US TG 4 activities of QA Forum

QA Task Force 4 ; Diode, Shading & Reverse Bias

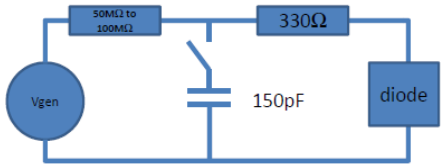
Contains no confidential information.

Feb. 28 – Mar. 1, 2012 ***@NREL PV Reliability work-shop***

Vivek Gade(Jabil Circuit) and
Paul Robusto(Intertek)

Overview, Working groups and areas of focus

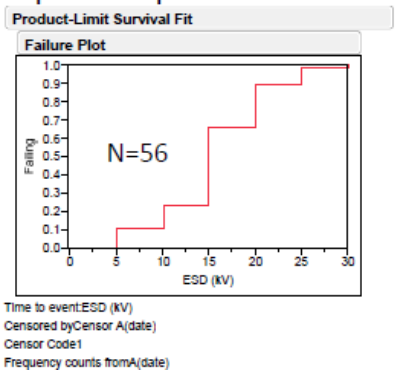
- Working group 1: Lead by Kent Whitfield working on HBM surge testing
  - PV Manufacturing facility static voltage measurement
  - Performed ESD event in combination with reverse bias at high temperature
  - Conduct tests and compare life distributions from the 10-surge and 100-surge program
- Working group 2 and 3: Lead by Vivek Gade and Paul Robusto
  - Reverse bias at high temperature and reverse bias transition survivability
  - Forward bias thermal cycling and fatigue issues.
  - Scope of the testing not limited to diodes but apply to Junction box level testing.
- Working group Task 4 Japan Lead by Yasumori Uchida, JET
  - Human body model ESD
  - Thermal runaway at reverse bias

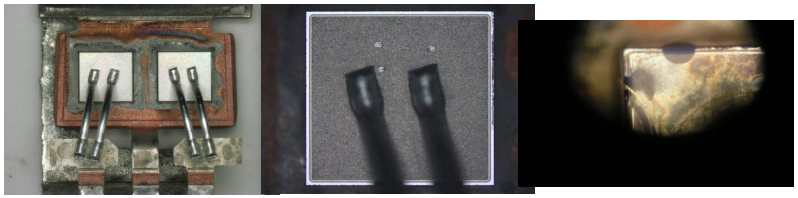


HMB surge testing

- Handling by personnel on the manufacturing line and in the field results in surge events that damage Schottky diodes.
- Surge events can lead to higher reverse bias leakage current which can exacerbate a thermal runaway failure. Some failure analysis suggesting root cause of diode shorting events indicates surge damage
- Basis of ESD Test – IEC 61000-4-2
- 150pF, 330 ohm impendence circuit. This is interpreted to be a human-body-model impedance circuit.
- This work did NOT confirm a correlation between reverse leakage current and ESD event below the failure threshold.
- A fifth group of 56 diodes (restricted to a suspect date code) was subsequently subjected to an ESD-to-Failure test exhibited 100% mortality.
- This work does suggest that there is significant difference between the failure distribution of diodes subjected to an ESD-to-Failure test program and reports on a significant change in the failure distribution for one diode type when restricted to a particular date of manufacture.

A-Fails
Groups 5 suspected date code



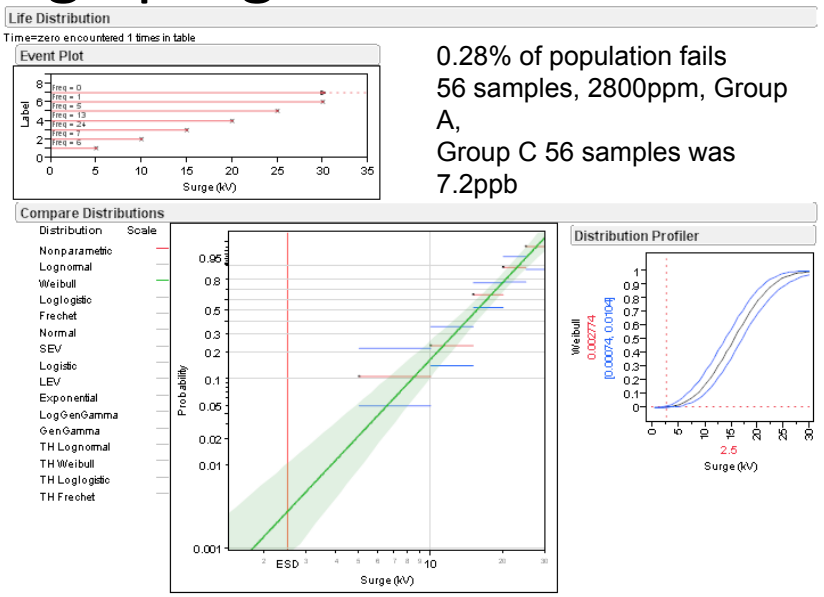


Typical failure: ESD mark observed after die top metal removal.

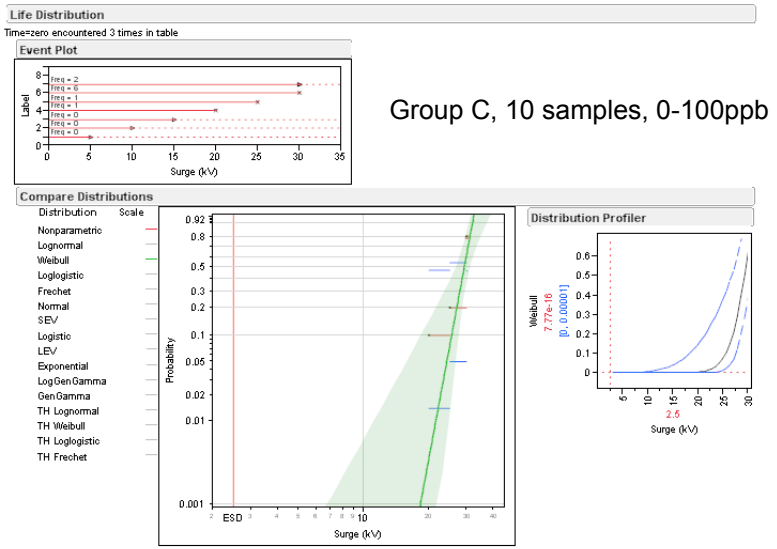
JBOX INSTALLATION STEP (measurement date 10 Oct 2011)	Measured Voltage (V)
Opening shipping container and measuring jbox potential while still in box	+1,260
Preparation table resting voltage	+90
Removal of Jbox from box and placement on table. Resulting jbox voltage.	+470
Placing two strips of double-sided tape on jbox. Max voltage.	+120
Jbox voltage after applying perimeter silicone adhesive.	+130
Jbox voltage after removing double-sided tape release liner. Max voltage.	+2500
Placing Jbox on laminate. Maximum box voltage.	+50
MODULE TESTING CONDITIONS	
Flash simulator curtain voltage. (NOT JBOX)	+200
Flash simulator structure voltage. (NOT JBOX)	+50
LAMINATE CONDITIONS	
Laminator outfeed belt voltage (NOT JBOX).	+250
Laminate on outfeed conveyer belt (NOT JBOX)	+110
Laminate on table post backsheet trimming operation	+110
SEPARATE WORK AREA KNOWN TO HAVE A HIGH STATIC POTENTIAL	
EVA Roll	-3500
Backsheet Roll	-56,000

HMB 10 surge and 100 surge program

- 56 parts per group and three groups tested.
  - Surge-to-failure program in 5kV steps using simple DMM check for short-circuit following surge (no elevated temperature reverse current leakage test).
- 5 surges anode + 5 surges cathode with 10 seconds between surges per stress step.
  - A group of ten diodes was tested using 50 surges anode + 50 surges cathode (100 total) with a 10 second rest between surges and the life distribution from this sample is compared to the baseline 10 surge program.
- A Weibull curve used to fit data enabling estimation of number of failures that may occur at a specific level of ESD potential.
  - We have substituted surge voltage for time in this analysis
  - The cumulative distribution function is thus interpreted to mean fraction of all units in the population which will fail by V voltage of ESD.
  - Shaded region indicates a 95% confidence interval around the median line.
- Static voltage measurement used to estimate ESD potential levels in a PV facility
- Significant difference seen in resulting failure distributions.
- Good similarity between the life distributions from the 10-surge and 100-surge program is indicated.



0.28% of population fails
56 samples, 2800ppm, Group A,
Group C 56 samples was 7.2ppb

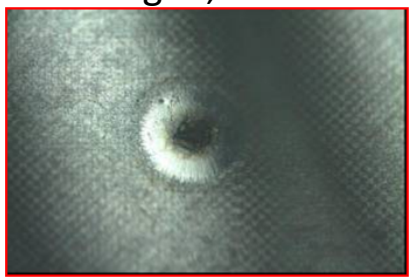


Group C, 10 samples, 0-100ppb

HTRB, Transition and forward bias testing

- The reliability is currently not determined by HTRB by Tj Reverse voltage resistance of diode in J-box similar to “By pass Diode Thermal Test(IEC61215) need to be considered
- The reverse current does experience increase by orders of magnitude with increasing temperature and needs to be considered. Reverse bias thermal runway due to transition and thermal cycling will be studied by working group 2.
- Elevated temperature combined with repeated power cycling could drive fatigue at the die attach.

Forward bias extended testing and issues such as fatigue, cracks in case, solder joints were observed and nee



- Reliability problems are rarely reported and rectifiers are very low on the Pareto analysis for returns
- Schottky diode failure is seldom due to wear out mechanisms.
- Several known quality problems in the manufacturing process exist
  ESD problems of up to 50kV (ESD remains the Nr 1 problem in the industry)
- A bigger source of problems than reliability concerns is latent defects introduced according to diode manufacturers.

Japan Task force #4

- Machine Model (M.M) for ESD
  MM should be applied to avoid ESD failure experienced during PV module manufacturing process and field installation. The diode in J-box should be evaluated by the reverse bias at high temperature in order to avoid the thermal runaway. Arrive at rationale to pursue most relevant tests under specific conditions.
- The diode in J-box should be evaluated by the reverse bias at high temperature in order to avoid the thermal runaway.
- Consideration of reverse bias withstand voltage of diode in J-box as for "Bypass Diode Thermal Test(IEC61215)".
- Report on recommendations and applicability to diodes and J-box testing.
- Arrive at rationale to pursue most relevant tests under specific conditions.