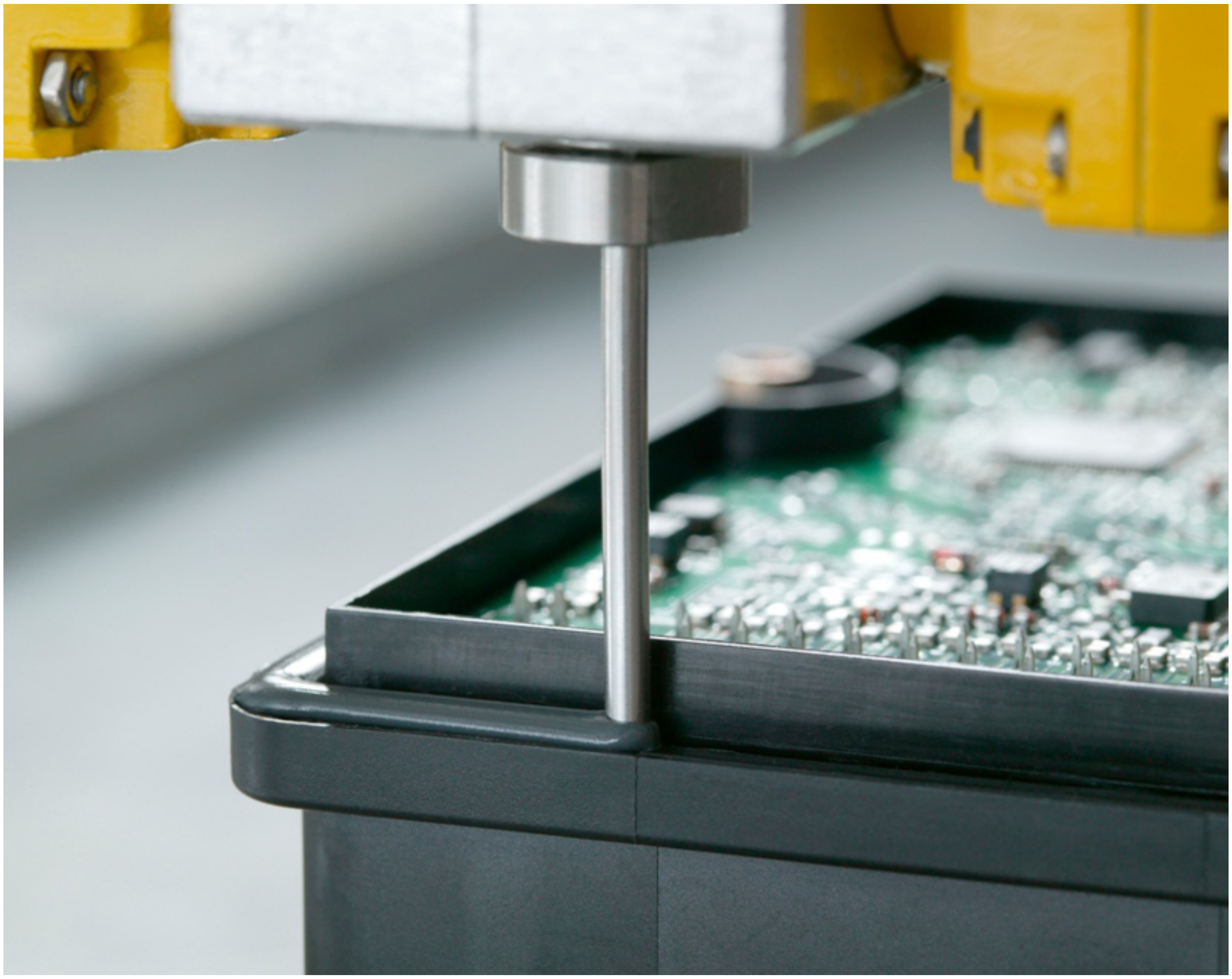

# ADHESIVE BONDING OF THERMOPLASTICS IN AUTOMOTIVE

WACKER

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Governments around the world are enacting myriad policies in an effort to reduce greenhouse gas emissions (GHGs) and combat the growing climate change crisis. As the transportation sector is a leading source of GHGs, much attention is focused on this industry.

In the U.S., for example, the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) enacted the Safer Affordable Fuel Efficient (SAFE) Vehicles Rule in 2020. SAFE mandates that automakers must improve the fuel efficiency of their vehicles for model years 2021-2026 by 1.5% per year.

Car manufacturers are taking various steps toward these goals. One key effort involves lightweighting (i.e., reducing the vehicle's weight in order to improve fuel economy and reduce emissions), which can be achieved through materials replacement. Examples include the use of plastics instead of metals and adhesives instead of traditional fasteners such as screws and rivets.

## PLASTICS IN AUTOMOTIVE ASSEMBLY

According to the American Chemistry Council, plastics comprise 50% of a modern car's volume.[1] Plastic materials of various grades can be found throughout the vehicle's interior and exterior, with ubiquitous materials such as polypropylene and Polybutylene Terephthalate (PBT), finding applications ranging from electronic control units to sensors to dashboards.

Thermoplastic materials used in automotive applications can be engineered to feature advanced properties such as superior strength and durability, as well as resistance to chemicals, corrosion, and temperatures of 150˚C and more. Due to their advanced properties, these high-performance plastics often find use in critical, harsh environments such as automotive engines.

Thermoplastics also offer the key benefit of being lighter in weight than most types of metals that are traditionally used in automotive manufacturing. Indeed, the ACC reports that plastics represent merely 10% of a vehicle's weight, despite comprising half of the volume.[1] As a result, the adoption of thermoplastics as a replacement for metals is growing as carmakers seek ways to meet increasingly stringent regulatory requirements.

## CHALLENGES WITH THERMOPLASTICS

While thermoplastics offer multiple benefits especially in electronics, they can also present challenges during assembly when they are bonded using adhesives. The main issue is the low surface energy of most thermoplastics. A substrate's surface energy (also known as surface-free energy) is essentially the amount of extra energy available on the surface of the material.

For reference, a newly waxed car's surface has low surface energy. As a result, water beads up on the car's surface instead of pooling or spreading along the surface of the car.

Generally speaking, the higher the substrate’s surface energy, the better the adhesive bond. When applied to a substrate with low surface energy, adhesives are not able to “wet out” (i.e., spread across it), which is essential when developing an adhesive bond. High surface energy leads to better adhesion, as the adhesive is able to wet out on the substrate and create a strong bond.

A secondary challenge arises for thermoplastics when they are strengthened through the addition of materials such as minerals. While reinforced thermoplastics offer enhanced mechanical properties in terms of strength and durability, the added materials can also introduce contaminants that negatively impact adhesion.

Surface pretreatment methods, such as the use of ultraviolet (UV) light and plasma, can be incorporated in the automotive assembly process to increase a substrate’s surface energy and thus create a stronger, longer-lasting adhesive bond. Plasma pretreatment is additionally effective in removing contaminants from the surface of the material.

Plasma pretreatment essentially oxidizes the substrate’s surface, increasing the surface energy and providing additional opportunities for the chemical reactions necessary for adhesive bonding to take place. It can also micro-etch the substrate’s surface, which serves to clean the substrate while enabling increased mechanical interlocking.

## ADHESIVE CURING MECHANISMS AND CHEMISTRIES

Adhesives can be generally categorized as one- or two-component products. One-component adhesives do not require mixing with any additional material in order to cure; however, an external source such as heat or moisture is needed to initiate the curing process. These types of adhesives are generally easy to use and apply, but the cure time can be lengthy and dependent on atmospheric conditions such as humidity.

With two-component adhesives, curing generally begins almost immediately once the two materials are combined. Applying an external source such as heat can additionally speed the curing of two-component adhesives. While the application of two-component adhesives may require more handling than their one-component counterparts, their enhanced cure speed results in faster processing time and higher throughputs.

Adhesives are formulated to address specific end-use requirements; as a result, adhesive chemistries vary widely. Epoxy- and silicone-based adhesives are two types commonly used in various elements of automotive assembly.

Generally speaking, epoxies provide a strong, hard bond. Their hardness can lead to challenges in high-temperature applications, however. Particularly in the automotive engine, where temperatures vary widely, epoxies struggle without the flexibility needed to accommodate the expansion and compression of the engine’s components.

Silicone adhesives retain a degree of rubber-like flexibility while still providing strong adhesion. As a result, they are less susceptible to the thermal stresses endured in automotive engine assemblies. This high-temperature flexibility and strength lead to a more durable assembly and longer service life less likely to degrade over time even under harsh conditions.

## STUDY DETAILS

### Materials

A series of tests was conducted to study adhesion in relation to three polyphenylene sulfide (PPS) substrates, as well as the potential benefit of plasma pretreatment. PPS is a high-performance thermoplastic characterized by resistance not only to temperature but also chemicals and abrasion, making it ideal for use in harsh automotive applications. The three PPS substrates used in this study differed in the amount and type of filler/reinforcement: PPS1, 40% glass filler by weight; PPS2, 50% glass/mineral filler by weight; and PPS3, 60% glass/mineral filler by weight.

Three silicone-based WACKER adhesives were studied: SEMICOSIL® 987, ELASTOSIL® RT 725, and ELASTOSIL® N 198.

#### SEMICOSIL® 987

A one-part, heat-cured silicone elastomer, SEMICOSIL® 987 typically shows good primerless adhesion to most substrates, including thermoplastics. It features a pronounced shear thinning effect, making it easily dispensed. SEMICOSIL® 987 is ideally cured at 125˚C or more. At a 1-cm thickness, curing ranges from 10 minutes at 150˚C to 6 hours at 100˚C.

#### ELASTOSIL® RT 725

ELASTOSIL® RT 725 is a two-part, heat-cured silicone. It cures within minutes at temperatures between 80˚C and 100˚C, forming a rubber with high tensile strength and high elongation. Its short curing time significantly improves the production efficiency of automatic dispensing processes.

#### ELASTOSIL® N 198

A one-part, moisture-cure product, ELASTOSIL N198 cures to a flexible silicone rubber on exposure to water vapor in the air. It shows good primerless adhesion to many substrates.

### Testing Processes

Single-lap shear tests were conducted in two batches according to a modified ASTM D1002-10 standard.[2] Samples in the first batch were left untreated. In the second batch, samples underwent plasma treatment prior to adhesive application.

All test substrates were cut into 1-in. strips and cleaned with isopropyl alcohol. The adhesives were applied at 1-mm thick on each sample, with a ½-in. sample overlap.

Tests were conducted to study the effects of heat aging (180˚C), thermal shock (-45˚C to 150˚C), and environment (85˚C and 85% humidity). Samples in the heat ageing and environment tests were evaluated after 500 and 1,000 hours. Samples in the thermal shock tests were evaluated after 250 and 500 cycles.

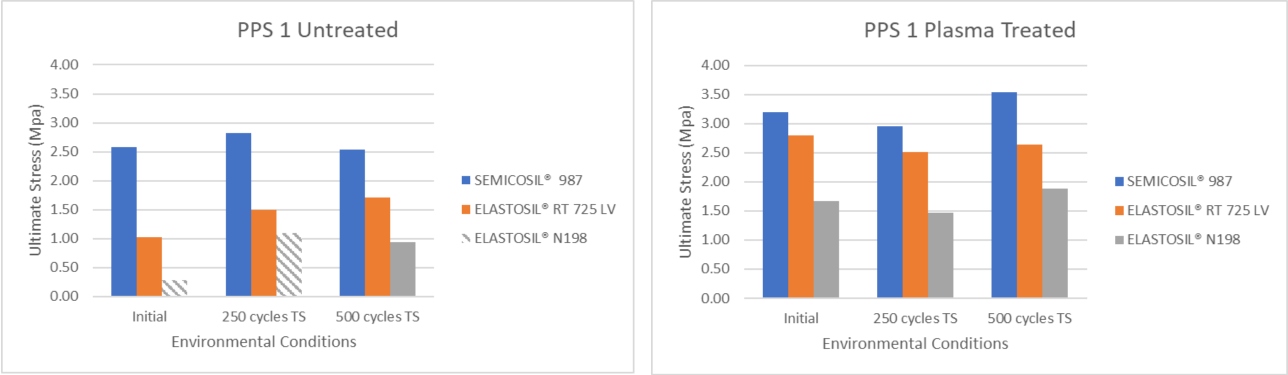
## RESULTS

In most of the samples, plasma pretreatment improved adhesion during heat ageing. SEMICOSIL® 987 was least successful in terms of heat aging, losing significant adhesion on both PPS1 and PPS2 despite having the highest initial strength of the three adhesives. ELASTOSIL® RT 725 exhibited more bond strength than ELASTOSIL® N 198 on all samples, particularly PPS1.

Plasma pretreatment also proved to be beneficial during the thermal shock tests, resulting in improved adhesion for all samples and adhesives. SEMICOSIL® 987 maintained the strongest adhesive bond among the three adhesives in each stage and on each substrate, followed by ELASTOSIL® RT 725 and ELASTOSIL® N 198.

As a moisture-cure product, ELASTOSIL® N 198 perhaps unsurprisingly struggled during the environmental tests, losing adhesion on all samples. Here again, however, plasma pretreatment led to improved adhesion for all samples and adhesives, and SEMICOSIL® 987 maintained the strongest adhesive bond among the three adhesives in each stage and on each substrate, followed by ELASTOSIL® RT 725.

Interestingly, thermal shock and environmental testing on PPS3 resulted in substrate failure in 10% of the untreated samples and 7% of the treated samples. This effect was not seen with the other plastics.



*The charts above summarize the data from a recent silicone adhesion study run by WACKER technical experts. Bonded plastics were run through multiple legs of extreme environmental exposures to measure bonding reliability. All silicones tested showed varying performance and benefits. Plasma treated samples demonstrated a significant increase in cohesive bond strength. The solid colored bars indicate cohesive failure while the striped bars indicate adhesive failure.*

*Solutions for thermoplastics sealing and bonding represent a matrix of challenges; WACKER technical experts can help align substrate and adhesive selections with best practice processes.*

## CONCLUSIONS

Many types of adhesives are feasible for automotive assembly applications, with different silicone-based products offering strength and durability under heat ageing, thermal shock, and environmental conditions. In addition, the plasma pretreatment of thermoplastic substrates is an effective method to improve adhesion for these demanding applications.

Partnering with a knowledgeable supplier is recommended to ensure the best adhesive product fit in order to reach optimal end product quality and production levels. When collaborating with WACKER's technical service and expertise, silicone adhesives can be tailored to ensure the successful bonding of thermoplastics in specific harsh automotive assembly applications. To learn more, visit www.wacker.com/contact.

## REFERENCES

1. Plastics: Major Markets—Automotive, https://plastics.americanchemistry.com/Market-Teams/.
2. ASTM D1002-10(2019), Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal), https://www.astm.org/Standards/D1002.htm.