Article
Journal Electrical Engineering
December 2023, Vol.7 No.19 38-42

Evaluation of the adherence of thermoplastic polyurethane (TPU) as an alternative material for the protection of solar cells

Evaluación de la adherencia del poliuretano termoplástico (TPU) como material alternativo de protección de celdas solares

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DOI: 10.35429/JEE.2023.19.7.38.42 Received July 30, 2023; Accepted December 30, 2023

Abstract

At present, the care of the environment as well as the use of solar energy are of great importance. One way to use solar energy for clean energy generation is through the use of photovoltaic modules. The performance of the crystalline silicon PV module is mainly determined by the efficiency of the silicon cells, but the properties of the other components, such as the encapsulant material, also have a high impact. The objective of this study was to evaluate the adherence of Thermoplastic Polyurethane (TPU) as an alternative material for the protection of solar cells, since the encapsulating material most used in solar production to date is Ethylene vinyl acetate (EVA) and it serves as a comparison of possible advantages and disadvantages. The tests carried out were in accordance with the International IEC 61215 and 61345 Standards. The adhesion results were sufficiently good and without optical defects. It is concluded that TPU can be used as an alternative material for encapsulating solar cells.

Photovoltaic module, Encapsulating material (EVA, TPU), Solar cell

Resumen

Actualmente el cuidado del medio ambiente así como el aprovechamiento de la energía solar son de gran importancia. Una manera de utilizar la energía solar para la generación de energía limpia es por medio del uso de módulos fotovoltaicos. El rendimiento del módulo fotovoltaico de silicio cristalino está determinado principalmente por la eficiencia de las células de silicio, pero las propiedades de los otros componentes, como el material encapsulante, también tiene un alto impacto. El objetivo de este estudio fue evaluar la adherencia del Poliuretano Termoplástico (TPU) como un material alternativo para la protección de celdas solares, ya que el material encapsulante más utilizado en la producción solar hasta la fecha es el Etilen vinil acetato (EVA) y sirve como comparación de posibles ventajas y desventajas. Las pruebas realizadas fueron conforme a las Normas Internacionales IEC 61215 y 61345. Los resultados de adherencia fueron suficientemente buenos y sin defectos ópticos. Se concluye que el TPU se puede utilizar como material alternativo para el encapsulado de celdas solares.

Módulo Fotovoltaico, Material encapsulante (EVA, TPU), Celda solar

Citation: SALAZAR-PERALTA, Araceli, PICHARDO-SALAZAR, José Alfredo, PICHARDO-SALAZAR, Ulises and BERNAL-MARTÍNEZ, Lina. Evaluation of the adherence of thermoplastic polyurethane (TPU) as an alternative material for the protection of solar cells. Journal Electrical Engineering. 2023. 7-19:38-42.

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Introduction

Polyurethanes are polymers that contain urethane groups in the molecular chain, and specifically, thermoplastic polyurethanes are made up of linear block copolymers in which rigid segments alternate, formed by a diisocyanate and a chain extender, and flexible, formed by macrodiols. Sometimes they can be formed by different types of molecules that make them have different energies and ways of interacting between the polymer chains and form a material with specific properties [1, 2, 3].

Urethane thermoplastic elastomers. They are block copolymers and are formed by polyaddition of long-chain organic compounds, the so-called diols. TPUs offer very good processing options due to a mix of hard and soft meltable segments. In polyaddition, short-chain glycols that react with diisocyanates (hard molecule segments) and long-chain polyesters or polyethers that react with diisocyanates (soft molecule segments) are mixed in a suitable ratio [2]. Different mixing ratios of soft and hard segments result in materials with different levels of hardness, but nevertheless elastic [4].

Function of the protective material

Nowadays, the shielding material is one of the most important components of a solar module today and must meet many requirements [5, 6, 7]. It is mainly used to bond and encapsulate solar cells and is intended to protect them from the effects of weather in the long term. The protective materials used must have the best possible resistance against water vapor and oxygen, otherwise the metal contacts and interconnections can corrode and as a result the solar module becomes unusable. The inclusion material can also be damaged by excess oxygen or water vapor absorption, whereby it turns yellow and therefore causes a loss of transmission. A high degree of transmission of light is very important for the materials used, since the transmission of the material is directly related to the generation of electricity. The higher the transmission of a material, the more light the cell can absorb and convert it into electricity [8, 9].

Furthermore, a good embedding material should have relatively high heat resistance on the one hand and good thermal conductivity on the other, as the modules can heat up to 90 degrees in direct sunlight [10, 11]. Materials have this so-called blur or string slippage when the embedding material softens at higher temperatures. When the embedding material softens at higher temperatures or liquefies it can no longer provide the necessary support. The better the thermal conductivity of the encapsulation materials, the better the heat can be dissipated and the higher the performance that can be achieved [12]. The embedding material also ensures that the module remains stable and serves as protection in the event of glass breakage. The materials used must, among other things, have a high level of stability against UV radiation, since shortwave radiation can yellow the material and cause transmission losses [13]. Due to the different incorporated materials with different coefficients of thermal expansion, the embedding material must compensate for the stresses that occur so that they do not cause cell ruptures or damage to the module. All the properties listed here must be fulfilled by a good material so that durable and efficient modules can be produced.

Methodology to develop

This study was carried out as follows. Conforms to International Standards IEC 61215 and 61345.

- 200 x 200 mm samples of the encapsulating material TPU were taken, as well as 200 x 200 mm samples of the encapsulating material EVA (Ethylene Vinyl Acetate).

- The samples were rolled in the Spire Brand Laminator. Figure 1.

- The lamination conditions were the following: Temperature 150°C ± 3°C. evacuation time (vacuum) of 210 seconds, and a pressure time at 800mbar of 360 seconds.

- Twelve laminated samples of each encapsulating material, were placed in the Temperature/Humidity climatic chamber with the following conditions: 1000 h at 85°C ± 2°C and relative humidity of 85 ± 5%.

- Twelve laminated samples of each encapsulating material, were submitted in a chamber for Ultraviolet tests with the following test conditions: 1000 h and irradiation of $15kWh/m^2$.

- The measurement of the adhesion was carried out after the laminate with a dynamometer for manual use. Figure 2. With a capacity of 50N, applying tensile force with an angle of 180° for maximum load application.

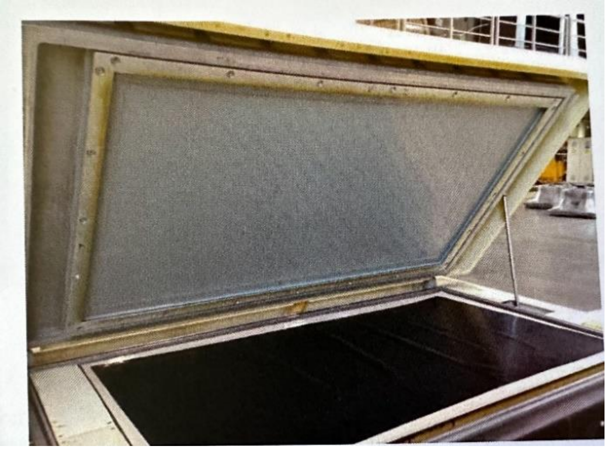

Figure 1 Laminator marca Spire
Source: Own elaboration

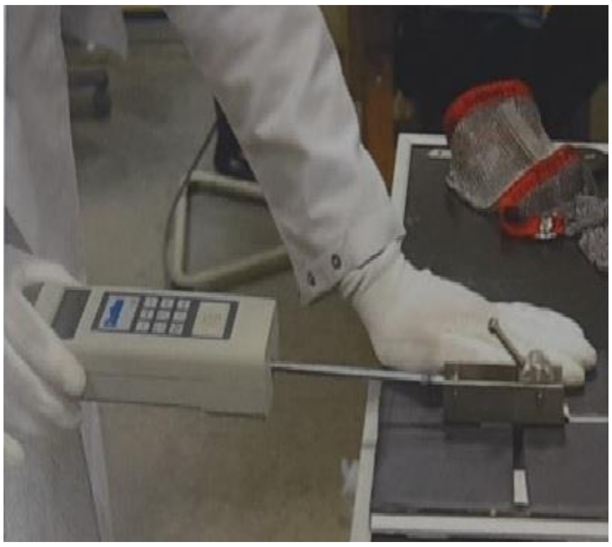

Figure 2 Adhesion test Dynamometer
Source: Own elaboration

Results

After the tests the results obtained were the following:

- As can be seen in Table 1. The values of resistance to adhesion of the EVA material, as well as those obtained from the TPU material, comply with the specification established in the Standard (25N minimum). After aging in a climatic chamber with (1000 h at 85°C ± 2°C and relative humidity of 85 ± 5%), the Eva presented adherence values of 25 to 40 N/cm. On the other hand, the TPU withstood more than 50N/cm.

Sample number	EVA N/cm	TPU N/cm
1	30	> 50
2	25	> 50
3	25	> 50
4	40	> 50
5	40	> 50
6	40	> 50
7	35	> 50
8	35	> 50
9	36	> 50
10	36	> 50
11	37	> 50
12	38	> 50

Table 1 Resistance to adhesion in N/cm of EVA and TPU after aging in a climatic chamber (temperature and humidity)
Source: Own elaboration

- After the aging test in a UV chamber (1000h) with irradiation of 15kWh/ and a temperature of 60°C±3°C, the values obtained with the EVA were: 40 to 50 N/cm, instead the values obtained with the TPU they were greater than 50N. Table 2.

Sample number	EVA N/cm	TPU N/cm
1	40	> 50
2	40	> 50
3	45	> 50
4	50	> 50
5	50	> 50
6	45	> 50
7	50	> 50
8	46	> 50
9	48	> 50
10	49	> 50
11	49	> 50
12	50	> 50

Table 2 Resistance to adhesion of EVA and TPU in N/cm after 1000h in a UV chamber
Source: Own elaboration.

Acknowledgments

To Jehovah God who provides health and understanding to be able to do research

To the Tecnológico Nacional de México, to which the Tecnológico de Estudios Superiores de Jocotitlán belongs, for its scientific and moral Support.

To the Tecnológico de Estudios Superiores de Jocotitlán for the support with the Research hours provided. And the Center of Academy-Industry Linkage.

To all my collaborators who with their support make teamwork possible. to carry out these studies.

Conclusions

The adhesion test measures the resistance between the individual materials and is given in N/cm.

In all tests, the adhesion must not be less than 25 N/cm and must be distributed as evenly as possible throughout the laminate. The adhesion of the embedding materials must have, on the one hand, good adhesion to glass and, on the other hand, guarantee good adhesion properties to the carrier films. There are some differences in the chemical structure and surface treatment of the backsheets, which have a great influence on the adhesion to the inlay material.

In this study, the adherence results obtained in a comparative way of the 2 materials EVA and TPU can be observed after having been submitted in a humidity and temperature climatic chamber (1000 h at 85°C ± 2°C and relative humidity of 85 ± 5%), according to the results it can be deduced that the adhesion resistance of TPU is higher than that of the EVA material currently used.

According to the results obtained after the test in a UV chamber with an irradiation of 15kWh/m2, and a temperature of 60°C±3°C, it is also observed that the adhesion resistance values of the TPU exceed the resistance values of EVA.

In this test, the focus was on the adhesion of the inlay material. good enough and without optical defects for the 2 materials EVA and TPU.

It is concluded that the encapsulating material TPU is an alternative option to be used in the encapsulation of solar panels.

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