From Rigid to Flexible: The Real Challenge of CIGS Module R&D

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Introduction

Solarion develops and manufactures solar modules in pilot stage, based on CIGS thin-film solar cells on ultra thin plastic substrate employing a proprietary ion beam-assisted manufacturing process, that deposits a thin layer of copper indium gallium diselenide (CIGS) at reduced deposition temperatures. The cell materials Molybdenum, CIGS, the buffer layer and ZnO front contact are manufactured in a continuous roll-to-roll process to the 25 micron plastic film substrate. A thin contact grid of silver conductive paste is printed on top of the cells. These will be converted to single cells and sorted to several power classes. These cells can be encapsulated in rigid glass-glass modules as well as in flexible encapsulation systems.

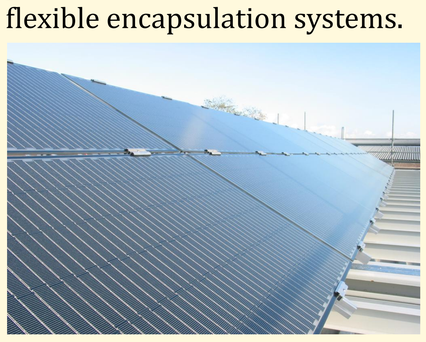

Fig. 1: View of our modules

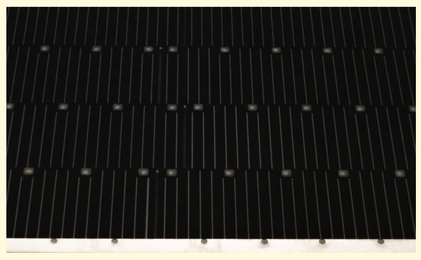

Fig. 2: Front side view of interconnected cells

Since it is very difficult to predict the lifetime of solar modules using accelerated weathering methods for a defined and limited time, it is necessary to extend the tests beyond the advised limits. This approach leads to a deeper understanding of the development of single defects in the module system and their spreading in the module leading to complete failure.

Experimental Setup

A variety of accelerated weathering tests with scheduled measurements of the performance are carried out for the qualification of flexible or rigid solar modules. Our methods of internal module qualification meet international standards (IEC61646/61730) and go even further.
The modules have to withstand for example more than 400 temperature cycles from -40 to 85 °C as well as damp-heat testing for more than 2000 hours to pass our internal qualification. Also combined and sequential UV/moisture tests are applied to the modules.
Different module configurations with rigid glass barriers and several flexible barrier films have been investigated.
The modules encapsulated with different commercial and lab-stage barrier films were exposed to damp-heat (85% relative humidity, 85°C) for more than 2000 hours . Performance testing and electro-luminescence imaging were carried out in 600 hour intervals for rigid modules and in 100 hour intervals for flexible modules.
A standard AAA pulsed solar simulator according to IEC60904-9 was used for electrical characterization of the samples.
Electroluminescence imaging was performed with a 4 megapixel IR CCD-camera for failure identification .

Durability of Solarion's CIGS on Plastic: Solar Cells in a Glass-Glass Encapsulation System

Weathering tests under damp-heat exposure were performed at rigid glass-glass modules for more than 8000 hours.
In previous studies by Sample et. al. [1] modules using similar CIS technology showed at least 30% power loss relative to the initial value under 4000 hours of damp-heat exposure.
Significantly better results could be achieved in internal tests with our own rigid glass-glass module encapsulation technology. A light power loss of 3% could be observed after the first 1500 hours attributed to a light glass corrosion and water stains.
After intensive cleaning the module showed an increased performance due to the better transmission.
The module performance still remained above 96% of the initial value after 8000 hours in damp-heat testing. No signs of delamination could be found.
Additionally, the wet leakage test was done according to IEC 61646. The isolation resistance was three times higher than required even after such a long time of weathering and completely uncritical. CIS and CdTe modules tested by Sample et. al. [1] failed in this category between 3000 and 4000 hours damp-heat exposure.

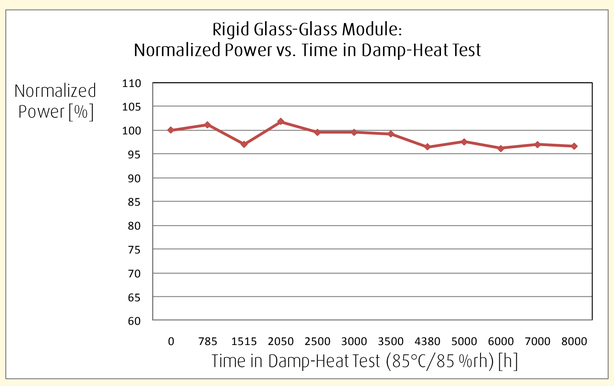

Fig. 3: Normalized maximum power peak (MPP) for rigid modules after damp-heat weathering

Durability of Solarion's CIGS on Plastic: Solar Cells in a Flexible Encapsulation System

Smaller samples with three cells per module were used for the investigation of the flexible barrier systems. These samples were exposed to damp heat for more than 2000 hours. Different encapsulation systems were used including industrial and lab-stage products.
Typically, flexible barriers show a wide range of results in their damp-heat behavior. Aside from complete failures due to moisture ingress after 250 hours of damp-heat exposure very stable barrier materials could be identified.
One lab-stage barrier has already been tested successfully for 4000 hours in damp-heat. The modules show a power loss of only 5% compared to its initial value.

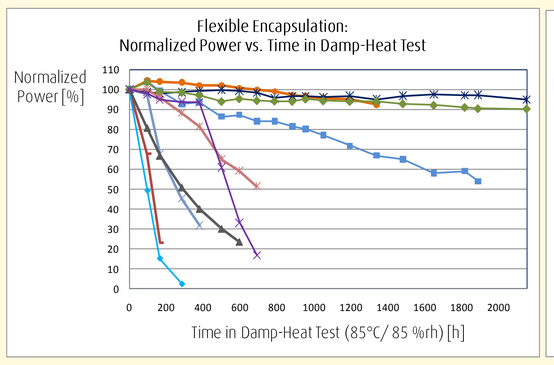

Fig. 4: Normalized maximum power for modules with different flexible barrier materials after damp-heat weathering

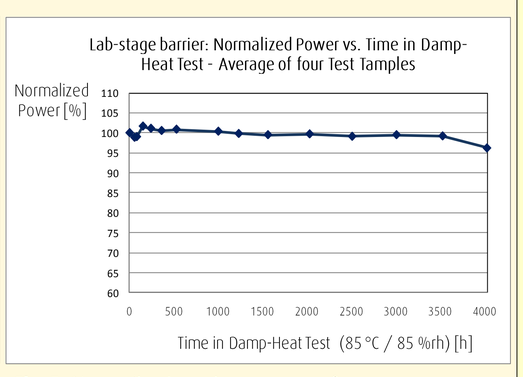

Fig. 5: Normalized maximum power for a module built with a flexible lab-stage barrier after damp-heat exposure of 4000 hours

Conclusion and Outlook

Solarion's rigid glass-glass modules internally tested show very stable behavior. The module performance remains above 95% of their initial power after 8000 hours of damp-heat exposure at 85°C and 85% relative humidity (Fig. 3). These results of the accelerated weathering tests exceed the IEC 61646 standard requirements for thin-film photovoltaic modules for eight times and demonstrate that long-term moisture stability for rigid modules can be achieved.
Also modules with different flexible barrier materials were tested. It was demonstrated that flexible module encapsulation and damp-heat stability for at least 2000 hours do not exclude each other. These results show the feasibility of reliable damp-heat stability for flexible CIGS modules.
Further studies regarding the reliability of barrier systems, including temperature cycling, dry UV and combined UV/damp-heat exposure are already performed or still ongoing and show promising results. Additionally, future works for investigating the mechanical behavior before and after accelerated weathering of flexible CIGS modules will complete our studies.

Acknowlegements

The work was partially funded by the German Federal Government under contract No.03SF0389C.

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[1] Tony Sample, Artur Skoczek, Michael Field, Michael Köhl, Dieter Geyer, Werner Hermann: *Accelerated Ageing of seven different thin-film Modules by sequential Exposure to Damp-Heat or Damp heat with either additional applied Voltage or Ultraviolet Light*; Proceedings of 24th European Photovoltaic Solar Energy Conference, September 2009, Hamburg, Germany
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