



# ELECTRICALLY CONDUCTIVE ADHESIVES IN PV MODULES: A PERSPECTIVE ON RELIABILITY AND SUSTAINABILITY

PETER MILLER, GIUSEPPE GALBIATI, PRO CHAUDHURI,  
MARC ESTRUGA

RELIABILITY OF PV MATERIALS AND BOS COMPONENTS  
SOPHIA WORKSHOP 2022



# AGENDA

1. Henkel Adhesives Overview
2. ECAs in PV Modules
3. Reliability Testing of Interconnects
4. Perspective on Sustainability

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# ADHESIVE TECHNOLOGIES AT HENKEL

## Automotive & Metals

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### Solutions for:

Automotive OEMs  
& Components, Metals

## Packaging & Consumer Goods

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### Solutions for:

Packaging, Consumer Goods  
& Lifestyle Products

## Electronics & Industrials

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### Solutions for:

Semiconductor Packaging &  
Electronics Assembly,  
Aerospace, **Solar**, Industrial  
Assembly

## Craftsmen, Construction & Professional

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### Solutions for:

DIY, Craftsmen, Construction,  
Professional Users in  
Manufacturing &  
Maintenance

# HENKEL PV CAPABILITIES IN DÜSSELDORF

**New “Inspiration Center”  
recently built in Düsseldorf**



**Two Labs Devoted to Adhesives for  
Electronic Applications**

## **Product Development**

- DMA
- SEM
- Ion Milling
- 3D Microscope
- DSC
- Instron Mechanical Testing
- Die Shear Strength Testing
- UV-Cure Equipment

## **Application Engineering**

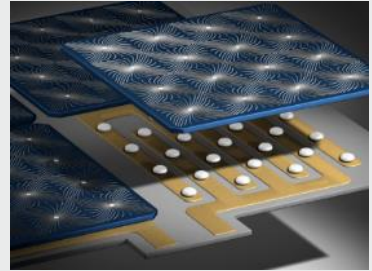
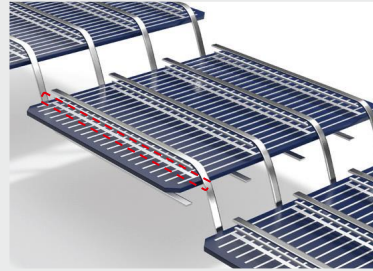
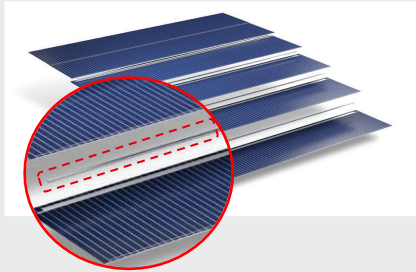
- Semi-automatic and Manual Hand Printers
- Solar String Shingling Tool
- High Speed Stencil and Screen Printer
- X-ray Microscope
- Precision Laser Cutting Tool
- Jetting and Dispensing Equipment

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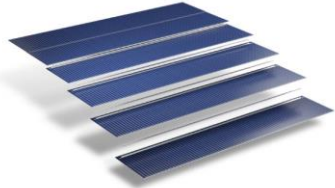
# HENKEL ECA FOR PV MODULES

Interconnection type	Shingling	Ribbon Attach	Back Contact
Cell type	c-Si, PERC, HJT	c-Si, PERC, HJT	IBC, MWT
Chemistry	Epoxy, Acrylate, Silicone	Acrylate	Epoxy



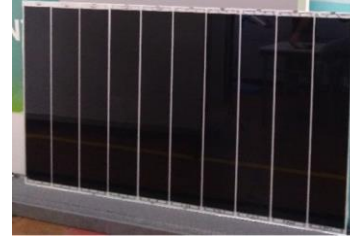
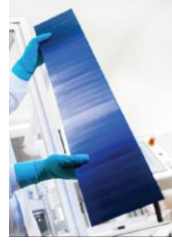
# ECA FOR SHINGLE ATTACH

## Shingled Module



## Growing Market

- $\approx 10\%$  power increase
- Lower TCOO and compatible with multiple cell types
- Aesthetics



## ECA for shingle bonding

- Electrical contact
- Mechanical strength

## ECA Technology

### Conductive filler package

- Percolation threshold
- Bulk and contact resistivity
- Current capacity
- Rheology

### Polymer resin

- Cure speed
- Adhesion
- Mechanical prop.
- Reliability

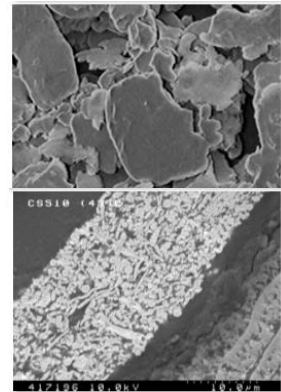
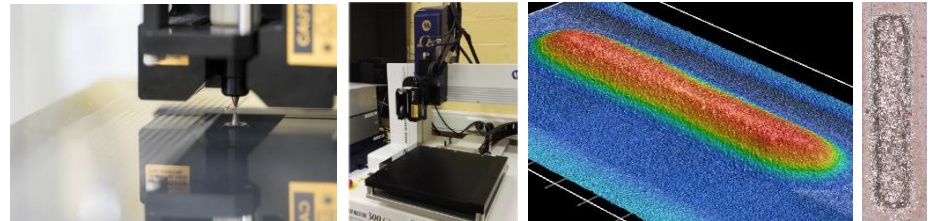
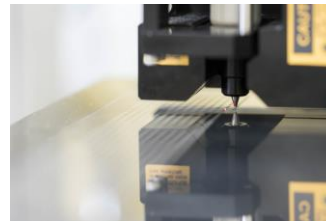
Acrylate

Epoxy

Silicone

## ECA application technique

- Printing: screen and stencil
- Dispensing
- Jetting



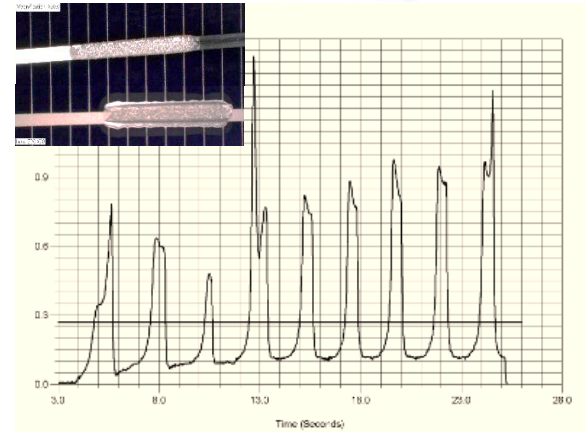
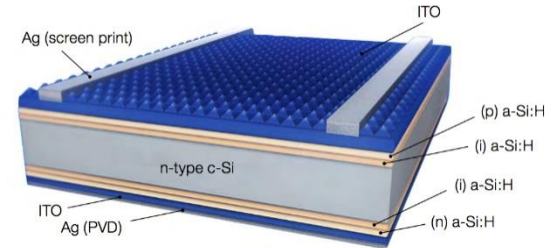
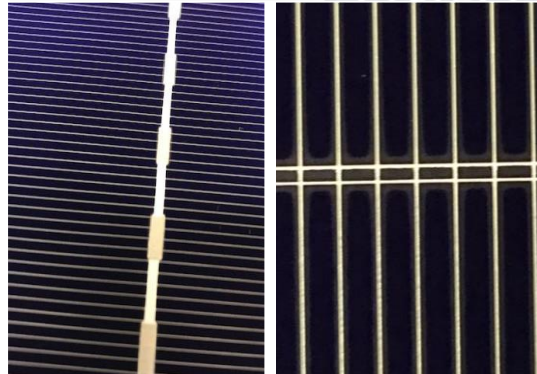
Cross section of an ECA bond



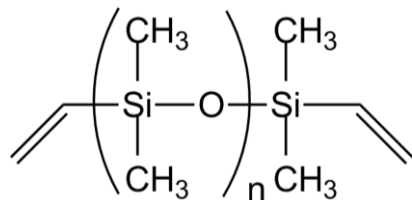
# ECA FOR RIBBON ATTACH

## HJT cells

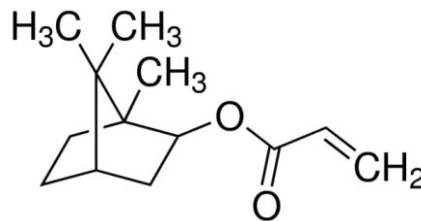
- Temperature sensitive:  $\leq 200^{\circ}\text{C}$
- Low Ag usage for low TCOO
- High peel strength
- Low and stable contact resistance to TCO



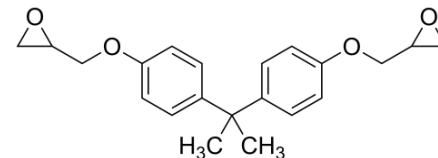
# COMPARISON OF ECA RESIN CHEMISTRIES



**Silicone**



**Acrylic**



**Epoxy**

Modulus/Tg	<b>Low</b>	<b>Medium</b>	<b>High</b>
Cure Speed	<b>Slow</b>	<b>Fast</b>	<b>Medium/Fast</b>
Adhesion	<b>Low</b>	<b>High</b>	<b>Medium/High</b>
Humidity Resistance	<b>Good</b>	<b>Poor</b>	<b>Good</b>

# ECA FORMULA TOOLBOX

<b>Polymer Resins</b>	<b>Cure Package</b>	<b>Conductive Fillers</b>	<b>Additives</b>
<ul style="list-style-type: none"><li>• Epoxy</li><li>• Silicone</li><li>• Acrylate</li><li>• Morphology</li><li>• Functional Group</li></ul>	<p>Chemistry dependent:</p> <ul style="list-style-type: none"><li>• Amines</li><li>• Peroxides</li><li>• Metal Complexes</li></ul>	<p>Silvers with various properties and morphologies</p>	<ul style="list-style-type: none"><li>• Adhesion promotor</li><li>• Rheological agents</li><li>• Diluents</li><li>• Flexibilizers</li><li>• Tougheners</li></ul>

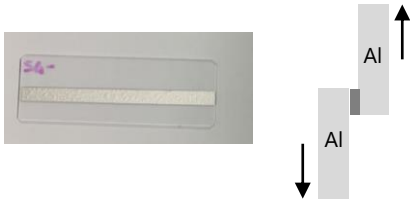
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# OVERVIEW OF VALIDATION PROCESS

## Screening of Materials

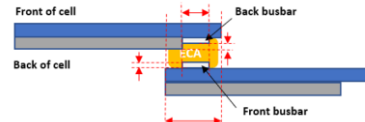
- Electrical
  - Volume Resistivity
  - Contact Resistance
- Mechanical
  - Lap Shear
  - Elongation
  - Tg and Modulus



Pass

## Cell-Cell Reliability Testing

- Environmental Ageing at Bond Joints
  - Damp Heat (DH)
  - Thermo Cycling (TC)
  - 1-3 months



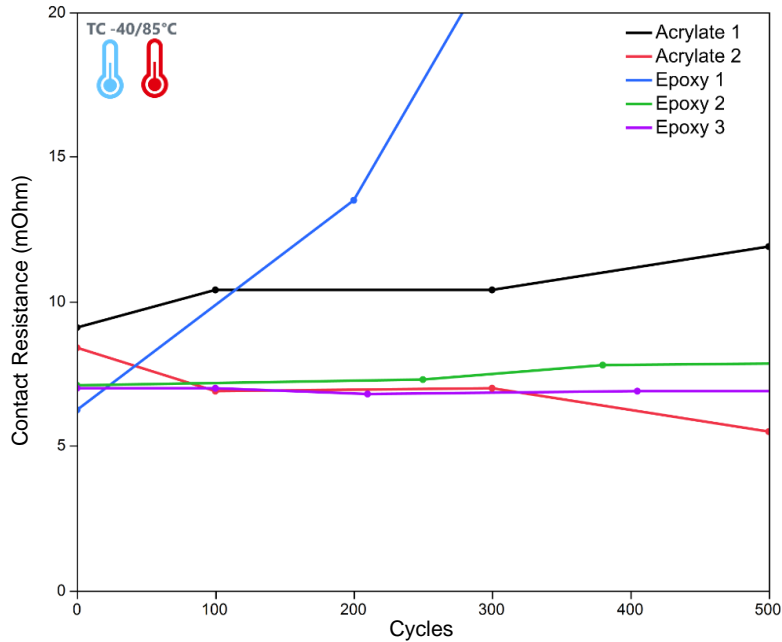
Pass

## Module Reliability Testing

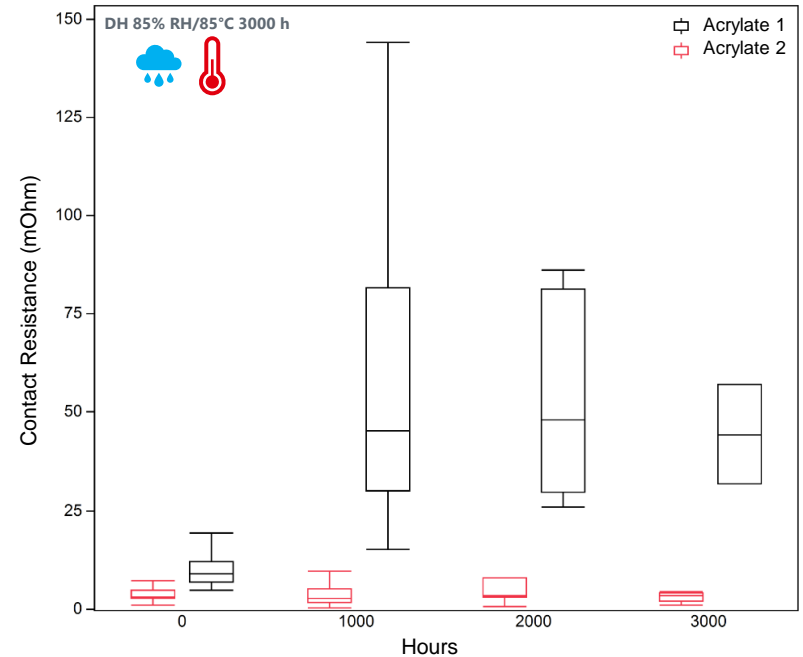
- Environmental ageing
  - DH/TC
  - Customer or certification specific
- Electrical
  - Power loss after on/off cycles
  - Customer specific
- Mechanical
  - Static/dynamic load

## Application Specific Validation

# TEMPERATURE CYCLING AND DAMP HEAT



- More rigid epoxies can fail TC
- Acrylates and silicones have very few issues



- Acrylates can have issues in DH
- Epoxies and silicones have very few issues

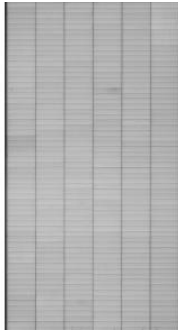
# STATIC MECHANICAL LOAD TESTING

## Procedure

- 5 x 1 hour cycles at 2400 Pa
  - Pull/Push/Pull/Push/Pull
  - Measure EL and IV
- Push at 5400 for 1 hour
  - Measure EL and IV



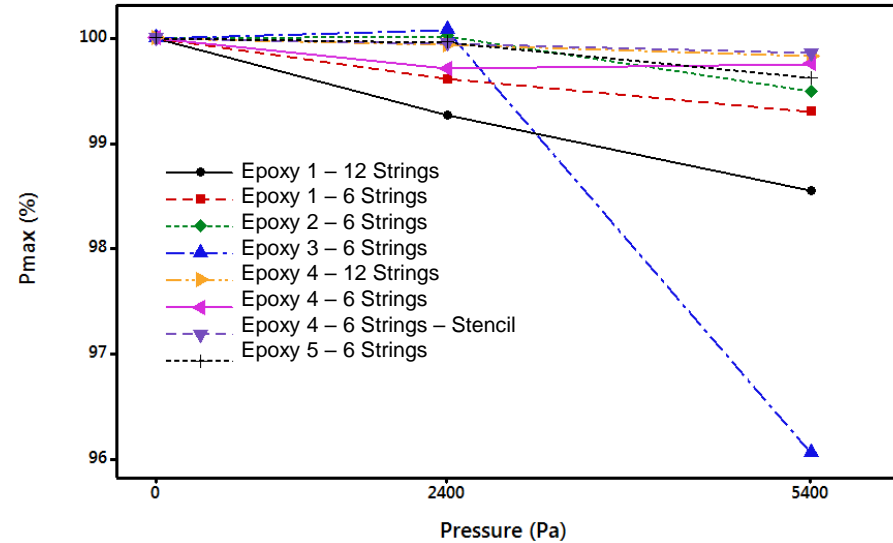
Initial



After MLT



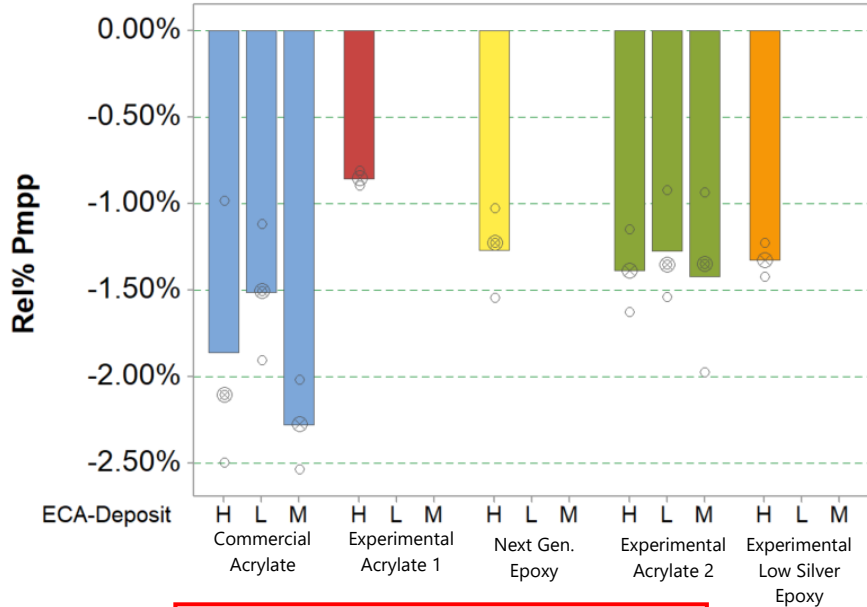
Effect of MLT on Pmax



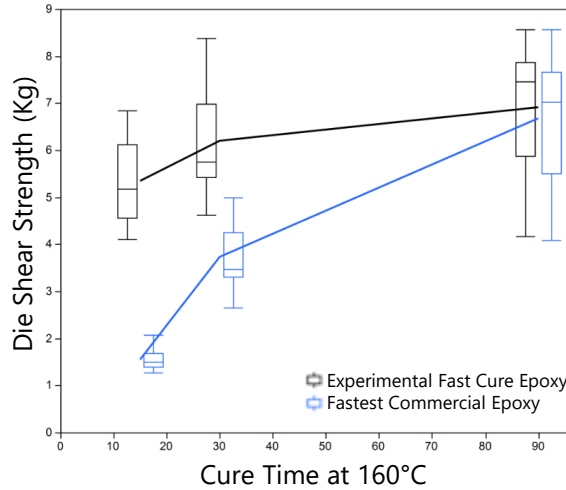
- Epoxy ECAs were formulated to have varying modulus
  - Higher modulus correlated with MLT failure
- Printing morphology can impact usage

# NEW ECA DEVELOPMENTS AND RELIABILITY

## ECAs Used for Shingling HJT Cells at PI Berlin



Promising TC performance for experimental low silver ECA



### Fast Cure Epoxy

- Designed to increase module throughput
- Assembled module TC and DH is underway

### Other Development Work

- Compatibility with less noble metal busbars
- ECA with low volume resistivity
- Ribbon to finger attach
- Low usage and comparable performance



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# SUSTAINABILITY AT HENKEL



## CO2/energy saving & dematerialization

- Prevent/reduce resource consumption
- Less CO2 intensive raws
- CO2 saving/footprint reduction in production & logistics
- CO2 emission savings in the use phase



## Circular economy

- Biobased, recycled and CO2-based raw materials
- Sustainable packaging
- Waste reduction in products
- Compatibility with recycling
- Debonding
- New designs
- Biodegradable products



## Health & Safety

- Enhance safety in production
- Enhance safety in application
- Enhance safety in end-use



*Water\*: Increase quality & accessibility, reduce consumption & waste*

# ECA SUSTAINABILITY FOR PV APPLICATIONS

## Sustainability Contributions

- **Increased Performance:** longer lifetime by improved reliability in the use phase of modules
- **Emission reduction** in the module use phase: Saving 600 kTn CO<sub>2</sub>
- **Energy savings** in application phase of next gen. adhesives
  - 80% faster application speed
  - 50% shorter cure time
- **Module recyclability** by easy debonding

## More Sustainable Formulating

- Committed to no CMTs or hazardous raw materials
- **Reduce conductive filler:** main CO<sub>2</sub> contributor
- Compatibility with more sustainable modules
- **Reliability testing is crucial!**



# THANK YOU.

## **Contact Information:**

**Peter Miller**

[peter.miller@henkel.com](mailto:peter.miller@henkel.com)

**Giuseppe Galbiatti**

[giuseppe.galbiatti@henkel.com](mailto:giuseppe.galbiatti@henkel.com)



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