HOLISTIC RELIABILITY: ACCELERATED TESTING OF ADHESION

Mason Terry, Thomas Dang, Christopher Alcantara, Jeff Dee, Daniel Inns, Homer Antoniadis
DuPont Silicon Valley Technology Center, Sunnyvale, CA, USA

2015. December

NIST
DuPont: The Leading Specialty Material Supplier in PV

- **Solamet® metallization pastes**: Driving higher energy conversion efficiency
- **Tedlar® backsheets**: Protecting PV modules
- **Elvax® and Ionomer encapsulants**: Delivering long-term protection of cells
- **Rynite® PET Zytel® Nylon composite materials**: Reducing system costs and speeding up installation
• Develop **test protocols** that differentiate materials with regards to durability

• Evaluate **durability for PV materials**, their interactions and synergies in module

• Provide **science-based understanding** of materials-related lifetime performance

• Develop products with **highest durability** to deliver more power output to **maximize ROI**
Field Studies Reveal Quality Issues

DuPont Field Module Program
• Inspected >60 global installations (>200 MW & 1.5 million modules) in NA, EU, & AP ranging from 0-30 years installed
• Data includes c-Si modules from > 45 module manufacturers

IEEE PVSC (New Orleans, 2015, A. Bradley et al)

Cell and Interconnect Reliability
• Little understanding of how the different components in the module interact.
• Metallization formulation changes every 1-2 yrs.
• Need science based understanding of what modulates metallization failures!

2/3rds of defects in inspected modules attributed to the cell and metallization.
Materials Selections Help Mitigate Risk

- Unreliable materials can cause premature power degradation, module and system failures, and safety issues
- Adopting proven, high quality metallization pastes, encapsulants and backsheet materials are critical to long term module performance and safety


Fabrice Didier, EU PVSEC – Investors day, September 26th, 2012.
Shortcomings of Extended Qualification Stress Testing

• Current accelerated tests do not adequately predict fielded performance
  – Power loss mechanism is **different** from the **field**
  – e.g. Hydrolysis damage occurring beyond DH1000 is **not observed in the field**
• Infant-mortality failures occur in the **beginning of the working life of a PV module**.

• IEC testing useful for **infant-mortality detection**.

• Questionable if IEC testing will **predict module midlife to end of life failure**.
Development of Relevant Accelerated Test Methods

Extended Damp Heat test:
→ Yellowing of PET is NOT observed

Yellowing of Fielded Modules:
→ High degree of yellowing in PET Modules
→ Almost no yellowing in Tedlar® PVF Modules

Test with DH, UV
→ UV matches field data better than DH

- Damp Heat is over-tested
- UV Exposure is under-tested:
  → UV exposure from module front and back needs to be incorporated
- Sequential and Combined tests better match field observations

*UVA (65W/m² (250-400nm), 70°C BPT, continuous)
Risk of Low-Laydown Architectures

**Motivation:**
- Modern low-laydown structures might **pose risk for durability**

**Goals:**
- Provide **critical limit** to durability for laydown
- Deliver cost-saving metallization architectures, while **excluding compromises in long-term stability**
Motivation:

• Demand for high adhesion between paste and ribbon is common
• Justification for pull force targets often not clear
• Adhesion testing method is varied and **not standardized**
• Mono-Si vs multi-Si adhesion is different due to surface structure!

Goals:

• **Understand mechanisms** of adhesion and relevance for durability
• Identify range of adhesion **safe for reliability**
• Develop accelerated tests that:
  • Simulate **long term field** exposure
  • Will predict **long term field performance**
  • Further refine pastes that have these features
Paste laydown – How to drive Adhesion

**Double-print Method**

Vary busbar thickness; fingers constant

→ **Busbar thickness drives adhesion**

→ Wide adhesive force range: **0.3 – 3N/mm**!

→ Is there an impact on module durability?

![Graph showing the relationship between busbar thickness and maximum adhesive force.](attachment:image.png)

![Graph showing the normalized output power for different module sizes.](attachment:image.png)
- Paste-driven adhesion does not affect module durability under Standard Tests
- Tests are currently extended (TC>500, Sequential testing, etc.)
DuPont Pastes Show High Adhesion

- Adhesion for all DuPont pastes exceeds requirements considered safe for durability.
Impact of High Temperature on Adhesion: 85°C + TC50

Bake at 85°C for varying time, then measure adhesion

TC 50 does have an impact after 85°C bake.
Still above 1N/mm for all pastes.
Does this infer long-term reliability?
Impact of High Temperature on Adhesion: 120ºC + TC50

Bake at 120ºC for varying time, then measure adhesion

TC 50 doesn’t have an impact after 120ºC bake?
Still above 1N/mm for all pastes.
Does this infer long-term reliability?
Borrowing from Microelectronics industry a test method
Bake at 150ºC for varying time, then measure adhesion

(Adhesion after exposure to 150ºC for varying durations)

The latest generation Solamet® PV19x retains highest adhesion after exposure to 150ºC
Is this a fielded module accelerated relevant test?
Motivation:

- Corrosion is critical failure mode for pastes

Goals:

- Assess corrosion resistance of Solamet® using relevant tests
- Understand effects and develop superior pastes
• **Adhesion:**
  - **DuPont** is studying role of metallization pastes for module durability.
  - **Adhesion of 0.9 N/mm** passes 3x IEC 61215.
  - **Paste-driven adhesion** component does not affect module durability under IEC-Based Test Conditions.
  - **All DuPont pastes** exceeds requirements considered safe for durability.

• **Aged Adhesion:**
  - 85°C followed by TC50: Change is seen; Why? Will this provide accelerated testing of metallization materials that is relevant?
  - 120°C followed by TC50: No change detected; Why? Is this relevant or applicable to the module with respect to long-term reliability?
  - 150°C followed by TC50: Big change seen; What is the reason? Is this relevant based on the multitude of data from the microelectronics world?
  - How will **metal contact corrosion** combined with **temperature cycling** affect reliability?
  - What will be the affect as **laydowns are further pushed down**?
  - Can we develop/adopt a relevant testing standard to **solve the time issue**?