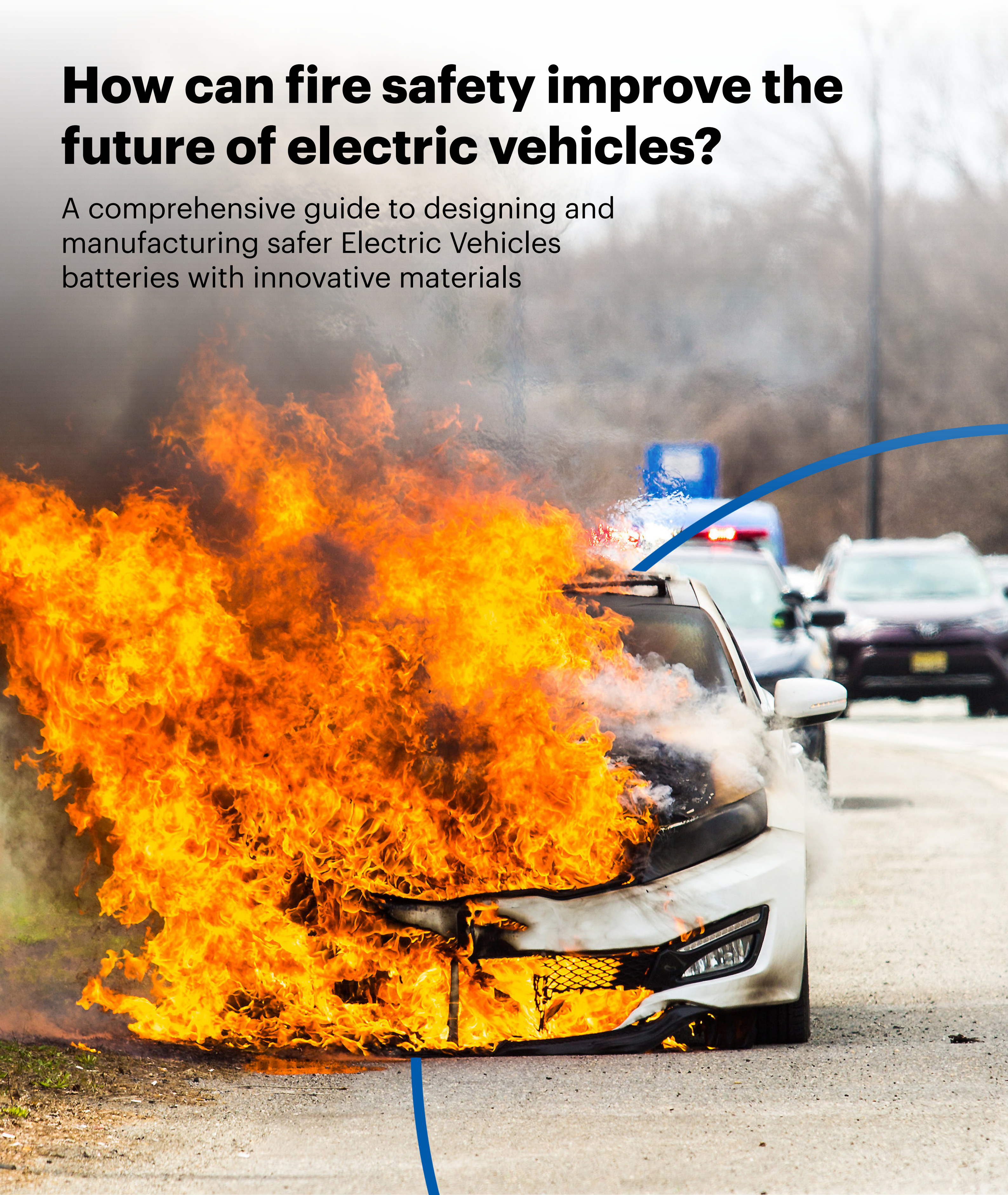
How can fire safety improve the future of electric vehicles?

A comprehensive guide to designing and manufacturing safer Electric Vehicles batteries with innovative materials



MITSUBISHI CHEMICAL GROUP

Introduction

With an increasing number of electric vehicles (EV)on the road, regulators are turning their attention to the fire risks associated with EVs - and increasing pressure on manufacturers to prevent and mitigate them. Innovations in battery system materials technology and processes can help to keep EV industry leaders ahead of the curve.

The rise of electric vehicles (EVs) and a burgeoning battery market are two of the major stories emerging from the accelerating energy transition. The lithium-ion battery industry is on an astronomical growth trajectory, with GlobalData projections suggesting it will reach $400 billion in revenue by 2035 – up from just under $90 billion in 2022. This translates to an impressive 12.5% compound annual growth rate (CAGR). According to McKinsey, mobility applications will account for at least 90% of battery demand by 2030. And GlobalData research suggests EV production is expected to hit 17.3 million units by 2025, making up 18.4% of total light vehicle production – rising to 28.3 million units, accounting for 28% of production, by 2028.

Can anything slow the momentum of EVs? Concerns over safety represent one potential obstacle, particularly the risk of battery fires. Determined by factors including the size, type and position of the battery cell as well as the properties of flammable materials involved, a rapidly expanding battery industry is under scrutiny.

It means that EV battery fires, while currently rare, are anticipated to become more frequent as the number of EVs on the road increases and vehicles age. To what degree remains unclear. According to EV FireSafe, a company that monitors global EV battery fires, inadequate reporting, and the industry's relative infancy, means precise details on common causes are still being uncovered. But data suggests collisions, manufacturing defects, and electrical faults are significant contributors. From 2010 to June 2023, there were 488 reported light-duty EV fires globally. Defects in the Chevrolet Bolt and Hyundai Kona, both of which were subsequently recalled, led to a notable spike in 2020 and 2021.

Regulators have moved quickly. For instance, recent legislation in Austria mandates stringent new measures for EV charging stations in parking garages, including collision protection and restrictions based on garage size. China has introduced rigorous safety requirements for EV batteries to prevent thermal runaway, while the Netherlands has created a task force to advise on EV fire safety. New Zealand's government is focused on research and developing fire mitigation measures. The UK has issued interim fire safety guidance for EVs and charging stations. In the US, the National Highway Traffic Safety Administration (NHTSA) is leading efforts to establish a comprehensive framework for global EV safety.

It points to a tension that manufacturers will have to address amid the unfolding battery revolution: maximising efficiency while ensuring safety. As this report explains, however, new innovations are offering a way forward. Safety and efficiency are increasingly going hand in hand. Section one considers the materials that are entering manufacturing pipelines to protect passengers from thermal runaway while keeping vehicles light and speedy. The second section zooms in on new approaches to battery cells and systems that enable them both to operate at maximum efficiency and mitigate fire risks. The third section looks at how processing innovations, particularly in the testing of battery systems and the materials of which they are made, are more rigorous and robust than ever before. And the final section concludes that picking the right partner can bring all the benefits of safe and efficient battery systems to manufacturers big and small today.

1 Materials

As EVs hit the mainstream, the need for advanced materials that can handle the thermal and mechanical stresses of high-density energy storage is vital: both safety and performance depend on them. Batteries must operate within a narrow temperature range of 15°C to 60°C. Extreme temperatures can cause extreme problems: cold weather hampers performance and range, while excessive heat degrades the battery and poses safety risks.

Innovations in thermally conductive materials are one notable leap forward. For instance, a thermally conductive polyurethane structural adhesive used in advanced EVs helps maintain battery temperatures around 25°C - the sweet spot for performance. Battery life is prolonged and safety is assured: heat can be transferred efficiently and hot spots are prevented.

Plastics feature heavily in modern automotive engineering, imparting durability and agility. But the high-energy environment of EVs presents unique challenges, including the risk of electrical malfunctions and battery fires. A new generation of flame-retardant plastics and composites are starting to make their mark. Flame-retardant polymer compounds are essential in myriad EV components, from battery enclosures to high-voltage connectors. These materials prevent the spread of fires and contain potential ignition sources, safeguarding against thermal runaway.

Advanced lightweight fiber reinforced flame-resistant polymer composite solutions can be used for battery pack covers for example, simplifying design processes, reducing system weight, and enhancing thermal management. Composites offer a range of benefits including corrosion resistance, weight savings, parts consolidation, and multi-functional properties such as EMI shielding. Specific to battery covers, composites offer a lightweight alternative to industry standard steel, geared towards protecting passengers from thermal runaway.

Silicones are also making headway in the world of battery thermal management. Offering exceptional thermal stability, silicones can perform in temperature ranges spanning ranging 40°C to 200°C, making them ideal for automotive batteries' demanding conditions. They are resistant to thermal shock, oxidation, moisture, and automotive fluids. Little wonder silicone adhesives, encapsulants and gap fillers are now integral to EV battery design. Low viscosity and superior flow properties ensure minimal gaps and maximum thermal contact between interfaces, bolstering the efficiency of battery heat dissipation. And silicones can be formulated to avoid slumping on vertical surfaces while staying put after dispensing, making production smooth and simple.

Turning to some of the industry leaders in innovative material development provides a window into the future of EVs. Mitsubishi Chemical Group's Sol-Rite™ electrolytes, for instance, are formulated with functional additives that improve battery performance under high voltage and temperature conditions. Consisting of organic solvents and lithium salt electrolytes, they enhance safety by protecting electrodes and suppressing gas generation - crucial for maintaining stability in high-energy environments. Meanwhile their anode materials, such as modified graphite, catalyse smooth absorption and release of lithium ions, reducing reaction resistance and preventing temperature surges.

But materials are just one part of the puzzle when it comes to thermal management. Trailblazers in the field spend just as much time dwelling on tweaks to battery systems that can help performance and safety to go hand in hand. It is to this topic the next section turns.

MITSUBISHI CHEMICAL GROUP

2 Battery cells and systems

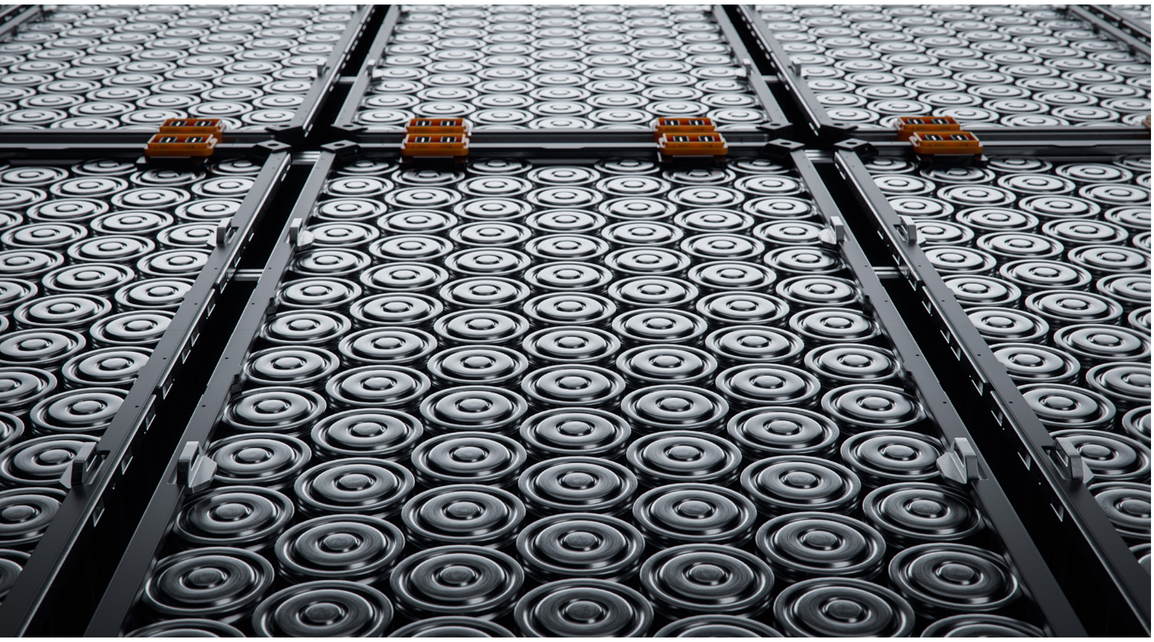
Battery systems are complex. Picking the right materials contributes to their efficiency and safety. But how these materials are arranged and constructed is just as important.

One example relates to battery enclosures. Modern battery enclosures are now equipped with sophisticated thermal management systems designed to keep battery temperatures within an optimal range and insulate them from the rest of the vehicle – most importantly, the passengers. Made from multifunctional materials that combine properties including electromagnetic interference shielding as well as flame resistance, they are built to provide comprehensive protection against a wide range of hazards. Mitsubishi Chemical Group have a wide array of fiber reinforced composites for lightweight battery enclosures, including thermoset carbon fiber SMC (FMC™) and Prepreg materials for structural applications, and thermoplastic glass fiber (GMT™, KyronTEX™) with various flame retardant resin systems. Composites offer design flexibility typically not available using traditional methods, while achieving significant weight savings.

Another example is the rollout of thermal responsive spacers. These spacers play a crucial role in controlling heat flow and mitigating thermal runaway. In the event of thermal runaway, these spacers slow the fire's spread, allowing additional time for passengers to safely escape. Top-of-the-range batteries use spacers to neatly combine performance with safety. They offer high heat conductivity under normal operating conditions, ensuring efficient heat exchange. But at high temperatures, their conductivity decreases, effectively isolating the heat source and preventing the spread of fire.

Other examples of safety-enhancing battery system innovation include novel deployments of foam and the addition of custom-made cooling tubes. Mitsubishi Chemical Group's Hostaphan™ PET film is an example of the former, employed as a process liner to create foam that manages heat expansion between EV battery cells. A smooth surface texture created by the film contributes to efficient heat management, preventing hotspots and ensuring uniform temperature distribution. For the latter, cooling tubes are an essential component of battery thermal management; working with cutting edge materials like MODIC™ and ADTEX™ can help, offering excellent durability for glycol-water mixtures and heat resistance up to 110°C. By enabling multi-layer designs that efficiently house cooling fluids, they can massively amp up the flame resistance profile of a car's battery.

Even when the latest cell system solutions are deployed, boasting trailblazing fireproof materials, there is still scope for errors to creep in and things to go wrong. The marriage of safety and efficiency can only be assured if it is put to the test – as the next section explores in detail.



3 Processes

Any innovative material or new battery system is subject to a testing process - a crucial aspect of automotive engineering, and one on which these materials and systems may stand or fall. As material and system sophistication has gathered pace, so too has the tests they undergo.

The evolution of fire safety testing methods reflects the automotive industry's broader shift towards electric mobility and the corresponding need for updated safety standards. The EV transition has seen industry testing moving away from exposing combustion engine parts to intense heat and towards scrutinising battery enclosure materials. These are at the heart of unique fire safety challenges present from thermal runaway in lithium-ion batteries.

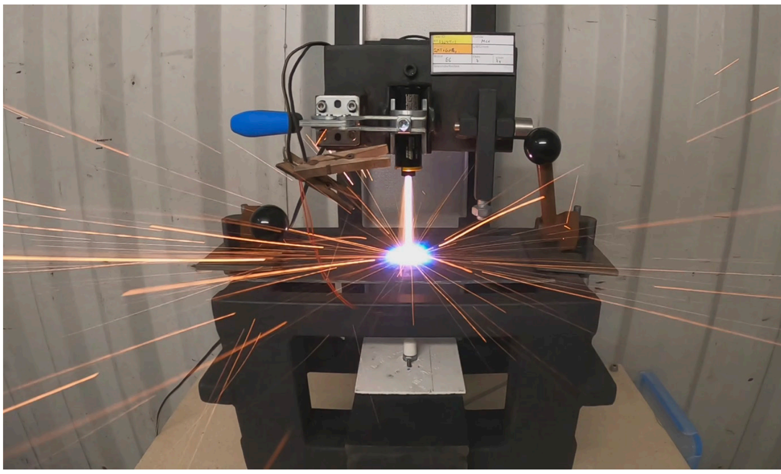
Traditional fire safety tests, like the burner test, involved exposing materials to flames at temperatures ranging from 1000 to 1200°C for several minutes. The goal was to observe the material's burning behaviour, including whether it ignited, how it burned and if it self-extinguished. These tests, however, cannot replicate the dynamic and high-energy conditions of actual battery fires. Materials that passed these tests often failed when subjected to real-world scenarios. Lack of high kinetic energy, for example, meant mimicking the rapid flame propagation characteristic of battery fires was impossible.

New methods were needed. One outstanding example from recent years is the arrival of the Rocket Test, an innovative approach deploying a modified rocket motor to simulate the massive force and temperature of a jet flame emitted by a battery during thermal runaway. The rocket test accurately replicates the extreme conditions of a real battery fire: high-speed flames that can reach temperatures of up to 1400°C. And it does so in a repeatable and cost-effective manner. "What we started measuring was not only the temperature but the dynamic force of the flame," explains Leonard Lichtblau, technical Manager R&D Composites at Mitsubishi Chemical Group and pioneer of the Rocket Test. The method ensures that materials are exposed to the same conditions they would encounter in a real battery fire. In doing so, it has yielded critical insights into the performance of battery materials under extreme conditions. Many of these insights have turned conventional wisdom on its head. Composites previously thought to have high battery flame resistance demonstrated weak performance, while others were able to maintain their integrity and prevent the propagation of flames, making them suitable candidates for battery enclosures in electric vehicles. The findings highlight the importance of selecting appropriate materials that can withstand the unique challenges posed by battery fires. And they illustrate that only the most up-to-date testing processes will guarantee passenger safety in an EV-driven future.

Mitsubishi Chemical Group's novel equipment and testing techniques have already had a tangible impact on the testing and design of new materials. Engineers are constantly seeking new data to aid development processes – and that is exactly what the Rocket Test has provided. The discovery that composites made of glass fibres combined with temperature resistant polymers exhibited particularly strong resistance to the intense heat of battery thermal runaway, for example, represents a major development.

Looking ahead, process evolution will have to continue. Lithium-ion batteries will remain the industry standard for the next decade. The Rocket Test ensures they will do so safely. However, as energy densities increase, so do the safety concerns associated with these batteries. Higher energy densities result in more aggressive thermal runaway events. The imperative to develop and deploy materials that can provide enhanced fire protection is one manufacturers cannot ignore.

Stricter regulations are expected to be implemented to ensure fire safety in electric vehicles. Current standards requiring that no flames reach the passenger compartment within five minutes of thermal runaway may be extended or strengthened to prohibit any visible flames outside the vehicle. Additionally, differing regulations across the various global regions will tend towards unification and standardization of testing methods. These regulatory changes will drive the development and adoption of ever-more rigorous testing methods, ensuring battery enclosures meet the highest safety standards Manufacturers will need to stay tuned and keep up.



The Rocket Test. Credit: MCG

4 Picking the right partner

The electric battery revolution is surging forward. How can manufacturers ensure end-passengers get to their destinations safely? Rooting their projects in the expertise of a material, battery system and testing process pioneer can keep risks to a minimum. This is where Mitsubishi Chemical Group comes in. Their portfolio of innovative materials and technologies puts them at the forefront of EV fire safety innovation. Some of the elements of this portfolio have been discussed in previous chapters. But it is worth returning to the major ones.

Battery enclosures can be designed with Thermoset (FMC™, Prepreg) and/or Thermoplastic (GMT™, KyronTEX™) materials from Mitsubishi Chemical Group. These materials can be designed with Carbon, Glass, or other reinforcements, with a wide range of resin systems depending on the application, including battery covers that require a high degree of flame resistance and battery trays that need increased structural properties.

The MODIC™ and ADTEX™ materials, for example, can play a key role in multi-layer systems including battery cooling lines and tubing applications. Offering unmatched thermoformability and heat resistance, they can improve thermal management – particularly when combined with thermal responsive spacers to harness heat flows. By mitigating the chances of fire breaking out and preventing its spread when it does, fire breakout risks to passengers can be drastically reduced.

Mitsubishi Chemical Group have also developed a range of flame-retardant polymer compounds. These are essential in preventing the spread of fires within EV components such as battery enclosures and high-voltage connectors. Their Hostaphan™ PET film is used as a process liner to create foam managing heat expansion between EV battery cells. And their Sol-Rite™ electrolytes are formulated with functional additives that significantly improve battery performance under high voltage and temperature conditions. They enhance safety by protecting electrodes and suppressing gas generation - crucial for maintaining stability in high-energy environments. Meanwhile, anode materials, such as modified graphite, offer unmatched power performance and longevity. They are specifically designed to reduce reaction resistance, thereby quenching ignition risks.

Mitsubishi Chemical Group is the manufacturers' premium partner in the EV revolution. As regulators puzzle over the tension between safety and efficiency, Mitsubishi's record of innovation lights the way towards a future for electric vehicles that combines both. From advanced flame-retardant polymers and thermally conductive materials to cell and system solutions facilitating comprehensive thermal management, they address critical fire safety concerns while enhancing overall vehicle performance.

Mitsubishi Chemical Group's commitment to rigorous testing and continuous improvement guarantees that manufacturers can deliver safe, reliable and high-performing electric vehicles, speeding towards the future of sustainable mobility with confidence. **Get in touch today to find out more.**

This guide was produced by GlobalData in cooperation with Mitsubishi Chemical Group.

MITSUBISHI CHEMICAL GROUP

Get in touch

Mitsubishi Chemical Americas,
9115 Harris Corners Parkway, Suite 300,
Charlotte, NC 28269

automotive.mcgc.com

MITSUBISHI
CHEMICAL
GROUP