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Adhesives and Sealants in Battery and Hybrid Electric Vehicles

WHITE PAPER

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Online Resources

Resources for individuals seeking information on adhesives and sealant in automotive and battery & hybrid electric vehicles (links):

- **Cars, Trucks, and Buses Industry Page on Adhesives.org**

Selection Guides:

- **OEM Body Shop Adhesive & Sealant Selection Guide**
- **OEM Paint Shop, Trim & Final Assembly Adhesive & Sealant Selection Guide**

ASC Whitepapers & Presentations:

- **Adhesives & Sealants as an Enabling Technology for Lightweight, Safe, and High Performing Steel Vehicles**
- **Adhesives & Joining Methods in Land Transportation**
- **Adhesive Opportunities & Outlook in Light Vehicles**
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- **Adhesives & Sealants in Battery and Hybrid Electric Vehicles**

ASC Transportation Blogs:

- **Adhesives.org/blog**

Adhesive & Sealant Sourcing Tool:

- **VendorSelect Tool**

Introduction

Adhesives and sealants have played an important role in the advancement of vehicle electrification technology and will remain at the forefront of the development of hybrid (HEV) and battery electric (BEV) vehicle battery cells, modules, packs, and motors. Battery technology in cars today has been adapted from consumer electronics. In order to meet the more stringent requirements of the automotive industry, battery makers need to find ways to achieve a 12 to 15-year vehicle life while operating at extreme temperatures and enduring the shock and vibration generated from on and off-road driving. Adhesives and sealants have played a significant role in meeting these challenges in many BEV and HEV powertrain applications.

This paper will focus on the unique challenges and benefits that adhesives and sealants deliver in EV powertrain applications and a provide brief overview of the amount of adhesives used in the electric powertrains of these vehicles in 2018. The primary benefits adhesives and sealants bring to electrified vehicle powertrains are:

- Joining components while shielding them from damaging shock and vibration
- Isolating components from shock and vibration, while creating a pathway to conduct heat away from the cells and modules
- Conducting thermal energy to cool the battery cells and modules, but electrically isolating the components to prevent shorts and reduce the risk of fire

Adhesives and sealants also play a significant role in body construction, paint, and vehicle assembly of hybrid and battery electric vehicles. Since reducing the weight of EVs helps extend their range, OEMs put significant effort into reducing the weight of components of the body, interior, and powertrain.   As a result, EVs often require bonding of non-traditional or dissimilar materials, such as lightweight composite tailgates for SUVs or hatchbacks. Those applications are similar to conventional vehicle construction and are discussed in the following ASC publications: **Adhesive and Sealant Selection Guide for OEM Body Shops** and **Adhesive and Sealant Selection Guide for OEM Paint, Trim and Final Assembly Shops**. Refer to those guides for more information about adhesives and sealants in light vehicle body construction and assembly.

The Market for HEVs and BEVs

The global market for battery and hybrid electric vehicles is expected to grow significantly over the coming decade, as HEVs and BEVs will be critical to helping OEMs meet increasingly stringent carbon dioxide emission standards across the globe, which are often expressed as increases in required fuel efficiency in miles per gallon. Electric powered vehicles, which include both HEVs and BEVs, accounted for 4.5 million of the 94 million vehicles produced in 2018, just under 5% of all light vehicles produced. Over half of the 2018 production of electrified vehicles came from Asia, due to the prevalence of hybrid electric vehicles in Japan and mandates for battery electric vehicles in China. Many forecasts show electric powered vehicles representing 25% or more of global light vehicle production by 2030. This incredible growth rate is predicated upon improvements in battery technology that extend the range of electric vehicles, shorten EV recharging time, and reduce the cost of the batteries themselves. Adhesives and sealants will play a big role in that growth because they are enabling technologies that help EVs charge faster, travel further, and last longer.

2018 Production of Electrified Vehicles – 4.5 MM units

Source: LMC, Industrial Market Insight

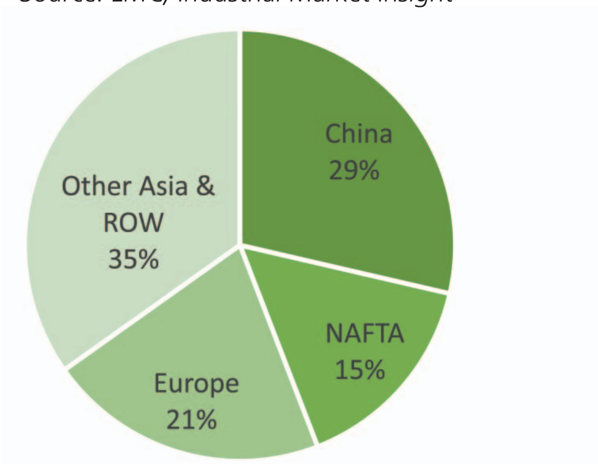


Figure 1: Production of Electrified Vehicles by Region

Comparision of Historical and Enacted Passenger Car Fuel Economy Standards

Source: ICCT, Industrial Market Insight

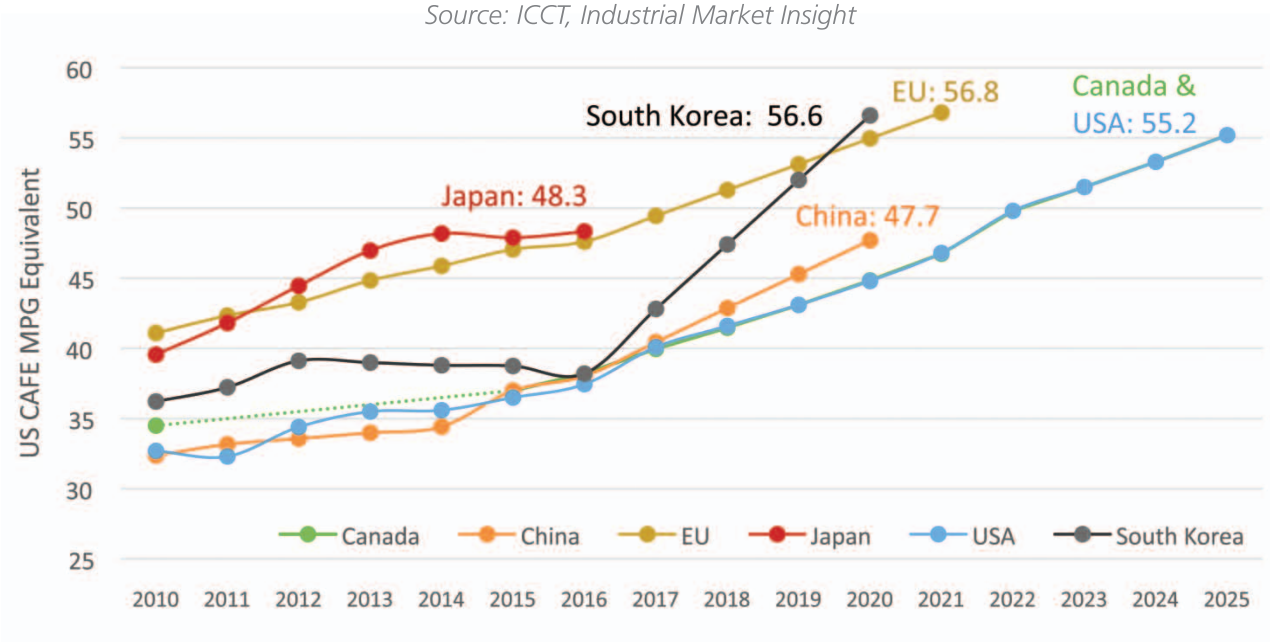


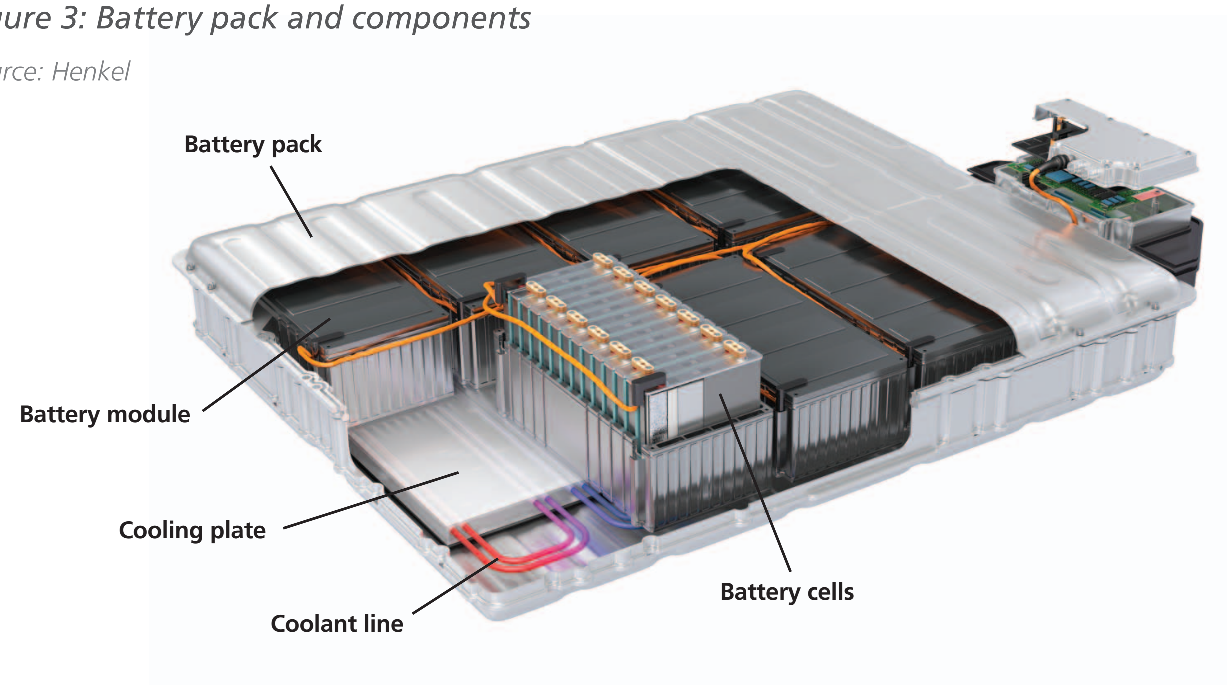
Figure 2: Comparison of Global Passenger Carbon Dioxide Emission Standards, stated in US CAFE MPG Equivalent

Battery Components in BEVs and HEVs

The technology landscape in EV powertrains is changing rapidly, and there is little standardization in the design and production of batteries for BEVs and HEVs. However, some basic components can be found in all electric vehicle powertrains. The basic functions of the battery cells, battery modules, and battery packs are described below:

Figure 3: Battery pack and components

Source: Henkel



Battery Cells

The battery cells are the most basic units that store energy for hybrid and electric vehicles. There are three types of battery cells used in electric vehicles: cylindrical, prismatic, and pouch. Each battery cell has an anode and a cathode that are separated from each other, but the execution is different in each cell type.

Cylindrical cells are the most mature technology and the least expensive to produce per kilowatt-hour (KWh) of energy storage. However, due to their circular cross section, they do not pack as efficiently as other cells, making cylindrical packs larger and heavier than other cell types.

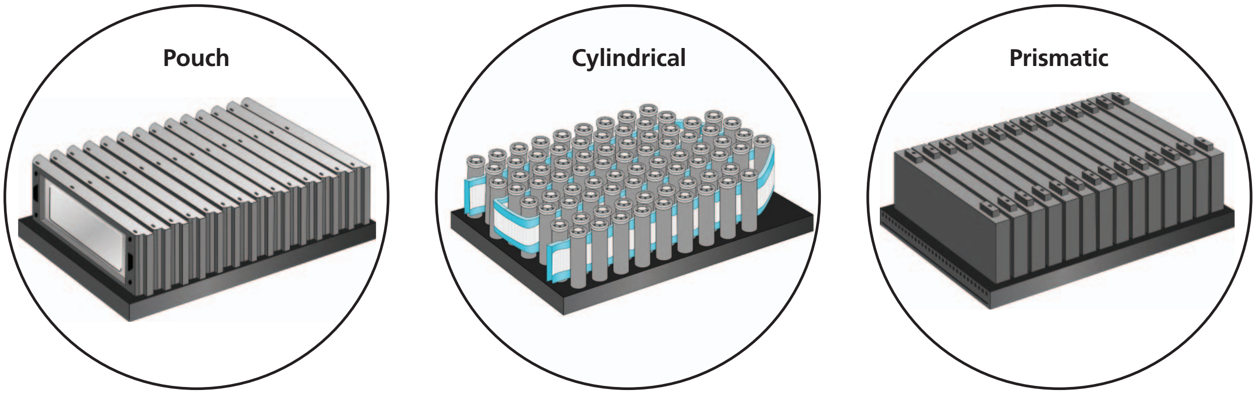
Prismatic cells can be packed more efficiently than cylindrical cells due to their rectangular shape, making them smaller and lighter, but more expensive, than cylindrical cell packs.

Pouch cells are the smallest and lightest cell technology but are also the newest and most expensive. The small size and light weight allow OEMs to maximize usable vehicle space and driving range of EVs, so developing technology to reduce the cost of pouch cells is a priority for automotive supply chain.

Pouch and prismatic cells experience more expansion and contraction during the usage cycle than cylindrical cells, which factors into the selection of adhesive products such as foams. Although relatively little adhesive and sealant is used in the manufacture of the cells, the cell type has implications to the design of the modules and packs, as well as the requirements of the adhesives and sealants used therein.

Figure 4: Pouch, cylindrical, and prismatic battery cells. Notice the cooling loop running between the cylindrical cells. Cooling can be improved with the use of thermally conductive adhesive beads or tapes.

Source: 3M



Battery Modules

A battery module encompasses a group of battery cells that are contained to protect them from the shock and vibration of the automotive environment. The modules must be fashioned in a way that allows the cells to be cooled (or heated, if necessary) and enables them to safely and efficiently charge and discharge.

Battery Pack

The pack is the single power storage unit that is assembled onto the vehicle. It typically includes several battery modules, controllers, and a cooling system. Battery packs for electric vehicles are very large and consume a good deal of the space under the floor of the vehicle and are enclosed and sealed to prevent intrusion of outside elements that would affect battery performance or life.

Battery Electric Vehicles (BEV) vs Hybrid Electric Vehicles (HEV)

Electric powered vehicles include both Battery Electric and Hybrid Electric powertrains. The primary difference between BEVs and HEVs is the source of electricity that is stored in the batteries. BEVs get power by being plugged in to an external power source, while HEVs have a gasoline engine and generate their own electricity. Since a BEV must store a greater quantity of energy than a HEV, the battery packs int the BEV are significantly larger. For example, BEV battery capacity is generally in the range of 40 -- 75 KWh and they contain a few thousand cells, whereas the high voltage HEV battery capacity may be 2-8 KWh and contains about 100 cells. As a result, BEV batteries are roughly five times the size of HEV batteries, and BEVs use substantially more adhesive than HEV on a per vehicle basis. On average, a BEV powertrain contains 7 lbs of adhesives or sealants while a HEV powertrain contains under 2 lbs.

Each OEM has its own philosophy regarding the selection of cells and the design of modules and packs. Cylindrical, prismatic, and pouch cells are in production vehicles today, and there is little standardization of componentry or design. Modules and packs can be made of metal or plastic and use adhesives and sealants to varying degrees. Typical uses of adhesives and sealants in battery packs and modules are discussed below.

Adhesive & Sealant Consumption in HEV & BEV Batteries and Motors, Global Total 2018

Source: Industrial Market Insight

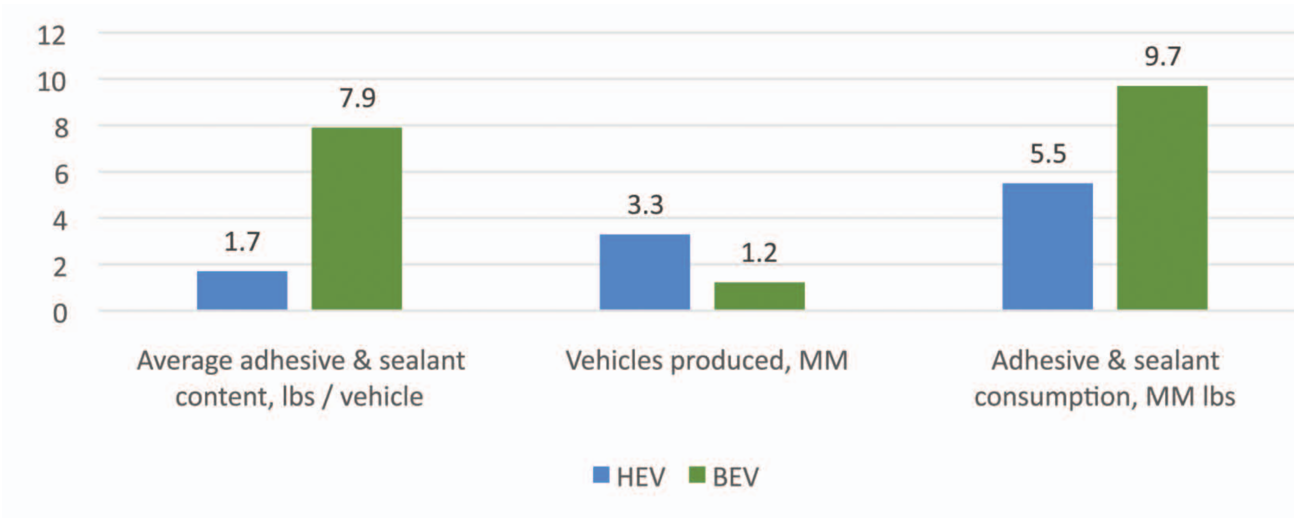


Figure 5: Global Adhesive & Sealant Consumption in HEV & BEV Batteries & Motors, 2018

Adhesive and Sealant Applications in Battery Modules

Each module contains groups of battery cells. The cells generate heat during their usage cycle, and they must be cooled to operate efficiently and safely. Cooling is most commonly achieved by system that circulates a glycol-based fluid through a cooling plate, similar to the way radiator works in a gasoline engine. The cells must make firm contact with the cooling plate in order for heat to be efficiently conducted away by the coolant. Thin layers of gap-filling, thermally conductive adhesives are used to bond the cells to the cooling plate and ensure good contact with the plate. Pads of conductive thermal interface material can be used for this purpose instead of adhesives. Adhesives can simplify the assembly process and eliminate the inventory of thermal interface pads.

Although thermally conductive, the adhesive must electrically insulate the cells from the cooling plate to prevent a short circuit. Therefore, high dielectric strength and fire resistance are musts for adhesives in this application. Epoxy, silicone, polyurethane, and methacrylate adhesives are used to bond battery cells to the cooling plates.

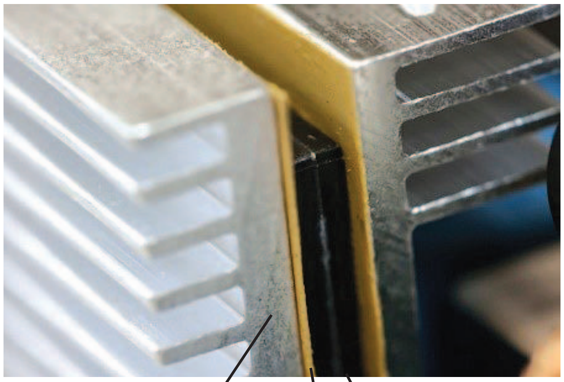


Figure 6: Thermal interface material bonding battery component to heat sinks.

Source: Henkel

Although the cells in the module are fixed to the cooling plate, they sometimes need additional support and protection from the mechanical shock and vibration experienced as the vehicle travels, or if it is involved in a collision. This support and protection can be provided through the use of adhesive or sealant foams or tapes. Adhesives used in these applications must have sufficient flexibility to allow for expansion and contraction of the cells in the usage cycle. Flexibility is particularly important with prismatic and pouch type cells, which expand and contract more than cylindrical type cells as they charge and discharge.

There are two different methods of protecting the battery cells using adhesives or sealants:

Adhesive and Sealant Foams can be used to fill a portion of the module cavity and surround the cells, holding them in place. Foams that encase battery cells can be thermal conductors or insulators, depending if the battery cells are actively or passively temperature controlled. For actively temperature conditioned systems, where the cells are both heated and cooled to keep them in the ideal operating temperature, insulating foams are desired. In either case, the foam must be an electrical insulator to prevent the creation of a short circuit. Adhesive and sealant foams can also be formulated to slow or stop fires in the event a battery becomes overheated or damaged. Bulk-dispensed foams are easy to deliver to fill irregular shapes, such as the gaps between cylindrical battery cells.

Tapes or Ribbons of Extruded Adhesive can be wrapped around the cells. Tapes allow for better control of the amount and location of adhesive compared to bulk dispensed adhesives or sealants. This minimizes the weight and cost contribution of the adhesive or sealant to the battery pack. Reducing the weight of the pack is essential in EV because lighter weight equates to extended battery range. Application of tapes can also make for easier assembly, particularly for prismatic cells, because the rectangular shape of the cell lends itself to tape dispensing.

Figure 7: Foam encapsulating battery cells inside a battery module. Foams can be used to support and protect battery cells and may also slow or stop the spread of fire if there is a problem with the battery.

Source: H.B. Fuller

Adhesive and Sealant Applications in Battery Packs

Automotive battery packs contain multiple battery modules, controllers, and a cooling system. The battery pack is sealed with a mechanical gasket, sealant, or adhesive to protect the contents from outside elements, such as water, dust, road salt, and automotive fluids. Since the pack enclosures can be made of steel, aluminum, or a variety of composites, adhesion to a wide variety of substrates is important. Battery enclosure materials often do not have typical automotive pretreatments, such as e-coat, so the ability to bond to substrates such as bare aluminum and composites is a factor into adhesive selection.

The pack itself can be mechanically fastened or bonded to the vehicle body or frame. Packs are positioned so that the vehicle frame will support and protect them from damage in the event of a crash. Structural adhesives can be used not only to join, but to add strength and stiffness to the completed assembly, which allows for the use of lighter materials and structures for the pack. Structural epoxies and polyurethanes are generally selected for these applications due to their high strength and the ability to bond to metals, as discussed in "Structural Bonding of Light Vehicle and Heavy Truck Bodies and Cabs" on pp 11-16 of the ASC OEM Body Shop Adhesive & Sealant Selection Guide. Crash-toughened adhesives are used in some applications because these adhesives absorb crash energy with less deflection of the frame, which helps reduce potential for damage to the batteries in the event of a crash.

The structural and crash toughened adhesives are similar to adhesives used in OEM body shops, but must cure at room temperature because the battery pack is not subjected to the heat of the paint or e-coat ovens used to cure adhesives applied in the OEM body shop.

Figure 8: Light vehicle frame with battery pack installed

Source: Sika

Inside the battery pack, adhesive and sealants are used to seat the modules and fix them in position. Similar to bonding cells inside the module, the adhesives and sealants must allow for efficient heat transfer to the cooling system by being thermally conductive and filling gaps to ensure firm contact is made between the surfaces. A wide variety of technologies are used in this application, including silicone, epoxy, polyurethane, and methacrylate adhesives. In some instances, tapes and thermal interface pads are also used instead of bulk applied products.

Serviceable and Non-Serviceable Battery Packs

There are two schools of thought on battery packs. Some have components that can be replaced if they malfunction, while other packs are not intended to be serviced and must be replaced if they have problems. There are implications to adhesives or sealants used in the bonding or the sealing of the battery pack.

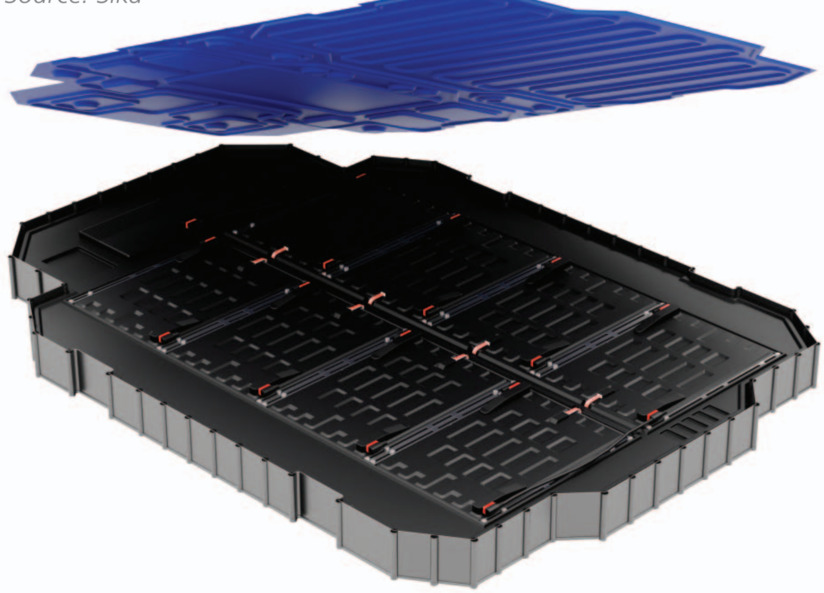
Non-Serviceable Battery Packs – Have a permanent enclosure that is mechanically fastened, welded, or bonded with a structural adhesive. Since the pack is not intended to be opened, adhesives that will cause substrate failure when removed are acceptable for these applications. In fact, this can be a benefit, as there will be evidence that the battery pack has been accessed for an attempt at an unauthorized repair. Non-serviceable battery packs can be bonded with a structural polyurethane, epoxy or methyl-methacrylate adhesives, since there is no concern about the substrate remaining intact if the pack is opened. Non-serviceable batteries can also use flexible adhesives, sealants, or gaskets to seal the pack.

Serviceable Battery Packs – Have a cover that can be removed and replaced. Serviceable batteries can use a mechanical gasket or a flexible polyurethane, silicone, or silane terminated product to seal the case. Removal of the pack lid may require cutting the adhesive in a manner similar to that of automotive glass replacement, which is acceptable as long as the cover remains fit for use. OEMs desire to use a seal that can be reused rather than replaced when the pack is opened and resealed, a challenge that manufacturers of adhesives and sealants, as well as mechanical gaskets, are working to address.

Whether serviceable or not, adhesives and sealants used for bonding battery covers must be fire-resistant and are often required to be electrically resistive, in addition to meeting typical automotive environmental and chemical exposure tests.

Figure 9: Cover of a battery pack bonded with an adhesive or sealant

Source: Sika



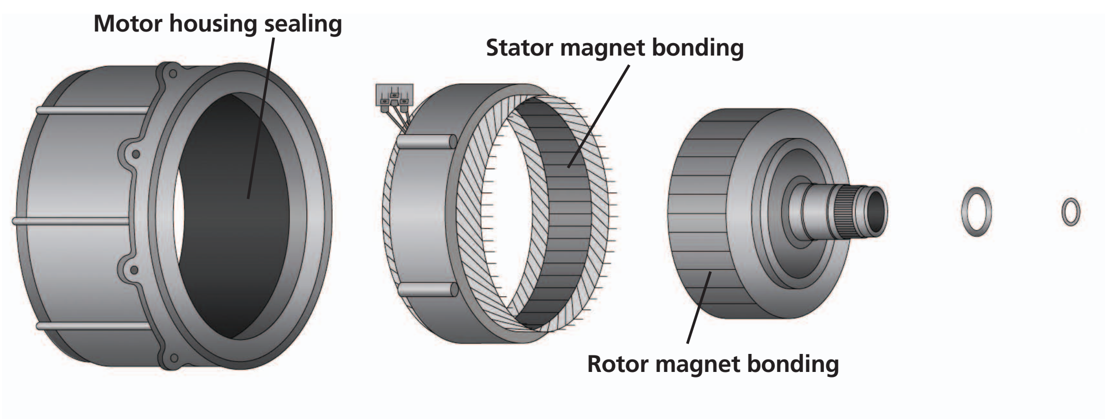
Adhesive and Sealant Applications in Electric Motors

Aside from the battery applications, adhesives are also an enabling technology in high performance motors that power electric vehicles. Adhesives bond permanent magnets to rotors and stators, and in some cases, for the encapsulation of the stator. Epoxies are generally used for these applications due to the high operating temperatures ranging from 180 to 220°C, but cyanoacrylates are sometimes also used in magnet bonding applications. These adhesives must be thermally conductive to allow the motor to cool during operation, which in turn permits greater power output for a given motor size. They also require high temperature resistance, due to the heat generated by the motor during operation, and resistance to the synthetic oils that are used to lubricate it.

Electric motors also have multiple gaskets that are used to seal the housing and keep water, dust, and other contaminants away from the motor. These gaskets require resistance to the same temperature and fluids required for the magnet bonding and stator encapsulation. Silicone sealants, formed-in-place gaskets, or pre-formed gaskets are used for motor gasketing applications.

Figure 10: Motor and stator adhesives and sealant applications.

Source: 3M



Quantity of Adhesives and Sealants Used in BEV and HEV

About 15 MM lbs. of adhesives and sealants were used in the powertrain of the 4.5MM HEVs and BEVs produced in 2018. This includes BEVs, such as the Tesla model 3, S, and X, the Nissan Leaf, and the Chevy Bolt, as well as several models that are produced in China for the local market by OEMs such as BAIC, SAIC, BYD, Geely, and others. The Toyota Prius is nearly synonymous with "hybrid" or HEVs, but this category also includes hybrid powertrains incorporated into mainstream nameplates from many major OEMs, such as the Honda Accord, Ford Fusion, and Chevy Malibu. Although this averages to 3.3 lbs. of adhesive and sealant in each powertrain, the average quantity consumed per vehicle is not a good measure due to the substantial differences in design and engineering of the batteries and components. Some OEMs use adhesives and sealants extensively, while others prefer mechanical fasteners and thermal interface pads rather than liquid dispensed products.

BEVs use a greater amount of adhesive and sealant on a per unit basis than HEVs because the battery packs are larger. BEV batteries have capacities in the 40-75 KWh range versus a 2-8 KWh capacity of the high voltage battery on a HEV, and the packs of BEVs are roughly five times the size of a HEV pack. Although BEVs accounted for only a third of the electric vehicles produced in 2018, they used nearly two thirds of the adhesives and sealants overall for both types of vehicles.

Sealing of packs and modules is the largest application and represented over 40% of the mass of adhesives used. This is the bonding of the perimeter of the enclosures for the packs and modules that use adhesives or sealants rather than a mechanical gasket.

Thermal interface bonding was the second largest application and accounted for just under 40% of the adhesives and sealant volume. These are thermally conductive, electrically resistive adhesives that are used to bond battery cells to cooling plates or tubes.

Battery cell encapsulation and motor bonding and gasketing accounted for about 10% of the mass of adhesives and sealant dispensed.

Volume of Adhesives & Sealants in HEV & BEV Powertrain Applications
15.2 MM lbs (2018)

Source: Industrial Market Insight

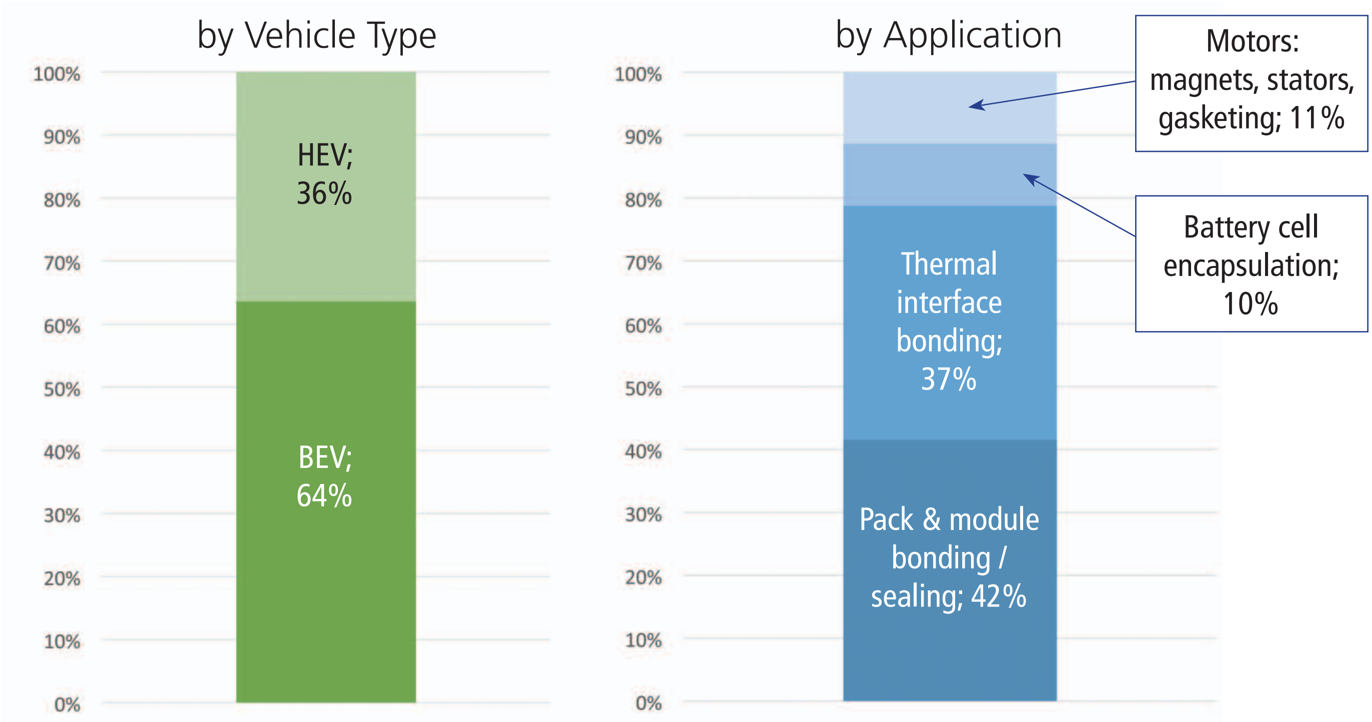


Figure 11: Global adhesive and sealant use BEV and HEV battery packs, modules, cells, and motors by vehicle type and application in 2018.

Summary

Adhesives and sealants are poised for growth in both HEV and BEV powertrain applications because they help component manufacturers and OEMs address critical performance, safety, durability, and manufacturing challenges confronted during the introduction of these electrified vehicles.

As battery technology has evolved from consumer electronics to automobiles, the adhesive and sealant industry has developed no-compromise solutions with an improbable combination of physical, mechanical, thermal, and electrical properties in easy to use products. Adhesives and sealants help solve difficult fastening issues with multiple substrates, protect batteries from mechanical shock and vibration to make them more durable, assist in cooling to improve efficiency and extend life, and increase safety by preventing electrical shorts and suppressing fires. As designs mature and with annual production volume of BEVs and HEVs forecast to increase significantly from the 4.2 MM vehicles produced in 2018, the outlook for adhesives and sealants in electric vehicle powertrains is bright.

Manufacturers:

3M
Ashland always solving
Avery Dennison
Bostik smart adhesives
Click Bond
DAP
DHM Adhesives, Inc
DuPont
Eclectic In the Home & On the Job Products
Evans Experience. The Difference.
Franklin International
H.B. Fuller Polymers
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