AiSoVoL Project: A Photovoltaic Generation Solution as an Alternative Construction Material

INTRODUCTION

AiSoVol project consists on the development, manufacturing and testing in a controlled environment of a new concept of photovoltaic modules, conceived for facilitating their use as architectural elements.

Thus, the modules will be fabricated by encapsulating its constituent electrical elements (cells and interconnections) with sandwich lamination techniques at low curing temperatures and using different types of transparent thermoplastics instead of tempered glass, as well as binding materials structurally strengthen by a grid made of high-tenacity yarns, such as the ones used in sail technologies and thus avoiding the need for aluminum frames.

This type of solution will provide not only lighter but, due to the nature of the constituent materials, virtually geometry free PV modules which can adapt to any surface. In this paper it is described the methodology followed to define a suitable lamination process compatible to obtain reliable AiSoVol photovoltaic modules.

What it is investigated in this work is the degree of compatibility that combinations of these materials present when laminated together employing the same techniques and equipment available at PV module manufacturing lines.

Results achieved from materials and processes validation will pave the way for manufacturing the prototypes in next project phase.

METHODOLOGY

At this initial phase of the AiSoVol project the focus has been put on the materials validation and its compatibility with processes involved in PV module manufacturing.

Study of thermal, optical, physical, electrical and mechanical properties of several transparent thermoplastics raised the polycarbonate (PC) as best option to be used as superstrate for the AiSoVol BIPV modules.

All samples have been manufactured in a (16.5 x16.5) cm size format.

The rest of the package constituent materials are the encapsulant, PV cells, reinforcement grid made of high-tenacity yarns and the backsheet. The sublayer structure of this new BIPV product differs notably from that of conventional PV modules. What is investigated in this work is the degree of compatibility among combinations of these materials when laminated together employing the same techniques and equipment available at PV module manufacturing lines.

First approach is focused on defining the lamination process required to produce samples fulfilling minimum requirements regarding cure degree of the encapsulant, adhesion force between layers and visual aspect. The second aspect is the susceptibility of polymeric materials to suffer UV degradation when used for outdoor applications.

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EXPERIMENTAL

1. Adjustment of lamination process

The lamination parameters must be set taking into account the limitations of polycarbonate. Regarding EVA, different sets of samples have been produced varying temperature and time in the lamination process. Polycarbonate sheets of 2 mm and 4 mm, have been used.

Three diagnosis tests are conducted to evaluate the quality of the samples obtained:
a) Visual appearance b) Peel-off test c) Degree of cure of EVA

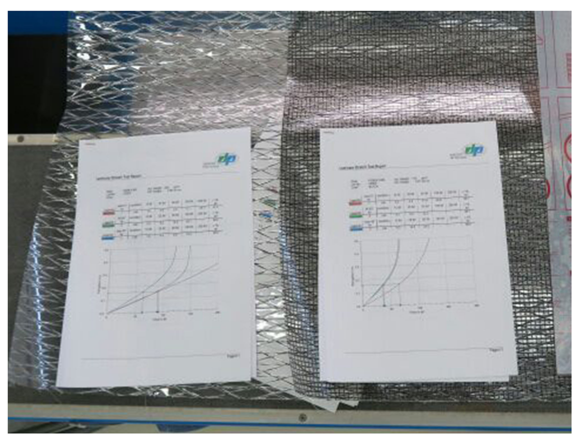


Figure I: Reinforcement grid

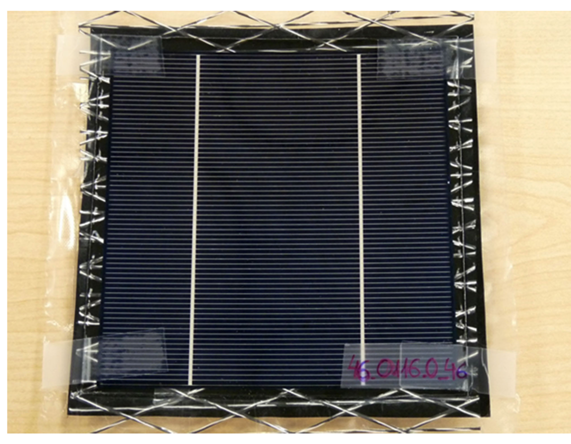


Figure II: Sample

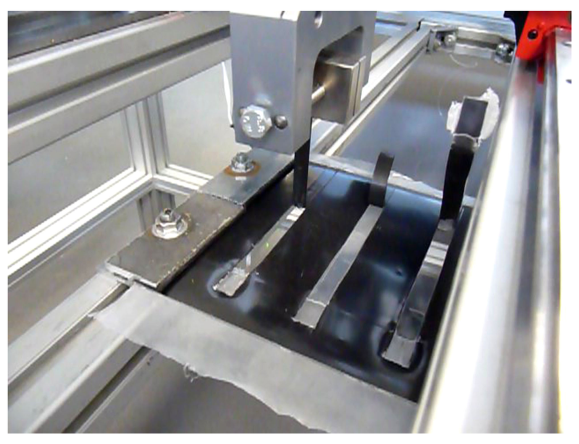


Figure III: Peel-off test

2. Optical characterization

Polycarbonate samples laminated with EVA have been optically characterized, including the measurement of the spectral transmittance (from 385 nm to 1600 nm) and the yellowness index (YI), which was obtained from it. This optical characterization allowed quantifying the influence of ultraviolet weathering on polycarbonate samples laminated with EVA.

RESULTS AND DISCUSSION

1. Lamination process

The lamination process has been evaluated in two different steps depending on the number of layers present in each sample. Initially the process is validated for type A PC superstrate, two EVA foils and the backsheet (PPE). Once the laminate fulfills the quality requirements, the rest of the materials (solar cell, extra EVA sheet and reinforcement grid) are included in the package.

Type A

Analysis of the diagnostic tests conducted over samples 15 to 17 shows that there is not enough crosslinking degree of the encapsulant for the selected process temperatures. The peel test performed over two interfaces show that minimum adhesion force of 50 N/cm has been achieved in all cases.

Characterization results from this second round show that the more suitable lamination processes for each package system are 135 ºC and 17.5 minutes for the sample with 2 mm thick PC sheet.

Sample Code	Process	Package
16	115 ºC-20.5'	Type A (2mm PC)
15	125 ºC-12.5'	Type A (4mm PC)
17	125 ºC-30'	Type A (4mm PC)

Table I: Process parameters and package description for the first set of laminates

ID	INSPECTION	DSC (%)	PEEL TEST (N/cm)	
Code No.	Visual aspect	Cure degree	PC-EVA	PPE-EVA
16	OK	37	84	60
15	OK	44	50	-
17	OK	48	100	65

Table II: Results on first set of laminates evaluated

Type B

The characterization of the samples is restricted, in this case, to visual inspection and DSC analysis of the EVA foil extracted between the reinforcement grid and the backsheet.

A final tuning recipe is proposed to define proper lamination parameters for each complete package. The curing time is increased to 15 minutes for the sample with 4 mm thick PC to obtain higher crosslinking degree in the cold side of the sample.

Sample Code	Process	Package
44	140 ºC-15'	Type B (4mm PC)
45	131 ºC-17.5'	Type A (2mm PC)
46	131 ºC-17.5'	Type B (2mm PC)

Table III: Process parameters and package description for the fourth set of laminates

ID	INSPECTION	DSC (%)	PEEL TEST (N/cm)	
Code No.	Visual aspect	Cure degree	PC-EVA	PPE-EVA
44	Bubbles	-	-	-
45	OK	58	114	97
46	OK	61	-	-

Table IV: Results on fourth round of laminates tested

2. Effect of ultraviolet weatherings

With the aim of investigating durability aspects of outdoor exposure, 3 polycarbonate samples (2mm thick) laminated with EVA using different lamination conditions have received a total ultraviolet irradiation of 28 kWh/m2 (94% corresponding to UVA and 6% to UVB). Polycarbonate side was placed facing the incident ultraviolet irradiation.

As can be appreciated from the previous table, the average transmittance shows a slight decrease from 86.0% to 85.9% due to the ultraviolet test.

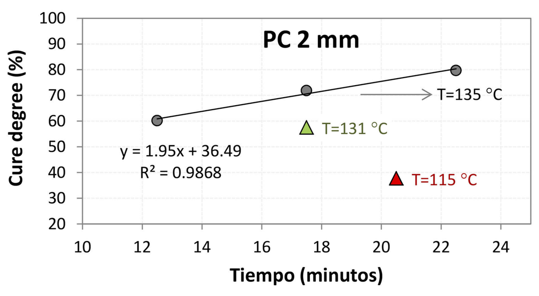
CONCLUSION

The BIPV module lamination processes for 2mm and 4mm thick polycarbonate (PC) frontsheets proposed in the AiSoVol project have been adjusted and validated. A fine control of the lamination parameters has been achieved:
- 131 ºC and 17.5 minutes for the sample with 2 mm thick PC.
- 140ºC and 12.5 minutes for the one with the 4mm thick PC.

The results of the peel test for type are:
- 114 N/cm in the PC(2mm).
- 97 N/cm and 117 N/cm in the EVA-backsheet with 2mm PC as frontsheet.
- The peel forces measured in the type A sample with 4mm thick PC are 120 N/cm and 117 N/cm for the same interfaces.

Temperature gradients through the complete package during lamination processes have been measured.

An increase of one ºC in lamination temperature implies 3% improvement in the curing degree and 5 minutes longer cycles at a fixed temperature represents 10% higher curing rates. Polycarbonate samples laminated with EVA have undergone an ultraviolet weathering test. 3 samples (2mm thick) have received a total ultraviolet irradiation of 28 kWh/m2, (94% corresponding to UVA and 6% to UVB). As a result of this test the average transmittance showed a slight decrease from 86.0% to 85.9%. On the other hand, the yellowness index was clearly influenced by the ultraviolet weathering test, increasing its average value from 2.53 to 3.11.



ID	LAMINATION		Before T(%)	Before YI	After UV T(%)	After UV YI
44	125 °C	12.5'	86.2	2.50	85.8	3.18
45	120 °C	20.5'	86.0	2.59	85.9	3.05
46	115 °C	20.5'	85.8	2.51	85.9	3.09
		Average	**86.0**	**2.53**	**85.9**	**3.11**

Lamination and optical characterization results

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