PCB and Systems Assembly

Technical Manual

Thermal Radical Cure™ Technology

DOWSIL™

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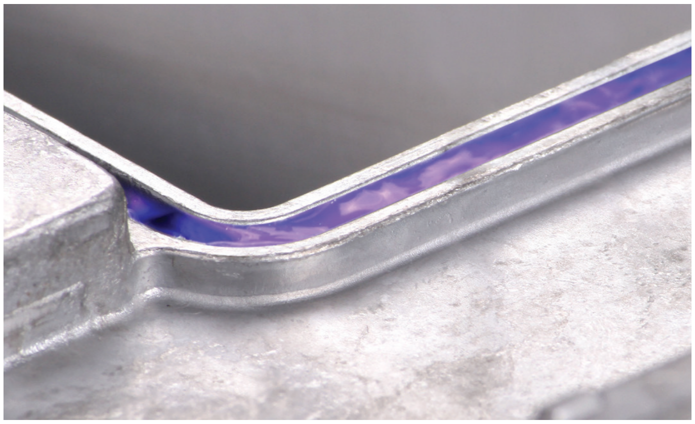
Introduction



This manual is intended to provide guidance on a new technology — Thermal Radical Cure™ (TRC) — and the silicone adhesives from The Dow Chemical Company that are created with this science.

This manual will aid in developing a basic quality assurance program around the use of these TRC adhesives in printed circuit board (PCB) systems assembly applications. The recommendations made in this manual are based on Dow's more than 70 years of experience with silicones and adhesives for PCB systems and device assembly applications.

Note: Since applications vary in design and requirements, this manual cannot be considered a comprehensive guide for every situation.

Silicone Performance

As the market for reliable device assembly has grown over the past two decades, so too has the need for materials that can protect these components under the diverse and demanding conditions in which they must function. One material's technology has emerged as ideally suited to the task: silicones.

In these applications, silicones are specifically designed and formulated to function as:

- Durable dielectric insulation
- Stress-relieving shock and vibration absorbers over a very wide temperature/humidity range
- Barriers against environmental contamination
- Thermal management materials

Silicones are resistant to extreme temperatures and moisture, ozone and ultraviolet degradation. Special silicone formulations can also provide enhanced chemical stability and resistance. And their pliable elastomer or gel-like forms contribute to their ability to provide stress relief during mechanical or thermal shock.

DOWSIL™

silicones by Dow

About Dow and Performance Silicones

The Dow Chemical Company
The Dow Chemical Company (Dow) combines science and technology knowledge to develop premier materials science solutions that are essential to human progress. Dow has one of the strongest and broadest toolkits in the industry, with robust technology, asset integration, scale and competitive capabilities that enable it to address complex global issues. Dow's market-driven, industry-leading portfolio of advanced materials, industrial intermediates, and plastics businesses deliver a broad range of differentiated technology-based products and solutions for customers in high-growth markets such as packaging, infrastructure, and consumer care. Dow is a subsidiary of DowDuPont (NYSE: DWDP), a holding company comprised of Dow and DuPont with the intent to form three strong, independent, publicly traded companies in agriculture, materials science and specialty sectors. More information can be found at **dow.com**.

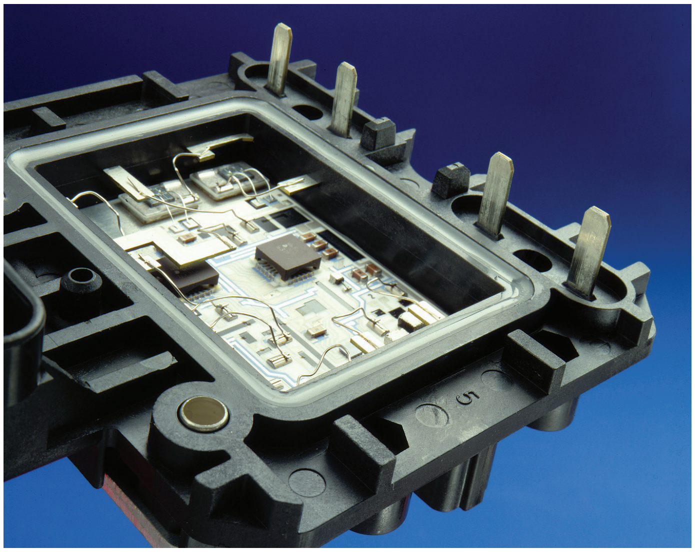
Performance Silicones
Performance Silicones, a unit within Dow's Consumer Solutions business, delivers a portfolio of performance-enhancing solutions to serve the diverse needs of customers and industries around the world. From transportation and lighting to building and construction and chemical manufacturing, Dow's Performance Silicones business helps our customers solve their most challenging problems. As a global leader in innovation and silicon-based technology, we are committed to bringing new solutions to the market that do more for our customers and continue to improve the lives of consumers worldwide.

Visit **consumer.dow.com/pcb** to learn more.

Silicones as Adhesives

Silicone adhesives from Dow are substances capable of holding materials together by surface attachment. Silicone sealants are materials applied to a joint or gap to form a seal against gas or liquid entry. They provide:

- Excellent electrical properties
- Good weather resistance
- Stability and flexibility over a wide temperature range
- Outstanding adhesion (normally primerless) to a variety of substrates
- Heat-accelerated or room-temperature cures
- Better flexibility and a broader service temperature range than epoxy adhesives and sealants
- Stronger unprimed adhesion to metal substrates and a broader service temperature range than urethane adhesives



Challenges and New Solutions

PCB Systems Marketplace

With more and more electrical systems and components proliferating and converging across the consumer, transportation and military platforms, manufacturers are continuously looking for ways to improve PCB module assembly while also lowering the cost of ownership.

In these competitive markets, solutions may focus on materials offering high levels of protection, adhesion, thermal performance and reliability, which also allow design and processing flexibility for smaller boxes, higher power density and greater cost-effectiveness.

New Chemistry for New Adhesion

Dow is investing research time and resources to make a difference in the PCB systems assembly industries by expanding our portfolio of silicon-based solutions. This includes reinventing the science behind the curing of adhesives.

Based on marketplace needs, Dow scientists set out to develop adhesives that would cure and adhere at lower temperatures — and/or in less time — than other products previously available.

Dow created a new chemistry that enables improved adhesion performance between different types — and new types — of substrates. The new adhesives may help reduce a module's cost of ownership in various ways, including removing some processing steps, lowering cure temperatures, and/or reducing curing times.

Thermal Radical Cure™

Definition and Overview

For more than 30 years, PCB systems assembly manufacturers have been adapting their processes to work with the benefits and limitations of some silicone products.

Traditional silicones
While hydrosilylation silicone adhesives have a long assembly time, provide a reasonably fast cure at >125°C (257°F), and bond to many common substrates, they also require a hot oven and, in some cases, can be sensitive to contamination from sulfur- and amine-containing compounds.

Traditional moisture-cure silicone adhesives don't require ovens, are not as sensitive to contamination, and bond to a wide variety of substrates. They are, however, slow to reach their full cure and offer a short assembly time. If heated before they cure, they are prone to bubbles and voids and a center that may be soft or weak.

New technology
Dow experts developed and patented the Thermal Radical Cure™ (TRC) silicone technology to address these challenges and more — harnessing some of the best features from traditional silicone adhesives and eliminating or reducing many of the drawbacks.

After years of development, the first TRC adhesives were put to the real-world test — and proven — with a beta group of Tier 1 and original equipment manufacturers (OEMs).

The new adhesives have the advantages that silicone materials provide, such as good stability and a wide temperature range, combined with a new cure profile, adhesion versatility and adhesion strength performance for a broad range of PCB systems assembly applications.

TRC adhesives offer these benefits:

Design enabling and material savings

- Robust adhesion to a wide variety of substrates
- Adhesion includes wet substrates (conditions dependent)

Process savings

- Rapid/low-temperature cure with robust adhesion
- 100-percent cohesive failure in minutes
- Little to no pretreatment for activation
- Potential for reduced cleaning requirements

Low voiding

- Cure below boiling point of moisture

Robust to contamination

- Not sensitive to typical traditional heat cure trace contaminations (such as sulfur species, amines, etc.)
- May eliminate expensive pretreatments

Product Grades

Thermal Radical Cure™ from Dow is a cure mechanism that can support a range of products, where rheology, cure, thermal conductivity or other properties may be adjusted to meet the needs of specific customers and applications.

2015 R&D 100 WINNER

The innovative and patented Thermal Radical Cure™ technology from The Dow Chemical Company received a prestigious R&D 100 Award in 2015.

In this manual, we will be discussing the product family of TRC adhesives:

As a starting point, DOWSIL™ EA-7100 Adhesive cures at 100°C (212°F) in approximately 15 minutes.

For an even lower-temperature cure, where lower temperatures are required, please contact your local Dow sales representative to discuss your options.

DOWSIL™ TC-2022 Adhesive is a thermally conductive adhesive in this new product family. It is a companion product for co-cure applications.

More TRC products are in development.

TRC Adhesives

Basic Properties

For the typical properties of the individual TRC adhesives, refer to the technical data sheets at **consumer.dow.com/pcb**.

FIGURE 1: Example* properties of TRC adhesives from Dow

Specification Writers: These values are not intended for use in preparing specifications. Please contact your Dow sales office or your Global Dow Connection before writing specifications on this product.

Property	Unit	Result
Viscosity	cP mPa-sec Pa-sec	360,000 360,000 360
Thixotropy	—	5.8
Pre-Assembly Time @ 25°C (77°F) (open time after dispense)	minutes	60
Assembled Pre-Cure Time @ 25°C (77°F)	hours	>24
Recommended Heat Cure Time @ 100°C (212°F) (time/temp at bondline)	minutes	15
Specific Gravity (cured)	—	1.09
Tensile Strength	psi mPa kg/cm^2	490 3.4 34
Adhesion — Lap Shear to Aluminum	psi mPa N/cm^2	350 2.4 240
CTE	ppm/C	247

*Example only. Refer to technical data sheets for specific product properties and more information.

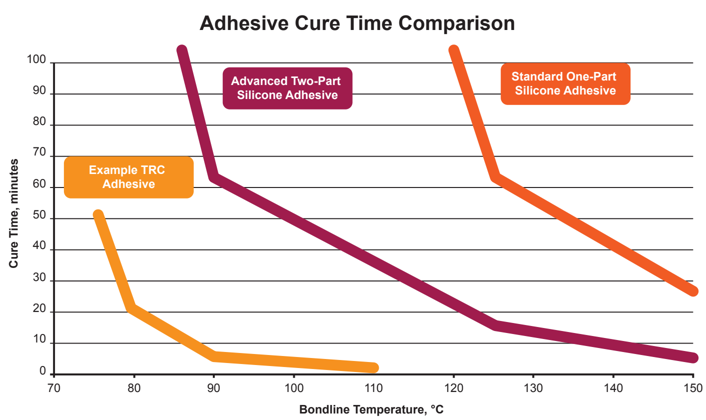
Benefits Summary

TRC adhesives from Dow are very fast, low-temperature curing silicone adhesives that bond to a far wider selection of substrates than typical silicone adhesives. Consequently, TRC adhesives enable new designs with alternative materials.

There are many benefits from this curing technology, including:

- Lower cure temperatures and/or faster cure times than traditional silicone adhesives
- Adhesion to a broader range of substrates (plastics, metals, cured silicones and wet substrates)
- Durable adhesion strength
- Adhesion forms simultaneously with cure
- Working life of up to four weeks (depending on specific product and conditions)
- Adhesion in harsh environments
- Potential elimination of some cleaning steps

FIGURE 2: Fast/low-temperature cure for reduced cycle time



Savings. The new TRC adhesives may reduce PCB modules' costs by removing process steps, lowering temperatures, reducing time and more.

Potential time and cost savings

- Reduce part heat-up time
- Reduce cure time — from 30 to 60 minutes down to three to 15 minutes
- Reduce cool-down time
- Reduce oven length (smaller ovens)
- Reduce electricity use with lower temperatures
- Greatly reduce cycle time (Figure 2)
- Increase manufacturing schedule flexibility with longer working time
- Reduce cleaning (possible)
- Eliminate part drying (possible)
- Reduce/eliminate voids
- Reduce scrap (possible)
- Greatly broaden plastic choices for design flexibility
- Eliminate contaminant sensitivity (no cure poisoning/inhibition from contaminants)
- Positive results in reliability testing

Applications

TRC technology is typically used for the assembly of device housings made from plastic and/or metals and for attaching connectors, electronic control units (ECUs) or sensors on to substrates.

Most sealing applications are viable, including lid seals, connector seals and vibration staking. Some of the applications could include:

Transportation

- Powertrain
- Braking
- Safety
- Driver assistance
- Convenience/comfort
- Power distribution
- Cameras
- Displays

Industrial

- IGBT modules
- Smart utility meters
- Energy conversion
- Power supply
- Power and automation

Cure

Cure Mechanism ("Inside-Out" Cure)

Development of the Thermal Radical Cure™ technology from Dow required several formulation advances. The one-part polydimethylsiloxane (PDMS) materials have an innovative dual-cure system.

Primary cure

First, the adhesive contains an organic peroxide that initiates the cure extremely fast — at lower temperatures than typically possible with heat-cure silicone adhesives. As the adhesive is heated, this peroxide dissociates to create free radicals that then propagate the adhesive bond.

This adhesive cures in the bulk and at the bondline first. Outer areas can take longer to solidify because the material is oxygen-inhibited. As a result, the very last areas to cure tend to be the outermost surfaces in contact with the air. Because of this, the adhesive may have a thin, wet outer surface, even while the bulk of the material has cured and obtained a level of strength and adhesion.

Secondary cure

To compensate for this, the formulation also contains moisture-cure components that typically result in a non-tacky, dry adhesive surface within 24 to 48 hours of room-temperature aging. It is normal for this adhesive to have a tacky or sticky outer surface until this "secondary cure" has finished.

Subsequent heat exposures or reduced oxygen levels during this time may accelerate the surface cure. Higher cure temperatures and/or longer heat-cure times lessen this effect. Heat exposure can accelerate the surface cure because, with heat, the cure kinetics are faster than the oxygen diffusion rate.

FIGURE 3: General tack-free guidelines for TRC adhesives in a low-oxygen environment (solder reflow oven)

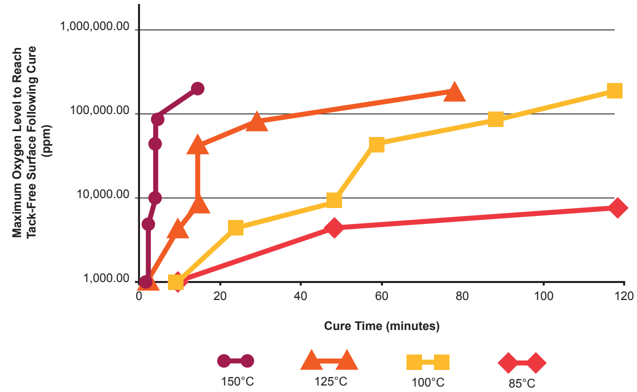


Figure 3 shows the cure times, temperatures and oxygen levels needed to achieve a surface that is solidified (not a wet liquid) but is still quite tacky/sticky. A dry surface was obtained after 24 to 48 hours of room-temperature aging. Note that cohesive adhesion within the bondline was obtained in much shorter cure times.

FIGURE 4: Cure comparison in a typical lid seal design in oxygen environment

One-Part Moisture Cure

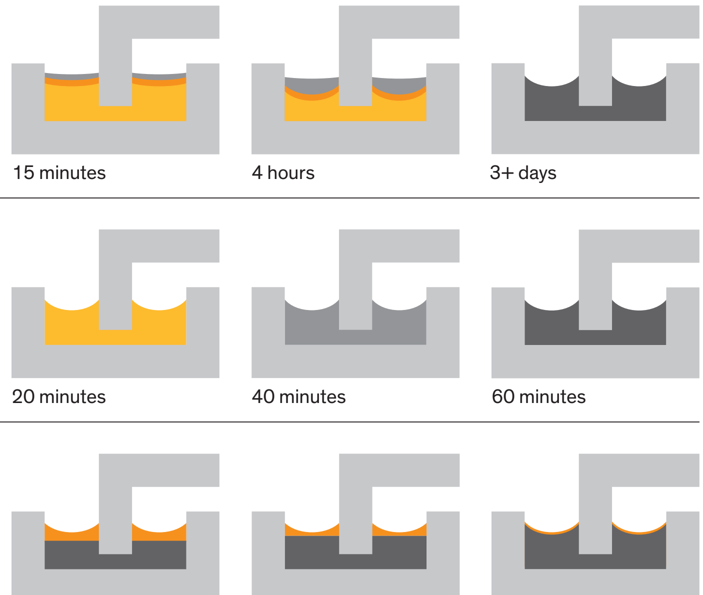
- DOWSIL™ 7091 Adhesive Sealant
- At 25°C
- Cured adhesive "skin"
- Liquid adhesive

One-Part Addition Cure

- DOWSIL™ 3-6265 Thixotropic Adhesive
- At 125°C
- Liquid adhesive

One-Part Thermal Radical Cure™

- DOWSIL™ EA-7100 Adhesive
- At 100°C
- Liquid adhesive
- Adhesion forms simultaneously with cure



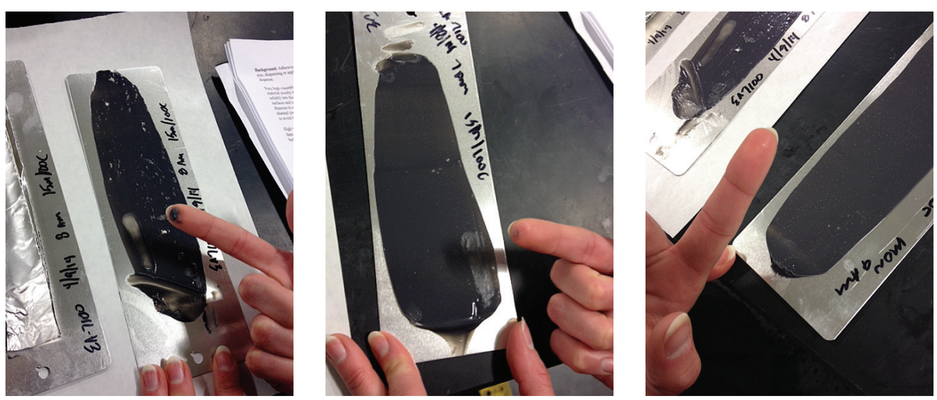
Simultaneous Crosslink and Adhesion

With the TRC technology, cure and adhesion occur simultaneously — from the inside out. The cure and adhesion happen at the bondline before skin-over time.

Cohesive adhesion begins to develop in as fast as three minutes at 100°C (212°F). The adhesives are hot test curable, allowing for immediate testing.

The bondline between the two substrates is cured with complete adhesion (100-percent cohesive failure) immediately after the cure, even though the exposed material may still appear wet or uncured.

FIGURE 5: Tacky surface



Initial | 24 hours | 48 hours

Processing

Cure Profiles (Time/Temperature)

The cure time will depend on the level of cure required by the process or application. An initial question: what level of cure is required for the specific application? If the application simply needs a seal, then that is formed very quickly. If a more structural cure is needed, then that cure would take additional time. Depending on the level of cure needed for the application, the cure time may be shortened — thereby shortening the cycle time even more.

The cure profile is the recommended time at bondline temperature — not including warm-up time. Every part will require a different warm-up time.

A benefit of lower temperature curing is the opportunity for shorter cycle times. With less oven warm-up time needed for ramping the temperature (heating the bondline) and then less cool-down, time can be reduced on both ends of the cycle. Additionally, smaller/shorter ovens can be used with less energy.

With heat-cured adhesives, bonding may sometimes be improved by curing longer or hotter. Greater adhesion strength may develop with subsequent heat exposures. In some rare cases, since the TRC adhesives include moisture-cure components, full adhesion may not be observed until 24 to 48 hours of room-temperature aging. (This has been observed with some forms of polyethylene, for example.) The lap shear adhesion value may increase by approximately 15 percent over the next few days.

TRC adhesives from Dow are formulated with all necessary ingredients for cure — making deep-section or confined cures possible. They can be dispensed and parts left unassembled for 60 minutes at room temperature. Once assembled, parts can generally be held for at least 24 hours at room temperature before heat curing.

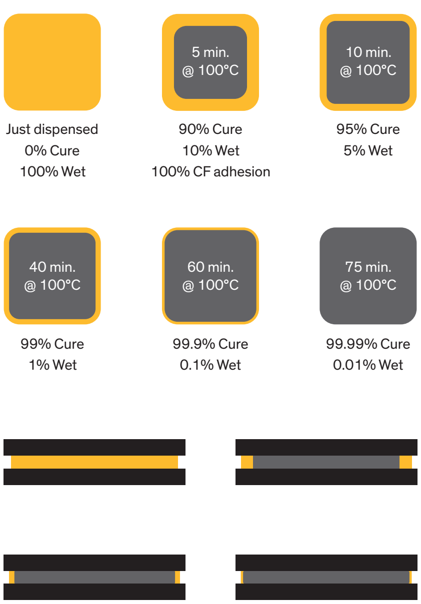
Cycle Time Advantages

Several TRC attributes lead to greatly reduced cycle times, including:

- Reduced part heat-up time
- Reduced cure time — from 30 to 60 minutes down to three to 15 minutes
- Reduced cool-down time
- Reduced oven length (smaller ovens)
- Hot test curable (for immediate testing option)

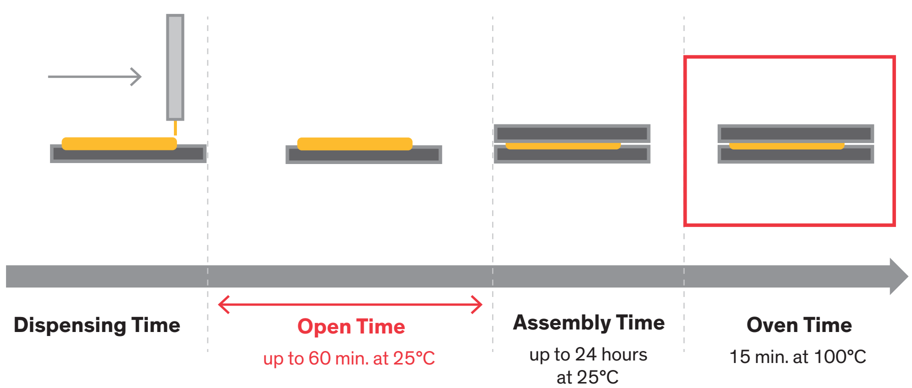
Reduced energy enables cost savings.

FIGURE 6: When is the TRC adhesive cured enough for the application?



TRC example shown is DOWSIL™ EA-7100 Adhesive

FIGURE 7: Open time of TRC adhesives



Testing Method:

- Example shown is DOWSIL™ EA-7100 Adhesive
- Unassembled samples for X minutes at 25°C
- Cure at 100°C
- Record failure mode and adhesion strength

Voiding

The unique chemistry of the Thermal Radical Cure™ adhesives from Dow does not suffer from hydrogen off-gassing.

Air entrainment
Handling the material by hand increases air introduction.

Sample Preparation

Since TRC adhesives bond through a different chemical mechanism, they require little to no pretreatment or cleaning for activation.

Contaminants
Traditional addition-cure silicones can be sensitive to certain contaminants, such as select sulfur species and amines, which interfere with bonding and/or with cure.

The TRC adhesives are highly robust to surface contamination and do not display this sensitivity. They behave similarly to moisture-cure silicones.

Surface treatments like plasma, UV and corona processes and priming may not be needed. In fact, over-treatment may decrease the bonding ability. However, heavy contamination on the surface may need to be removed before bonding.

Substrate testing
Due to the wide variety of substrate types and the differences in substrate surface conditions, general statements on adhesion and bond strength are impossible.

To ensure maximum bond strength on a particular substrate, 100-percent cohesive failure of the adhesive in a lap shear (or similar adhesive strength test) is desired. This ensures compatibility of the adhesive with the substrate being considered. Also, this test can be used to determine minimum cure time or to detect the presence of surface contaminants, such as mold release agents, oils, greases and oxide films.

Equipment Recommendations

The equipment required is the same as other typical dispensable adhesives.

Because of the low-temperature-cure catalyst, the working time is limited at elevated temperatures. As the ambient temperature approaches the activation temperature of the catalyst, that will initiate the cure and limit the working time. Refer to product-specific application bulletins at **consumer.dow.com/pcb** for information on working time.

Cold storage and cold shipment are required.

The material is highly thixotropic and may require a different valve design or needle size to achieve higher flow.

Curing in a low-oxygen oven can reduce the surface tack (Figure 3, page 7).

The chemical bond to organic substrates (plastics) is incredibly durable, and additional substrate preparation is often not required. Unlike traditional heat cures, pretreating plastic substrates with extensive plasma treatments can decrease adhesion (depending on the conditions and level).

Adhesion

Substrates

TRC adhesives provide robust adhesion to a wide range of surfaces. These adhesives allow the bonding of both traditional and new, alternative materials. The compatibility with so many diverse substrates enables improved performance and new designs — including those that use alternative plastics to reduce overall manufacturing costs.

Dow scientists continue to add to the following list of substrates*:

Plastics

- Polybutylene terephthalate (PBT)
- Poly(methyl methacrylate) (PMMA) (Plexiglas)
- Polycarbonate (PC)
- Liquid crystal polymer (LCP)
- Polyamide (nylon) — no drying needed
- Polyvinyl chloride (PVC)
- Phenolic
- Epoxy
- Polyimide
- Polyethylene (low-density polyethylene/LDPE, crosslinked polyethylene/PEX)
- Polyphenylene sulfide (PPS)

Metals

- Aluminum
- Steel
- Brass
- Copper

Cured silicones

- Addition-cure silicones
- Some moisture-cure silicones

Other substrates (contact Dow)

Ceramics

- Glass
- Aluminum oxide

*Typical 100-percent cohesive failure in peel @ 30-40 ppi, 21-28 N/cm lap shear, 300-450 psi, 2-3 MPa.

TRC adhesives have been specially formulated to provide unprimed adhesion to many reactive metals, ceramics, glass, laminates, resins and plastics, including plastics to which traditional silicone adhesives do not bond well. Additionally, these adhesives have been shown to have good self-adhesion, bonding strongly to cured samples of themselves and to many other silicones.

However, predictable adhesion cannot be expected on non-reactive metal substrates or non-reactive plastic surfaces, such as nickel, fluorinated materials, or certain plastics. Special surface treatments, such as chemical etching or plasma treatment, sometimes can provide a reactive surface and promote adhesion to these types of substrates.

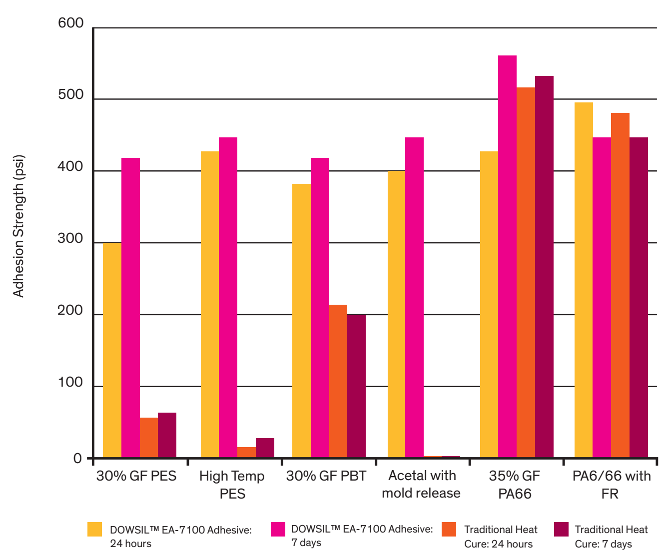
Poor adhesion may be experienced on plastic or rubber substrates that are highly plasticized because the mobile plasticizers act as release agents.

Small-scale laboratory evaluation of all substrates is recommended for validation before production trials are made.

Compatibility with Other Silicones

TRC adhesives have not been observed to degrade plastics or other surfaces to which they are applied and cured. Other silicones, such as moisture-cure or addition-cure silicones, can be co-cured in the same closed module and/or near the TRC products. However, addition-cure silicones may experience some cure issues when in direct contact with cured or uncured TRC adhesives.

FIGURE 8: Examples of adhesion to typical substrates



One-part, moisture-cure (organo-titanate catalyzed) silicones
There are no known compatibility issues with curing TRC adhesives and moisture-cure silicones. However, moisture-cure silicones by themselves are prone to forming voids or bubbles if they are exposed to temperatures above approximately 65°C (149°F) before they are fully cured. TRC adhesives have been found to bond strongly to some moisture-cured silicones. Testing should be performed to verify this in any application where it may be required.

Two-part, condensation-cure (organo-tin catalyzed) silicones
There are no known compatibility issues with curing TRC adhesives and condensation-cure silicones. However, two-part, condensation-cure silicones by themselves are prone to forming voids or bubbles if they are exposed to temperatures above approximately 65°C (149°F) before they are fully cured. TRC adhesives have not been found to bond strongly to this type of silicone.

Addition-cure (organo-platinum catalyzed) silicones
TRC adhesives can be cured directly in contact with addition-cured silicones and, in many cases, have shown good bonding to these materials. They can be co-cured together, even in closed containers. However, if they are in contact, there may be incomplete cure of the addition-cure silicone in a very thin layer at the interface. It is recommended to space them at least one millimeter apart.

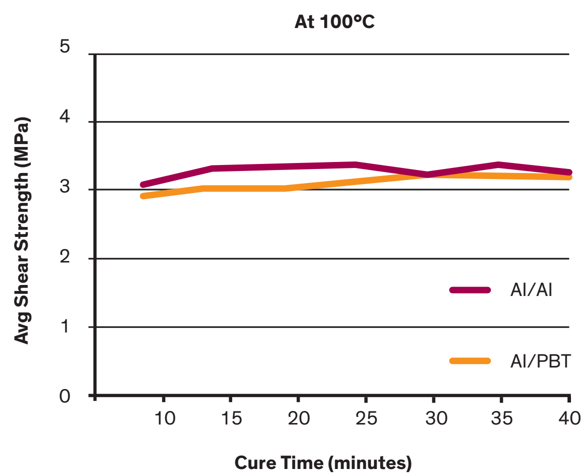
Compatibility with new gap fillers
The platform of gap filler technology recently launched by Dow encompasses a broad range of thermal conductivity levels for varied performance needs. There can be some degree of sensitivity to inhibition of the gap filler product — in particular with the low thermal conductivity (Tc) grades of these products (i.e., Tc of ~1.5 W/mK) when used in non-direct contact with the DOWSIL™ EA-7100 Adhesive.

If the application requires a combination of gap filler and TRC adhesive, compatibility testing in the application/cure process is recommended to verify complete cure will occur. This sensitivity exists in a co-cure process.

Lap Shear

Figure 10 shows that the example TRC adhesive adheres as strongly to either aluminum (Al) or polybutylene terephthalate (PBT) — and that the bond is developed very quickly.

FIGURE 10: Shear strength of one example TRC adhesive bonding to various substrates



Lap shear, 7-mil bondline, Celanex 3300D PBT (30% GF), 2"/minute rate on Tensometer. (DOWSIL™ EA-7100 Adhesive is product example.)

FIGURE 9: Cure compatibility of organo-platinum (Pt) catalyzed (addition-cure) silicone and TRC adhesive

Heat cure without contact — no incompatibility.

If TRC adhesive is applied *in contact* with cured Pt catalyzed silicone, the TRC adhesive will cure — and *even bond strongly.*

If uncured Pt catalyzed silicone is applied *in direct contact* with cured or uncured TRC adhesive, there can be inhibition at the point of contact. (Approximately one millimeter of Pt catalyzed silicone may not cure.)

DOWSIL™ 3-6265 Adhesive (Pt Catalyzed)

DOWSIL™ EA-7100 Thermal Radical Cure™ Adhesive

Durability

DOWSIL™ silicone adhesives retain their original physical and electrical properties over a broad range of operating conditions, which enhances devices' reliability and service life. The stable chemistry and versatile processing options of these adhesives offer benefits for a variety of needs, including increasing component safety and reliability, potential cost reductions and increasing the performance envelope of devices or modules.

Useful temperature ranges

For most uses, silicone elastomers should be operational over a temperature range of -45 to 200°C (-49 to 392°F) for long periods of time. However, at both the low- and high-temperature ends of the spectrum, behavior of the materials and performance in particular applications can become more complex and require additional considerations.

For low-temperature performance, thermal cycling to conditions such as -55°C (-67°F) may be possible, but performance should be verified for your parts or assemblies. Factors that may influence performance are: configuration and stress sensitivity of components, cooling rates and hold times and prior temperature history.

At the high-temperature end, the durability of the cured silicone elastomer is time and temperature dependent. As expected, the higher the temperature in processing, the shorter the time the material will remain useable.

Solvent exposure

When liquid or vapor solvent or fuel exposure can occur in an application, the TRC silicone adhesives are intended only to survive splash or intermittent exposures. They are not suited for continuous solvent or fuel exposure. Testing should be done to confirm performance of the adhesives under these conditions.

Aged Studies

In Figures 11 and 12, there is no significant drop in adhesion performance shown over time and exposure to either dry heat or damp heat conditions.

FIGURE 11: Adhesion with aging, at 150°C (302°F)

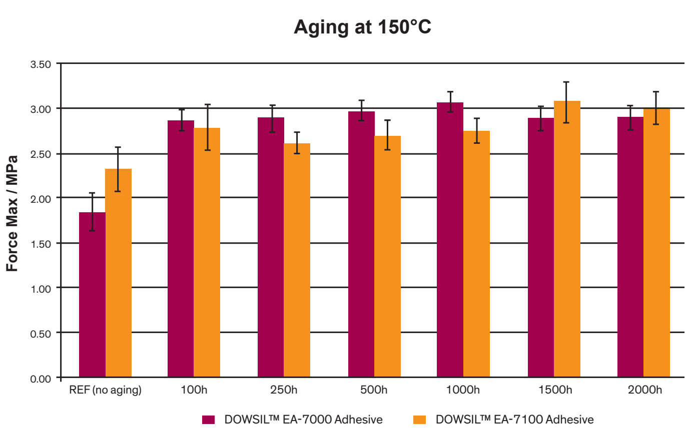
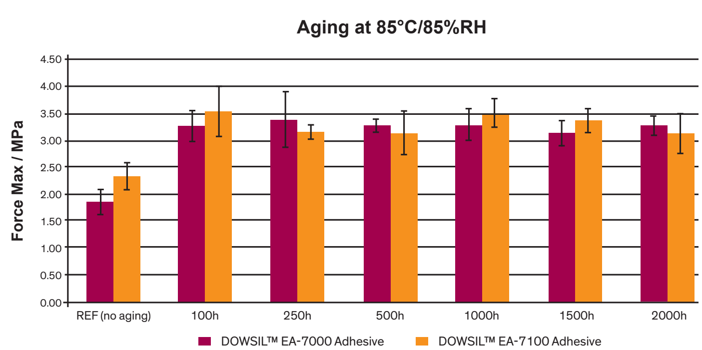


FIGURE 12: Adhesion with aging, at 85°C (185°F)



Inhibition

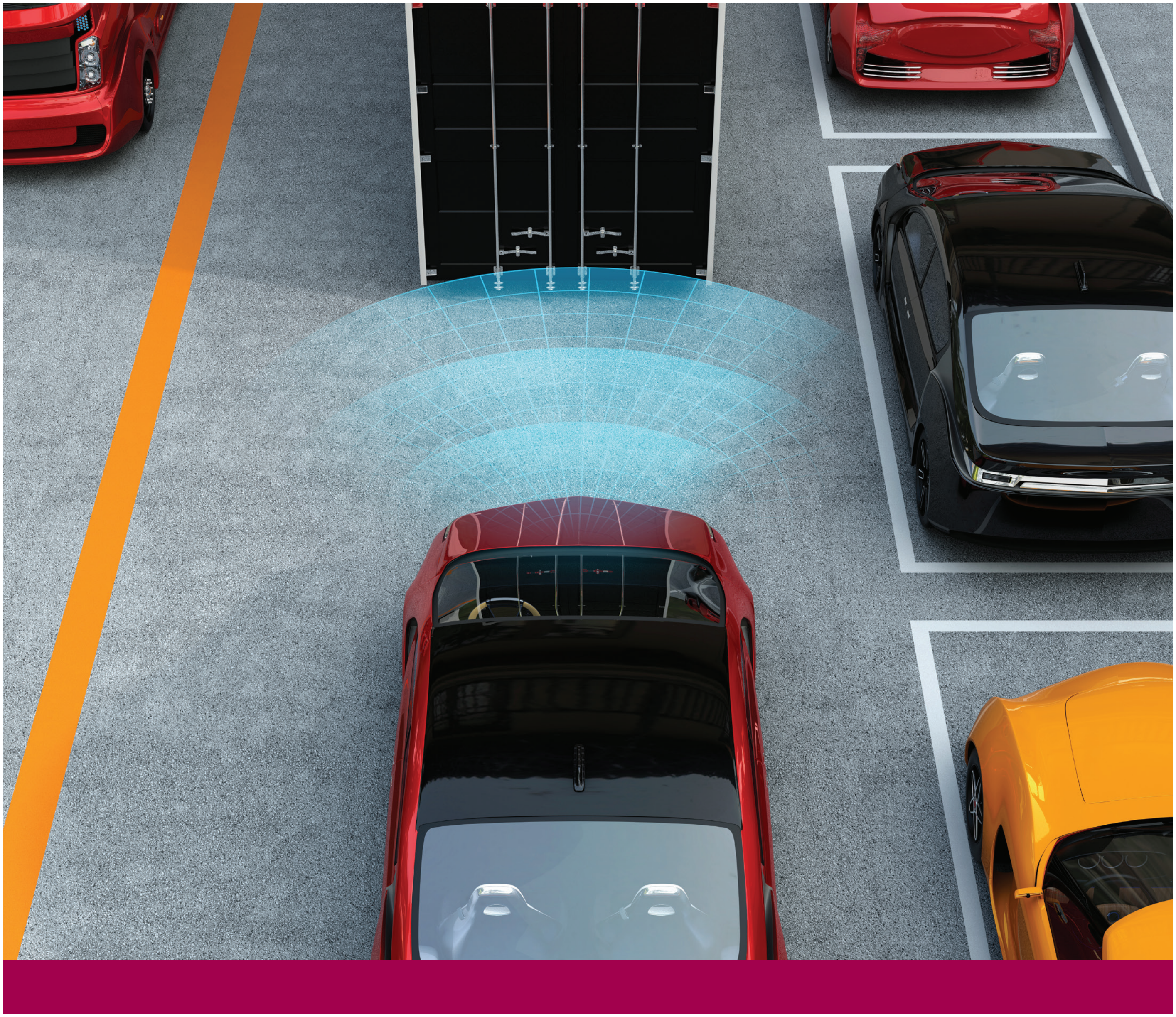
Typical Platinum (Pt) Poisons

Traditional addition-cure adhesives utilize platinum catalyzed systems that can be sensitive to inhibition. Certain species — such as amines, sulfur, phosphorous and many nitrogen-containing materials — can have the tendency to complex with the platinum, tying up the catalyst and limiting the reactivity levels required for cure.

This new family of TRC adhesives does not use platinum to initiate cure, so it is not sensitive to traditional platinum inhibitors. This results in a chemistry that adheres readily to a broad range of substrates, regardless of these historically contaminating species.

Oxygen

Because the TRC adhesives are oxygen-inhibited, curing in a low-oxygen oven can reduce surface tack (Figure 3, page 7).

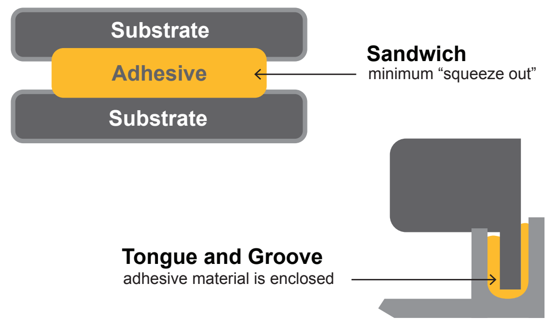


Design Recommendations

Because TRC adhesives are inhibited by oxygen, it is desirable to expose the least amount of TRC product to oxygen as possible.

Two common industry designs are the tongue and groove and the sandwich designs (Figure 13). In the sandwich design, for example, it is desirable to minimize the "squeeze out" of the adhesive material to reduce exposure to oxygen. In the tongue and groove design, the material would be enclosed and not exposed to oxygen.

FIGURE 13: Typical designs



Storage and Handling

Shelf Life

In order to achieve the very fast and low-temperature cure performance, TRC materials are formulated with temperature-sensitive ingredients.

Cold storage at or below 5°C (41°F) is required to achieve a shelf life of at least six months.

Warm-up Times

Before opening and using the product, allow containers of TRC adhesives to warm up until moisture will no longer spontaneously condense onto the package. Moisture condensing onto the adhesive during or after it is dispensed can cause voids or bubbles to form in the bondline during cure. Typically syringes and cartridges may require one or more hours to warm up, while larger packages may require 16 to 24 hours.

Working Life

Refer to the product application bulletins located in the product finder at **consumer.dow.com/pcb** for specific working life information.

As a TRC material progresses toward the end of its working life, the viscosity will increase and the material will become more difficult to dispense. (This increase in viscosity provides feedback to the operator.) The adhesion performance is retained during this transition. (If you can pump it, it will adhere.)

Exposure to higher room temperatures will greatly reduce working life times.

Dispensed, pre-assembly open time
TRC adhesives contain moisture-reactive components. Once the material is exposed to air, these components will begin to react at the surface.

Typically, we have found that when parts at 25°C (77°F) are assembled within 60 to 90 minutes after dispensing, the normal wet-out, cure and adhesion performance are maintained.

Longer times may be possible in some applications, but, at some point as the surface begins to cure, it will not properly wet-out when the part is fully assembled. That may not give the desired sealing or adhesion performance. Less open time may be experienced at temperatures higher than 25°C (77°F).

Dispensed, assembled, pre-cure time
As long as parts are assembled within the guidelines described above, part assemblies can be held for at least 24 hours before oven curing without affecting the final cured adhesion performance.

Processing and Dispensing

All equipment must be grounded, and standard dispense equipment can be used effectively with this material. This product is a highly thixotropic material so you may need to adjust the valve to achieve desired flow rates.

It is recommended to use 304 or 306 stainless steel grades for valves and fittings.

In temperature-sensitive environments or warmer climates, we suggest using cooled lines or pail chiller technology to minimize high-temperature exposure of the material.

Extended Downtime

When ending production or when there will be extended downtime, the processing equipment should either be purged or chilled to prevent the material from setting up in the equipment.

Chilling
Working life is directly related to the accumulated exposure to elevated temperatures. Chilling or cold storage can help with the material's life.

One option is to cool the line area. For example, one customer built an acrylic housing around the line, chilling inside the housing to extend the life of the material.

During downtime, another option is to chill the dispense unit (the head, nozzle, etc.). Using this method, another customer has the dispense unit on a wheeled cart, which workers can roll into a cooler for holidays and shutdowns to maintain shelf life.

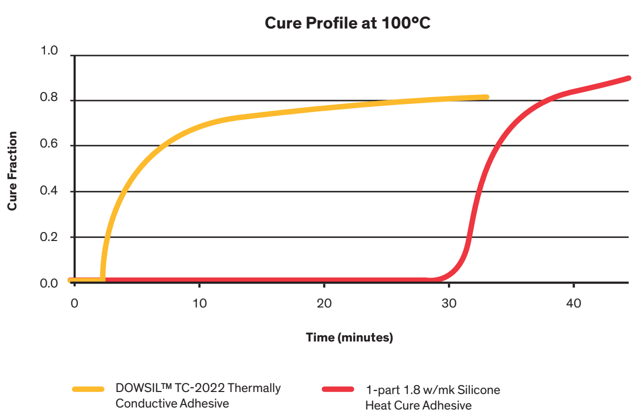
Purging
To purge the processing equipment after using TRC adhesives, we recommend using DOWSIL™ 200 Fluid 300,000 CST as the purge material. The chemistry and the viscosity of this purge material are carefully selected so it will "drag" through the system to clean the equipment walls.

Purge timing and volume suggestions
The volume should typically be three times the line volume. Purge timing should be for any extended high-temperature exposure beyond the working life recommendation or extensive shear/ temperature environment in the line.

Thermally Conductive Thermal Radical Cure™

With decreasing geometry boundaries and increasing power density requirements, many applications will require a thermally conductive adhesive to help direct heat to the sink and out of the device. Recognizing the limitations in processing for multiple cure cycles, this material was designed to co-cure effectively, with the adhesive enabling designers to use one-material chemistry and cure the device in one process. Following several technical breakthroughs, now both the lid seal adhesive and the thermally conductive adhesive can be simultaneously cured using the same low-energy profile, and customers can begin "greening" their production — while saving on operating costs and cycle time.

FIGURE 14: Comparison with current technology



Electric and hybrid-electric vehicles often rely on very large capacitors, which require substantially longer heating times when curing a thermally conductive adhesive to intimately bond the capacitor to the heat sink. At 100°C, DOWSIL™ TC-2022 Thermally Conductive Adhesive (the first product in this thermally conductive platform) begins to cure after just a few minutes, whereas a standard silicone one-part thermally conductive adhesive generally starts to cure after more than 30 minutes at 100°C or higher. Similar to DOWSIL™ EA-7100 Adhesive, DOWSIL™ TC-2022 Adhesive also rapidly develops adhesion to varied substrates. With these adhesives advances, the cost to manufacture vehicles can be more effectively managed, and design boundaries in material selections can be broadened.

This thermally conductive material provides the robust adhesion exhibited in the adhesive while adding the conductive filler technology specifically designed to manage dispensability and conductive performance. This new thermally conductive adhesive, as the name suggests, must do two things well: transport heat away from PCB system components and adhere the PCB and/or device to a metal housing (heat sink). While heat transport during operation is critical, the under-hood environment requires other rigorous testing as well. Like previous silicone composites, this product helps PCB modules pass the stringent battery of tests (including high-temperature operation, thermal cycling, thermal shock, vibration, dry-heat aging, humid aging and drop testing) that enables ordinary drivers to operate their vehicles confidently in harsh weather conditions on roads around the world.

FIGURE 15: Cure is accelerated by increased temperature

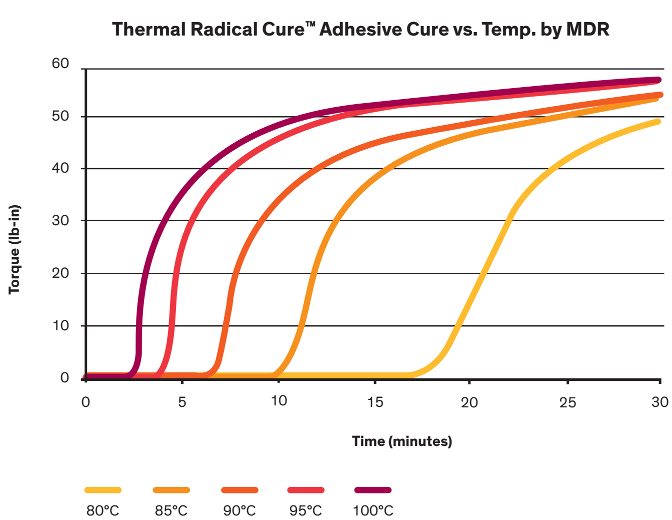
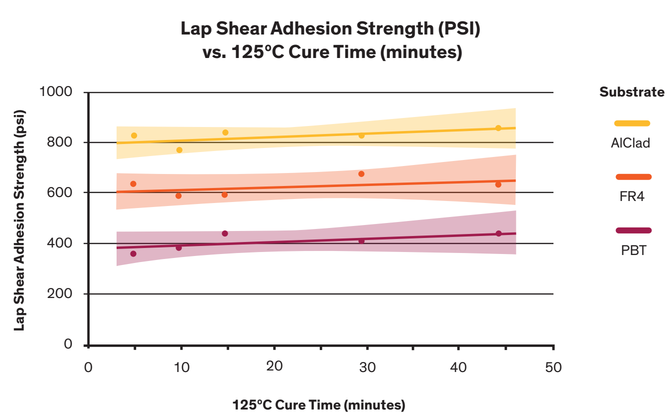


FIGURE 16: Adhesion to typical substrates for thermally conductive adhesive



Troubleshooting

"It didn't cure."

Even if the material looks sticky, wet and seemingly uncured, the material likely has cured/adhered at the bondline. The outer layer of the exposed material (squeeze out) may remain tacky/wet for 24 to 48 hours.

"I need to shut down for a week of holidays."

It is best to purge or to disconnect the dispense unit and chill if temperatures will be elevated. Working life at 35°C (95°F) is limited.

"I have lower adhesion than expected."

Adhesion is a surface interaction between a substrate and an adhesive. Strong and durable adhesion is normally obtained when an adhesive can thoroughly wet-out and chemically bond to the substrate surface. TRC technology was specially formulated to bond to a much wider variety of substrates than typically possible with standard silicone adhesives — without extensive surface cleaning or treatment. This occurs primarily with the activation of the cure chemistry and, secondarily, with the moisture-cure components included in the adhesive.

With heat-cured adhesives, bonding may sometimes be improved by curing longer or hotter. Greater adhesion strength may develop with subsequent heat exposures. Since TRC adhesives include moisture-cure components, full adhesion may not be observed until 24 to 48 hours of room-temperature aging in some rare cases. (This has been observed with some forms of polyethylene, for instance.)

Since these adhesives bond through a different chemical mechanism, surface treatments such as plasma, UV, corona or priming are typically not needed. Some levels of treatment may even decrease the bonding ability. In many cases, reducing the surface treatment or eliminating it altogether may improve bonding performance. Severe surface contamination will likely still need to be cleaned off.

Also consider that some plastics can have a weak outer "skin," depending on how they were processed or molded. An example is liquid crystal polymer (LCP). The TRC adhesive may bond quite well to such an outer surface, but when it is removed, the remaining plastic surface may appear fairly smooth and without adhesive residue.

This could lead to a conclusion that the adhesive did not bond well. However, magnified inspection of the surface may show evidence that the weak outer skin of the plastic has sheared off. In this case, the adhesive may have bonded more strongly to this weak surface skin than the plastic's skin did to the underlying plastic.

"I detect an odor."

TRC adhesives contain silicone polymers with chemically different end-groups compared to other silicones, resulting in a characteristic odor to the material. These end-groups impart a characteristic odor to the material that some may associate with acrylic materials (similar to a common house paint). The odor tends to be strongest in the uncured material and when it is first heated to cure.

Over time at room temperature, or with subsequent heat exposure, the odor greatly diminishes and may become completely unnoticeable. This odor is normal to the unique silicone polymers used. Local ventilation can be used to minimize odor.

Imagine



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We bring more than just an industry-leading portfolio of advanced silicone-based materials. As your dedicated innovation leader, we bring proven process and application expertise, a network of technical experts, a reliable global supply base and world-class customer service.

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