Back Contact Module Technology

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Back contact modules manufactured with MWT cells comprise a higher efficiency than standard x-Si modules made with H-patten cells, due to low fill factor losses of only 0.8%. The cell-module concept is a truly integrated concept with a simplified manufacturing process. The modules show high stability in reliability testing, with only 1.9% loss in relative power after 2000 hours of testing in damp heat. IEC61215 and IEC61730 certificates have been obtained. The MWT modules also show higher outdoor performance due to lower series resistance. The material costs are dominated by the conductive back sheet and conductive adhesive. Potential routes for cost reduction are discussed in this paper. Large scale production is now starting to take off, with MWT production capacity to reach up to 1 GWp in 2012.

Introduction

PV module power output is determined by the cell efficiency and the optical- and resistance losses in the module. The yield of the module manufacturing process is determined by the amount of cell breakage occurring, particularly during the interconnection process. In order to reach significant cost reduction for solar modules, the efficiency of the module must be increased, the material cost reduced and the process yield increased.

ECN Solar has developed a novel process to manufacture solar modules, with a higher efficiency and with an interconnection process which has very low cell breakage. Furthermore, the module manufacturing process is also suitable for thin wafers, allowing for significant cost reduction. This module process is based on back contact MWT cells and a conductive back sheet foil, with a low temperature interconnection process which is combined with the lamination process. This integrated cell-and module architecture form an important technology development.

The concept and manufacturing process will be discussed, as well as reliability test results and analysis of failure mechanisms, which have served for further improvement in the module design to reach longer module lifetimes. Indeed, ECN has obtained IEC61215 and IEC61730 certificates for this technology and large scale market introduction is currently taking off. At the 3rd MWT workshop held in Freiburg, Germany, companies have stated to have a MWT production capacity nearing 1 GWp in 2012 (1).

The STC module power output compared to a standard reference module shows a higher module output for the back contact module. The outdoor performance of the back contact module was measured at the outdoor test facility at ECN. Results will be given of the current and power output as function of the irradiance of a back contact module, compared with a standard H-pattern module.

The module design and process also allow for future cost reductions and this roadmap will be discussed.

Module Design and Manufacturing

The advantage of back contact cells is not only a higher cell efficiency (2), but also the fact that different interconnection and module designs are possible. The fact that all contacts are on the rear side of the cell allows interconnection by tabs (3), or by placing the cells on a conductive back sheet with the interconnection pattern integrated into this foil (4,5). Electrical contact between the cells is established either by conductive adhesive or a solder (6). The adhesive approach allows simultaneous curing of the encapsulant and the adhesive during lamination and is hence a fully integrated approach. The module build-up is schematically shown in Fig. 1. The interconnection foil consists of a laminate of Tedlar-PET, with a conductive metal grid on top of the PET and an insulation layer on top of the Cu (except at the contact points).

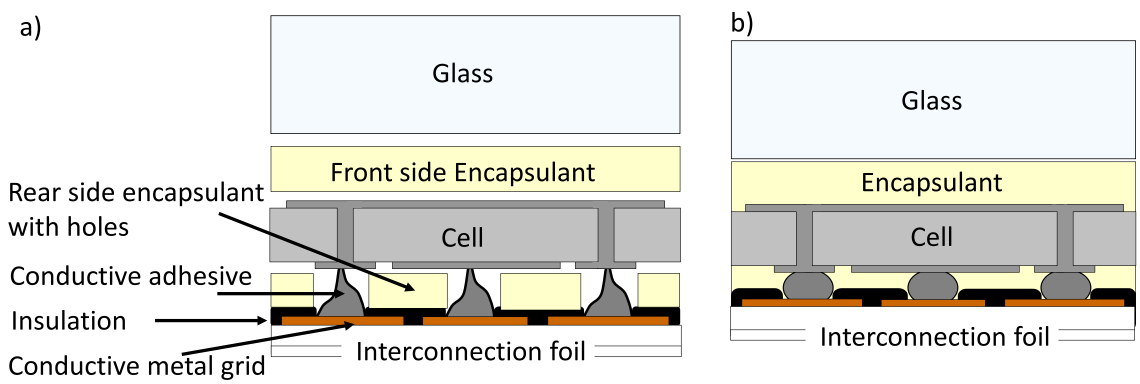

Figure 1. Schematic drawing of a) the build-up of an MWT back contact module with conductive backsheet foil and adhesive as interconnection and b) a cross section of such a module after lamination.

This module design also allows for a different manufacturing technique, as soldering on a tabber-stringer is no longer required. In this module manufacturing process, developed together with the Dutch company Eurotron (5), the module is made by 1) placement of the conductive foil, 2) stencil printing of the adhesive, 3) punching of holes in the rear side encpasulant sheet, 4) pick-and-place of the cells, 5) placement of the front side encapsulant sheet, 6) placement of the front glass plate, 7) flipping of the module (for glass side down placement on the laminator) and 8) lamination. The steps of this manufacturing process are compared to standard module manufacturing with tabber-stringing in Fig. 2.

a)

Manufacturing process H-pattern modules

1. Front side glass placement
2. Front side encapsulant placement
3. String manufactring in tabber-stringer
   Solder ~ 300°C
4. String inspection
   (Repair of broken cells)
5. String placement on front side glass/encapsulant
6. Placement and soldering of bussing between strings and bussing to junction box
7. Placement rear side encapsulant
8. Placement rear side foil
9. Lamination, 150C
10. Framing, sealing + junction box placement

b)

Manufacturing process MWT modules

1. Placement conductive back sheet foil
2. Printing conductive paste
3. Punching + placing rear side encapsulant
4. Cell pick and place
5. Placing front side encapsulant
6. Placing glass
7. Combining lamination and interconnection, 150C
8. Framing, sealing and juntion box placement

Figure 2. a) Steps in standard module manufacturing using tabber-stringing of cells. b) Steps in MWT back contact module manufacturing using conductive backsheet foil and conductive adhesive as interconnection.

This means the cells are only handled once by the pick-and-place robot, and the only heating step occurs during lamination at 150°C. This module manufacturing process thus allows handling of thinner and more fragile cells. Moreover, the process up to lamination is faster up to a factor of 4 and requires less personnel per Wp production, by a factor of 1,5.

Besides the advantages of reduced cell handling, lower temperature and faster processing, the draw back until now is the fact that two new materials are applied in this module, namely a conductive back sheet and conductive adhesive. These raise the issue of large scale availability, cost and reliability. In this paper, we will address these topics and show that reliability is proven, failure mechanism are understood, cost criteria can be met and large scale production is on-going.

Reliability results

Back contact modules made with two types of back sheet foil (2 different insulation coatings) and EVA encapsulant have been studied in thermal cycle test and in damp heat test, both according to IEC61215 ed. 2 test protocol. Thermal cycle has shown no significant degradation (7), up to 300 cycles a maximum degradation in relative power up to 3% was observed. Infra-red (IR) imaging showed no hot spots are present after 300 thermal cycles (7).

MWT back contact modules with the same materials have also been tested in damp heat, up to 2000 hrs at 85C and 85% relative humidity as shown in Fig. 3a. In this case, significant degradation can already occur after 1000 hrs of damp heat, and for both types of insulation coating, failure had been observed after 2000 hrs of damp heat testing. Compared with results of our previous study (7), we can conclude that significant failure occurs in damp heat testing, the exact time of failure is not constant and likely to depend on material batch variations.

In order to improve the reliability of this type of module, the failure mechanism needs to be known. Opening of the failed modules after damp heat has shown that it is the insulation coating which is delaminating from the Cu foil, see Fig. 3b. This results in local stress around the interconnection, leading to interconnect failure.

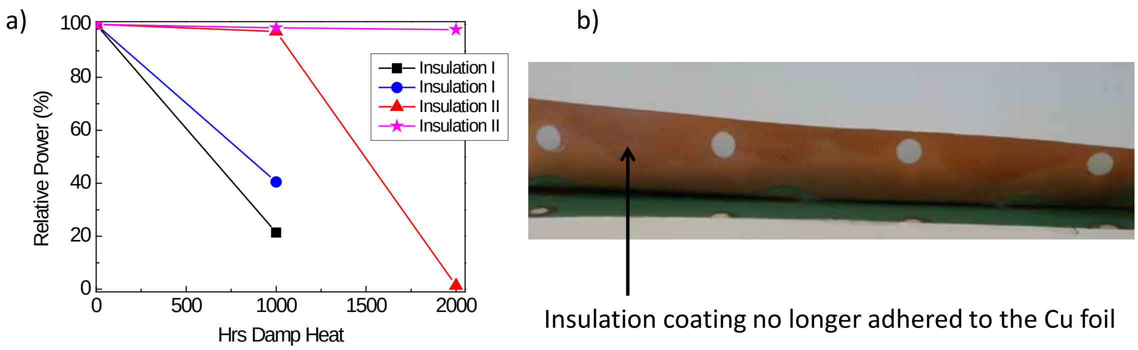

Figure 3. a) relative power of MWT back contact modules comprised of EVA and back sheet foil with insulation coating, as a function of damp heat exposure, up to 2000 hrs (2xIEC) b) photographic image of an MWT module opened after 2000 hrs of damp heat testing. The insulation coating is no longer attached to the Cu foil.

The cause of the delamination of the insulation coating is likely to be related to an interaction between the coating, the EVA encapsulant and moisture. To prove this, and to improve module reliability, two more sets of modules were built and tested. Modules with the same insulation coatings were made with a different encapsulant (thermoplastic) and modules using a conductive back sheet with no insulation coating were made with both EVA and the thermoplastic encapsulant. All modules show excellent stability in damp heat testing up to 2000 hr; the maximum observed relative power degradation at 2000 hrs is 1.9% as shown in Fig. 4.

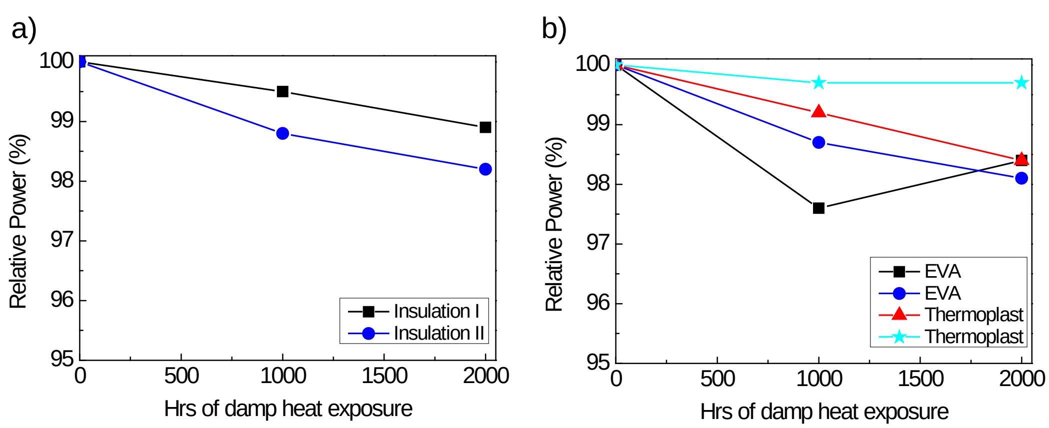

Figure 4. Relative power of MWT modules as a function of damp heat exposure. a) MWT back contact modules comprised of thermoplastic and back sheet foil with insulation coating b) MWT back contact modules comprised of either EVA or thermoplastic and back sheet foil without insulation coating.

Wet leakage tests were performed on these modulesafter damp heat tetsing, showing good insulating behavior, even for modules made using foil without insulation coating. ECN has recently obtained an IEC 61730 certificate for MWT back contact module technology, showing this concept is intrinsically safe.

Indoor and outdoor performance comparison

Back contact modules should result in higher module output due to lower fill factor losses (4,8). Indeed, MWT modules have been compared to similar H-pattern modules (8). This study shows that H-pattern modules with an output of 265 Wp compare to 273 Wp for the MWT module. This is due to the fill-factor loss, which is 3% for the H-pattern module and only 0.8% for the MWT module.

The outdoor performance of a 60 cells back contact and a 54 cells H-pattern module has been measured at a tilt of 30° during a period of 14 months at the outdoor test facility at ECN. In this facility, an IV curve is measured (measuring time: 1 second) every 10 minutes. From the IV curves the values for Isc and Pmpp were extracted. The irradiance is measured by an x-Si reference cell, placed in plane with the modules. The temperature of the modules is measured by a PT100 thermocouple as fixed at the back in the middle of each module. Using this temperature, the values for the Isc and Pmpp at 25°C were calculated by assuming temperature coefficients of 0.03% and -0.45%/°C for the current and power output, respectively.

In Figure 5 the temperature corrected short circuit current Isc25 is given as function of the irradiance. This figure clearly shows that the current is directly proportional with the irradiance and equal for both modules. For STC conditions, the Isc is 8.23A as comparable with the indoor flash measurement of the back contact module.

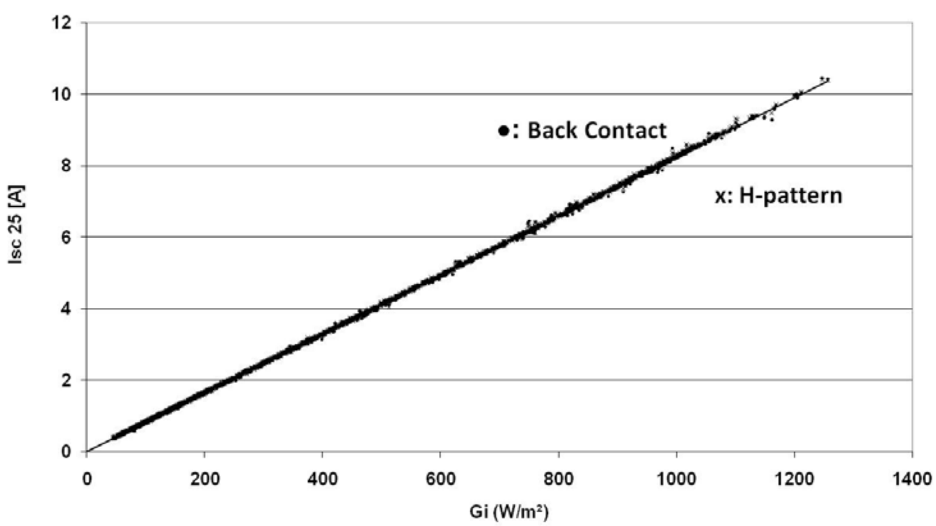

Figure 5. Temperature corrected short circuit current as function of the irradiance of the back contact and H-pattern module (June 2010).

In Figure 6 the same results are given for the temperature corrected power output. For a direct comparison between the modules, the power output is given per cell. The power output of the back contact module is directly proportional with the irradiance, showing the low series resistance of the back contact module. The power output calculated at STC conditions, is 227Wp, as comparable with the indoor flash measurement. For the H-pattern module the power output starts to deviate at higher irradiance due to the series losses being higher of H-pattern modules compared with back contact modules.

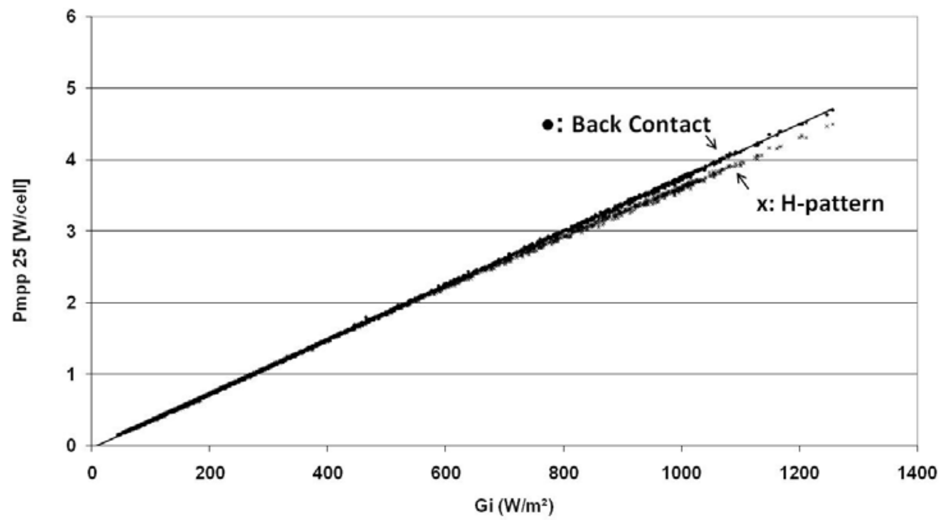

Figure 6. Temperature corrected maximum power output per cell as function of the irradiance of the back contact and H-pattern module (June 2010)

In Figure 7 the temperature corrected efficiency is given as function of the irradiance. For a fair comparison, the efficiency calculation is based on the aperture area of the modules. Due to the low series resistance of the back contact module, the efficiency is constant for higher irradiance. For the H-pattern module the efficiency decreases for higher irradiance. These results clearly show the benefit of the low series resistance of the back contact module concept of ECN.

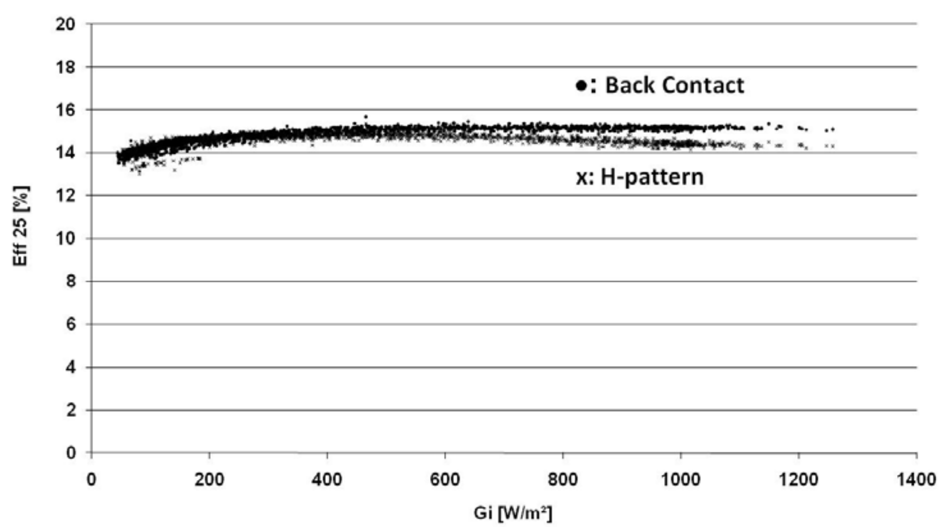

Figure 7. Temperature corrected efficiency (aperture area) as function of the irradiance of the back contact and H-pattern module (June 2010)

Roadmap for further cost reduction

The simplified manufacturing and higher efficiency result in lower module costs, but the conductive back sheet foil and conductive adhesive are two components which determine the overall price of the MWT modules. Hence, these are the main drivers in cost reduction. The back sheet foil as currently used is comprised of a laminate of Tedlar, PET and Cu foil. The Cu is etched and an insulation coating is printed on top of the Cu. Ag contacts are placed on the Cu for contact improvement.

Our reliability study has shown the insulation layer and Ag contacts are not necessary for well performing, reliable modules, resulting in a cost saving of 3 euro/m^2. Another significant cost driver will be finding a cheaper alternative to Cu and simplified processing. Firstly, thinner Cu can be applied (4,8), or alternatively Al can be applied instead of Cu, resulting in cost savings of 2 euro/m^2. Alternatives for Tedlar are also appearing on the market and can result in cost reductions of 2 euro/m^2. Several companies have indicated they can manufacture back sheet foil for the required break-even price of 12-15 €/m2 at the MWT workshop (1).

The interconnection of made by the conductive adhesive, which is silver based. At prices around 2000 euro/kg, the adhesive cost contribution to the module is 11 euro/m^2. Significant reduction can be achieved by using adhesives based on lower silver content (1).

The compatibility of the module manufacturing process with thinner cells will allow for further cost reductions.

Conclusions

ECN has successfully manufactured MWT back contact modules. Back contact modules manufactured with MWT cells comprise a higher efficiency than standard x-Si modules made with H-patten cells, due to low fill factor losses of only 0.8%. The cell-module concept is a truly integrated concept with a simplified manufacturing process. The modules show high stability in reliability testing, with only 1.9% loss in relative power after 2000 hours of testing in damp heat, and IEC61215 and IEC61730 certificates have been obtained. The MWT modules also show higher outdoor performance due to lower series resistance. Large scale production is now starting to take off, with MWT production capacity to reach up to 1 GWp in 2012. Large scale introduction requires low material costs as well. Material costs of MWT modules are dominated by the conductive back sheet foil and conductive adhesive. These can be reduced sufficiently to reach the break-even point with standard H-pattern modules.

Acknowledgments

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