DEMYSTIFYING THE FORMATION OF MICRO-CRACKS

There have been a lot of academic resources spent in understanding the effects of micro-cracks in solar modules, but it is still difficult to predict the exact causes that make micro-cracks appear, especially after the modules are installed in the field. In this article, we attempt to share some specific situations, from the production stage to installing in the field, which may cause micro-cracks, and solutions to mitigate the micro-crack related issues.

Since the solar market became aware of micro-cracks, mechanical and thermal stresses have been blamed as causes to the problem. Therefore, module manufacturers worldwide have worked closely with independent testing laboratories, putting modules through Mechanical Loading (ML), Thermal Cycling (TC), Humidity Freeze (HF) and other popular tests to confirm the long term reliability of their modules under mechanical and thermal stresses. But these tests only help people identify the effects of micro-cracks, not necessarily the causes of them. It takes years of industry experience to analyse the causes of micro-cracks and find solutions to them.

Different types of micro-cracks

In WINAICO, we classify the occurrences of micro-cracks into three categories: during production, transport, or in the field. Micro-cracks that appear during production are usually caused by inexperienced operators and poorly tuned production equipment, and can be remedied by improving production processes. Transport and handling induced micro-cracks happen after solar modules have been packaged and shipped out of the production facility. Improper transport methods and handling errors make micro-cracks appear, and these can be mitigated by redesigning product packages with added protection and padding. The most common type of micro-cracks appears in the field, caused by constant wind stresses and heavy snow during long winters. The solution to the field defects is to structurally strengthen the solar cells, with WINAICO's patented HeatCap technology, to defend against the propagation of forces.

Solutions to micro-cracks occurring in production

In a solar module production line, a poorly tuned stringing machine or manually soldered joints may exert excess forces during the soldering process and cause hairline cracks around the busbars. These cracks worsen after the lamination process, as both the pressure from lamination and thermal expansion cause the cracks to lengthen and widen. If the cracked modules manage to slip through the quality management system, they become the weakest link in the solar array, as more micro-cracks will grow from the hairline cracks to severely impact the power output of the solar module. The best way to mitigate the micro-cracks caused during production is to only use automated soldering equipment with experienced engineers to optimize the machines. At least two stages of Electroluminescence (EL) should be included in the production line to complement visual inspection to screen out defects so they do not leave the factory.

Solutions to micro-cracks occurring during transport

In order to improve the stacking capability of solar modules in warehouses, companies are inclined to use vertically packaged modules in cardboard packaging on wooden pallets. Further cost-cutting measures lead to thinner and weaker cardboard boxes that require fully-packed modules to help support pallets in the upper deck. These poorly designed packages may not be able to handle the rigorous vibration exhibited in cross-ocean journeys, and solar modules in the lower pallets tend to crack under the weight of upper pallets. WINAICO has performed extensive research in the reliability of module packaging, and settled on a reinforced design that carries all the weight of upper decks without putting pressure on modules during transport. This way we can make sure WINAICO modules are delivered to customers' doors micro-crack-free.

HeatCap as a solution to micro-cracks in the field

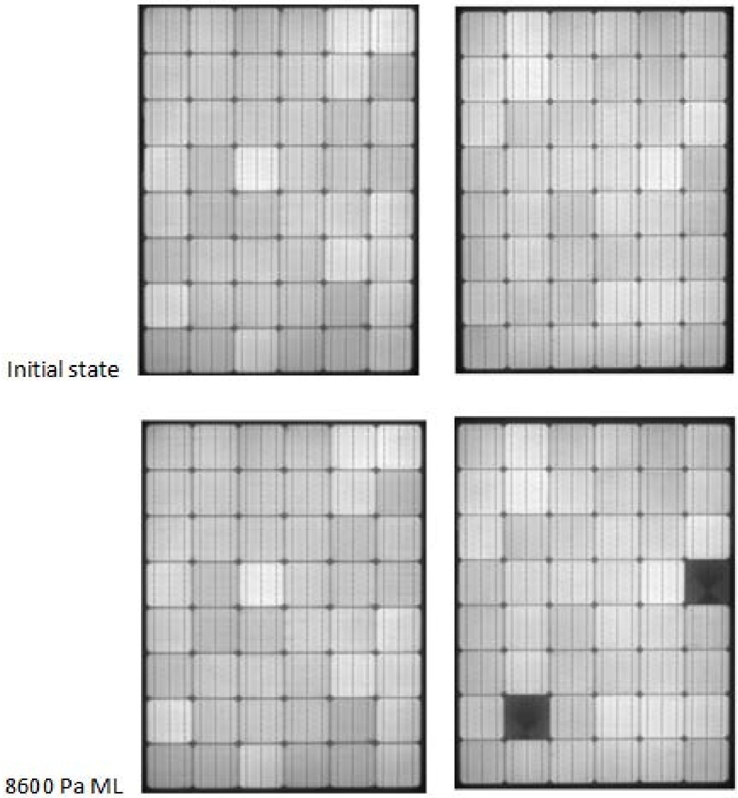
Micro-cracks that occur in the field after installation are usually caused by external forces, such as snow and wind. When such forces act on each module, the solar cells bend according to the construction of glass, frame and mounting structures. For example, when uniformly settled snow acts on a module clamped on the long sides, the principal forces on the long side cause the module to sag in places not supported by the clamps, while the short side of the module would fold toward the unsupported centre. As a result, the solar cells are forced to bend in the same directions dictated by the glass, and may crack in both x and y axes. Conventional wisdom may be to improve the thickness and strength of glass and frame, but the added reliability has the downside of increased module weight. Therefore, only a solution like WINAICO's own patented, HeatCap technology, can improve the solar cell strength without impacting the weight and usability of solar modules.

Figure 1: HeatCap technology applied to the back of a solar cell.

WINAICO's own HeatCap technology is a film that can be applied to the back of any silicon solar cell, before being assembled into modules, shown in Figure 1. It has the effect of structurally strengthening each solar cell to prevent micro-cracks. HeatCap is exclusive as an added feature to WINAICO's high efficiency product line. WINAICO's internal evaluation shows evidences of HeatCap improving the ultimate stress a solar cell can withstand up to 18.12%. WINAICO also worked with Taiwan's leading research institute, ITRI, to evaluate the reliability of HeatCap technology at the module level through Mechanical Load (ML) and Dynamic Mechanical Load (DML) tests to simulate static snow and dynamic wind loads on solar modules.

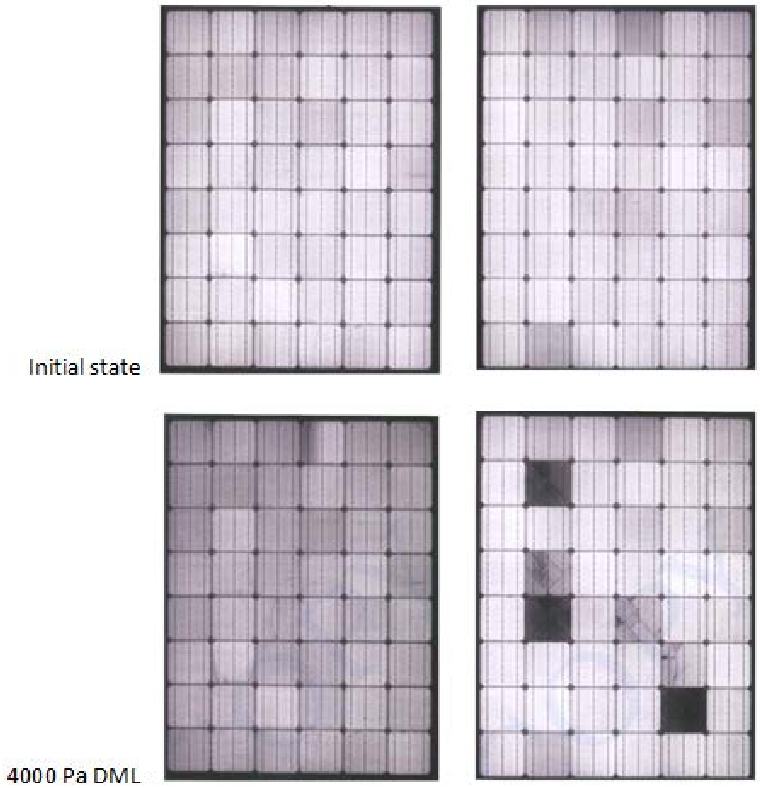
Based on the EL results shown in Figure 2, the HeatCap module is able to withstand up to 8600 Pa of ML test without any visible micro-crack, while the reference module has two obviously cracked cells after 8600 Pa ML test.

Figure 2: Comparison of EL pictures before and after 8600 Pa ML tests for left) HeatCap module, and right) reference module.



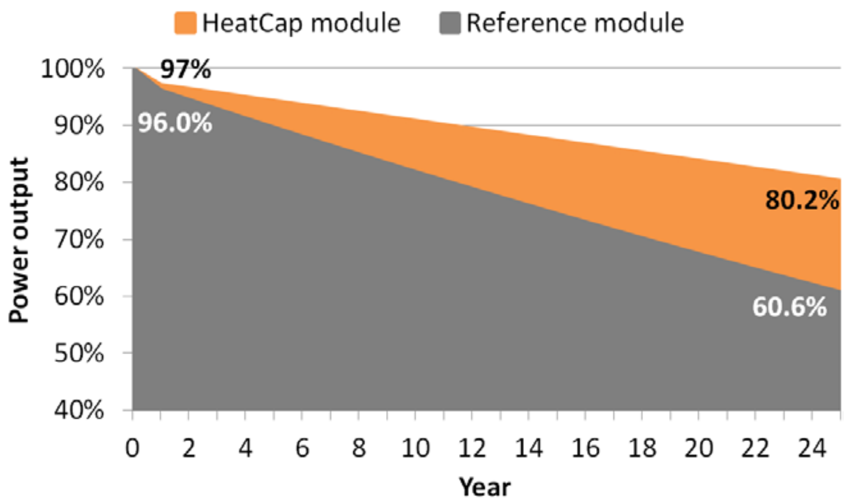
The HeatCap module's ability to withstand up to 4000 Pa of DML test is illustrated in Figure 3. The EL pictures once again show the HeatCap to be almost unaffected by the DML, while the reference module has six severely cracked cells after 4000 Pa ML test, resulting in power degradation.

Figure 3: Comparisons of EL pictures before and after 4000 Pa DML tests for left) HeatCap module, and right) reference module.



A conservative estimate of the impacts of micro-cracks in the field can be summarised in a solar module power diagram in Figure 4. The orange graph is what most module companies promise customers in a 25-year linear power guarantee, where the module is guaranteed to output at least 97% of STC rated power after one year, followed by 0.7% power degradation each year to reach 80.2% output at year 25. For a reference module that is not protected against strong-winds and other micro-crack-inducing damages in the field, we estimate the degradation due to micro-cracks is a further 1% per year. Therefore, the combined effects of normal wear-and-tear of the solar module, and micro-cracks from strong winds, lead to the power output shown in the grey graph, up to 11.8% reduction in total energy output over 25 years.

Figure 4: Comparisons of long term power outputs between HeatCap and reference modules.



In conclusion, the best ways to reduce micro-cracks in modules depend on the likely causes. For micro-cracks that occur during production or transport require different remedies. In order to provide an all-round protection to solar cells in the field, WINAICO's own HeatCap technology is the best solution, as it improves the overall reliability of solar cells by increasing the structural strength. Neglecting the effects of field micro-cracks can result in as much as 11.8% reduction in total energy output over the 25 year lifetime of solar modules.