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NEW TECHNOLOGIES IN SILICONE ADHESIVES

Silicone-based film adhesives, PSAs and tacky gels each offer unique advantages.

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Two-part silicone film adhesives, silicone pressure-sensitive adhesives (PSAs) and silicone tacky gels are often used in vastly different applications, from scar treatment therapies to solar cell assemblies. When seeking the most suitable type of silicone for a specific application, knowing the differences among these materials is essential. Adhesion, cure time and physical strength are among the factors to consider.

Perhaps the most advantageous feature of silicone is that its properties can be modified and optimized as needed. Comprising the siloxane polymer backbone of a silicone are repeating helical silicon-oxygen bonds whose bond angles yield large amounts of free volume, leaving space for design (see Figure 1). The virtually complete freedom of rotation around (and potential interaction with) the Si-O-Si bonds is accounted for by the large atomic volume of the silicon atoms and the size and position of constituent groups. A silicone's properties can be tailored to suit an application's needs by varying these functional pendant groups (R) on the polymer chain or by adding fillers.

FILM ADHESIVES

Film adhesives are one- or two-part silicone systems with varying adhesion strengths. The properties of a two-part film adhesive can be adjusted by adding fillers to the part A component, such as when bonding through-wires on the back of a solar panel. Because the wires need to go through the array substrate where electricity from the solar cells is collected, it is paramount that these adhesives be electrically dissipative. Such silicone films often contain non-electrically conducting ceramic fillers, like aluminum oxide or zinc oxide, that impart a thermal conductivity of up to 1 W/mK and resistivity from 108-400 ohm-cm. For other uses, carbon black can be added for electrical conductivity.

The part A component of a two-part film adhesive is a semi-solid film supplied on a release liner, while the part B is a liquid activator (or catalyst) similar to a primer. The part A ranges in thickness from 0.18-0.76 (7-30 mils) and, if left uncatalyzed by the part B, has practically unlimited shelf life. This film is a firm, uncured silicone that requires no mixing and can be handled, die-cut or pressed onto substrates while maintaining its dimensions.

Figure 1. Silicone Polymer Chain

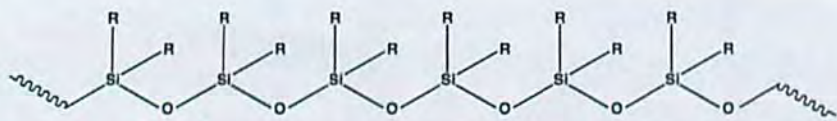
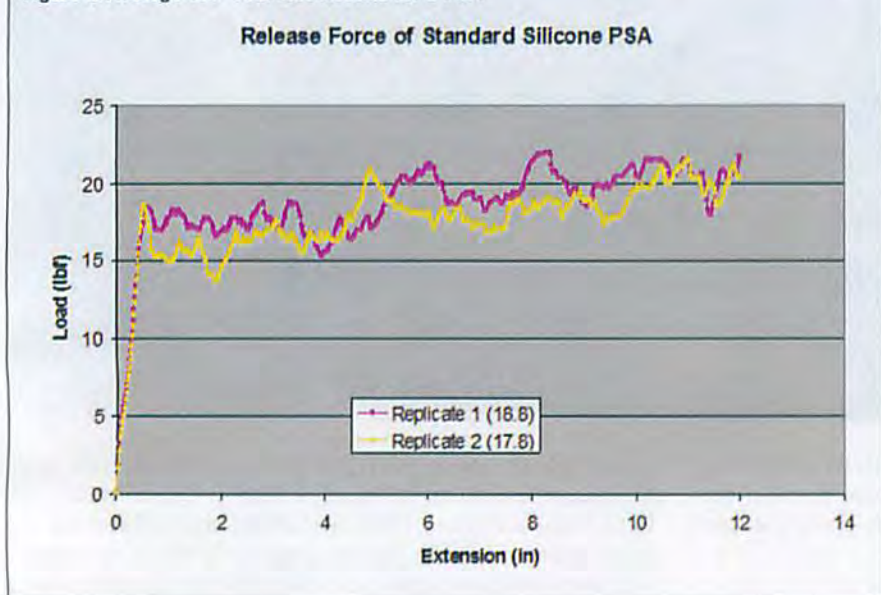


Figure 2. Average 180° Peel Test Results for a PSA



To apply a film adhesive, the liquid part B must be wiped onto a surface and the solvent permitted to evaporate for 15 min before the part A film is applied and the two substrates to be bonded are pressed together. Regardless of humidity, film adhesives can be heat accelerated at 60°C for four hours or permitted to cure for 24 hours at room temperature.

Generally speaking, two-part film adhesives provide permanent bonding and offer higher adhesion strengths compared to tacky gels and PSAs. For this reason, they are often chosen for adhering appliqué such as logos or tail numbers on commercial aircraft. They are also commonly used when adhering catheter balloons, die-cut components from sheeting, or other device assemblies for healthcare and medical device applications.

TACKY GELS

A silicone gel is a loosely crosslinked network of polymers containing no reinforcing fillers. Although silicone tacky gels lack the silica or resin credited with supplying adhesive strength to the system, they are still able to provide enough tack (short-term, pressure-induced attachment) for certain adhesive applications. Known for modifiable

tack and superior breathability, silicone tacky gels are ideal for processing into sheets or pads for applications requiring a temporary adhesive. They are commonly found in wound care and scar management therapies, transdermal therapeutic systems, face masks, and ostomy and incontinence care products.

Because they lack the reinforcement that film adhesives contain, gels tend to be lower in viscosity in the uncured state, allowing flexibility for various processing techniques. Gels can be formulated to cure at low temperatures, making them ideal for use with pharmaceutical agents that are unstable at higher temperatures; expanding application options include multi-laminate, reservoir or monolayer drug-in-adhesive delivery systems. In addition, the crosslink density of the silicone polymers can be designed to yield a very firm or soft and compliant gel. This versatility makes tacky gels ideal candidates for virtually any application requiring a silicone material with low or temporary adhesion strength.

PRESSURE-SENSITIVE ADHESIVES

As the name denotes, PSAs are sensitive to pressure, meaning that they produce tacky bonds instead of the strong adhesion

found with many two-part film adhesives. The typical adhesion strength and thickness of a silicone PSA are 1.0-3.5 N/cm (1-2 lb/in.) and 25-75 microns (0.0075-0.003 in.), respectively. With adhesive properties similar to those of tacky gels, PSAs are commonly used in the same applications as tacky gels, as well as in cosmetic and prosthetic devices.

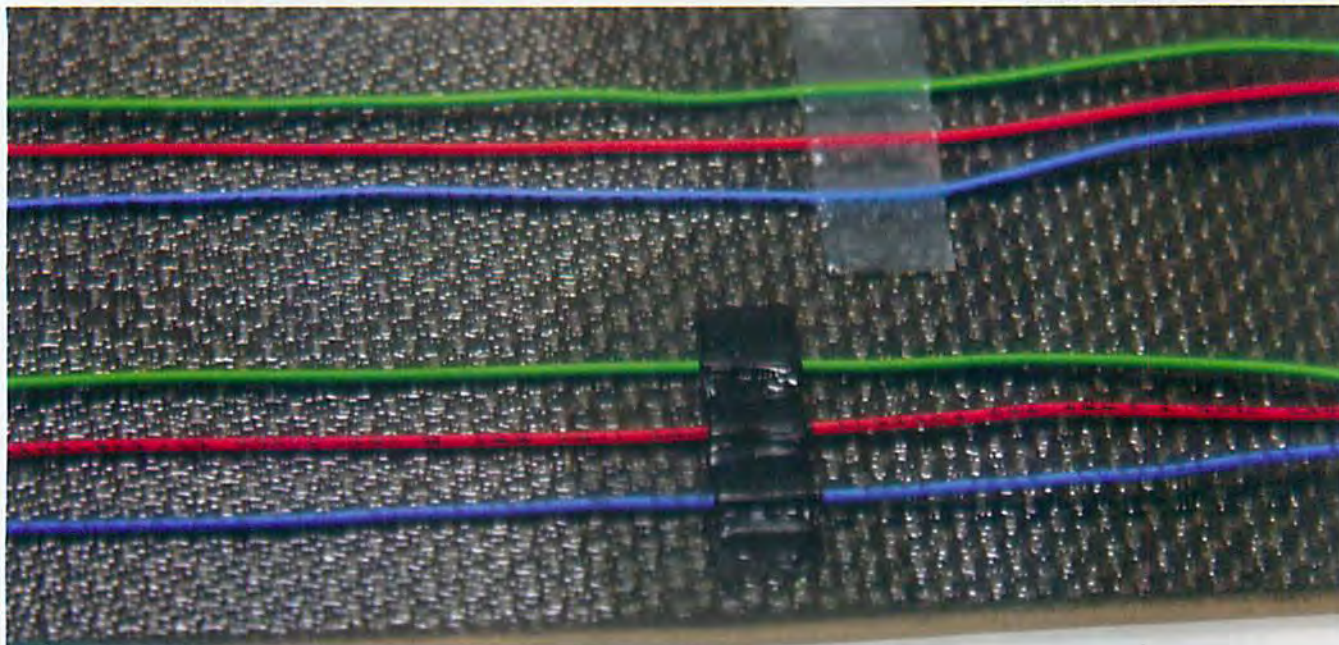
A PSA is a one-part system made by partially crosslinking a silicone polymer with a silicone resin. PSAs can be provided in liquid form or pre-coated on a release liner as a semi-cured film. Like their two-part alternatives, PSA films offer initial tack with no mess, and can be die-cut to specific shapes prior to application. Controlled bond lines provide the opportunity for rework, making both PSA and two-part films good interface materials. A drawback to using films is that they are sometimes difficult to work with because they easily tear, bubble and stick to themselves. Plastic and other types of liners can facilitate handling. Converters of tape and adhesive-backed components take the liquid PSA and either wet coat in sheet form for small applications or in roll form (e.g., pilot coat and full-width production coat) when large quantities are required.

Processing can be problematic for certain applications because of the solvent in which liquid PSAs are often dispersed. For example, while the solvent serves to provide viscosity control, it may also restrict the design of transdermal drug delivery systems. PSAs can be formulated to be further crosslinked via a platinum or peroxide catalyst. PSAs that use peroxide systems require an elevated temperature to cure, which may negatively impact active agents. This limitation may require that the PSA is processed in a separate step before application.

PSAs hydrogen bond with substrate surfaces to create adhesion that is typically low at initial contact but improves significantly as the PSA wets onto the substrate. Depending on the bonding strength desired, adhesion can be formulated from low tack, or low adhesion, for temporary bonds that can later be easily removed or from a higher tack PSA with good adhesion of approximately 3.5 N/cm (2 lb/in.) for more permanent bonds. Usually 24 hours after a PSA is applied, adhesion is measured by a 180° peel or lap

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Cured film adhesives tack down wires on a composite board.



shear test, which quantifies adhesion strength by calculating the amount of force required to break the bond between the adhesive and substrate. Results of a 180° peel test on a standard silicone PSA are shown in Figure 2 (p. 29).

One advantage of PSAs, in both *healthcare and non-healthcare-related* applications, is clarity. Due to their high light transmittance, PSAs are often ideal adhesives for applications requiring optical coupling between substrates, such as bonding cover glasses to solar cells. For this application, adhesives are required to exhibit > 95% transmittance through the visible light region, a standard that PSAs surpass by 2% at 400 nm. In addition to being transparent with a refractive index of 1.41, these silicone adhesives are also resistant to yellowing and can be partially crosslinked for better high-temperature resistance, such as for use in extraterrestrial projects.

Suitable for use in space environments, low outgassing PSAs can be made by removing most of the low molecular weight species of a typical silicone PSA. Generally, these low outgassing adhesives exceed the outgassing requirements of ASTM E 595 testing specification of 1.0% total mass loss (TML) and 0.1% controlled volatility condensable material (CVCM). The PSAs with lower outgassing properties can be thicker than the terrestrial-grade PSAs—up to 125 micron (5 mils)—and offer adhesion strengths as low as 0.17 N/cm (0.1 lb/in.)². Like their non-space-grade versions, the low outgassing PSAs are supplied in solvent and can be coated onto different substrates or delivered on a release liner to make a free film.

FIND THE RIGHT OPTION

When it comes to silicone PSAs, tacky gels and film adhesives, what is ideal for one application may not be suitable for another. Two-part film adhesives and PSA films offer cut peel-and-stick options for quick manufacture of parts with little to no wait time for the cure; dissimilar adhesion strengths determine utilization. Tacky gels and liquid PSAs work well where low-viscosity materials with short-term adhesion are required. Variations in processing, performance and physical characteristics define these silicone adhesives as viable candidates for use wherever their qualities are desired.

For more information, contact NuSil Technology at 1050 Cindy Lane, Carpinteria, CA 93013; phone (805) 684-8780; or visit www.nusil.com.

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