EXTENDING MODULE LIFETIME USING DESICCATED EDGE SEALANT

ABSTRACT:

Learn the benefit of adding a desiccated butyl edge sealant to the photovoltaic (PV) module package by examining the impact of desiccant on moisture breakthrough time and the test results demonstrating adhesion to qualify as a cemented joint.

INTRODUCTION

PV module packaging materials have a tough job. They must provide several critical performance characteristics, including:

- Resistance to heat, humidity, UV radiation and thermal cycling
- Excellent adhesion

All PV cell designs continue to evolve at a rapid pace, from those currently considered “not moisture sensitive” such as crystalline silicone (c-Si), to “extremely sensitive to moisture” perovskite solar cells (PSC) and organic photovoltaic (OPV) cells. Within this range of varying sensitivities, cadmium telluride (CdTe) and copper indium gallium diselenide (CIGS) cells are well known to require edge sealant for functional module lifetimes whose module warranties now extend to 30 years. With proper edge sealant and design width, every type of PV module can potentially add decades of field service and high power output through a significant increase in module durability.

Several factors make such a durability improvement possible:

- Blocking moisture ingress
- Maintaining adhesion in testing and deployed field use
- Having excellent heat stability and UV + water resistance
- Sealant flexibility through a wide temperature range
- Resistance to flow and edge pinch during lamination
- Design of sealant dimensions optimized based on PV cell moisture or oxygen sensitivity

WHAT INFLUENCES MOISTURE INGRESS?

Starting with module design, focus on blocking moisture ingress at all the locations where moisture can enter. This includes near the junction box as well as at the perimeter. Such consideration expands the review of polymer permeabilities to include the junction box adhesives, such as acrylic tapes and silicone sealants. Figure 1 compares the steady state water vapor transmission rate (WVTR) of a few known PV sealants and encapsulants at 37.8°C, 100% RH, which is near the most extreme climate conditions in some actual global locations. Note the different orders of magnitude that relate to years of differences in moisture migration.

To understand how polymer systems may behave in accelerated weathering, such as damp heat (85°C, 85% RH) or over decades of field deployment, Figure 2 examines WVTR at 85°C, 100% RH of the three most desirable PV components from Figure 1.

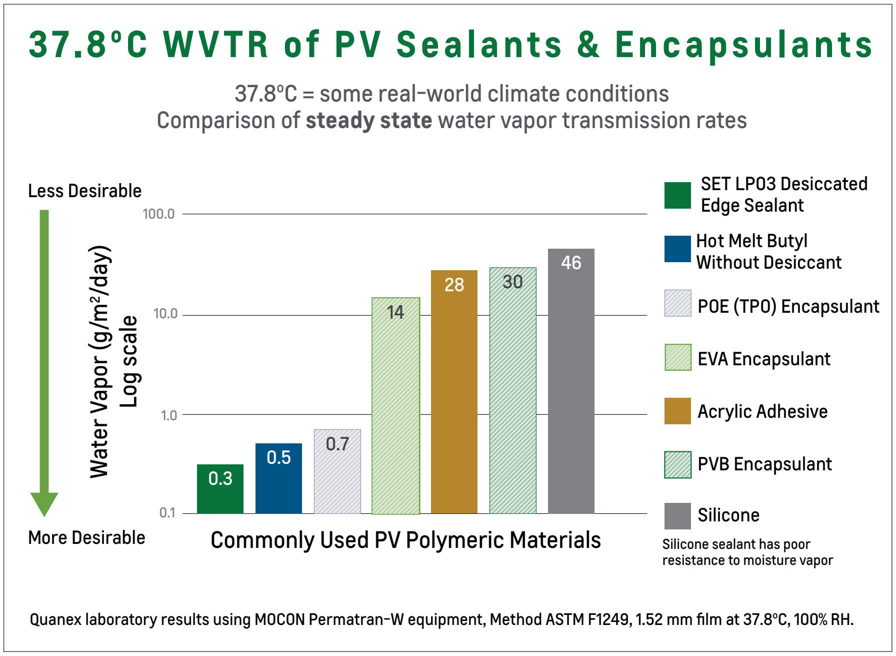


Figure 1
Comparison of the steady state WVTR of common PV sealants.

Figure 1 and Figure 2 may lead to the conclusion that thermoplastic polyolefin (TPO) encapsulant alone might provide enough protection without the added step of an edge sealant. This is not the case. It has been documented by Kempe, et.al. 2013[1] that desiccant in edge sealant is required for lifetime performance improvement. A low WVTR sealant or encapsulant alone is insufficient. The reason comes down to breakthrough time. Typical discussion about permeability relates to steady state transmission. With regard to a PV module, WVTR is the constant flow of moisture that has already passed any barrier. The benefit of incorporating desiccant is to delay the start of transmission. This can be called the lag time. International Electrotechnical Commission (IEC) 62788-6-2 defines a method to quantify the time that it takes to reach 10% of the steady state WVTR ($\tau_{10\%}$) as breakthrough time (BTT).

Figure 3 compares the BTT at 85°C, 100% RH of the same low WVTR materials in Figure 2. What you see is that, without desiccant, moisture immediately begins to cross the barrier and diffuse into the module.

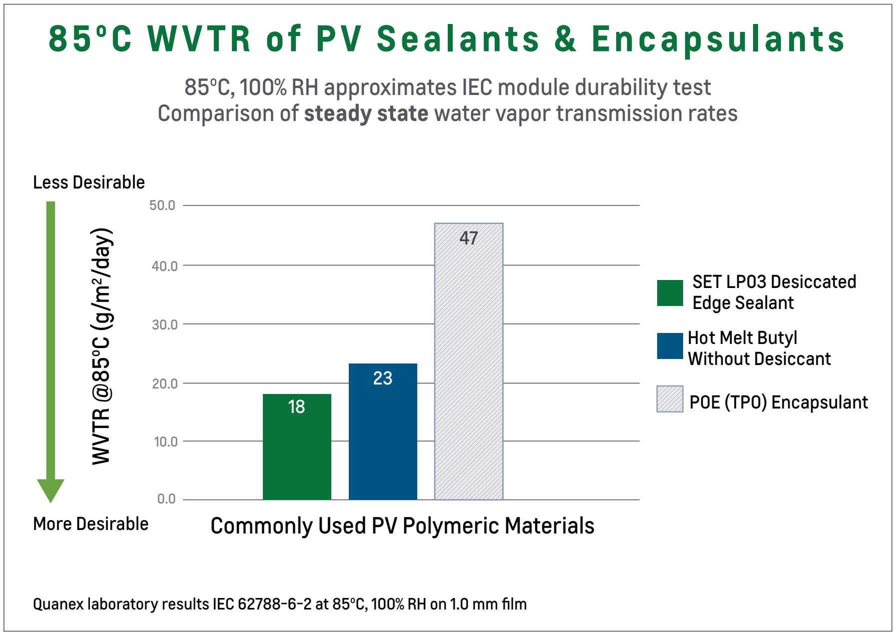


Figure 2
Comparison of WVTR of the three most desirable PV components.

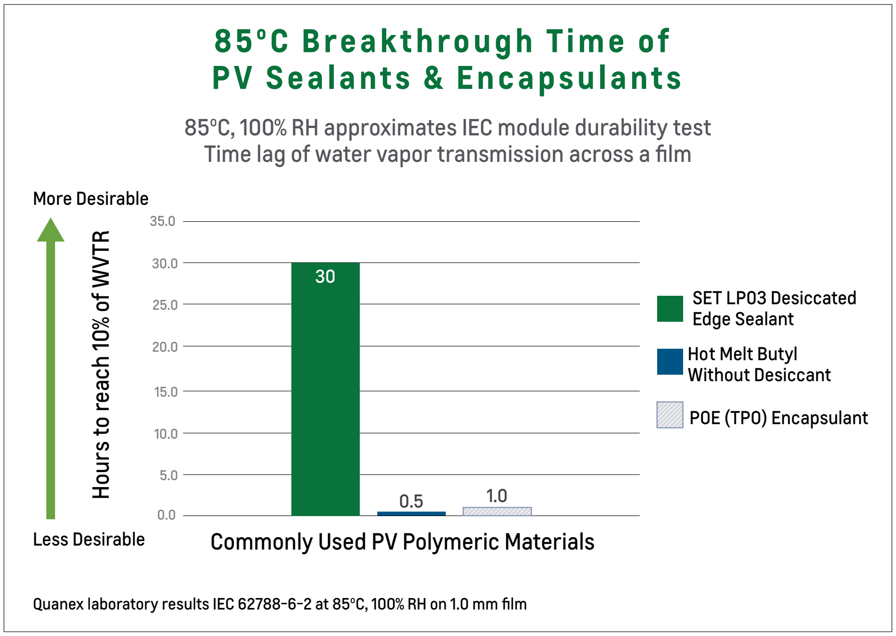


Figure 3
Comparison of breakthrough time of the same low WVTR materials in Figure 2.

DESIGNERS' CHOICES INFLUENCE MODULE LONGEVITY

These comparisons in Figures 1, 2 and 3 are for the same thickness of material. However, module designers can choose how much edge sealant width to use. Different cell types need different bond widths. A small width can protect c-Si and heterojunction technology (HJT) cells and soldered connections. PSC may need wider bond widths than traditionally used with CdTe and CIGS. Increasing the bond width will increase the lag (or breakthrough) time and delay when moisture crosses the edge sealant to begin interacting within the modules. Figure 4 shows how the moisture ingress time delay will differ as the bond width increases. The curves in Figure 4 are visual representation of how lag time would differ (not based on data) as if X, Y, Z widths differed such as 6 mm, 10 mm and 14 mm, for example.

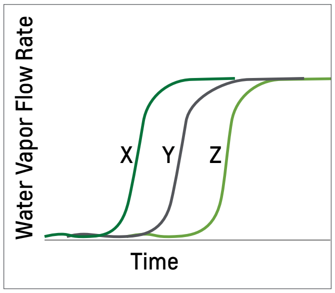


Figure 4
Moisture ingress time delay might differ as the bond width increases.

The choice of bond width may be modeled, such as by Kempe, et.al.[2], where it is predicted that a 10 mm wide butyl (polyisobutylene) sealant with desiccant may delay moisture ingress for 25 years.

Consider all entry points, since using high permeability sealant at the junction box is like having a hole in the perimeter that is 40 mm wide. A system with a low WVTR at all locations is the module designer's best choice.

The above information about WVTR is bulk material property, which is important to material selection and module design. However, the adhesive properties after heat, UV and water are critical to actually achieve greater module longevity. Kempe, et.al. makes this point as well in the paper[1].

ADHESION PROPERTIES OF GLASS COUPONS

What are the material tests for adhesion durability to be considered when evaluating an edge sealant? IEC 62788-5-1 lists many tests to discuss with your edge sealant supplier or which you may perform yourself. Specific tests were required to obtain UL component recognition for QIHE2 Photovoltaic polymeric materials. Ratings on the UL Yellow Card™ of Quanex SolarGain® SET LP03 listed on the UL Product iQ®—a public directory of UL-certified products—and additional extended UV exposure tests are shown in Table 1.

Table 1
Test on UL Yellow Card™

Evaluation on Glass	Sealant on Glass Test	Quanex SET LP03 UL E322203
Adhesion Strength After High Intensity UV 93.4 kWh/m²	Shear test after 2000 hours UV (A5 condition 85°C per IEC 62788-7-2 Black Panel 110°C)	>70% retention (similar to UL minimum UV requirement)
Electrical Resistance After High Intensity UV 93.4 kWh/m²	Dielectric breakdown per UL assembly after 2000 hours UV (A5 condition 85°C IEC 62788-7-2 Black Panel 110°C)	>70% retention (similar to UL minimum UV requirement)
Adhesion Strength After UV 20.4 kWh/m²	UL 746C: Shear strength after UV ASTM G155 cycle 1	Meets or exceeds UL property retention requirements
Electrical Resistance After UV 20.4 kWh/m²	UL 746C: Dielectric breakdown after UV ASTM G155 cycle 1	
Adhesion Strength After Water Immersion	UL 746C: Shear test immersed in 70°C water for 7 days	
Electrical Resistance After Water Immersion	UL 746C: Dielectric breakdown immersed in 70°C water for 7 days	
Adhesion Strength After Heat Exposure	RTI = 105°C UL 746B	
Electrical Resistance After Heat Exposure	RTI = 105°C UL 746B	

The battery of tests required by UL for use as a PV edge sealant validates the ability of a sealant to remain adhered following a variety of accelerated aging conditions. Even when tested to conditions exceeding UL test methods, such as more intense and longer UV exposure, Quanex SET LP03 shows exceptional property retention.

EDGE SEALANT ADHESION IN MODULES

To be a commercially viable product, modules must pass all the required certification tests. However, module manufacturers often perform extended tests, multiples of individual requirements, as well as additional tests. Some additional tests include intense UV exposure where the edge sealant bond must remain adhered. Modules with Quanex SET LP03 desiccated edge sealant perform extremely well in extended module durability tests in addition to IEC module safety and design qualification tests.

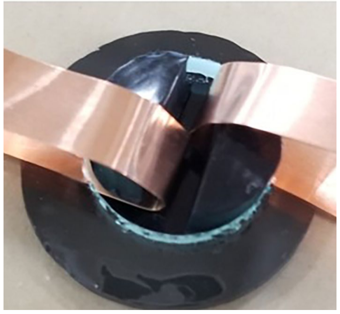
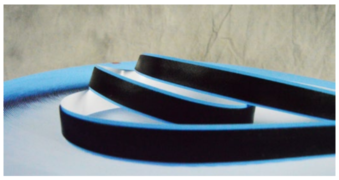


Image of a pass-through hole filled with desiccated butyl sealant.

As you can readily see from the above information, a barrier of desiccated butyl, such as Quanex's SolarGain® Edge Sealant LP03 as an edge sealant or a pass-through hole sealant, enhances the module design and performance by keeping moisture away from the key performance components of the module significantly longer than polymeric components without desiccant.

EXPERTISE IN EDGE SEALANT DESIGN, APPLICATION AND LAMINATION FROM QUANEX



Available packages

SolarGain® Edge Sealant LP03 has proven performance in thin-film PV module applications for the past 20 years and, as has been borne out by our published research and testing[3], can additionally help c-Si modules form greater protection for cells, connections and transparent conductive oxide coatings from corrosion and degradation. This can result in slower module power decline over time, generating more total power during service lifetime.

Further, Quanex has over 50 years of experience in insulating glass (IG) sealant and spacer manufacturing designed to slow moisture entry between glass panes. These solutions must demonstrate many of the same attributes required in our solar module sealants, including UV resistance, flexibility through a wide variety of temperatures and the ability to delay the migration of moisture. Our teams are ready and able to apply our long history and expertise to the solar industry, helping you create more reliable modules that your customers can depend on.

With this amount of time supporting the needs of our customers, Quanex understands optimizing module design and the application of our products in this industry. We use this expertise in supporting each customer's development and testing through trials and samples, making sure the best possible outcome is achieved. We work with equipment suppliers to ensure the capabilities and performance of our products are maintained.

If you're interested in learning more about how the Quanex Team can support you with our SolarGain® Edge Sealant, get in touch with our experts today:

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Want a deeper dive into solar edge sealants? Scan the QR code to gain access to our white paper, *Improving the Performance of Crystalline Modules with Edge Sealants.*

REFERENCES:

1. Kempe, M.D., Dameron A.A., Reese, M.O., "Evaluation of moisture ingress from the perimeter of photovoltaic modules," *Prog Photovolt: Res Appl*, https://doi.org/10.1002/pip.2374 2013

2. Kempe, M.D., Nobles, D.L., Postak, L., Calderon, J.A., "Moisture ingress prediction in polyisobutylene-based edge seal with molecular sieve desiccant," *Prog Photovolt. Res Appl.* 2018; 26:93–101. https://doi.org/10.1002/pip.2947

3. Postak, L., Daroczi, S., "Reducing Power Degradation in c-Si Modules using Edge Seal," 2019 NREL PV Reliability Workshop, Golden, Colorado, NREL/PSII-29-74405.