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Accelerated Testing of Performance of Thin Film Module

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Abstract

There is an interest in identifying localised effects when investigating durability of devices. The combination of tests might also have an influence on test results. This is investigated for single junction amorphous silicon modules. The modules were put under accelerated testing including thermal cycling, light soaking and annealing test. I-V measurement and LBIC system as characterisation tools are used to investigate the possible degradation occurring in the devices both before and after certain stages of the test. Results have shown that there is a difference between modules which have experienced light soaking before being exposed to thermal cycling, indicating that the initial light soaking resulted in a UV activation of the material, which then changed the durability of the lamination.

1 Introduction

PV modules are normally designed to be used outdoors under prolonged exposure and be able to withstand the changing environmental conditions. Several manufacturers guarantee that at the end of 10 or 20 years in operation, the modules will still generate the power within certain range from their nominal power. Evidence from field experiences has demonstrated that PV modules for power generation installed outdoors for more than two decades are suffering from losses of performance and energy production [1]. Today, accelerated tests [2] should ensure that the modules have 25 years of reliable operation. To what extent devices change their behaviour depends on the PV technology, processing quality, encapsulation, operation and geographical location where the devices are installed. These losses involve, for example, the physical damage of cell and module, the delaminating or corrosion of material or the degradation of electrical properties which occur during the course of operation [3].

In order to minimise the chances of module failure or losses influenced by the long

term outdoor exposure, several test methods have been employed by manufacturers or standard organisations. Since real time scale testing needs an enormous effort and investment, the most common method is accelerated testing. It is where the PV modules are put under extreme conditions in a shorter time scale. The climatic or environmental chamber for example can provide tests such as thermal-cycling, annealing or damp heat test where temperature and humidity can be fully controlled.

This testing method has normally been applied to individual PV components and c-Si PV modules in the past. This paper focuses on a thin film PV technology to identify the effects of running only selected parts of the cycle and investigates the effects on the overall durability. This is because firstly, materials such as glass, TCO or EVA when fabricated into PV module may interact with each other and change their properties which could cause the module to degrade. Secondly, because large area deposition and monolithic interconnection are the main structural differences of thin film device to its c-Si counterpart, the impact may not always be uniform throughout the module. In this case, it can cause non-uniform degradation and one could use spatially resolved measurements to investigate the causes of the failure, to improve durability of the devices as a whole.

In this paper, thin film PV modules are subjected to several simulated test conditions in order to study the influence of such conditions on their material properties and performance. The modules are experiencing thermal cycling and annealing tests in an environmental chamber and light-soaking test by simulated light sources following the IEC Standard 61646 [2]. Both electrical and optical properties are investigated on local and global scale. Possible causes of damage or degradation could also be identified. This information in the end is useful to improve the quality and processing of PV modules, minimise the possible losses due to the prolonged exposure and correctly predict module lifetime.

2 Experimental Setup

Test samples are four single junction amorphous silicon modules, three of which have an area of 30 cm x 30 cm and the other of 92 cm x 30 cm. They were divided into two groups where each of the group is subjected to different test sequences. The first test sequence starts with light-soaking, followed by annealing and then thermal cycling test. The second test is thermal cycling test only. The test diagram is shown in Figure 1.

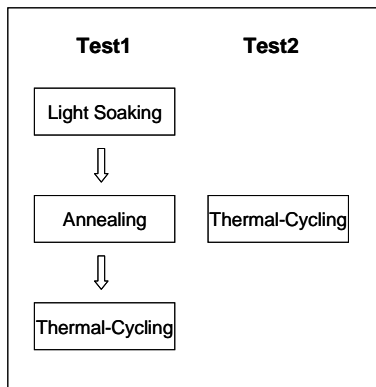


Figure 1 Diagram of test sequence, Test 1 and Test 2

The thermal cycling and annealing tests are conducted in an environmental chamber produced by Sanyo-Weiss-Gallenkamp as shown in Figure 2. The former test specifically is by varying the temperature between -40°C to 85°C as shown by the graph in Figure 3 while the latter is set at constant temperature of 85°C . For the light soaking test, the modules were put under the simulated sunlight of intensity approximately $800\text{-}1000\text{ W/m}^2$ for 24 hour and then in total of 140 hours.



Figure 2 The environmental chamber used in the experiment

After certain test cycles, a number of characterisation methods including module I-V curve measurement by solar simulator, current mapping by LBIC system [4, 5] are used to examine in detail the damage or degradation that may be induced during the tests. The I-V measurement provides the overview of module performance with key PV parameters while the LBIC generates the spatial measurement of current signal map.

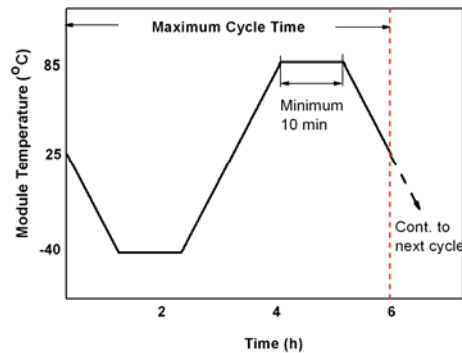


Figure 3 Thermal cycling test programme

3 Results and Analysis

For test1, module 1 and 5 were first measured by simulator and LBIC system to obtain the initial condition. Their initial LBIC measurements are shown in Figure 4 and Figure 6(a) respectively. The scan results indicate the performance variation between the modules and among cells in each module represented by colour differences, with redder marks indicating greater current signal. This suggests that although these modules are identical in physical structure and were made from the same production processes or even made in the same batch, there is always a discrepancy found between them.

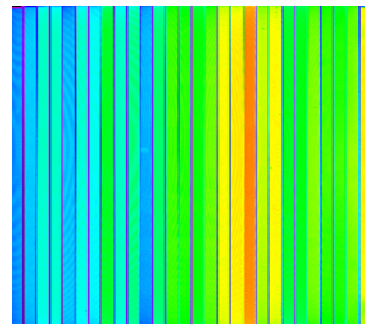


Figure 4 Initial LBIC measurement of module1

They were then put under stress, starting with light soaking test to separate the light-induced degradation effect from other degradation. Similarly, after that the modules

have been annealed to separate the annealing effects before went into thermal cycling test.

The measurement shows that after the first 24 hours of light soaking test the modules degrade dramatically with the reduction of Pmax from its initial of module 1 and 5 by 18.5% and 13.4% respectively. After that, with further light soaking, the modules show less degradation rate as shown in Figure 5. With a total of 140 hours light soaking test, inclusive of the first 24 hours, the Pmax of module 1 and 5 decrease up to 23% and 19%. However, after 20 hours of the annealing test, Pmax recover back with the gains of 5-6% for both modules.

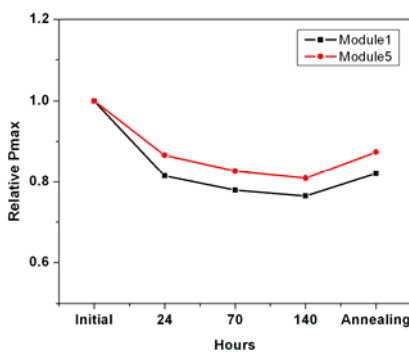


Figure 5 Maximum power (Pmax) of module 1 and 5, each stage after light soaking and annealing, relative to their initial

After 100 cycles of thermal cycling test the LBIC measurements were made. The result is then compared with that of initial stage. LBIC scan of module 5 is shown in Figure 6 a) initial, b) after thermal cycling.

The scan shows that most of the difference is accounted for by light induced degradation effect where the measured signal for nearly all of the cells has decreased (cannot see from the picture). The signal strength among cells is relatively the same as indicated by colour. One should also keep in mind that the measurement result is from a low number of modules, in this case a single device. The devices are plotted using the same scale. Spatially, there is not a huge change but some isolated cells are showing a reduced signal. While the results are not quantitative, this is an indication that some cells seem to be more affected than others. Interestingly the cells at the edge, where instead of decreasing, their signals are increasing. This however requires further study to truly understand the effect.

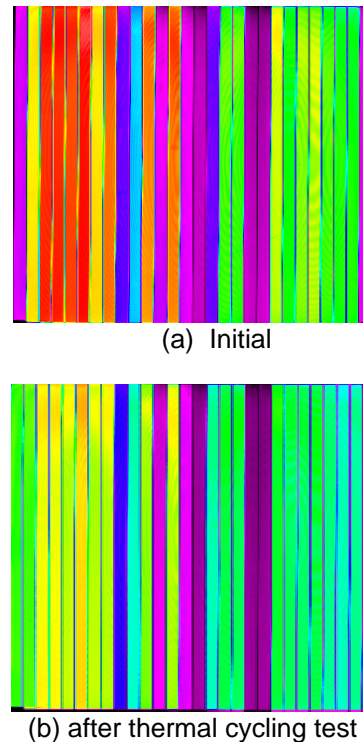


Figure 6 LBIC measurement of module 5, (a) initial, (b) after thermal cycling test.

For test 2, module 2 and 3 were put under thermal cycling test only. Results have shown that there is a difference between two tests. For test one where modules initially experience light soaking shows a drop in efficiency after the thermal cycling process while that of test two is marginally increase as shown in Figure 7. This would indicate that the initial light soaking resulted in a UV activation of the material, which then changed the durability of the lamination. Similar to test1, the finding from LBIC measurements shows no evidence of physical damage or major degradation.

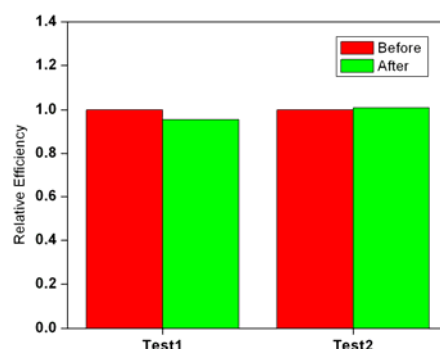


Figure 7 Normalised average module efficiency before and after the thermal cycling process of modules in test 1 and 2

4 Conclusions

The accelerated testing – thermal cycling, annealing and light soaking test - has been performed on single junction amorphous silicon modules. IV measurement and LBIC system were used as a characterisation tools for key PV electrical parameters and spatial measurements. Little sign of obvious damage or physical degradation after cycles of thermal straining has been detected by LBIC measurement, with indications that the cells at the sides are more affected than the cells within the modules. Longer term accelerated testing would need to be performed to be able to clearly see the physical damage and then performance degradation.

Acknowledgements

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