REDUCING THE COST OF MWT MODULE TECHNOLOGY BASED ON CONDUCTIVE BACK-SHEET FOILS

I. J. Bennett, M. J. A. A. Goris and W. Eerenstein
ECN Solar Energy, P.O. Box 1, 1755 ZG Petten, The Netherlands
Phone: +31 88 515 44709, Fax: +31 88 515 8214, E-mail: bennett@ecn.nl

ABSTRACT: MWT cell and module technology has shown to result in modules with a higher power output than H-pattern modules and to be suitable for use with thin and fragile cells. In this work, the use of low-cost module materials and their effect on module performance and reliability has been assessed. These materials include a conductive back-sheet patterned by milling with no silver plating at the contacts on the foil and no isolation coating on the copper and a low-silver content conductive adhesive. The sensitivity of module performance for the anti-corrosion coating on the copper of the conductive back-sheet is measured, as is the reliability in climate chamber testing of mini-modules made with these materials. The results show that these low cost materials can be used to manufacture module with good performance and reliability. Options are given for further cost reduction.
Keywords: MWT, module technology

1 INTRODUCTION

ECN has developed an integrated module technology for MWT cells using a conductive back-sheet foil. The modules have shown to reduce cell to module losses when compared with H-pattern modules, resulting in 5% higher power output. MWT modules have proven to be reliable in climate chamber testing and IEC certification has been achieved [1-4]. Manufacturing equipment is available with has a very high level of automation. The first industrial production has recently started [5].

Large scale industrial implementation of this module technology requires availability of the materials at low cost, in particular the conductive back-sheet and the conductive adhesive. The cost of the back-sheet is partially related to the processing used to pattern the foil. The cost of the conductive adhesive is dominated by the silver content.

In this work, conductive back-sheet foils patterned by milling and conductive adhesives with a silver content of 10% were used to manufacture mini-modules. The modules were characterised and the reliability tested in climate chambers (damp-heat and thermal cycling) according to the tests descibed in IEC61215. The performance was compared with reference modules manufactured with etched foils and a high-silver content adhesive. Suggestions are also made for further cost reduction.

2 MWT MODULE TECHNOLOGY

ECN has developed an integrated cell and module approach, which allows easy manufacturing of back contact modules. The module technology requires a conductive back-sheet foil and conductive adhesive for interconnection (see Fig. 1). The adhesive is cured during the lamination process resulting in a low-stress interconnection making the module technology suitable for very thin cells. Further advantages of MWT cell and module technology include reduced shading at the front of the cell due to the absence of bus-bars and tabbing and improved conductivity of the conductive back-sheet with respect to tabbing in an H-pattern module. Due to this, it is possible to achieve higher cell efficiencies and module power output as mentioned above [4].

The conductive back-sheet foil consists of a sheet of copper laminated to a PET-PVF laminate as used in a standard H-pattern module. The copper is patterned to match the contact pattern on the rear side of the MWT cells. During the module manufacturing process, the conductive back-sheet foil is fixed to a vacuum carrier after which conductive adhesive dots are stencil printed at positions corresponding to where the contact pads of the cells will be positioned. Next, a sheet of perforated EVA is placed on the back-sheet with the openings in the EVA corresponding to the position of the conductive adhesive dots. The conductive adhesive dots have a height greater than the EVA thickness. The cells are then placed on the stack, so making contact with the conductive adhesive. The stack is finished with a second sheet of EVA and a glass sheet. The stack is then inverted and laminated, curing the adhesive and EVA at the same time (see Fig 1 for a cross section of the MWT module).

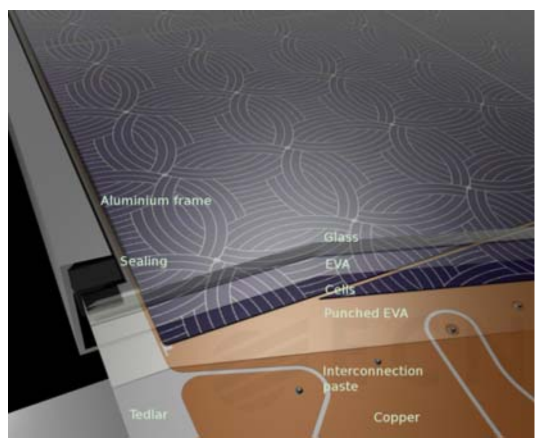

Figure 1: Image of MWT module showing patterned conductive back-sheet foil, with position of conductive adhesive (interconnection paste), punched EVA and cells

The original foil design incorporated an isolation coating on top of the copper with openings in the coating where the adhesive is printed. These opening were plated with silver, as the adhesive available at the time were not compatible with direct contact to copper. In 2010, modules made with this type of foil were certified to the IEC61215 standard.

The price of the back-sheet foil is largely dominated by the etching process, as well as by the application of the silver plating and the isolation coating. In this work, an alternative, cheaper method of foil patterning (milling) is assessed, as are foils without the isolation coating and silver plating of the foil. The performance of low-cost conductive adhesives is also tested.

3 DEVELOPMENTS CONDUCTIVE BACK-SHEET AND CONDUCTIVE ADHESIVE

With the introduction of conductive adhesives suitable for direct contact with copper, it was possible to remove the silver plating from foil production. These adhesives showed a similar contact resistance to a copper foil as the original adhesives to a silver coated foil.

One of the functions of the isolation coating was to act as a mask for deposition of the silver plating, ensuring that silver was only deposited at the contact points and not over the whole foil area. The other function was electrical isolation. However, the electrical isolation in the module is dominated by the encapsulant between the cell and foil, making the isolation coating redundant for an adhesive compatible with copper.

Taking the above into account, a second generation foil was manufactured without silver contacts and isolation coating (see figure 2).

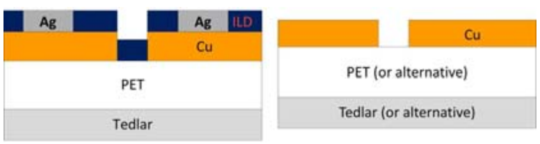

Figure 2: Cross section drawings of conductive back-sheet foil, left, first generation, with insulation lacquer (ILD) and plated Ag contacts, right, second generation, with no insulation lacquer and no Ag contacts

In addition to the removal of the silver plating and isolation coating, an alternative method of patterning the copper layer was introduced. Instead of etching, the foil was mechanically milled to produce the same interconnection pattern. Milling is estimated to reduce the conductive back-sheet cost by up to 10% relative to the etched foil. A patterning tool can be integrated into the module manufacturing line allowing foil laminates from several suppliers to be used independent of the ability of the suppliers to pattern the foils themselves.

Further cost reduction is achieved by reduction of the silver content of the conductive adhesives. The original adhesive contained between 80 and 85% silver by weight. The use of alternative filler materials has allowed this to be reduced to less than 20% so lowering the cost of the adhesive significantly.

4 EXPERIMENTS

4.1 Contact resistance to copper foils

The copper foils used for conductive back-sheets typically have a protective coating to prevent corrosion. The protective coating can be an OSP (organic surface protection) or a zinc chromate. The influence of these coatings on the cell to module loss in fill-factor was measured for a number of foils. The results are shown in Table I.

Table I: Cell to module loss for mini-module made with foils with different or no surface protection on copper

Module code	Surface protection	Fill-factor cells	Fill-factor modules	Cell to module loss FF
A1374	OSP	77.4	75.9	2.0%
A1375	OSP	77.9	76.1	2.3%
A1399	$ZnCrO_4$	75.3	73.3	2.7%
A1400	$ZnCrO_4$	77.4	73.9	4.5%
A1401	$ZnCrO_4$	77.1	73.0	5.3%
A1402	$ZnCrO_4$	77.8	74.9	3.8%
A1403	$ZnCrO_4$	77.5	74.2	4.2%
A1404	removed	77.0	75.8	1.6%
A1405	removed	77.2	75.1	2.7%
A1406	removed	77.6	75.6	2.7%
A1407	removed	77.5	75.5	2.7%
A1408	removed	76.4	75.3	1.6%

The results in Table I show that for the conductive adhesive used the zinc chromate coating results in the largest cell to module loss in fill-factor. An OSP coating gives a similar loss to modules where the surface protection has been removed mechanically just before module manufacture. Similar results have been presented by others showing an increase in contact resistance for conductive adhesives on copper foil depending on the type of finish on the copper and also on the adhesive used. [6, 7].

The results also show that the low-silver content adhesive used in this work can give a module with similar performance to adhesives with a high silver content with similar fill-factor loss values for the 2x2 module configuration.

4.2 Module manufacture and climate chamber testing

To assess the effect of surface protection of copper on milled conductive back-sheet foils on durability, the mini-modules manufactured above were subjected to damp-heat (85°C and 85% relative humidity) and thermal cycling (between -40 and 85°C) climate chamber testing. The power output of the module was measured at the start of the test and at 500 and 1000 hours for damp-heat and 100 and 200 thermal cycles to allow any degradation to be followed.

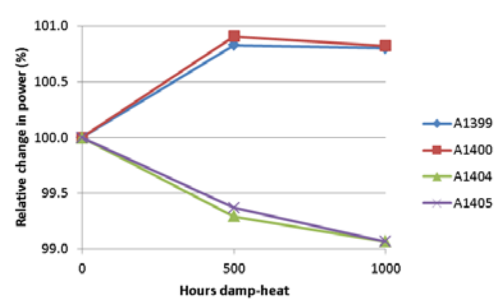

Figure 3: Relative change in power output for modules in damp-heat normalised to the power output at t=0

The results of damp-heat testing (Figure 3) show low degradation for all modules. The power output for the modules with a zinc chromate coating on the copper (A1399 and A1400) show a rise of almost 1% in power output. This is most likely a result of post-curing of the conductive adhesive reducing the series resistance in the module. The modules with the coating removed (A1404 and A1405) show a reduction in power output of just less than 1%, well within the 5% limit defined in the IEC61215 standard.

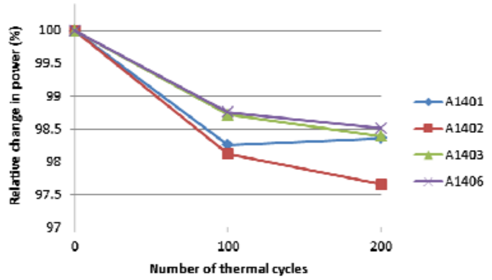

Figure 4: Relative change in power output for module in thermal cycling normalised to the power output at t=0

In thermal cycling, the presence or not of the foil surface coating has little effect on the degradation rate for the materials tested in this work. A loss of between 1.5 and 2.5% in power output is seen for these modules (see Figure 4). Most of the degradation occurs within the first 100 cycles indicating than it is a results of stabilisation of the p-type cells due to the current applied during the test. After 100 cycles, the degradation rate flattens off and remains well within the 5% limit.

4 CONCLUSIONS

The results show that it is possible to manufacture a module with a back-sheet foil without silver plated contacts or an isolation coating and that patterning the foil by milling has no negative consequences on module performance or reliability. There is an effect of the surface protection on the copper. For the adhesives tested in this work, a difference in initial performance is seen with better performance for the foil without surface protection,and both types of foil show good stability in damp heat testing, with the modules with coated foil even showing an increased output related to post-cring effects. In thermal cycling the effect of the presence of the protective coating is less significant with similar degradation rates seen for foils with and without a protective coating. The protective coating has been removed just prior to module manufacture which is a process that is not considered suitable for industrial application. Based on the performance and reliability results in this study, it is concluded that removal of the surface coating is not necessary, provided the initial contact resistance between the adhesive and the foil surface is low.

The low silver content adhesive used in this work shows no disadvantages in comparison to high silver content adhesives used in previous work. The conductivity is sufficiently high that there is no noticeable effect on the power output or fill-factor of the modules. In climate chamber testing, modules made with the low silver content conductive adhesive show very little degradation up to 1000 hours damp-heat and 200 thermal cycles.

The implementation of the materials used in this work results in a significant cost reduction for the MWT module as mentioned previously. The reliability of the materials has been demonstrated by the results presented in this paper.

Further options for cost reduction currently being investigated include the use of an aluminium conductive layer in the back-sheet and the use of a thinner encapsulant between the cells and the back-sheet. Aluminium is significantly cheaper than copper even after taking into account the increased thickness needed to overcome its higher resistance. It does require the development of an alternative interconnection approach as direct contact to aluminium at low temperature is not possible. Use of a thinner encapsulant allows the use of less adhesive to bridge the gap between the cells and the foil. The current encapsulant has a thickness of 200 µm. Reducing this to 100 µm can give a reduction of up to 70% in conductive adhesive usage. Implementation of these technologies will make MWT modules even more attractive on price compared to H-pattern modules, whilst maintaining their advantage in terms of increased power output and suitability for use with thin and fragile cells - the latter even allowing further price reduction of the module.

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