HIGH-RELIABILITY AND LONG-DURABILITY DOUBLE-GLASS MODULE WITH CRYSTALLINE SILICON SOLAR CELLS WITH FIRE-SAFETY CLASS A CERTIFICATION

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ABSTRACT: Double-glass modules provide a heavy-duty solution for harsh environments with high temperature, high humidity or high UV conditions that usually impact the reliability of traditional solar modules with backsheet material. Double-glass modules have increased resistance to cell micro-cracking, potential induced degradation, module warping, degradation from UV rays, and sand abrasion, as well as alkali, acids or salt mist. In addition, because of less micro-cracks and less moisture ingress, double-glass modules present a much lower risk of so-called “snail track” generation. A double-glass module was designed to pass fire-safety class A certification and UL1500V system voltage certification. The double glass module design offers not only much higher reliability and longer durability but also significant Balance of System cost savings by eliminating the aluminum frame of conventional modules and frame-grounding requirements. The application of double-glass modules covers multiple markets including utility, residential and commercial.

Keywords: High-Reliability, Long-Durability, Double glass, fire-safety Class A, PID

1 INTRODUCTION

Due to the increasing demand for higher reliability, longer durability for PV modules and due to the increasing concerns about issues like UV degradation, delamination, Potential Induced Degradation (PID) or the so-called “snail tracks”, an extensive study of the root causes of failures have shown that backsheet materials are responsible for most of them. Among other factors, moisture ingress and water diffusion through the backsheet are partially responsible for PID, snail tracks, and delamination;

- UV exposure is responsible for backsheet degradation, leading to yellowing, increased brittleness, delamination and cracks;
- High thermal expansion coefficient of the backsheet is responsible for delamination and cracks;
- Backsheet can be seriously damaged by long-term exposure to sand blasting in desert environments.

Therefore, an extensive program was undertaken to design a highly reliable PV module. It appeared quickly that replacing the backsheet with a glass panel was the best alternative for remedying most of the reliability issues. The development efforts were focused on designing a low-weight PV module with a good resistance to mechanical loading. Technical problems such as manufacturing yield, extra weight and the lack of frame support were solved by selecting a double heat-strengthened glass structure with a thickness of 2.5mm (or 2mm) on both sides and a special edge sealing by silicone material. The mechanical strength of the structure was demonstrated by finite element numerical simulation of the stress in the glass panels under different conditions of attachment and loading.

2 DESIGN OF THE MODULE

The purpose of this work was to design a new concept of PV module featuring a significantly improved reliability compared to the conventional design without losing the advantages of traditional modules.

2.1 Consideration of reliability

A Double-Glass frameless structure was chosen to remedy most of the reliability issues in PV module design. The traditional backsheet materials of conventional solar modules was replaced with toughened (heat strengthened) 2.5 mm-thick glass. To reduce the weight of the module, the front glass thickness was also reduced to 2.5mm（Fig. 1）. After numerous finite element simulations of the mechanical stress of the module with several different attachment configurations and different types of mechanical loading, it was found that the aluminum frame could be eliminated without impacting the module mechanical strength. A silicone edge sealing was applied to protect the module from mechanical shocks (Fig. 2).

Fig. 1: Structure of double glass

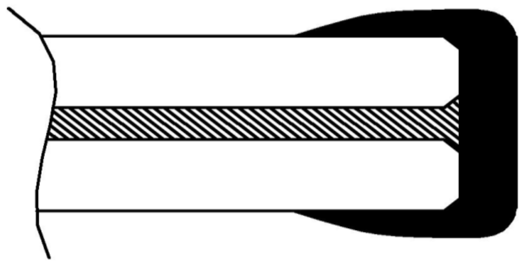

Fig. 2: Edge protection with silicone

2.2 Consideration of weight

Although double-glass PV modules have existed for years, they are usually much heavier (~50Kg) than conventional ones. By choosing heat strengthened glass panels on both sides, we have been able to use a thickness of 2.5mm and to demonstrate an excellent module resistance to all standard mechanical tests (up to 6700 Pa), even without a frame, and a weight of 24kg, only 25% heavier than a standard module.

2.3 Consideration of safety

For roof top PV systems operating with a system voltage as high as 600V or even 1500V, the resistance to fire is quite critical. Therefore it was decided to design the new module for the highest fire safety. While designing the double-glass module, it was also decided to increase the distance between the edge of the cell and the edge of the module, allowing for an increase of the maximum system voltage from 1000V to 1500V.

3 EXPERIMENTAL

To fully understand the reliability and durability performance of double glass module compared to standard module design with backsheet, a series of several different accelerated stress tests and characterization were conducted within the State Key Lab of PV Science and Technology (PVST) in Trina Solar. PV modules are rated for maximum power (Pmax) under standard test conditions (defined as 1,000 W/m^2 irradiance at 25℃ cell temperature) prior to and after different accelerated stress tests. Visual inspection is also performed according to IEC 61215 after stress conditions. A total of twelve conventional modules with backsheet and twelve double glass modules were selected to perform the fair comparison. To minimize the testing error, all accelerated stress testing were carried out under the same conditions, with the same operator, the same chamber and same metrology instruments. The double-glass modules and the conventional modules with back sheet were submitted to twice the requirements of IEC 61215 standard [2], i.e. 400 thermal cycles (-40℃ to +85℃), 2000 hours of damp heat (85℃, 85% R.H.) and 20 humidity-freeze cycles (+85C to -40C, 85% R.H.) after 50 thermal cycles.

Mechanical Load test: When PV modules are mounted in the field, they are exposed to mechanical stress due to wind and snow loads. To determine the ability of the module to withstand wind, snow, or ice loads, a rigid test base which enables the modules to be mounted with front side up or front side down was used. The test base enables the module to deflect freely during the load application. On the front side, a uniform load was applied gradually and was maintained for one hour. The same procedure was used to apply the mechanical load on the backside surface of the module. The mechanical load test was applied three times. The mechanical load was gradually increased from a minimum of 2400Pa as required by IEC61215 standard [2] up to 6700Pa.

A frameless double-glass module and a traditional PV module with a 3.2mm glass with an aluminum frame were both qualified to withstand heavy accumulations of snow and ice under a high pressure of 5400Pa up to 6700Pa.

System voltage durability test: In the field, PV modules are connected electrically in series until a maximum string voltage of 600 volt or 1,000 volt is achieved. National electrical codes in most countries dictate that the PV module frame must be electrically grounded. This grounding interconnection results in a potential difference (voltage) between the grounded frames and the cells in the PV modules, which may lead to a module degradation called Potential Induced Degradation (PID). With rising concerns about Potential Induced Degradation (PID) of PV modules [4-5], it was important to demonstrate the performance stability of new double-glass design under PID testing. It was assumed that a frameless module with a double-glass structure would offer a much better protection to PID than a traditional module with frame and backsheet. The first reason is that the absence of frame reduces the risk of high electrical potential between the cells and the water raining down on the module. The second reason is that the rear glass panel offers a much better protection against moisture ingress than backsheet and therefore a much better protection against degradation of the EVA encapsulant. A system voltage durability test was performed on two double glass module samples.

Fire safety class testing: PV systems operate with high string voltage, typically from 600V to1500V, the fire resistance performance is quite critical, especially for roof-top PV systems. When it is exposed to a source of fire originating from the building, modules with poor fire resistance will combust rapidly and help propagating the fire. To demonstrate the fire resistance performance of double glass modules, two double-glass samples for flame spreading test and one double-glass module for burning brand test were prepared and sent to 3rd party UL LLC, Northbrook, IL for certification according to UL 7903 Standard test methods for fire tests of roof coverings [3].

4 RESULTS AND DISCUSSION

4.1 Relative degradation in Maximum Power after thermal cycling test.

Compared to traditional modules with backsheet, modules with double glass are stronger and more durable, presenting less degradation due to thermal cycling stress. Results from the thermal cycling test up to 400 cycles show about 35% to 43% less degradation with double-glass modules than with traditional modules with backsheet (Fig. 3).

4.2 Relative degradation in Maximum Power after damp heat Stress

Compared to traditional modules with backsheet, double-glass modules have almost zero-water vapor transport through the glass, which results in 33~38% less degradation after damp heat stress test up to 2000 hours (Fig. 4) and there is not occurrence of delamination at all.

4.3 Relative degradation in Maximum Power after Humidity-Freeze Stress

Compared to traditional modules with backsheet, the almost-zero water vapor absorption of the double-glass modules is responsible for the excellent performance under Humidity Freeze reliability tests, which were carried out up to 20 cycles. The test results show about 30% to 58% less degradation than with traditional backsheet modules after humidity-freeze stress test (Fig. 5).

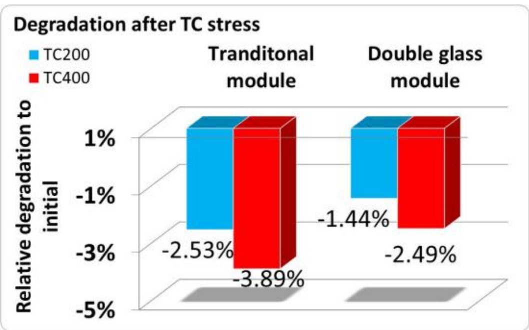

Fig. 3: Less degradation after TC

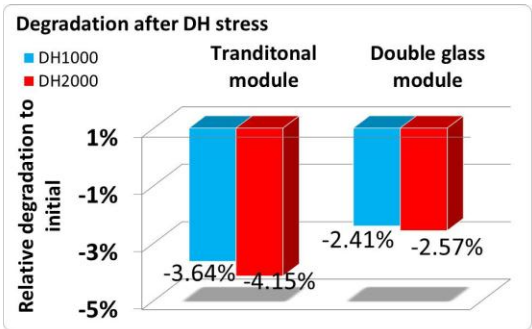

Fig. 4: Less degradation after DH

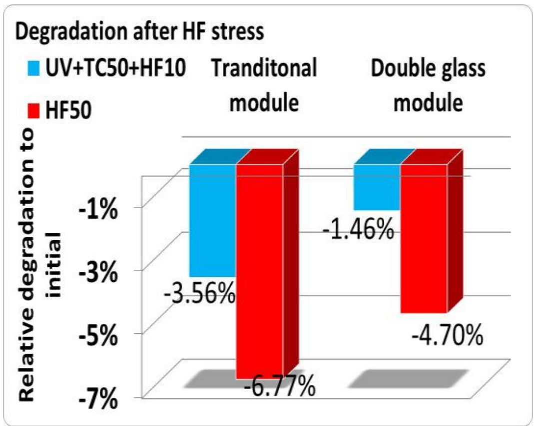

Fig. 5: Less degradation after HF

4.4 Mechanical loading performance

Because of the strength of the toughened double-glass structure, double-glass modules exhibit good mechanical loading performance even without aluminum frame (Fig. 6). They have the same level of mechanical loading performance and can pass 5400Pa mechanical loading test. From the EL (electroluminescence) picture after mechanical test, some micro-crack can be seen on traditional modules but no micro-crack found on double-glass module instead (Fig.7).

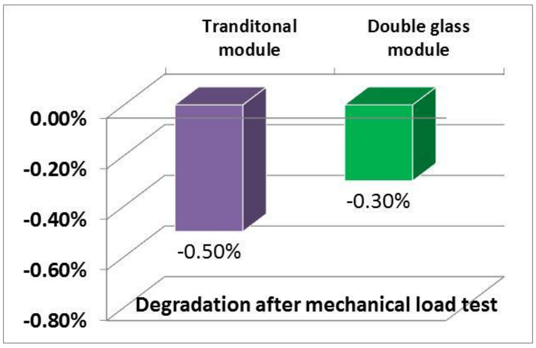

Fig. 6: Less degradation after mechanical load test

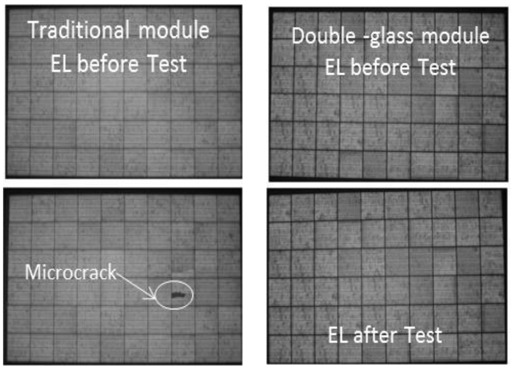

Fig. 7 EL picture of Traditional module and double-glass module before and after mechanical test

Simulation result also shows that the deformation of double-glass module is much more uniform than traditional module with backsheet (Fig.8) even under much higher pressure up to 6700pa,Which means the double-glass solar module will have much less micro-crack in case of shock, vibration or drop in the transport processes

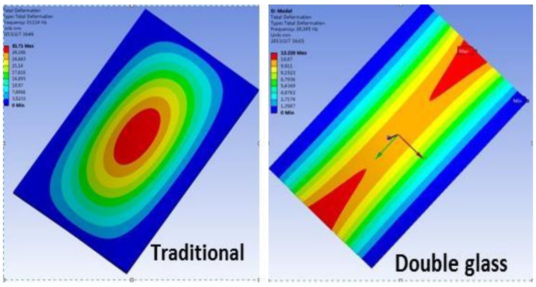

Fig.8 Deformation for Traditional modulesand double glass module

4.5 Potential Induced Degradation (PID)

Higher leakage currents can be caused by water vapor entering the solar panel causing the encapsulation material becoming more conductive [5], which is one of the factors involved in PID. Double glass modules have superior moisture barrier properties and are expected to have a much better resistance to PID.

Four Double-glass modules were subjected to a PID test under different conditions (-1000V, 65℃ and 85℃, 85% R.H.) for 96 hours. The average observed power degradation was -2.4% and -3% respectively, with normal cells which were not particularly fabricated with a special anti-PID technology (Fig. 9). It was also certified by 3rd party laboratory TUV SUD to the test conditions of 192 hours under 1000V DC negative system bias voltage and with a temperature of 85 ℃ and 85% R.H.

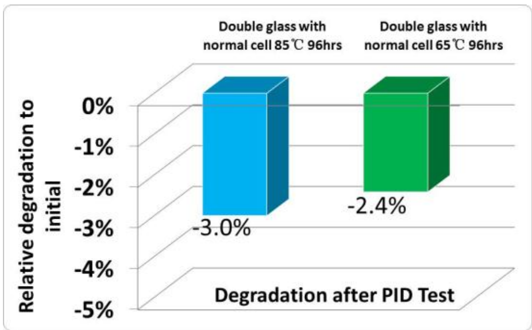

Fig. 9: Degradation after PID test

4.6 Fire resistance performance

It was demonstrated during extensive fire testing that the double-glass module offers a high degree of fire protection, and reached Class-A certification according to the criteria of UL790 [3]. Traditional backsheet polymers typically degrade and burn at temperatures between 200 ℃ and 350 ℃, unlike glass panels which do not burn but would slowly deform or crack at temperature over 1000 ℃. Test results show that double-glass module is effectively very resistant against severe fire exposures test including spread-of-flame and burning-brand tests. Under exposure of a strong burning fire, double-glass modules present a high degree of resistance to ignition, do not propagate fire to the roof deck or other building material, do not slip from their mounting position, and are not expected to produce any flying burning debris. (Fig. 10, 11)

Fig. 10: Traditional module after fire burning test

Fig. 11: Double glass after fire burning test

5 CONCLUSIONS

Double-glass modules have shown excellent performance under different stress conditions such as damp heat, thermal cycling, humidity-freeze, mechanical loading (static and dynamic), and potential induced degradation (PID). In addition, double-glass modules have passed the UL790 fire class A test, and UL1500V system test. The double-glass module design offers not only a much higher reliability and longer durability but also significant cost savings in Balance of System (BoS) by eliminating the grounding requirements and a significant reduction of LCOE due to the extension of the module life and reduction of the degradation rate. The applications of double-glass modules are large, including utility, residential and commercial applications.

6 REFERENCES

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