HOW CONDUCTIVE ADHESIVES CONTRIBUTE TO HETERO-JUNCTION MODULE TECHNOLOGY

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ABSTRACT

Silicon hetero-junction solar cell technology has the potential to obtain high efficiencies with thin wafers. This requires low stress and low-temperature interconnection of individual cells at module level. Also, hetero-junction cells are known to be susceptible to moisture ingress inside the module. Single cell modules have been manufactured using conductive adhesive as interconnection and using moisture blocking back sheet to protect the cells. The series resistance losses due to conductive adhesives are very low while the optical losses in the module were negligible. The modules have been exposed to climate chamber tests (damp-heat and thermal cycling) according to the IEC 61215 ed. 2 standard. Modules made with moisture blocking back-sheets showed that the modules did survive 1500 hours (1.5 times IEC) of damp heat and over 340 thermal cycles with less than 5% reduction in power output. The industrial feasibility of this module technology was demonstrated by manufacturing 72-cell modules, using cells obtained from an industrial party.

1. INTRODUCTION

Reliability tests were conducted on 125 x 125 mm² pseudo-square mono crystalline silicon hetero-junction cells [1] manufactured at INES-CEA with a cell thickness of 170 µm and cell efficiencies up to 19%. At ECN a novel module design was developed to achieve long-term stable modules for these solar cells. The module design focused on low stress interconnects based on conductive adhesive, and moisture blocking at back-sheet level for the hetero-junction modules.

2. CELL TO MODULE RESISTANCE

The transmission line model (TLM) was used to determine the specific contact resistance between the interconnection materials. In particular to determine the specific resistance (ρc) of the contact area between a silver plated copper tab and a low-temperature silver paste bus-bar that is adhered with dots of conductive adhesive (CA). The result of the TLM measurements will present a value for the sum of the contact resistance between the conductive adhesive and the tab (ρc,CA-Tab), the conductive adhesive and the silver paste (ρc,CA-Ag).

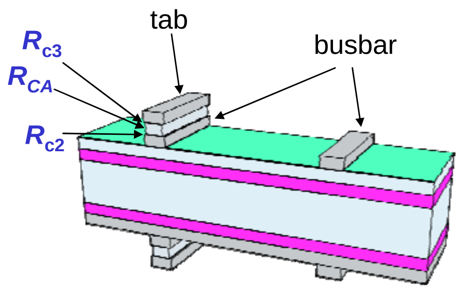

Fig.1 Cross section of cell and interconnection

Contact resistance values can be obtained from TLM measurements. The contact resistances from bus-bar to conductive adhesive (R_{c2}) and from conductive adhesive to the tab (R_{c3} see Fig. 1) have not been separately measured. The total contact resistance of R_{c2} + R_{c3} was measured to be equal to 0,11 mΩ per cell. The bulk resistivity of the conductive adhesive (R_{CA}) is in the order of $5 \bullet 10^{-4}$ Ωm which contributes roughly 0.15 mΩ per cell. The series resistance losses in the tabs, with a bulk resistivity of $2 \bullet 10^{-8}$ Ωm, dominate to total series resistance. Tabs contribute to the series resistance with 2.33 mΩ per cell. These results show that the series resistance of the tab is 15 times higher then the series resistance of the conductive adhesive (bulk and contact resistance included). Therefore, the interconnect losses as a result of applying conductive adhesives are of minor importance.

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3. DAMP-HEAT AND THERMAL CYCLE TEST

Reliability tests have been conducted on single cell modules by performing damp heat and thermal cycle according to IEC61215 ed. 2 and beyond. Damp heat testing was extended to 1500 hours and thermal cycle testing was stopped after 345 cycles. Previous experiments indicated that the hetero- junction cells are prone to humidity. Preventing degradation was anticipated by adding a protection layer to the back-sheet. Damp-heat testing showed that the module with added humidity protection easily passed 1000 hours of damp-heat testing. Some of these modules survived up to 1500 hours of damp-heat exposure. The modules showed a power loss of 2.3%, 4.0%, 5.6% and respectively 2 modules with 6 % of original power. The observed degradation of the modules can be attributed to the loss in short-circuit current. The fill factor losses are less significant. This indicates that the interconnection with conductive adhesives is more stable than the cell itself. If cell degradation could be prevented, the modules would only show limited degradation. The observed cell degradation is likely to be caused by moisture ingress through the edges of the module. Sufficient edge sealing should thus prevent the cell degradation observed here. Humidity as a cause of cell degradation was evident as one module comprised a standard TPT back sheet for reference purposes. This module showed severe cell degradation during the first 500 hours of damp heat testing.

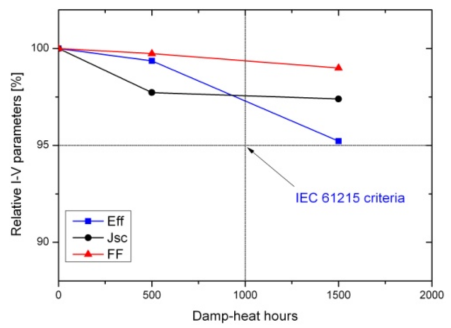

Fig. 2 All modules have been made with a humidity blocking back-sheet. Note that the efficiency, Jsc and FF are an average of the 5 modules mentioned. Eff denotes module efficiency as a function of DH exposure. Jsc the short circuit current and FF the fill factor as a function of DH exposure.

The purpose of thermal cycling is to determine the ability of the module to withstand thermo mechanical stresses caused by repeated changes of temperature.

A total of 5 single cell modules were subjected to temperature cycling. A total of 345 thermal cycles did not lead to a significant degradation of the modules and the results are fair within the 5% power limit dictated by the IEC61215 protocol.

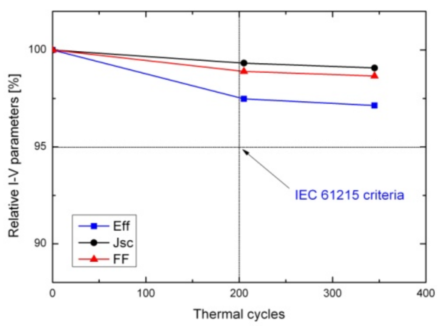

Fig. 3 Results of climatic chamber testing of 5 modules containing hetero- junction cells. Degradation was normalized to 100% of original output power.

A module with 72 industrially supplied hetero-junction cells was constructed. Assembly of the modules was done with the aid of the ECN tabber- stringer installation. From a manufacturing point of view the assembling went well as the structural integrity of the cells has been of high quality. Breakage of the cells did not occur during interconnection and fast introduction of elevated curing temperatures. The measured performance was compared against simulated expectations. The module performance is in close agreement to simulated results.

4. CONCLUSIONS

Hetero-junction modules have been successfully manufactured using conductive adhesive as interconnect material. The series resistance losses due to the use of conductives does not have a significant impact on the module fill factor. The tab series resistance is dominating the interconnect losses. Series resistance losses in the tab are roughly 15 times higher then the contact resistance losses due to conductive adhesives. The stability of the interconnections also proved to be good for thermal cycling with a power loss of only 2.5% during extended testing. The loss in power output after damp heat reached the 5% limit according to IEC61215 after an extended test duration of 1.5 times IEC, i.e. 1500 hrs. Damp heat testing showed that the interconnection with conductive adhesives remains stable, but the cell itself can show degradation. Hetero-junction cells appear to be the most critical component with respect to moisture ingress. Standard TPT back sheet does not block moisture ingress sufficiently for module manufacturing when using these cells. Additional care must be taken with the edge sealing of the module to prevent moisture ingress. Large scale modules containing 72 cells were also manufactured showing our interconnection method to be industrially feasible.

ACKNOWLEDGEMENTS

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