Elkem

Mobility & Transportation

Battery Thermal Management in Hybrid & Electric Vehicles

Silicone solutions for efficient insulation and conduction

Delivering your potential

Silicone Solutions for Efficient Insulation and Conduction

1 Overview

Battery Thermal Management in Hybrid & Electric Vehicles

To best manage the heat insulation and heat conductivity of batteries in Hybrid & Electric Vehicles (H&EV), Elkem offers silicone solutions to protect these sensitive components in the vehicles of the future.

Who is this Paper Intended for?

■ This study is primarily addressed to Materials Engineers in the automotive industry (OEMs or Tier 1 suppliers) involved in designing and producing innovative solutions to improve battery performance.
■ This study also provides key information for non-specialist decision makers, including Executive Managers, Industrial and Procurement Managers, as well as Financial Officers or Marketing and Sales people, to enable them to understand how Silicone Technology works and why it is essential to improve their competitiveness.

Why Elkem?

■ Elkem is fully vertically integrated as a leading global supplier of silicone solutions.
■ Elkem is active in Hybrid & Electric Vehicle market building from foundational historical automotive and incorporating to emerging technologies.
■ Elkem provides solution to meet electrical insulation to thermal management in order to meet performance requirements to comply with automotive quality standards (PPAP, ISO, etc).

2 An Overview of the H&EV Industry and Growth Forecasts

H&EV Markets Are Growing Exponentially Worldwide

The demand for Hybrid and Electric Vehicles (H&EV) is growing exponentially, with production generally doubling every year. When talking about H&EV, we're not only considering cars but the whole new generation of vehicles that revolution today mobility (light electric vehicles, electric trucks, electric buses, electric boats, even electric wheelchair). It is estimated that by 2030, H&EVs on the road, will account for 15% or more of the cars in the world. As electronic and car battery technologies evolve and as the consumer demand for clean energy vehicles increase, experts consider even more H&EV on the global market [Global EV Outlook 2017]. Major OEMs have commited to various platforms for H&EV in the next five years with a burst of start-ups globally also fueling this initiative.

H&EV Production doubles every year

There are 3 million pure EVs on the road today, with global leaders such as China accounting for 67% of the total, Norway with 20% followed by US & Canada.

China, the Nordic countries and Canada are growing fastest.

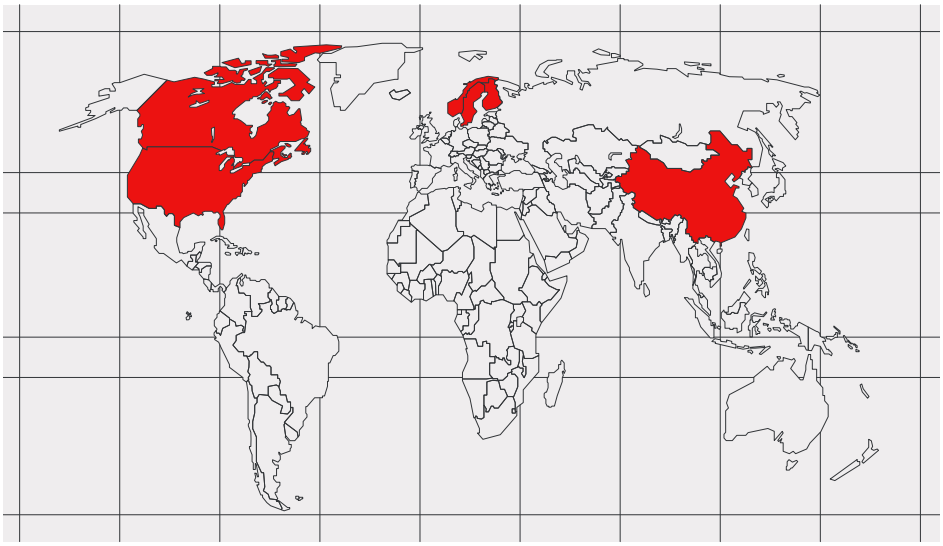
The major technical challenge to make EVs more attractive to consumers is to increase their autonomy through higher-performance and faster-charging batteries. As they prepare for mass production, many OEMs have announced partnerships with battery manufacturers, seeking insight into specialist questions, previously not in their R&D scope.

OEMs are partnering with battery manufacturers

"Partnering with battery producers should provide automakers with insights into the main challenges faced in battery production. Furthermore, close collaboration will enable OEMs to integrate new battery chemistries into vehicle designs more effectively, "according to industry watchdog Fleetcarma. As these alliances with OEMs and Tier 1 producers advance and as governments offer financial incentives to environmentally-concerned citizens, 2019 is shaping up to be a big year in growth and innovation. By 2025 EVs could make up 15% of the total vehicle fleet.

By 2025, EVs could make up 15% of all vehicles

GLOBAL EV OUTLOOK 2017
MCKINSEY REPORT
ELECTRIC VEHICLE OUTLOOK 2019



3 Thermal Management Systems (TMS)

The Challenge for Battery Manufacturers and H&EV Carmakers

Thermal management: the keys for energy and heat control

Definition for Thermal Management

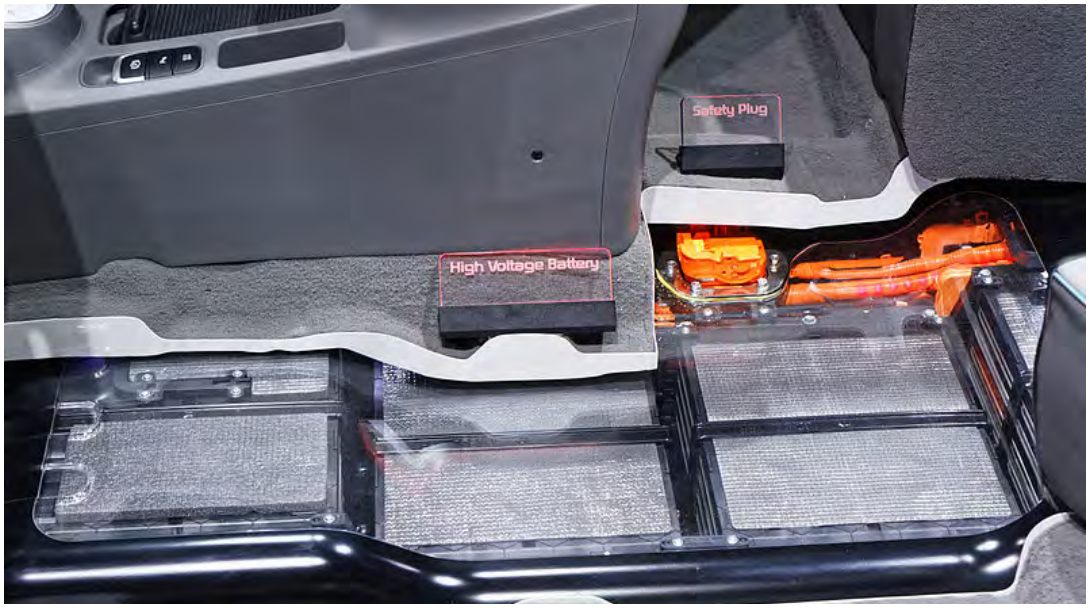
Thermal Management is a term identified as the ability to control the entire temperature system of a battery array, by means of technologies that lower thermodynamics, transfer or insulate heat. Thermal Management is an important discussion topic in battery-powered systems when considering insulation, heat and power transfer, conduction and convection, in order to maintain the battery pack temperature within a tight tolerance to reduce thermal runaway.

In Thermal Management Systems (TMS), temperature is the main variable when analyzing the state of the system, which is the primary indicator of its energy level. Each system has a given ability to store or dissolve energy. This ability is referred to as its heat capacity, and can be calculated by measuring the mass and the specific heat capacity of all materials in the system. When energy is transferred into the system or energy is created by an internal source, the energy level of the system can rise. Higher energy levels of the materials in the system cause the temperature of these materials to rise. The specific heat capacity defines the connection between absorbed or dissolved energy and the change of temperature.

Thermal Management fundamentals

Heat capacity: the connection between energy and temperature

INHECO: THERMAL MANAGEMENT



Ensuring Insulation, Conductivity and Conduction for All Climates

Operating in all climates and environments

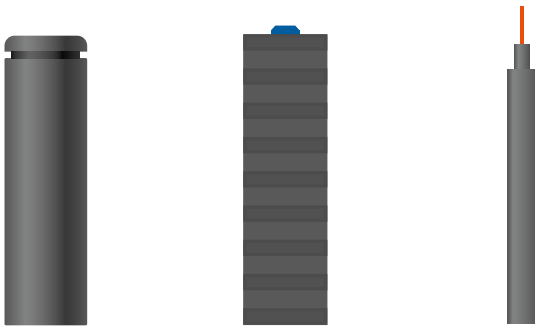
Thermal management of batteries in H&EVs is essential for the effective operation of motors in all climates and environments and is the main focus in the design of battery modules and packs for pre-production prototypes or serial production. Design thinking and technologies are constantly evolving to address these various issues. Design and material engineers are addressing the trade-offs between performance, functionality, volume, mass, cost, maintenance, and safety issues.

Regulating temperature, & reducing weight, volume and costs

Thermal and Materials Management challenges for Batteries in H&EVs:

- Maintain temperatures within an optimal range, with very few variations
- Reduce weight and volume
- Align power sources in efficient arrays that can be easily recharged and/or changed
- Ensure safety & reliability
- Ease of processing

3 types of batteries cells



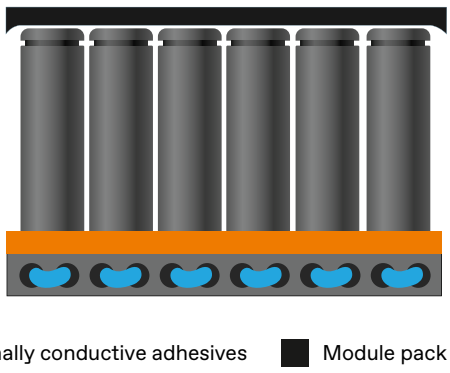
Cylindric Prismatic Pouch

There are two possible approaches in ensuring a balance between all these performance factors, both based on optimizing TMS. The choice between these options is determined by several factors, depending on the design of the battery pack and the types of cells deployed. Common battery configurations are: cylindrical, pouched, prismatic.

- The first approach is based on the thermal insulation of the cells to avoid overheating and propagate temperature increases to other cells, while at the same time insulating individual batteries to limit the impact of cold environments on its temperature.
  - To achieve this double insulation, Elkem offers a range of foams featuring a low thermal conductivity coefficient, ideal for this purpose because of their high temperature resistance. In addition, these foams have low densities that do not negatively impact total weight and energy consumption.

Two effective approaches: Thermal Insulation & Thermal Conduction

- The second approach is to use thermally conductive materials that can evacuate heat from the cells.
  - The Elkem range includes thermally conductive adhesives, gap fillers, encapsulants and gels to deal with the variety of design differences in battery packs.



Conductivity is the ability of a material to conduct electricity, heat, fluid or sound while conduction is the conveying of heat or electricity through materials. Silicones offer solutions for flexibile cure for thermal conductivity requirements with electrical insulation.

The Long-term Goal: Increased Safety, Performances and Lifetime of Batteries

Heat dissipation is critical not just for reaching the desired levels of performance and reliability in EV applications when needed, but also to enable batteries to function for their intended lifetime. Much of the industry is moving to lithium-ion batteries to provide the power needed for EVs and the secondary power for hybrid vehicles, but without proper thermal management, batteries can overheat during charging or discharging. There can also be a non-uniform temperature distribution within the battery packs which may affect optimal performance, ranging between 15°C and 35°C. When the battery pack temperature exceeds this optimal range, the efficiency and shelf-life decreases.

Avoiding overheating and non-uniform temperature distribution

Several types of TMS are used for the electrical components in electric vehicles. These may include liquid cooling systems, direct refrigerant cooling systems, air-cooling systems, thermo-electric cooling systems, etc. Thermal interface materials (TIMs) play a key role in the effectiveness of the TMS. TIMS ensure heat is conducted efficiently away from components by filling air gaps, and reducing interfacial thermal resistance between the TMS and heat generation or heat isolation of electrical components.

Thermal Management systems and interface factors

Understanding the thermal conductivity of both thermal interface materials and thermal insulating materials is key to being able to determine how well these materials will perform in an application.

Elkem works closely with end users to determine the ideal material best suited for the intended application. With complete vertical integration, Elkem has the ability to control the entire value chain from silicon metal to silicone adhesives, with the capacity to customize at scale, on demand. The base offering of conductive silicone products include the BLUESIL™ ESA 6700 and ESA 7700 family which vary from thixotropic gap fillers to low viscosity thermally conductive options with varying adhesion strengths ranging from 0.4 W/mK to 3 W/mK. Having consistent conductivity test methods that correlate to the end application is an absolute critical aspect of the material selection process.

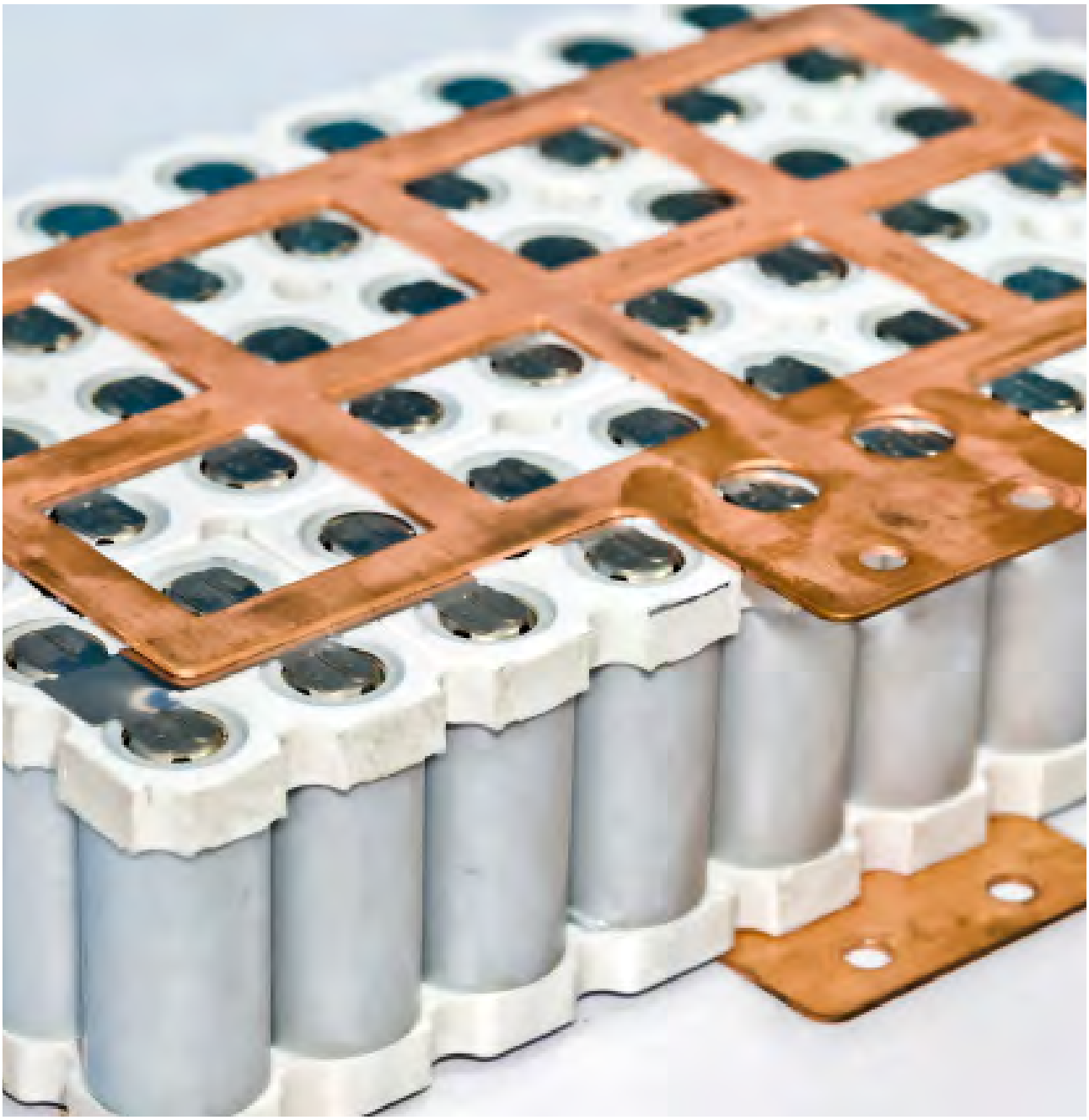
Elkem: controlling the entire value silicon chain to provide customized solutions

To find out more on the technical details and testing methods we apply at Elkem , we invite Materials Engineers to read the following detailed analysis:

READ OUR WHITE PAPER ON THERMALLY CONDUCTIVE SILICONES TEST METHODS

A White Paper for experts on conductivity and conduction calculation and testing methods

4 Understanding Silicones and Other Materials



The Underlying Chemistry of Silicone Polymers

No one can deny, this paper is focused on silicone applications in Thermal Management for H&EV vehicles and battery arrays. But we thought it was equally important to give you the key learnings on silicone alternative technologies (ie: epoxy resins and polyurethanes). This should help you to better understand how the best thermal management materials differ from one to another.

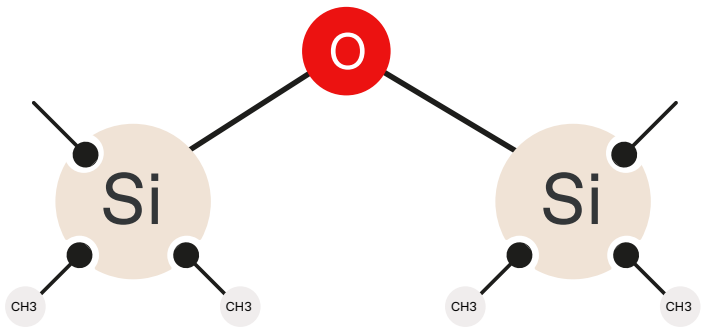
Silicones are inert synthetic compounds that come in a variety of forms: oils and gums that can be formulated in fluids (emulsions, resins, greases, compounds) or elastomers (HCR, LSR, RTV-1 or RTV-2). Thanks to its versatility, silicones are used in a wide range of applications. Typically, silicones are presents in every technologic devices for protecting micro-electronics with potting and encapsulation, as well as in every car in the world for sealing and bonding functionalities. In the meantime, one of the fastest growing application cases is for thermal management of new generation electric battery powered vehicles.

Silicones are polymers that contain silicon, combined with carbon, hydrogen and oxygen and, in some cases, other elements.

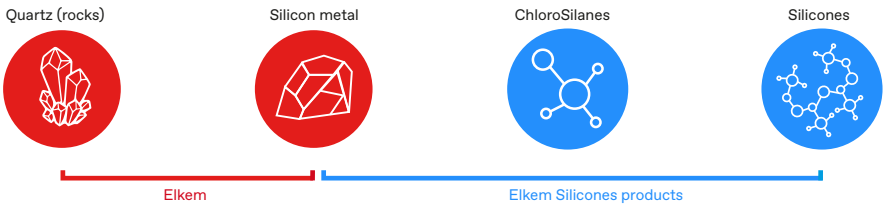
The basic structure of silicones

Silicones are made up of polyorganosiloxanes, where silicon atoms are linked to oxygen to create the silaxone bond. The remaining valences of silicon are linked to organic groups, mainly methyl (CH3):

- PolyDiMethylSiloxane (FLD 47)
- Phenyl, vinyl, hydrogen



The basic structure of silicone materials



Transforming silicon raw materials to silicone products

The Intrinsic Features of Silicone Products

The versatility of silicone materials

Key properties of silicones

- Thermal stability (from -80°C to 250°C), ensuring proper viscosity in a wide temperature range, which means good upstream process uniformity (excellent spread and coating capabilities) and reliable downstream operating performance in extreme weather conditions
- Resistance to natural ageing (oxidation, UV)
- Low hardness
- Low modulus for compensation of stress in high temperature or cycling conditions.
- High fire resistance capabilities, including low emission of smoke and toxic fumes, self-protection, ceramization of ashes
- Low surface energy
- Good wetting on many substrates
- Hydrophobia (beading effect) to ensure waterproofing
- Easy re-workability or strong adhesion depending on requirements
- Extremely low inner stress on potted components, preventing delamination from the housing substrate

Some drawbacks, which can be compensated to ensure longer lifecycles

However there are some trade-offs when considering other materials:

- Although the adhesion of silicones onto various substrates can be optimized, epoxies have the inherent nature of adhesion. On the other hand, silicones are great in flexible bonding.
- Both epoxy resins and polyurethanes present higher shear modulus than silicones, which is an interesting feature when you're looking for a hard and resistant system but can be a drawback when re-workability and ease of processing are the awaited benefits.

BROWSE THROUGH THE SILICONE SCHOOL TO LEARN MORE

A Comparative Table of Materials: Silicones vs. Epoxy & Polyurethanes

On this table, we summarize the basic features of silicone materials and compare these to the performance of polyurethanes and epoxy resins.

Features	Silicones	Epoxy Resins	Polyurethanes
Temperature Range	-50 to 200°C	-50 to 150°C	-30 to 120°C
Elasticity	Elastomer – gel	Rigid resin	Rigid resin - Elastomer
Modulus	Low	High	High
Mechanical strength	Medium	Strong	Strong
Adhesion Strength	Medium - high	High	Medium
UV Resistance	Excellent	Poor	Poor
Ionic Impurities	Minimal	Medium	Medium
Combustion	Self-extinguishing	Non-self extinguishing	Non-self extinguishing
Dielectric stability	High	Medium	Low
Coeff. thermal exp	High	Low	Medium

Temperature range and elasticity

Strength, adhesion and resistance features

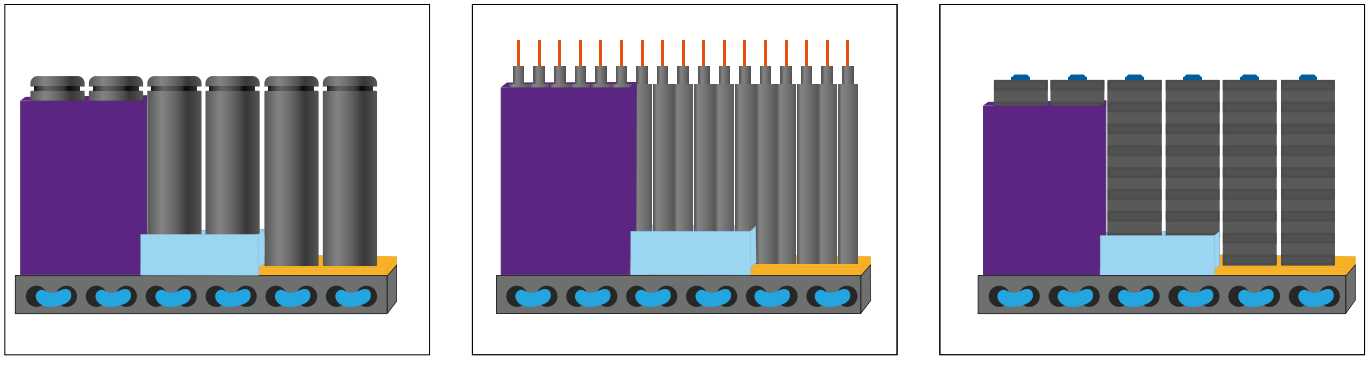
Combustion and diaelectric behavior

Another key advantage is that silicones are available in a variety of forms: RTV-2, RTV-1, foams, gels, adhesives or even gap fillers. Elkem offers protection to improve performance, safety and longevity for all components and can be easily integrated into different processing environments:

Silicones are available in a great variety of forms

■ RT foams are ideal lightweight solutions for thermal insulation
High performance Gels are especially adapted for on-board electronics. They can be thermally conductive and are often used for heat management of power electronics
Adhesive and Gap Fillers (RTV-2 technology) are solutions of choice for heat-transfer
Adapted viscosity RTV-2 are also great materials for potting and encapsulation for electronics protection in the most demending environment.

Silicones can be customized to meet all design requirements



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5 Understanding How Silicones Can Help Battery Engineers

H&EV Markets Are Growing Exponentially Worldwide

What Are the Specific Challenges for Thermal Performance in H&EV vehicles?

Thermal performance and management are essential for the effective operation of all types of motor vehicles in all climates and environments. Batteries tend to heat quickly at different times in their operating cycle, including when they are running at full capacity or in the charging (or fast charging) process. **This is particularly true for fast-speed recharging systems**, where research is focusing on offsetting damage to Lithium-ion batteries at certain temperatures through efficient insulation. There is also the problem of producing a rise in ambient temperature in the battery housing, further reducing charging capacities and potentially damaging electronic components. Silicone offers low thermal conductivity, which means that it transfers heat at a low rate compared to other materials and also has the ability to maintain its properties and structure over a wide temperature range. Silicones of different sorts can be designed to provide required functions and find the right balance between conductivity, conductiveness and insulation for each specific stage in battery operations. For example, **Elkem foams are efficient in insulation, while our adhesives and gap fillers are thermally conductive.**

Fast speed charging is putting pressure on thermal management engineers

Why Are Silicones Essential for Lightweight Vehicles?

Reducing weight is a major challenge for EV vehicle designers and builders in their quest to reduce power consumption, but also to increase autonomy, which is today the biggest stumbling block for consumer acceptance. **A 10% reduction in vehicle weight can result in a 6%-8% fuel economy improvement.** Replacing traditional steel and iron components with lightweight materials such as high-grade metals, alloys, carbon fibers and polymer composites can directly reduce the weight of a vehicle's body and chassis by up to 50% and, in turn for EV vehicles, reduce the battery weight they carry. This loss of weight can also be used for adding advanced emission control systems, safety devices, and integrated electronic systems. It's a virtuous circle. In addition, if these lightweight components contribute to the overall efficiency and autonomy of the electrical motor (through better TMS and efficient insulation and conductivity), it's a big step forward on the road to consumer acceptance. Silicones are an essential part of this progress since they affect all these factors and because of their intrinsic features, such as the high-performance insulation performance of **lightweight silicone foams**, ensuring longer vehicle life and therefore becoming even more ecological and economical alternatives to traditional motor vehicles.

Silicones can be formulated in many forms: foams, gels, encapsulant...

Vehicle weight impact the battery heat, and so the overall energy consumption

Silicone can be lightweight insulation foams.

Are the Adhesion Qualities of Silicones Important for Battery Designers?

While the advantages of lightweight silicone foams for insulation and the coating efficiency of silicone gels for encapsulation and potting spring to mind quite readily for battery designers, their adhesion features may be less obvious. In fact, in advanced TMS systems, many components come into play and, often, they must be bonded with efficient adhesives. For example, to ensure thermal conduction in batteries, designers use a metal cooling plate as an interface. **These plates must be secured to the battery, usually with an adhesive.** There are two requirements to be fulfilled in this undertaking: the process must be simplified and the bond must be reliable and long lasting. Specially designed silicone self-adhesive bonds are therefore widely used for to achieve these two goals. These silicone adhesives do not require priming either of the surfaces beforehand, they are stable and they resist ageing across a wide range of temperatures. Silicones can also be purpose designed to provide the right mix of adhesion characteristics, as well ensure greater safety, in particular because they are not combustible and act as fire retardants.

Silicones can be self-adhesives materials.

LIGHTWEIGHT MATERIALS FOR CARS AND TRUCKS

How Easily are Silicones Integrated into H&EV Processing Systems?

Your dispensing line will love silicone flowability

H&EV production has reached a threshold. While in the past, these vehicles appealed to environmentally-aware consumers and/or were highly subsidized by public authorities, they will now have to fend for themselves in the automotive markets. To achieve this, they must not only enhance electrical performance per se, but must also improve processing as manufacturers ramp up to mass production and assembly automation. Silicones will play a major role in this development cycle. For example, their flowability is a major advantage in automated processing compared to other materials, in particular polyurethanes. Also, silicones can be formulated in a wide range of forms (liquids, gels, foams, etc.) and can be customized to variable potting times (pre-installation) and curing times (final reticulation or hardening) at given temperatures, to fit into existing or future processing systems. This flexibility and capacity to adapt is a major advantage for processing specialists, as they have told us now for many years in traditional automotive assembly, and is even a greater leveraging factor in H&EV manufacturing.

Low Volatile Content in Silicones: a Field of Continuous Improvement

Thermal management and battery experts convinced of the superiority of silicone performance in H&EV motoring systems are sometimes reticent to adopt these materials because of the presence of volatile molecule (cyclics) in the polymers and their formulations. These species of molecules can be dispersed in the atmosphere and pollute the working surface, including the surrounding floorspace and nearby machines. There can also be a problem for operators since they need to protect themselves when they breathe the air in the area, which can contain volatile particles. This can generate problems for some manufacturers, who have to redesign their assembly lines and the organization of their processes to make sure the silicone is handled in controlled spaces and do not affect their environment. Hopefully, silicone polymers can now easily be cleaned of these volatile molecules through a purification process. Therefore, Elkem specialists are available to assist during the purification step to protect people and machines. The purity of silicones is important for having a safe usability on a production line, which is a key requirement as carmakers . As a fully integrated silicone manufacturer, we ensure all of the ingredients are strictly selected to have clean formulations. As battery specialists and materials engineers integrate silicone into their thinking and their processes, we at Elkem are working alongside you to invent better and safer products for the future.

Full vertical integration is the key for a clean silicone production.

Click here to contact us

6 Elkem Silicones Product Lines and Comprehensive Support Services

Thermal Insulation Solutions: the BLUESIL™ RT Foam Range

Products	Application	Description	Viscosity (mPa.s)	Density	Pot life	Curing conditions	Thermal conductivity (W/m.K)	Max service Temp. (°C)
RTF 3242 A/B	Potting	Flowable foam, V0 on 10 mm thick	A: 15 000 B: 15 000	0,25	2-8 min	15 to 30 min @ RT	0.1	250°C
RTF 3244 A/B	FIPFG-gasketing	Thixotropic, RT curing, V0 on 10 mm thick	A: 20 000 B: 10 000	0,25	1-3 min	10 to 30 min @ RT	0.1	275°C
RTF 3250 A/B	interstitial fill	Thermal insulation	A: 1 350 B: 1 400	0,63	4-5 min @RT	10 to 30 min @ RT	0.1	TBD

BLUESIL™ RT Foam Application Fields

	Applications					
Products	Frame sealing of battery pack	Assembly PCU, ECU	Cell insulation	Potting	Gap filling	availibility AM /AP/ EMEA*
RTF 3242 A/B				■	■	on request** for AM/AP
RTF 3244 A/B	■	■				Yes
RTF 3250 A/B			■			on request** for AM EMEA

* AM = Americas; AP= Asia Pacific; EMEA = Europe middle-East Africa
** need to be validated by the region

Click here to contact us
We also invite you to get in touch with us directly to continue our dialogue and provide you with specific solutions for your R&D and manufacturing needs.

GET OUR BROCHURE :
ACCELERATE THE TRANSPORTATION REVOLUTION WITH ELECTRONIC SILICONE SOLUTIONS FOR HYBRID & ELECTRIC VEHICLES