

# AN EVALUATION OF SEALANTS USED IN PHOTOVOLTAIC (PV) MODULE MANUFACTURE

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## ABSTRACT

Over recent years, there has been an increase in the use and manufacture of solar modules. One area which has seen development has been the silicone sealants used in PV Module Assembly with a typical application being attachment of the PV Junction Box to the back-sheet material as well as the sealant to the frame. The paper will describe the performance of the silicone adhesives used in module assembly as well as the requirements for the adhesion to and the sealing of the assembly.

Tests will also compare the sealing performance for a range of sealants by exposing the sealants to high temperature and humidity over a period of time measuring mechanical properties such as the change in tensile strength, elongation and hardness. An assessment will also be described of the different reaction rates of certain sealants with different EVA films. Tests will cover the need to bond the sealant over materials such as TPT, PET, with example peel strength assessments conducted on these substrates after damp-heat testing.

The sealant evaluations will also cover processability of the sealants to assess whether the sealant glue line applied has a large number of air bubbles which could affect the sealing and reliability of the system and whether the glue line could break more frequently with the need to add more sealant.

Key words: Sealant, Tensile Strength, Solar, Photovoltaic, Elongation, Hardness, Peel Strength.

## INTRODUCTION

With the increase in the manufacture of PV modules, silicone sealants have been increasingly used to seal the PV module frame as well as the junction box to the back sheet of the PV module.

As the industry was developing, the silicone sealants used were based on sealants used from other industries. With increasing silicone sealant usage in the PV module manufacturing industry, there has been a need to assess the sealants currently used in respect to their applicability to PV

module manufacturing. A series of tests were conducted on a range of sealants to determine their applicability to PV module manufacturing in relation to mechanical properties at time zero and after ageing as well as processability of

sealants and their compatibility with other materials used in the PV modules. The evaluations are discussed in the following sections.

## EXPERIMENTAL

Five sealants were used in the evaluations which were silicone sealants used in PV module assembly labeled Sealants A, B, C, D and E. Of the 5 materials tested, Sealant A, B and C were de-oxime type sealants whereas Sealant D and E were de-alcohol type sealants.

Sealant A is a silicone sealant which was UL Test certified (HB, HWI 2, HAI 0, RTI 105) and IEC61215 [1] and IEC 61730 [2] certified which are test standards used in the PV module manufacturing industry. Sealant D was UL test certified (HB, HWI 3, HAI 2, RTI 105).

The sealants were subjected to a series of tests at time zero and after ageing to determine their suitability in PV module manufacture which are described.

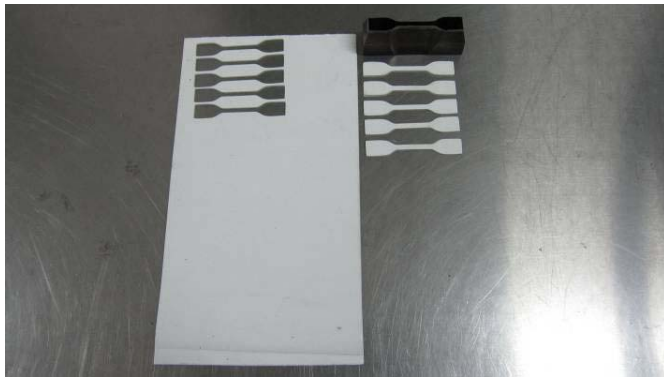
### Time Zero Tests

The tests conducted at time zero were sealant density, surface cure time (tack free time) and sealant extrudability at  $(23\pm 2)$  °C,  $(50\pm 5)$  % RH. Extrudability was measured as the time to extrude 20 grams of sealant onto an electronic weight balance using a pneumatic dispensing adhesive gun with a pressure of 0.3MPa and a nozzle diameter of 3mm. The uncured performance tests were done according to an internal company standard.

### After Ageing Tests

The curing conditions for the samples prepared for the ageing tests for the 5 sealants were:  $(23\pm 2)$  °C,  $(50\pm 5)$  % RH, with a curing time of 21 days for the sealants.

For the cured performance tests, the sealants were tensile tested and hardness tested before and after ageing. Tensile testing before and after ageing was done according to ISO37 standard [3]. The tensile samples used are shown in Figure 1.



**Figure 1: Tensile test samples for sealants**

Hardness testing before and after ageing was done according to ISO7619 Type M Hardness test standard [4] as shown in Figure 2.



**Figure 2: Shore A Hardness Testing of Sealant**

Ageing conditions were 85°C and 85%RH for 1,000 hours according to the Damp Heat test referred to in IEC61215 standard [1].

#### Application Tests

In addition to mechanical property testing, sealant application testing was done on the PV module frames to assess the processability of the sealants during PV module manufacture.

Compatibility testing was also done between certain sealants and the EVA films as well as peel strength tests of the sealant on different substrates. The results are reported in the following sections.

## RESULTS AND DISCUSSION

### Time Zero Tests

Table 1 shows test data measured on Sealants A to E for sealant density, surface cure time and extrudability. For surface cure time Sealant A and B appeared to have the fastest surface cure time (tack-free time) of 5 minutes.

Sealant	Density (g/cm <sup>3</sup> )	Surface Cure Time (min)	Extrudability (s/20g)	As-received Appearance
A	1.4	5	7	White paste
B	1.04	5	-	White paste
C	1.04	10	-	White paste
D	1.4	15	-	Black paste
E	1.4	12	8	White paste

**Table 1: Initial test results for different sealants**

### Ageing Tests

Table 2 shows the change in tensile strength and elongation rate at break and Table 3 shows the hardness after ageing with the ageing condition being 85°C and 85%RH for 1,000 hours. The smallest reduction in tensile strength after ageing was observed with Sealant A. The smallest change in elongation and hardness after ageing was also observed with Sealant A. The smaller the change in hardness, elongation and tensile strength after ageing, the better the sealant ageing performance would be. Sealants A, B and C had de-oxime based curing agents whereas Sealants D and E have de-alcohol based curing agents.

After aging tests the surface of Sealants B, C and E appeared to have a more viscous appearance.

Sealant	Time zero tensile strength (MPa)	Change in Tensile Strength after ageing (%)	Change in Elongation rate at break after ageing (%)
A	3	23	14
B	1.7	55	36
C	1.7	72	85
D	2.2	39	27
E	2.1	53	25

**Table 2: Sealant performance after ageing for tensile strength and elongation rate at break (1,000 hour damp heat test at 85°C, 85%RH)**

Sealant	Shore A Hardness value after ageing	Change in Hardness after ageing (%)	After ageing sealant appearance
A	46	15	Light yellow, Slightly sticky
B	23	61	Light yellow, Sticky
C	24	83	Yellow, Sticky
D	33	48	Black, Sticky
E	31	70	Yellow, Sticky

**Table 3: Sealant performance after ageing for hardness (1,000 hour damp heat test at 85°C, 85%RH)**

### PV Module Assembly Tests

#### Sealing Application

After the mechanical property tests additional testing was done on application tests during frame sealing on modules.

Sealant A was found to be able to be worked with auto-dispensing system at relatively high efficiency with a uniform appearance. In line production, the glue line appeared to be continuous and uniform without air bubbles being formed. Sealant A was found to be suitable for both auto and manual dispensing.

Sealant B was found to have in the line production evaluations a glue line which had a large number of air bubbles and broke frequently so glue would need to be added manually. This problem could lead to low glue dispense efficiency and non-uniformity in appearance. Adding additional glue manually could also lead to an increase in air bubbles in the glue. The bubbles inside the glue line could be an issue to the sealing and potentially the reliability of the system.

Sealants C to E were also found to have the same issue as Sealant B in terms of a large number of air bubbles in the glue line as well as the glue line breaking frequently during sealant application.

Based on this application test on the frames Sealant A appeared to have the least amount of air bubbles in the sealant during dispensing and a more uniform appearance which would indicate better processability in production.

#### Compatibility Testing with EVA film

Sealants A and E were then tested against a range of EVA films to understand compatibility of these sealants with EVA films after damp heat ageing conditions of 85C and 85%RH for 1,000 hours.

The testing results with the De-oxime type silicone Sealant A showed there was no reaction (i.e. no yellowing) with the EVA film produced by EVA film suppliers X, Y, Z. The testing results with De-alcohol type silicone Sealant E showed a reaction with the EVA films from EVA suppliers X, Y and Z to various degrees as shown in Figure 3. The byproduct of the de-alcohol type silicone rubber is

methanol. Methanol can react with EVA materials in PV components which can cause a yellowing of the EVA. The yellowing of the EVA will decrease its light transmittance and can lead to the hot-spot effect in solar modules reducing module efficiency.



**Figure 3: Evaluation of De-oxime Sealant E (Top row) versus De-alcohol Sealant A (Bottom row) on three different EVA materials (X, Y, Z) after damp heat ageing tests showing EVA yellowing with Sealant E on the EVA films tested.**

These test results were also confirmed by various PV module manufacturing plants which showed that the de-alcohol type silicone sealant rubber (Sealant E) reacted with EVA materials showing yellowing of the EVA versus the de-oxime type silicone sealant rubber (Sealant A).

#### Peel Strength Testing Results

Based on the results for curing, ageing, and application processing it was decided to conduct peel tests for Sealant A on a range of materials that would be part of the PV module. Table 4 shows testing on PET and TPT substrates which indicate good peel strength results for Sealant A before and after damp heat testing at 85C, 85%RH for 1,000 hours.

	Sealant A (Time Zero) [N/mm]	Sealant A (After Damp Heat) [N/mm]
PET-PET	1.1	0.85
TPT-TPT	1.35	0.85

**Table 4: Peel Strength results before and after damp heat testing for Sealant A on PET and TPT substrates**

In addition peel test results for Sealant A on glass and electrodeposited Aluminum also showed good results. An example of the peel strength testing conducted on the test samples is shown in Figure 4.



**Figure 4: Peel strength testing of test samples joined by the sealant**

### **CONCLUSIONS**

Based on the results, there was the ability to differentiate different sealant materials in terms of their application to PV module assembly based on the tests conducted. Some of the main results include:

1. After 1000 hours damp heat testing, Sealant A had the least change in tensile strength, elongation and hardness of the five sealant materials tested which indicated it had the best performance after ageing of the five sealants tested.
2. Sealant A performed well in processability tested sealing PV module frames with minimal air bubbles formed and a more continuous glue line compared with Sealants B to E.
3. Sealant E was tested with various EVA films and the Sealant E which was a de-alcohol type silicone sealant was found to react with the EVA film products after ageing causing yellowing of the EVA which could affect the life of the module.
4. Sealant A which was a de-oxime type silicone sealant did not react with the EVA film products after ageing.

### **FUTURE WORK**

The work discussed has shown the differences in mechanical properties, processing and compatibility that can occur for different silicone sealants used in PV module assembly.

Some areas of work which would be done would include new developments of sealants with improved ageing performance, more testing of sealants with other materials used in PV module manufacture as well as evaluation of sealants with faster cure times for PV module assembly.

### **ACKNOWLEDGEMENTS**

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### **REFERENCES**

1. IEC 61215 standard, Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval, 2005.
2. IEC 61730 standard, Photovoltaic modules, 2004.
3. ISO 37 standard, Rubber, Vulcanized or Thermoplastic - Determination of Tensile Stress-Strain Properties, 2005.
4. ISO 7619 standard, Type M Hardness Test, 2004.