INDUSTRIALISATION OF APOLLON SOLAR'S NICE MODULE TECHNOLOGY

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ABSTRACT: APOLLONSOLAR's NICE (New Industrial Solar Cell Encapsulation) technology makes use of an air and humidity tight sealing technology known from the insulating glass industry and based on the application of an organic sealing material from the family of poly-isobutylene (PIB). Important features of the NICE technology are the absence of EVA lamination and the use of an underpressure inside the module to provide the electrical series connexion between solar cell contact lines and metal interconnectors, thus suppressing the soldering of metal interconnectors to the solar cell busbars, which is the most widely used technology today. Other important features include a specially developed metal foil that is used as for the metal rear surface and new external connector which is integrated in the edge-sealing of the module. From a production point of view, the NICE module technology presents a largely simplify module assembling technology since it allows for a complete inline operation which can be fully automated. This paper presents first results obtained with the new NICE pilot production line, realised by VINCENT INDUSTRIES. The pilot line incorporates all necessary automated production stations without the automatic loading and sorting.

Keywords: Modules, Encapsulation, Sealing quality

1 INTRODUCTION

APOLLONSOLAR's NICE module technology was first introduced in order to overcome limitations of the state-of-the-art module encapsulation technology based on EVA lamination and to reduce production costs of PV modules. The NICE technology was inspired by a sealing technology, using a poly-isobutylene (PIB) material, which is already in use and validated in the insulating glass industry. The widely used EVA lamination is thus replaced by a PIB sealing line which is applied around the perimeter of the module sheets. The PIB sealing assures very high and long term air/humidity tightness as well as the mechanical contact between the module's front and rear sheet. In addition, PIB is used as an adhesive glue to keep solar cells and metal interconnecting ribbons in place. In difference to the state-of-the-art technology, the electrical series connection of solar cells is obtained by creating an under pressure inside the module, thus suppressing soldering of the metal connectors to the cells busbar. High module fill factors and low series resistances have been regularly obtained with this type of electrical series connection by pressure. A detailed description of the NICE technology, including first test results can be found in previous publications [1, 2]. The NICE technology presents a 100% in line operation, that is completely automated and thus requires few operators, 3 per shift for a 45 MW/year line. Due to its compactness, as can be seen in Figure 1, the required floor space is drastically reduced by a factor 5 of compared to a state-of-the-art module assembly line. The purpose of the pilot line is the industrial validation of the NICE technology, starting with the manufacturing of the required number of modules for the certification according to the IEC standard 61215. This paper presents the most recent version of the NICE technology as well as first results and experiences obtained with the new pilot line.

2 THE NICE PROCESS

This section gives an update on the latest developments of the NICE process compared to previous presentations [1,2] and a number of results from evaluation tests, starting with a reminder of the generic process flow, presented in Figure 2. This process flow also corresponds to the order of the different units of the pilot line shown in Figure 1.

2.1 Metal rear sheet

As an alternative to a glass or a Tedlar sheet, the NICE technology uses a metal sheet as module rear

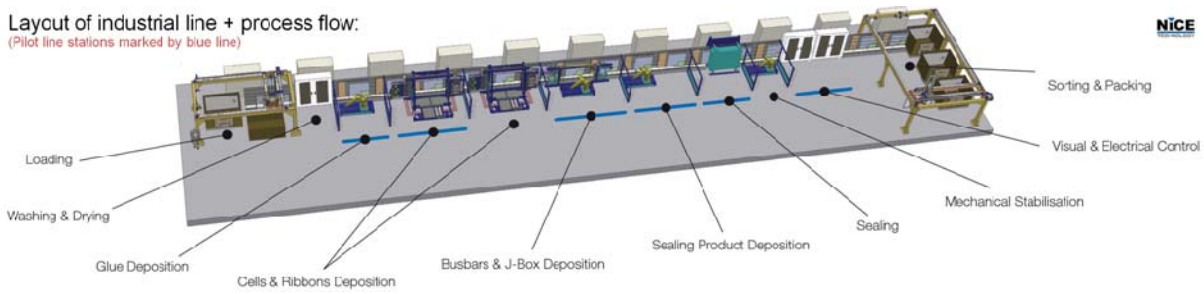

Figure 1: Schematic drawing of a NICE production line – the units underlined by a blue bar constitute the now operational pilot line. The process flow is from left to right.

surface. This metal foils presents a light weight option, that at the same time provides mechanical re-enforcement of the module while keeping a certain flexibility that allows to adapt to the profile of cells and metal connectors after the creation of under pressure.

Glue deposition on rear sheet

Positioning of metal connectors and cells on rear sheet

Positioning of external connector and module busbars

Deposition of sealing material around perimeter of rear sheet

Mounting of front and rear sheets (closing of sandwich)

Pressing of sandwich to desired thickness
Flooding of module interior with neutral gas

Creation of under pressure in module interior

Figure 2: Generic process flow of NICE process.

The metal rear surface for the NICE technology has been developed in collaboration with Arcelor Mittal. The selected material is a Fe/Ni alloy under the trade name INVAR™, whose thermal expansion coefficient of $\leq 2.10^{-6}/°C$ between –40°C and +110°C matches the thermal expansion coefficient of Silicon. The thickness of the metal sheet is 100 to 200 micron; however, variations of this thickness can also be used. In order to provide mechanical strength, the edges of the metal foil are bent upwards at a length that corresponds to the thickness of the used glass front sheet plus the thickness of cells and metal interconnectors. The metal rear sheet is presented in Figure 3, which shows the rear side of a finished module. It can be clearly seen, that the metal deforms and adapts to the profile of the cells and metal interconnectors within the module, once the under pressure inside the module is established.

An important point is the electrical insulation of the inner surface of the metal sheet, which is in contact with the solar cells. A suitable solution has been found in collaboration with the French company VON ROLL, by using their UV curable resin DAMILUX™ which has excellent adhesion properties to metal surfaces and can be easily applied to the metal sheets prior to their incorporation into NICE modules. The usual thickness of the insulating coating is 300 micron.

The electrical insulating properties of this resin coating have been certified by the TÜV, Germany, for a maximum permissible system voltage of 855 VDC and a layer thickness of 300 micron, after a successful partial discharge test according to the IEC 60664-1 standard. An increased layer thickness will certainly allow to increase this voltage.

2.2 External connector

A new external connector (see Figure 3a and 3b) has been specially designed for the NICE Module Technology and manufactured by Huber+Suhner. This connector is integral part of the PIB edge sealing, comprises the protection diode for a string of series connected solar cells and is automatically integrated during the module assembling process. It serves to provide the electrical connection to the outside of the module.

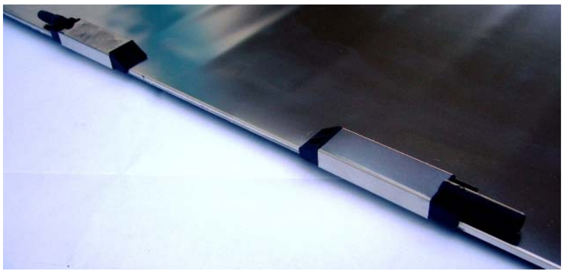

Figure 3a: Rear surface of a NICE module, showing the metal foil at the rear and the external electrical connectors.

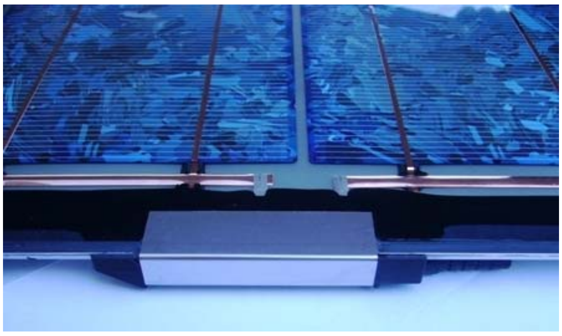

Figure 3b: Front surface of a NICE module, showing the the external electrical connectors.

2.3 Evaluation of tightness of the PIB sealing

The organic PIB sealing material used for the sealing of the modules has been further developed by APOLLON SOLAR's partner Kömmerling. This work focussed on improving the adhesion properties of the sealing material to the surfaces to which it is applied to, for example glass or metal. In addition to only physical bonding of the so far used material the new material features chemical bonding as well, thus increasing the overall adhesion properties. The stability of the sealing material at higher temperatures has also been increased.

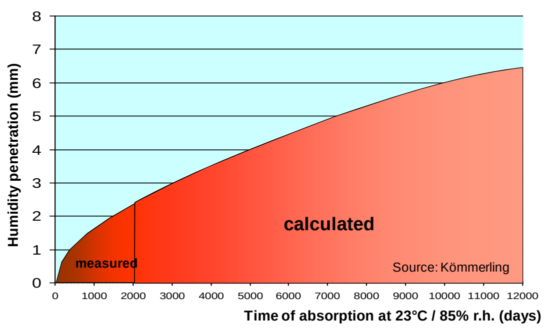

Figure 4: Humidity penetration in the sealing material as a function of time to exposure to 85% relative humidity at 23°C. The left part of the curve represents 2000 days of test, while the left part is extrapolated from it.

Figure 4 shows test results on the humidity tightness of the sealing material as a function of time. Indicated is the depth of humidity penetration, when exposed to 85% relative humidity at 23°C.

A typical NICE module features at least a 10 mm wide sealing line which, according to the results presented in Figure 4, is largely sufficient to assure humidity tightness for more than 30 years.

The gas tightness of the organic PIB sealing has been tested under IEC conditions with a Glass/Metal foil module and 125 mm multi-c-Silicon cells, by using the under pressure induced deformation of the metal rear sheet as an indication. The deformation of the metal sheet follows the profile of the super positioned metal connectors and cells inside of the module. Depending on the underpressure the metal rear sheet is thus more or less deformed and a loss in underpressure transfers directly into a change of the amplitude of the mechanical deformation profile. Figure 5 shows the evolution of the deformation of the metal foil above a solar cell and the corresponding metal interconnectors before and after thermo-cycling (-40°C to + 85°C). As can be seen, the average variation of deformation of the metallic rear sheet is about 0,03 mm after 1 000 thermo-cycles and corresponds to a pressure variation of <6% compared to the initial under pressure in the module.

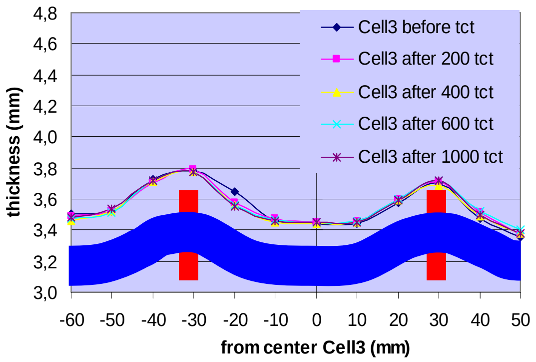

Figure 4: Deformation profile of the metal rear sheet before and after 200, 400 and 600 thermo cycles represented by the 4 thin lines in different colours. The thick blue line on the bottom represents the solar cell, the red rectangles the cross section of the metal connectors.

3 INDUSTRIAL NICE PILOT LINE

A pilot line, comprising the major assembling station of Figure 1 was developed, manufactured and put into operation at the beginning of 2008 by APOLLON-SOLAR's partner VINCENT INDUSTRIES. This equipment will serve to validate the industrial feasibility of the NICE technology. As a first step the required number of modules for the certification according to the IEC standard 61215 has been produced with the pilot line. The certification is currently under way.

The pilot equipment is designed for:

- double glass or glass/metal-foil modules with a surface area up to 1,4 x 2,1 m
- solar cell dimensions up to 156 x 156 mm with either 2 or 3 busbars
- front and rear contact cells as well as back contact cells and thin film modules
- cycle time per station ≤ 2 min
- entire process at normal atmosphere and ambient temperature

In the following figures, the different production units of the NICE pilot line are presented. The first step consists of the deposition of the PIB material on the rear sheet which comes in ready to use, which means in the case of the metal sheet with the electrical insulating layer already deposited. Figure 5 shows a photo of the PIB deposition nozzles

Figure 5: PIP sealing deposition unit: Two nozzles are in place, one for the deposition of gluing stripes for the fixation of the different components (cells, ribbons, module busbars and external connectors), the other nozzle for the sealing line on the perimeter of the module.

Once all PIB lines are in place, the different module components are automatically positioned by robots: The solar cells, the copper interconnectors, the module bus bars and the external connectors. The corresponding unit is shown in Figure 6. Before the copper interconnectors are positioned, they are unrolled from a spool, straightened, preformed and cut to the required length to connect two cells. The automatic straightening also releases residual mechanical stress in the ribbon.

Figure 6: Cells and Ribbons deposition station with unrolling, straightening, forming and cutting of copper ribbons serving as metal interconnectors.

After all components are in place on the module rear sheet, both, front glass and rear sheet are transported into the pressing unit (see Figure 7) which serves different purposes: Apart from pressing the sandwich together and sealing the module, during the pressing operation the module interior is flooded with neutral gas and the under pressure is created. The module is now finished.

Figure 7: Module Press for the flooding with neutral gas, establishing the under pressure and the assembling of rear and front sheets.

The finished module is electrically characterised using the FMT-320 flash tester by Sinton Consulting.

4 CONCLUSIONS

The promising results of previous tests and process investigations [1, 2] since 2003 have led to the design and realisation of a pilot equipment, allowing the industrial and economical validation of the NICE module technology.

Important parts of the technology like the organic sealing material have been further developed and show an increased performance now.

The NICE Technology represents a new fully automated module assembly technology, increasing the module reliabilities accompanied by a drastic cost reduction.

5 ACKNOWLEDGEMENTS

APOLLON SOLAR attaches great importance to acknowledge the important contributions provided by the following cooperation partners to the development work related to the NICE project:

- VINCENT INDUSTRIE, France, development and manufacturing of pilot line,
- Lenhardt Maschinenbau, Germany, technology for the organic sealing deposition,
- Kömmerling Chemische Fabrik, Germany, organic sealing material,
- Huber+Suhner, Switzerland, development and manufacturing of the new external connector
- Arcelor Mittal, France, development of the metal foil
- Von Roll, France, development of the insulating coating material on the metal foil

Further on, the CEA-INES Institute and Photowatt are acknowledged for their technical assistance. The French innovation agency OSEO is gratefully acknowledged for co financing the NICE project.

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