Low Stress Silicone Encapsulant Enables Distributed Power Generation

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Introduction

The way electric power is generated, distributed and used is presently undergoing a revolution. From a centralized generation in large power plants combined with an extensive transmission infrastructure and a one-way-only transport, there is a transition towards more distributed power generation and more local and complex power transmission. This is caused by the advent of renewable energies such as photovoltaics and wind power, the introduction of smart electric devices that communicate with the grid, the emergence of affordable battery storage, and the progressive introduction of electric vehicles. Power conversion and conditioning plays a crucial role in this transition, such as inverters and DC-DC converters. Many of those devices are exposed to widely varying and sometimes extreme weather conditions, for instance micro-inverters and power optimizers at the back of photovoltaic modules, or DC to DC converters and traction inverter modules in electric vehicles. Demands on reliability are however extremely stringent for those devices. Their lifetimes need to match the lifetime of the systems they are part of, while acceptable failure rates are very low. At the same time, the manufacturers of those devices need to meet high productivity and low capex requirements for their products to be cost-effective.

A key component in those devices is the circuit protection material. This can be a conformal coating, a relatively thin layer of specially designed polymer that covers all circuit components and protects them from moisture vapor and possibly liquid splashes. However, to provide effective protection even in extreme circumstances, for instance standing water inside the device housing because of a faulty lid seal, the designer might choose an electronics encapsulant. An encapsulant is a curable fluid applied to completely immerse circuit boards and sometimes to fill the complete space between the circuit board(s) and device enclosure. This encapsulant not only protects the electronics, preventing water from reaching the components and causing corrosion, but also helps dissipate any heat generated, therefore preventing excessive temperatures. Several products are available in the market for this application, often based on poly-urethanes. Dow has developed a silicone encapsulant with properties that are particularly well suited for this application.

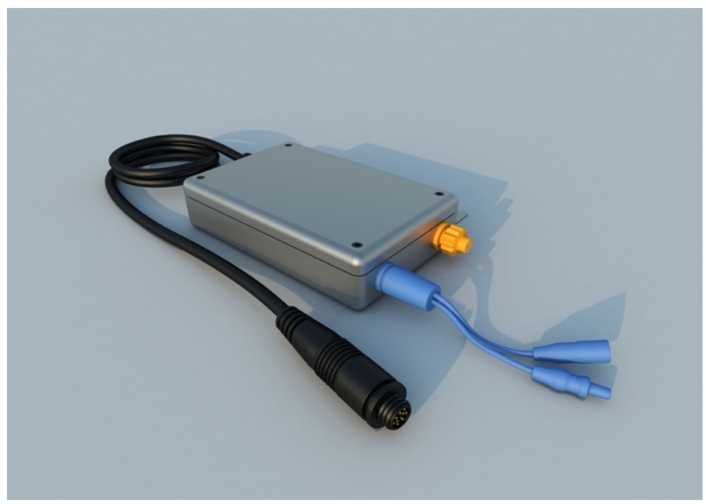

Figure 1: Example of a small power conversion device, typically mounted at the back of advanced PV modules.

Why are silicone materials the right choice?

Silicone materials have inherent properties that make them attractive for this type of applications. They have a Si-O-Si-O chain instead of the C-C backbone of organic polymers. The larger bond energy of Si-O bonds (~110 kcal/mol vs. ~80 kcal/mol for the C-C bond) confers silicones a superior stability and durability against ultraviolet light and high temperatures. As a result, silicone materials are often used in applications where excellent durability and performance in harsh conditions are required. Moreover, silicone materials are good electrical insulators and have a very low glass transition temperature, below the operating temperature range. As a result, mechanical properties vary only weakly when cycling in temperature.

Dow: A Leader in Silicone Materials

Dow was active at the start of the silicone materials industry and remains to this date a leader in that field. In the electronics market, Dow has a long track record of developing materials that meet the specific needs of various applications. In particular, a broad range of encapsulants for electronics devices is available, including low viscosity materials designed to provide void-free encapsulation of very complex circuit boards, high thermal conductivity materials applied when heat dissipation is critical, and some hard materials where impact protection needs to be provided.

DOWSIL™ EE-3200 Low Stress Silicone Encapsulant: a new encapsulant designed to meet stringent demands of distributed power conversion devices

In order to meet the specific requirements of power conversion devices that are exposed to outdoor conditions, Dow has developed a new encapsulant called DOWSIL™ EE-3200 Low Stress Silicone Encapsulant. The components in these devices undergo large thermal mismatch-related stress, not only related to heating up as a result of device operation, but additionally to the thermal cycling caused by sometimes extreme outdoor temperature variations. To minimize stress on the electronic components, DOWSIL™ EE-3200 Low Stress Silicone Encapsulant is very soft after curing, resulting in low stresses within electronics modules and thereby preventing breakdown of electronic components due to thermal expansion. Reliability of these devices is therefore improved. To illustrate this stress-releasing effect, results of a comparative test with a typical polyurethane-based encapsulant is shown in Figure 2. In a closed system, the pressure generated from the encapsulant due to its coefficient of thermal expansion (CTE) can cause damage to the device it is trying to protect. It can be seen that the pressure is 60 to 70% lower with DOWSIL™ EE-3200 Low Stress Silicone Encapsulant than with the polyurethane encapsulant.

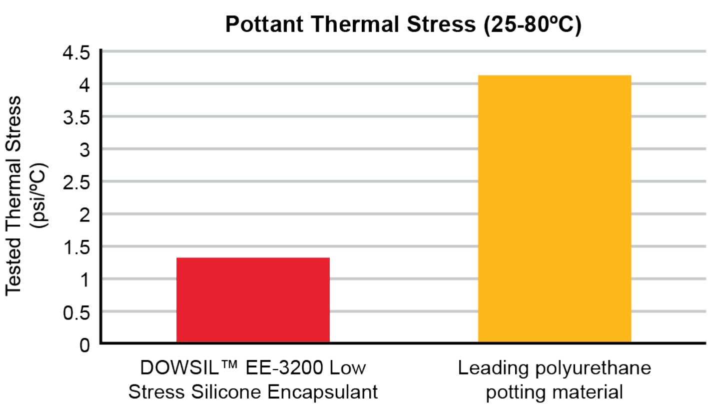

Figure 2: Thermal stress in a completely filled electronic module with DOWSIL™ EE-3200 Low Stress Silicone Encapsulant on one hand and with a polyurethane encapsulant on the other hand.

Apart from the low stress property, DOWSIL™ EE-3200 Low Stress Silicone Encapsulant has other advantageous features such as a lower viscosity than conventional encapsulants, allowing for faster, bubble-free filling of modules; good adhesion on common module enclosure materials; safe UL recognition; and a fast and convenient room temperature cure.

Case study: DOWSIL™ EE-3200 Low Stress Silicone Encapsulant used in micro-inverters

As an example, we present the use of DOWSIL™ EE-3200 Low Stress Silicone Encapsulant in micro-inverters for PV modules. While most photovoltaic modules have DC output and need to be connected in series to a large string inverter, so-called AC modules have recently emerged as an attractive alternative option for PV systems. These modules have micro-inverters mounted directly on the back of the module and result in an AC output at the module level. There are numerous advantages to AC modules. No special DC cabling is required and the electric arc hazard caused by DC output is eliminated. Moreover, PV system developers enjoy enhanced modularity and flexibility in the system design. Finally and critically, systems made with such modules show a much better behavior in shaded conditions than systems with conventional modules and lead to optimal operating point and energy yield. The main barrier to the adoption of AC modules was for a long time the lack of reliable, durable, low-cost and efficient micro-inverters.

Dow worked with a micro-inverter company that aimed to improve the reliability of their devices while meeting aggressive cost targets. Through discussion, understanding of the key requirements and several iterations of product modification and testing, the development of DOWSIL™ EE-3200 Low Stress Silicone Encapsulant was finalized and was found to provide the combination of enhanced, reliability, manufacturability and cost that the company needed. The manufacturer now provides a 20 year warranty on their micro-inverter, matching the typical warranty for PV modules and greatly expanding the application field of micro-inverters.

Thanks to the efforts of micro-inverters companies such as this one, AC modules have become a real alternative on the market and as a result AC modules sales have soared.

Conclusion

Distributed power generation requires efficient, durable and reliable power conversion devices. Dow has developed a new encapsulant called DOWSIL™ EE-3200 Low Stress Silicone Encapsulant that contributes to the penetration of this technology by ensuring that components are only exposed to very low stress during thermal cycling, therefore leading to enhanced reliability, durability and ultimately lifetime of power conversion conversion devices.

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