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Adhesives in Transportation Series

WHITE PAPER

Improving EV Battery Performance with Adhesives & Sealants

WHITE PAPER

*Published January 2026

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- **Adhesives & Sealants in Battery and Hybrid Electric Vehicles**
- **Improving EV Battery Performance with Adhesives & Sealants**

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Introduction

As one of the largest consumers of structural adhesives and sealants, the automotive industry continues to be a proving ground for the versatility of these materials. Adhesives and sealants have helped facilitate historic junctures – like enabling complex, multi-component assemblies for lightweighting, improved safety, durability and noise performance. And more than ever, they are now being tapped to increase the reliability and performance of hybrid (HEV) and battery (BEV) electric vehicle cells, modules, and packs.

Increasingly, adhesives and sealants are becoming functional and structural tools in the pursuit of an extended EV lifetime. They are vital to a battery's ability to operate safely at extreme temperatures and endure the shock and vibration generated from on and off-road driving. Advanced technologies are being developed to bond and debond on demand to facilitate repair and maintenance of batteries, which reduces inefficiency, waste and cost while making advances toward the circularity of HEV/BEV's.

As the race to electrify mobility continues, battery manufacturers and OEMs that engage with adhesive and sealant suppliers early in the design process are generating a growing list of wins that address HEV/BEV industry challenges. Examples of innovations that are reshaping the EV landscape will be shared to demonstrate how collaboration is enabling improved battery life, safety, reliability, repairability and circularity with a keen eye on keeping manufacturing cycle time, cost, capital and waste to a minimum.

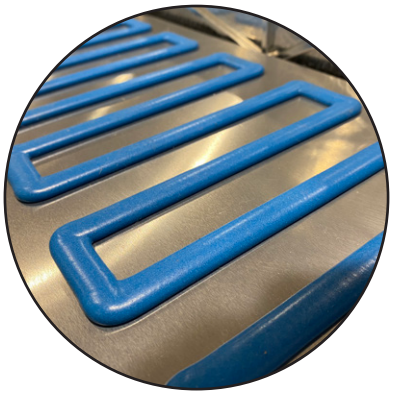
Recognized Benefits of Adhesives & Sealants

Most OEMs are now familiar with use of adhesives and sealants for:

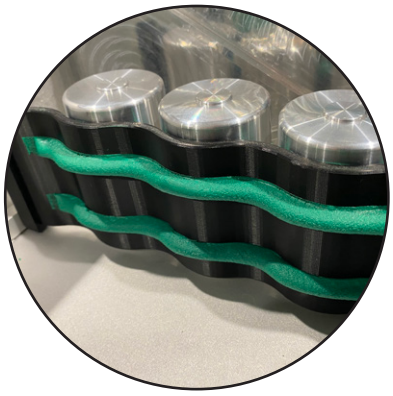
- Thermal energy management and fire suppression
- Shock and vibration resistance
- Structural joining, providing design flexibility and sealing that is not possible with single-point fasteners or welds
- Overcoming assembly and bonding challenges from complex designs and mixed materials
- Proven ability to meet demanding automotive specifications for exposure to extreme temperatures and chemicals

Adhesives and sealants play a critical role in EV battery thermal and mechanical performance, and a variety of materials have been developed to make batteries safer and more reliable. Foams and thermal interface materials help regulate battery temperature and prevent flame spread, greatly reducing the incidence and risk of thermal runaway. Gap fillers and structural adhesives provide strength and resistance to impact, shock, and vibration to extend the life of EVs beyond the 12-to-15-year design life. Despite the established reputation for performance and results, vehicle and battery manufacturers have voiced the need for further development of adhesives and sealant technologies for specific applications and challenges.

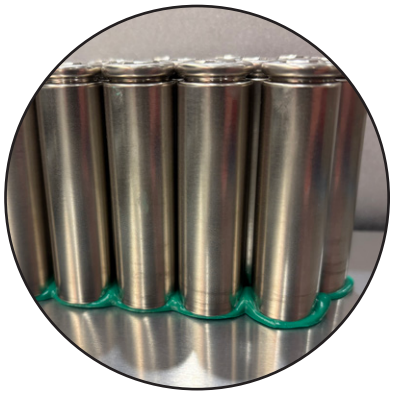
Gap Filling



Cooling Ribbon



Cooling Plate Bonding



Source: DuPont

Challenges for Adhesives & Sealants

EV powertrains continue to change and advance globally with little standardization in the design and production of batteries for BEVs and HEVs. Battery technology is rapidly changing with no clear winner yet. Without a standardized design, managing investment risk remains a vital priority. Key challenges voiced by OEMs and BEV/HEV battery manufacturers include:

- Faster, more streamlined, and efficient manufacturing processes that eliminate the need for pretreatments
- The ability to remove batteries or components for rework or repair
- Total lifecycle considerations, including planning for reuse of batteries, recovery of materials, and increased bio-based content

In addition to these challenges, OEMs are reluctant to add more materials, process steps or pretreatment requirements without a clear, long-term value proposition. Changing an established assembly process typically adds cost with the associated capital, time, floor space, workforce training or inventory management required. While all of these concerns are valid, OEMs and battery manufacturers are capturing value through adhesive and sealant innovations not thought possible even 5 years ago.

Simplifying the Manufacturing Process

For any adhesive or sealant, the desired outcome is for reliable bonding of the intended surfaces. Streamlining the assembly process (reducing the time, steps and materials used) and supporting modular assembly are foundational. EV designers, battery manufacturers and OEMs are looking for adhesives and sealants that offer:

- Short, reliable cure times
- No need for pretreatment of the substrates
- Ideally, one-component systems that are easy to dispense

Put simply, productivity, efficiency and cost reduction are key input variables for any manufacturing process, including those involving adhesives and sealants.

INNOVATION IN ACTION

DuPont Adhesives Meet Cycle-Time Goals with No Pretreatment for Improved Pouch Cell Performance and Productivity

THE OPPORTUNITY: Pouch cells are newer to the automotive EV market than cylindrical and prismatic cells. They are lighter and smaller than other formats, because the packing efficiency of the rectangular shape allows OEMs to maximize usable vehicle space while extending EV range. For that reason, pouch cells are expected to gain market share from other formats over time. One drawback is that the soft-sided pouch cell can be more susceptible to damage than other cells. To increase strength and durability in pouch battery packs, adhesives are used for cell-to-cell or cell-to-plate bonding. However, the materials used in pouch cells, such as bare aluminum foils and laminates, create bonding challenges.

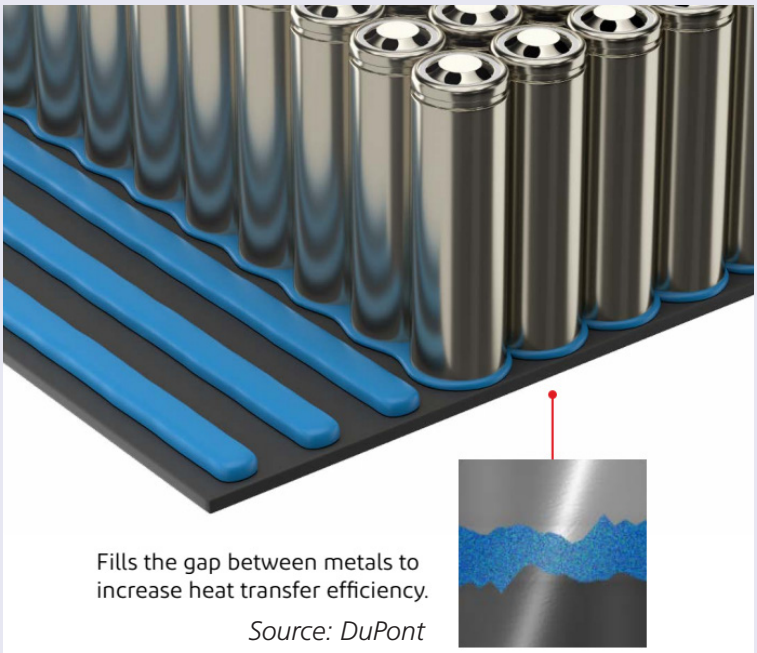
THE CHALLENGE: OEMs are looking for solutions to join pouch cells faced with uncoated aluminum foils in order to improve pack toughness and temperature management while simplifying the production process. In this case, DuPont's customers were looking to overcome:

- Unstable adhesion to the bare aluminum film encasing each cell, which leads to poor toughness, low bond reliability, and decreased aging resistance
- The need for primers or surface treatments prior to bonding the uncoated aluminum foil, which add cost and complexity while consuming valuable manufacturing floor space.
- The need for high temperature curing ovens or carefully controlled humidity levels during assembly and storage
- Rapid operating windows for adhesive dispensing and assembly

COLLABORATING FOR BETTER ALTERNATIVES: Developed specifically for broad application in EV battery assemblies, DuPont's patented elastic structural adhesive has numerous advantages for pouch cell bonding thanks to its ability to bond aluminum-laminated films without primer or pretreatment. Created in collaboration with a global pouch battery manufacturer, the two-component system fit within its existing manufacturing footprint. This new curing system was recognized with a 2024 R&D 100 Award in the Mechanical/Materials category. More importantly to its customers, this new curing system and product technology:

- Provides higher bond strength on aluminum-laminated film compared to incumbent materials with no need for primers or pretreatment
- Can be used within existing manufacturing footprint and processes
- Provides a longer dispensing and assembly window (at least one hour), reducing defects and waste

- Enhances flexibility and aging resistance of the pouches, with excellent elasticity after curing and stable mechanical properties before and after aging
- Reduces energy consumption with room temperature curing
- Incorporates 30% renewable, bio-based content to assist in meeting customers' sustainability initiatives



Fills the gap between metals to increase heat transfer efficiency.

Source: DuPont

While developing this technology required focused effort and expertise from DuPont, its successful integration into production was made possible through strong collaboration with the pack manufacturer. Because the part had to be inverted during the assembly process, the adhesive required rheology modifiers to suit the existing process. The final product selected was a 10:1 polyurethane chemistry. Metering equipment was carefully selected to ensure that the product would be delivered on-ratio and properly mixed every time, and temperature and humidity controls were put in place to encourage appropriate curing of the adhesive.

"This technology is another example of DuPont's ongoing commitment to provide innovative solutions to both the industry and our customers," said Frank Billotto, Marketing & Business Development Manager-EV, AMS at DuPont. "We continue to develop new formulations that can enable fast handling, reduce or eliminate cleaning and surface pretreatment steps and also feature wider operating tolerances requiring no baking to save expense and energy usage for a wide variety of applications beyond pouch cells."

INNOVATION IN ACTION

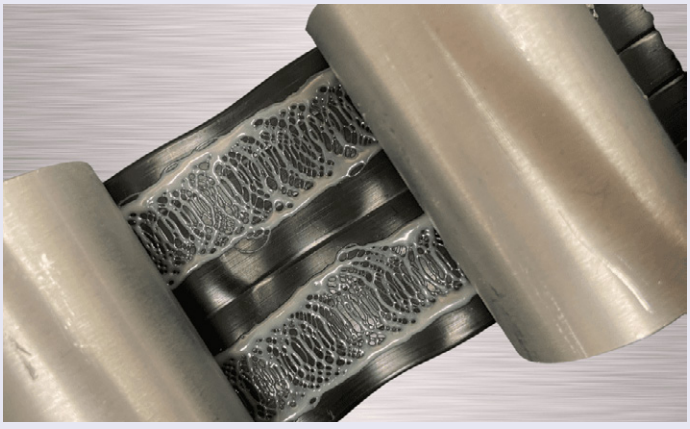
H.B. Fuller Reactive Pressure Sensitive Adhesive Keeps Battery Assembly Moving

THE OPPORTUNITY: Higher volumes of batteries will need to be produced at a lower cost if electric vehicles are to be cost competitive with internal combustion engines. This will require evolutionary, if not revolutionary, changes to battery technology. In turn, new materials will be utilized, and manufacturing processes must be created. As these new technologies mature, processes and cycle times that were acceptable during prototyping or for low-volume production often need to be rethought or reworked to achieve high volume, high yield production that minimizes overall costs.

THE CHALLENGE: A US-based vehicle manufacturer was experiencing difficulty with adhesive failure of a thermal barrier material in battery packs assembled in Mexico. The material was detaching as it was moved between manufacturing operations because it had not adequately cured. Due to the nature of the construction, the assemblies could not be reworked and had to be scrapped. Failure of the adhesive was extending cycle times and resulting in untenable loss of work in progress. Although the design was sound, the need to quickly move parts during manufacturing had not been duplicated during the prototyping process, and the problem was only detected once production had scaled up.

COLLABORATING FOR BETTER ALTERNATIVES: H.B. Fuller responded by developing a reactive adhesive for this application. The new adhesive exhibited pressure sensitive behavior for an extended time after initial application, before curing and reaching a strength of 10x greater than the adhesive it replaced. This innovation enabled the elimination of manual steps in the manufacturing process, shaving several minutes of cycle time, while eliminating scrap generation and related financial losses. The resolution of multiple issues in a mass production setting delivered an enormous savings that was "almost too high to calculate" according to Katie Johnson, Global Business Director, ePower and Energy Storage at H.B. Fuller, who shared that "Earlier involvement of adhesive suppliers can help identify and resolve these issues before they reach production."

This example underscores the importance of designing with the manufacturing process in mind, as prototypes are often made with different equipment at a pace that may mask problems until the start of mass production. Early collaboration with adhesive suppliers can help streamline processes and mitigate scale-up issues.



Source: H.B Fuller

Facilitating Disassembly for Repair and End-of-life Recycling

Robust adhesion and seals are vital for assembly and during use of automotive components. Yet, permanent bonds between mixed materials can present challenges as consumer and regulatory expectations for EV battery repair and circularity grow.

The battery's contribution to the cost of a new EV is considerable, typically accounting for 30-50% of the total purchase price. The cost of lithium-ion batteries continues to decrease as the technology matures, and OEMs are striving to make batteries account for less than 20% of the cost of an EV by 2030. However, after the point of sale, EV battery replacement costs remain highly variable and are a key concern for consumers, both from a cost of ownership and insurance perspective.

Consumers are looking for lower cost EV options that meet their needs for driving range and recharging time. There is regional disparity in EV adoption for these shorter-term considerations, but also for the longer-term consideration of cost of ownership defined by battery life or failure. The ability to cost effectively repair or replace the battery benefits consumers and OEMs alike. Repairability enables OEMs to offer warranty terms that instill consumer confidence while mitigating the financial risk of doing so.

Plus, the regulatory landscape for EV batteries continues to evolve, with new EU rules for battery passports and recycling quotas. These guidelines are creating pressure on OEMs to design EV batteries in a way that enables repairing, remanufacturing and recycling of those batteries—while always ensuring full transparency and traceability. Longer battery life and better reliability translate into less need for repair, more useful life and less waste. In response, industry suppliers, including Bostik and Henkel, have developed unique solutions that allow for bonded components to be removed to allow for repair or recovery of battery components.

INNOVATION IN ACTION

Bostik Collaborates with Porsche for Thermally Conductive Gap Fillers that Enhance Battery Life, Repair and Recyclability

THE OPPORTUNITY: Using thermal interface materials, such as thermally conductive gap fillers, is one way to help prevent EV batteries from overheating and failing. By filling air gaps between battery cells and cooling systems, they provide electrical insulation to the rest of the battery module and assist in proper thermal management. When a battery uses gap fillers, it is less susceptible to short circuiting and overheating, both of which can cause thermal runaway. By working with both the battery manufacturers and OEMs, Bostik developed gap fillers that improve battery performance and reduce waste, downtime and manufacturing complexity. "The ability to repair a battery pack by removing and replacing components provides a potentially enormous cost savings, which helps OEMs to mitigate risk", says Terry Smart, Business Development Manager, Automotive and EV Battery.

THE CHALLENGE: Gap fillers offer temperature resistance, a capability that allows the battery to operate at different temperatures for charging, discharging, and operational use. However, some common gap fillers can decrease production efficiency, increase waste or add to sustainability challenges. Common limitations include:

- Aluminum oxide, which is often used in gap fillers, is exceptionally hard and can be abrasive, straining the dispensing machines and increasing the need for maintenance or downtime.
- Solid pad gap fillers typically rely on time-consuming manual compression or require complex equipment to apply constant pressure to remove the air and ensure adequate connection.
- Two-component, reactive gap fillers can pose battery component disassembly challenges if their bond strength is too high, making component removal difficult and contributing to landfill waste and increased material usage.

COLLABORATING FOR BETTER ALTERNATIVES: Bostik has partnered with several vehicle manufacturers, including Porsche, to tailor-make removeable gap fillers using aluminum trihydrate, which is lighter and softer than aluminum oxide. These thermally conductive gap fillers can pass through dispensing machines easily with little to no abrasion, with a Mohs hardness of three versus nine out of 10 for incumbent aluminum oxide-based materials.

Source: Bostik

Bostik's solution exploited the fact that, in this application, high bond strengths are not necessary, as the primary function is to create a consistently mated surface to facilitate heat transfer. Removability is achieved through the low bond strength and the fact that the material does not cure or harden over time. If component removal is necessary, it can be achieved with the application of a relatively low force. Bostik's removable gap fillers are designed to streamline production and ease air removal that can contribute to defects, waste and downtime costs. They are successfully being used in 5-6 different vehicles from multiple OEMs, including cars, buses and trucks. "The design of the beads is important to manage the release force and prevent damage to the components being removed, says Smart, "this is an area that adhesive suppliers can assist their customers during design and planning for manufacturing"

Key benefits include:

- Their lower thermal resistance helps extend battery life, provide charging efficiencies and support a more sustainable battery overall.
- They can be removed by lightly scraping, or with commercially available solvents or cleaners.
- Their versatility and availability in 1K and 2K systems can be incorporated into most manufacturing environments.

Bostik's innovation addresses the need for removability when non-structural bonding is required. The ability to remove structural bonds on demand has long been on the wish list of automobile manufacturers but was considered out of reach. However, recent innovations by Henkel are making selective disbanding of structural adhesives a viable solution for disassembling EV battery packs within the next year.

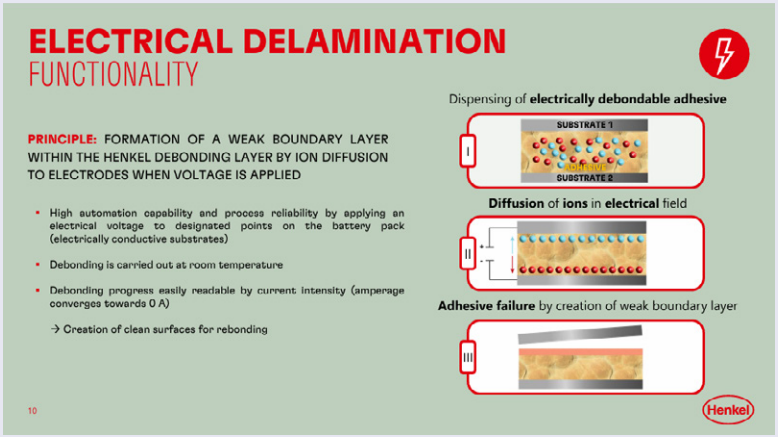
INNOVATION IN ACTION

Henkel Adhesives that "Debond on Demand," Reducing Waste, Enabling Repair and End-of-Life Recycling

THE OPPORTUNITY: Non-destructive dismantling is a high-priority objective for a more economic use of batteries. The ability to repair high-value components like EV batteries can reduce cost, rework, scrap and landfill waste for the manufacturer. Adhesives that can debond on demand will also allow OEMs and component manufacturers to repair downstream assemblies, reducing their cost, scrap and waste. Plus, the ability to conduct aftermarket repairs will extend EV lifetime and enable selective recycling. Parts can be dismantled into smaller units (modules/ stacks) which allow easier handling and selective recycling at any stage of manufacture or ownership.

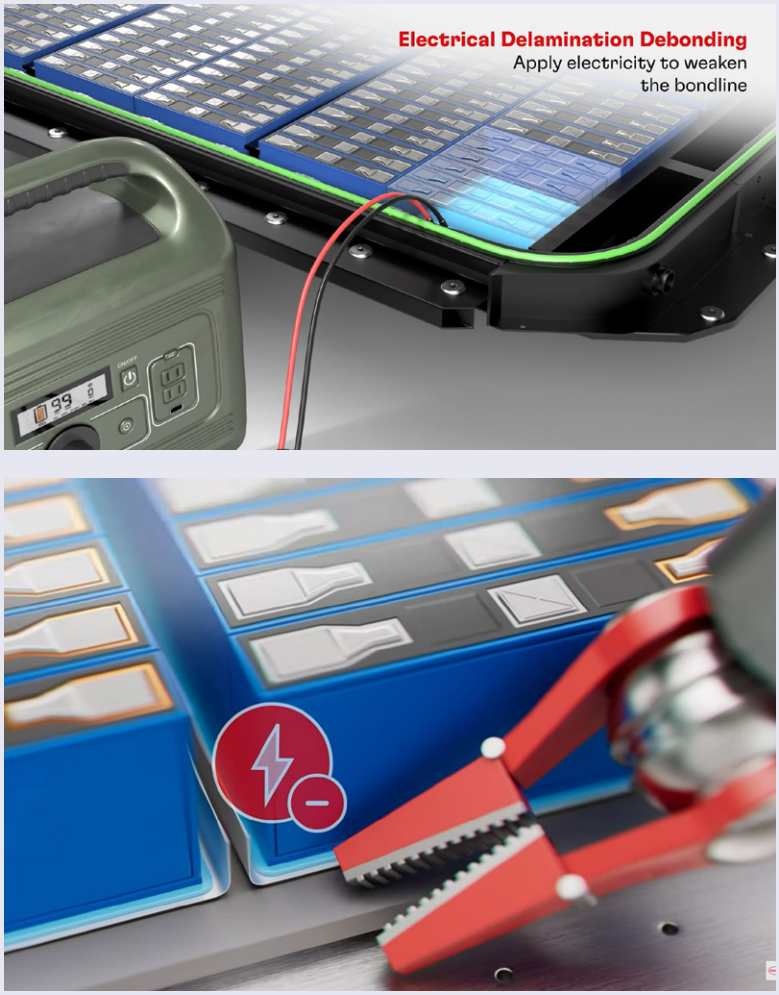
THE CHALLENGE: Right to Repair regulations are gaining traction in the EU, Canada and parts of the U.S. Electronics manufacturers, including EV battery manufacturers. Designers of electronic devices across every industry are working to meet existing and upcoming regulations. The need to make disassembly safe and successful without the need for special equipment requires designing with end-of-life in mind. That includes anticipating the added challenges associated with expanding where such repairs or recycling may be conducted and by whom. Automotive engineers must not only consider which materials can help components meet assembly and in-use specifications but also select materials that meet safe and successful disassembly requirements. Depending on the in-use application and the disassembly scenarios, innovators need to evaluate the most appropriate bonding and debonding triggers for in-use and end-of-life conditions.

COLLABORATING FOR BETTER ALTERNATIVES: Henkel has designed adhesives with a variety of debonding mechanisms, including electrical, thermal, and others. The appropriate mechanism is selected based on the requirements of each application, and technology has already reached high-volume production in the consumer electronics market. "Debonding by electric current is most likely to be employed in the near term for EV battery packs as a high strength structural adhesive with a bond of over 10 MPa,



Source: Henkel

according to Dalton Conlon, Key Account Manager - eMobility, "versions for sealing and gasketing are in development at Henkel's global network of Battery Application Centers, which includes a facility in Madison Heights, Michigan, to support growth of our battery and electric vehicle customers in North America."



Source: Henkel

For EV battery applications, the adhesive is typically used in a sandwich structure between battery cell and cooling plate. The adhesives are also suitable for structural bonding of the cell to the top frame or to side panels. The key is to design the joint with conveniently placed contacts that can be quickly and easily accessed when it is time to release the bond for repair or recovery purposes. As current is passed through the contacts to complete the circuit, the adhesive releases, and the component can be removed. It is important to design the circuit not only for easy access, but also to protect against unwanted debonding. Early involvement of the adhesive supplier is helpful in incorporating best practices for manufacturing and disassembly into the design. Given the strength of the debondable structural adhesives, they could potentially be a solution to improve the repairability of body structures as well as battery packs that are constructed using these adhesives.

Overcoming the Limitations and Misconceptions of Adhesives Past

Even with the many examples of where adhesives and sealants are advancing EV battery performance, a key challenge is overcoming the perceived limitations and past experiences with adhesives and sealants. One of the most important factors in generating positive outcomes is early engagement of adhesive and sealant suppliers to enable collaborative problem solving while there is still an opportunity to influence material selection, joint design, and manufacturing/disassembly parameters.

As the automotive industry continues to march toward an electric future, manufacturers are being faced with new challenges in terms of materials, manufacturing, and managing performance along the entire battery lifecycle.

Great strides are being made to overcome concerns with:

- **Bonding and sealing at room temperature:** Without the heat from a paint oven that is present in most OEM body shops, new solutions for room temperature curing are being developed. These include novel one and two component formulations, as evidenced by the examples provided. While the examples from DuPont, HB Fuller, and Henkel focused on higher bond strength, Bostik's one- and two-component thermal structural adhesive alternatives demonstrate what can be achieved when it is recognized that bond strength is not always the primary measure of adhesive or sealant performance.
- **Safe, efficient, and cost-effective manufacturing,** as demonstrated by all four of the case studies featured, with designs that reduce the need for pretreatments, complex curing scenarios, and use of solvents for disassembly. Anticipating final assembly processes, and diligence in the selection of metering equipment and control of the manufacturing environment contribute to success.
- **Circularity and waste reduction,** was another common theme in the featured case studies. In addition to capabilities that enable repair and recycling or battery materials, adhesives are increasingly incorporating bio-based content to meet automotive sustainability targets.

Early Engagement of Suppliers Yields Results

While adhesives and sealants are often used as necessary solutions to problems that are identified late in the design process, the best results are achieved when the design and materials are selected with intention early in the design process. Foams, adhesives, and sealants have been used effectively in remedying mechanical, thermal, and acoustic problems that are sometimes found during scale up or once mass production has begun. However, by engaging suppliers early in the design process, the type, amount, and placement of materials can be optimized to balance cost and performance.

Summary

Adhesives and sealants are vital enablers for assembling EV battery systems that meet industry expectations for safety, performance, and durability while allowing for repair and end-of-life material recovery. While the consumer and regulatory landscapes continue to evolve globally toward and electrified future, the challenges become greater, and the adhesive and sealant industry continues to deliver groundbreaking innovations that push the limits of possibility.

To learn more or get information on adhesive or sealant solutions for your application, visit **Buyers Marketplace - Adhesives/Sealants.org.**

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The following ASC Member Manufacturers and Suppliers provide adhesives and/or sealants in the automotive and battery & hybrid electric vehicles market:

***Note: Logos are clickable.**

Raw Material Suppliers:

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Manufacturers:

3M, ADFAST, Avery Dennison, bond it, Bostik, Colquimica Adhesives, DAP, Dow, DuPont, Eclectic In the Home & On the Job Products, FasTech, H.B. Fuller Polymers, Helmitin, Henkel, Hodgson Sealants, ICP, IPS Adhesives, Isotec The Chemistry Behind Performance, ITW Polymers Adhesives North America, J-B Weld, Jowat Adhesives, arti melt Collano, Matrix Adhesives Group, Meridian, Premier Building Solutions, Quin Global, RH Adhesives The Right Glue, Sika Building Trust, Stanley, Technical Adhesives, The Reynolds Company Adhesives & Coatings, Tremco, Wacker, weiss, Worthen

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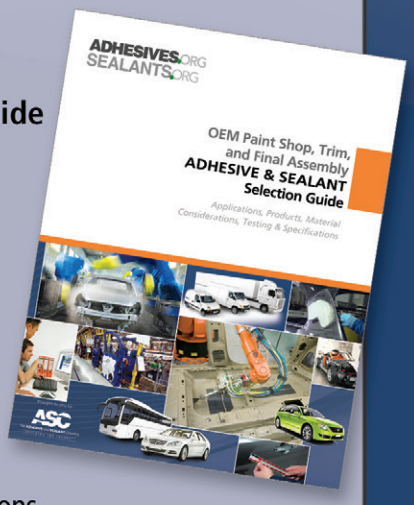

Topics covered include:

- Common joining methods
- Joining considerations and reliability factors
- Design and materials selection, including dissimilar materials considerations
- Applications and products
- Fuel economy and safety factors
- Weight reduction techniques
- Testing & specifications
- Markets, growth, drivers, key applications
- Regulatory requirements

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