International PV Module QA Task Force: Thin-Film Task Group Kickoff Meeting

Notes from the Thursday afternoon discussion session

In the first break out: Pick 4-6 failure modes that we are most concerned with for thin film products. In the second break out: How do we move forward to address thin-film failure modes identified in first break out? Can we work with current groups?

The items in red differ for thin film compared to silicon

- Broken glass (breakage in field, corrosion during storage, etc.) Annealed, heat strengthened, tempered glass; strain caused by films themselves
- Corrosion Chemical attack – salt, sulfur, Ammonia-induced corrosion Corrosion of/around scribes (e.g. due to moisture ingress or sodium diffusion, or…)
- Peeling (multiple types including monolithic interconnection, metals (e.g. films), etc.)
- Delamination: Junction box delamination; encapsulant delamination, tape
- Non-soldered busbar disconnection
- Electrical connections with shingled cells
- Junction failure – Semiconductor degradation by diffusion (e.g. Cu); Light-induced degradation – is this "failure"? Contamination by water, oxygen, carbon
- Hot spots
- Shunts at scribe lines – Decreased low-light performance (creation of shunts) – sometimes results in hot spots?
- Mounting–induced failure (incorrect clamping) – Frame failure
- Hail damage (foil packages and non-strengthened glass are more susceptible)
- Back foil cracking (is chalking a failure?)
- Solder fatigue
- Mechanical failures – Leads falling off, Connector failures, Rail detachment or creepage, Snow, wind damage,
- Diode failures – Foils can lead to static?
- Arcing (can lead to fires) (can be ground fault or disconnected circuit) – Ground fault
- Thin-film specific corrosion issues: Edge seal failure, TCO resistivity change System-voltage degradation – (at scribe lines, TCO delamination, Na into cell)
- Encapsulant browning
- Isolation scribes (poor edge delete) can lead to leakage and ground faults
- Soiling
- Alignment of the scribe lines with soil line – don't have a dirt stripe that covers an entire stripe.
- Cohesive failure of encapsulants, adhesives, edge seal, direct-roof bond
- "Rodents" Animals chewing through cables.

- Flexible modules – bending, walked on modules
- Mismanagement of box cutter
- Aesthetic issues – change of color (discoloration); nonuniform color;
- Puddles of water causing damage for flat-mounted modules.

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This list taken from PVMC list

Failure mode	Root cause	What happens? Failure mechanisms	Studies needed to understand the failure mechanism
Glass/Mo - Adhesion	Defects in glass, Cleaning, process parameters in Mo deposition conditions	Na diffusion, Si-O-H bonds break causes moisture ingress and accelerate pH increase at the interface.	Understand the interfacial surface chemistry at the interface
Barrier layer	Impurities from substrate	Diffusion	Quantify impurities detrimental to the performance
Mo-corrosion	Increase in sheet resistance (related to P1 scribe)	Mo-Oxide formation	Acceptable MoSe thickness and Mo-Oxide effects
Absorber	Resistivity of CIGS absorber decreases (increases shunting) Loss in Voc	Increasing defect density in the bulk or at the grain boundaries of the CIGS absorber, and by a shift of the Fermi level at the CIGS/CdS interface	Bulk vs. surface characterizations to understand band diagram . Grain boundary and defect density correlation (PES and IPES)
Junction failure	Loss in Voc and FF- Vertical effects	Compositional changes induced due to moisture ingress, lifetime studies, interlayer diffusion	Junction studies EBIC,CL, TRPL, and PL and surface and bulk studies
Buffer	R shunt, Pinholes	Diffusion of Cd in the grain boundaries and replacement of Cu	PL, Surface and interface characterization
TCO	Sheet resistance increases, FF	Higher ohmic losses in the front contact, and by imposing a shift of the built-in electric field toward s the n-region, which will increase the electron barrier at the interface	EBIC, Band Diagram-PES and IPES
Interconnects, Bus bar failure	Increase in R series	Current and voltage limitations, soldering /ECA material properties diffusion	TLM studies with the TCO,
Monolithically interconnected P1- (Mo-CIGS)	Resistivity of CIGS absorber decreases increases shunting loss	Increasing shunting currents in the P1 cell definition scribes-diffusion	Diffusion
Monolithically interconnected P2- (Mo-ZnO)	ZnO:Mo contact resistance increases by a factor of 10-100	Formation of an Oxide layer, ZnO-Al- Depleted free carriers @ interface	Surface analysis, Hall measurements
Monolithically interconnected P3 - (Mo)	Mo in P3 scribe degrades- Sheet resistance increases by a factor of 100 + performance loss	Formation of an Oxide layer, Diffusion of impurities	T&R, Hall measurements, Surface analysis
Edge shunts, Weak diodes, Hot spots,	Edge deletion debris, Non-uniform absorber, pinholes,	p to n type conversion	IR spectroscopy, Quantifiable EL and PL measurements