Electrically Conductive Adhesives for PV Applications

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DuPont: the Leading Specialty Material Supplier in PV

- **Solamet® Metallization Pastes**
  - Driving higher energy conversion efficiency

- **Tedlar® Backsheet Films**
  - Protecting PV modules

- **Elvax® and Ionomer Encapsulants**
  - Delivering long term protection of cells

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Electrically Conductive Adhesive (ECA)

What is an ECA?
An electrically conductive adhesive (ECA) is a glue that is primarily used for electronics.

An ECA composed of:
1). Conductive particles: building continuous conductive path;
2). Binder: sticky component holding the particles together.

ECA Features (vs solder)
- Lower thermal stress
- Adhesion to diverse substrates (especially useful for non-solderable substrates)
- Smaller feature size
- Multiple options for lower temperature processing
- Rework ability (select ECAs)
- Removes Pb from interconnections

Challenges for ECA using in PV modules
- Ag powder (conventional): high-cost
- Ag-coated base metal powder: poor stability; low efficiency and high cost of processing
- Epoxy based binder (major incumbent): brittleness; storage and transportation at temp. < 0°C; processing limit
- Other alternative binder materials did not solve all issues
What is Conductive Adhesive?

- Adaptable to various cell architectures
- “Easy-to-use” application processes
### DuPont Electrically Conduct Adhesive

DuPont is developing a novel ECA based on
- High performance elastomer, and
- silver (Generation 1) or, base-metal particles (Generation 2).

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<th>Key Features of DuPont binder</th>
<th>Value Delivered</th>
<th>Comparison with incumbent binders</th>
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<td>DuPont ECA</td>
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<td>High adhesion (vs. diverse substrates)</td>
<td>Meeting process standard</td>
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<td>High reliability (thermal; moisture)</td>
<td>Meeting reliability standard</td>
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<td>High temperature durability</td>
<td>Use in high temperature applications</td>
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<td>Printable</td>
<td>Feasibility for processing</td>
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<td>No Bleed out</td>
<td>Avoids shading and waste</td>
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<td><strong>Dispensable</strong></td>
<td>Feasibility for processing</td>
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<td><strong>Room Temperature Storage</strong></td>
<td>Lower cost of shipping and storage</td>
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<th>Key Features of DuPont filler</th>
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<td>DuPont ECA</td>
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<tr>
<td>Low bulk resistivity</td>
<td>Meeting PV standard</td>
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<td>Low contact resistance</td>
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<td>High stability (oxygen &amp; moisture resistance)</td>
<td>Meeting reliability standard</td>
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<td><strong>Can be used with Sn-coated ribbon</strong></td>
<td>Lower cost, Higher efficiency</td>
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<td>Low cost</td>
<td>Lower material cost</td>
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Opportunities for ECA Applications in Multi-Busbar (MBB) Modules

Higher cell and module efficiency via multi-busbar design

The model showed that cell efficiency scales proportionally with the number of busbars.

Benefits of using an ECA: Avoid Yield Losses & Cost Reduction
- Lower thermal stresses (less cell breakage)
- Potentially eliminate alignment losses
- Reduce or eliminate FS Ag BB (30% of total) and BS Ag
- Overlap cells: Keep printed Ag but eliminate ribbon
Binder in DuPont™ ECA Gen 1

New developed adhesive binder based on a high temperature fluoro-based elastomer

- Good adhesion of DuPont™ ECA on F-Ag, B-Ag, F-SiNx and B-Al

![Graph showing peeling strength](image)

High adhesion (> 2N/mm) and low resistivity (< 3 x 10^{-4} ohm-cm) have been achieved on diverse substrates after vacuum lamination, including fired front side Ag busbar, back side Ag tabbing, fired Al thick film and silicon wafer surface (SiNx).

After pre-attaching process, DuPont ECA gives enough green strength to lift > 5 cells (one ribbon), and to lift a stringer containing 14 cells (4 ribbon).
Addressing the Cost Challenge: DuPont™ ECA Gen 2 with Base Metal Filler

Coated base metal filler with low resistivity and high stability

- High conductivity (< 1.0E-03 ohm-cm, required for PV applications) and stability of coated base metal particles has been demonstrated by ECA and PV module performance tests, and both meet the performance goals.
- Enough adhesion was achieved on Gen 2 ECA without losing conductivity for module assembly.

DuPont ECA prepared with base metal particles coated with various protective layers (A through D) shows low resistivity that is stable under direct exposure to 85°C/85%RH conditions.
Processing Approaches of DuPont™ ECA for MBB Applications

- Unique Processing Flexibility of DuPont™ ECA
  -- “Easy-to-Use” application processes

Dispensing or Screen Printing

Module Maker
“Attachment” (not soldering)

Coater/Ribbon Manf
Gen 1 DuPont ECA shows **excellent reliability and durability** in 4-BB one-cell modules made with different configurations by taking advantage of **good adhesion to the various substrates** indicated in the figure.

- Passed 2 x IEC in damp heat aging under 9A operation current and 3 x IEC in thermal cycling.
- Power outputs were comparable to solder and remain stable.
One-cell modules with ECAs: DuPont™ ECA Gen 2

Excellent durability of DuPont™ ECA Gen 2 with DuPont base metal fillers
-- DH and TC test with operation current

- Quality of the Base Metal particles is critical
- Testing under current is necessary to differentiate quality
- Passed 2 x IEC in 85°C/85% RH damp heat aging and 3 x IEC in thermal cycling test under current; compared well with ECAs made with pure silver and commercially available silver-coated copper
Superior oxygen and moisture resistance of DuPont base metal filler

SEM analysis of ECAs with different metal particles after long term 85°C/85%RH aging under current indicate that DuPont base metal particles show less corrosion than commercially available Ag-coated Cu particles.
Summary

• DuPont developed a new family of ECAs based on protected base metal particles dispersed in a high performance elastomeric matrix for PV applications.

• Compared with incumbent ECAs, the new elastomeric binder possesses low-temperature flexibility and low elastic modulus, room-temperature storage and transportation, broad processing window, long-term stability at high temperature (>200 °C).

• DuPont is also addressing cost challenge by developing low-cost base metal fillers, which show long term stability and offer an alternative to high cost silver and silver–coated particles in ECAs.

• DuPont™ ECA can be applied for PV module assembly via printing or dispensing, on cell or ribbons. Mini modules passed durability testing of 600 thermal cycles and 2000 hrs 85°C/85% RH damp heat aging, under operating current.

• DuPont™ ECA enables novel module architecture innovations like multi-busbar and no-busbar.