A prototype for junction boxes in photovoltaic systems is made of a flame-retardant polyamide that has already been successfully established in the electrical/electronics industry
(figures: BASF)

A Sticky Question

Adhesive Tapes. Junction boxes for photovoltaic systems are produced from flame-retardant polyamide among other materials. Until now, these junction boxes have been bonded to the crystalline or thin-film solar modules with silicone adhesives. However, this gives rise to high production costs due to the lengthy curing process. Extensive trials have shown that time and money can be saved by using acrylic adhesive tapes as an alternative.

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The photovoltaic (PV) industry is going through a phase of consolidation. Besides reductions in feed-in rates, manufacturers in Germany also have to endure cost pressure due to imports of cheap photovoltaic modules from Asia. In the end, only companies with new technologies and low production costs will be able to survive.

One way of saving production costs is offered by the use of adhesive tapes to fix junction boxes to crystalline or thin-film solar modules. This method eliminates the lengthy curing time required with the silicone adhesives currently employed for this purpose. For some years now, BASF SE, Ludwigshafen, Germany, has been supplying its Ultramid A3X flame-retardant polyamide (PA) grades for junction boxes in photovoltaic systems **(Title picture, Fig. 1)** as an alternative to the established product classes such as modified polyphenylene ethers (m-PPE) and polycarbonate (PC). In an exhaustive study, the compatibility of adhesive systems with the different plastics was tested.

Requirements and Regulations

Photovoltaic systems are generally designed for a lifetime of 25 years, during which they are exposed to harsh ambient conditions. The materials used for electrical connection of PV modules must therefore be very flame-retardant and also weathering-resistant. In particular, they must have good low-temperature impact strength. Plastics for use in junction boxes must meet the flame retardancy requirements of UL 94, flammability rating 5VA, for which they are tested with a flame power ten times higher than for the V0 to V2 ratings. Low-temperature impact strength is tested according to UL 1703 cold impact test. Components

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Fig. 1. Junction boxes for photovoltaic systems (picture left) can be produced from, for example, the specialty polyamide Ultramid A3XZG5; for connectors, the stiff grade Ultramid A3X2G7 is suitable (picture right)

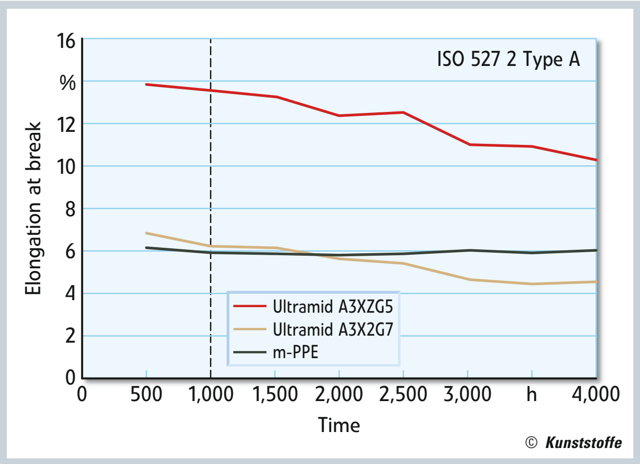

Fig. 2. The weathering resistance of materials for photovoltaic systems is determined in the damp heat test

pass this test if they exhibit no cracks or other damage after impact by a 535 g ball dropped from a height of 1.3 m at a temperature of -35 °C. In addition, the plastics have to comply with conditions specified for UV resistance (f1 outdoor use: UL 746 C) and hydrolytic resistance (85 °C/85 % relative humidity for 1,000 h: IEC 61215; **Fig. 2**).

Because of the high requirements, it makes sense for BASF to supply the solar industry with material grades that have already been established in the electrical/electronics sector for many years. These include Ultramid A3X2G7 and the impact-modified grade Ultramid A3XZG5.

Along with the polymer materials themselves, BASF also offers its cus- →

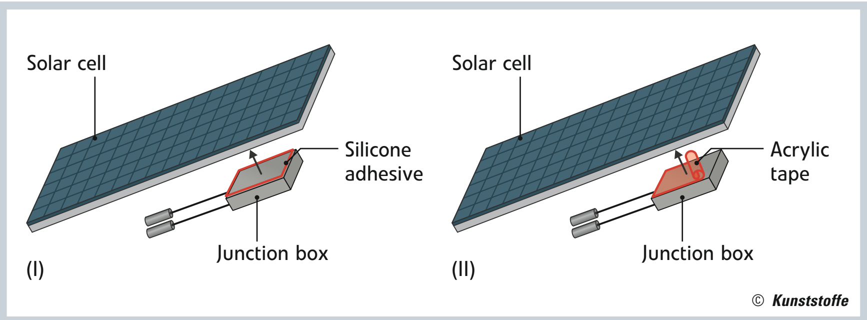

Fig. 3. For bonding junction boxes, RTV1 silicone adhesive (I) or a double-sided acrylic adhesive tape (II) is normally used

tomers comprehensive technical support, e.g. CAE competence, component design, and component testing. A good example of this can be seen in the adhesion trials that BASF carried out specially for bonding junction boxes with acrylic adhesive tapes, in response to a debate among industry experts.

The aim of the trials was to evaluate the adhesion of polyamide and other currently used plastics to different acrylic adhesive tapes using various pretreatment methods. For the sake of comparison, trials were also carried out with silicone adhesives **(Fig. 3)**, since they have previously been the adhesives most commonly used to bond junction boxes to the PV module.

Trial Methodology and Results

In the study, two different series of trials were carried out for silicone adhesives and acrylic adhesive tapes.

Silicone Adhesives: Test specimens produced from Ultramid A3XZG5 and m-PPE were bonded with a standard commercially available RTV1 silicone adhesive (room-temperature-curing, one-component) and pull-off force, i.e. tensile shear strength, was tested **(Fig. 4)**. Testing was conducted with both dry and conditioned plastic, as well as with unaged specimens and specimens aged for 1,000 hours at 85 °C and 85 % relative humidity. No significant difference in results between the tested plastics was found. It is notable that in this test, cohesive fracture always occurred, i.e. failure in the silicone adhesive itself. The bond between the plastic and adhesive thus remained intact, even after the test, and can be rated as very good.

Acrylic Adhesive Tapes: To test junction box adhesion to acrylic adhesive tapes, various plastic specimens were bonded to glass with different adhesive tapes with and without pretreatment by a primer. The specimens were first tested

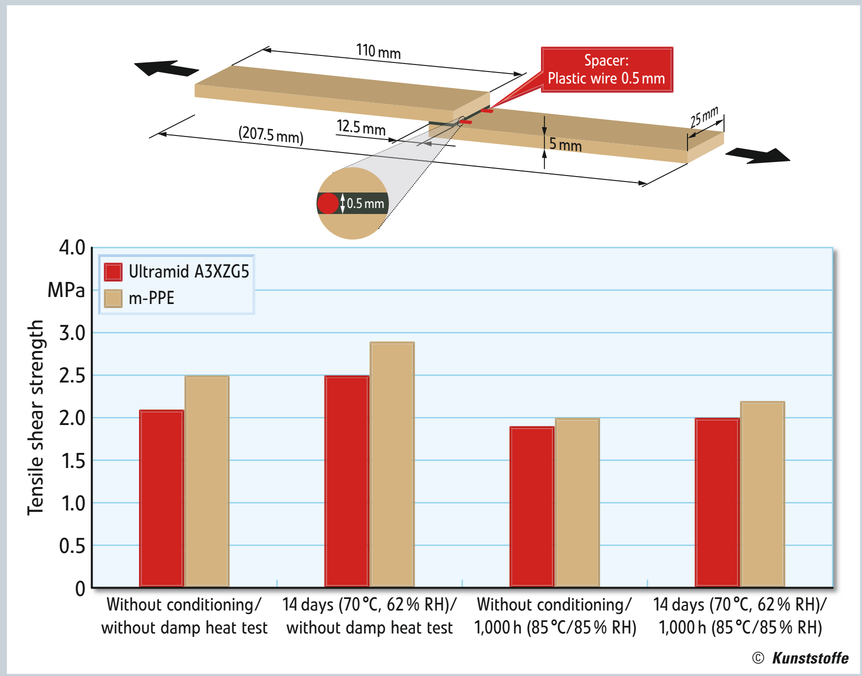

Fig. 4. Bonding with a standard commercially available RTV1 silicone adhesive: the tensile shear strength of the tested plastics is the same

		Time to failure [h]				
		With primer				
	Test specimen condition before the test	Acrylic tape 1	Acrylic tape 2		Acrylic tape 3	
m-PPE	Dry	✓	< 24	A	< 24	A
PC	Dry	✓	< 24	A	< 24	A
Ultramid A3XZG5	Dry	✓	84	A	500	A
Ultramid A3XZG5	Damp	✓	< 24	A	140	A

✓ No failure after 2,000 h at 85°C / 85% RH
A Adhesive fracture

Table 1. Bonding with acrylic tapes; tested after storage at 85 °C/85 % relative humidity in damp heat under a constant 250 g load. Very good adhesion irrespective of the type of plastic; very large differences in adhesion noted between the tapes

		Failure temperature [°C]							
		Without primer		With primer					
	Test specimen condition	Acrylic tape 1		Acrylic tape 1		Acrylic tape 2		Acrylic tape 3	
m-PPE	Dry	60–100	A	> 150	✓	90–100	K	140	A
PC	Dry	50	A	100/130	K	90–100	K	90	A
Ultramid A3XZG5	Dry	50	A	> 160	✓	90	K	> 140	✓
Ultramid A3XZG5	Damp	50	A	> 150	✓	90/110	K	110	A

A Adhesive fracture
K Cohesive fracture
✓ No failure

Table 2. Bonding with acrylic adhesive tapes; tested after storage in dry heat under a constant 500 g load. Pretreatment with the primer increases adhesion significantly irrespective of the type of plastic

under constant load at different high temperatures. This so-called dry heat test was started at 50 °C and the temperature was increased by 10 °C every 24 hours until failure of the specimens occurred. In a second series of tests, adhesion was measured after aging in a hot, humid environment (85 °C /85 % relative humidity) **(Fig. 5)**. So these tests did not measure strength but rather determined failure after a specified period of time **(Table 1)** or at a defined temperature **(Table 2)**.

The results show that pretreatment of the polymer substrate with a primer is necessary, no matter which plastic is used. The primer enables chemical bonds to be formed between the substrate and adhesive tape, which improves adhesion and creates a protective barrier against moisture.

Without the use of a primer, all the plastics in the test show adhesive fracture, i.e. failure of the bond between the plastic and adhesive, at only moderate temperatures between 50 and 100 °C. When the test is conducted on plastic specimens pretreated with a primer, no fracture at all takes place in some cases up to temperatures of 160 °C, while in other cases cohesive fracture occurs in the acrylic adhesive tape, with the plastic-adhesive bond remaining intact. Only in a few cases does the adhesion between the plastic and tape fail and then not until elevated temperatures. No difference between the types of plastic can be detected. The adhesive tapes used were standard acrylic foam adhesive tapes, while the primers were the products recommended by the respective adhesive tape manufacturers.

Taking into account the findings of the dry heat test, the very much more severe test under damp heat **(Table 2)** was only carried out on specimens that had been pretreated with a primer. This test now clearly showed up the differences between the adhesive tapes. While there were no adhesion problems with any of the plastics bonded with tape 1 after 2,000 h in a hot, humid climate, a considerable difference in adhesion behavior was observed when the plastic specimens were bonded with tapes 2 and 3. However, once again, the type of plastic did not appear to have any significant influence on this.

Summary

All the plastics tested can be bonded with currently available adhesive tapes as well as with conventional RTV1 silicone adhesive. The differences in adhesion behavior between the plastics are not significant. Flame-retardant Ultramid A3X polyamides show the same high level of adhesion as m-PPE und PC. There are, however, significant differences between the various primer systems and adhesive tapes.

This means that plastic junction boxes can be successfully bonded with acrylic adhesive tapes and silicone adhesives, irrespective of the type of plastic used. To obtain optimum results, however, the pretreatment must be suitably matched to the particular adhesive tape or silicone adhesive, a phenomenon also known from other areas of materials jointing. Provided the manufacturer's instructions are properly observed, acrylic adhesive tapes can be used as an alternative to silicone adhesives, so eliminating the lengthy curing process and cutting production costs. ■

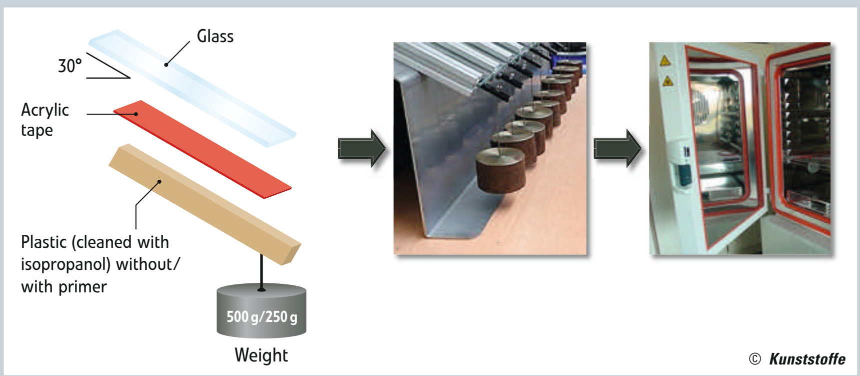

Fig. 5. Trial rig for bonding with acrylic tape

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