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STRESS TESTING AND MATERIAL SELECTION FOR A NON-GLASS CRYSTALLINE SILICON MODULE

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Thomas G. Hood and Dr. Sicco Westra
Giga Solar FPC, Inc. – Portola Valley, CA

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Abstract

There are benefits from reducing the weight of today's crystalline silicon module. Lighter weight modules can help to reduce costs associated with transportation, installation, and balance of systems (BOS). Reduction in module weight also provides opportunity for practical use of larger modules with lower BOS costs. Thin film flexible PV has historically been the technology of choice for lightweight applications. Unfortunately, thin film flexible PV has become increasingly uncompetitive in price and performance, and thus, scarcely available. The glass and aluminum frame constitute 85-90% of a traditional module's weight, and therefore, any significant weight reduction requires their replacement. However, glass and aluminum are inexpensive and durable, which makes finding a replacement difficult. The combination of high-efficiency, low-cost crystalline silicon cells with a lightweight, rigid, and low-cost substrate structure is a meaningful next step in the evolution of solar PV module construction. Two main challenges in accomplishing this design are cost and durability. This poster summarizes the results of durability testing of a 5-layer composite core sandwich that could provide a high stiffness, high strength, and low-cost substrate for crystalline silicon cells. The generic design of this lightweight substrate composite is shown in Figure 1. Three 170Wp Giga Solar modules built for rooftop exposure testing are shown in Figure 2.

Module Design

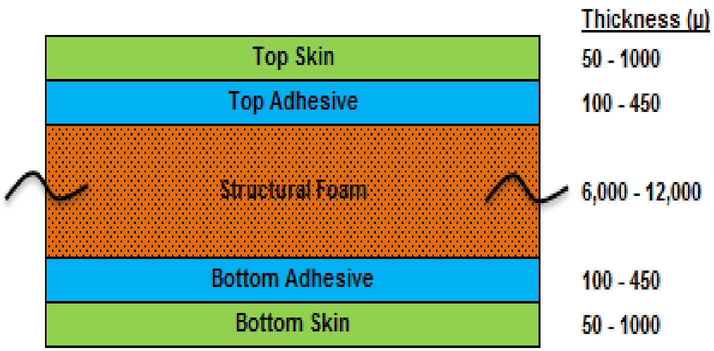

Figure 1 - Composite Cross-Section

Figure 2 – Three 170Wp Roof Panels
5 kg (11lbs) each

Composite Layer Contributions:

1. Skins – Carry both tensile and compressive stresses when the composite is under load
2. Adhesives – Bond the skins to the foam core, transferring stress across the interface; requires high shear strength
3. Foam – Supports the skins and maintains a constant distance between them, prevents buckling and requires high shear strength

Materials Evaluated:

1. Skins - PET, Aluminum, and glass fiber/thermoplastic
2. Adhesives – EVA and Silicone
3. Foam - PET, PES, and proprietary High Performance (HP)

Testing

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Giga Solar chose two tests from the IEC 61215 standard that are highly challenging for a non-glass/frame module: thermal cycling and damp heat. A third test was performed to investigate the effects of cycling load and deformation on the electrical integrity of this composite module.

Thermal Cycling (Shock)

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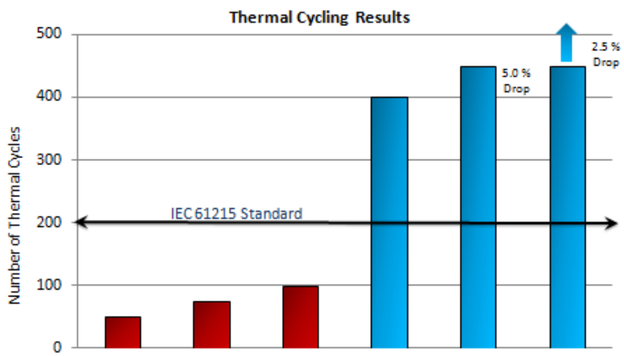
<u>Thermal Cycling</u> – IEC 61215 requires the module to be thermally cycled between -40°C and +85°C for 200 cycles with less than a 5% power drop. The challenge for a non-glass module is to find a material set that can perform over this temperature range and has a low coefficient of thermal expansion (CTE) to avoid interconnect fatigue and failure. The test was performed on a 1 x 2 cell sample at the rate of 50 cycles per day. Results are shown in Figure 3 to the right.



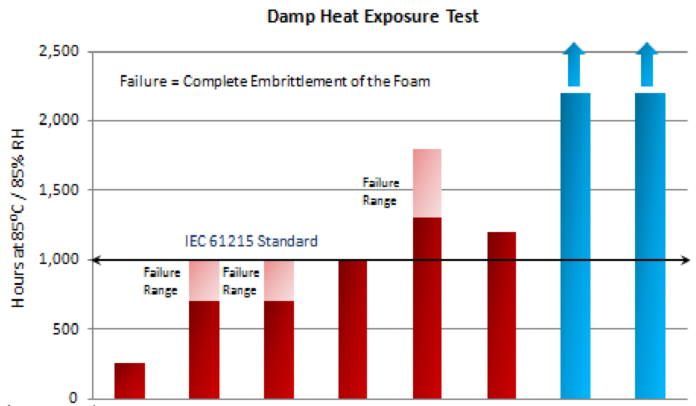
Foam	PET	PET	PET	HP	HP	HP
Skins	PET	Aluminum	PET/Al/PET	CFRTP-1	CFRTP-2	CFRTP-3
Adhesive	EVA	Silicone	EVA	EVA	EVA	EVA

<u>Observations from Thermal Shock (TS)</u>

1. Skins with a low CTE and good mechanical properties improve TS performance.
2. Softer, low temperature encapsulant did not improve TS performance.
3. Secondary effects may result from the foam selection – material, density and thickness.
4. It is possible for a non-glass, rigid module to exceed 400 thermal cycles with less than 5% drop in Pmax.

Damp Heat Test

<u>Damp Heat</u> – This IEC test exposes the module to 85°C and 85% RH for 1000 hours, continuously. Testing was done on the composite structure only. The retention of mechanical properties and adhesion were evaluated. Because PET is known to exhibit hydrolysis under these conditions, protecting the PET foam was a major focus in this test. A number of low permeability skins combined with edge sealing were investigated along with different structural foam chemistries. Results are shown in Figure 4 to the right.



Foam	PET	PET	PET	PET	PET	PES	HP	HP
Skins	PET	PET/Al/PET	PET/Al/PET	Al	PVF/Al/PET	PET	CFRTP-1	PET
Edge	None	Al - Acrylic	Al - Butyl	Al - Butyl	Al - Butyl	None	None	None
Adhesion	Poor - 100% Cohesive	Poor - 100% Cohesive	Poor - 100% Cohesive	Poor - 100% Cohesive	Poor - 100% Cohesive	Poor - 100% Adhesive	Very Good - 50% Cohesive	Excellent – PET Skin Fails

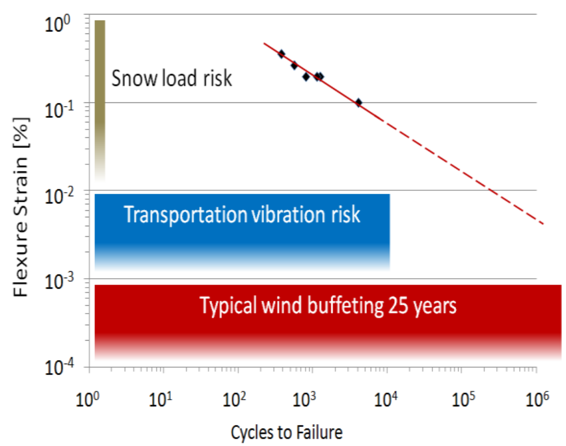
<u>Observations from Damp Heat</u>

1. Unprotected PET foam deteriorates rapidly at 85/85 conditions ~ 250 hours.
2. Low MVTR skins and edge tape combined assist greatly to extend PET foam composites to 1,000 hours, and more, but poor adhesion becomes a problem.
3. PES is a hydrolytically-stable polymer foam that performs well, but adhesion is poor with EVA.
4. HP is the only hydrolytically-stable foam that was shown to withstand several thousand hours of 85/85 without foam embrittlement or adhesion loss of the EVA and skins.

Dynamic Load

<u>Dynamic Load</u> – This test was done to simulate the mechanical stress on cell connecting ribbons caused by vibrations created during transportation and wind exposure, along with dead loads created by snow. Samples were mounted in an Instron Dynamic Fatigue tester and fixed at the short ends. A cyclic mechanical pressure was applied to the center of the sample to create a predetermined displacement. The number of cycles to reach electrical failure was recorded for different levels of displacement (i.e. strain). This experiment was done at room temperature.

Figure 5 – Dynamic Load Test



<u>Observations from Dynamic Load</u>

1. The composite material maintained its mechanical integrity over a wide range of dynamic loads
2. Cycles to failure were many times higher than what would be typically expected for stresses caused by transportation, wind buffeting or snow load.
3. It is possible to design a crystalline-silicon, non-glass module with sufficient mechanical strength to avoid mechanically-induced ribbon fatigue.

Conclusions

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The IEC 61215 test standard for flat plate PV modules presents a number of very difficult requirements for a non-glass/frame module. Thermo-mechanical stability over a wide range of temperature and at high humidity demand careful selection of the materials. The data reported here suggest that potential does exist for an all-polymer rigid PV module design that can meet the more demanding industry tests used to validate module reliability. Large sample evaluation over the full IEC 61215 regimen is now required to establish the next level of confidence that this concept is commercially feasible.