# MATERIALS CHALLENGE FOR SHINGLED CELLS INTERCONNECTION

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*Dow Corning*

**6th Workshop on Metallization and Interconnection of crystalline silicon solar cells**

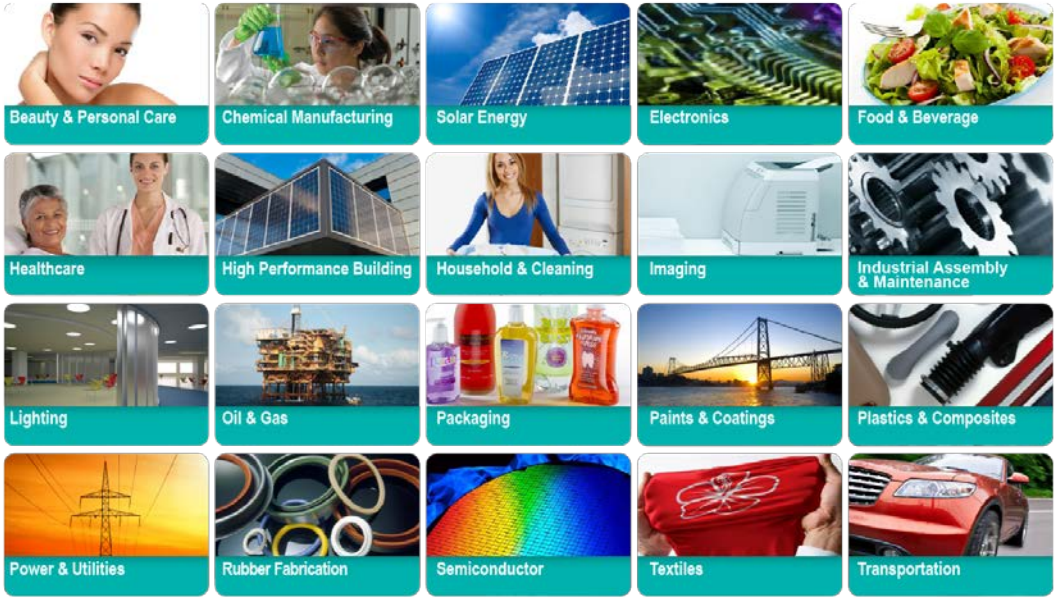
**Konstanz, 3 May 2016**

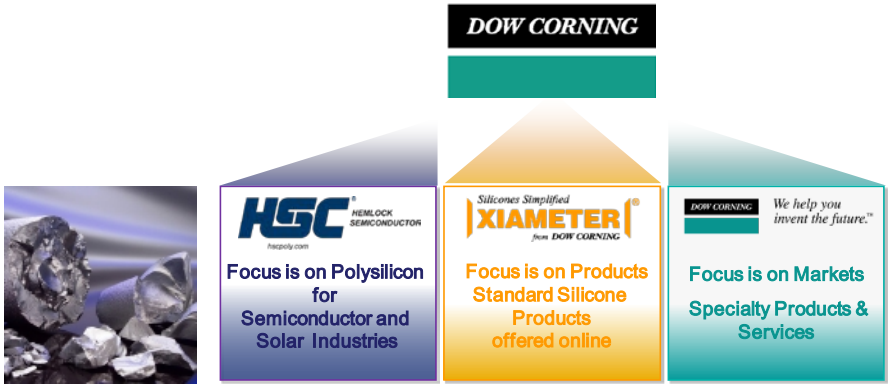
DOW CORNING

*We help you invent the future.™*

# Introduction to Dow Corning

- A global leader in silicones and high-purity silicon.
  - 7 000 products/services
  - 25 000 customers
  - Approx. 11 000 employees
  - $6.2 billion sales 2014
- Founded in 1943 to explore the potential of the silicon atom.
- Focus on innovation
  - 4-5% investment of sales in R&D
  - 5 066 active patents



# Ownership of Dow Corning

1943 – 2016: DOW + CORNING (Equal ownership)

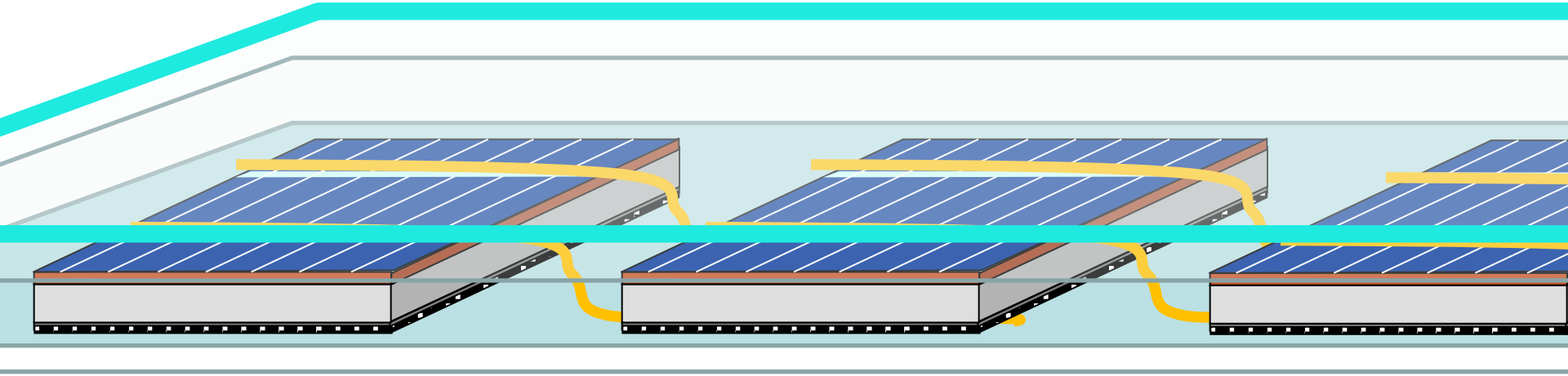
December 2015: Dow Chemical announce intention to acquire 100% ownership of Dow Corning Corporation

Q2 2016 onwards:

Subject to regulatory approvals,

- Dow Corning to become part of Dow Chemical
- Hemlock Semiconductor Group to remain with current shareholders
- No change in commitment to provide our customers with high-quality, reliable silicone products

# Traditional module technology based on H-pattern cells, ribbons and soldered interconnection

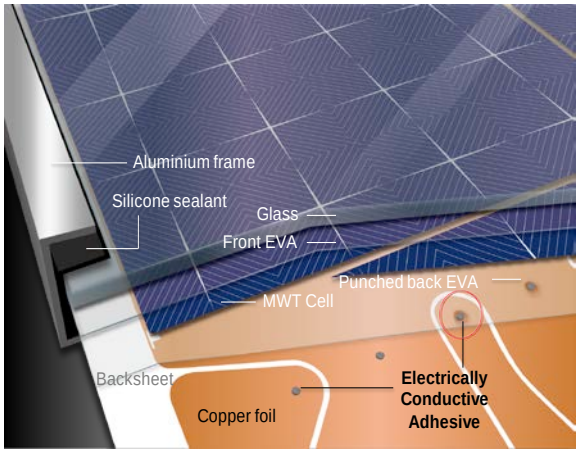


- Low-cost interconnection
- Robust and durable

- High shading losses
- Expensive metallization
- High resistive losses
- Incompatibility with very thin wafers
- Lead-containing solder

# Alternative interconnection technologies

## Conductive backsheet + Electrically Conductive Adhesive

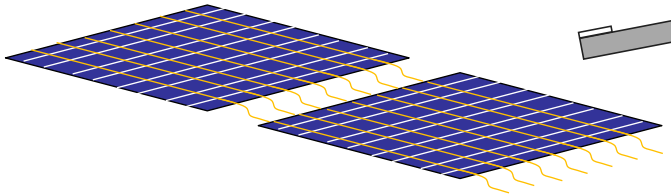



Cells : Back-contact cells (MWT or IBC)

Bulk interconnection material : Copper foil

Joints: ECA

## Multiwire technology

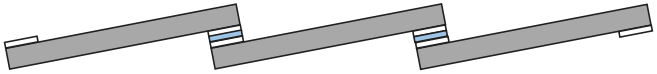


Cells : Busbarless cells

Bulk interconnection material : Copper wires

Joints: Low temperature solder

## Shingled cells module



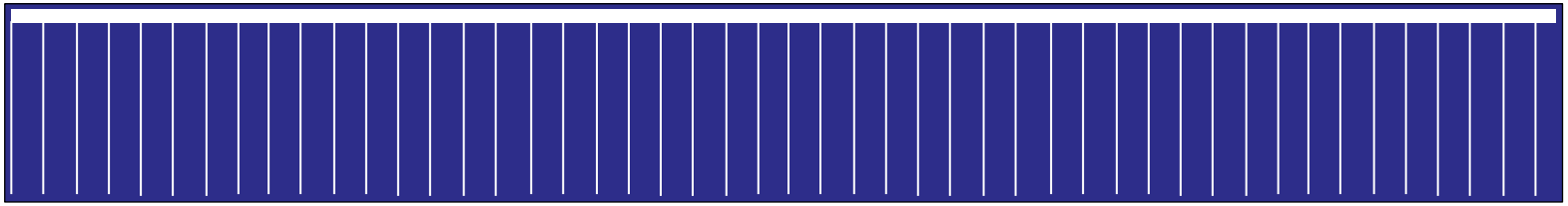
Cells : Busbarless cells (strips)

Bulk interconnection material : None

Joints: ? Solder or ECA

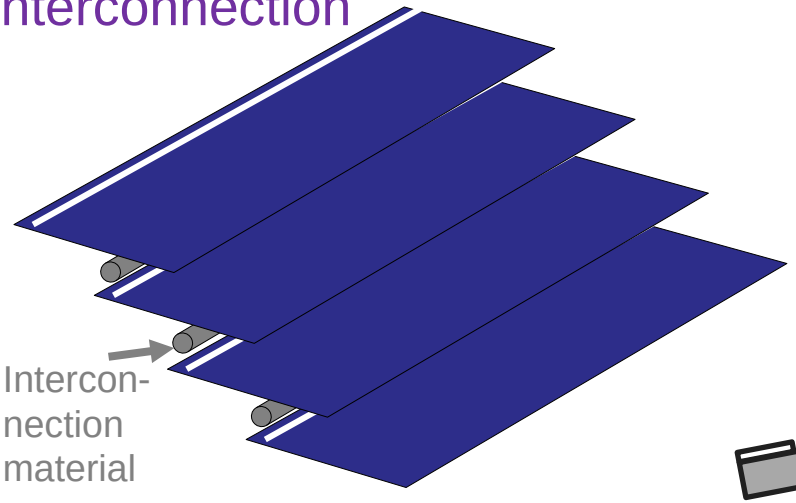
# Shingled cells interconnection

Front

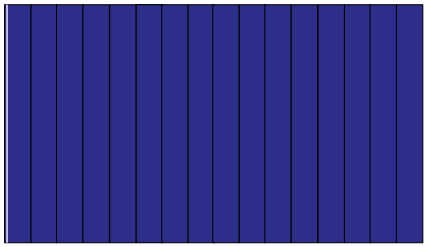


Back

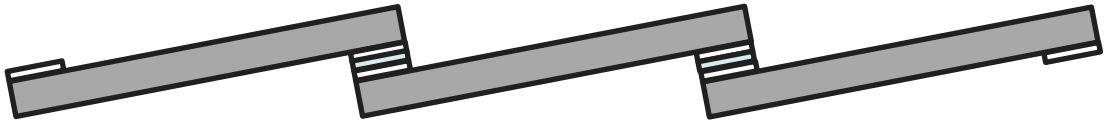
Interconnection




Top view



Cross-section



# Shingled cells interconnection : advantage and history

- Extremely high ratio active area / total area

  → Potential for very high efficiency

- 'Old' idea :
  - Development for early space modules in USA in -60's and -70's
  - High efficiency panels for solar car race in -90's

    e.g. '*20 000 PERL Silicon Cells for the 1996 World Solar Challenge Solar Car Race*', Zhao et al. Progress in Photovoltaics 1997

- Recent surge of interest for terrestrial modules
  - Step 1 : Start-ups developed technology : Cogenra, Solaria, …
  - Step 2 : Large PV companies acquiring technology and preparing for mass production : Sunpower 'Performance series module' ; Sunedison 'Zero White Space module', ….

# Thermomechanical challenge

- Thermal cycling of system with different materials
  - ➡ mechanical stress due to CTE mismatch

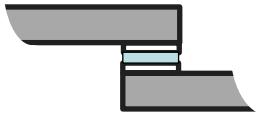
Traditional modules

High T

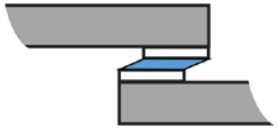
Low T

Shingled cells modules

High T

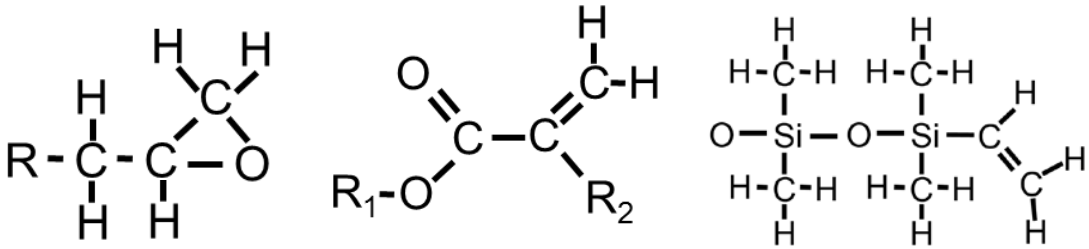


Low T



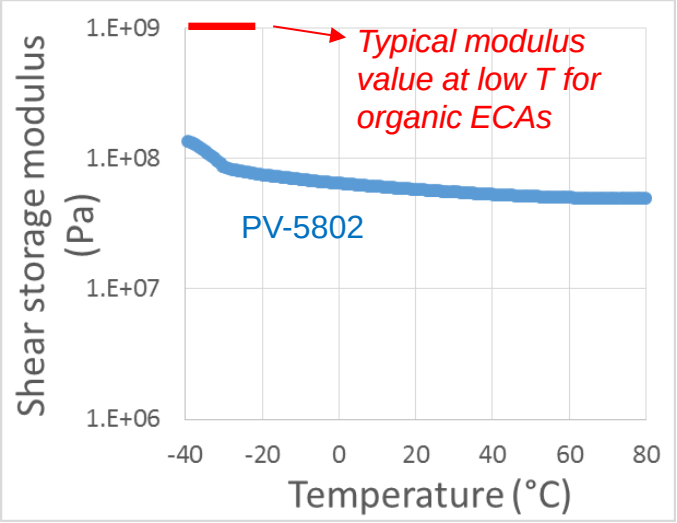
# Material options

- Materials for shingled cells interconnection
  - Solder
    - SnPb solder
    - Low T solder
  - Electrically conductive adhesive
    - Epoxy based
    - Acrylate based
    - Silicone based

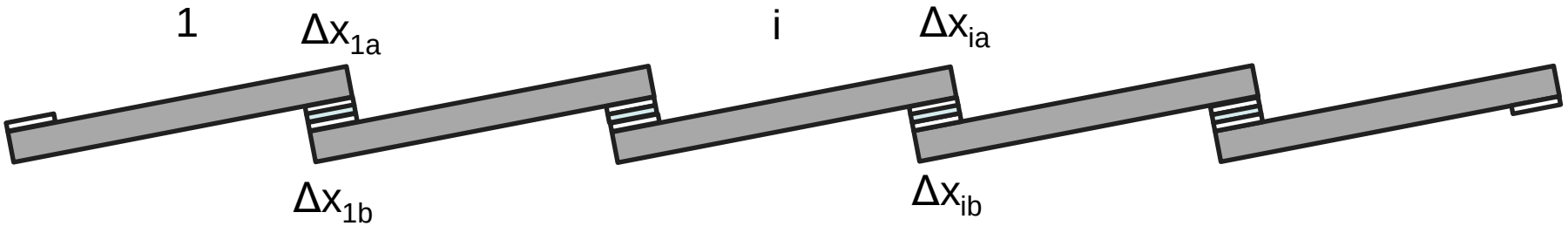


# Silicone Electrically Conductive Adhesive

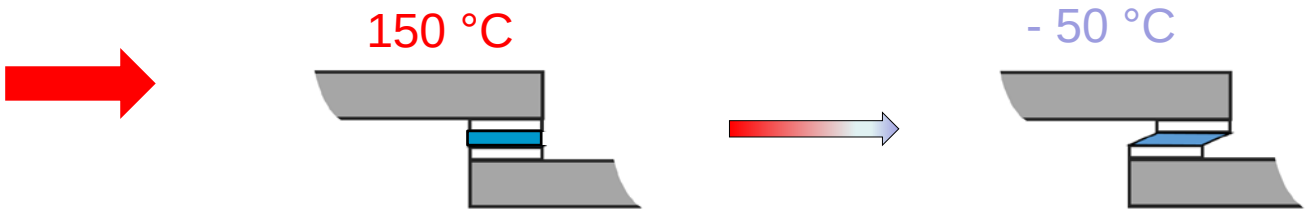
- *Dow Corning*® PV-5802 Electrically Conductive Adhesive : silicone-based ECA developed for advanced module assembly
- Thixotropic properties for stencil printing
- Low Ag content, yet high conductivity
- Compared to other ECAs : flexible, low modulus
- Compatible with various surfaces, including screen-printed Ag



# Analytical study of shear stress in joints




- Assumptions :
  - Glass imposes its CTE-induced movement to other laminate components (Bennett et al.,Energ. Proc. 2012) → also to shingled cells string




  - No external shear force on string (simplifying assumption to get lower bound of maximum joint stress)
  - All deformation located at joints, no cell buckling

# Outcome of analytical study

## Condition to avoid joint failure :

Shear modulus of joint material

Difference between stress-free temperature and lowest operating temperature

Length of glass at stress-free T

Number of cells in a string

Joint width

$$\frac{G(-\Delta T)\{L_0\alpha_{glass} - \alpha_{Si}[nl_0 - (n-1)w_0]\}}{\tau_{sh.str.}\, t(n-1)} < 1$$

Coefficient of thermal expansion of glass

Shear strength of joint material

Coefficient of thermal expansion of silicon

Joint thickness

Cell width

# Implications for joint material

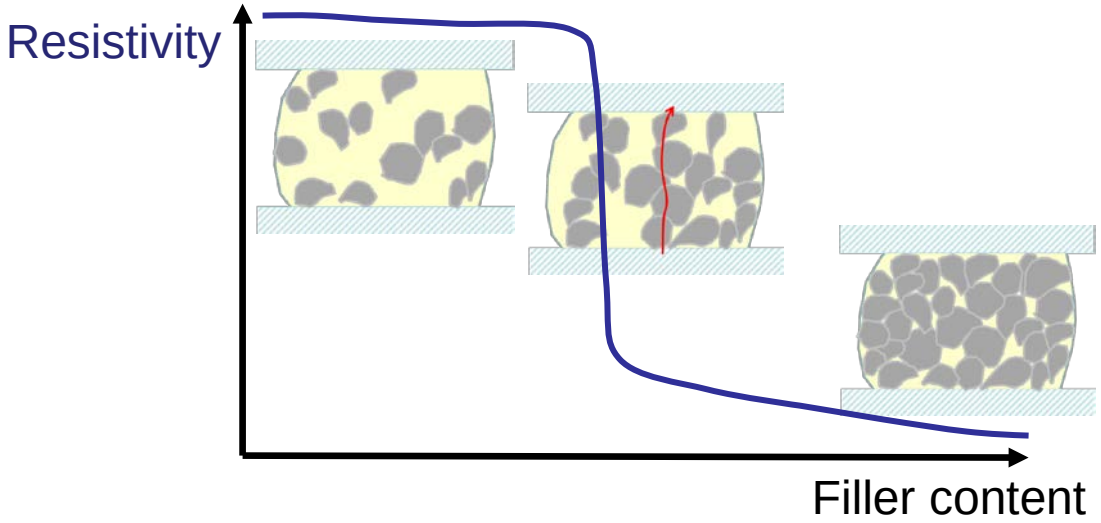
$$\frac{G(-\Delta T)\{L_0\alpha_{glass} - \alpha_{Si}[nl_0 - (n-1)w_0]\}}{\tau_{sh.\,str.}\,t(n-1)} < 1$$

→ Ratio $\frac{G}{\tau_{sh.\,str.}}$ should be as low as possible

Additionally, adhesion between joint material and metallization material has to be excellent (only cohesive failure)

# Conductivity versus strength challenge for ECA's

- Percolation threshold




→ Filler content always high

High filler content

No adhesion at particle/ substrate interface

Filler provides less cohesion than polymer matrix

→

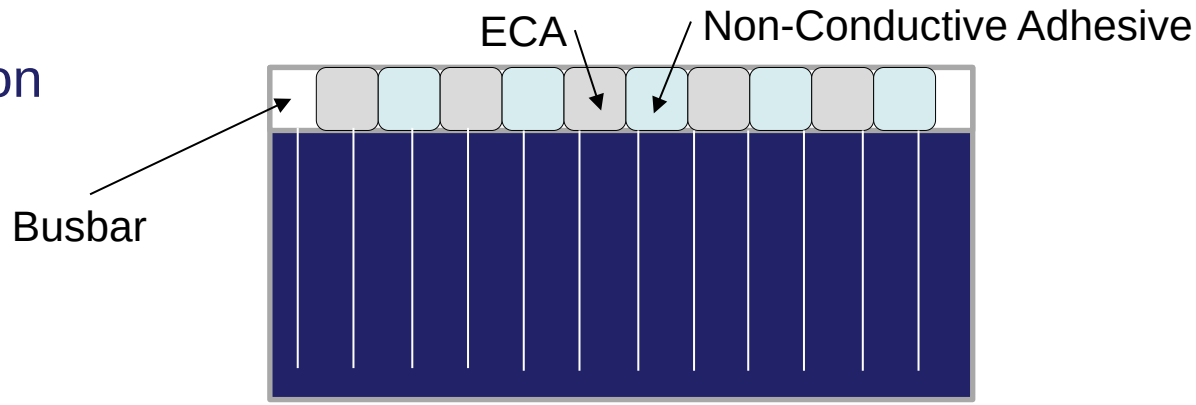
- **Strength is substantially lower than adhesive without filler**
- **Optimization needed for best resistivity with sufficient adhesion/strength**

# Optimization of material solutions

- Low G and high shear strength are needed

| | Eutectic tin lead solder | Epoxy ECA | Silicone ECA |
|---|---|---|---|
| **G (MPa)** | 12000 | 200 - 2000 | 10 - 100 |
| **$\tau_{sh.\ str.}$ (MPa)** | 40 | 5 - 10 | 0.3 - 1 |
| **$G/\tau_{sh.\ str.}$** | 300 | 20 - 400 | 10 - 300 |
| **Resistivity (ohm cm)** | $0.15 \times 10^{-4}$ | $1 – 25 \times 10^{-4}$ | $2 – 30 \times 10^{-4}$ |

- Two adhesives solution



# Conclusion

- Shingled cells interconnection : emerging interconnection technology
- Soldering : not suitable
- Joint material needs low $\frac{G}{\tau_{sh.\,str.}}$ ratio
- Silicone ECA : much lower G throughout temperature range
- Using a two adhesives approach could help solve assembly challenges

# Thank you !

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