The Influence of Various c-Si Module Encapsulants on WIR Performance

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Introduction:

Wet Insulation-Resistance testing according to IEC61215[1] is one of the regular manufacturing sampling tests performed at all SolarWorld production sites to ensure the continued high quality of our products. A designed experiment was performed to determine the impact of different module encapsulation materials on the measured Wet Insulation-Resistance (WIR) of crystalline silicon (c-Si) based modules. It was observed that compared to the other encapsulants, ethylene vinyl acetate (EVA) is the greatest contributor of variation in WIR performance. Wet leakage current, if sufficiently large and occurring on multiple modules within an PV array string, can lead to inverter faults and impact overall system reliability.

Figure 1 shows the different leakage paths through a typical c-Si module during WIR testing. The crystalline cells are embedded in an EVA material which itself is sandwiched between a sheet of glass on the front of the module and a back sheet on the rear of the module which is a laminate film consisting of layers of fluoropolymers and polyethylene/ polyester based materials. Cross connectors, junction box, silicone sealant, and frame complete the list of materials for a c-Si module.

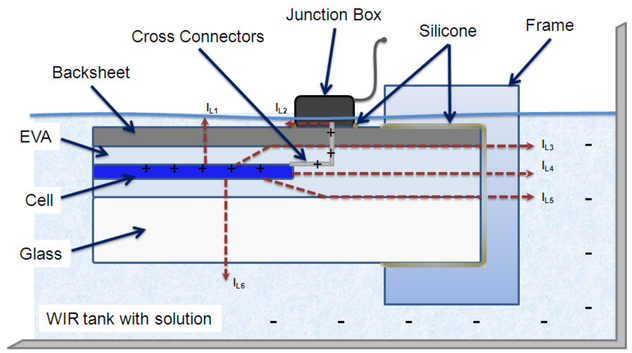

Figure 1 – Schematic of leakage paths of a typical c-Si PV module during WIR testing

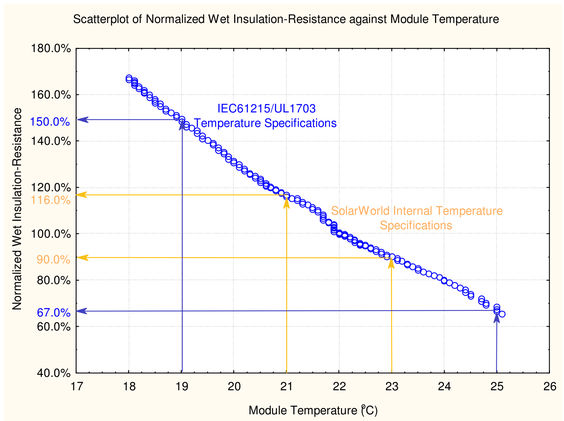

Figure 2 –Influence of the temperature of an exemplary module on measured wet insulation-resistance

Methodology:

A designed experiment was performed to determine the impact of different encapsulation materials on the WIR performance of c-Si modules. Multiple modules with different glasses, EVA, and backsheet materials were produced at three different SolarWorld production sites. The wet insulation-resistance (WIR) of each module was measured at both the respective production site and the IEC17025 certified module test laboratory at SolarWorld Innovations (SWIN).

Test Set-Up:

The IEC61215/UL1703 standards specify the set-up of the WIR test with a temperature control range of 22 ±3°C [1,2]. To assess the influence of temperature changes on the measured WIR values, we varied the temperature of the module and WIR test solution over the entire range of the test specification (19-25°C). The wet insulation-resistance varied by up to 50% even over this small temperature range (figure 2).

Subsequently, a tight temperature control of the device under test of 22±1°C was introduced as part of the standardization of the WIR test across all SolarWorld production and laboratory sites to reduce the measurement variability.

The resulting WIR test set-up adopted by SolarWorld is schematically shown in figure 3. Standardization of the entire WIR test set-up between production sites and the certified module test laboratory at SolarWorld Innovations in Germany allows for a very good reproducibility of WIR test results at various test locations (figure 4). All tests were performed using a 1000V bias corresponding to the maximum system voltage for the modules under test (according to IEC61215).

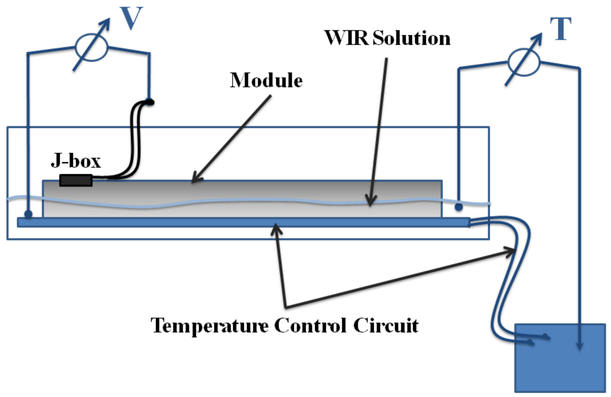

Figure 3 – Schematic of standardized WIR test set-up at SolarWorld

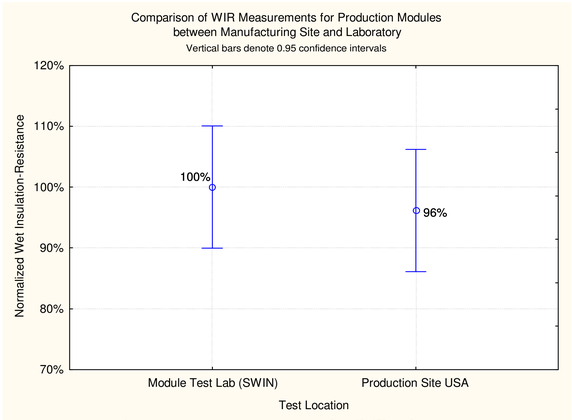

Figure 4 - WIR test reproducibility between test sites for actual production modules

Results:

Although all modules surpassed the specifications of the IEC61215/UL1703 standard of 40MΩ·m², results varied widely among the different material combinations (figure 5). EVA was identified as the main driver for this variability. Figure 6 shows the difference in WIR due to EVA for the same type of glass and backsheet. One EVA material stands out due to exceptional WIR performance. Figure 7 shows the relatively small contribution of glass and backsheet to the WIR variation between the tested modules .

Discussion:

The measured wet insulation resistance and leakage current depend strongly on the temperature of the electrolytic test solution. A tight control of the test solution temperature during WIR sampling of manufacturing products ensures that WIR measurements are consistent over time and across manufacturing sites.

The analysis of our DOE showed that the quality of the EVA tends to have a significantly higher impact on WIR performance than different types of glasses or back sheet materials. It was observed that WIR of EVA varied widely (by orders of magnitude) between different vendors. In the case of one evaluated vendor, EVA supplied from different manufacturing locations (EVA C and EVA D) showed a significant difference in performance due to different additives used at the respective vendor plants. The results reinforce SolarWorld's strategy to closely monitor the incoming quality of encapsulation materials and to audit and qualify each vendor production site separately. SolarWorld has standardized its testing methods globally and has implemented regular and frequent material tests in production.

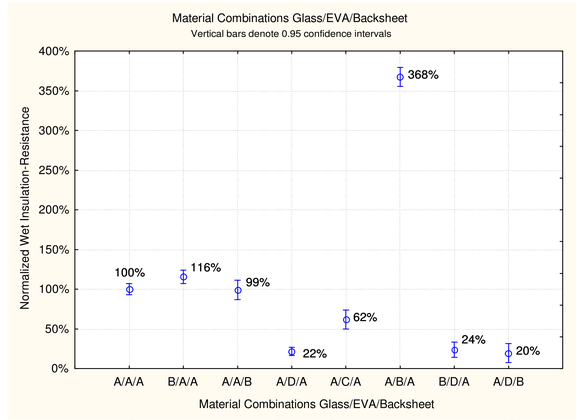

Figure 5 – Comparison of WIR performance of different combinations of encapsulants

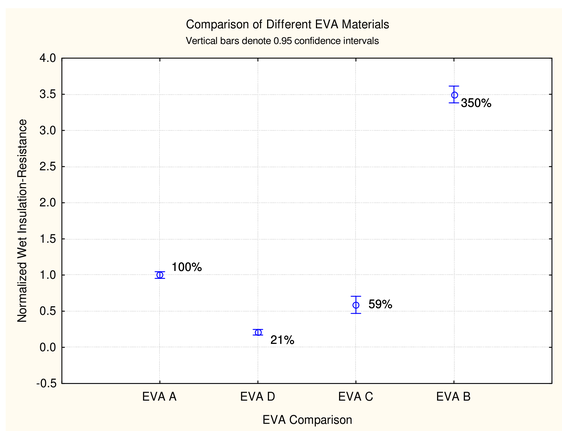

Figure 6 – Differences in WIR performance of different EVAs for same glass and backsheet

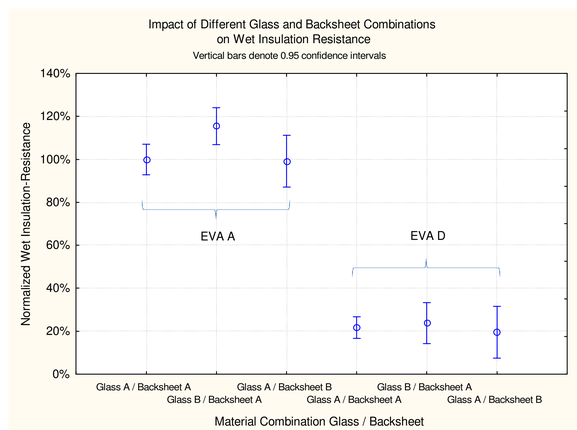

Figure 7 – Contribution of glass and backsheet on WIR for two different EVA materials

References:

[1] IEC61215 Ed.2, 2005

[2] UL1703 Ed.3, 2002

Acknowledgements:

Michael Eberspächer˚, Jens Weisse˚, Rainer Thiel˚, Nestor Rigonan, Max Selahi, Nguyen Dinh, Jason Wiser, Emili Woody*Δ*, Ryan Kumler*Δ*, Wolfgang Klemm*, Stephen Hunter

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