Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 38 (2013) 329 – 333
Energy Procedia

SiliconPV: March 25-27, 2013, Hamelin, Germany

Reducing the cost of back-contact module technology

Ian Bennett, Wilma Eerenstein, Victor Rosca

ECN, Westerduinweg 3, 1755LE Petten, the Netherlands

Abstract

Back-contact modules made using a conductive back-sheet foil have a number of advantages over standard H-pattern modules including a higher power output, compatibility with very thin cells and high throughput, high yield manufacturing. For a conductive back-sheet based module the most cost critical components are the conductive back-sheet and the conductive adhesives used to make the contact between the cells and the conductive back-sheet. In this paper a number of methods for reducing the module materials cost will be presented. Climate chamber testing of low cost foils without isolation coating and without silver contacts demonstrated that this type of foil is reliable in damp-heat, reaching 2000 hours at 85%RH and 85°C with a loss in fill-factor of less than 2%.

Selection and/or peer-review under responsibility of the scientific committee of the SiliconPV 2013 conference

Keynote: Back-contact module technology; cost reduction; module materials

1. Introduction

A novel industrial process for the manufacture of PV modules with back-contact cells has been developed, with a lower cell to module loss in efficiency than can be achieved with tabbing, with an interconnection process which results in very low cell breakage. Furthermore, the module manufacturing process is suitable for thin wafers, allowing for significant cost reduction. This module process is based on a conductive back-sheet foil, with a low temperature interconnection process which is combined with the lamination process.

In this article, the build-up of the module will be discussed and strategies for cost reduction will be introduced. For a couple of low cost solutions, climate chamber testing has been performed on full-size (60 cell) modules. These results and the impact on module cost will be shown.

1876-6102 © 2013 The Authors. Published by Elsevier Ltd.
Selection and/or peer-review under responsibility of the scientific committee of the SiliconPV 2013 conference
doi:10.1016/j.egypro.2013.07.285

2. Module design and manufacturing

2.1. Current module design

The advantage of back-contact cells is not only higher cell efficiency [1, 2], but also that different module concepts 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 is established either by conductive adhesive or solder [6]. The adhesive approach allows simultaneous curing of the encapsulant and adhesive during lamination. The conductive back-sheet consists of a laminate of polyvinyl fluoride (PVF), polyethylene terephthalate (PET) and a conductive metal grid on top of the PET with an isolation layer on top of the Cu (except at the contact points). Figure 1 shows a schematic representation of a 4-cell module containing metal wrap through (MWT) cells and a conductive back-sheet.

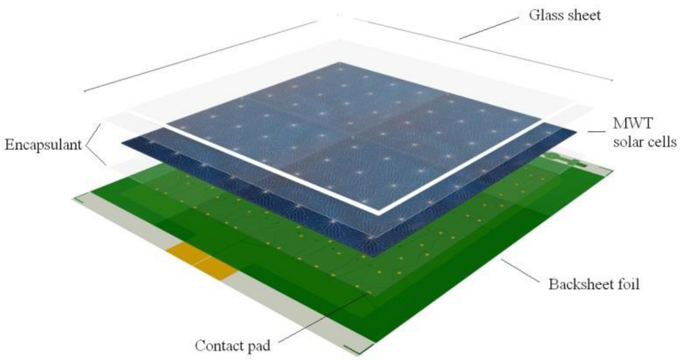

Fig 1. Schematic representation of a 4-cell MWT module showing the conductive back-sheet with green isolation coating. Conductive adhesive is printed at the contact pads on the foil. The pattern of the contact pad matches the pattern of the contacts on the rear of the cell. The layer of encapsulant between the foil and the cells is perforated to accommodate the conductive adhesive

2.2. Cost reduction

In order to make the foil-based back-contact module competitive with H-pattern modules, a number of cost cutting measures are needed. Of the materials used to make the module, the conductive back-sheet and the conductive adhesive have been identified as cost critical components. The cost of the conductive foil can be reduced by using an alternative for PVF, removing the isolation layer on top of the conductive metal grid, removal of the silver contacts on the foil and using an alternative method to pattern the metal grid (see figure 2). The aim is to obtain a foil for less than 10€/m^2. The cost of the conductive adhesive can be reduced by reducing the silver content in the adhesive. The original conductive adhesives used in back-contact modules had a silver content of over 80%. By changing the conductive filler it is possible to reduce the silver content significantly to <10%. For both the conductive foil and conductive adhesive, the effect of using these low cost components on module performance and durability needs to be assessed.

3. Experiments

To assess the suitability of foils without isolation layer or silver contacts for module manufacture, a number of foils were manufactured with copper as the conductive grid with or without isolation coating and silver contacts. Full-size modules were manufactured with MWT cells using these foils with EVA or a thermoplastic (TP) encapsulant and one of two conductive adhesives. The adhesive used with the foils without silver contact was known to be suitable for direct contact to copper (CA2), the other adhesive for contact to a silver coating on the foil (CA1). CA1 had shown good reliability in 2x2 cell modules subjected to climate chamber testing. Two different types of isolation were included in the test (iso 1 and iso 2). The materials used to make the modules are listed in table 1. The modules were characterised and subjected to damp-heat testing according to IEC61215.

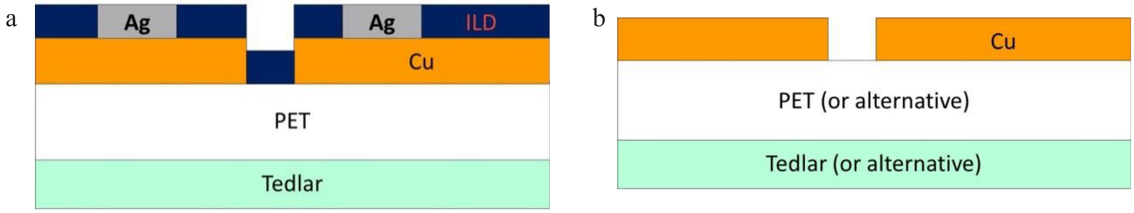

Fig 2. Schematic representation of a cross-section of (a) a first generation conductive back-sheet foil with isolation coating (ILD) and silver at the contacts to the conductive adhesive and (b) a second generation foil with no ILD and no silver at the contacts. The second generation foil requires a conductive adhesive that is compatible with contacting to copper

Table 1. Materials used in modules to evaluate foils without isolation layer and silver contacts

Module code	Isolation on foil	Contact	Encapsulant type	Adhesive type
Mod 1, Mod 2	iso 1	Ag	EVA	CA1
Mod 3, Mod 4	iso 2	Ag	EVA	CA1
Mod 5	iso 1	Ag	TP	CA1
Mod 6	iso 2	Ag	TP	CA1
Mod 7, Mod 8	no iso	Cu	EVA	CA2
Mod 9, Mod 10	no iso	Cu	TP	CA2

4. Results

The results of climate chamber testing are shown in Figure 3. The results show that the modules made with a conductive back-sheet with no isolation coating and with no silver at the contact points showed the least degradation in fill-factor. The modules (Mod 9 and Mod 10) made with a thermoplastic encapsulant had a drop in fill-factor of less than 1%. The modules made with EVA showed a decrease in fill-factor of less than 2%.

Modules made with an isolation coating showed more degradation that the foils without isolation coating. Failure was seen for Mod 1, 2 and 3 before 1000 hours damp-heat. Mod 4 failed between 1000 and 2000 hours. The modules showed large blisters at the rear of the module. Delamination was seen between the isolation coating and the copper resulting in breaking of the interconnection between the cells and the foil.

Modules with TP as the encapsulant all performed much better than their EVA equivalents, independent of isolation layer or contact pads.

The modules which passed 2000 hours were also tested for leakage current. All modules passed this test showing that the isolation given by the encapsulant is sufficient and that the isolation coating is not needed.

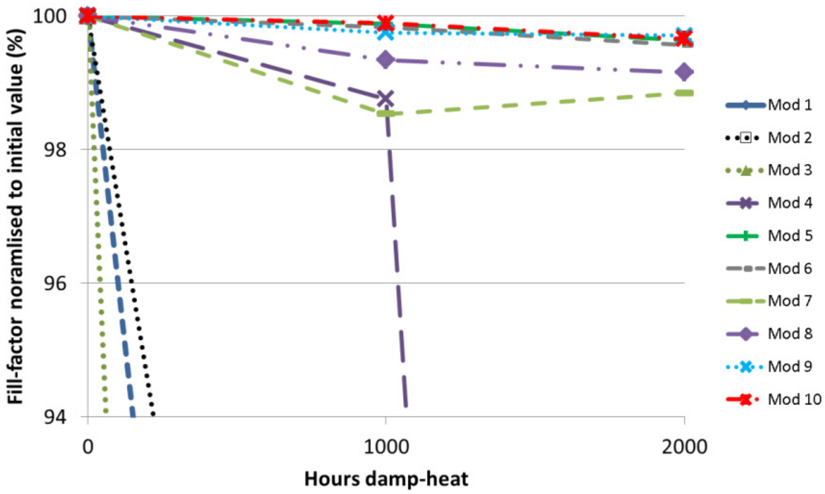

Fig 3. Decrease in module fill-factor for all modules normalized to the starting fill-factor. The best modules were manufactured with a conductive back-sheet without an isolation coating or silver at the contact point, with the best performance achieved with a thermoplastic encapsulant

5. Discussion

The results show that it is possible to manufacture a reliable back-contact module without isolation coating and silver contacts. The coating was included in the original foil to prevent contact between cells and the conductive back-sheet and to prevent leakage currents. EVA forms acetic acid when it degrades which will act as a conductive path. The modules manufactured without isolation coating and with EVA show that this concern is unfounded up to 2000 hours of damp-heat. The adhesion between EVA and copper is also sufficient to withstand the climate chamber test. This is in contrast with the results for the modules with isolation coating in combination with EVA. Here the majority of the modules showed premature failure caused by delamination of the isolation layer on the back-sheet. Once the isolation layer has delaminated, the contact between the cells and back-sheet is broken and the module fails.

6. Conclusions and further developments

The work done in this paper demonstrates the reliability of conductive back-sheet foils without isolation coating and silver contacts. By using these foils, a significant cost reduction can be achieved. In combination with a low-cost patterning process, a target price of less than 10 €/m^2 has been demonstrated [7].

Further cost reduction will be reached by use of aluminium as the conductive path in the back-sheet foil. To be able to do this, a solution needs to be found for the poor contact between the conductive adhesive and aluminium. Aluminium will form a non-conductive oxide at ambient conditions so increasing the contact resistance. One method is to (locally) apply a thin copper layer to the aluminium after removing the oxide. This will make the surface of the foil compatible with the conductive adhesives, with the bulk aluminium providing the required conductivity.

In addition to this, alternatives to PET and PVF in the back-sheet are being investigated as is the use of a thinner encapsulant. Use of a thinner encapsulant will reduce the amount of adhesive needed to connect the cells to be foil as the distance that needs to be bridged is reduced. Implementation of these developments will further reduce the cost of MWT modules based on a conductive back-sheet well below the cost of H-pattern modules, whilst retaining the higher power output provided by the cells.

References

[1] M. W. P. E. Lamers, C. Tjengdrawira, M. Koppes, I. J. Bennett, E. E. Bende, T. P. Visser, E. Kossen, B. Brockholz, A. A. Mewe, I. G. Romijn, E. Sauar, L. Carnel, S. Julsrud, T. Naas, P. C. de Jong, A. W. Weeber, "17.9% Metal-wrap-through mc-Si cells resulting in module efficiency of 17.0%", Progress in Photovoltaics 20(1), 62-73 (2011)

[2] Jonathan Govaerts, Kris Baert and Jef Poortmans. "An overview of module fabrication technologies for back-contact solar cells", Photovoltaics International 17th edition, 116-127 (2012)

[3] H. Wirth and U. Eitner, "Current status and future potential of back-contact (BC) module technology", Photovoltaics International 14th Edition, 122-129 (2011)

[4] P. C. de Jong, "Achievements and challenges in crystalline silicon back-contact module technology", Photovoltaics International 7th Edition, 138-144 (2010)

[5] M. Späth, P. C. de Jong, I. J. Bennett, T. P. Visser and J. Bakker, "A novel module assembly line using back contact solar cells", Proceeding of the 33rd IEEE Photovoltaic Specialists Conference, San Diego, California, USA, 2008, 708-713.

[6] L.M. Augustin, M.N. van den Donker, H. Scholten, M. Zell, W. Claussen, B. Van Straaten, C. Copetti, M. Fleuster, M. Feldhaus, D. Schier, U. Fliedner and K. Wangemann, "Mass production and field performance of durable metal-wrap-through integrated back contact foil based "Sunweb" modules", Proceedings of the 26th EPVSEC, Hamburg, Germany, 2011, pp. 3113-3116.

[7] B. Verschoor and J. Bakker, "Revolution of MWT module production", presented at the 4th MWT Workshop, Amsterdam, 2012