Room-Temperature Solar Cells Interconnection through Electrically Conductive Tape

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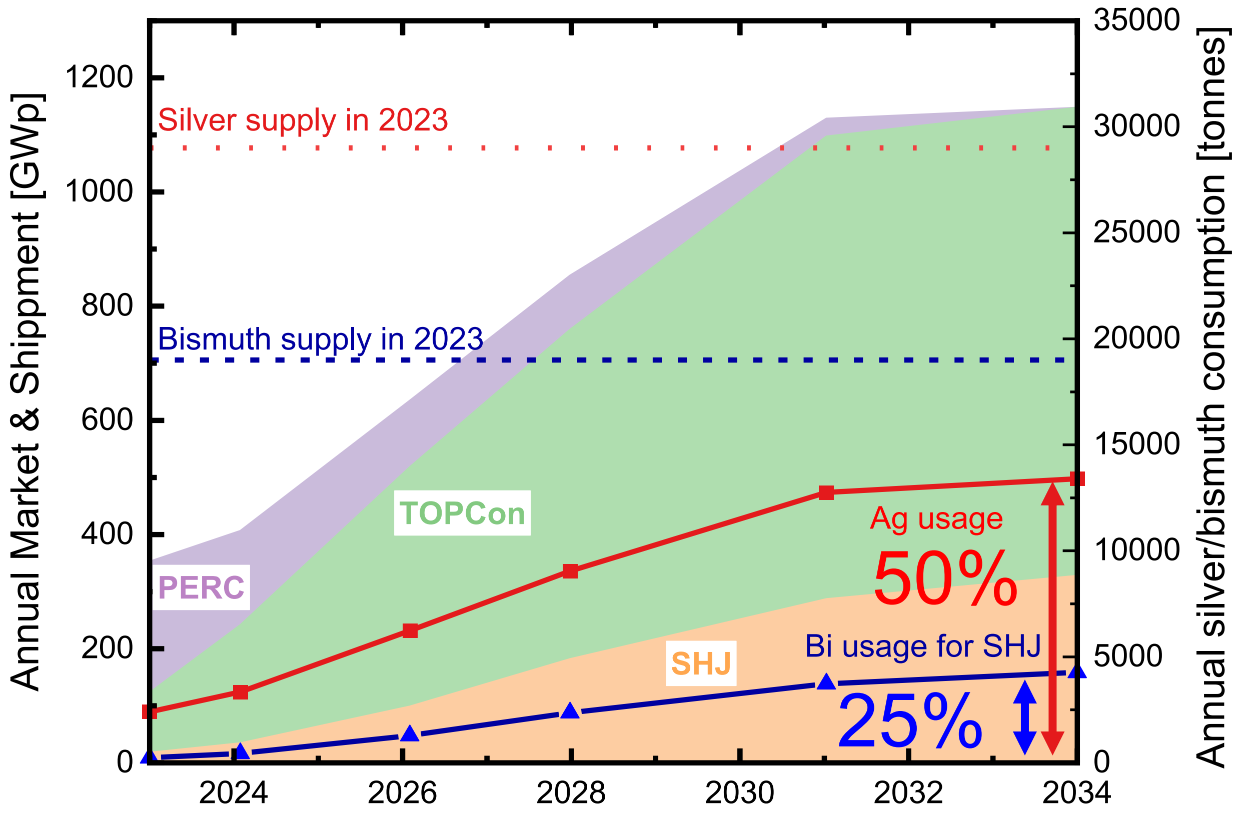
Challenges for Solar Module Interconnection

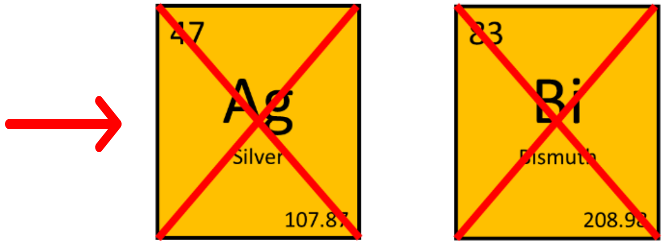
Silver and Bismuth Supply Risks in the TW-Scale PV Era



The PV industry is expected to reach multi-terawatt scale annual production by 2030.

PV share of global supply:

- 50 % of the silver
- 25 % of the bismuth



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Challenges for Solar Module Interconnection

Interconnection of heat sensitive solar cells like SHJ or perovskite tandem solar cells

Processes temperatures below

- 200 °C for SHJ solar cells

→ Prevent H effusion

- 110 °C for perovskite solar cells

→ Prevent perovskite decomposition

→ Find alternative cell interconnection methods to standard IR soldering

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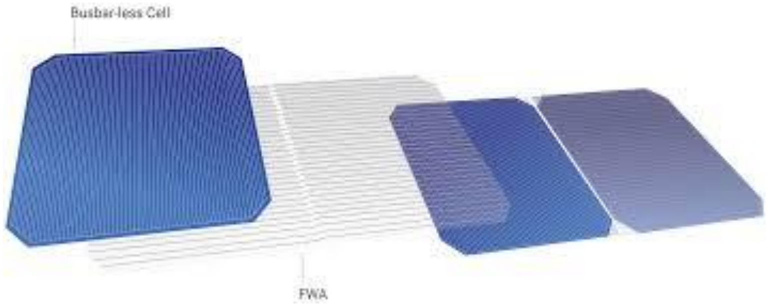
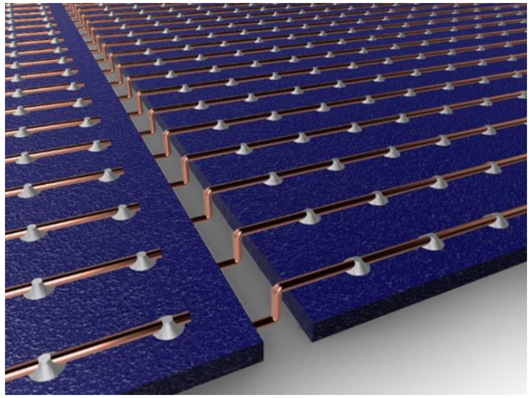
Alternatives Interconnection Methods tested at the FZJ

Potential for low process temperatures and less scarce material usage



Multi Wire Foil

Electrically Conductive Adhesive (ECA)

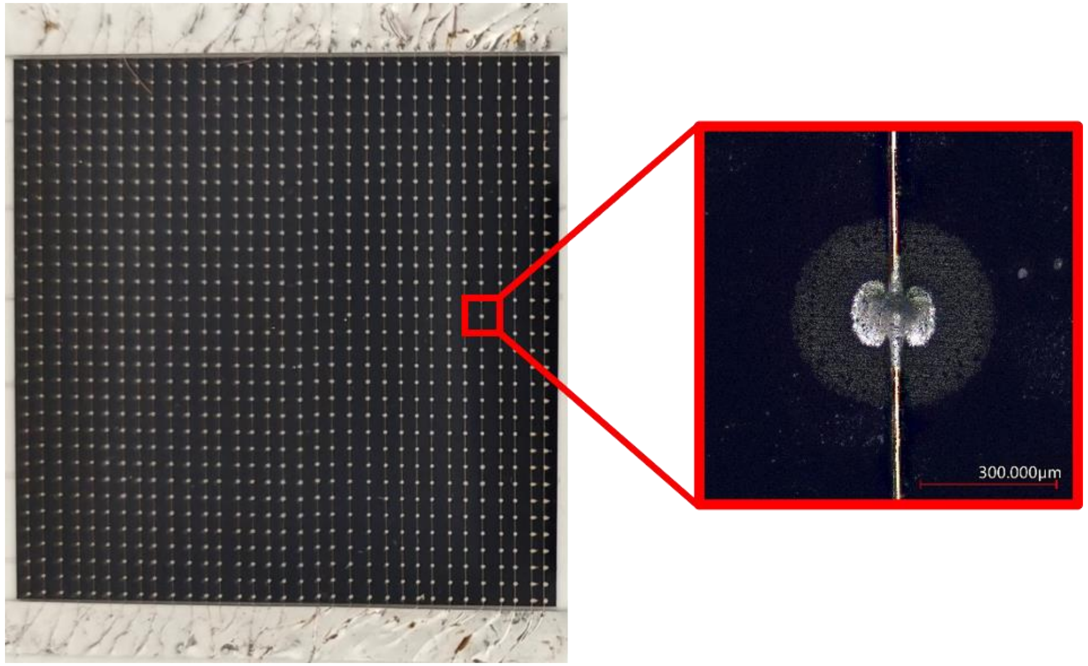


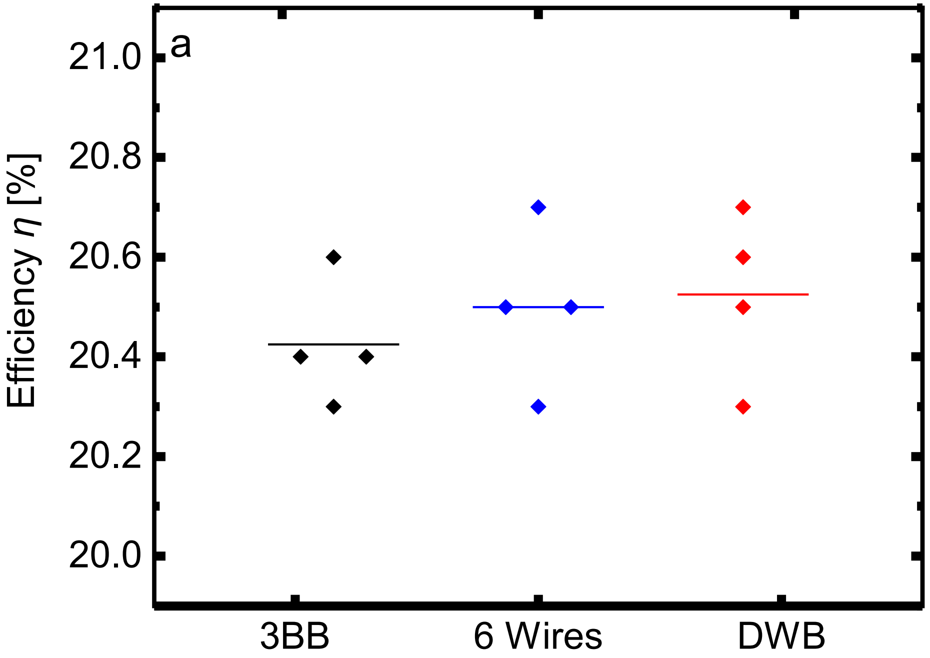
Direct Wire Bonding (DWB)

Electrically Conductive Tape (ECT)

Direct Wire Bonding (DWB)

Silver Reduction for Silicon Heterojunction Solar Cells





Liu, Yanxin, et al. "Silver reduction through direct wire bonding for Silicon Heterojunction solar cells." *Solar Energy Materials and Solar Cells* 282 (2025): 113412.

Alternatives Interconnection Methods tested at the FZJ

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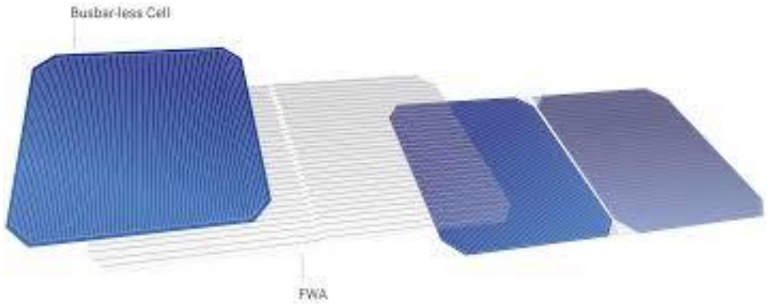

Multi Wire Foil

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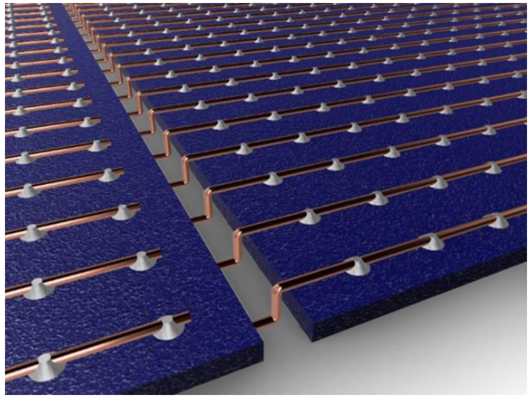
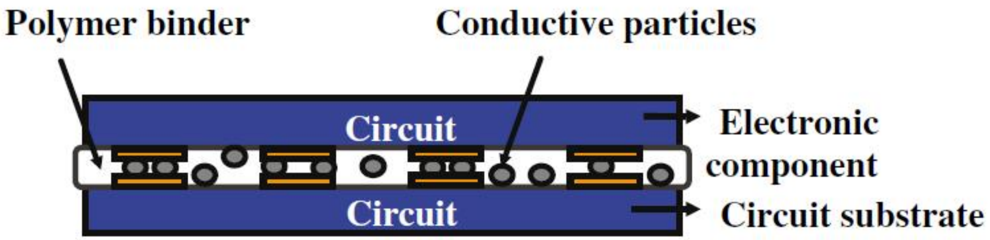


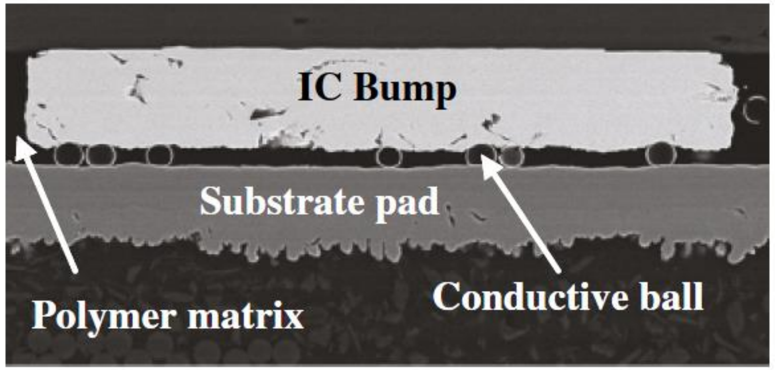
Direct Wire Bonding (DWB)

Electrically Conductive Tape (ECT)

Introduction: Electrically Conductive Tape

Application of ECT in Integrated Circuits (IC)



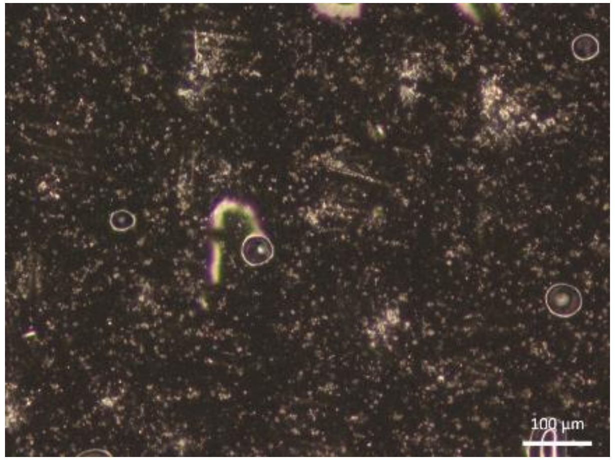


Li, Yi Grace, Daniel Lu, and C. P. Wong. *Electrical conductive adhesives with nanotechnologies*. Springer Science & Business Media, 2009

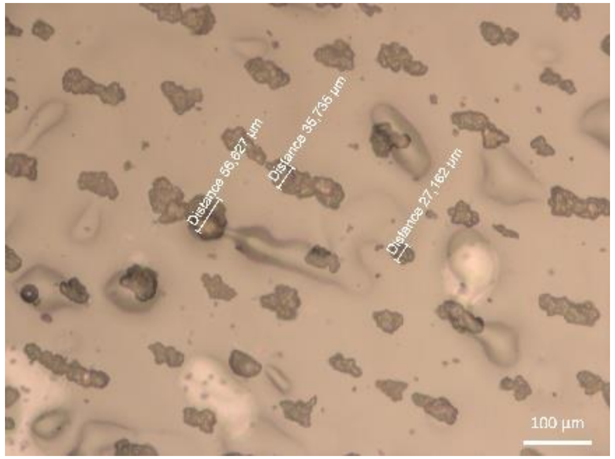
- Metal particles embedded in adhesive polymer
- Isotropic conductivity beneficial for IC interconnection

→ **Use ECT in solar cells**

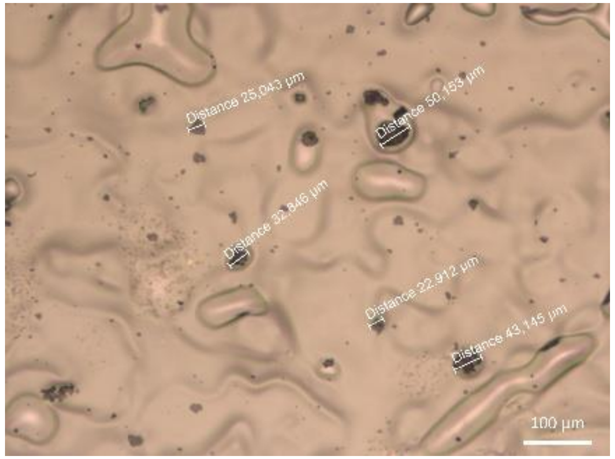
3 Tested Types of Electrical Conductive Tape



ECT1: 100 µm-thick; isotropic conductive woven fabric coated on both sides with conductive acrylic adhesive



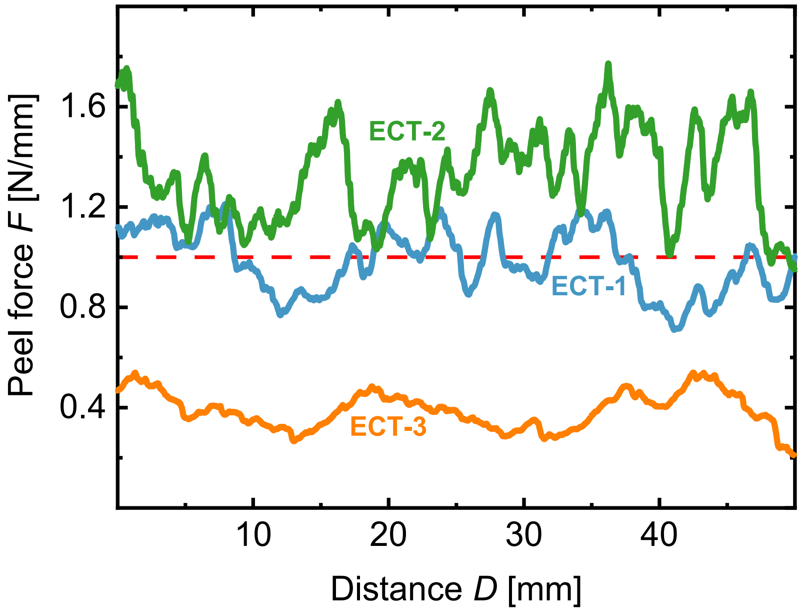
ECT2: 50 µm-thick; anisotropic tape with acrylic adhesive filled with Ag particles.



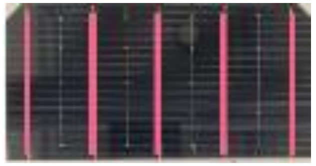
ECT3: 10 µm-thick; anisotropic tape with acrylic adhesive filled with Ni particles.

ECT Adhesive Thickness

Peel Force between Tabbing Ribbon and the Busbar

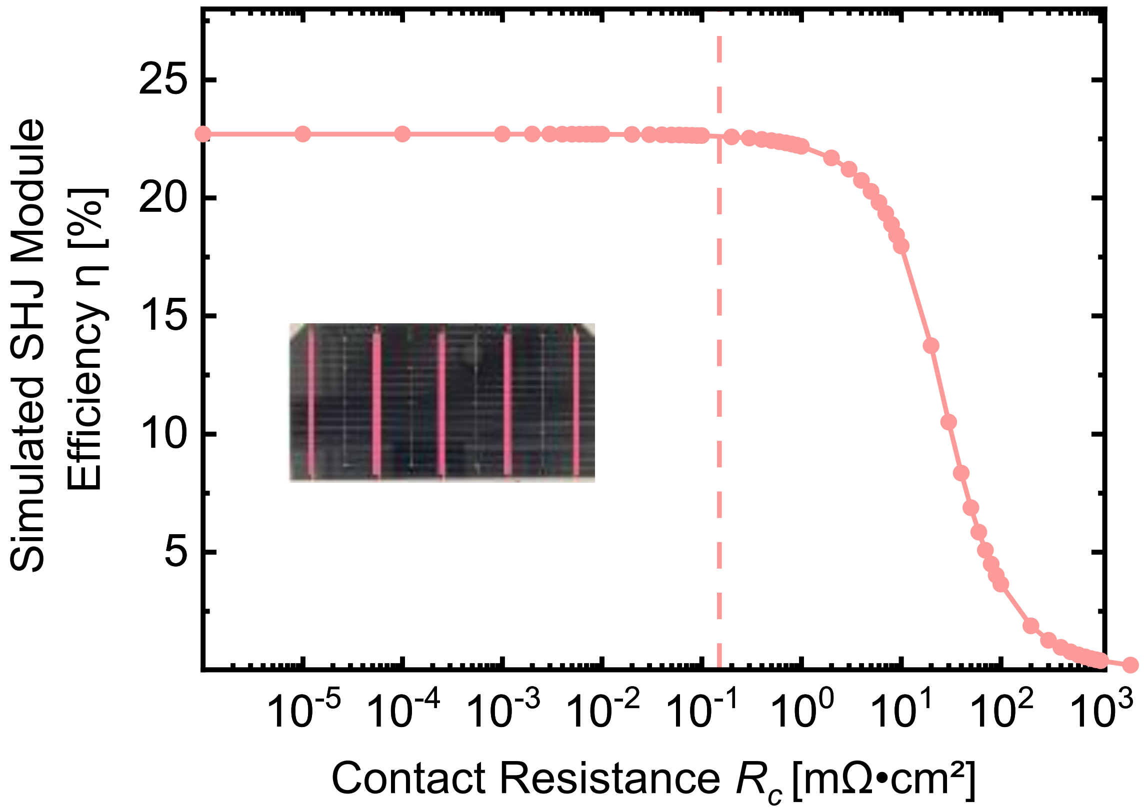


- **ECT1**: 100 µm-thick; isotropic conductive woven fabric coated on both sides with conductive acrylic adhesive
- **ECT2**: 50 µm-thick; anisotropic tape with acrylic adhesive filled with Ag particles.
- **ECT3**: 10 µm-thick; anisotropic tape with acrylic adhesive filled with Ni particles.



→Good adhesion for ECT1 and 2
→Lower adhesion for the ECT3 with thin adhesive

Solar cell Efficiency vs. Contact Resistance Calculated by Simulation



- 0.1%abs. efficiency loss at R_c = 0.015 Ω mm^2 according to simulation

→ Maximum acceptable ECT contact resistance

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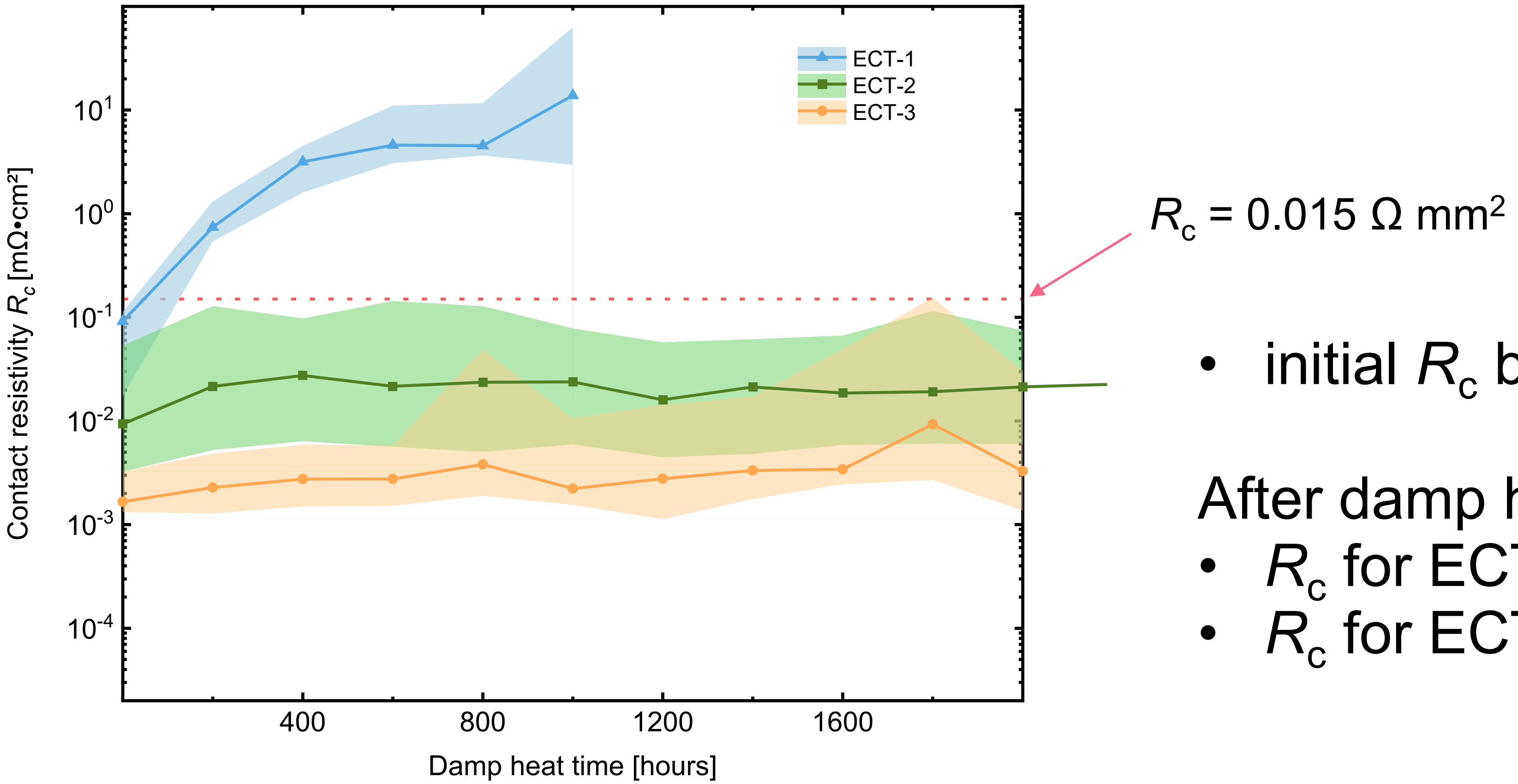
Evolution of Contact Resistance During Damp Heat Testing



- initial R_c below limit for all ECTs

After damp heat:

- R_c for ECT1 increase
- R_c for ECT2,3 is stable

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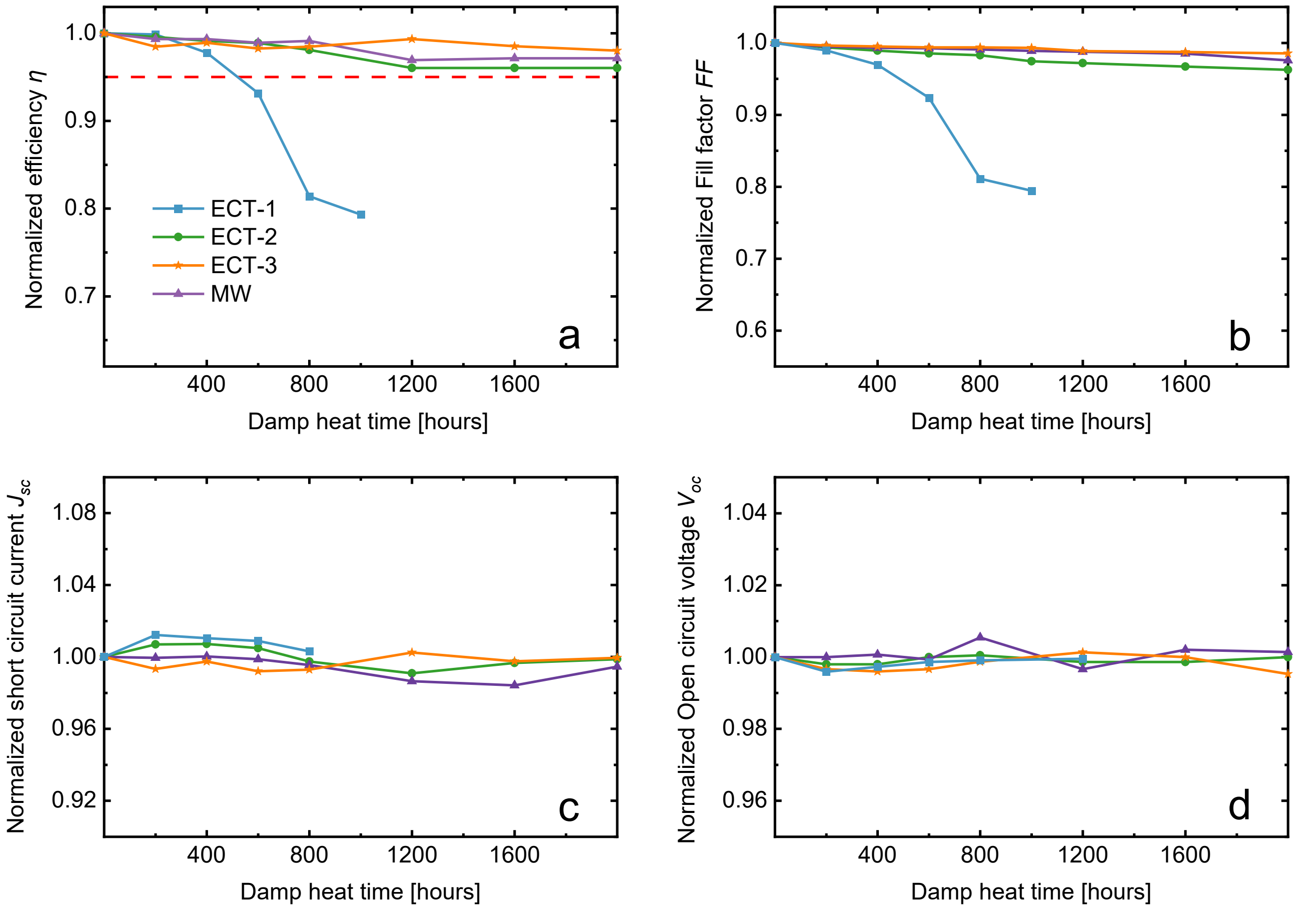
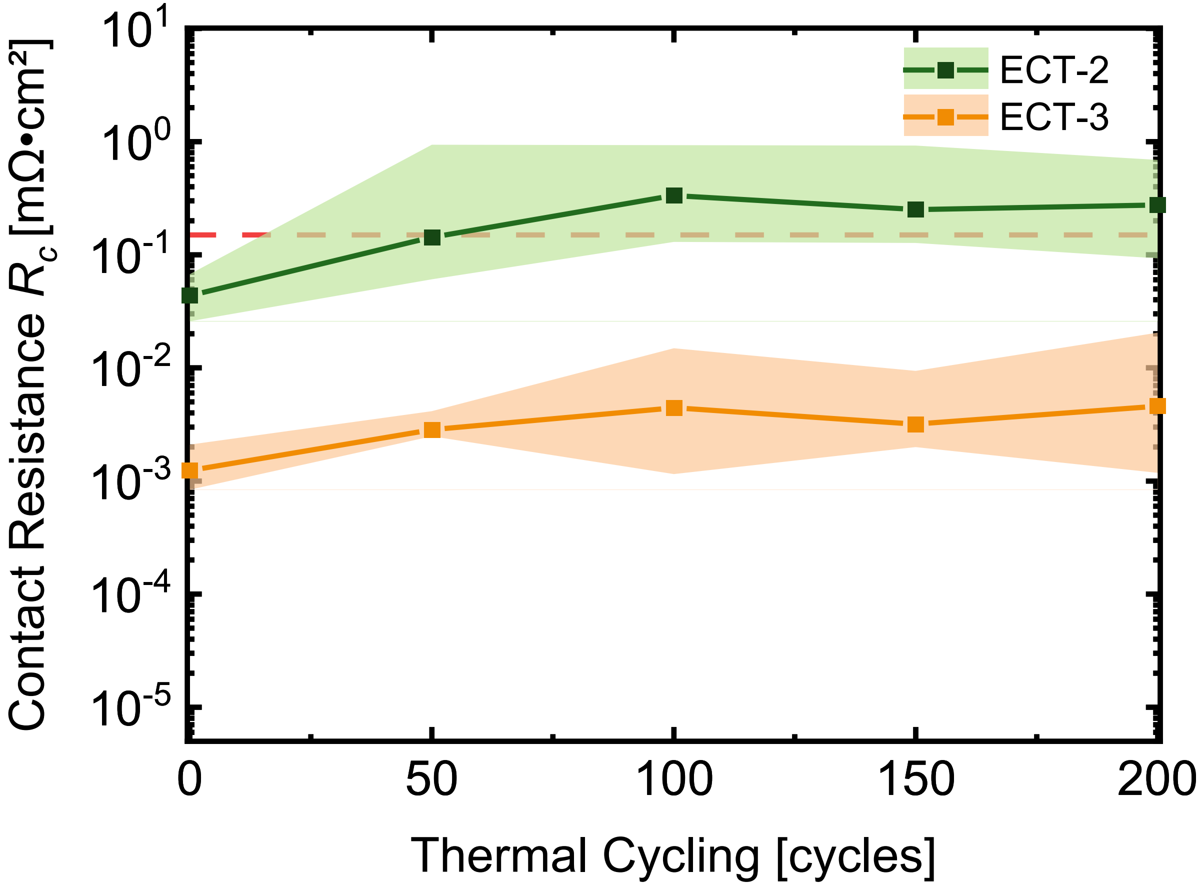
Relative Changes of SHJ Modules Connected via ECT during DH testing



- **ECT1 modules:**
  - Showed fastest degradation; >5% efficiency loss after ~500 h
  - Degradation mainly due to rising R_c → higher series resistance, reduced *FF*, lower power.
- **ECT2 & ECT3 modules:**
  - ECT3 was most stable (~2.5% loss, only 1% *FF* drop),
  - ECT2 had ~4% loss and 2% *FF* drop.

Evolution of Contact Resistance during Thermal Cycling Testing



ECT-2:

- R_c increases above the R_c = 0.015 Ω mm² limit

ECT-3:

- R_c increase during TC testing
- still way below the R_c limit even after 200 cycles

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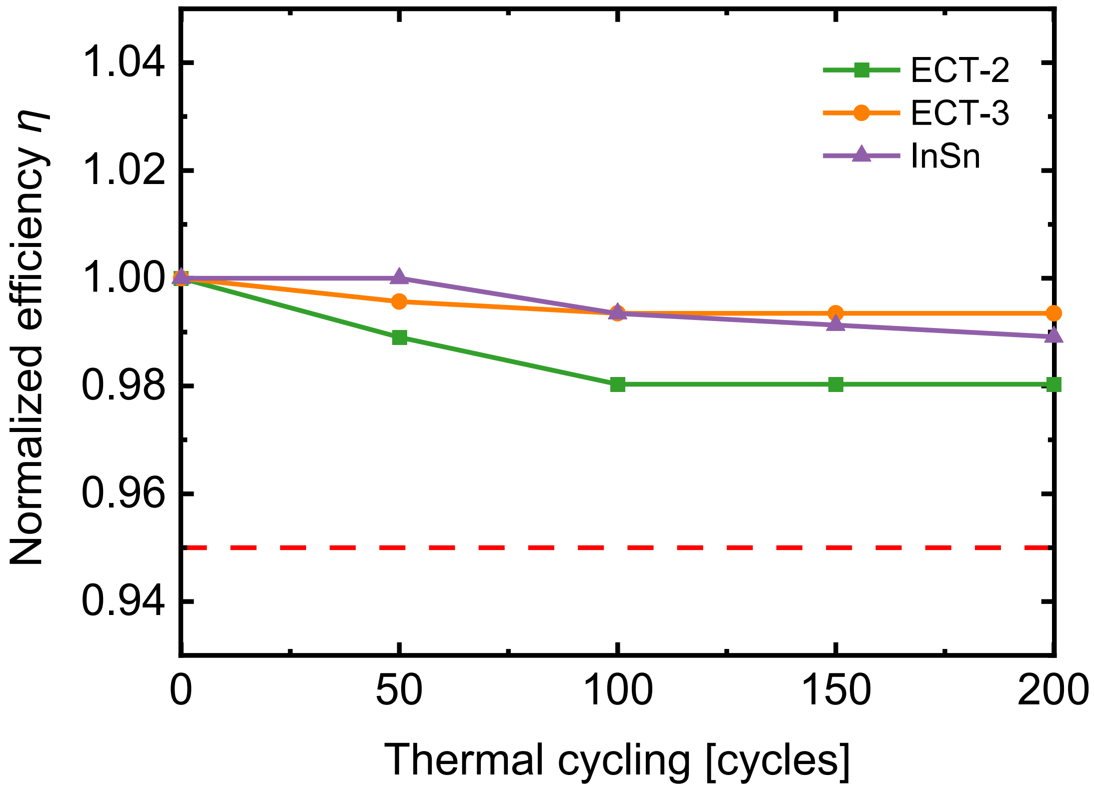
Relative Changes of SHJ Modules Connected via ECT during TC testing.



ECT-2:

- ~2% efficiency drop in the first 100 cycles, then stabilized

ECT-3:

- Very stable under TC
- efficiency loss minimal (<1% relative)
- V_{oc} and J_{sc} unchanged

Summary

ECT as alternative interconnection technology

✓Low temperature, solder free interconnection, cost efficient method

✓Reduces the Ag / Bi consumption of solar modules

✓Stable under damp heat / thermal cycling

✓Anisotropic tapes showed superior performance in contrast to isotopic tape

➢Optimize ECT for good stability combined with high peel force (ECT3 vs. ECT2)

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Projects:

SuperSolid

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