

Battery fire protection: Materials that can take the heat

Product selection guide

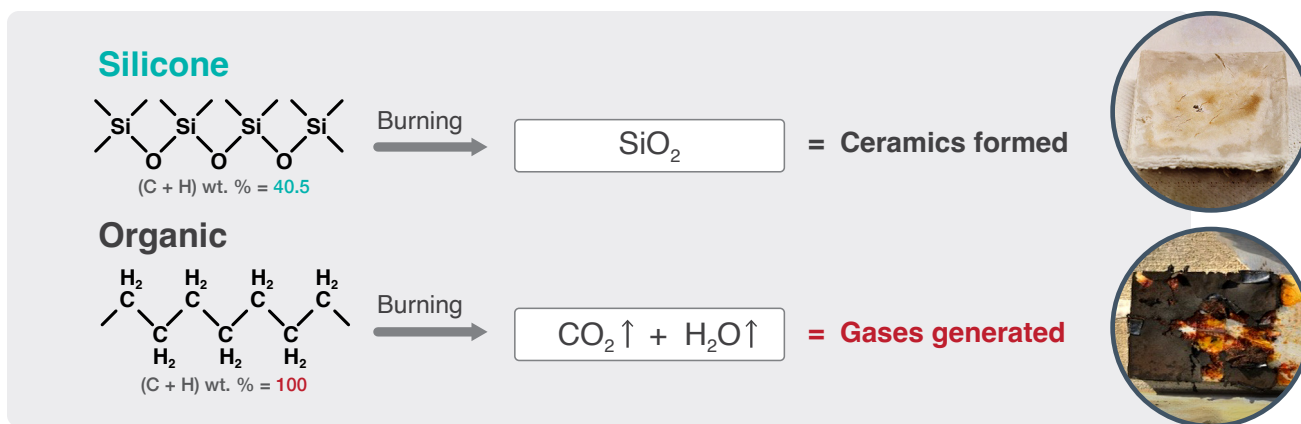


Does your EV have what it takes to keep you safe?

Dow advanced silicone materials can take the heat – meeting your battery fire protection challenges.

Lithium-ion battery design engineers continue to develop improved systems that balance performance, efficiency, and safety considerations. Whether cylindrical, pouch or prismatic cell types, assembly materials play many important roles in pack longevity, performance, and safety. There are a variety of materials that provide battery fire protection (BFP), both in terms of chemistry type and material form, which must be considered in providing cell-to-cell or module and pack level protection in case of a thermal event.

Silicones offer a unique set of properties that make them well-suited for BFP applications. They are thermally stable up to 250°C, and above 300°C they undergo ceramification instead of combustion, which reduces the amount of fuel and gases that could be generated during a cell thermal runaway event. When compared to organic materials, silicones are less likely to provide additional energy that could lead to thermal propagation.



Silicones' inherent benefits over organic and inorganic battery fire protection materials include:

- Easy application (dispensing) for battery cell encapsulation and protection
- Negligible heat generation during cure
- Elastomeric nature, providing low stress (damping) or tuned compressibility
- Excellent property consistency over a wide temperature range
- High thermal stability
- Reliability over many charge/discharge cycles
- Low flammability and ceramification response (rather than combustion) when exposed to extreme temperatures.
- Tunable properties – viscosities, working times, and cured material properties – to meet requirements of specific battery designs

Dow offers a full portfolio of silicone solutions that enhance BFP performance by enabling greater flexibility, durability, and thermal insulation, as well as improved longevity for different cell types and module and battery pack configurations.



Material type	Applications
Liquid silicone rubber (LSR)	Connectors, seals, and vents
High-consistency rubber (HCR)	Busbar, cable, sheets, and laminates
Gels, encapsulants, and foams	Encapsulation and sheets (cell protection)
Formed-in-place gaskets (FIPG) Cured-in-place gaskets (CIPG) Dispensed-foam gaskets (DFG)	Adhesives and sealants (for pack sealing)
Resins and coatings	Pack cover fire protection

We're dedicated to sustainability in our materials engineering, and our global footprint helps battery manufacturers worldwide meet electric vehicle (EV) battery fire protection materials challenges. Selecting the appropriate BFP materials can be a daunting task. These materials must provide anti-thermal propagation protection during a cell thermal runaway, as well as provide reliable performance under normal operations.

This guide will be helpful in determining which products are best for your application. We have identified materials and technology in four sections, and we'll look at some of the products' features and benefits which will help in narrowing your selection. Note that this is just a sampling of the products available, and our experts are continuously working on new product development. If you need different product specifications or have a specific challenge, contact your Dow technical support representative.

Global application testing to help in product selection

TESTING CAPABILITIES

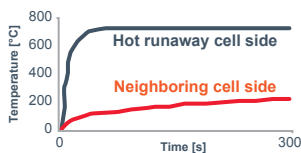
Various silicone-based solutions from Dow can help battery manufacturers, automotive OEMs and designers achieve the right level of protection required for diverse battery applications. However, selecting the right product for the specific application is crucial. Dow has a broad set of material-, simulation-, and application-based testing to help you select the right material.

See for yourself,
watch the video.



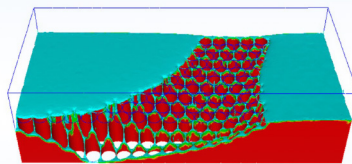
Thermal insulation testing

- Hot plate up to 800°C for sheet thermal insulation
- Compression to match specific pack requirements



Material modeling

- Flow, fill and performance



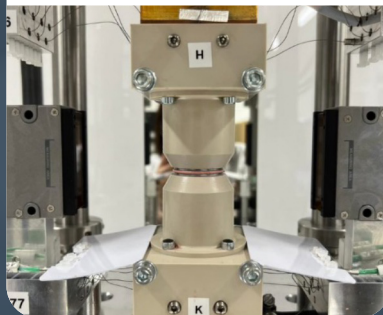
Hot particle flame / UL flammability

- High-temperature torch flame test/hot particle blast
- UL 94 flammability test lab

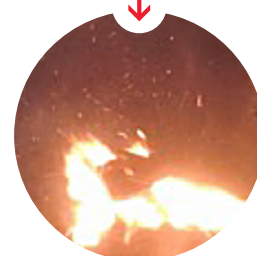


High-temperature thermal conductivity

- Measure thermal conductivity up to 1200°C



Mini-module thermal runaway test



Silicones for EV battery cell encapsulation

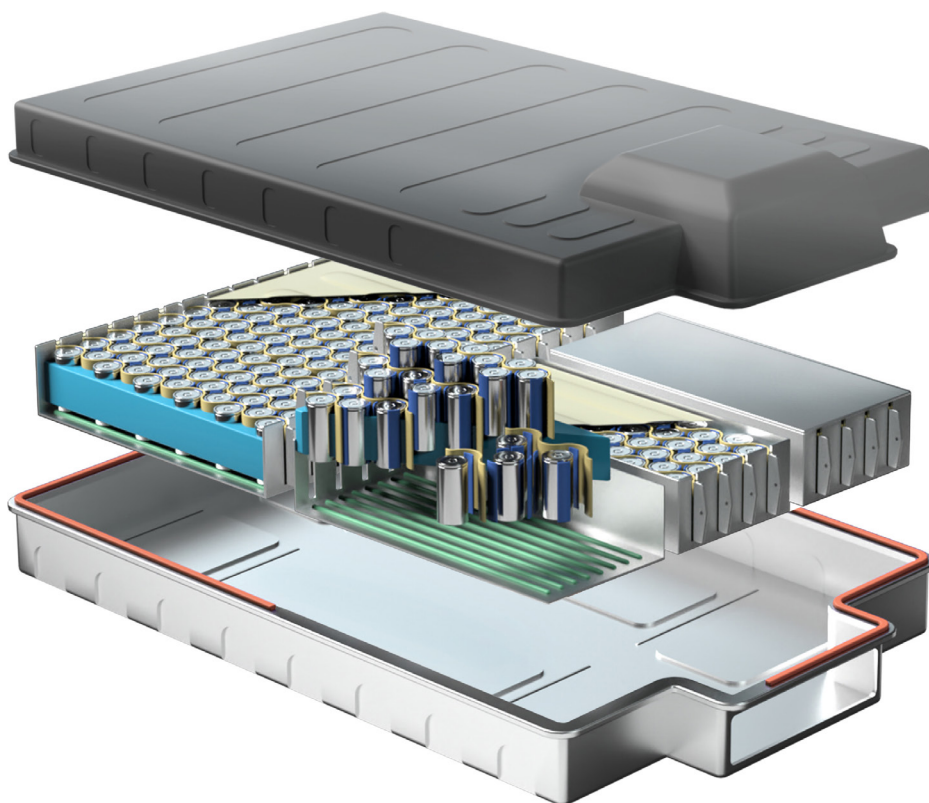
Liquid dispensable silicones are excellent candidates for EV battery cell encapsulation.

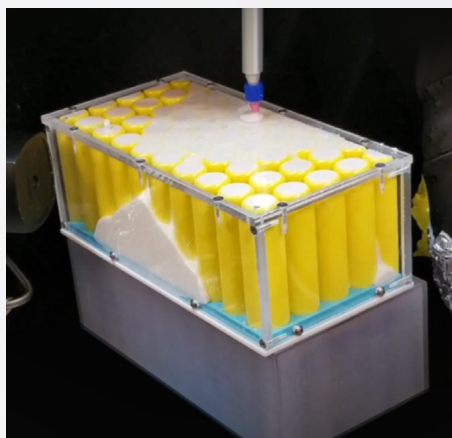
DOWSIL™ and SYLGARD™ silicones are suitable for easy dispensing and filling into dense battery modules for cell encapsulation and cell top potting. The material fills around individual battery cells and cures at room temperature (while generating negligible heat, important for cell safety) into its final product form, which can be a gel, elastomer, or foam encapsulant.

Silicone foams, gels, and encapsulants from Dow provide electrical isolation, mechanical protection, and stability during battery operation, and can survive many charge and discharge cycles over the lifetime of the battery pack.

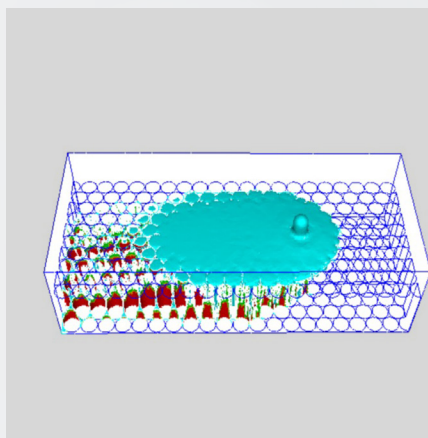
DISPENSING

The liquid precursors of gels and encapsulants are easily dispensed with standard two-part dispensing systems using a static mixer. For foams, static-dynamic, or dynamic mix heads are suggested for optimum foaming results (i.e., to yield optimum foam-cell formation and structure for Li-ion battery cell protection during thermal runaway and propagation events).

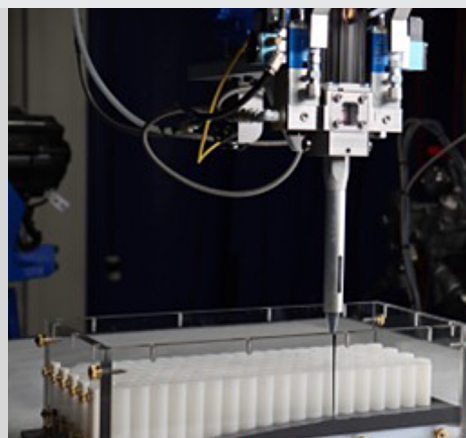




Silicone foam dispensing into a mock battery pack.



Simulation can assist with pack filling optimization



Exact module/pack specifications (size, cell arrangement and spacing, free-volume) and other design specifications can help determine which products are best for your application. For highly complex designs, flow modeling can further assist in product selection.

PRODUCT RECOMMENDATIONS

The following products are recommended for cell potting/encapsulation. Different viscosities of encapsulants, gels, and foams are available for different applications. For example, low viscosity gels and foams are excellent choices for potting cylindrical battery cells, while higher viscosity foams provide a great option for potting pouch cells where flow must be tightly

controlled. These materials have been proven as effective mitigation materials in application and mini-module thermal runaway testing and have been adopted for applications in battery electric vehicles, commercial EVs, E-scooters and bikes, and energy storage systems.

	Product	Viscosity [cP]		Working time [min.]	Cure time [min.]	Shore hardness	Dielectric strength [kV/mm]	UL 94 flame rating
		Part A	Part B					
FOAM	DOWSIL™ 3-8209 Silicone Foam	14,000	14,500	N/A	5	45 (OO)	5.9	V-0(1)**
	DOWSIL™ 3-8257 Silicone Foam	23,750	12,500	N/A	5	25 (OO)	5.0	V-0(1)**
	DOWSIL™ 3-8259 RF Silicone Foam	55,000	45,000	N/A	4	50 (OO)	7.7	V-0(1)**
	DOWSIL™ EF-6525 RTV Low Viscosity Silicone Foam	2,400	2,000	N/A	15	30 (OO)	6.8	V-0*
ENCAPSULANT	SYLGARD™ 170 Silicone Fast Cure Elastomer	3,400	1,300	4	12	42 (A)	14	V-0
	SYLGARD™ 170 Silicone Elastomer	3,200	1,100	15	24 (hr)	47 (A)	18	V-0
GEL	DOWSIL™ 3-4150 Dielectric Gel	475	450	7	90	N/A	15	–
	DOWSIL™ 3-4207 Dielectric Tough Gel	425	400	N/A	90	59 (OO)	–	V-1

* This is an internal test result base on the UL 94 test method. The material is not UL 94 certified. The material tested at 4 mm thick.

** Materials can achieve UL 94 V-0 in internal testing. Please contact Dow Technical Service for details.

DOWSIL™ Silicone Foam Sheets: Low-density solutions combining thermal insulation with compressibility.

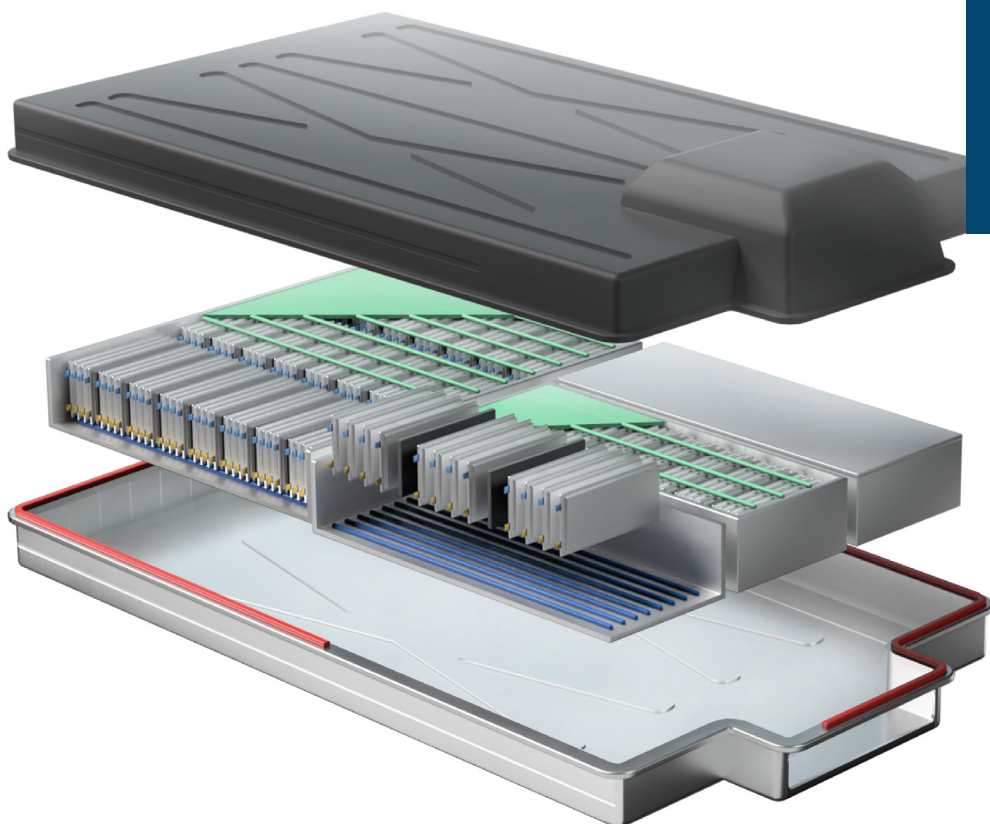
Offering a range of liquid silicone foam products that can be converted into foam sheets — solutions that meet your application needs.

DOWSIL™ Silicone Foams are two-part materials that are cured into elastomeric foams in a platinum-catalyzed polyaddition reaction, with a range of densities and mechanical properties. These silicone foams can be cured in a wide range of temperatures — from room-temperature

up to $> 100^{\circ}\text{C}$ — to account for the varying processing requirements in roll-to-roll production environments. DOWSIL™ Silicone Foams can be used in a variety of applications such as encapsulation, DFG, and manufacture of insulating foam sheets.

ADVANTAGES OF SILICONE FOAMS

- Tailored compressibility (up to 80%)
- Minimal hysteresis = Rapid recovery
- Fatigue resistance (>1000 cycles)
- No material loss as powder

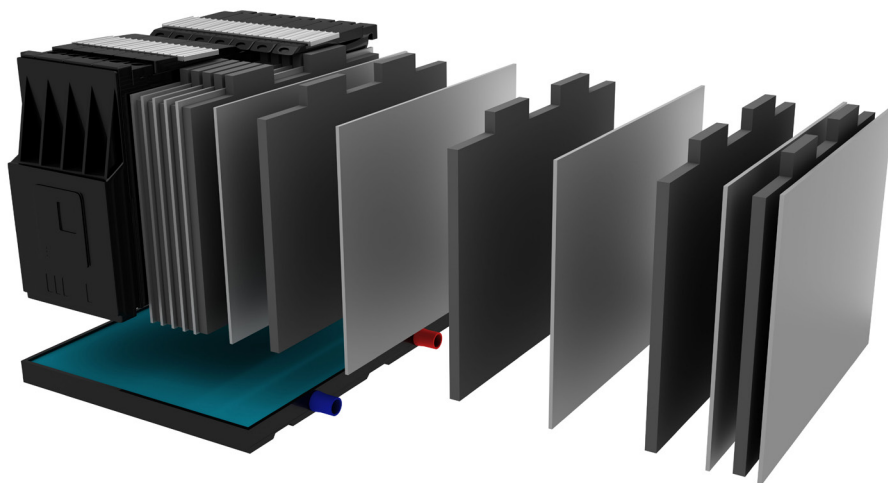


DOWSIL™ Silicone Foams are used to produce sheet form factors that provide a variety of benefits in an EV battery pack. These sheets can be easily placed or adhered between battery cells, battery modules, or in other areas of the pack. Silicone foams sheets are low-density materials that can function as a compression pad with low compression set (<10%).

These properties provide tuned compressive force to improve battery performance or maintain pack structural requirements for pouch and prismatic designs. They also provide excellent thermal insulation, enabling thermal propagation prevention mitigation in the event of a thermal runaway.

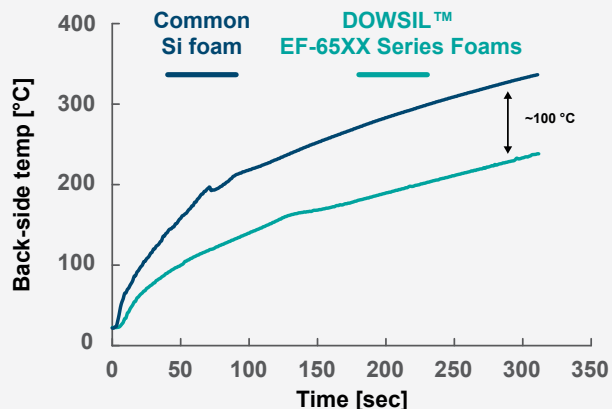
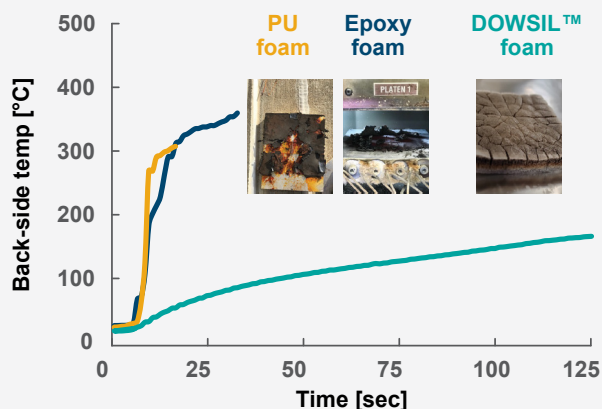
KEY PROPERTIES

DOWSIL™ EF-65XX Series Silicone Foams are designed to have a broad temperature range for thermal stability, and then to ceramify upon exposure to even higher temperatures or flame, where they maintain their structure, insulation performance, and dielectric protection. In addition, our innovative materials solutions have enabled the potential for drastic improvements in thermal-insulation performance.



DOWSIL™ EF-6500 Series Silicone Foams

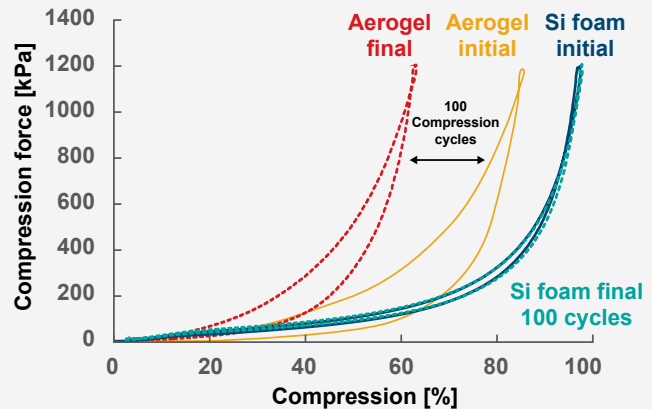
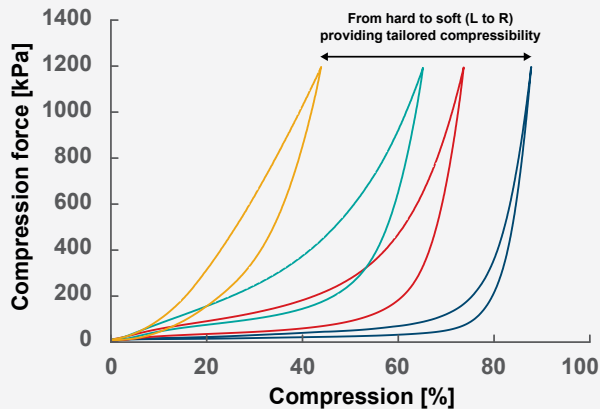
Thermal stability	Thermal conductivity	Dielectric strength	High-temperature performance	Flammability
-40 to 250°C	<0.1 W/mK	>5 kV/mm	Ceramification	UL 94 V-0 possible



DOWSIL™ foam sheets show significant advantages over common, flame-resistant epoxy or polyurethane foams. In addition, the DOWSIL™ EF-6500 Series Silicone Foams enable significantly improved thermal insulation compared to common

Si foams on the market, reducing temperature experienced by nearby cells during a thermal runaway event. Dow testing labs can provide data on our foam formulations under temperature, pressure, and thickness conditions most relevant to your design.

DOWSIL™ EF-6500 Series Silicone Foams



The tailored compressibility of our different materials options enables our thermal barriers to better meet design needs for pouch or prismatic cells, while maintaining excellent thermal insulation performance. In addition, when compared

to high-end aerogel materials in a compression cycling test, significant benefits in hysteresis, fatigue resistance, and overall compressibility are realized which enables less charge loss over multiple charge and discharge cycles.

PRODUCT RECOMMENDATIONS

DOWSIL™ Silicone Foams are engineered for improved performance in key areas required for EV battery pack safety. In addition, Dow partners with global fabricators that can

provide commercial quantities of foam sheets for series production tailored to your specific needs and energy storage systems.

	Product	Viscosity [cP]		Snap time [sec.]	Density [kg/m ³]	Recommended cure temperature	Durometer Shore [OO]
		Part A	Part B				
FOAM	DOWSIL™ 3-8235 Silicone Foam	77,000	91,000	200	208	RT to 100°C	35
	DOWSIL™ 3-8209 Silicone Foam	14,000	15,000	220	250	RT	45
	DOWSIL™ EF-6500 Series Silicone Foams – Tailored to meet your application needs with improved fire protection performance						
	DOWSIL™ EF-6555 Silicone Foam	28,000	31,000	300	240	60-120°C	38

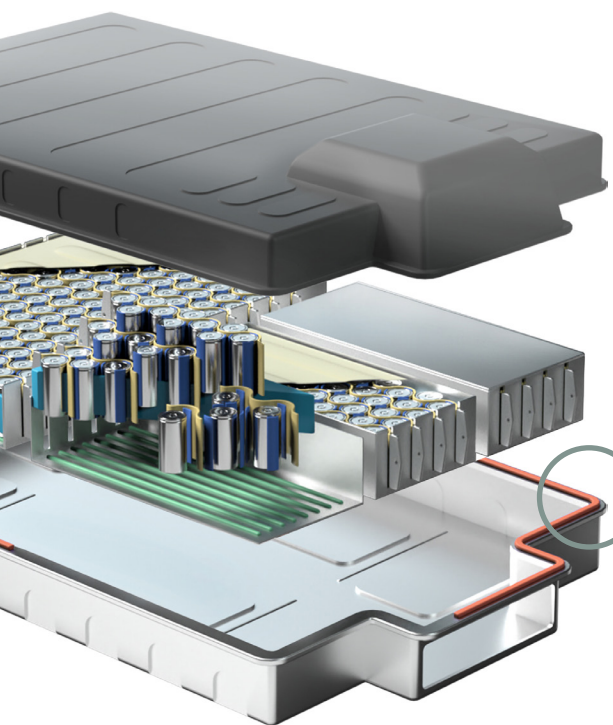
*Liquid or sheet samples available on request

DOWSIL™ silicone adhesives and sealants: fire-resistant materials performing over a wide temperature range.

With materials engineered to provide high strength, rapid curing, UL-ratings and other critical properties, Dow continues to offer innovative products that meet the challenges of the rapidly changing EV landscape.

DOWSIL™ silicone adhesives and sealants demonstrate high thermal stability and consistent properties over a wide temperature range.

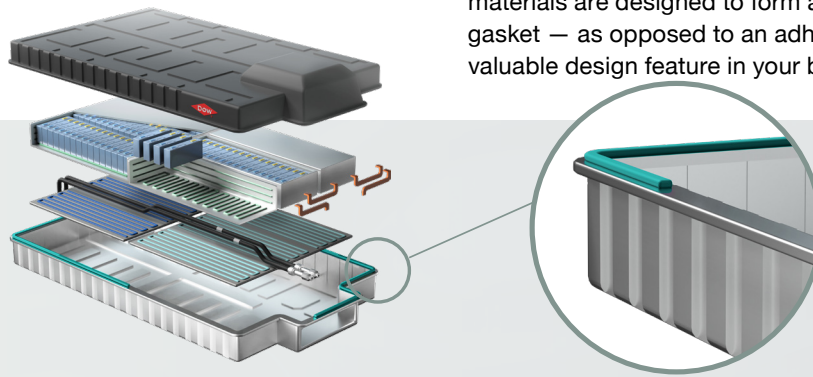
Keeping environmental elements such as moisture, salt, and dirt on the outside of the battery pack is key to battery longevity and safety but is no easy task. EV batteries experience wide swings in temperature, often over relatively short time periods, varying road (vibrational) conditions, and in a worst-case scenario, during a thermal event. Sealing the lid and all penetrations with the appropriate materials is critical to ensuring battery lifetime and safety.



Dow has developed sealants with a wide range of properties that can be dispensed manually or in serial production. From non-porous, liquid applied, cured-in-place gasket (CIPG) and formed-in-place gasket (FIPG) materials, to dispensed-foam gasket (DFG) formulations, DOWSIL™ sealants can be used to adhere and/or seal between a variety of substrates in an EV battery pack. These applications can include perimeter seals for battery modules and packs, assembly adhesive for various internal components, control module sealing, etc., and offer high thermal stability and low flammability when measured in accordance with UL standards.

Silicones can have a significant advantage over other sealants and adhesives in that they remain thermally stable at temperatures well over 100°C, which can provide significant benefit in a thermal-propagation event where a seal failure can result in additional safety hazards.

DOWSIL™ silicone elastomers are one- and two-part products that are cured into adhesives, gasketing, or sealing materials, and include FIPG adhesives/sealants, CIPG LSRs, and DFGs. They can be dispensed robotically, helping you select materials that meet your application needs. CIPG and DFG materials are designed to form a serviceable compression gasket — as opposed to an adhesive seal, which may be a valuable design feature in your battery pack.



DOWSIL™ silicones offer a unique benefit in terms of their high thermal stability and potential to achieve UL certification for flammability, which is important in a thermal-propagation event. These sealant and adhesive materials can be applied in a variety of ways according to specific battery configuration needs.

FIPG, DFG, AND CIPG MATERIALS COMPARISON

Technology	FIPG	DFG	CIPG
Seals by	Adhesion	Compression	Compression
Boundaries	No “service gasket”; Seal gap typically <2 mm	“Service gasket” Seal gap typically >2 mm	
Assembly method	Wet assembly (assembly prior to cure)	Dry assembly (assembly after cure)	
Recommended product group	One- and two-part RTV	Two-part RTV silicone foam	Two-part HTV (CIPG LSR)
Manual application	Yes	No	No
Application location	On assembly site	On assembly site or at tiered supplier	
Typical profile			



KEY BATTERY FIRE PROTECTION APPLICATION PROPERTIES

Product	Thermal stability [°C]	Volume resistivity [$\Omega \cdot m$]	Dielectric strength [kV/mm]	High-temperature performance	Flammability
DOWSIL™ Standard Sealants and Adhesives (FIPG)	-40 to 250	$>10^{13}$	20-30	Ceramification	UL-50E, UL 94 V-0 Possible
DOWSIL™ EV Pack Fire Protection Sealant	-40 to 450	5.4×10^{14}	15	Ceramification and maintained structural integrity	UL-50E, UL 94 V-0 Possible
DOWSIL™ Dispensed Foam Gasket Materials (DFG)	-40 to 250	$>10^{14}$	3-6	Ceramification	UL-50E, UL 94 V-0 Possible
DOWSIL™ Cure-in-Place Gasket Materials (CIPG)	-40 to 250	$>10^{14}$	10-20	Ceramification	UL-50E, UL 94 V-0 Possible

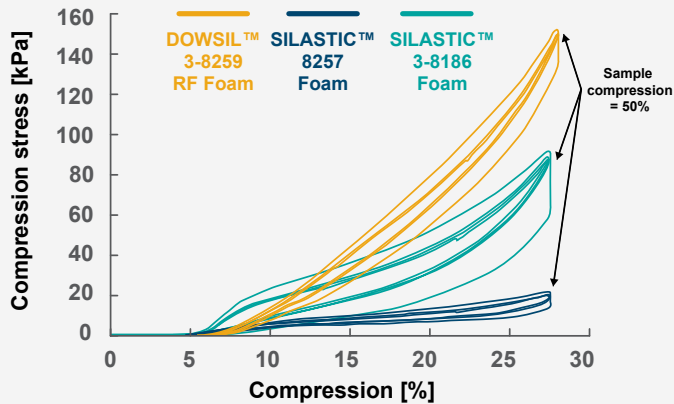
FIPG PRODUCT RECOMMENDATIONS

Product	Specific gravity	Viscosity $1s^{-1}$ [cP]		Tack-free time [min]	Durometer [Shore A]	Tensile strength [MPa]	Elongation [%]
		Part A	Part B				
DOWSIL™ 7091 Adhesive Sealant	1.4	1.3 mm (non-flowable)	N/A	28	32	2.5	680
DOWSIL™ 844 RTV Adhesive Sealant	1.4	1.3 mm (non-flowable)	N/A	15	37	2.2	400
DOWSIL™ 3-0115 Automotive Sealant	1.3	3 mm (non-flowable)	N/A	20-25	50	2.8	375
DOWSIL™ EA-3838 Fast Adhesive	1.3	350,000 to 450,000	550,000 to 700,000	5-8	40 (2:1)	>1.5 (2:1)	>250 (2:1)

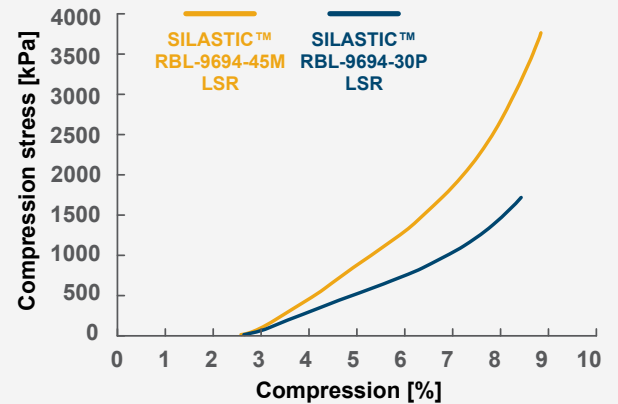
DFG AND CIPG COMPRESSIBILITY

DFGs and CIPGs from Dow provide a range of compressibility with low compression set — engineered to meet EV battery pack design requirements.

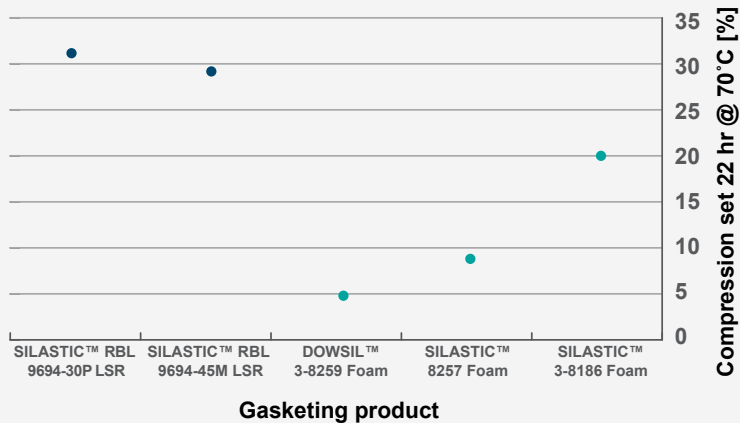
Compression stress deflection for select DFG materials from Dow.



Compression stress deflection for select CIPG materials from Dow.



SILASTIC™ CIPG and DOWSIL™ DFG compression set



DFG PRODUCT RECOMMENDATIONS

Product	Specific gravity		Viscosity, 1s ⁻¹ [mPa s]		Snap time [minutes]	Cured density [g/cm ³]	Durometer [Shore OO]
	Part A	Part B	Part A	Part B	1:1	1:1	1:1
DOWSIL™ 3-8259 RF Silicone Foam	1.1	1.0	65,000	62,000	2.5-3.7	0.3 - 0.4	50

**SILASTIC™ 3-8186
Thixotropic Foam**

1.1	1.2	135,000	125,000	3.5	0.2	40
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**DOWSIL™ 3-8257
Silicone Foam**

1.1	1	20,000	12,000	2.5-5.0	0.1 - 0.2	25
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CIPG PRODUCT RECOMMENDATIONS

Product	Cure conditions	Viscosity, 1s ⁻¹ [cP]		Specific gravity	Durometer [Shore A]	Tensile strength [MPa]	Elongation [%]	100% Modulus [MPa]	Developed for adhesion to	Compression set, non-post cure [%] 25%, 22 hrs. @ 177°C
		Part A	Part B							
SILASTIC™ RBL-9694-30P Liquid Silicone Rubber	5-10 mins @ 150°C	1,016,000	832,000	1.2	32	7.2	820	0.8	Plastics	31
SILASTIC™ RBL-9694- 45M Liquid Silicone Rubber		889,000	827,500	1.2	45	7.3	600	1.5	Metals	29



SILASTIC™ High Consistency Silicone Rubber (HCR) for flame resistant and ceramifying applications in electric vehicles.

Breakthrough technologies are driving notable innovation in electric vehicle powertrain systems. In addition to increased performance, key design trends include targeted improvements in safety, efficiency, component durability, driving experience, and optimized reliability.

SILASTIC™ HCR materials can help you meet these challenges with a wide range of intelligently designed materials to help to drive next-generation electric vehicle design.



RANGE OF HIGH-PERFORMANCE SILICONE MATERIALS

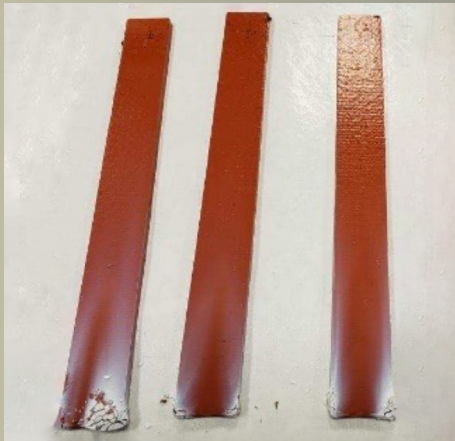
Silicones rubbers are remarkable versatile materials that can be produced in different formats for many applications within an electric vehicle. These materials can be formulated to meet specific performance and/or process requirements. With excellent dielectric properties coupled with resistance to extreme heat, cold, and aggressive fluids, SILASTIC™ HCR has shown to be an effective design solution in a wide range of electric vehicle powertrain applications.

Application	Design need HCR solution
High-voltage electric vehicle conductors	• High-temperature resistance • Excellent electrical properties • Excellent mechanical properties (i.e. tear resistance) • Available in multiple cure systems, including platinum
Battery seals	• Self-lubricating functionality • Fast cycle time • Good oil fuel resistance
Hoses	• Withstand wide range of service conditions • High mechanical strength • Options for co-extrusion and calendering

APPLICATIONS FOR SILASTIC™ HCR EXIST THROUGHOUT THE EV BATTERY ENCLOSURE.

- **Thermal and seal/valve:** Management and control of gases inside the battery enclosure; up to and including flame and gases from a thermal event.
- **Thermal barrier:** Provide robust, flexible barriers between various critical battery components, (eg. between battery cells, near connectors).
- **Busbar coating:** Insulation of high-voltage conductors, preventing arcing; provides electrical insulation before, during, and after a thermal event.
- **Hose protection:** Provide robust, flexible protection around cooling lines within the battery enclosure; provides thermal insulation before, during, and after a thermal event.
- **Connection cover:** Insulation of high-voltage components; can provide flame barrier and/or electrical insulation before, during, and after a thermal event.

Flame-resistant and ceramifying HCR materials provide safety and peace-of-mind in the unlikely event of thermal runaway within a battery enclosure.

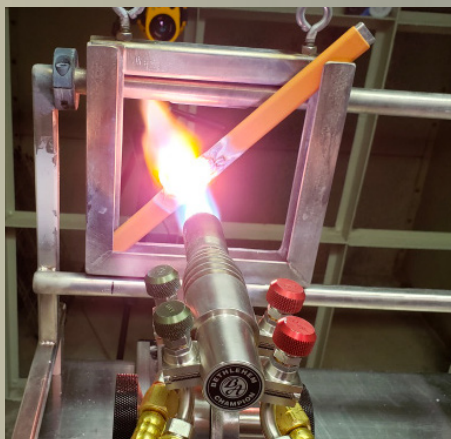


UL 94 flame bars, showing vertical burn orientation.

FLAME RESISTANT HIGH CONSISTENCY RUBBERS

SILASTIC™ HCR materials provide a barrier to flame and hot gasses during a thermal event:

- Maintain electrical and physical properties across wide temperature range and exposure durations, and thermal events
- Preferred fabrication methods include molding, extrusion, calender + die cut



High-temperature torch exposure performed on HCR coated busbar test part

CERAMIFYING HIGH CONSISTENCY RUBBERS

SILASTIC™ HCR materials provide a barrier to flame and ceramify during thermal event.

- Robust di-electric strength before and after ceramification
- Maintain physical properties across wide temperature range and exposure durations
- Preferred fabrication methods include molding, extrusion, calender + die cut

FLAME RESISTANT VERSUS CERAMIFICATION

	FLAME RESISTANT		CERAMIFYING		
Application	Thermal seal / valve	Thermal barrier / Connection cover	Busbar coating	Hose protection	Connection cover
Need	Thermal seal / insulation	Thermal barrier	Thermal / dielectric insulation	Thermal insulation	Thermal / dielectric insulation
Product recommendation (HTV-Dimethyl silicone rubber)	SILASTIC™ HCM 50-1339 FR RED	SILASTIC™ HCC 67-1347 FR RED	SILASTIC™ HCx 67-1352 EV FR ORG	SILASTIC™ HCE 60-1335 FR RED	SILASTIC™ HCC 65-1351 EV FR RED
Use form (Fabrication)	Injection, transfer, and compression moldable	Calender and compression moldable	Extrudable or injection, transfer, and compression moldable	Extrudable	Calender and extrudable
Product details	• 50 Shore A • Good thermal and flame resistance • Tested to UL 94 V-0, 4.0 mm	• 67 Shore A • Robust mechanical properties • Good thermal and flame resistance • FMVSS302, 2.0 mm • Tested to UL 94 HB at 2.0 mm	• 65 Shore A • Improved fabrication performance • Flame resistance • Forms ceramifiable layer • Color RAL 2003 (safety orange)	• 60 Shore A • Expandable over ridged substrate • Flame resistance • Forms ceramifiable layer	• 70 Shore A • Flame resistance • Forms ceramifiable layer



	FLAME RESISTANT		CERAMIFYING	
	SILASTIC™ HCM 50-1339 FR RED	SILASTIC™ HCC 67-1347 FR RED	SILASTIC™ HCC 65-1351 EV FR RED	SILASTIC™ HCx 67-1352 EV FR ORG
Specific gravity ASTM D792	1.2	1.3	1.7	1.4
Durometer [Shore A] ASTM D2249	49	67	65	71* / 68**
Tensile strength [MPa] ASTM D412	7.7	10.6	2.7	7.7
Elongation [%] ASTM D412	439	511	235	455* / 493**
Tear B [kN/m] ASTM D624	11.4	31.2	13.1	23* / 24**

* Molding ** Extrusion

HCR Compounds

SILASTIC™ HCR compound can be formulated for specific performance or processing requirements. These HCRs are fully compounded with ready-to-use, heat-curable blends of HCR bases, fillers, modifiers, catalysts, and color pigments.

A HCR custom compound can have:

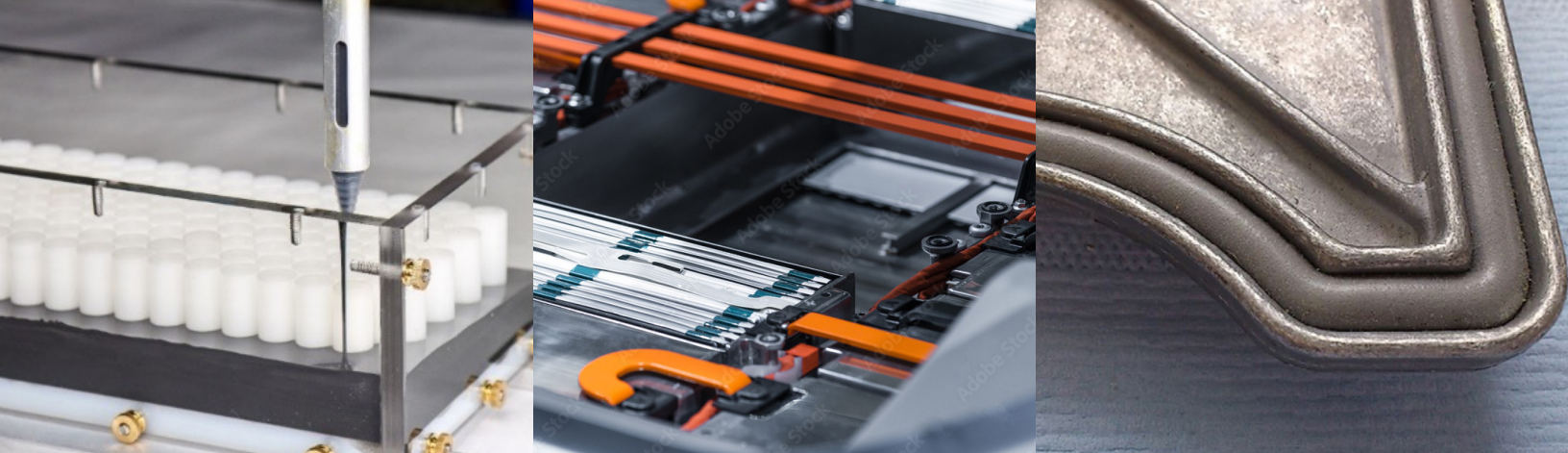
- Hardness range between 20-80 Shore A
- Tensile strength up to 12 MPa
- Elongation range between 100 and over 1000%
- Tear resistance up to 50 kN/m
- Compression set down to 10% and less after 22 hrs. @ 175°C
- Achieve food contact approval
- Temperature range between -60 and 200°C
- Good dielectric properties over a wide temperature range
- Volume resistivity >1E15 Ω-cm
- Deliver UL 94 V-0 flammability performance
- Up to 6 kV T&E

Custom compounding

Request a product designed to your specific needs. Visit dow.com/elastomers or simply scan the QR code to be taken directly to the custom compound request page.



With a wide range of attractive features and user benefits, SILASTIC™ HCR compounds are used in a wide range of diverse applications.



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