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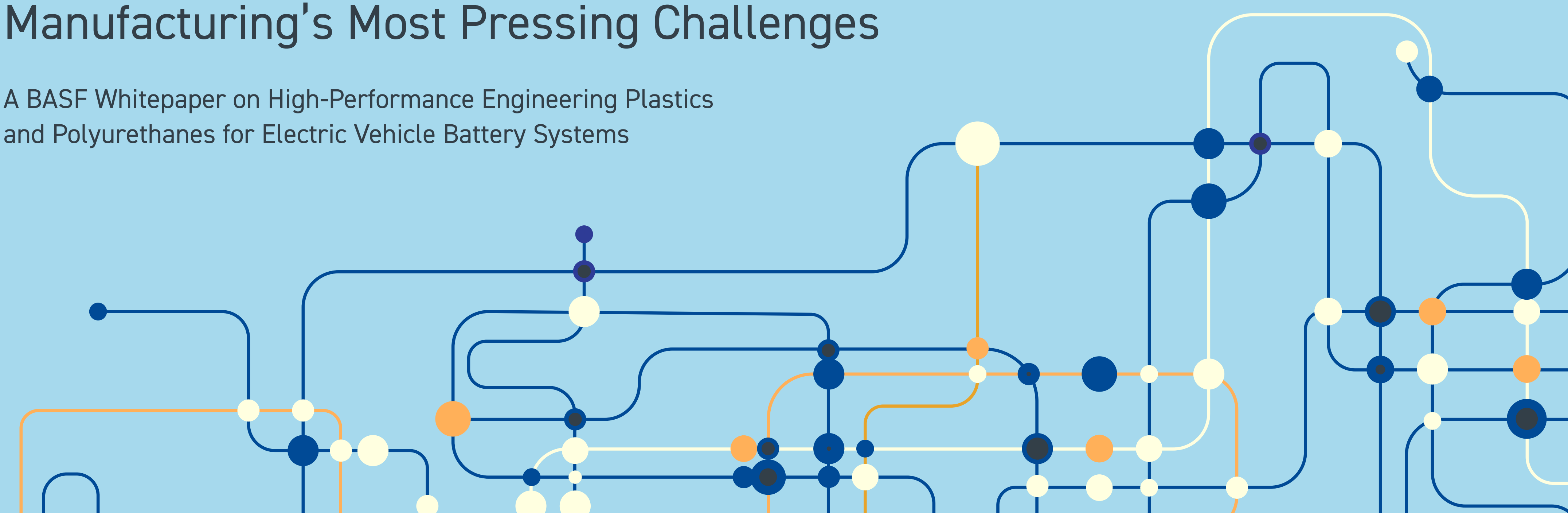
Innovative chemical solutions for eMobility

How Advanced Materials Are Solving Battery Manufacturing's Most Pressing Challenges

A BASF Whitepaper on High-Performance Engineering Plastics and Polyurethanes for Electric Vehicle Battery Systems



Executive summary

The electric vehicle revolution has entered a challenging second phase. Where early development focused on maximising range and charging speed, the industry now confronts a stricter imperative: safety, durability, and cost-efficient mass production. As battery energy density increases and architectures like 800-volt systems and Cell-to-Pack (CTP) integration become standard, conventional automotive materials are reaching their limits.

This whitepaper examines how high-performance engineering plastics (Ultramid®, Ultradur®) and specialised polyurethane systems (Elastolit®, Elastan®, Elastocoat®, Elastoflex®) are enabling a strong chemical architecture for eMobility. It highlights BASF's comprehensive material portfolio and strategic partnership approach, offering solutions that simultaneously enhance thermal management, secure safety regulation compliance (including China's stringent GB 38031-2025 standard), and unlock critical productivity gains through innovations like High Productivity Plus (HPP) and advanced foaming technologies.

The New Calculus of eMobility

The automotive industry's shift to electric propulsion represents a fundamental redesign of vehicle engineering, material science, and manufacturing economics. The battery - the vehicle's new heart - is a chemical and electrical ecosystem that defines performance, safety, and manufacturing cost. The challenge is structural: managing high power and stringent regulatory demands within commercially viable production cycles.

1.1. The Dual Pressure of Power and Production

High performance is driving the industry towards 800-volt architectures, essential for reducing charging times. However, this shift introduces higher demands on materials, where electrical insulation, tracking resistance, and fire safety cannot be compromised. As **Patrick Frey, Segment Manager eMobility at BASF,** observes: "The next generation of batteries is driving a transformational change that fundamentally demands new materials and design approaches."

Concurrently, manufacturers face immense pressure to achieve price parity with ICE vehicles. This economic viability hinges not only on raw material cost but on overall production line efficiency. Engineering plastic materials that reduce cycle times and offer integrated functionality are prized assets.

This environment requires constant adaptation. "The whole eMobility system is extremely dynamic," explains **Patrick Wilke, Segment Manager Chassis and Powertrain at BASF.** "The development of vehicles themselves is ongoing and consequently, materials must be flexible." Strategic adoption of high-performance plastics and polyurethanes enables replacement of heavier metal parts - vital for achieving the lightweight construction necessary for increased range and efficiency.

1.2. The Integrated Portfolio Approach

BASF's response is a comprehensive portfolio spanning high-temperature engineering plastics and versatile polyurethane systems. Wilke emphasises the company's breadth: "We have huge competence from a technical point of view. Not only for the battery system, but also for underbody, interior, and exterior, so we can support the customer across multiple applications." This integrated approach enables development of highly specialised products - like Ultramid® Expand (EPA, expanded Polyamide), "much more than an ordinary foam" - to solve problems that traverse traditional industry segments.

Navigating the Regulatory and Technical Imperative

The regulatory environment for BEVs is rapidly becoming more stringent, particularly regarding safety and thermal management. This is most apparent in evolving standards governing battery thermal events and high-voltage component resilience.

2.1. Next-Generation Thermal Protection for the World's Toughest EV Standard

China's GB 38031-2025 regulation represents a significant shift in global safety standards. While the original standard required approximately five minutes for passenger escape after a thermal runaway, the new rule sets a far more ambitious benchmark: two hours minimum with no conflagration, no eruption, and critically, no injurious fumes following a thermal incident.

Meeting this imperative cannot be achieved through passive thermal management or cell chemistry alone. It requires a sophisticated, multi-layered material strategy. **Thomas Stührenberg, Business Development Manager at BASF**, notes the challenge: "The new rule requires two hours during which there must be no fire, no harmful smoke for passengers, and no explosion - a significant challenge. The focus falls to material development and technologies to bring this about."

While Lithium Iron Phosphate (LFP) chemistry may offer inherent safety advantages, widely used high energy-density Nickel Manganese Cobalt (NMC) and Nickel Cobalt Aluminium (NCA) cells require additional thermal protection. Stührenberg confirms: "NMC and NCA cells require extra thermal protection, and our products can help achieve this standard." This is accomplished through specialised PU systems functioning as both insulation and fire-protective materials.

2.2. Ensuring Durable High-Voltage Safety Through Colour-Stable, High-CTI Materials

Complementing thermal protection, engineering plastics address a parallel safety imperative: ensuring reliable electrical insulation in high-voltage systems. High-voltage components require robust electrical insulation measured using the Comparative Tracking Index (CTI). A CTI of 600 permits smaller contact gaps, enabling more compact and lighter parts. Alongside performance demand there is additionally a strict visual requirement: high-voltage elements must be clearly recognisable in industry-designated orange in most in most cases (RAL 2003).

Frey notes: “RAL 2003 has become a de facto market standard for high-voltage components in electric vehicles for safety reasons, allowing immediate visual identification of 400-volt, 800-volt cables and connectors.”

Achieving this colour while maintaining electrical properties presents significant challenges. To keep a stable orange colour is always a challenge for Polyamide-based engineering plastics - especially in combination with heat ageing.

During charging or acceleration, temperatures rise and polymers are ageing. Polyamides are particularly sensitive - even uncoloured grades exposed to 130°C for 1,000 hours develop marked brown tints, with orange compounds experiencing more severe degradation. BASF’s response is the Durable Colour (DC) formulation. “To ensure colour stability,” **Frey** explains, “BASF developed DC, a formulation designed to maintain the orange shade for defined time and temperature ranges through a dedicated stabilisation system.” This has been engineered for PA6 and PA66 in both flame-retardant and non-flame-retardant variants. Complementing these solutions, BASF supplies PBT materials offering particularly strong resistance to discolouration.

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Patrick Frey,
Segment Manager eMobility, BASF

Engineering Plastics: Productivity and Lightweight

High-performance engineering plastics - primarily Polyamides (PA) like Ultramid® and Polybutylene Terephthalates (PBT) like Ultradur® - have evolved into strategic material integration, driving both manufacturing efficiency and essential high-voltage safety.

3.1. High Productivity Plus (HPP): Engineering for Cycle Time Reduction

In high-volume automotive manufacturing, cycle time dictates profitability. BASF's High Productivity Plus (HPP) product family - including Ultramid® B3EG6/G7 HPP (PA6) and Ultradur® B4300G2/G3/G4 HPP (PBT) - was developed specifically to address this bottleneck.

A Drop-In Solution for Immediate Gains

HPP's core innovation lies in tailored formulation achieving improved flowability, directly impacting injection moulding's most time-consuming phase: cooling.

The commercial strategy was deliberate. **Frey** highlights the objective: "The clear target was to have a new product still quite similar in terms of mechanical and rheological behaviour - mechanical strength, shrinkage, warpage - compared to standard materials. We wanted a drop-in solution to replace standard materials with an existing tool in an existing project."

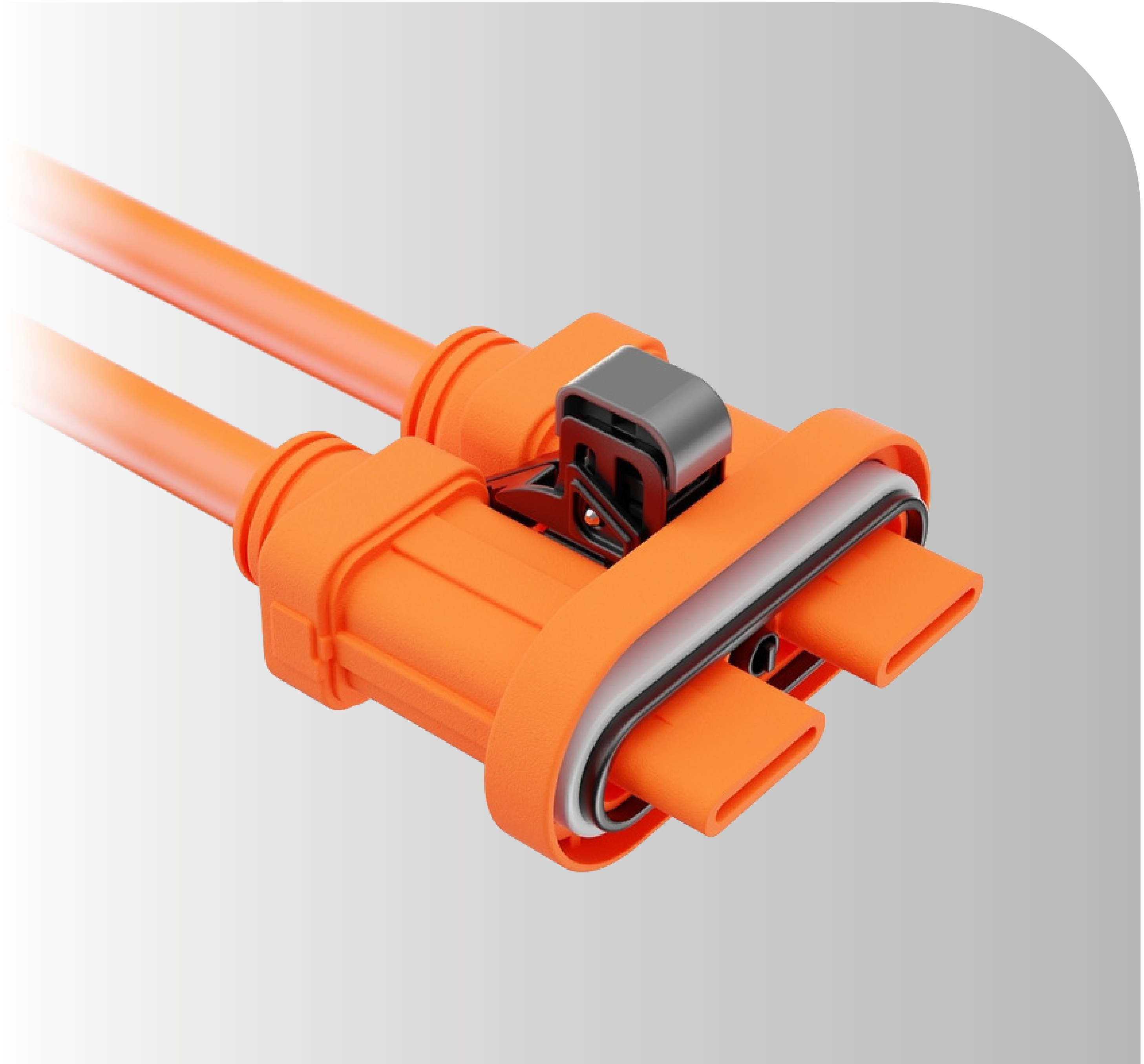
This "drop-in" capability means manufacturers realise immediate benefits without costly re-tooling. **Frey** confirms HPP products are "more than ready to be used in existing tools" - a key economic factor for rapid adoption.

Quantifying the Efficiency Boost

Frey notes initial testing results: "Typically, customers start testing the material with injection moulding machines, and we see cycle time reduction of approximately 15 - 20% directly." With BASF technical services assistance in parameter optimisation, "we've had very positive results - cycle time reductions up to 30%, even higher than initially seen."

These reductions translate directly into productivity gains. Higher output per unit time lowers cost per part, while total energy consumption decreases through increased throughput. Customers benefit from both economic savings and measurable energy efficiency improvements.

HPP materials can be processed at reduced melt temperatures. Combined with increased throughput, this enables approximately 15%-20% reduction in specific energy consumption. Frey summarises the economics: "Ultimately, we have lower process costs, which enables customers to reduce their total costs and improve the product carbon footprint."



3.2. Electrical Integrity: The Durable Orange Portfolio

The requirement for high CTI, V-0 flame retardancy, and orange colour (RAL 2003) represents a challenging intersection of electrical safety and material science. BASF's durable orange portfolio eliminates traditional trade-offs between these properties.

Ultradur® B4450G5 HR (PBT): This flame-retardant PBT grade achieves UL 94 V-0 at 1.5mm while maintaining CTI 600. It demonstrates excellent colour stability at 130°C for 1,000 hours and meets demanding USCAR2 Climate Change Test requirements - ideal for robust high-voltage connectors exposed to temperature and humidity variations.

Ultramid® A3U44G6 DC (PA66) and B3U42G6 DC (PA6): These grades achieve UL 94 V-0 at exceptionally thin 0.4mm wall thickness while maintaining CTI 600. Frey emphasises: "The three main topics are flame retardancy, CTI, and high mechanical properties. With the new orange portfolio, we meet all of them, especially with the V-0 at 0.4mm for A3U44G6." This thin-wall V-0 capability is indispensable for reducing size and mass of connectors in high-density power electronics.

3.3. Structural Lightweight: Ultramid® Expand (EPA)

The need for structural and heat-resistant battery pack components including thin wall geometries led to development of Ultramid® Expand (EPA), a polyamide 6-based particle foam representing a deliberate departure from standard expanded polypropylene (EPP) foams.

Structural Resilience and Processing Freedom

Ultramid® Expand is engineered for demanding BEV applications like cell holders, battery frames, and structural components requiring energy absorption. Key differentiating features include:

Thermal and Chemical Resilience:

Maintains excellent mechanical properties exceeding 120°C with strong chemical resistance against automotive liquids. It is even compatible with the e-coating process and can therefore be seamlessly integrated into existing production processes.

Structural Integration:

EPA offers geometric freedom for structural parts and the ability to realise wall thicknesses down to 1 mm. It can be can be overmoulded with standard engineering plastics, creating complex, multi functional parts. Wilke highlights the manufacturing advantage: "A key advantage is that injection overmoulding can be performed using standard parameters and pressures, which is not achievable with other foams. This enables production of highly complex components through conventional processing methods."

Versatility and Sustainability:

The material is processable via e-coating, laser-markable, glueable, and weldable, and can therefore be integrated into standard production processes. When overmoulded with a PA6 as a single-material solution - it enables straightforward recycling pathways, fully aligning with design-for-recycling principles and circular-economy goals.

Wilke summarises the potential:

"Ultramid® Expand is a material for challenging applications, and with so many associated efficiency gains, is much more than an ordinary foam."

Polyurethane Systems: Critical Battery Infrastructure

While engineering plastics provide visible structural components, polyurethane (PU) systems constitute the critical infrastructure enabling safe, durable, and manufacturable battery architectures. These systems deliver essential seals, structural adhesives, thermal interface materials, and fire-protective barriers necessary for managing thermal events and enabling advanced CTP and Cell-to-Body (CTB) integration.

Stührenberg positions the PU battery portfolio as essential: "We have a globally available material portfolio to help customers meet new safety standards and optimise battery pack design: Elastocoat®, Elastoflex®, Elastan®, and Elastolit®."

4.1. Thermal Runaway Mitigation: Fire Barrier Solutions

The GB 38031-2025 two-hour safety challenge requires robust, efficient thermal barriers capable of rapid assembly integration. This demands materials withstanding temperatures exceeding 1,200°C - well beyond conventional polymer capabilities.

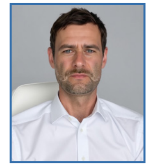
Elastocoat® Fire Protective Coating (FPC)

The answer is to secure the battery from burning through its cover by applying a fire protective material. Elastocoat® is a polyurethane system engineered to withstand extreme temperatures to 1,350°C with 1 MPa air blow during torch fire testing. Applied with a flat stream applicator the coating can be applied without overspray. Applied in layers just 1–2 mm thick, these formulations form non-intumescent fire barriers that char under extreme heat, creating an insulating layer that prevents thermal propagation.

Application flexibility represents a significant manufacturing advantage. The system can be robotically applied directly onto battery covers or complex 3D chassis shapes, providing compelling advantages over conventional inorganic materials like mica sheets. While mica has long provided thermal protection, it is complex and inflexible in various production scenarios, with its mining raising sustainability concerns, and its installation complexity driving costs.

In thermal runaway tests involving NCM811 single cells - among the most thermally volatile chemistries - FPC achieved maximum back-side temperature of max 300°C with just 1.2mm thickness, demonstrating performance comparable to mica.

Stührenberg emphasises manufacturing benefits: "We developed a fire-protective polyurethane coating that increases customer productivity through a one-step flat-stream application technology. It requires no temperature curing and can be applied to 3D shapes, even in overhead application."



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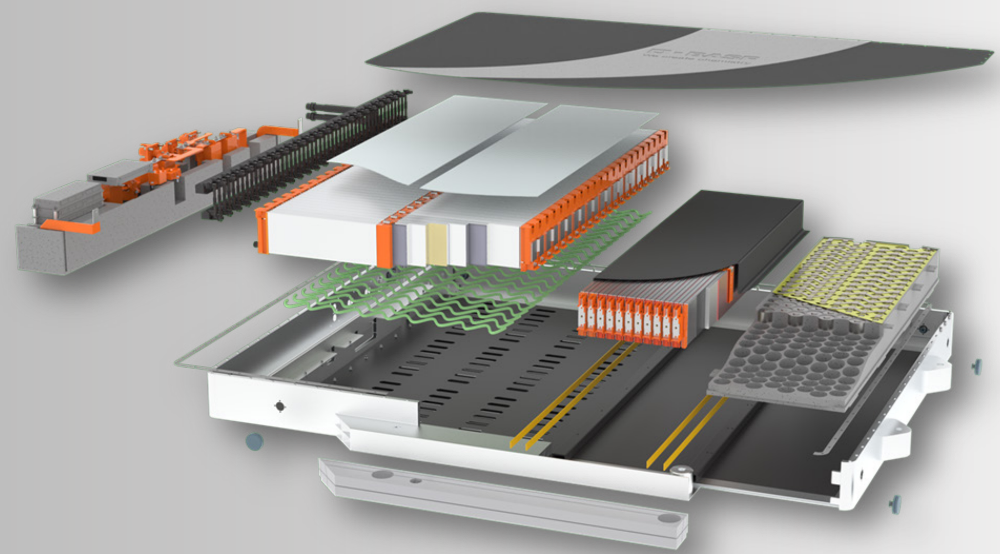


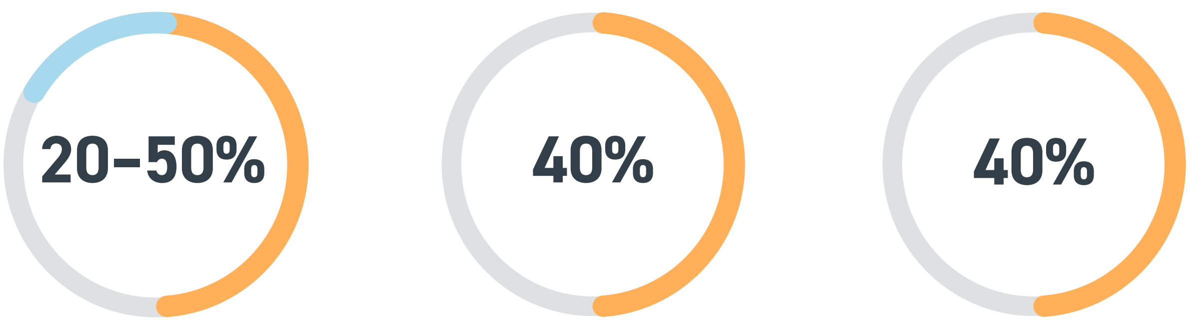
Elastoflex® Spray Transfer Moulding (STM)

The battery is one of the most critical components in an electric vehicle (EV). Also important is the enclosure that keeps these batteries safe, dry, and fully operational. Since battery packs can account for 25% - 30% of the total vehicle weight, engineers are increasingly seeking lightweight alternatives to metals - solutions that not only reduce weight but also deliver further functions like superior thermal management.

These composites produced by the spray transfer moulding process using Elastoflex® PU systems presents compelling advantages over both metallic alternatives and compression-moulded composites.

The STM process involves robotically spraying polyurethane resin onto fibre mats, followed by compression moulding and curing. This yields components with low density, high stiffness, and excellent flame-retardant properties - critical for achieving structural integrity while ensuring improved thermal runaway protection.

Resulting components achieve significant improvements:



weight reduction versus steel or aluminium

thickness reduction versus sheet moulding compound (SMC)

cost savings versus high-pressure resin transfer moulding (HP-RTM)

Stührenberg confirms effectiveness: "In the context of STM composite battery enclosures, the key consideration is the integration of multiple functions - fire protection, thermal management, EMI shielding, crashworthiness, sealing, and adhesion - into a unified design."

Due to increasing BEV safety requirements and geopolitical risks in global supply chains, BASF is co-developing a fibre-reinforced polyurethane with ElringKlinger, produced using STM technology and designated 'ElroForm TP-ECO'. This solution is not only a Mica replacement, but can be used on a system level as composite solution for high performance shielding. The advantages of ElroForm TP-ECO include design freedom with good 3D formability; lightweight construction (approximately 50% lighter than rigid mica at the same thickness); improved mechanical and thermal stability (including reduced delamination under stress); a lower scrap rate (easier handling in production); and technical cleanliness.

This partnership exemplifies the collaborative model increasingly necessary for battery technology advancement.

4.2. Precision Thermal and Structural Management

Modern battery pack designs increasingly adopt integrated CTP and CTB structures, placing heightened demands on thermal management and structural integrity. The transition to Cell-to-Pack architectures has elevated these materials from supporting components to critical enablers. Without module housings to provide load paths, adhesive and potting systems must simultaneously bond cells, dissipate heat, provide electrical insulation, prevent flame propagation, and provide structural integrity to the whole battery pack.

Elastan® Battery Adhesive: The Elastan® portfolio consists of Thermally Conductive Adhesives - Gap Fillers and Structural Adhesives. The Thermally Conductive Adhesives are needed to transfer heat and for fixation of cells, giving structural integrity to the whole battery. The Thermally Conductive Gap Fillers are used to fill the gaps and transfer heat between modules and cooling plate. The Structural Adhesives are mainly used for the fixation of battery components, giving structural integrity to the whole battery without significant thermal conductivity.

Stührenberg explains heightened demands: "Regarding thermal propagation and fast charging safety, higher energy density in modern battery pack designs (Cell-to-Pack/Cell-to-Body) thermally conductive adhesives must fulfil two key functions: efficient thermal management and mechanical stability."

BASF is offering a holistic solution – and not one merely optimising individual parameters. BASF's strategic advantage lies in its ability to adapt these products precisely to customer requirements in terms of performance and process management.

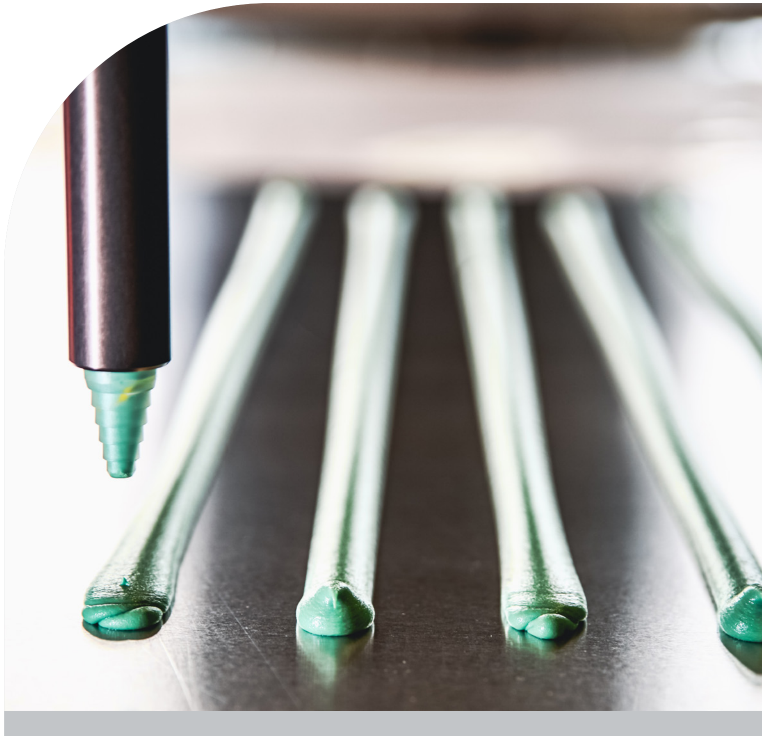
The portfolio offers performance tailored to specific applications:

Thermally Conductive Adhesive and Gap Fillers: Thermally conductive adhesives: By ensuring effective heat transfer and the secure structural fixation of the cells, these materials provide the structural integrity required for modern battery architectures. Specific requirements vary depending on the overall battery pack architecture and design approach.

The Gap Fillers required to fill the gap and transfer heat between the modules and the cooling plate, which are mainly used in cell-to-module approaches. Customer requirements can include removability and typically a thermal conductivity up to 3 W/mK with a trend toward lower TC values.

Structural Adhesives: A structural adhesive is crucial for fixing battery components and ensuring the overall stability of the battery packs. Battery cells and modules need strong and durable joining methods and long-lasting performance throughout the entire product's lifecycle. BASF's structural adhesives provide a bonding strength of more than 13 MPa and an elongation at break of more than 80%. Thermal conductivity is not a required property for these types of adhesives.

Perhaps most significantly for European manufacturers, all Elastan® battery adhesives are silicone-free.



Elastolit®: Potting for Cell-to-Pack Architectures

Elastolit® potting systems are crucial for encapsulation of cylindrical cells. Cell encapsulation addresses multiple challenges simultaneously: structural rigidity, thermal isolation between cells, electrical insulation, mechanical protection, and fire containment.

Stührenberg emphasises the protective role: "With the Cell-to-Pack Technology the requirements to battery potting changed. Due to the loss of structural support to the battery compared to the Cell-to-Module Technology, the BASF offers Polyurethane Potting systems which covers a broad range of higher mechanical properties to reach the required structural properties in Cell-to-Pack designs as well as a cost-down compared with current industry standards."

The portfolio is highly diversified, spanning from lightweight foams at 200 - 400 kg/m³ to high-modulus compact systems at 1,150 kg/m³:

Structural Foam:
Offers high elongation at break (up to 60%) with 400 kg/m³ density, providing robust yet relatively lightweight protection.

Structural Compact:
Offers high tensile strength (up to 55 MPa) and tensile modulus (up to 2000 MPa), ideal for applications requiring maximum mechanical rigidity.

All Elastolit® systems are characterised by excellent electrical insulation, fast demoulding, excellent ageing profiles, and flame-retardant variants achieving UL 94 V-0 classification - ensuring reliable performance and longevity.

The strategic value of the Elastolit®, Elastan®, Elastoflex®, and Elastocoat® portfolio extends well beyond simply meeting individual material property specifications. Development partnerships with OEMs typically begin with baseline formulations meeting approximately 80% of requirements, then iterate through joint testing to achieve 95 - 99% specification compliance. This collaborative approach, supported by BASF's Ultrasim® simulation capabilities for predicting flow behaviour, compresses development cycles while reducing tooling and prototype costs.

Beyond Materials: Strategic Development Partnership

The greatest value a chemical partner can offer is not merely high-performance compounds but the expertise and integrated service necessary for successful deployment. The pace of eMobility development is too rapid for conventional, linear R&D cycles.

5.1. Integrated Engineering, Testing, and Simulation

BASF's partnership approach is rooted in deep material-science expertise and advanced services that reduce risk and accelerate time-to-market. Frey highlights the available technical support: "One example is our technical service offering, where engineering-plastic processing experts from our application development team work directly with customers to identify the ideal processing parameters."

This ensures that manufacturers move beyond simple material substitution toward true process optimisation - particularly when implementing cycle-time-reduction solutions such as HPP. Services include advanced simulation tools such as Ultrasim®, which enable highly accurate early-stage simulations of engineering plastics. Frey highlights the benefits of this approach: "We're able to run preliminary simulations with remarkable accuracy to determine whether a plastic material fits the geometry and the intended application. This helps customers save money right at the start of a project by avoiding tool builds that don't match the material." This simulation capability substantially de-risks the design process for new and complex components and provides a critical advantage in the fast-paced development cycles of electric vehicles.

Wilke emphasises the breadth and reach of BASF's technical competence across the vehicle: "We deliver more than technical expertise - we provide solutions that help customers achieve their goals. Our capabilities span the entire vehicle, from battery systems to underbody structures, interior components, and exterior panels. This holistic approach ensures that material choices are optimised for interaction and overall performance, enabling customers to design safer, more efficient, and cost-effective vehicles."

This holistic perspective allows BASF to function as a comprehensive engineering consultant and development partner, rather than merely serving as a transactional supplier of raw materials.

"We deliver more than technical expertise - we provide solutions that help customers achieve their goals. Our capabilities span the entire vehicle..."

Patrick Wilke,
Segment Manager Chassis and Powertrain at BASF

5.2. Addressing the Next Frontier

This collaboration extends into anticipating and solving future challenges, particularly concerning extreme fast charging and next-generation battery designs where current material solutions are expected to reach their limits.

Frey confirms BASF's proactive innovation stance: "We focus on tailor-made flame-retardant products for eMobility applications - optimized for varying wall thicknesses and engineered to meet specific requirements. We're also innovating with new material classes, like Ultramid® Expand and driving the creation of new demonstrators." These demonstrators, such as next-generation battery cell holder models, allow OEMs to see the full potential of BASF's polymer portfolio in real-world applications.

Conclusion: Materialising Ambition

The shift to electric mobility is ultimately a shift in material science, where high-performance polymers and polyurethanes are the new structural, thermal, and electrical architects. By developing solutions like cycle-time reducing High Productivity Plus grades, high-CTI Durable Orange portfolio, lightweight structural foam Ultramid® Expand, and fire-mitigating Elastocoat® and Elastoflex® systems, BASF is directly enabling the next generation of endurance, efficiency, and safety in electric vehicles.

This partnership model - integrating deep chemical expertise with advanced simulation (Ultrasim®) and technical service - is critical to navigating the industry's pace. Frey summarises the value proposition: "BASF is the right partner for innovation in eMobility. That's the most important point. We have a highly motivated and talented team with a lot of additional services. In combination with our sustainability approach, we can offer our customers the ideal solution."

As the automotive sector embraces Cell-to-Pack and Cell-to-Body designs requiring materials that combine multiple complex functions, BASF is providing the essential chemical architecture needed to realise the transformation. Stührenberg reinforces this commitment to safety and innovation, stating that the products are designed to "help achieve this [GB 38031] standard," ensuring that the future of eMobility is built on a foundation of performance, sustainability, and uncompromising safety.

Find out more here