PROGRESS MADE WITH BACK-CONTACT MODULES USING CONDUCTIVE ADHESIVE INTERCONNECTION TECHNOLOGY

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ABSTRACT: A description is given of the development and testing of a module concept using back-contacted cells with an interconnection foil and conductive adhesive. The adherence properties of the adhesive were evaluated. Single cell modules using PUM cells were made and tested for durability in climate chamber tests. Four-cell modules were made with EWT cells. The configuration of the contacts to these cells results in a more severe loading of the conductive adhesive. The modules were also subjected to climate chamber tests. Using the knowledge gained in these experiments, full-size 36 cell modules were successfully made. The best performing module was installed for outdoor testing. The experiments showed that it is possible to construct a reliable module using back-contacted cells using an interconnection foil and conductive adhesive. Further automation of the manufacturing process will increase the reproducibility and reliability of the modules, and reduce the cost.
Keywords: Reliability, Conductive Adhesive, PV Module

1. INTRODUCTION

Increasing cell efficiencies and the use of thin and large solar cells are the main trends in reducing the costs of PV. In addition, high manufacturing yield requires easy module assembly. A method that has been proposed to achieve these goals is the use of back-contact cells in combination with an interconnection foil and conductive adhesive [1]. In this concept, current from the cells is not transported through ribbons or tabs, but through an interconnection foil. A conductive adhesive is used to establish the connection between the foil and the cells. The adhesive is designed to cure during lamination of the module. The adhesive is more elastic than solder and has a lower processing temperature, so will result in a lower stress at the connection with the foil. This will allow the use of thinner and larger cells. This paper discusses the reliability testing of the ECN back-contact module concept. Our aim is to show that conductive adhesives in combination with back-contact cells and interconnection foils can result in reliable modules.

2. APPROACH

From previous research [2] and additional tests the best performing conductive adhesive that was compatible with the lamination process was chosen. The mechanical properties of the adhesive were tested before and after accelerated aging tests. Single-cell, 4-cell and 36-cell back-contact modules were manufactured and subjected to several aging tests in climate chambers and in the field.

3. ADHERENCE PROPERTIES OF THE ADHESIVE

Butt-joint samples were used to measure the tensile strength of the conductive adhesive. The samples used were stainless steel rods with a diameter of 3 mm. The test surfaces of the rods were modified by attaching a piece of metallisation foil or silver metallised silicon wafer to the test end of the rod. This resulted in a test specimen with a surface representative of the condition in which the adhesive is employed. Five samples per surface type were tested with the adhesive applied and cure according to the standard procedures. Another test series was aged for 1000 hours at a temperature of 120°C. A final series was subjected to a damp-heat test at 85°C/85 %RH. The results, in Figure 1, show that aging seems to be beneficial for the tensile strength. This can be attributed to post-curing of the conductive adhesive. The increase in tensile strength in the damp-heat test is less than for thermal aging alone. This may indicate that humidity has a detrimental affect on the tensile strength, although the lower temperature of this test will reduce the degree of post-curing seen by this series. It can be concluded that the tensile strength of the conductive adhesive is not negatively influenced by temperature or by a combination of temperature and humidity, making it suitable for manufacture of modules that will be subjected to these conditions during testing and service life.

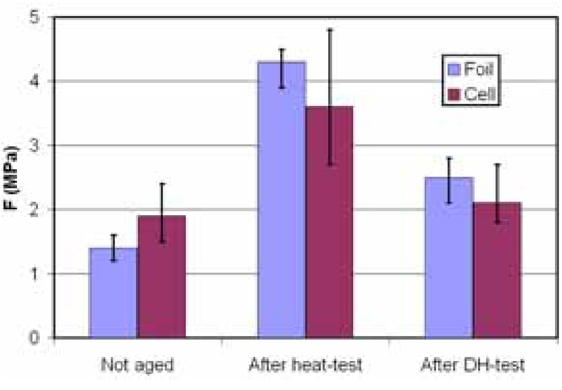

Figure 1: Tensile strength results for as-processed butt-joint samples, samples after a heat treatment and after a damp-heat test, either with an interconnection foil interface or with solar cell silver metallisation.

4. SINGLE-CELL MODULES

Twelve single-cell modules were made with the selected conductive adhesive. Eleven of them were divided between three aging tests, namely damp heat (85°C/ 85% RH), thermal cycle with an imposed current of 6.5 A (see Figure 2) and thermal shock (both -40/+85°C). The remaining module was used for metallographic inspection in cross–section (see Figure 3).

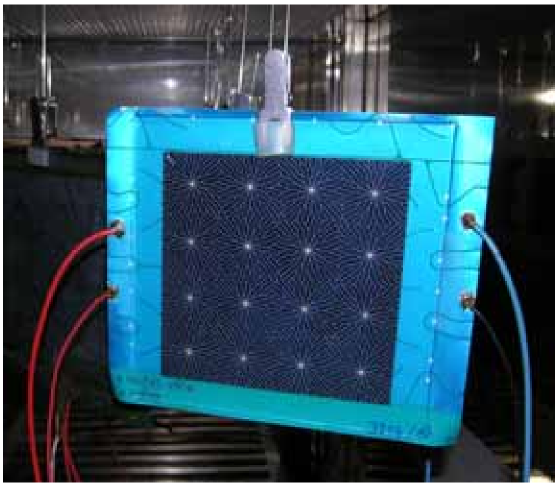

Figure 2: Single-cell module in a climate chamber before the test. The connected wires were for measurements in the solar simulator and for power supply in the thermal cycle test. The blue colour of the interconnection foil comes from an isolation coating.

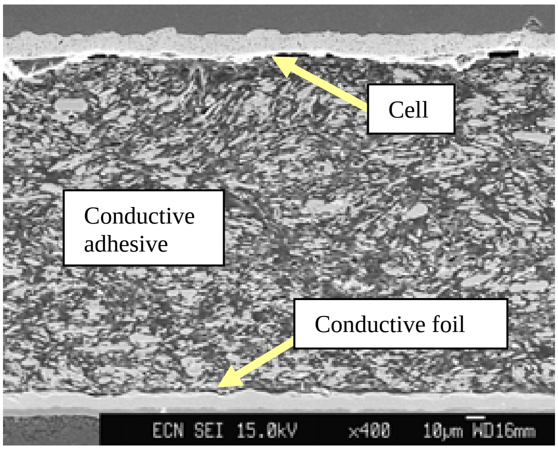

Figure 3: Cross-section of an interconnection. The solar cell with silver metallisation pad is visible at the top. The conductive foil is at the bottom. The silver particle distribution in the conductive adhesive is homogeneous and the adherence to both interfaces is good.

All samples passed the IEC61215 specification with a maximum of 5% power loss after 1000 hours damp-heat and 200 cycles of thermal cycling (see Figure 4). The thermal shock test was stopped at 1000 cycles and the power loss was 2 to 7%.

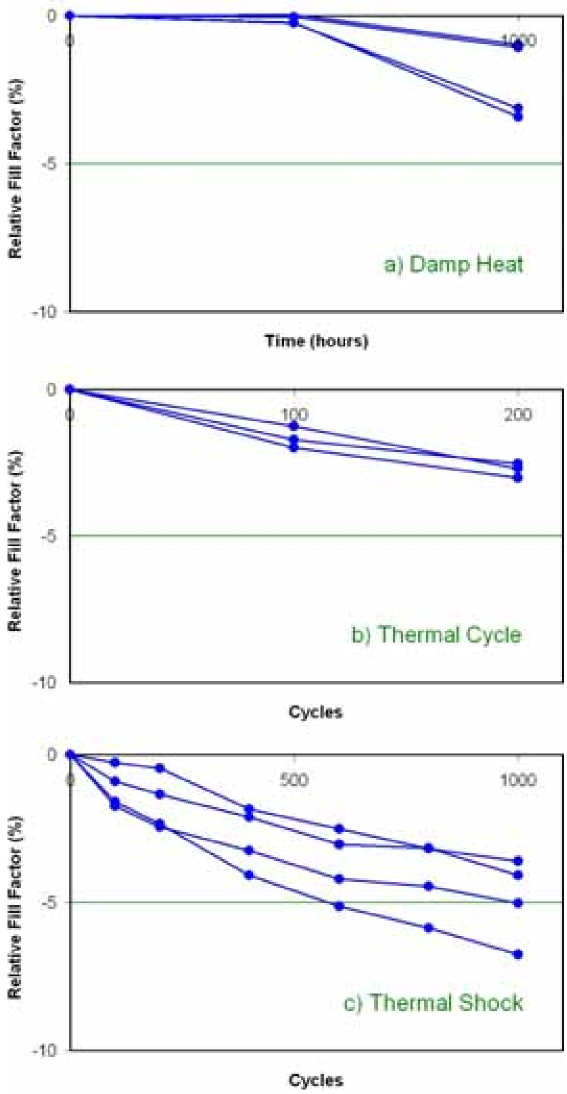

Figure 4: The development of fill factor for single cell modules made with a conductive adhesive and interconnection foil during a) damp heat testing, b) thermal cycling at 6.5 A and c) thermal shock testing.

5. FOUR-CELL MODULES

Up scaling towards full-size modules goes in several phases of development. We consider manufacturing and testing of four-cells modules to be a logical next step . Therefore, four-cells modules were made with EWT back contact cells. This was a more severe test of the concept because the cells have interconnection points only at six points as opposed to the 31 interconnection points of the PUM cell. The interconnection points of the EWT cells used are concentrated along the edges of the cell (see Figure 5). This will increase the stress on each interconnection point and is expected to increase the chance of failure of the module during climate chamber testing.

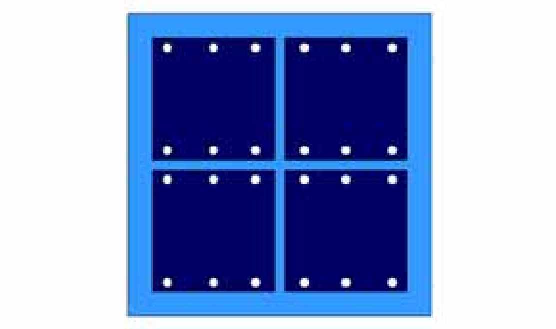

Figure 5: Layout of the EWT cells. The dark blue areas are the four cells, the light blue is the interconnection foil and the white points represent the cell contacts.

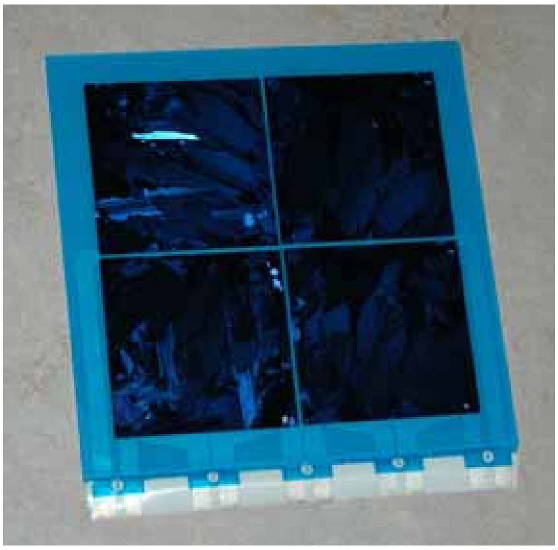

Figure 6: Four-cell module with EWT cells. The specially designed back sheet made it possible to flash test the complete module and each cell individually.

Several modules were manufactured successfully (see Figure 6) and five of them were tested in a combination of climate chamber tests. The test sequence started with 200 cycles of thermal shock. This had no significant effect on the modules. The testing continued with 1000 hours of damp-heat exposed to the same modules. Some degradation was observed. Finally, the modules were subjected to 50 cycles of thermal cycling and 10 cycles of humidity-freeze. Of the five modules tested, module C (Figure 7) showed a large drop in performance while in module D some contact points of one cell were found to be broken. Due to the severity of the test sequence and because of the high risk cell interconnect configuration of the EWT cells, it was concluded that the chances of constructing reliable full-size modules using conductive adhesive interconnections are reasonable.

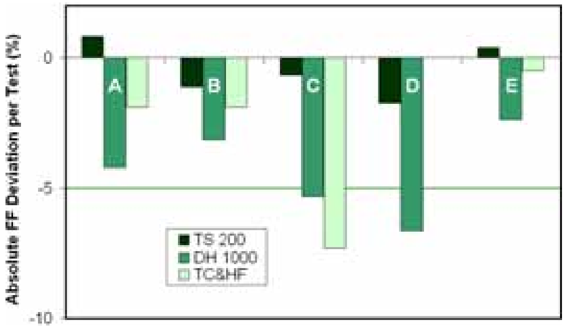

Figure 7: The absolute deviation in fill factor per test for the five four-cell EWT modules. Each module went through a combination of thermal shock, damp heat, thermal cycling and humidity freeze. All modules survived the first three tests. Modules C and D failed during thermal cycling and humidity freeze after thermal shock and damp-heat testing.

6. FULL-SIZE MODULES

Five full-size (4 x 9) modules were made with 150x150 mm^2 PUM cells using conductive adhesives and interconnection foil. The best performing module, made with PUM solar cells with an average fill-factor of 75.4% in the sun simulator, had a record-high fill factor of 74.9% in the flash test. It must be emphasised that this result was obtained with standard window glass, which was used to make post test analysis possible.

Figure 8: Full size 36-cell module during the outdoor test in Petten.

The best performing module has been monitored in an outdoor test in Petten, starting mid April 2007 (see Figure 9). The results after four months are promising as all electrical parameters remained stable. The test will continue until significant degradation is observed.

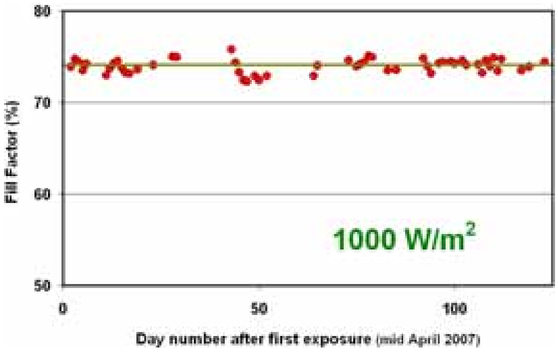

Figure 9: The fill factor during outdoor testing of the best performing module remained stable at about 74%. The selected measurements were binned at an irradiance range of 975 to 1025 W/m^2. The module temperature varied from 25 to 35°C.

The obtained results show that module manufacture using back-contact cells with conductive adhesive and an interconnection foil gives a reliable full-size module. The use of MWT cells with open rear side, the so called ASPIRe cells [3], will make it possible to manufacture >16% efficiency modules with this concept.

Further improvements to the concept will be provided by the installation of a prototype back-contact cell module manufacturing machine at ECN. This equipment will allow the automation of a number of the manufacturing steps so increasing the reproducibility and reliability of the modules.

7. CONCLUSION

We have shown that it is possible to obtain reliable back-contact modules with conductive adhesives and a conductive foil as interconnection technology. Single-cell and four-cell modules using back-contact solar cells successfully passed climatic chamber testing where they were exposed to thermal shock, damp-heat, thermal cycling and humidity-freeze durability tests. Full-size 36-cells modules were manufactured. The best module had a fill-factor of 74.9% and 15.1% encapsulated cell efficiency. The intermediate results of the outdoor test show that no degradation is observed at all.

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