

# New Silicone Gel Enabling High Temperature Stability for Next-Generation Power Modules

**DOWSIL™**

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## Abstract

The power electronics industry is continuously seeking higher operating temperature for power devices and modules in order to increase the current density and decrease cooling requirements in power systems. This is driven by market trends, together with the emergence of new technologies allowing higher temperatures of operation (such as silicon carbide- and gallium nitride-based devices). The higher temperature of devices implies that the packaging materials (housing and encapsulant materials) also need to follow the same trend. As a leader in the silicone industry, Dow developed encapsulant solutions for power modules to meet industry requirements: soft and tough silicone gels have been formulated in order to sustain a continuous temperature of 200°C. The integrity of the gels in terms of hardness, dielectric strength and adhesion to commonly used substrates is presented in this paper.

## Synopsis

Increasing operating temperatures of power modules is a trend which has been observed over the past few years. Most power module manufacturers offer a broad portfolio of solutions with operating temperatures rated at 150°C, and we see new designs and technologies with operating temperatures of 175°C. Considering advances in silicon

Figure 1. Hardness of silicone gels SYLGARD™ 527 Gel and DOWSIL™ EG-3896 Gel after aging in air at 200°C

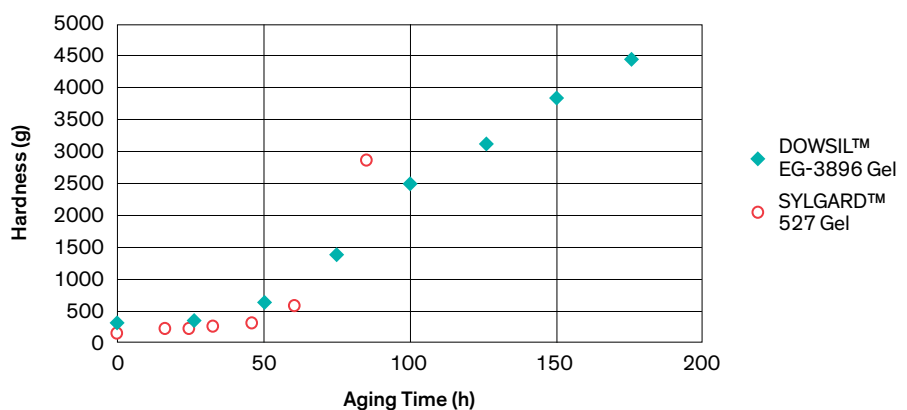
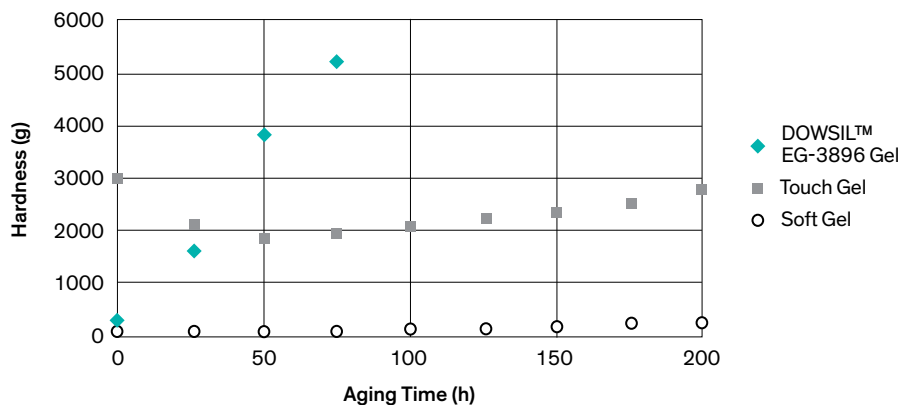


Figure 2. Hardness of silicone gels DOWSIL™ EG-3896 Gel (teal diamonds) and new formulations (tough gel with gray squares and soft gel with black circles) after aging in air at 225°C.



technology, together with the emergence and continuous broader adoption of silicon carbide in hybrid technologies, an operating temperature up to 200°C is not a myth anymore and becomes a reality.

Higher operating temperatures raise questions regarding the availability of materials suitable for the protection of power modules against moisture, dust and other external environment issues.

Over the past decades, Dow has the requirements of the power electronics industry in the protection field area by providing silicone gels suitable for operation up to 175°C in continuous mode. In order to meet the challenges of the next generation of power devices and power modules, Dow is developing a silicone gel solution capable of heat stability up to 200°C for extended periods of time.

Temperature has a strong impact on silicone gel properties in terms of hardness and integrity, thermally-driven oxidative degradation mechanisms occur when a polydimethylsiloxane silicone gel is exposed to elevated temperatures for an extended period of time. This is demonstrated in Figure 1 and 2, where we can observe that silicone gels rated for operating temperatures of 150°C (SYLGARD™ 527 A&B Silicone Dielectric Gel) and 175°C (DOWSIL™ EG-3896 Dielectric Gel) are hardening over time when exposed to a temperature of 200°C (Figure 1). This results in the cracking of the silicone material. Cracking occurs after 800 hours for the SYLGARD™ 527 Gel and after 1750 hours with the DOWSIL™ EG-3896 Gel. Such oxidation processes cannot be avoided in air environments due to the high permeability of silicones

to gases. However, it is possible to modify the formulation using additives in order to delay this degradation process, creating a silicone gel suitable for operation at higher temperatures.

Dow developed a high-temperature-resistant silicone gel suitable for continuous operation at 200°C. In order to meet the customer requirements in terms of power module lifespan, accelerated aging at 225°C has been used for the qualification of the products. Two new formulations were developed with different initial hardness to address the market needs. As depicted in Figure 2, both options could survive more than 2000 hours of aging at 225°C in air without cracking (squares and gray circles for the soft and hard versions, respectively). An increase in hardness is still observed (driven by oxidation degradation mechanism), but the speed of degradation was considerably reduced when compared to the DOWSIL™ EG-3896 Gel (blackoutlined circles).

The dielectric strength of the materials has also been measured after aging at 225°C. Despite the hardening of the silicone gels, the dielectric strength is preserved and unaltered by the aging at an elevated temperature.

We also investigated the adhesion and absence of delamination of the gel on different substrates commonly used in the power electronics industry. We could demonstrate that the adhesion on the substrate survived the aging condition at 225°C for more than 2,000 hours on gold, copper, aluminum, ceramic and silver.

The stability of the new formulations up to 200°C in continuous mode can also be used as a reliability enhancer for applications operating at a temperature below 200°C. This new family of silicone products can henceforth be extended to the entire range of power modules for reliability benefits.

### Conclusion

Dow developed a silicone gel suitable for operation at high temperature in order to meet the market trends. The silicone gel retains its integrity in terms of flexibility, dielectric strength and adhesion to substrates after several thousand hours of aging at 225°C.

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