What Not to Do

Presented at NREL PV Reliability Workshop
Feb 17, 2011

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Source: Spectrolab, Inc.

Introduction

- This talk shares some experiences with failure analysis in CPV cells and assemblies

- In some cases, root cause and corrective actions are discussed.
  - These are examples of solutions.
  - They are not intended to claim that these are the best solutions, or that products with other design features will not work as well or better.

- This presentation does not contain any proprietary or confidential information

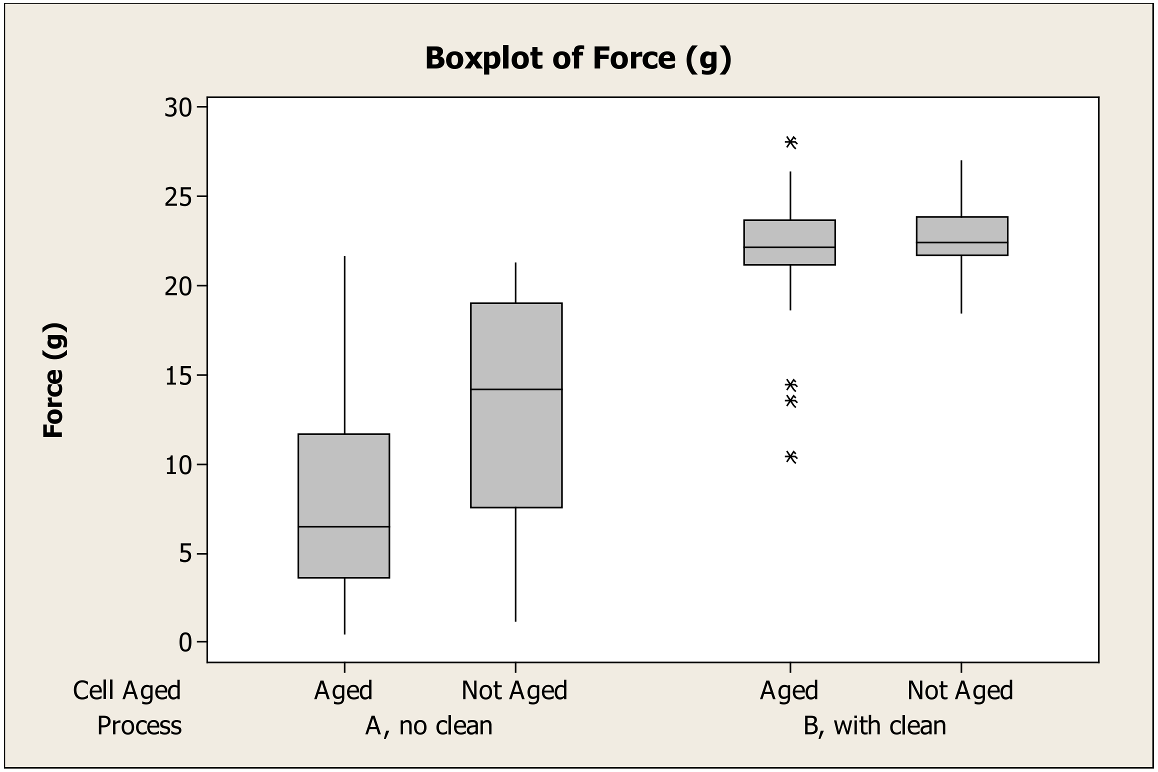
Agenda

- **Wire Bonding**
- Thermal Cycling
- Contamination in Cell Assembly I
- Contamination in Cell Assembly II
- Contamination in Enclosure I
- Contamination in Enclosure II

Cleaning Provides Higher Quality Bonds

- A split lot formed with several different groups of parts. Half parts were baked for 1 hr to simulate aging, half were not.
- Parts were wire bonded with two different processes.

Plasma Clean Improves Wire Bonding Robustness to Variation



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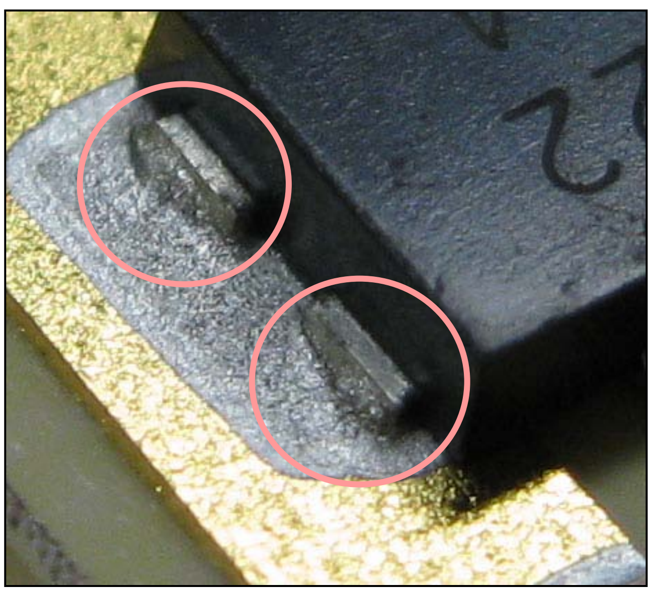
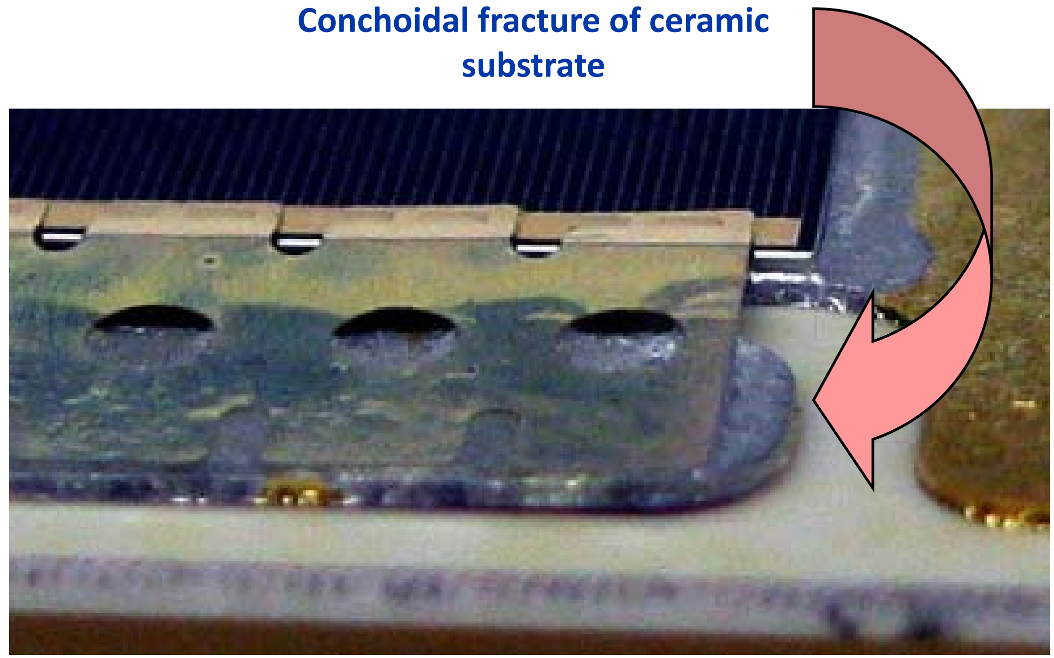
Assembly Design Failures

- Many CPV assemblies look similar, with cell bonded to DBC substrate. But reliable performance is in the details
- The following failures were observed after 500 IEC standard thermal cycles from -40C to +110C

Solder joint failure on surface mount diode



Conchoidal fracture of ceramic substrate

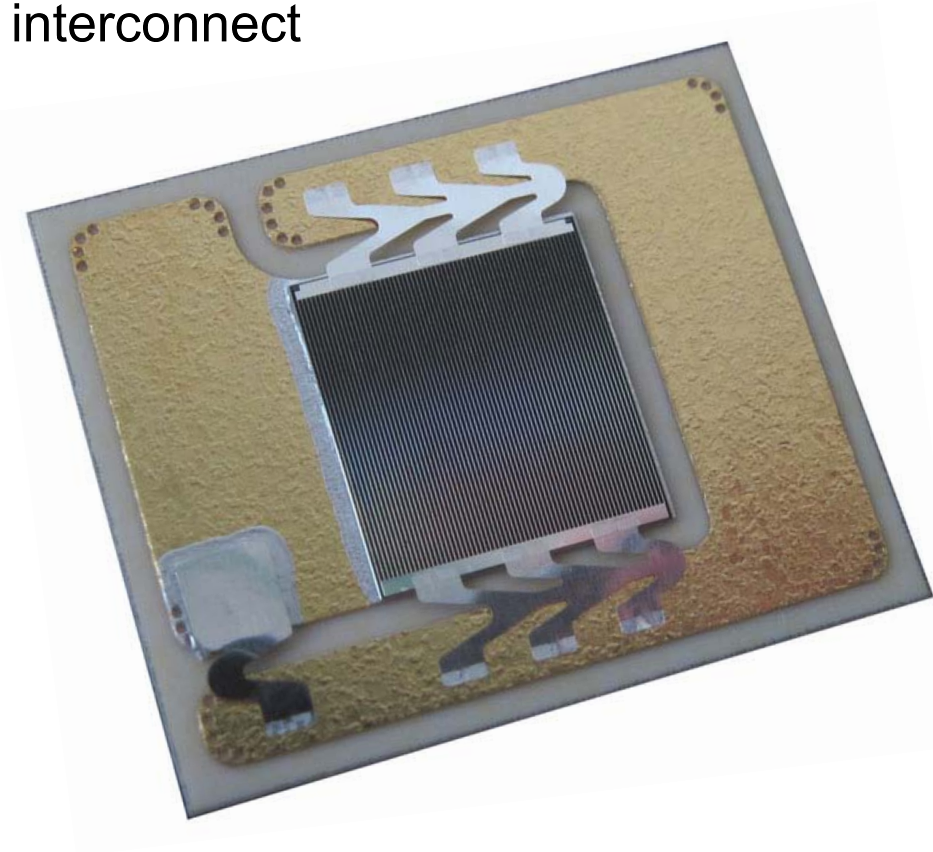


Corrective Actions

- Engineering to avoid most thermal cycle failures is well understood, it just requires requisite attention to detail
- Potential solutions to these failures include
  - Diode solder joint cracks
    - Stress relief in diode package
    - Less rigid attachment to substrate
  - Conchoidal fracture
    - Reduce thickness of Cu trace
    - Add dimples or other stress relief in Cu sheet
  - Solder disbond
    - Cleanliness and part preparation
    - Modeling and experiment with TIM material and process conditions

Improved Cell Assemblies

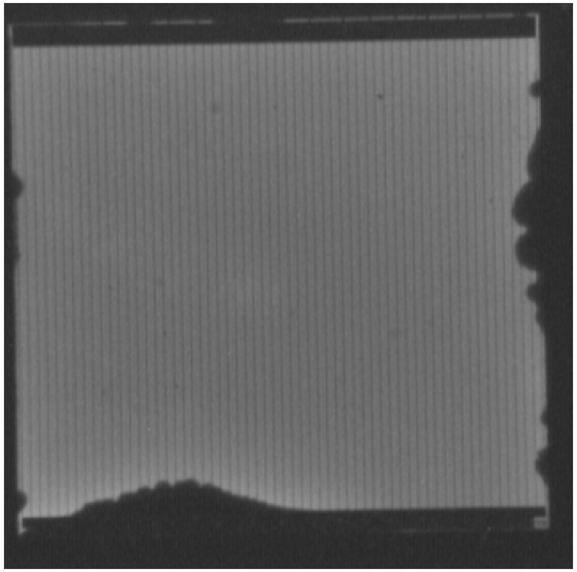
- New design
  - Improved stress relief in interconnect
  - Bare diode with stress relief in interconnect
  - 5 mil Cu thickness (from 8 mil)
  - Strategically placed dimples

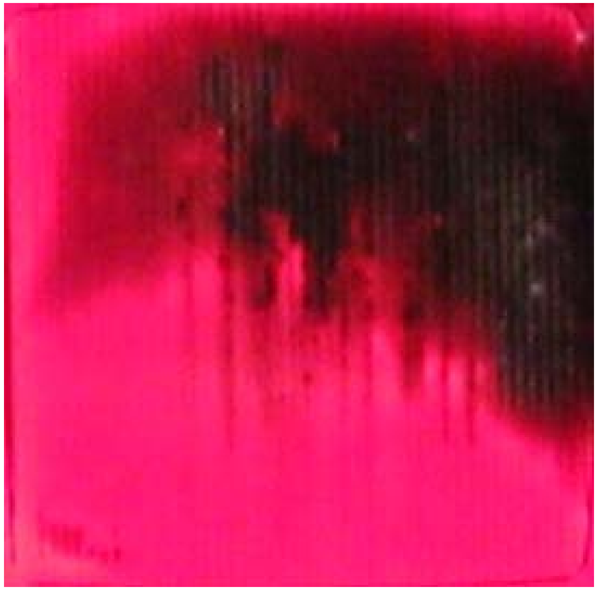


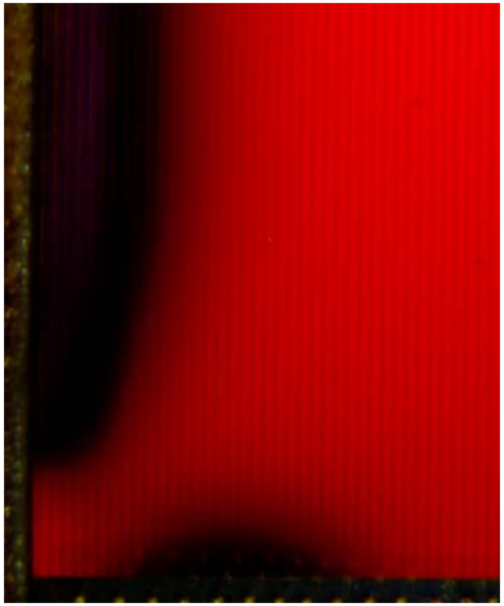
- Improved design shows no issues after new baseline of 1,500 thermal cycles from -40C to +110C

Cell Failures

- The electroluminescence images of cell failures look similar, but they have very different causes







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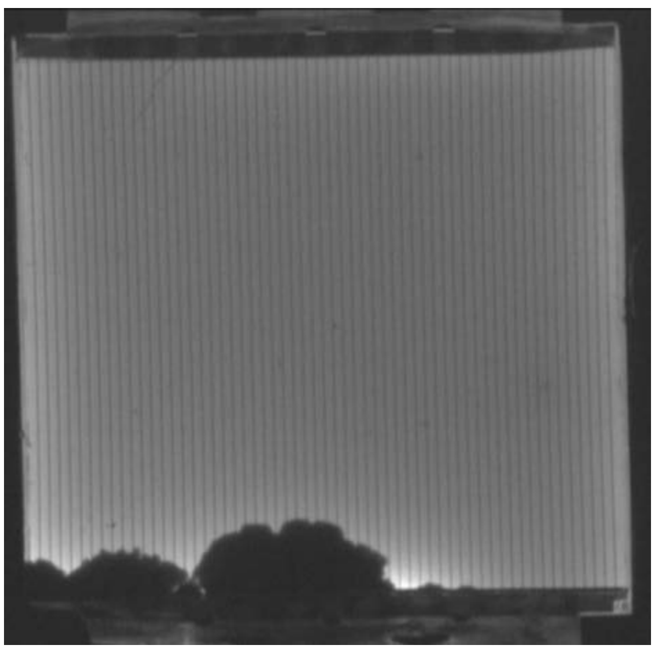
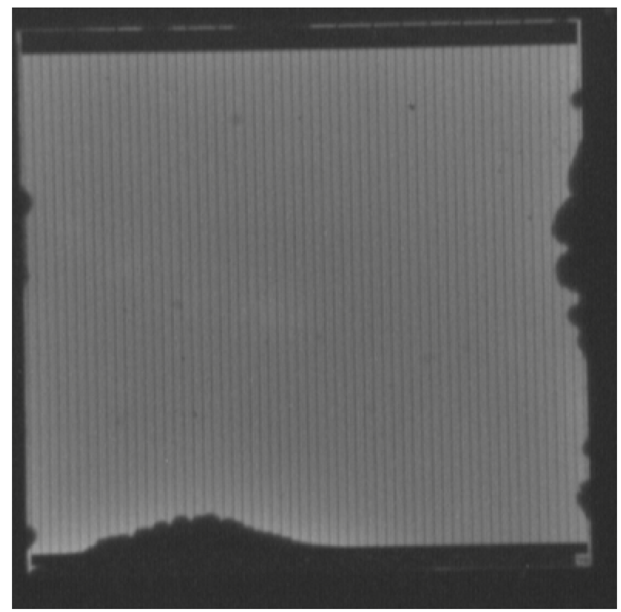
Contamination in Cell Assembly I

- Some assembly processes include liquid immersion, typically for flux removal or cleaning
- The solutions, even DI water, can become conductive from contamination or from material removed from the assembly
- If the solution becomes conductive, electrochemical reactions can occur
  - Driven by galvanic cell created between dissimilar materials (for example, Au-SnPb solder creates 0.65 V)
  - Driven by solar cell response to ambient indoor room lighting

Examples of Cell Damage

- Electrochemical reactions can perform many surprising feats
  - Plating of solder and substrate material on to cell surface
  - Wholesale or selective removal of cell layers





Recommendations to Avoid Electrochemical Reactions

- If possible, minimize or eliminate aqueous processing
- Regularly test conductivity of the bath, not just water supply
- When possible, minimize lighting over baths
- Consider electrochemical potentials of materials in assembly design
- Protect metal and semiconductor surfaces with encapsulants and/or dielectric materials

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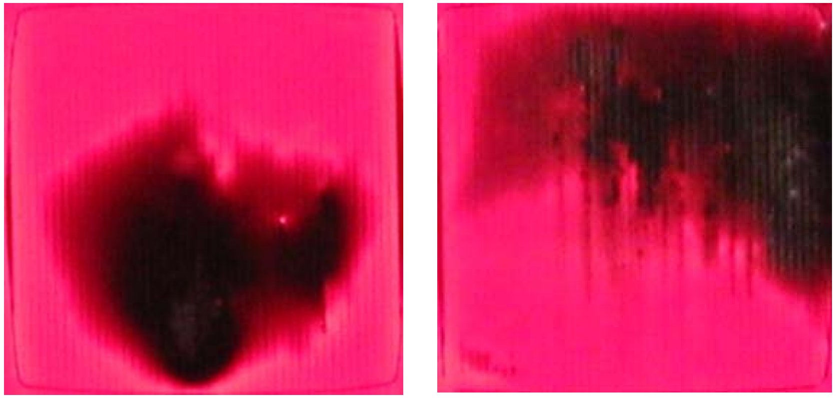
Contamination in Cell Assembly II

- Cells began to degrade after several months on sun.



- Assembly process used solder flux and flux cleaner containing bromine
- EDX & ESCA scans did not detect bromine on cell surface after assembly.
- After being placed on sun, bromine attacked front metal and was found all over cell surface
- Recommendation – use halogen free flux and flux cleaner

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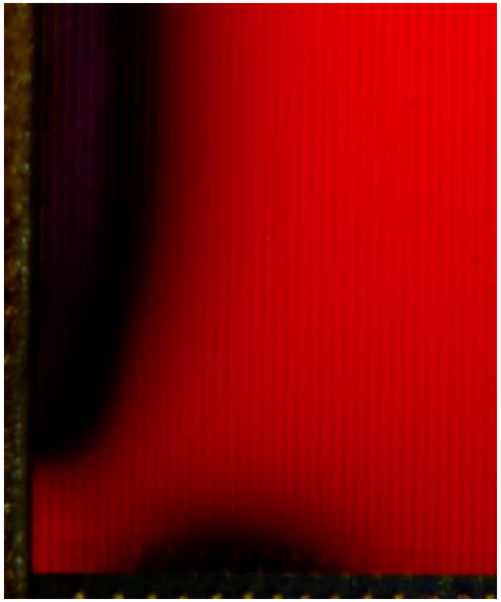
Contamination in Enclosure I



- Cell degradation observed during module / system accelerated life tests
- Failure analysis showed cells shunted around the perimeter
- Further investigation found a contaminant within the module enclosure which was corrected before product release.

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Contamination in Enclosure II

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- In another case, chlorine off gassing from edge sealant caused corrosion within the module enclosure and created significant power loss within months of installation.
  - Did not directly attack cell
- Investigation showed the CM substituted a different edge seal from the one specified.
- Recommendation
  - Avoid halides at all phases.
  - Consider environment within the module

Conclusion

- This paper has described failure analysis of CPV components and modules at various levels of assembly and some potential solutions
- Some recommendations for reliability
  - Dimples and stress relief improve thermal cycle lifetime, but require larger substrate
  - Always maintain high resistivity in aqueous solutions and avoid voltage generators such as galvanic couples and light
  - Avoid halides in processing and as constituents of components inside modules
  - Protect cells with encapsulation, and design system to avoid damaging materials that can penetrate encapsulants

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Acknowledgements

- The authors would like to acknowledge contributions and support from the entire Spectrolab team. Peichen Pien, Omar Al Taher, Randy Brandt, Jim Ermer, Russ Jones, Xiaobo Zhang, William Hong, Daniel Law and Mark Takahashi
- The authors would also like to thank various unnamed suppliers, customers and partners for useful data, discussions and support
- Some of this material is based upon work supported by the Department of Energy Solar America Initiative under contract DE-FC36-07G017052