TAPE INTERCONNECTION FOR SILICON SOLAR CELLS WITH EXTENDED LONG-TERM STABILITY

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ABSTRACT: The purpose of this work is to reduce production cost for conventional photovoltaic modules by reducing the amount of silver used in the grid on the photovoltaic cell and simplify the method of interconnection of individual PV cells. A novel method of applying bus bars and interconnecting individual cells into a module is proposed. The new method have the possibility to reduces the amount of silver by 25%. Furthermore, the interconnection of individual cells to a module is simplified, thus making the production less costly and more robust. Finally, soldering can be completed without the use of lead and at a lower temperature (150-160°C) which enables the use of cells featuring advanced temperature sensitive architecture like HIT cells.

It is very important to ensure a long lifetime for all PV modules. For the proposed new interconnection method we believe that the most important tests to ensure a long lifetime are the UV-exposure test and the thermal cycling test. To ensure that the proposed interconnection tape do not discolor during the PV module´s lifetime this work will therefor test for extended UV exposure of 100kWh/m². This work will also expose the modules for extended thermal cycle test of up to 600 cycles. Because of the lower process temperature with this novel method the modules should be more robust to thermal cycles. A cross-section analysis with SEM of the interconnection between the tape and the grid fingers will also be conducted and shown in this work. Finally, electro luminescent measurements of the tested modules will be disclosed.

Keywords: Long term stability; Energy conversion; Silicon; silver; module production; cost reduction

1 INTRODUCTION

The purpose of this work is to reduce production cost for conventional photovoltaic modules by reducing the amount of silver used in the grid on the photovoltaic cell and simplify the method of interconnection of individual PV cells. One of the contributing cost factors for photovoltaic modules is the silver used in the grid on the PV cells. The grid consists of closely spaced narrow fingers and three to five wide bus bars perpendicular to the fingers. A novel method of applying busbars and interconnecting individual cells into a module is proposed. The new method holds the possibility to reduces the amount of silver by 25%. Furthermore, the interconnection of individual cells to a module is simplified and the process temperature is decreased significantly, from 240 to 160 degrees C, thus making the production less costly and more robust. All 60 cells in one PV module can be connected in a single step in the lamination process. Finally, soldering can be completed without the use of lead and at a lower temperature which enables the use of new high efficiency cells with delicate p/n junctions. The decreased process temperature also decreases the risk for cracking during soldering and makes the module more robust to thermal changes.

2. EXPERIMENT

PV cells are electrically interconnected in series to form a PV module. In this work, we are testing mini modules consisting of 6 cells, two rows each with 3 cells for thermal cycling tests and 2 cells modules for extended UV-test and electro luminescent measurements. These modules were produced with the proposed novel interconnection method and are tested for extended thermal cycling tests according to IEC 61215. We will disclose the test results and discuss it in detail to describe the difference between this low temperature interconnection and normal soldering when it comes to robustness to thermal cycles.

2.1 The proposed method for module production

The proposed tape method, enables a simplification of the production process and a reduction of cost of material. The tape act as a carrier for tabbing ribbons. In the production process, the tape with tabbing wires is placed on the top glass and the first EVA sheet. Tape with tabbing wires for a complete row or a complete module are laid out. After this a row (or rows) of cells is placed on the tape with tabbing wire. A row of cells is now placed on the previously placed tabbing wires. The active side, the topside, of the cell is here contacting the tabbing wire on the tape. The process continuous with a second layer of tape with tabbing wires which are placed on the back side of the cells. After this a second EVA sheet is placed on the cells and tabbing wires. This is followed by a back sheet. The module is finalized in the laminator step. When the increased temperature and high pressure on the tape and cells form a solid interconnection between cells. A schematic of the building of modules with the tape method is shown in figure 2.
The tape with tabbing wires is designed in such a way that an interconnection in series between cells is obtained in the lamination step, see figure 2.

By using the tape, the two steps, Stringing and lamination is merged into one step. The production process and production equipment is simplified and the required factory area is reduced. Also, the amount of silver can be reduced.

In the soldering method used today the cells are heated to of about 240 ^{0}C to solder the tabbing wires to the busbars. The temperature raise takes a few seconds and this fast increase from room temperature to 240 ^{0}C adds a risk of cracking of the thin cells. The soldering with the tape method is gentle and the risk of cracked cells is reduced because the soldering takes place in the lamination in which the increase from room temperature to 160 ^{0}C takes of about 10 minutes. Here it shall be noted that there is a trend towards using thinner cells which are sensitive to temperature gradients.

2.2 Description of tape with tabbing wire

The tape with tabbing wire is applied on both sides of the cell. The tabbing wires are cut and interrupted in such a manner that the individual cells are interconnected in series in the lamination process. A single string of tabbing wires on a tape is shown in figure 1. However, the tabbing can also be carried out by integrating the tape onto the EVA sheets. This is shown in figure 1.1.

Figure 1. Single string of tape. and. EVA sheet prepared with tape

3. DISCUSSION

The main reason for having the silver busbar on the PV cell in the traditional way of building modules is to increase strength in the bond between the cell and the tabbing wire. The high strength in the bond is needed because the row of 10 cells soldered together is moved from the soldering station and placed on top of the EVA sheet and top glass. Also, note that a turning of the row is needed. This strength is not needed when using the tape method. Because in the tape method, the cells are directly placed on the EVA sheet and top glass and the interconnection of cells is formed in the lamination process in which all the parts of a module are laminated into one unit. In this way, the process temperature for connecting the PV cells does not have to be above 160 degree C. This means that the Delta T, from the highest temperature the PV module experience during its lifetime to the lowest for the thermal cycling test or in real life out in the sun, is decreased dramatically. By approximately 80 degrees C (240C -160C). Finally, this gives a longer lifetime for the PV module and a lower price for the electricity it will produce during its lifetime.

4. RESULTS

The thermal cycling test was carried out at RISE - Research Institutes of Sweden and the UV- and cross-section analysis at Fraunhofer ISE.

Thermal cycling 600 cycles

The test was carried out by RISE according to the IEC 61215 standard. The thermal cycling test showed very small degradation even after 600 cycles. We tested 3 modules and the worst result was 2,3% and the best was only 1,1% degradation of maximum power after 600 cycles. See figure 4.1 below.

Tabell 2. Resultat initialt

Objekt	I_{sc} [A]	I_{mp} [A]	V_{oc} [V]	V_{mp} [V]	P_{mp} [W]	FF [%]	Cell eff, [%]	Module eff, [%]
160329 #01	8,74	8,12	3,81	2,96	24,06	72,22	16,48	11,88
160329 #02	8,76	8,19	3,81	3,05	24,95	74,80	17,09	12,32
160329 #03	8,70	8,10	3,81	2,96	24,01	72,35	16,44	11,85

Tabell 5. Resultat 600 cykler

Objekt	I_{sc} [A]	I_{mp} [A]	V_{oc} [V]	V_{mp} [V]	P_{mp} [W]	FF [%]	Cell eff, [%]	Module eff, [%]
160329 #01	8,72	8,09	3,80	2,94	23,79 **(-1,1%)**	71,84	16,30	11,74
160329 #02	8,74	8,13	3,80	3,00	24,37 **(-2,3%)**	73,45	16,70	12,03
160329 #03	8,73	8,00	3,80	2,93	23,44 **(-2,3%)**	70,78	16,06	11,57

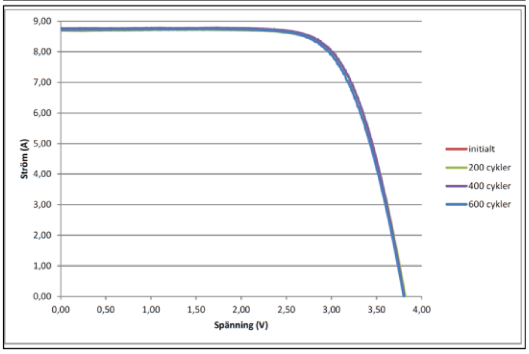


Figure 4.1 IV measurements before and after 600 cycles of thermal cycling -40 to + 85 C.

Extended UV test 100 kWh / m² with electroluminescence (EL) characterization

In figure 4.2 below the EL pictures before and after at 8 A is shown. No cell cracks or local interconnection issues visible, the dark areas at the lower and upper cell show contact finger interruptions which are a metallization issue. There is now visible degradation in EL after the 100 kWh of UV exposure.

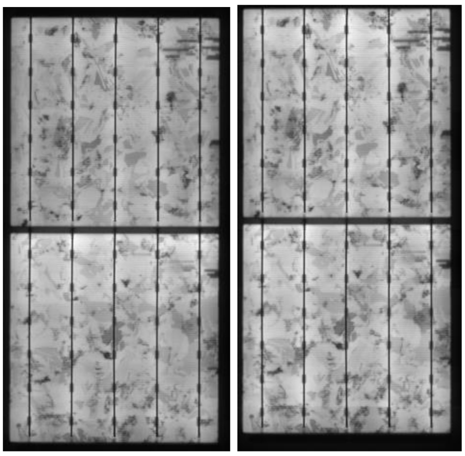


Figure 4.2 Electroluminescent pictures before UV expositor 100 kWh/m² to the left and after the test to the right.

Cross-section analysis with SEM

To determine the contact between the tape and the cell we carried out cross section analysis with the help from Fraunhofer ISE. The conclusion from this analysis was that maybe the process temperature was a little low. The tested module was manufactured at 150° C. In the picture 4.3 below you can see cavities at the metallization edges and there is almost now intermetallic phase growth at the boundary layer between solder and metallization.

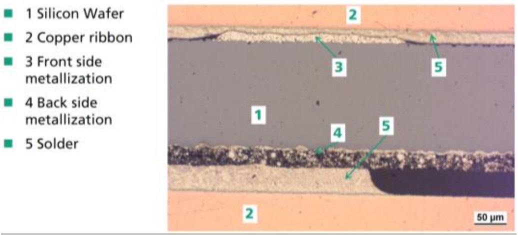
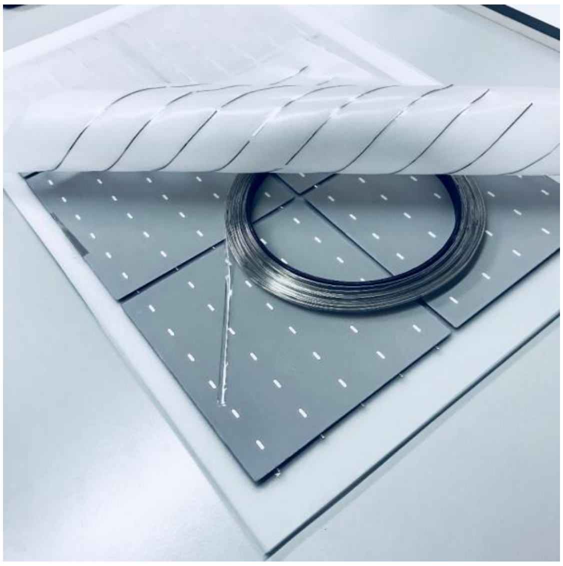


Figure 4.3 SEM cross-section analysis.

5. CONCLUSION

A novel tape method, of applying bus bars and interconnecting individual cells into modules reduces the amount of silver in the module. Also, the tape method enables simplification of the production process. The TC 600 and the 100kWh UV test was successful but the cross-section analysis indicated that the process temperature could be increased from the tested 150° C to maybe 160° C for a better connection.

6. TAPE PICTURES



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