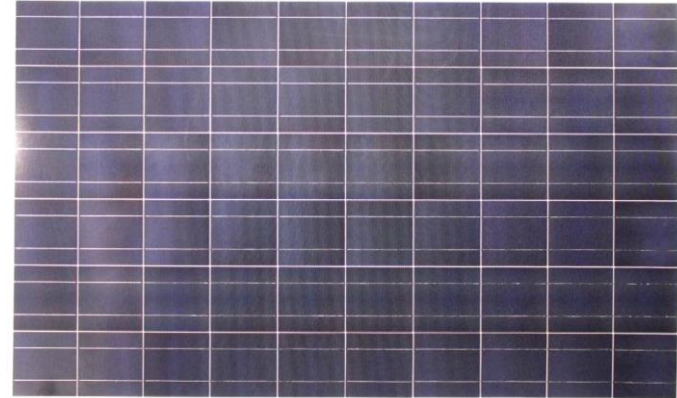
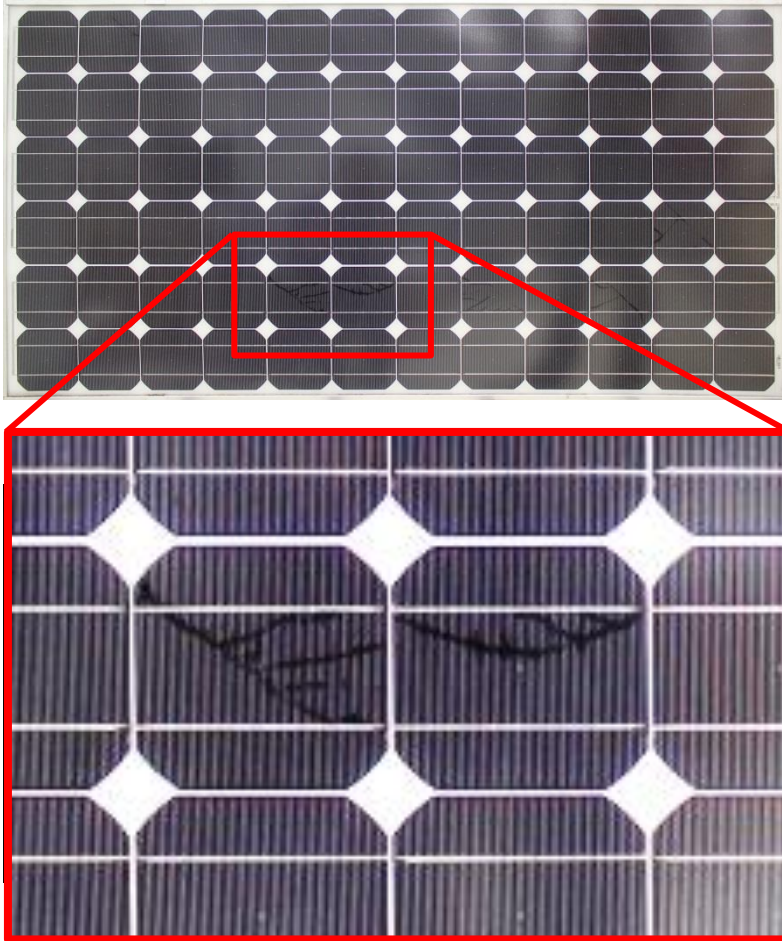
- mechanical failures in modules
 - copper ribbons
 - solder bonds
 - crack propagation in Si
 - drifting of crack fronts



Top: *Performance Loss (rel.)* after mechanical loading (2.4 kPa) and TCT 200*
Bottom: *EL-Image* after mechanical loading (left), TCT 200 (right) *

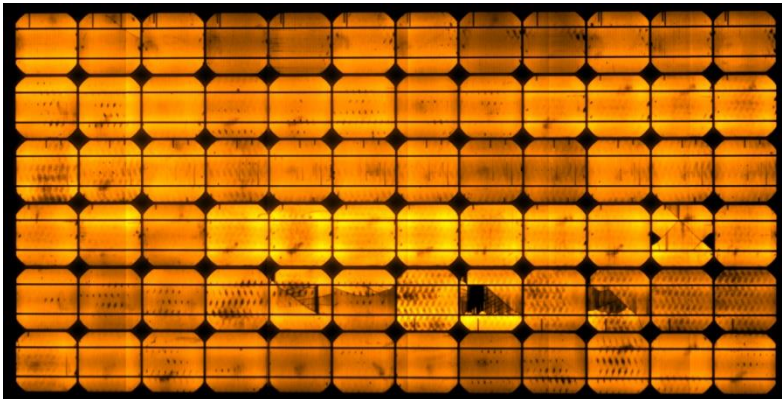
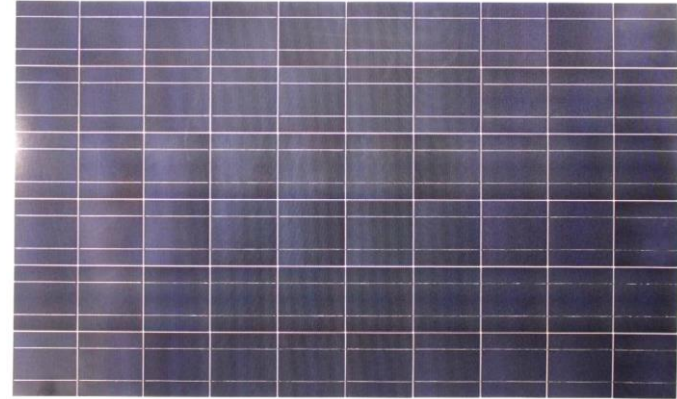
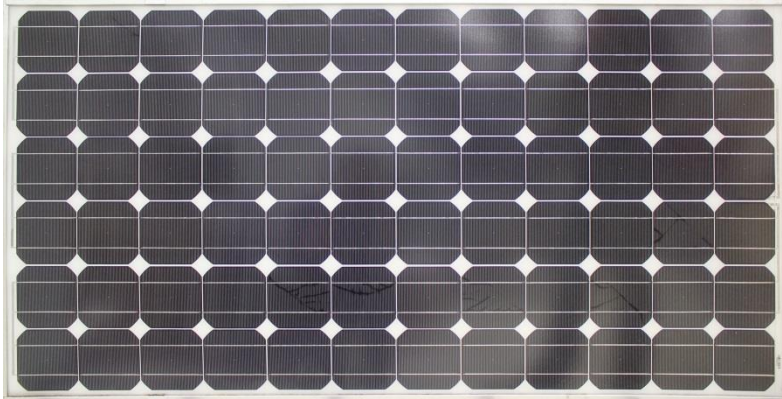


Motivation

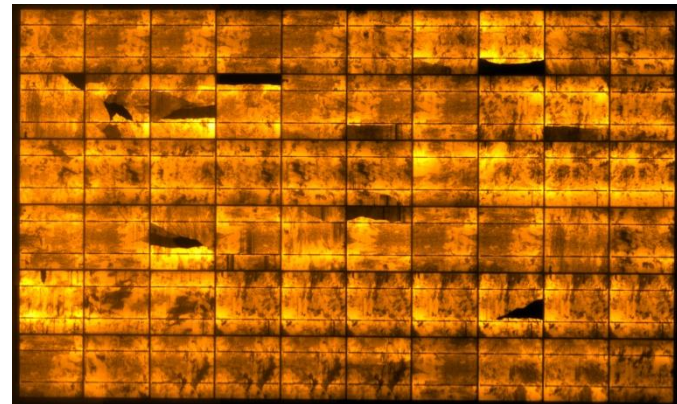


Elektrolumineszenz

Motivation



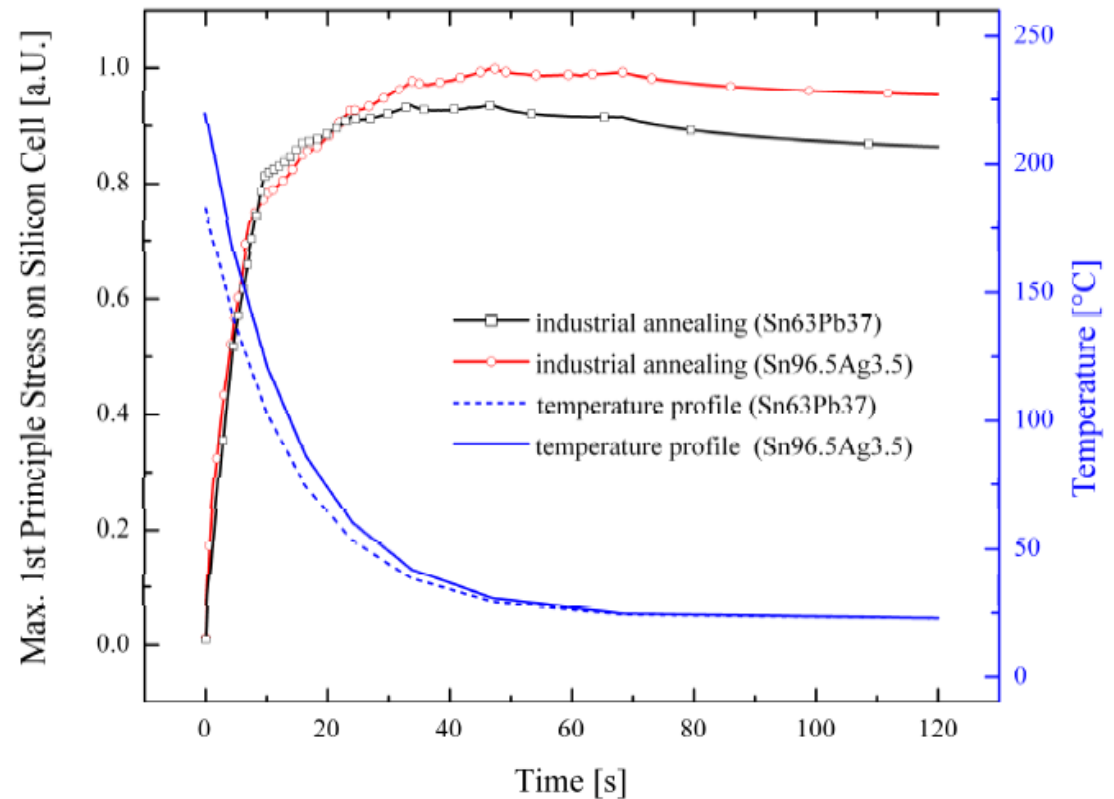
Elektrolumineszenz



Elektrolumineszenz

Motivation

- Different solders with different melting temperature cause different stress levels after soldering



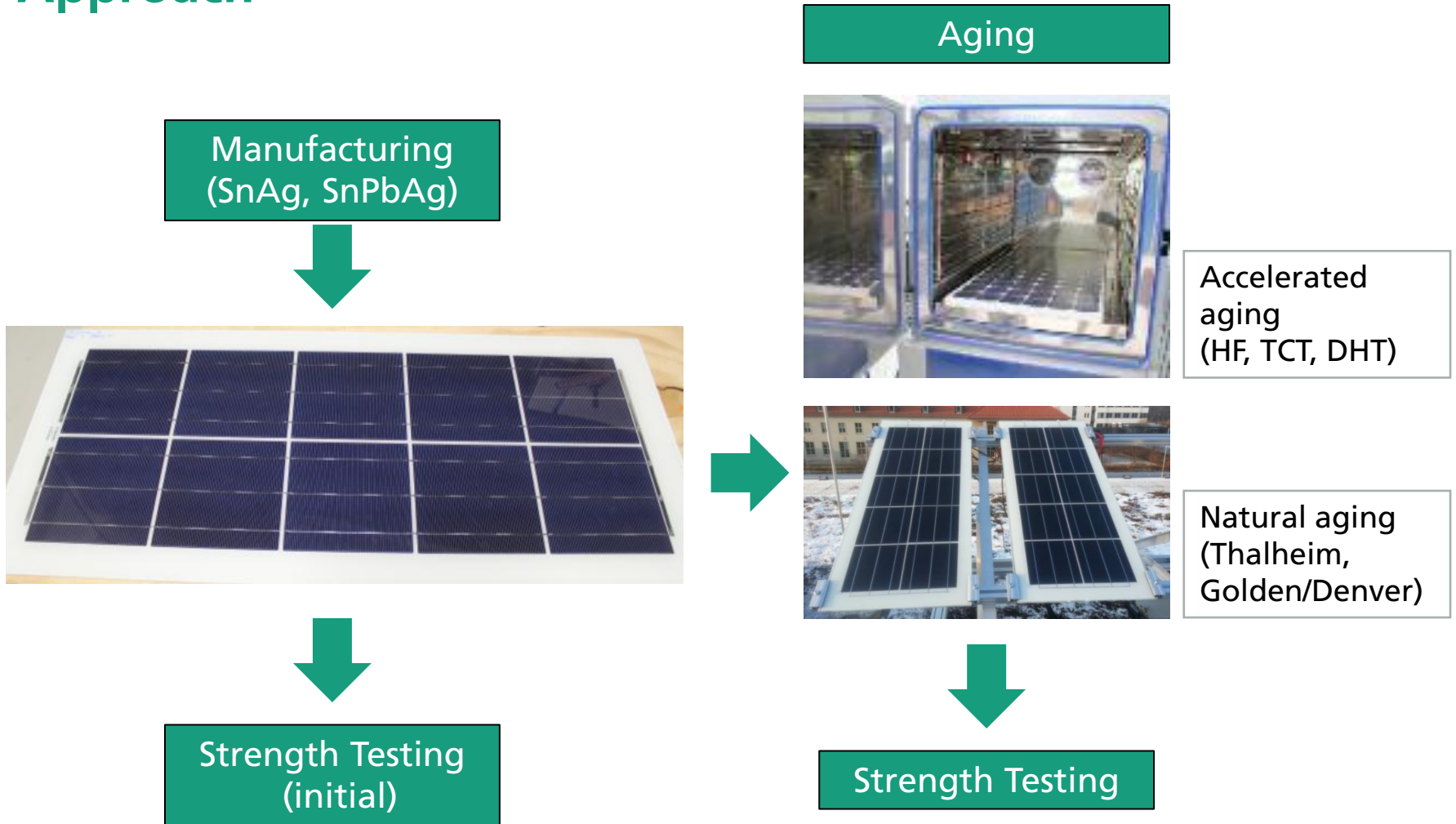
Methods

Approach

- Investigation of the in-laminate strength of solar cells and degradation of solar modules
 - Accelerated aging and natural weathering
 - Influences of temperature changes, humidity
 - Criterion for assessment
 - Cell breakage under mechanical loading

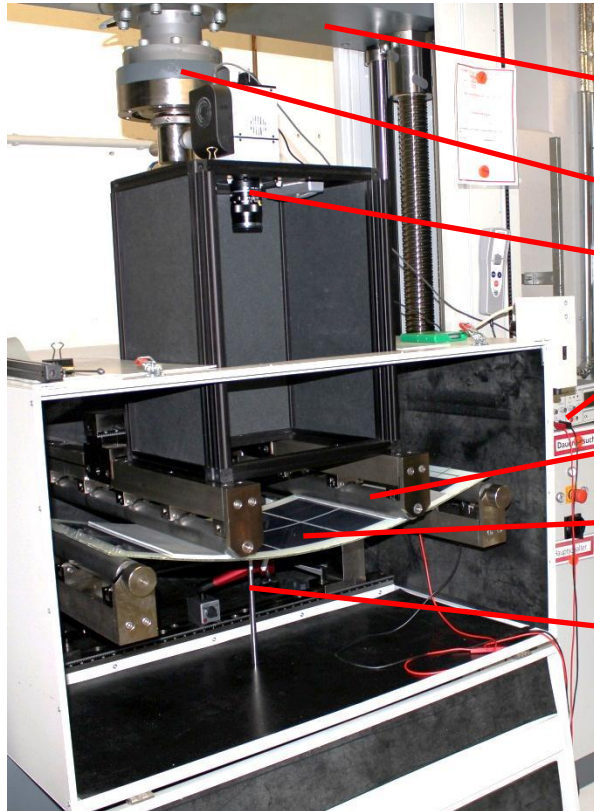
Methods

Approach



Methods

Experimental Setup



Cross bar

Load cell

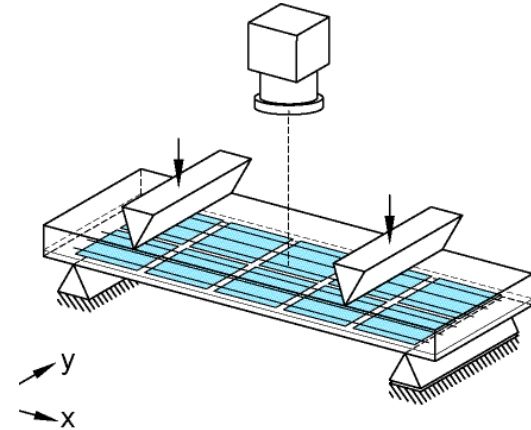
EL-Camera

Power supply

Load roller

Specimen

Displacement sensor



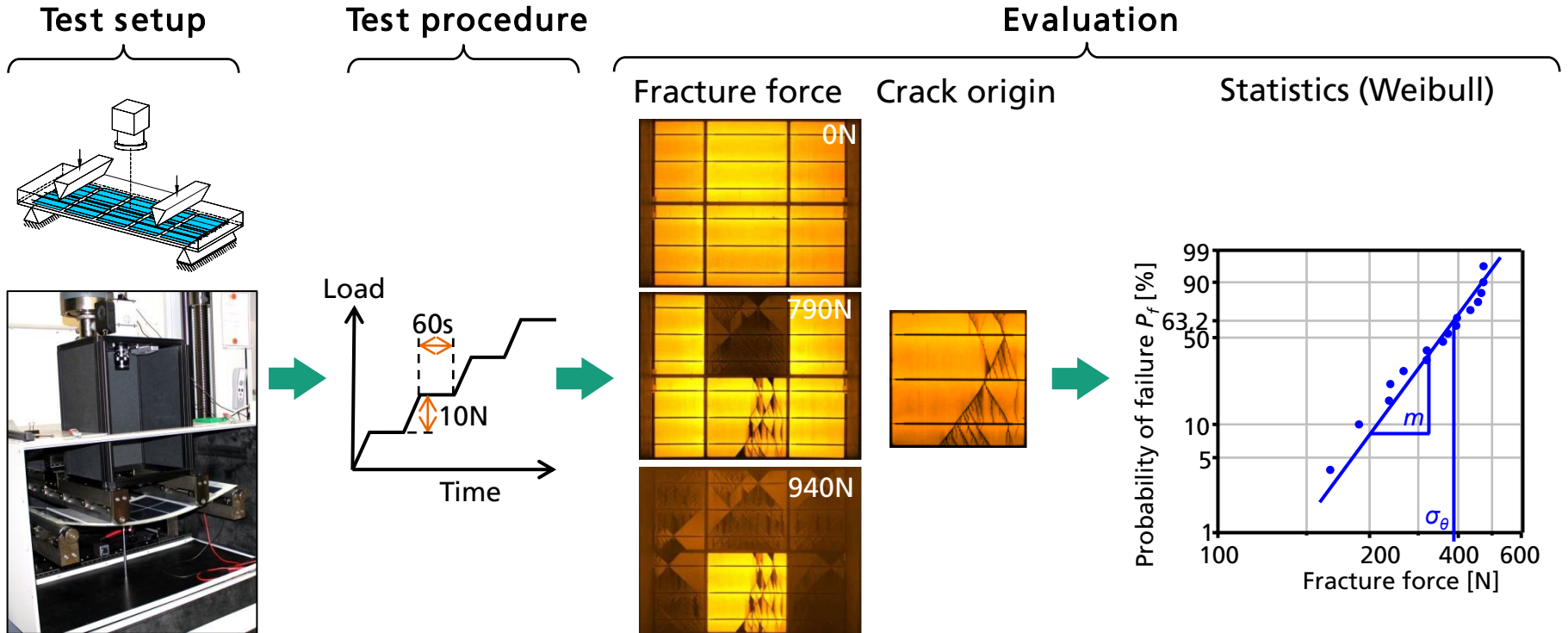
Distance support rollers = 840 mm

Distance load rollers = 400 mm

Load increment 10 N

Methods

Strength Evaluation

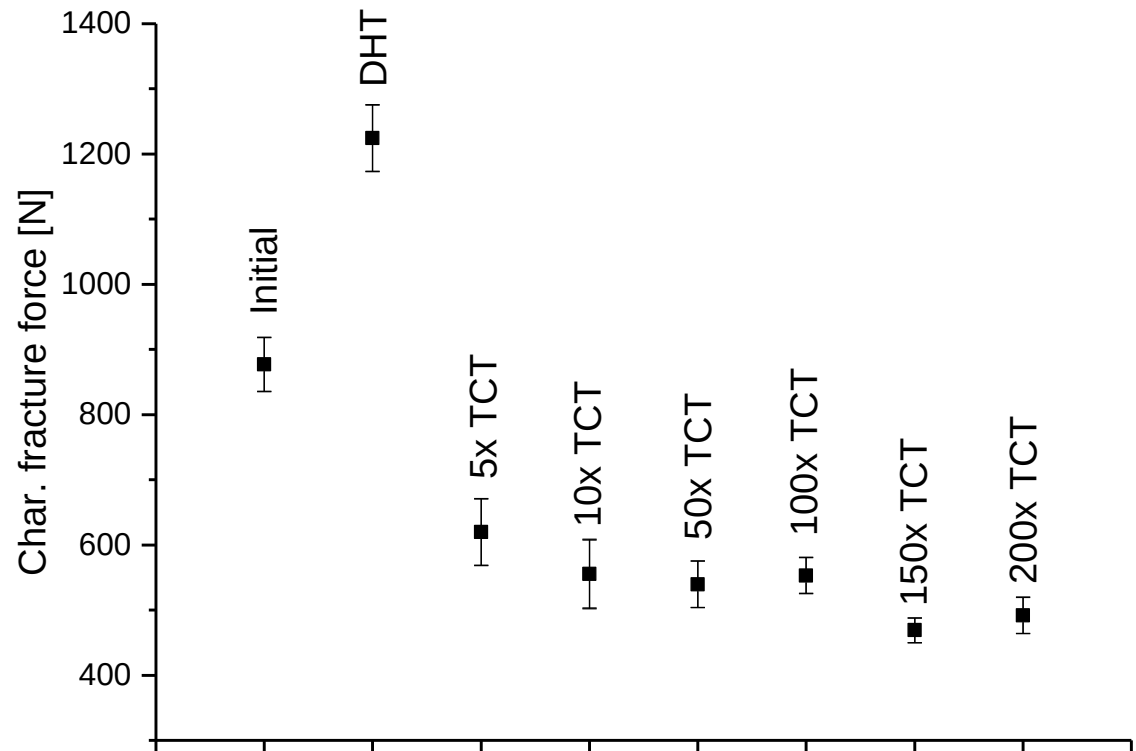


- Statistical evaluation of crack occurrences
- Utilization of Weibull distribution function $P_f(\sigma) = 1 - e^{-\left(\frac{\sigma}{\sigma_\theta}\right)^m}$
- Determination of characteristic force F and stress σ_θ and Weibull modulus m

Results

Influences of accelerated aging

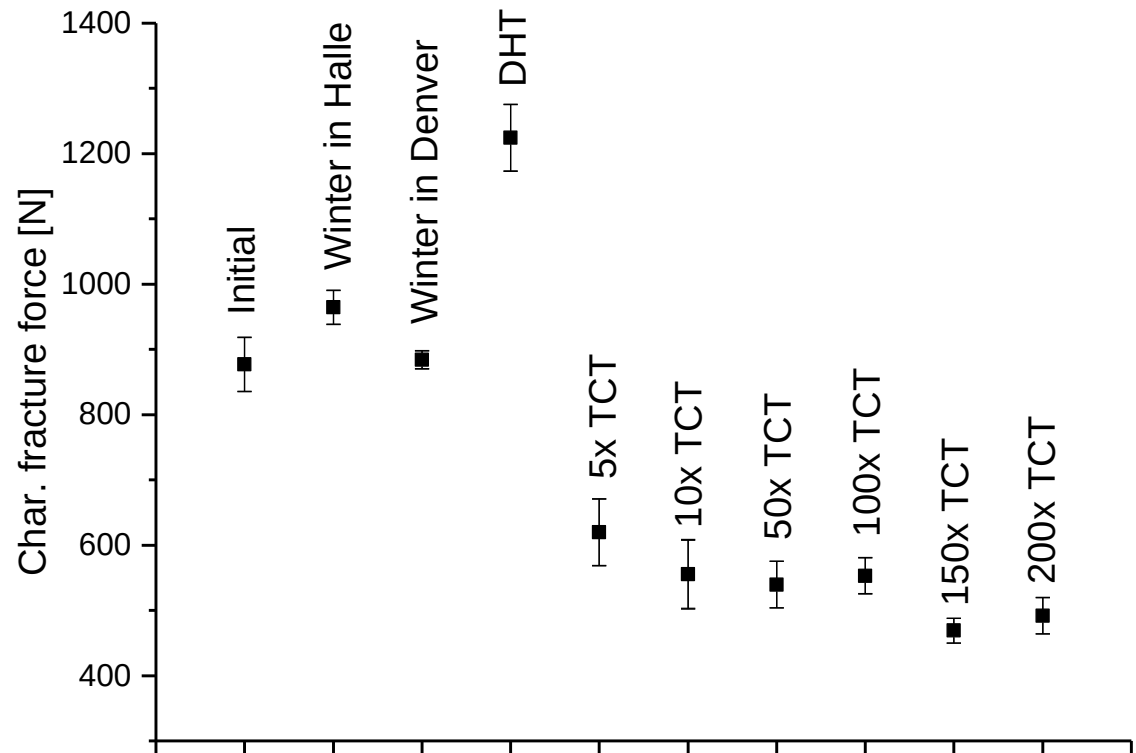
- Strength decrease during TCT (-40°C/+85°C) after few cycles
- no visible cracks before mechanical load
- Stress increase after damp heat test at +85 °C and 85 % r.h.



Results

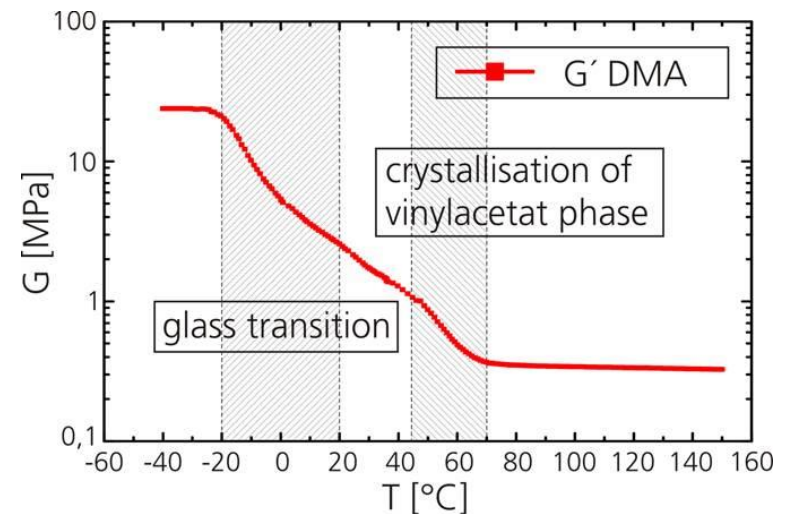
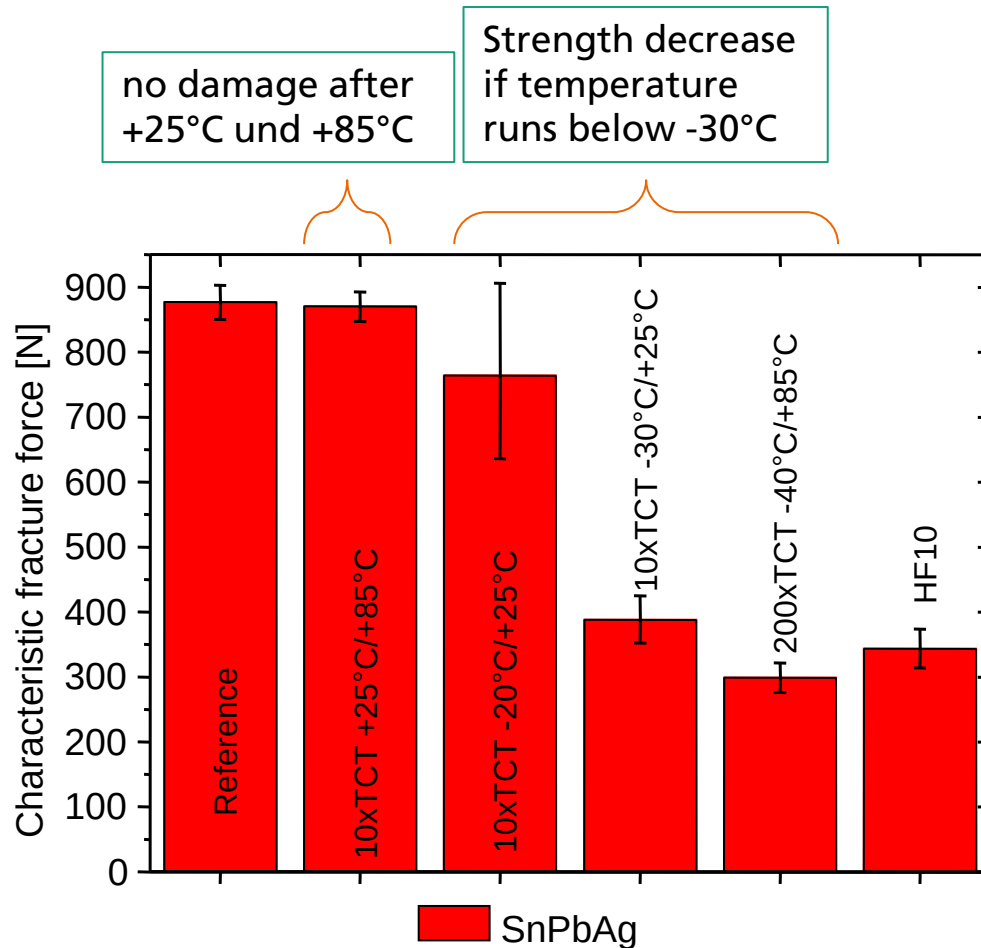
Influences of accelerated aging

- Strength decrease during TCT (-40°C/+85°C) after few cycles
- no visible cracks before mechanical load
- Stress increase after damp heat test at +85 °C and 85 % r.h.
- Outdoor
 - Halle: -17 °C ($T_{\min}$)
 - Denver -23 °C ($T_{\min}$)



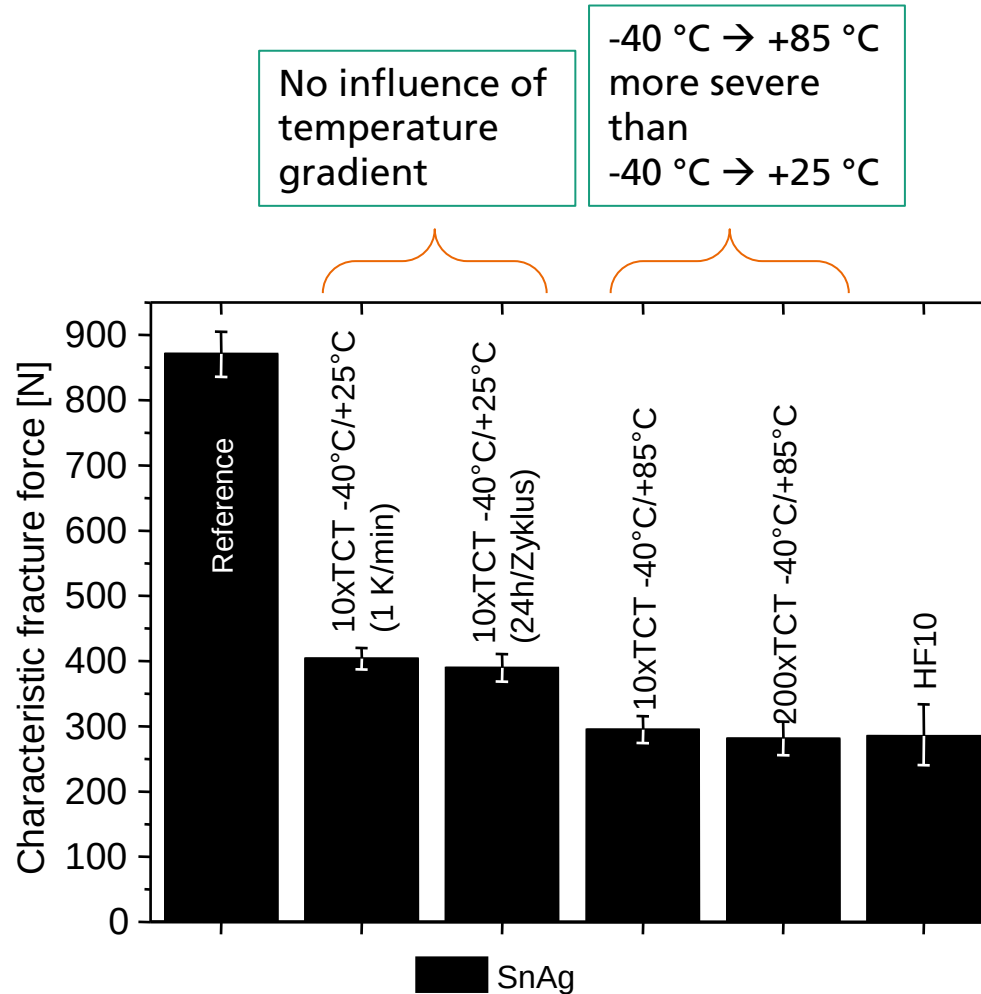
Results

Influences of accelerated aging



Results

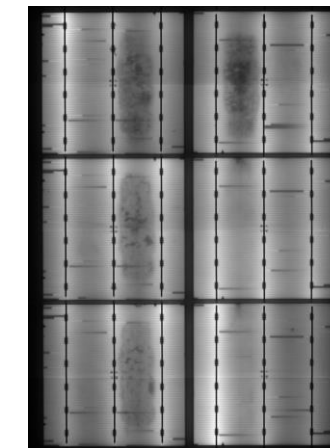
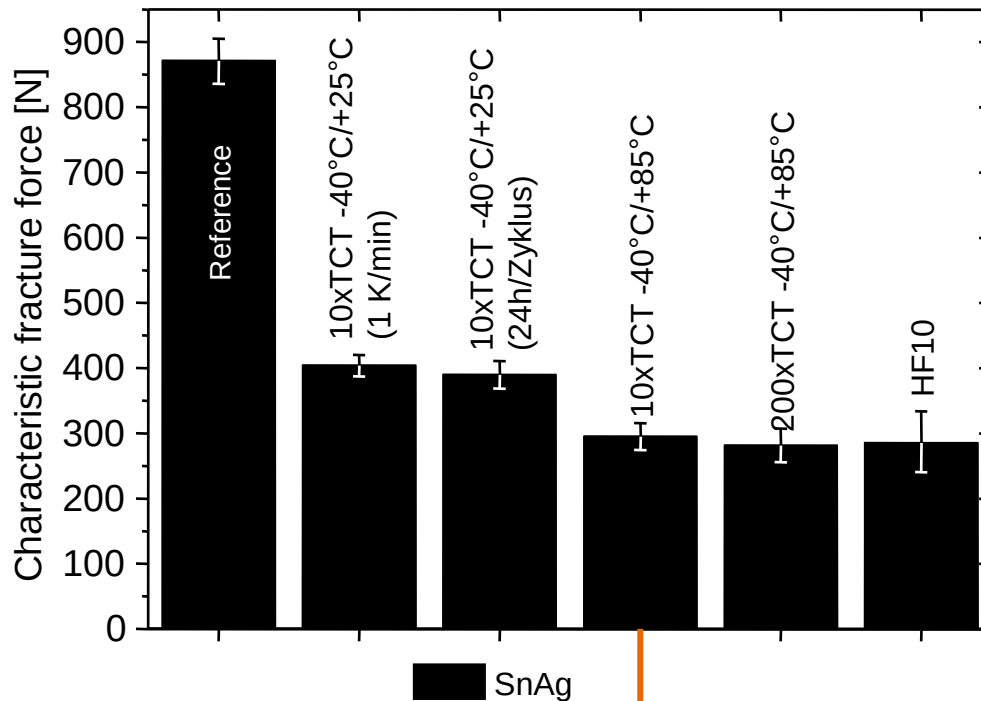
Influence of solder material



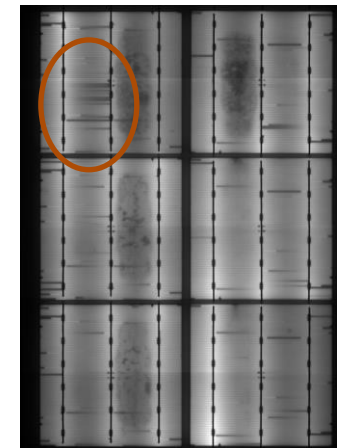
Results

Influence of solder material

- strong reduction of fracture force
- fracture of grid fingers
→ Increase with number of temperature cycles
- possible causes:
→ fatigue of grid fingers or plastic hardening of solder and copper



Vor TCT10
(1337003)

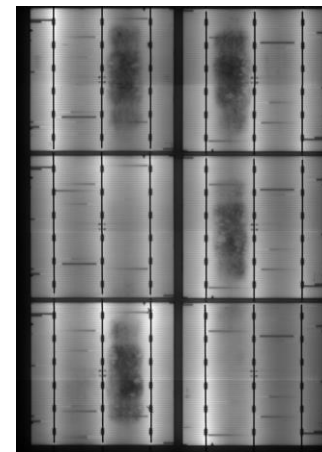
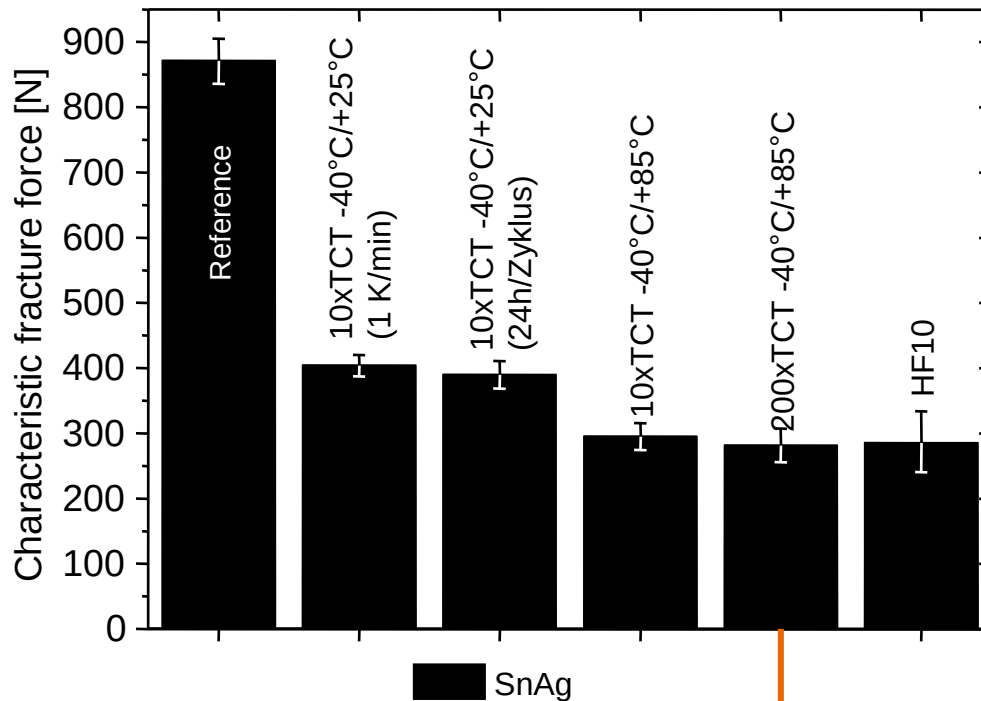


Nach TCT10

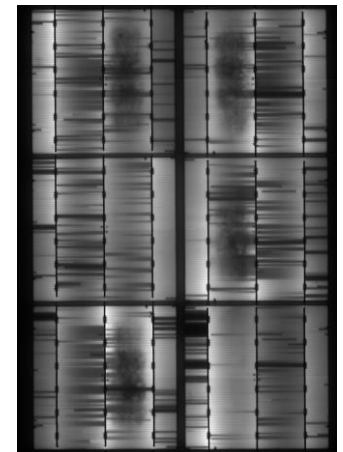
Results

Influence of solder material

- strong reduction of fracture force
- fracture of grid fingers
 - Increase with number of temperature cycles
- possible causes:
 - fatigue of grid fingers or plastic hardening of solder and copper



Vor TCT200
(1337006)



Nach TCT200

Conclusions

- climatic influences may affect loading capacity of solar modules in the long term with respect to cell breakage
 - humidity → increases → softening of EVA due to water ingress
 - temperature cycles below glass temperature → reduction
→ critical for regions with temperatures below glass transition of EVA ($< -25\text{ °C}$)
- type of solder shows no influence if properly processed
- quantity of finger interruptions don't correlate to loading capacity

Thank you for your attention

Thanks to:

Dr. Martin Sander

Frank Wenger

Dr. Matthias Ebert

The authors gratefully acknowledge the financial support by the **German Federal Ministry of Education and Research** within the framework of the Leading-Edge Cluster Competition and the research cluster Solarvalley Central Germany under contract No. 03SF0400A ("xμ-Module II")



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