

### Multiwire Interconnection with SnBi Alloy for Perovskite/Silicon Tandems

V. Depauw, B. Luo, B. Reekmans, H. Javanbakht Lomeri, R. Van Dyck, M. Casasola Paesa, J. Govaerts, H. Sivaramakrishnan Radhakrishnan

F. Saenz, Q. Jeangros :: CSem



#### Me at the Metallization & Interconnection Workshop...



What my friends have in mind



What my colleagues have in mind



What I had in mind (6 months ago)

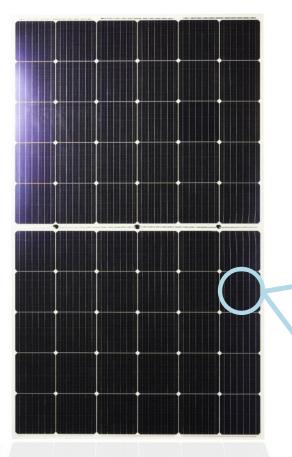


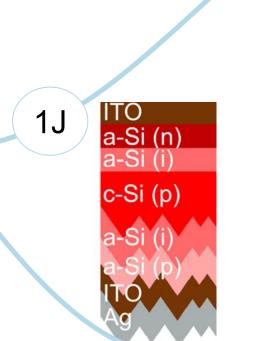
What I had in mind (2 days ago)

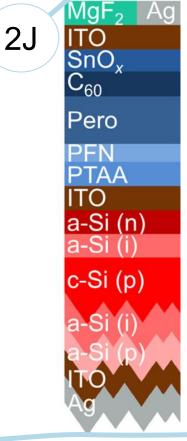


#### Perovskite/Si multijunction modules

Increased materials complexity









3J



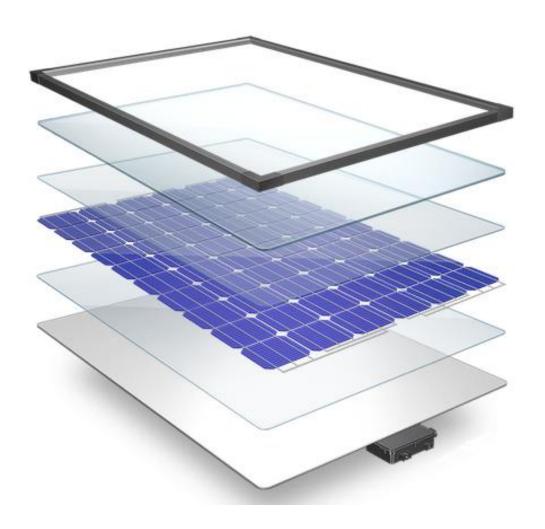
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Schematics: **Fischer** Solar RRL 2023 **Heydarian** ACS Energy Lett. 2023

#### Perovskite/Si multijunction modules: amplified constrains





- Pk cell degrades at elevated temperatures
  - Keep below < 150 °C</li>
  - Ideally < 130 °C and only a few minutes</li>



- Sensitive to thermomechanical **strain/stresses** 
  - Limit thermal amplitude/rate/time
  - Limit pressure/shear stress



- Very soft material
  - Risk of punching through and shunting
     0.2-.06 GPa (Pk) vs. 2 (Cu) vs. 13 (Si)
     Baumann, Energy Environ Sci 2024

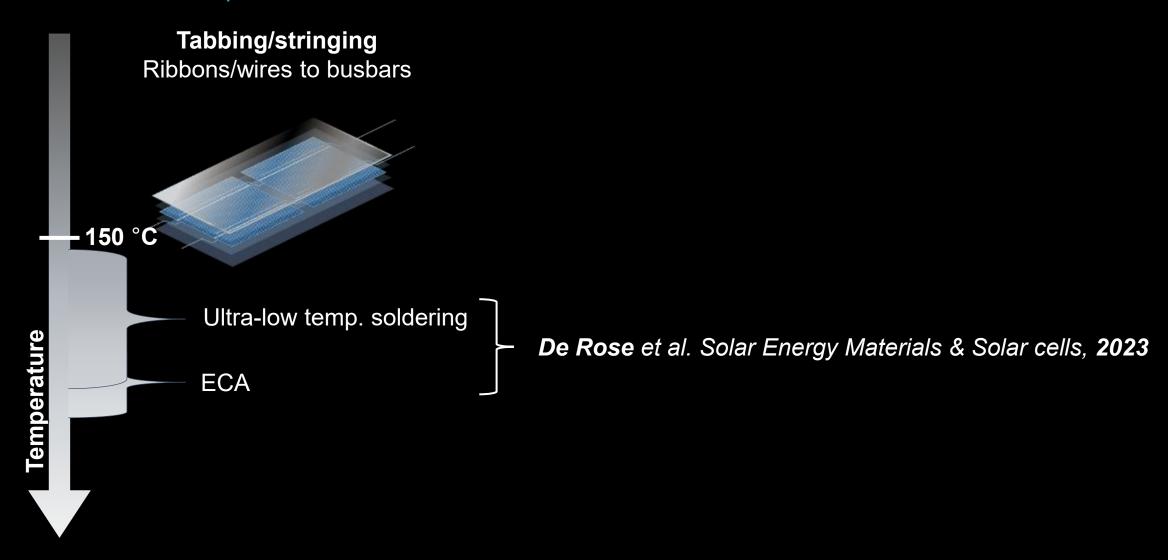


- Reactivity with standard environmental conditions
  - Prevent moisture + oxygen ingress
  - Avoid formation of by-products





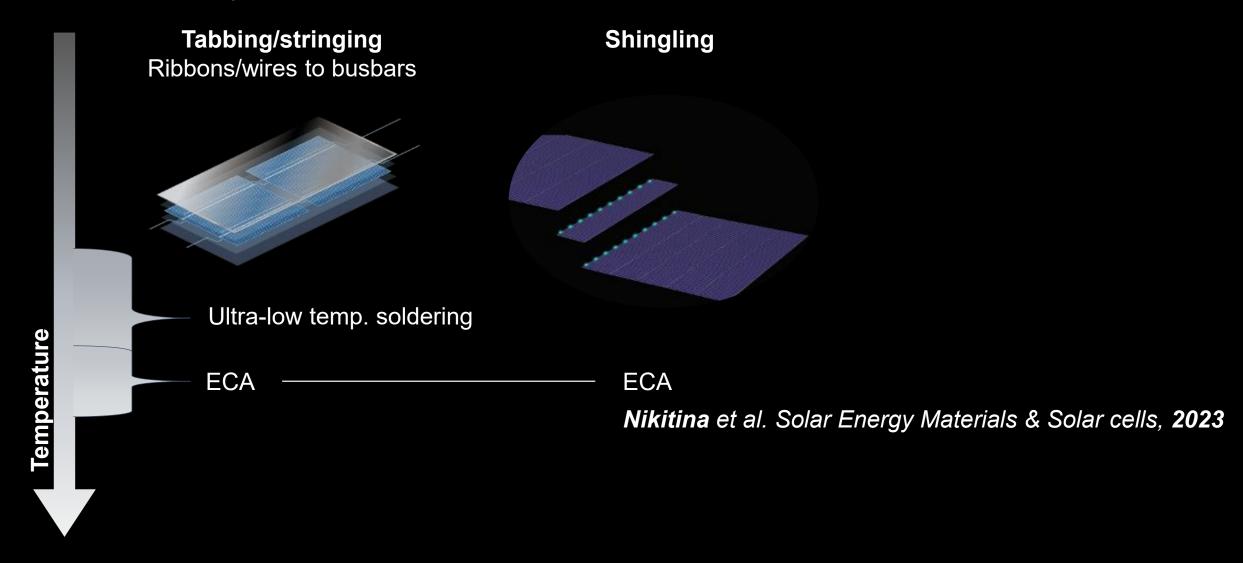
What has been reported in literature







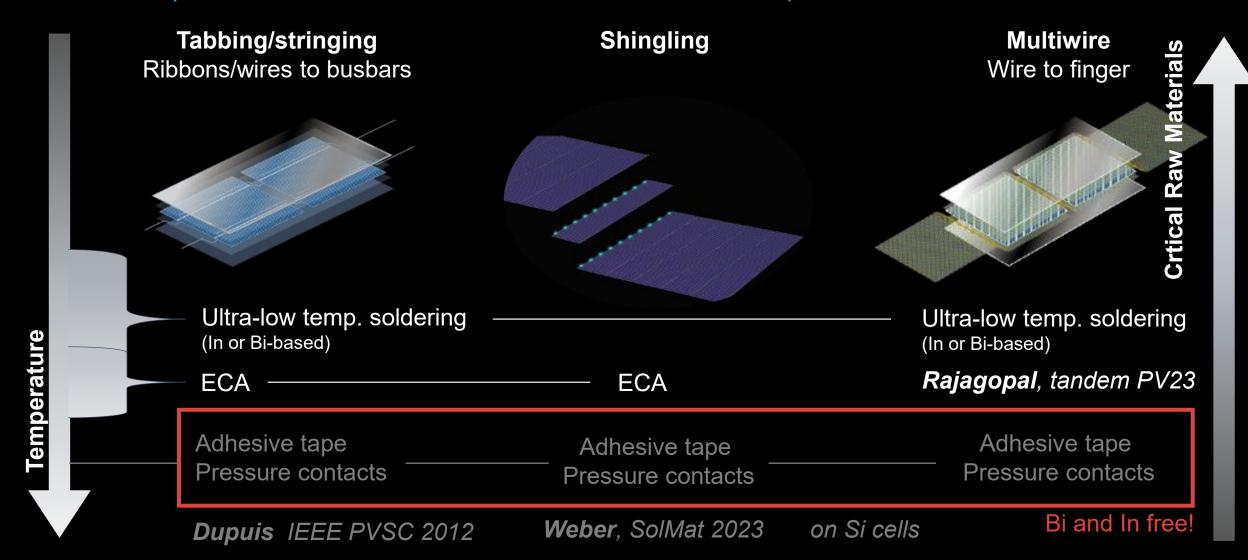
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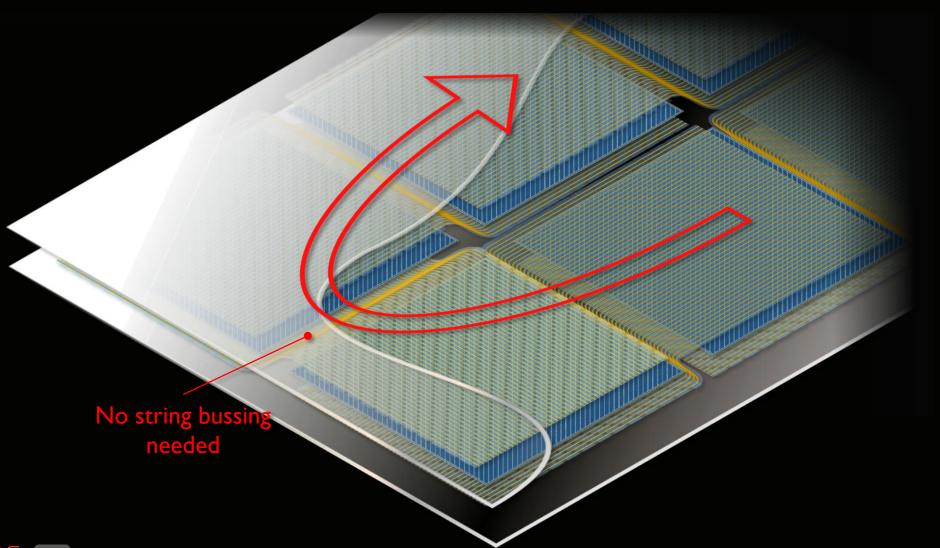
Ultra-low temperature & CRM-free interconnection is to be developed







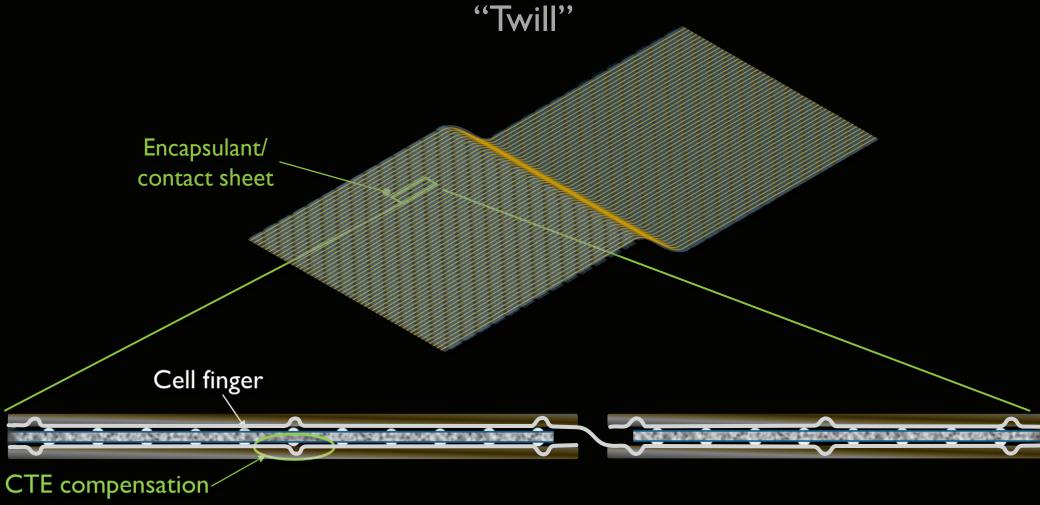
## Multi-Wire Encapsulant-based Contact Sheet "Twill"



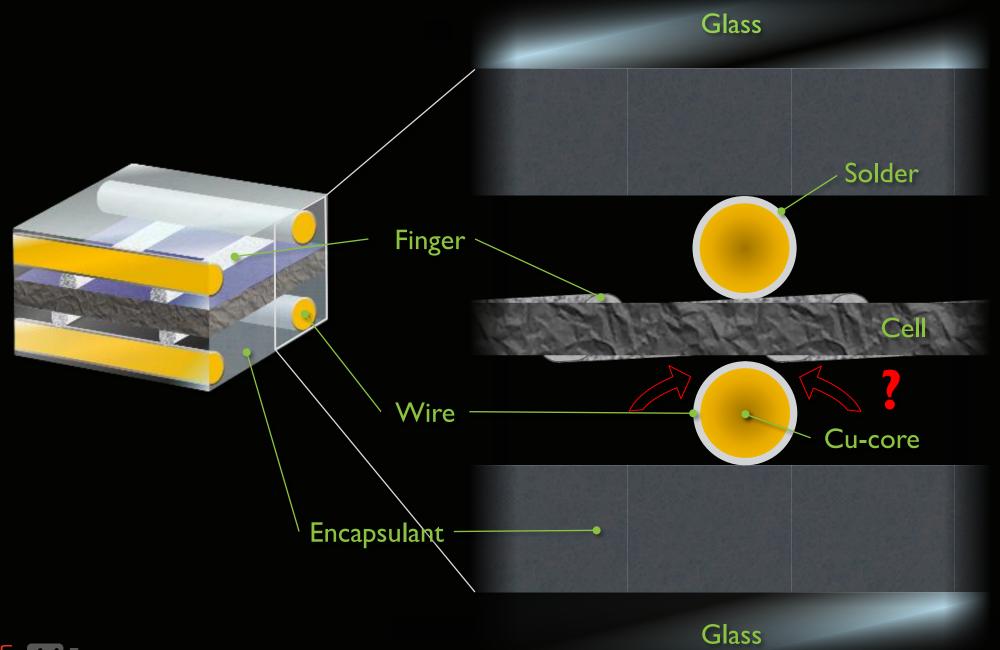




#### Multi-Wire Encapsulant-based Contact Sheet



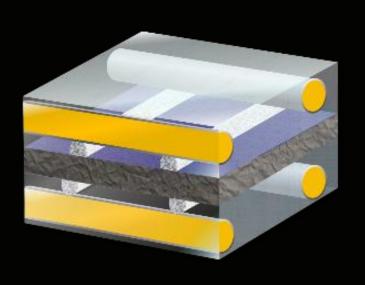


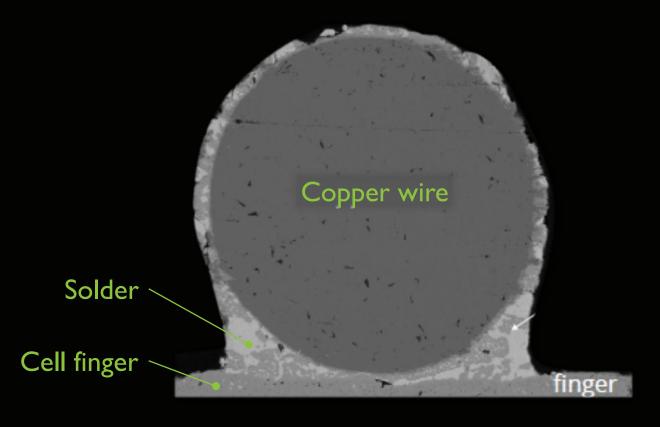






V. Depauw et al., @MIW 2025 Courtesy: T. Borgers

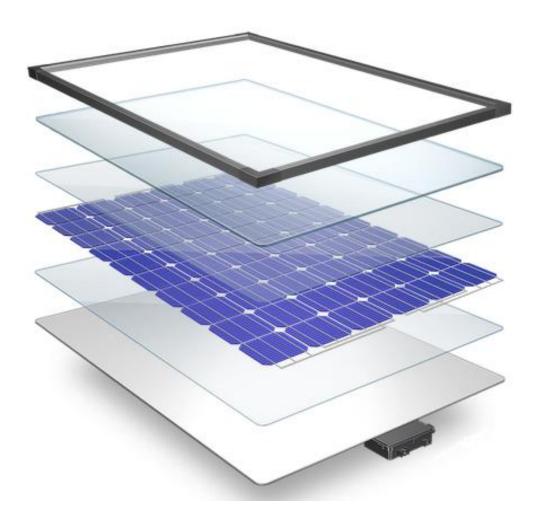








#### Pk/Si multijunction modules: amplified constrains







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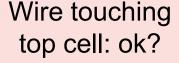




#### TWILL: Advantages & Questions for multiwire tandem cells



Temperature low enough with SnBi?





Single thermal step (thermal budget/uniform)

No handling for interconnection

Foil designed for stress relief (slack)

Thermoplastic encapsulant: no by-products, less shrinking





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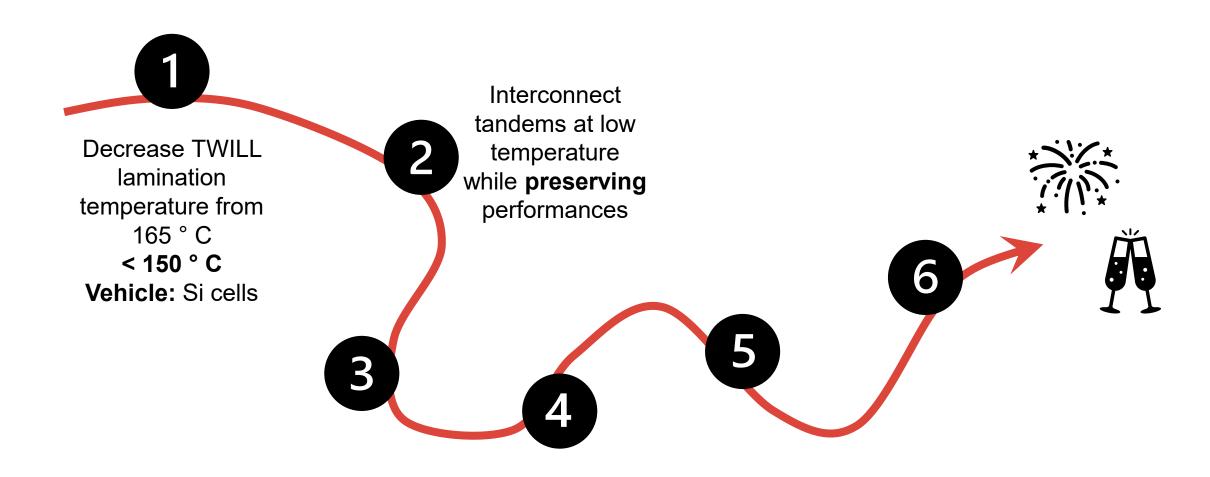


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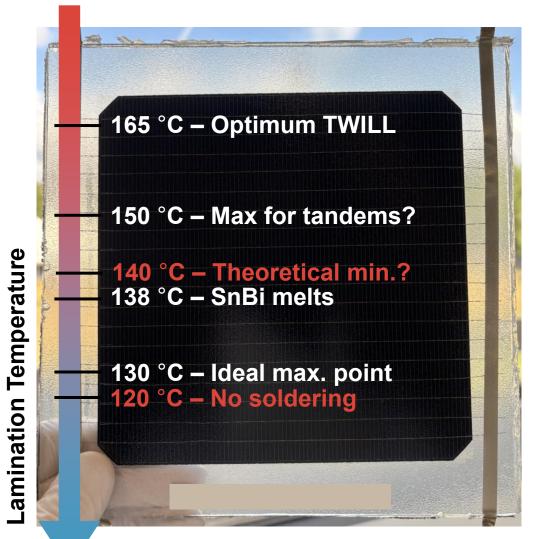
#### How to develop TWILL interconnection for pero/Si tandems cells?

The (simple) plan



#### Can TWILL work < 150 °C?

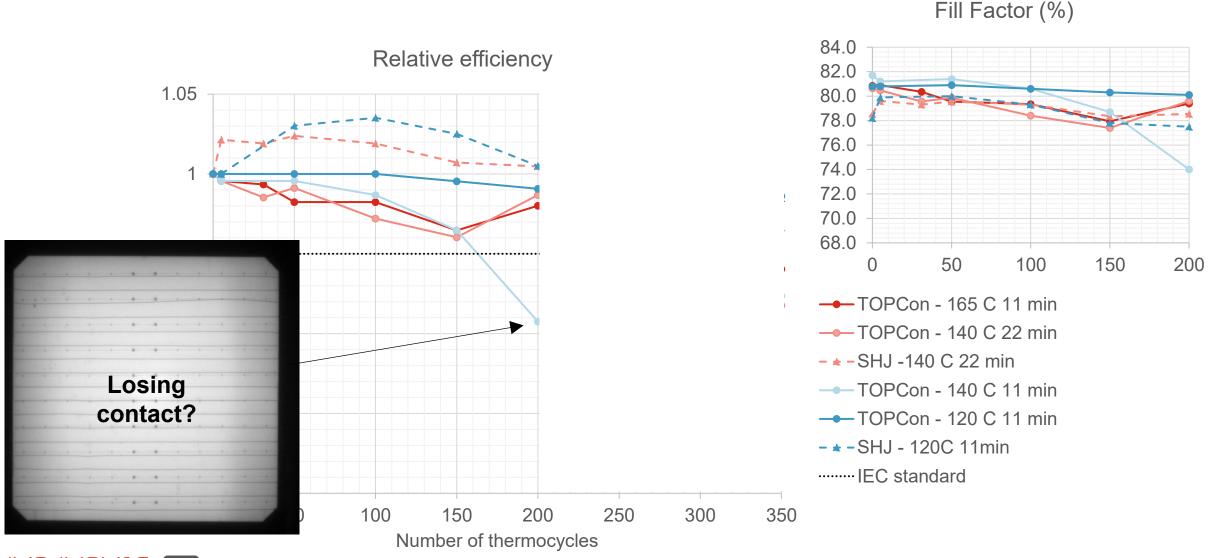
#### Methodology – Reliability testing on 1-junction silicon solar cells



- Make 1-cell laminates, 3 per split
  - Glass/glass, no edge sealant
- Evaluate contact reliability via thermocycling (85/-40C)
- 2 cell types: Impact of Ag paste (different solderability, finger shape)?
  - Low temperature, heterojunction SHJ
  - High temperature, TOPCon
- Start with 3 temperatures
  - 165 °C 11 min => process of **reference**
  - 140 °C 11 min / 22 min => theoretical **minimum**
  - 120 °C 11 min => no soldering, as **reference**
- NB: actual process temperatures checked (thermocouple)

#### Efficiency/fill-factor retention over 350 thermocycles (so far)

Surprisingly good performance of TWILL in pressure-contact (no solder) at 120 °C



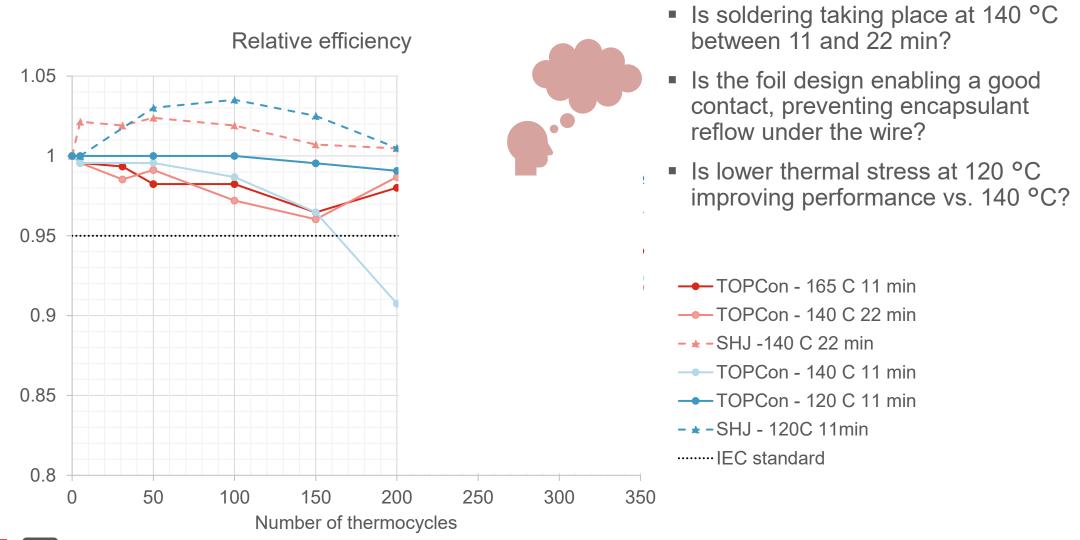
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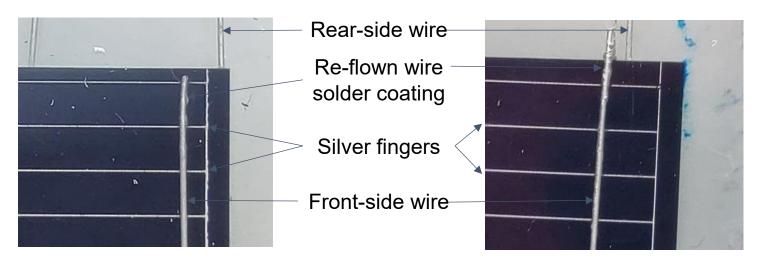
#### Efficiency/fill-factor retention (or not) over 350 thermocycles

Surprisingly good performance of TWILL in pressure-contact (no solder) at 120 °C



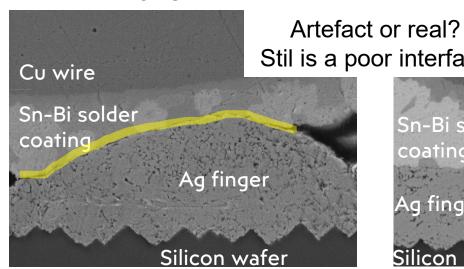
#### Soldering or no soldering at 140 °C?

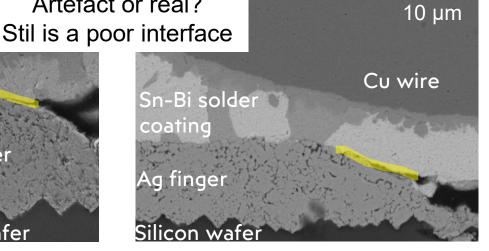
More microstructure characterization is needed – and reliability results to be repeated

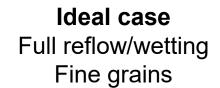


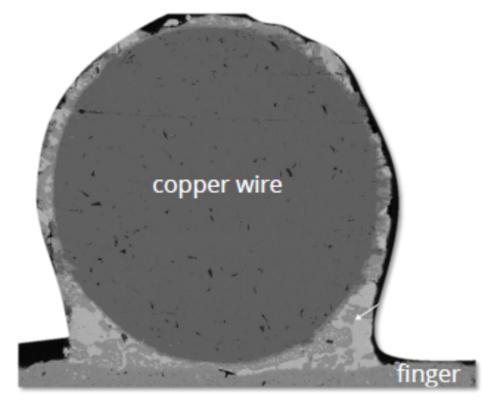
140 °C - 11 min

Reference: 165 °C - 11 min







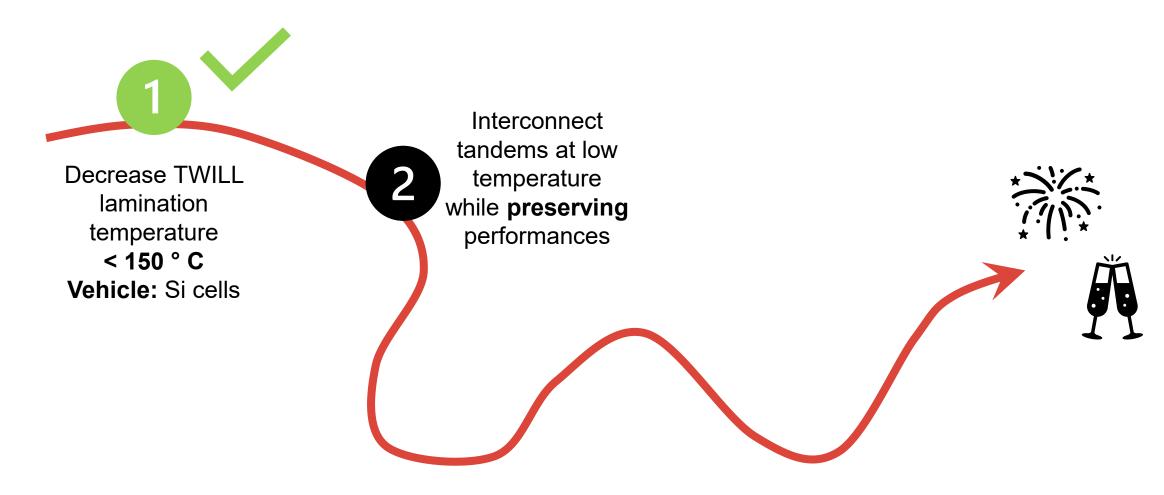






#### How to develop TWILL interconnection for pero/Si tandems cells?

The (simple) plan



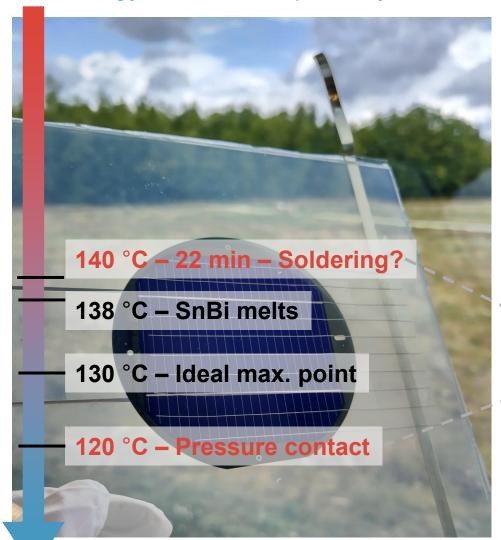




# amination Temperature

#### Can TWILL work for tandem pero/Si solar cells?

Methodology – A first compatibility test



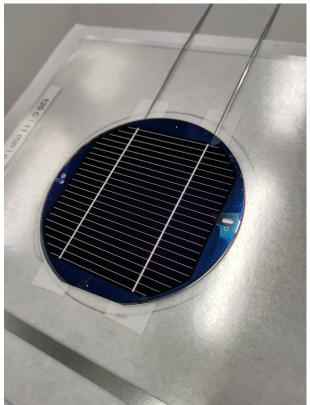
- Make 1-cell laminates
  - Glass/glass
  - No edge sealant
  - TWILL encapsulation lacking direct reference with ECA!
- Evaluate impact of lamination temperature by I-V / visual
- Evaluate contact reliability via thermocycling
  - Keep 1 cell as monitor
- Test 2 temperatures
  - 140 °C 22 min => some soldering?
  - 120 °C 11 min => pressure contact
- 60 cm<sup>2</sup> tandem test cells (3+4)
  - Were not optimized for encapsulation / reliability testing
  - Screen-printed Ag front, solderable (thick)
  - Evaporated Ag rear (too thin to solder well?)

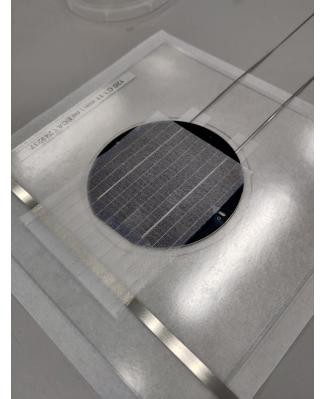




#### A simple, lean, module layup for interconnection and lamination









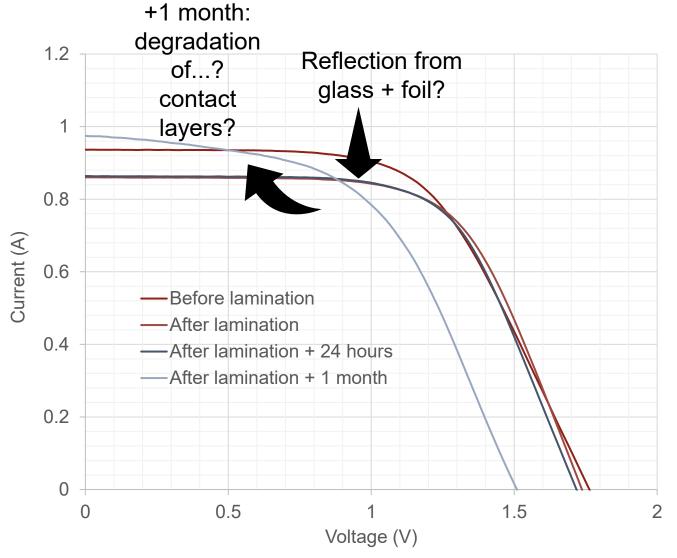
Lamination = ~ 30 min





#### **Example of I-V performance before/after lamination**

Voc and FF could be preserved by lamination - but the solar cells degraded afterwards

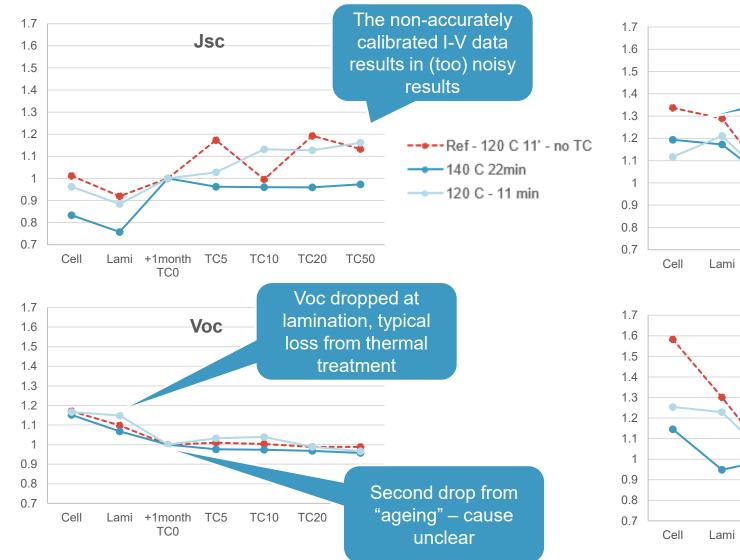


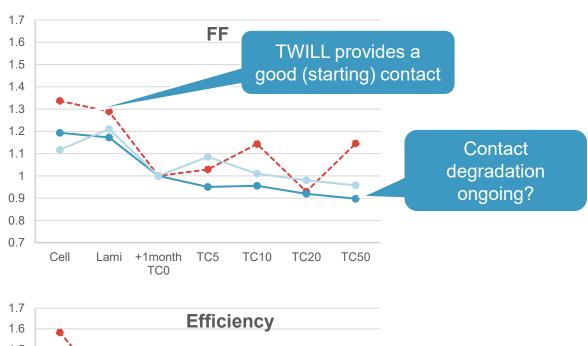


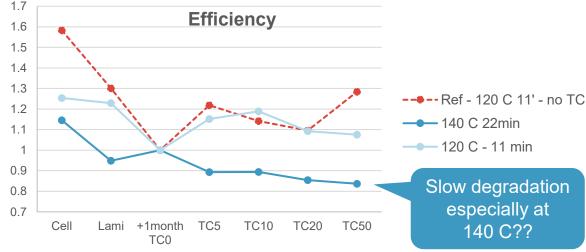


#### From cell to module and to thermocycled module (TC50)

Intrinsic solar cell degradation and module degradation cannot be easily discriminated here











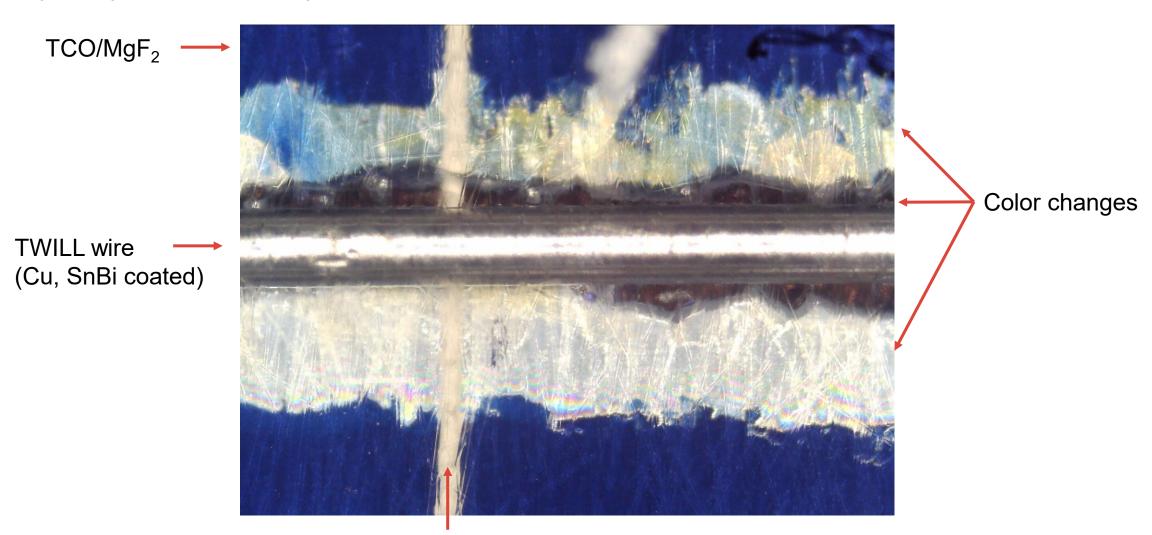
## Thermocycling caused a visible degradation The damage spreads along the TWILL Cu wires TC0 **TC20**





#### Reaction/diffusion of a material or delamination of a layer?

Microscope inspection of a sample laminated at 120 C for 11 min







#### Testing how various lamination parameters affect this defect

All cells are defected after lamination, during cooling down – suggesting the issue is a delamination

Lowered lami pressure



Longer degassing



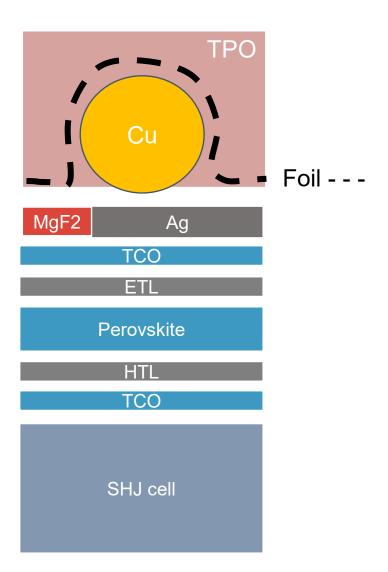
**Higher temperature (soldering)** 





#### **Delamination: at which interfaces?**

More characterization would be needed (but how?)



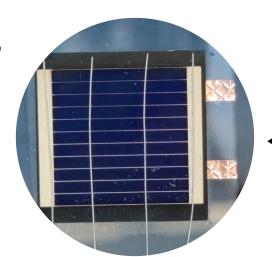




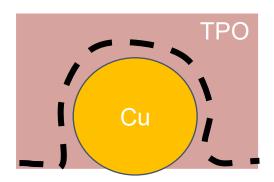
#### **Delamination: at which interfaces?**

More characterization would be needed (but how?)

In fact: no "delamination" on 4-cm<sup>2</sup> cells (no MgF<sub>2</sub>)



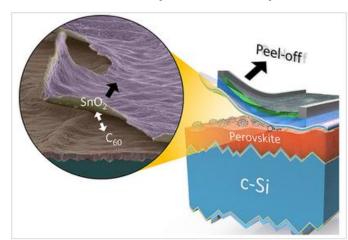
— TWILL foil/MgF $_2$  or TCO? ←



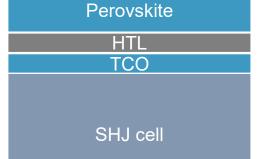
-oil - -

MgF <sub>2</sub>	Ag
TCO	
ETL	

Usual suspect: C60/pero? ←



**De Bastiani**, ACS Energy Letters 2022 **Bristow**, Solar RRL 2024

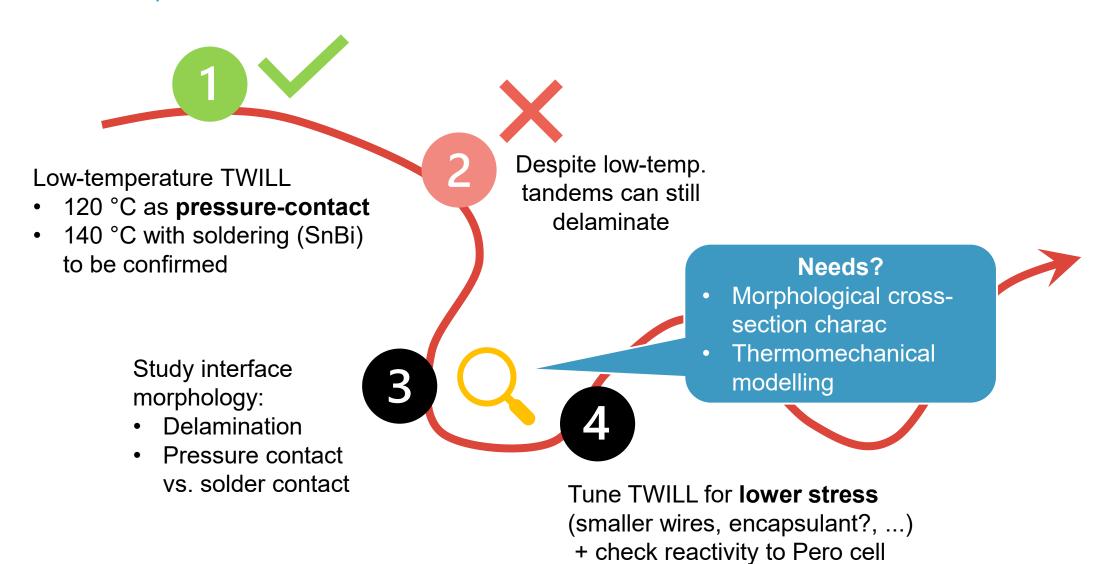






#### **Conclusions & Outlook**

Towards a pressure-contact based multiwire interconnect for tandems







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What my friends have in mind



What my colleagues have in mind



What I had in mind (6 months ago)



What I had in mind (2 days ago)



What I have in mind **now** 





#### **Acknowledgments**

- Partners in TRIUMPH: R. Niemann and H. Weber (QCells)
- Project TRIUMPH has received funding through Horizon Europe, the European Union's flagship research and innovation programme, under the grant agreement no. 101075725.
- FWO Research Foundation Flanders has partially funded this workshop contribution

#### Thank you!











Ultra-low temperature & CRM-free interconnection is to be developed

