Stress Testing and Failure Analysis Methods for Determining the Reliability of Metal Buss Tapes

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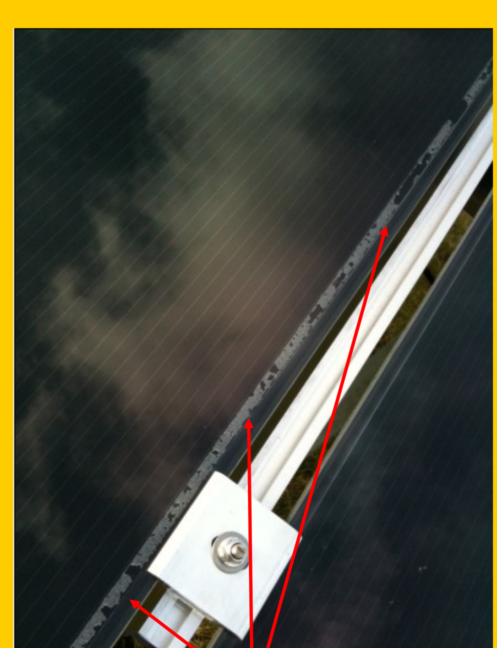
Abound Solar

Background

The use of conductive metal buss tapes is widely used by thin film PV manufacturers. These tapes are key to providing a low resistance contact to the anode and cathode of PV cells and to conduct current within the PV module. The ability of these tapes to withstand the harsh environments created during the lifetime of a solar panel can be difficult to simulate and therefore accelerate in the lab. Existing industry certification tests such as thermal cycling, reverse current overload, damp heat, and humidity freeze often fail to detect what will ultimately become field reliability failures. Classical tape adhesion pull and shear tests are informational, but can be difficult to calibrate to actual product requirements as they don't effectively measure ohmic ampacity, the ability of a conductive tape to maintain a low ohmic contact / high current carrying capability.

Characteristics of Buss Failure

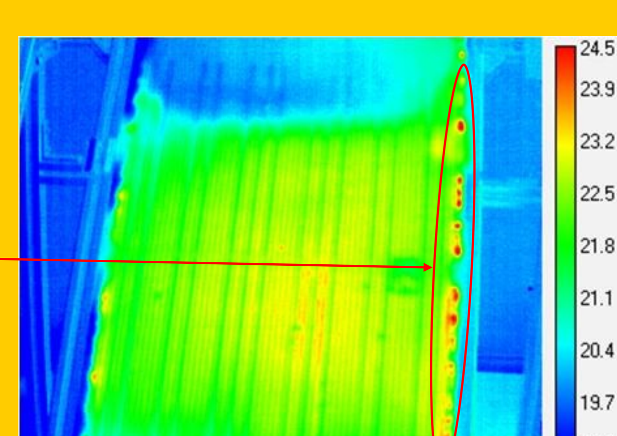
Buss failure typically begins with an increase in the series resistance between the tape and semiconductor back-metal that is induced by thermal fatigue and localized heating. The increased resistance is the result of decreased electrical contact surface area between the buss tape and back-metal resulting in the current being channeled through a diminishing amount of electrical contact points. This increased current density in turn generates more heat and continues to reduce electrical contact points creating a thermal runaway condition that ultimately results in sporadic or completely open buss tape to back-metal contact.

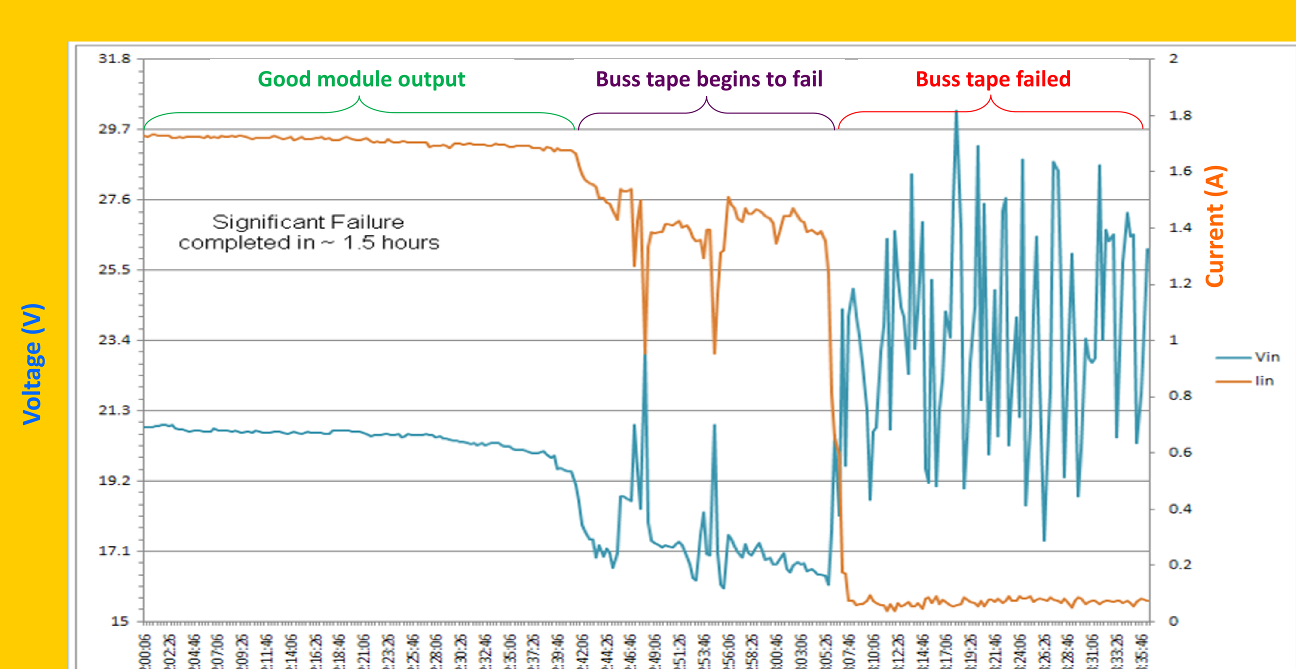


Buss tape failure resulting in film damage along length of thin-film cell

Buss tape failure as seen from the backside of the module

IR (Infrared) image showing poor ohmic contact areas along metal buss tape prior to failure





Voltage (blue) and Current (orange) characteristics at time of buss tape failure

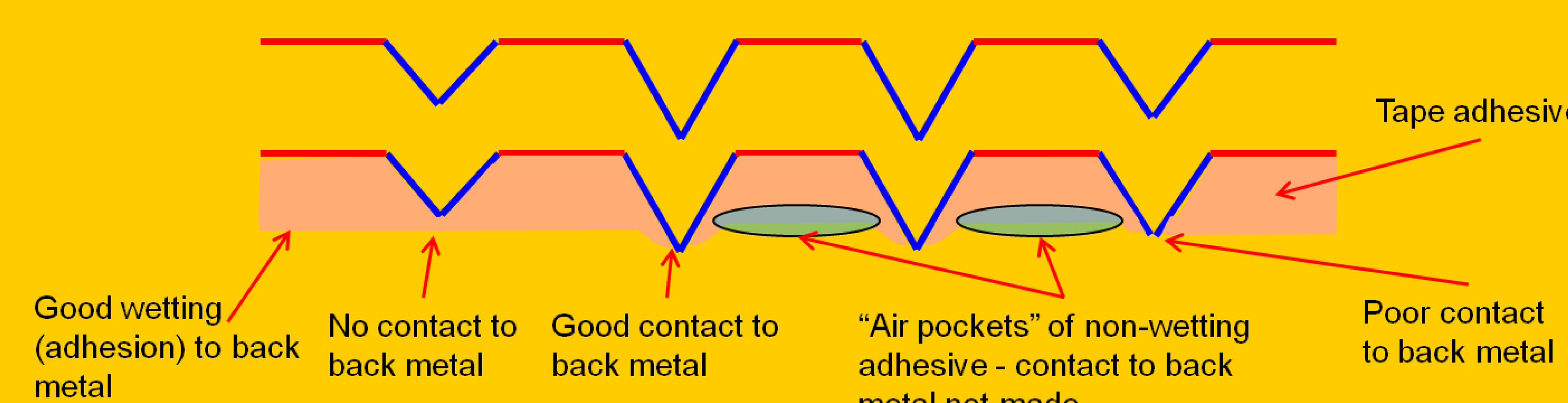
Lab Acceleration of Failure Mechanism

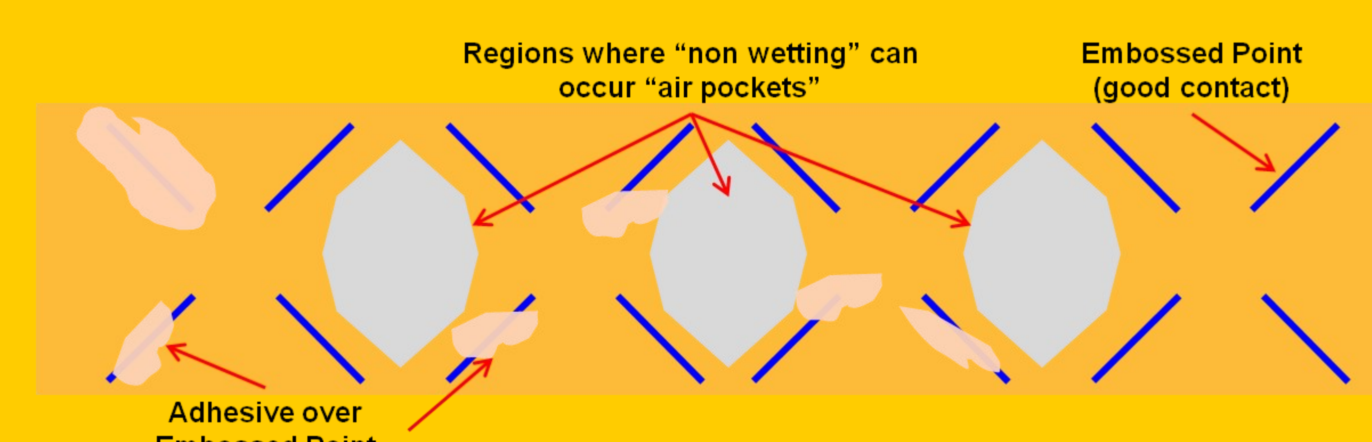
Industry certification tests failed to identify the metal buss tape failure mechanism primarily because they don't stress the failure mechanism adequately or are not performed for a long enough duration.

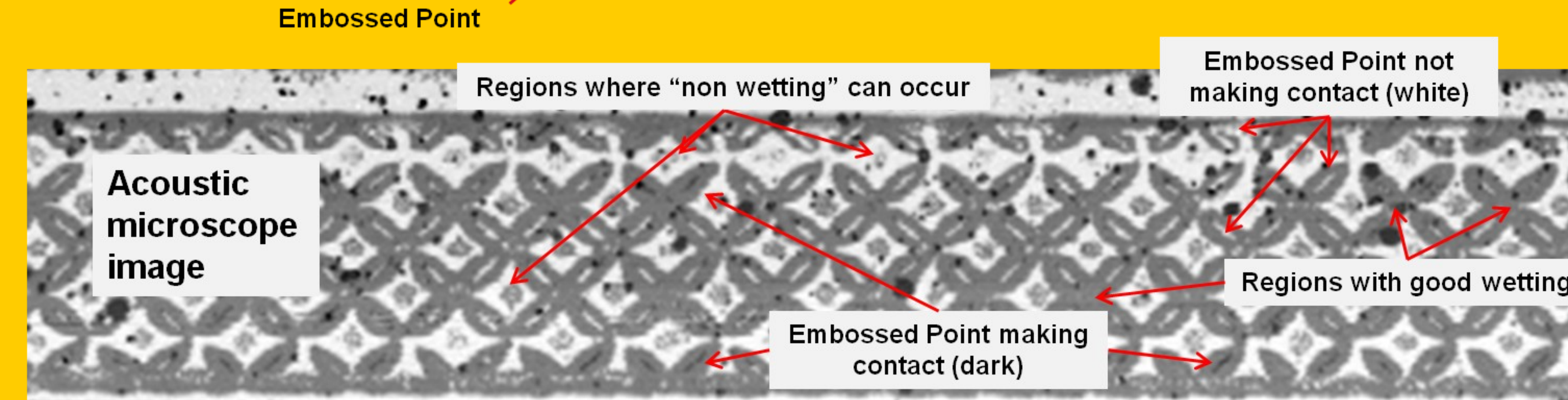
Stress Test	Catch Buss Failure Mechanism?	Reason
Temperature Cycling Test: UL1703, 35 (-40C to +90C, 200 cycles, small fwd bias current to assure continuity during cycle)	No	Failure mechanism requires both thermal fatigue and ***high current flow*** during cycles
High Temperature Bake (90C, 1000 hours, with and without high fwd bias current)	No	Failure mechanism requires both ***thermal fatigue*** and high current flow
Reverse Current Overload: UL1703, 28 (Fwd bias at 130% of fuse rating, 1 hour)	Rarely	Failure mechanism requires ***thermal fatigue***. Much higher current flow (>200% of fuse rating and longer stress duration increase chances of detecting failure mechanism)
Damp Heat: IEC61646, 10.13 (85C, 85% R.H., 1000 hours, unbiased)	No	Failure mechanism requires both ***thermal fatigue*** and ***high current flow***
Humidity Freeze: UL1703, 36 (-40C to +85C/85%R.H., 10 cycles, small fwd bias current to assure continuity during cycle)	No	Failure mechanism requires both thermal fatigue and ***high current flow*** during cycles. Ten cycles is insufficient to provide enough thermal fatigue.
Modified Temperature Cycling Test (-40C to +90C, test to failure, high fwd bias current, >2x I_{mp})	Yes	Failure mechanism requires both **thermal fatigue** and ***high current flow*** during cycles. Must test to failure in order to get to tape wear-out.

Buss Tape Adhesive Wetting

Cross-sectional representation of possible tape conditions prior to application. Due to embossing variability, not all emboss points are "cleared" of adhesive during embossing. Areas of higher emboss might not fully wet during application, leaving an air pocket between the back metal and the adhesive.





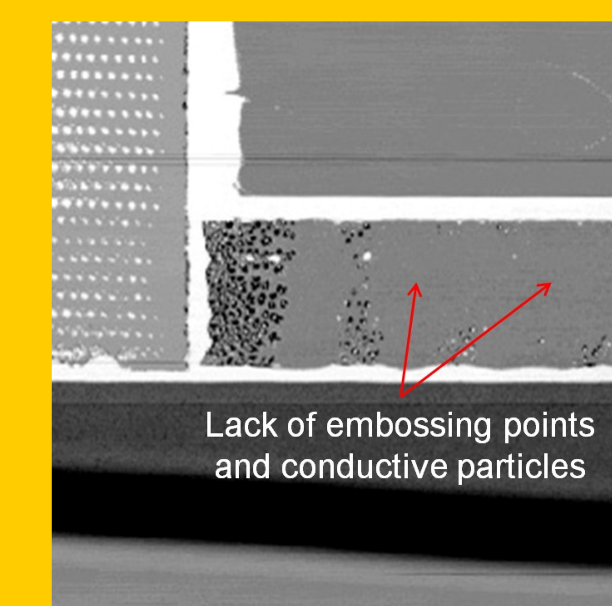


Top-down pictorial and acoustic image of buss tape specifically showing where embossed points make and don't make contact to the back metal and where adhesive wetting is both good and bad. The non-wetting regions are where air pockets exist between the back metal and the adhesive due to insufficient tape application.

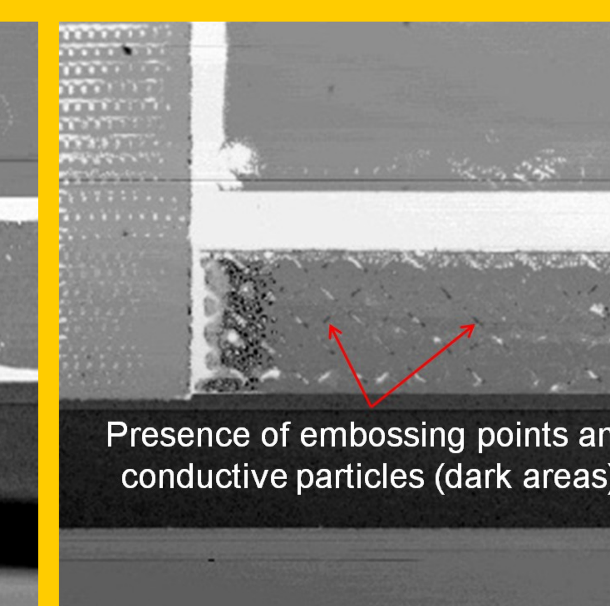
Buss Tape Application Considerations

- Roller force
- Roller durometer
- Speed of tape application
- Surface quality and cleanliness
- Back metal composition
- Embossed vs. smooth tape
- Adhesive properties
- Inclusion of conductive filler particles
- Composition of conductive filler particles

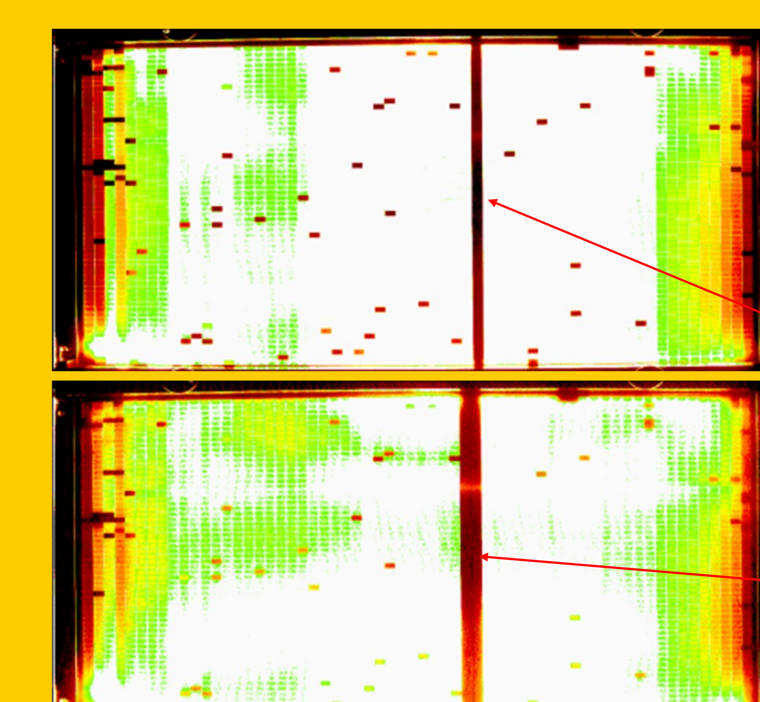
Failure Analysis Techniques



Acoustic image of poor tape application that results in buss tape failure



Acoustic image of good tape application that results in reliable buss tape



LBIC (Laser Beam Induced Current) image of a perpendicular, isolation laser-scribed module

Dark vertical line shows location where a 2 cm length of the metal buss tape is not making contact with the back metal

After additional stress testing, another 2 cm length of metal buss tape has failed

Conclusions

- Industry tests (UL1703, IEC61646/61730) are inadequate to detect thin-film buss tape reliability failures because they don't stress the failure mechanism adequately or are not performed for a long enough duration
- Creative use of failure analysis tools such as LBIC, IR and Acoustic Microscopy can be used to optimize tape application and observe incipient failure

Future Work

- Determine Coffin-Manson inverse power law relationship of various metal buss tapes
- Use Coffin-Manson relationship to project product lifetimes in various climates