TECHNOFORM

Using plastic components to optimize high-voltage batteries

Tailored engineering
plastics solutions

Summary

The technology of high-voltage batteries for electric vehicles is constantly evolving and presenting developers with new challenges. The demands upon performance, safety and sustainability are rising. At the same time, batteries must be as light and compact as possible, and be economical to manufacture and recycle.

Beyond its core components (cells, battery management system and cooling system), a battery system possesses a number of further components that may be relevant for optimization of the system as a whole. The technical design of these components – cell/module holders, spacers, covers, media lines and the components of the battery case – must satisfy numerous requirements and properties, some of which conflict with each other. Materials are required for this purpose that are flexible in the combination of their properties and in their design geometry.

Thermoplastics offer significant benefits and properties that make them a high-performance and sustainable alternative to familiar materials such as metals and thermosets. They constitute a wide range of materials suitable for almost any application, and can also be customized by the use of additives.

This guide introduces product developers to the benefits and possible applications of plastics in high-voltage batteries for electric vehicles.

Contents

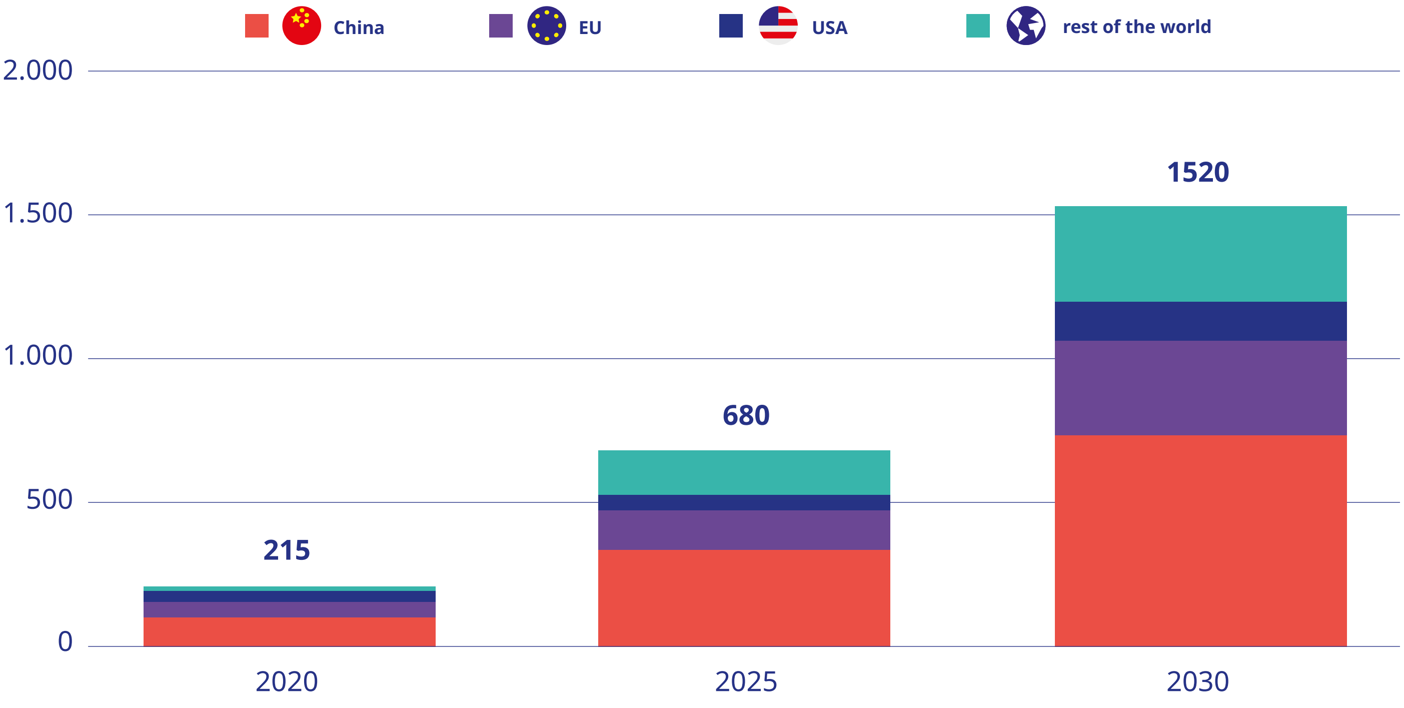
1. Introduction

Demand for batteries for electric vehicles is rising

Around the globe, more and more electric vehicles are appearing on the roads. Electric mobility is essential if mobility is to become climate-neutral by no later than 2050 and the climate targets of the Paris Agreement, which has been adopted by 195 countries around the world, are to be reached.

The VDA, the German Association of the Automotive Industry, estimates the total number of electric vehicles worldwide to be around 10 million[1]. The demand for lithium-ion batteries for electric vehicles grows with every new vehicle registered, and is predicted to increase seven-fold by 2030.[2]

Forecast for the global demand for lithium-ion batteries for electric vehicles, by region (in GWh)



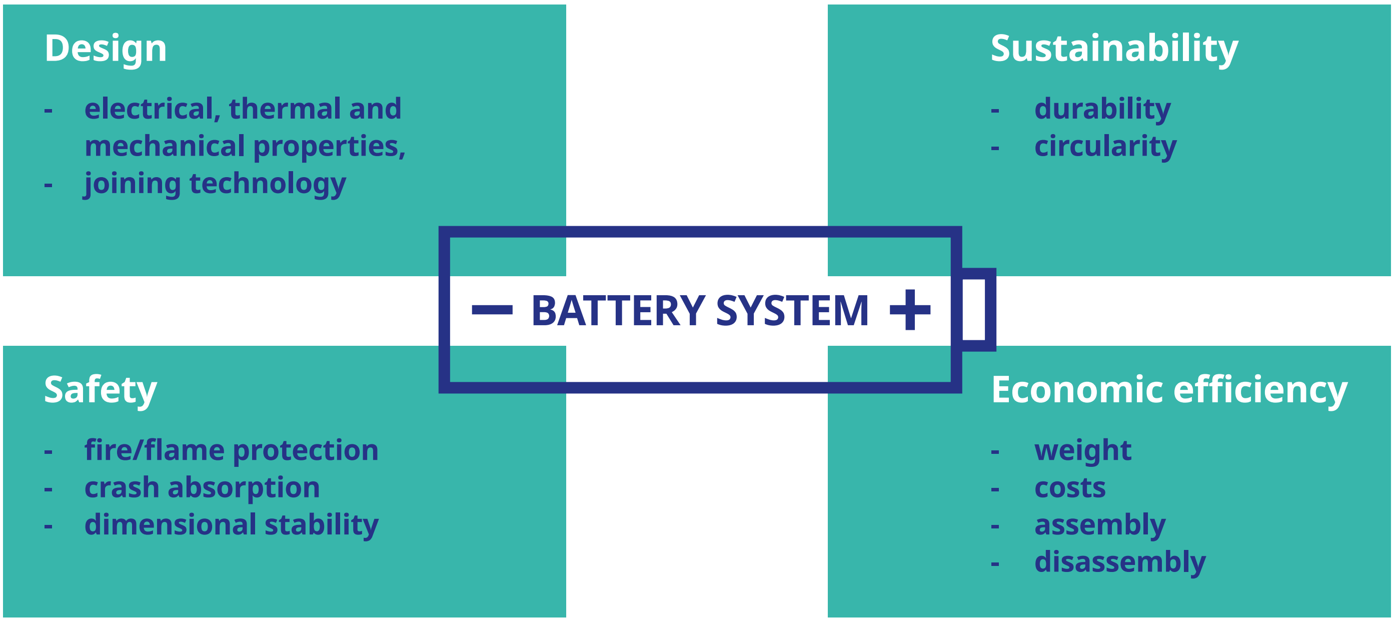
Source: Statista

22 July 2021

The challenge facing battery manufacturers

The development of lithium-ion batteries has by no means run its course. In order for electric vehicles to meet with acceptance in the long term, manufacturers are making considerable efforts to increase both the power of batteries and the range they deliver, reduce their weight, improve their safety, including fire safety, and their sustainability, and reduce their costs.

Developers of high-voltage batteries* must continually optimize materials and design concepts and regularly review their own product decisions.



Design

- electrical, thermal and mechanical properties,
- joining technology

Sustainability

- durability
- circularity

− BATTERY SYSTEM +

Safety

- fire/flame protection
- crash absorption
- dimensional stability

Economic efficiency

- weight
- costs
- assembly
- disassembly

Rising use of plastics in high-voltage batteries

Although metals often play a central role in high-voltage battery systems, they are not always suitable owing to their weight, cost and sustainability.

For this reason, developers in industry and research institutions are seeking ways of substituting metal components with more effective solutions involving plastic materials.

*In the automotive sector, ‘high voltage’ (HV) refers to voltages above 60 V DC, see also *Spannungsklassen in der Elektromobilität* (Voltage classes in electromobility), published by VDE.

Research projects: plastic battery cases

Example 1: In 2020, an international consortium comprising 46 companies launched a project in conjunction with AZL Aachen. The project studied a range of concepts for battery cases manufactured from multiple materials and analysed their competitiveness.

Result: Plastics-based solutions offer high potential savings over aluminium in terms of weight (up to 36 %) and manufacturing costs (up to 20 %). [3]

Example 2: In 2021, manufacturers Lanxess and Kautex Textron developed a near-production battery housing tray with crash structure, housing cover and underbody protection, manufactured from PA6 LGF fibre-reinforced thermoplastic, and reinforced locally by organic sheet.

Result: Single-step manufacture with short cycle times is possible; large cases can be produced in a small number of steps; the number of discrete components is substantially reduced.[4]

Example 3: The Fraunhofer Institute for Structural Durability and System Reliability LBF developed a lightweight battery pack consisting entirely of fibre-plastic composites.

Result: Weight savings of up to 40 % compared to aluminium. Finished lightweight battery cases are produced within just two minutes, with no need for reworking.[5]

These examples demonstrate that engineering plastics are an ideal substitute for metals in key areas of battery design.

Advantages of plastics in battery development

Thermoplastics exhibit a combination of electrical, thermal and mechanical properties that are relevant for structural components in high-voltage batteries. At the same time, compared to metals, plastic offers impressively low weight and high design flexibilty.

Components such as cell holders, spacers, covers, media lines, module carriers and battery cases can be manufactured as one-piece items. By contrast, the corresponding metal item would require several parts.

Example: Aluminium must often be insulated electrically, for example by the use of film. Plastic components do not require such insulation, owing to the polymers’ electrical insulation properties.

Components manufactured from plastics can satisfy the functional requirements by selection of the appropriate material, additives (such as graphite or boron nitride for thermally conductive thermoplastics) and intelligent design (such as the use of clips rather than adhesive bonding).

2. Material requirements in HV batteries

The battery is a core component of an electric vehicle, and usually the most expensive.

The cells, which take the form of modules or packs, constitute the heart of an HV battery. A battery system encompasses numerous further components including the cooling system, battery management system, case and parts for mechanical integration of these components.

Important requirements concerning the mechanical integration of components are their electrical insulation, heat resistance, flame retardant properties and, depending on the component, further criteria such as dimensional stability, resistance to chemical attack and impact resistance.

The table below summarizes the essential requirements to be met by the individual components of the battery system.

Material requirements for components in high-voltage battery systems[6]

Requirements	**Flame retardancy**	**Chemical resistance**	**Dimensional stability/ low warpage**	**Heat resistance**	**Design freedom**	**Creep resistance**	**Color stability / colorability**	**Crash resistance**	**Electrical Insulating property / Dieelectric strength**	**Electro-magnetic shielding**
Components										
Battery pack	●	●	●	●	●	●		●	●	
Battery housing	●	●		●	●			●	●	●
Charging system	●					●	●	●	●	●
High-voltage connectors	●		●			●	●		●	●
Cooling units		●	●		●			●		

Requirements for the materials used

Electrical requirements

- insulation / shielding against dielectric breakdown

Thermal requirements

- optimal heat dissipation (cell) versus insulation (ambient temperature)

Lightweight construction

- weight reduction
- integration of functions

Mechanical requirements

- protection against crash / intrusion / vibration
- mechanical integration (e.g. fixing) of components

Sustainability

- optimisation for assembly, maintenance and recycling

Fire protection requirements

- temperature resistance
- flame retardancy

Source: BMW

Trend: As the power of electric vehicles increases, the requirements for battery systems in terms of electrical insulation, electromagnetic shielding, flame retardancy, crash resistance, lightweight, etc. will also grow.

3. Properties and benefits of thermoplastics

Gone are the days when engineers could simply draw on know-how and experience gained over many decades when selecting materials for vehicles with internal combustion engines. Nowadays when it comes to electric vehicles the criteria for the materials are often much more specicfic.

The 'one size fits all' approach followed in traditional vehicle manufacture is unsuitable for electric mobility. Standards in other industries, such as electronics, are now influencing the selection of materials. Not only do thermoplastics offer inherently favourable properties for use in HV batteries, they can also be adapted-flexibly in response to specific requirements.

Background: Thermoplastics – semi-crystalline and amorphous plastics – differ in their molecular structure and thus in their properties. Semi-crystalline thermoplastics (e.g. PA 6, PA 66, PBT) offer advantages over amorphous plastics (e.g. PC, PVC) owing to their mechanical properties and resistance to deformation under heat. The addition of additives, in particular, is enabling growing numbers of semi-crystalline polymers to meet the stringent criteria of electrical mobility applications in terms of electrical safety, flame retardancy and mechanical properties.

3.1 Electrical properties

Electric vehicles are operated at high voltages of around 400 V, rising to 800 V and more for elevated power requirements. Higher voltages reduce power losses and permit faster charging. However, they also place higher demands, for example on the electrical insulation of the battery systems.

Plastics are by their nature electrical insulators, whereas metals are electrical conductors. Plastic is therefore the material of choice in HV batteries where electrical insulation is required.

Dielectric strength

The trend towards miniaturization of electronic components in high-voltage batteries means that insulating materials are increasingly becoming thinner, even though voltages are rising. This increases the risk of electrical breakdown.

Electrical breakdown can destroy components or damage them irreparably, and cause fire. The dielectric strength is therefore a crucial parameter for materials intended as electrical insulators.

The dielectric strength (kV/mm) characterizes the resistance of insulating materials to high voltage, i.e. the maximum electric field strength they are able to withstand without electrical breakdown (arcing, sparking) occurring. The higher the dielectric strength, the better the insulating properties of the material.

The dielectric strength depends on a number of factors including the temperature, atmospheric humidity, atmospheric pressure, duration of exposure to the voltage and surface structure, and is not therefore a material constant.

Variables influencing the dielectric strength[7]

- The dielectric strength decreases with rising temperature. A general rule of thumb is that an increase of 10 °C in the operating temperature reduces the life by 50 %, as it causes the dielectric strength to decrease progressively over time. This must be taken into account in the choice of plastic.
- Protection against mechanical stress: insulators subjected to mechanical stress (for example in the form of leakage paths caused by defects within the material) exhibit significantly lower dielectric strength values.
- Factors attributable to the manufacturing process, such as weld lines in injection mouldings or minute flaws, may impair the dielectric strength.

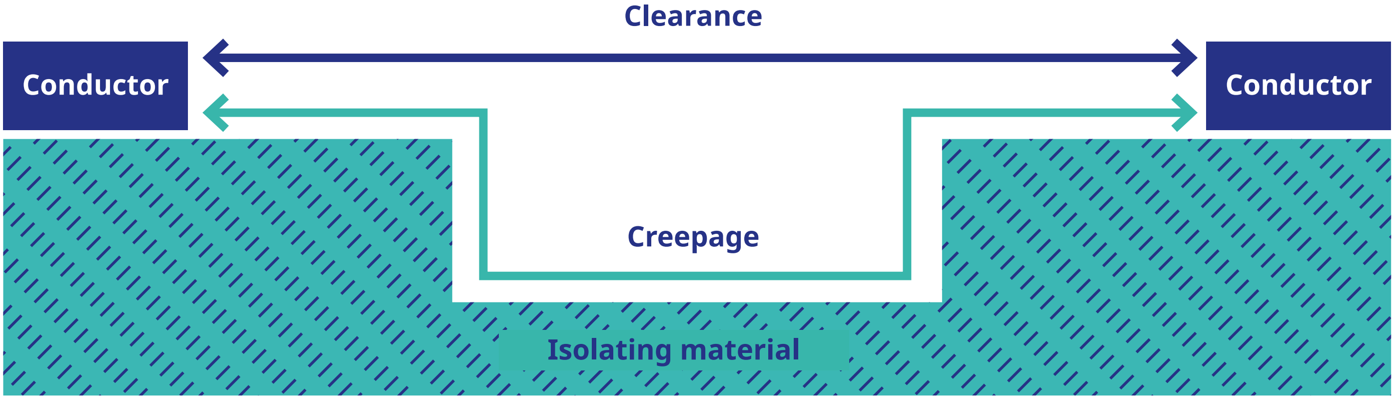
Tracking resistance

A further important parameter for evaluation of a material's electrical insulation property is the tracking resistance (CTI, comparative tracking index). This value characterizes the dielectric strength across the material's surface and expresses its resistance to the formation of tracking current.

If the surface is soiled, for example by abraded material or dust, and the atmospheric humidity is also sufficiently high, a conductive coating can form. The higher the voltage, the higher the required CTI value.

Influencing variables: measures against tracking

- Sufficient clearance (air gap) between live components, or the provision for example of ribs or recesses to increase the tracking distance. Owing to the constrained installation space and the particular geometries within batteries, the possibilities here are however often limited.
- Protection against soiling: tracking may occur when the surface of an insulating material becomes carbonized, causing its conductivity to rise. This carbonization is a result of surface contamination caused by ions present in moisture, dust or other particles that accumulate on the surface of the plastic over time.
- Use of materials that prevent tracking in confined spaces: plastics such as PA, PP or PE exhibit a tracking resistance of over 600 V (insulation material group I to IEC 60112)[8].



The tracking distance is the shortest distance between two conductive points over the surface of an insulating material; the air gap is the shortest distance through the air between two conductive points.

Example application:
Battery cells/modules must be secured and insulated in a way that saves space whilst also preventing tracking and breakdown voltage. A possible solution is an insulating retaining profile manufactured from specially formulated PA 66 GF 25. This material has a CTI of 600 V and shields against breakdown.

Our recommendation:
Use of a plastic with an intrinsically elevated CTI value. This also permits smaller clearances between components and thus helps to reduce the required installation space.

Important:
Standard thermoplastics, such as PVC, exhibit high dielectric strength; they are, however, not generally suitable materials for electronic components in high-voltage batteries, which are subject to high mechanical and dimensional stability requirements.

As a general rule, no single standard plastic exists that perfectly satisfies all conceivable requirements for high-voltage batteries; rather, the advantage of plastic is its that a formulation can be selected that meets the requirements, for example by the use of additives.

Plastics such as PBT or PA 66, which exhibit very good mechanical properties, can be modified to attain a CTI value well above 600 V. Polyamides are already available on the market that are resistant to tracking even at voltages in excess of 900 V.[9]

Electrical properties: conclusion

- **Higher power levels and shorter charging times increase the demands upon the electrical insulation in battery systems.**
- **The dielectric strength and tracking resistance are essential electrical properties of components in HV batteries.**
- **In this respect, thermoplastics already offer very good intrinsic properties, which can be modified further as required by the use of additives.**

3.2 Thermal properties

The performance of high-voltage batteries depends to a large extent on the temperatures of the application. Owing to their chemical properties, the optimum operating temperature range of lithium-ion batteries is 20 °C to 40 °C.[10]

At very low temperatures, the chemical processes in the battery are retarded significantly, which reduces the charge and power capacities.

Very high temperatures may cause a battery to self-destruct (thermal runaway) or catch fire in extreme cases.

Thermal management is therefore crucially important for the performance and safety of high-voltage batteries. Components manufactured from plastic fulfil important tasks in this area, both for insulation of the battery case against external thermal influences, and for the desired dissipation of heat from cells and components within the battery system.

Thermal insulation

Most plastics exhibit low thermal conductivity and are therefore good thermal insulators. They are used for good reason in the construction sector, for example for thermal insulation of windows and outside walls, in order to maintain constant indoor temperatures. Reliable and sustained maintenance of the ideal operating temperature of cells in high-performance batteries usually requires active heating or cooling of the battery. This in turn requires energy.

Plastic enclosures shield batteries against cold and heat better than those made of metal.
They thus help to reduce the energy required to heat and cool high-voltage batteries and to make electric vehicles more efficient.

Heat dissipation

In addition to thermal insulation of the battery housing, controlled dissipation of heat within the battery system is of key importance in the thermal management of high-voltage batteries. Heat generated during cell operation must be reliably and continually dissipated to prevent overheating.

Aluminium heat sinks are often used to dissipate heat between modules or to the exterior of the battery case. Heat transfer pastes and gap fillers are used to ensure optimum transfer of heat between the cell/module and the heat sink, and to even out geometrical irregularities.

Solutions such as these have the drawback of adding weight, having a chemical impact on the environment and making recycling of the batteries difficult owing to the bonded connections. Reversible fastening elements such as spring rails manufactured from thermally conductive plastic are a weight-saving, recyclable alternative in this scenario.

Thermally conductive plastic compounds permit solutions that attain thermal conductivity values similar to those of heat transfer pastes (approx. 5 W/mK) whilst also assuming further functions such as electrical insulation, mechanical functionality and more flexible joining technology.

Example of multifunctional components manufactured from plastic:

Module housing and mechanical connection elements (clips) manufactured from thermally conductive plastic.

Background: The intrinsic polymer properties of thermally conductive plastics are modified by fillers to produce a moulding compound suitable for thermoplastic processes and possessing the highest possible conductivity.

Filler types:
- Carbon-based (graphite): high thermal and electrical conductivity
- Ceramic/mineral: thermal conductivity coupled with electrical insulation

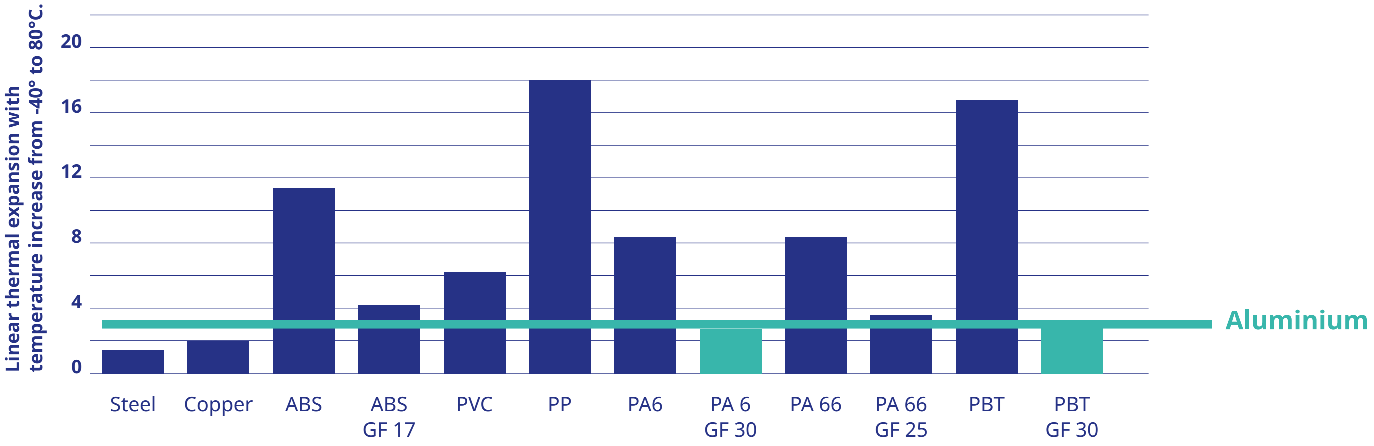
Plastics with ceramic/mineral fillers, such as boron nitride, are particularly suitable for use in electrical applications such as high-voltage batteries, as they do not require further elements for electrical insulation.

Thermal linear expansion

The volume of any material changes as a function of the temperature. Most materials expand as the temperature rises. The design of high-voltage batteries must make allowance for possible changes in the length of structural components.

The linear expansion is dependent upon the initial length, the temperature difference and the coefficient of thermal expansion of the material used.

Plastics expand some ten times as strongly as metals in response to a rise in temperature.[11] This must be taken into account during the design of systems manufactured from different materials.



Thermal linear expansion in response to a temperature rise from -40 ° to 80 °C[12]

Where a battery contains components manufactured from different materials and with a mutual influence upon each other, the challenge lies in attaining similar thermal rates of linear expansion for all of them, by the use of materials with the same or similar coefficients of expansion.

The diagram above shows the thermal linear expansion of plastics without fillers (e.g. ABS, PP, PA6 or PBT) to be significantly higher than that of aluminium.[12] An additive for example in the form of glass fibres significantly reduces the thermal linear expansion: PBT GF 30 or PA 6 GF 30, for example, attain the same values as aluminium.[12]

Example application:
Use of thermoplastics to locate/insulate aluminium heat sinks.
By the use of additives (e.g. glass or mineral fibres) to match the thermal linear expansion of the plastic to that of the aluminium, the design dimensions of components and drilled holes can be reduced and the required space thus reduced to a minimum.

Thermal properties: conclusion

- **Thermal management is of key importance for the performance and safety of high-voltage batteries.**
- **Plastic components assume important thermal management functions: both for thermal insulation of the battery case, and for controlled dissipation of heat from cells and components within the battery system.**
- **Thermally conductive plastic compounds permit solutions that not only dissipate heat, but also assume further functions such as electrical insulation, mechanical functions and more flexible connection technology.**
- **By the addition of glass fibres, for example, the thermal linear expansion of plastics can be significantly reduced and, where required, matched to that of metal components.**

3.3 Mechanical properties

Besides electrical and thermal properties, mechanical properties such as stiffness, strength and impact resistance are particularly important in the selection of suitable materials for structural components of high-voltage batteries.

The mechanical design of batteries aims to attain the best possible stability and reliable protection against mechanical effects such as vibration and mechanical shock, but without detriment to the electrical and thermal requirements.

For battery cells/modules to be integrated into a battery system securely and with economical use of space, they must be located and fixed precisely and mechanically robustly. Components manufactured from fibre-reinforced plastic exhibit very favourable energy-absorbing properties for this purpose.

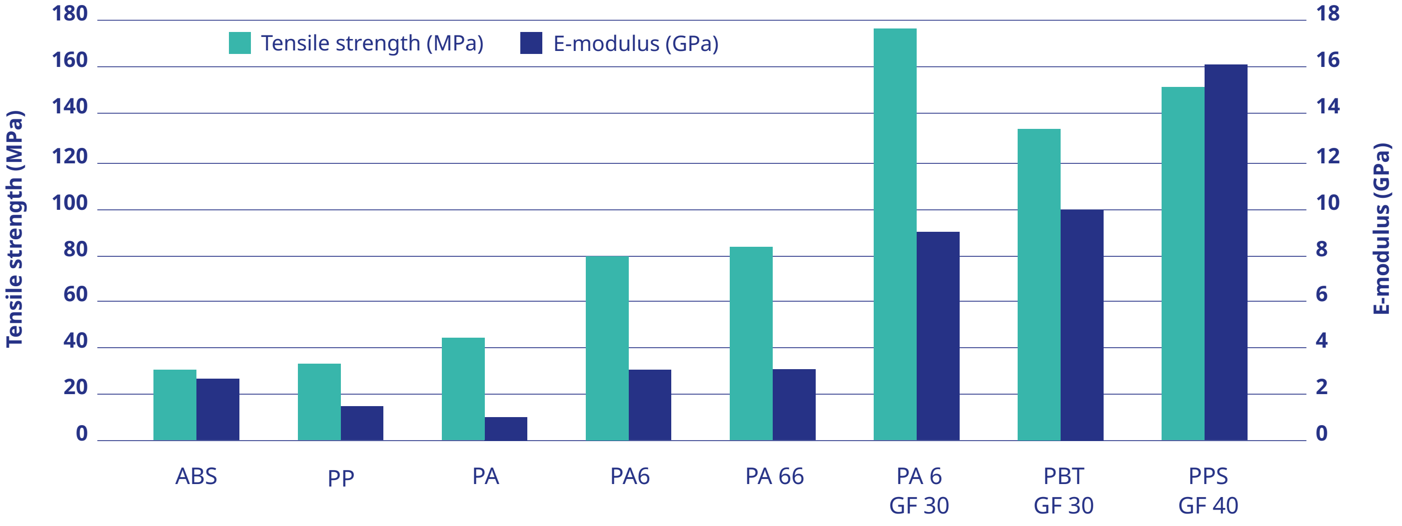
Stiffness and tensile strength

Key parameters for evaluating the mechanical properties of plastics are the stiffness (Young's modulus or modulus of elasticity) and the tensile strength.

Assuming the elastic behaviour of a solid body to be linear, the **modulus of elasticity** describes the stiffness, i.e. the relationship between the stress upon the body and its elongation.
The greater the modulus of elasticity, the lower the deformation (e.g. bending).

The **tensile strength** is a material parameter characterizing the maximum tensile stress in N/mm^2 to which a material can be subjected before it fails permanently (cracks). The greater the tensile strength, the greater the force that a material can withstand.

Comparison of mechanical properties of unfilled and filled thermoplastics[13]



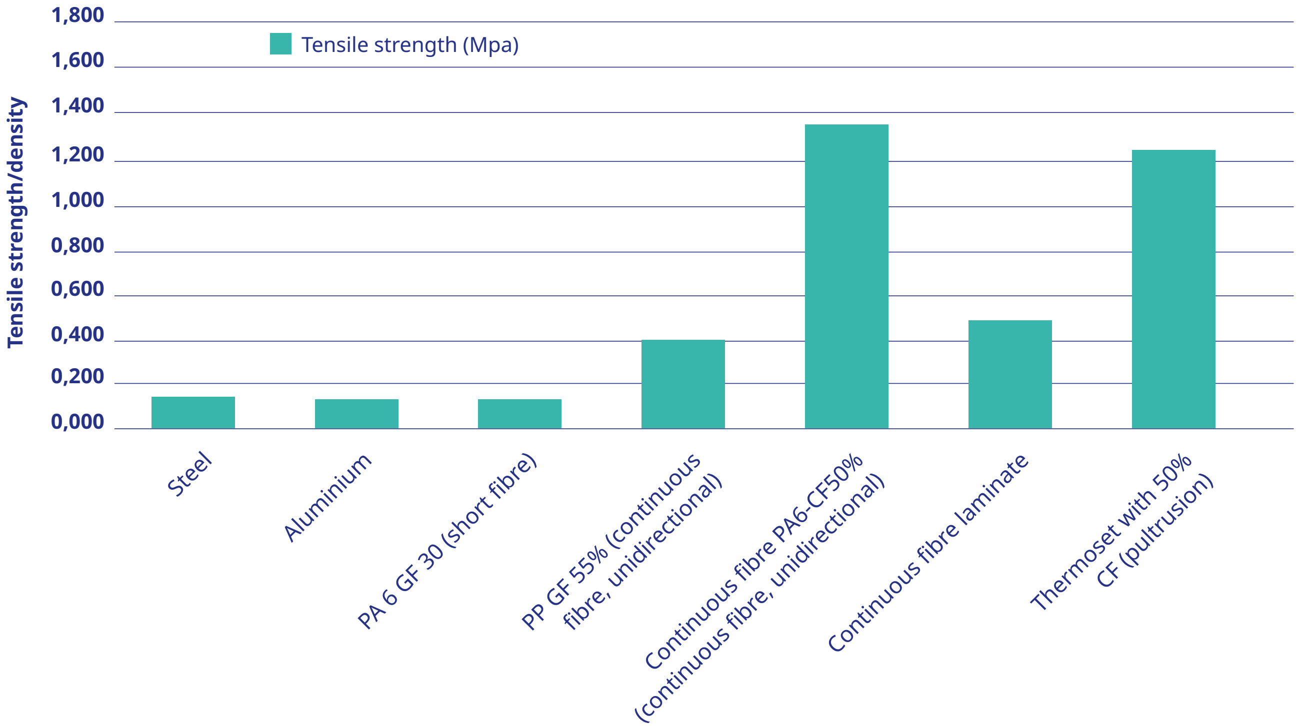
The modulus of elasticity, in particular, of the thermoplastics shown is seen to be increased significantly by the addition of glass fibres. In the example, the glass fibre-reinforced polyamide PA 6 GF 30 attains particularly good values for the tensile strength.

Lightweight design properties of battery components

In the development of battery systems, every gram of weight counts. During the search for the ideal material, mechanical properties such as a material's stiffness and tensile strength must therefore always be considered in relation to its weight. Steel, for example, exhibits very high stiffness, but is much heavier than other materials.

If steel is used despite not being justified by the mechanical loads, the resulting over-dimensioned design is likely to bring with it a weight penalty, and thus a missed opportunity to implement solutions with the best possible lightweight design. The table below shows the tensile strength in relation to the material density:

Comparison of the lightweight properties of metals and fibre-reinforced plastics[14]



The results at a glance:

- PA 6 GF 30, a polyamide with a 30 % filling of short glass fibres, already achieves values similar to those of aluminium and steel.
- When reinforced with continuous fibres, thermoplastics attain significantly better values than those of metals.
- Continuous fibre-reinforced plastics benefit significantly from the outstanding mechanical properties of carbon and glass fibres, and as a lightweight material are superior to metals in terms of their tensile strength.

Conclusion

For applications that place very high demands upon the mechanical strength and stiffness, the addition of reinforcing fibres – particularly continuous fibres – is a solution that delivers considerable weight savings and thereby exploits the lightweight design potential of plastics to the full.

More on this topic can be found below under "Potential for lightweight design". >>>

Impact resistance properties

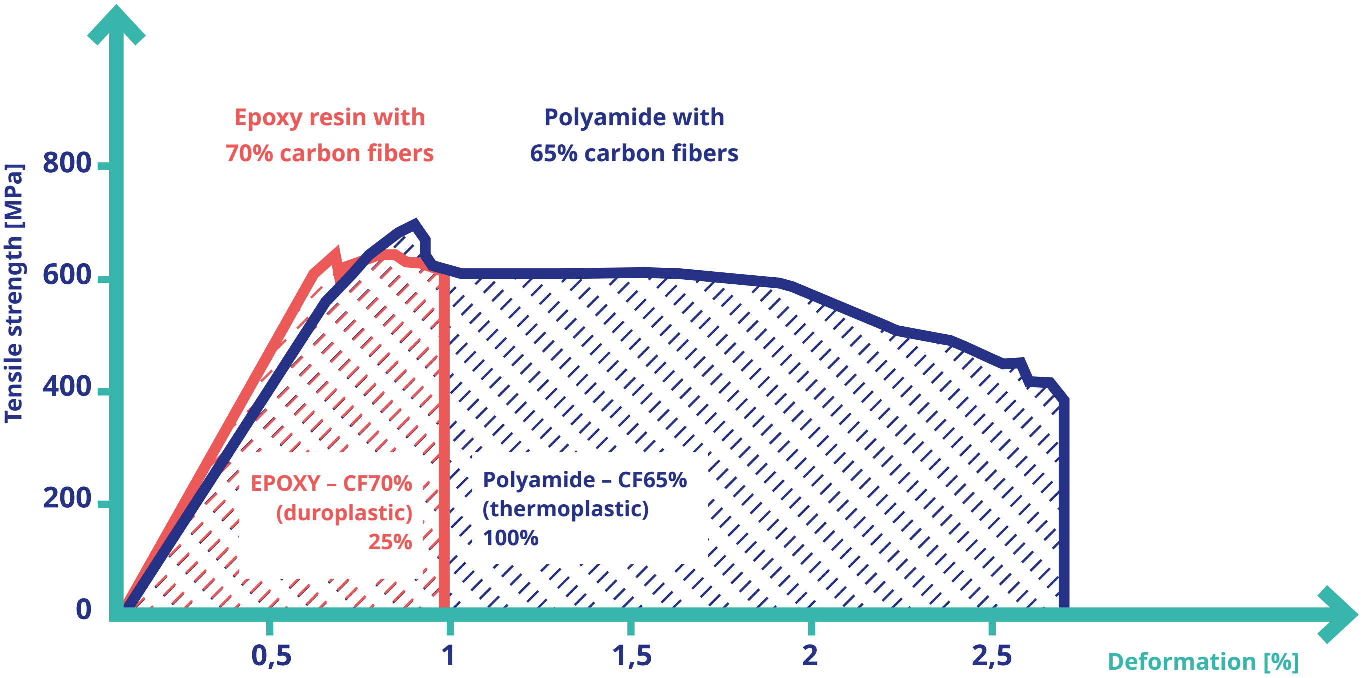
Electric vehicles are generally heavier than those with internal combustion engines. It follows that should an accident occur, higher energies will be released. This gives rise to demanding and possibly complex requirements for the crash safety of high-voltage batteries.

The battery cases must be particularly rigid and strong, and capable of absorbing energy. They must also be flame-retardant in case the vehicle should catch fire or the electrical cells suffer thermal runaway, and their design must lend itself to integration into the vehicle structure.[15]

At present, the impact resistance requirements for batteries are attained primarily by the use of metal components, although their properties vary widely depending on the specific material used, the geometry and the forms of stress. Some fibre-reinforced plastics have a maximum specific energy absorption (SEA) significantly higher than that of comparable aluminium or steel structures.[16]

Among fibre-reinforced plastics, thermoplastics are particularly notable for their crash safety properties: their energy absorption capacity is much higher than that of the more brittle thermosets, and they are therefore significantly more tolerant of damage.

Comparison of the impact absorption capacity of a thermoplastic (polyamide) and a thermoset (epoxy), with reference to the example of components reinforced by continuous carbon fibres[17]



Energy absorbing capability until breakage at 4-point bending test according to DIN ISO 14125

In addition to the material used in an energy-absorbing structure manufactured from fibre-reinforced plastic, its geometry is also of crucial importance. The impact absorption capacity can be improved further, for example by use of a ribbed or corrugated structure or by hollow chambers.

Fibre-reinforced plastics, particularly thermoplastics, can contribute significantly to the lightweight design approach, as they are lighter than metals such as steel and aluminium, yet absorb energy comparably well or even better.

Dimensional stability

A material's dimensional stability is its ability to retain its dimensions under changing environmental conditions (such as temperature and humidity). A dimensionally stable plastic is characterized by low moisture absorption and low thermal expansion. The material chosen is always a compromise and must take account of all the requirements, as the following examples show:

- Unreinforced polyamide (PA) absorbs a lot of moisture but exhibits mechanical values that favour its use in high-voltage batteries.
- Polybutylene terephthalate (PBT) absorbs little moisture, but exhibits a poorer CTI value.
- Acrylonitrile butadiene styrene copolymer (ABS) absorbs little moisture but exhibits high thermal linear expansion.
- Here too, the dimensional stability, together with other properties of engineering plastics, can be improved by modifications such as reinforcement with glass fibres to meet the requirements of a specific scenario.

Mechanical properties: conclusion

- **Mechanical properties such as stiffness, strength and impact resistance should be given particular consideration during selection of suitable materials for structural components in high-voltage batteries.**
- **The addition of continuous fibres makes it possible to adjust the stiffness and tensile strength of thermoplastics as required and to achieve lightweight construction properties that are significantly better than those of metals.**
- **Of the fibre-reinforced plastics, thermoplastics have particularly favourable impact resistance properties. Their energy absorption capacity is considerably higher than that of the more brittle thermosets and they are thus significantly more tolerant of damage.**
- **Properties such as the dimensional stability of thermoplastics can be adjusted to specific requirements by modifications such as glass fibre reinforcement.**

3.4 Fire safety and flame retardancy

A key objective in the design of HV batteries for electric vehicles is fire safety and retardancy. Intelligent battery management systems help to prevent battery overload and the generation of critical heat levels.

Flame-retardant and heat-resistant materials such as thermoplastics help to prevent or significantly retard fires.

The top priority: fire prevention

A research project, funded by the German Federal Ministry of Education and Research (BMBF) and also examining fires on electric vehicles, concludes that electric vehicles do not burn more violently than vehicles with internal combustion engines, but that they burn differently. The rate at which heat is released, the composition of the gases emitted and the development of the fires differ in some cases significantly.[18]

Batteries consist of several hundreds or thousands of cells capable of releasing energy very quickly and violently (thermal runaway). Furthermore, the battery cases are usually installed in the floor of the vehicle, where they are difficult to access with extinguishing agents. As a consequence, fire fighting is difficult and prolonged.

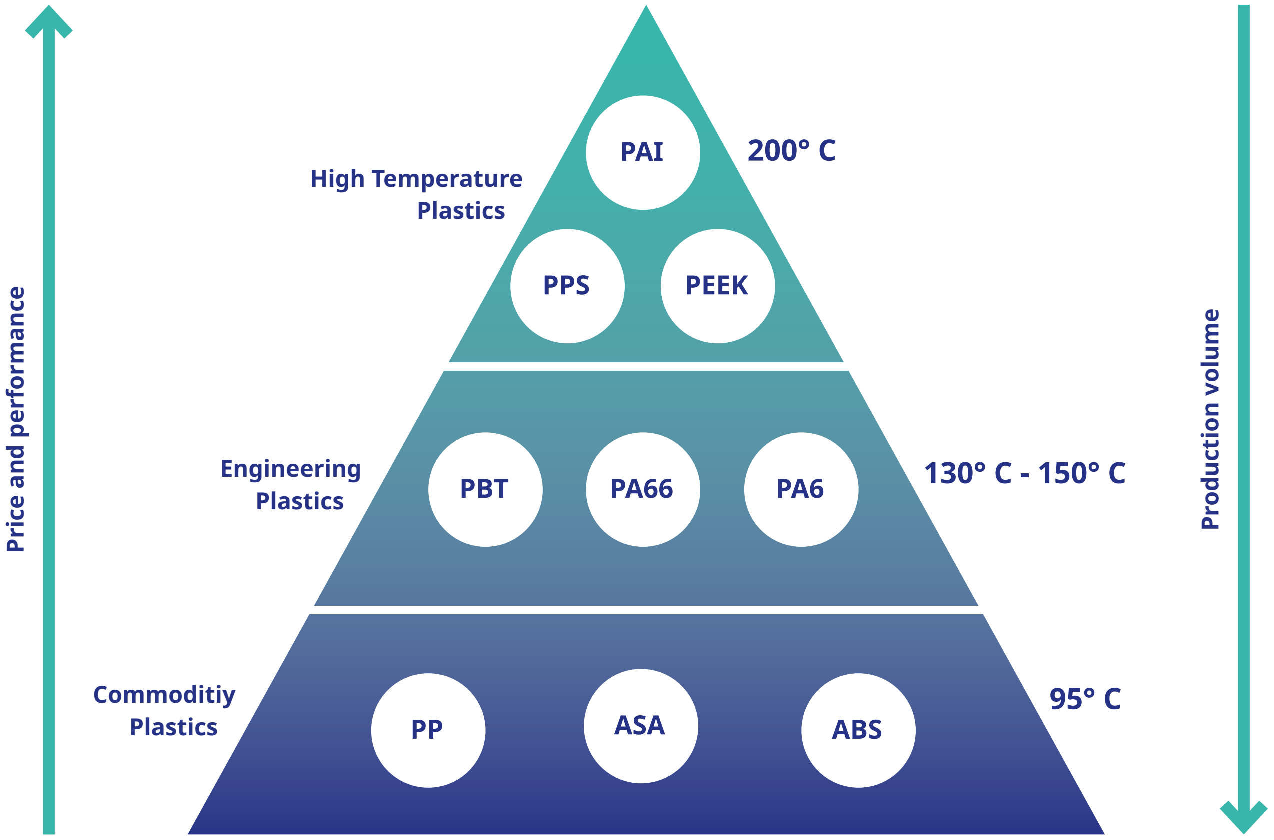
This places particular demands upon the temperature resistance and flame retardancy of the materials used for battery components.

Temperature resistance

The electric powertrain places high demands not only on the electrical and mechanical properties of the components, but also on their temperature resistance: some components may reach continuous operating temperatures of over 200 °C.

Engineering thermoplastics such as PBT or PA 6/66 and high-performance thermoplastics such as PPS are particularly suitable for high-voltage batteries, depending on the requirements for temperature resistance.

Thermoplastics and temperature classes at a glance



Besides the temperature resistance for normal operation, the most important factor for selection of the appropriate material is its flame retardancy.

Flame retardancy

Electric vehicles rarely catch fire. Preventing the risk of fire is nevertheless important. Possible causes of fire include short circuits, overheating and accidents. When a thermal runaway occurs, an unstoppable chain reaction can be set in motion in one cell and result in the battery catching fire or exploding. Temperatures of 800–1,100 °C may be reached in such cases.[19]

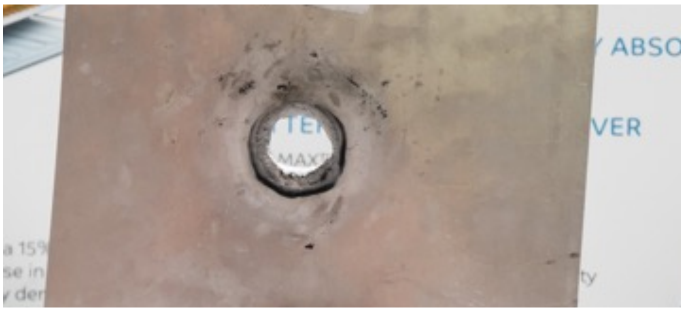
Design measures for avoidance of this situation are thermal barriers (e.g. insulating film), clearance between cells/modules (assured for example by spacers) and, increasingly, the use of flame retardants. Flame retardants intervene chemically in the combustion process, thereby extinguishing the flame or inhibiting and retarding the development of a fire.

Halogen-free flame retardants to IEC 61249-2-21 are increasingly being used. They have the advantage that should a fire break out, they do not release bromine or chlorine, which can form corrosive, toxic compounds.

Aluminium vs. plastic composite

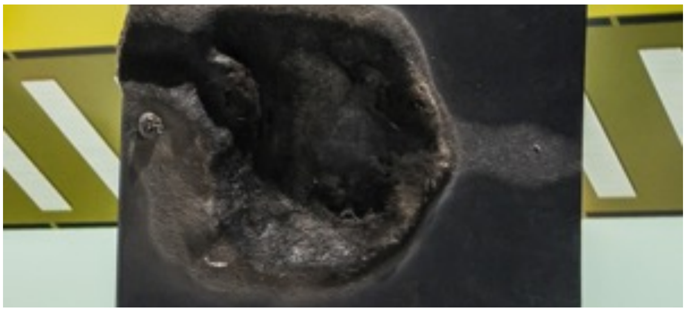
Tests have shown plastic composites to be substantially more resistant to flame and heat than aluminium, thus supporting the stringent fire safety requirements of China's new safety standard (GB 38031-2020).

Example: Presentation by SABIC at the Battery Show Europe 2021:[20]
Sample plates manufactured from aluminium and thermoplastic, after 5 minutes exposure to 1,000 °C



Aluminium sheet:

- High thermal diffusivity
- Melting point below 700 °C
- 1 mm thick sheet melts after 2.5 minutes
- High thermal expansion (buckles towards flame)



Thermoplastic sheet:[21]

- The side exposed to the flame endured the flame for > 5 minutes without breakthrough occurring
- Non-exposed side: temperature increase < 200 °C

Background: Chinese safety standard GB 38031-2020

In 2021, China introduced the GB 38031-2020 safety standard, containing new safety provisions for traction batteries. The standard supplements existing standards. One such new provision in GB 38031-2020 is the thermal propagation test. This test has the purpose of ensuring that following thermal runaway of a cell in the battery pack, a fire does not break out or explosion occur for at least five minutes, leaving the occupants of the vehicle sufficient time to exit from it. According to TÜV Süd, it can be assumed that this standard will become mandatory for other regions worldwide.[22]

The consequence for fire safety is that the requirements to be met by structural components in high-voltage batteries will become stricter. A powerful substitute for aluminium and steel is already available to manufacturers: fibre-reinforced plastics optimized for flame retardancy.

Fire safety and flame retardancy: conclusion

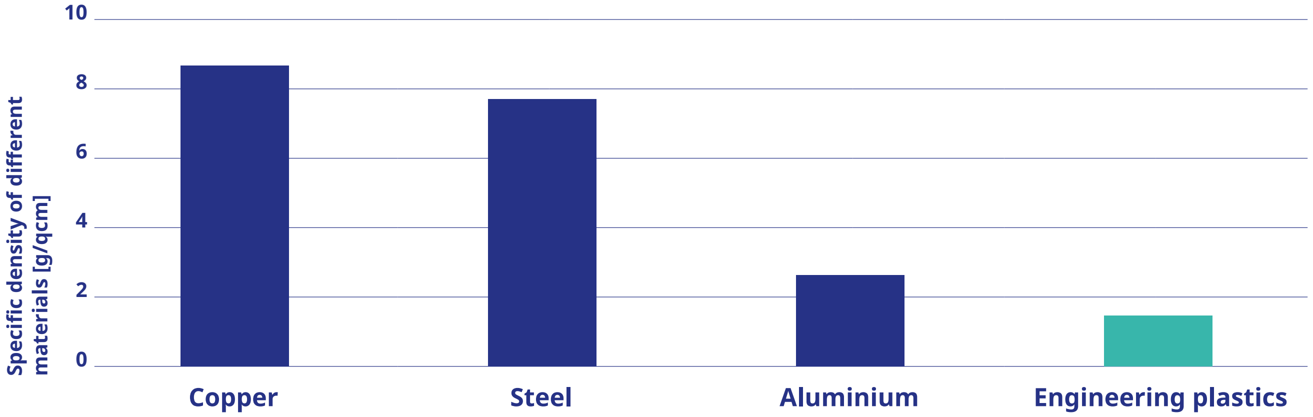
- **A key objective in the design of HV batteries for electric vehicles is to prevent or retard fires.**
- **Manufacturers already have a powerful substitute for aluminium and steel at their disposal, in the form of fibre-reinforced plastics optimized for flame retardancy.**
- **Tests have shown plastic composites to be significantly more resistant to flame and heat than aluminium and to satisfy the strict fire safety specifications of the Chinese safety standard (GB 38031-2020).**

4. Potential for lightweight design

Their batteries make electric vehicles heavier than comparable vehicles with internal combustion engines. Weight reduction is thus a crucial factor in the design of electric vehicles, and especially in battery design.

The relative densities of materials commonly used in high-voltage batteries speak for themselves: for a given performance, engineering plastics are significantly lighter than metals, even very light metals such as aluminium and magnesium.

Comparison of the density of commonly used metals and engineering plastics[23]



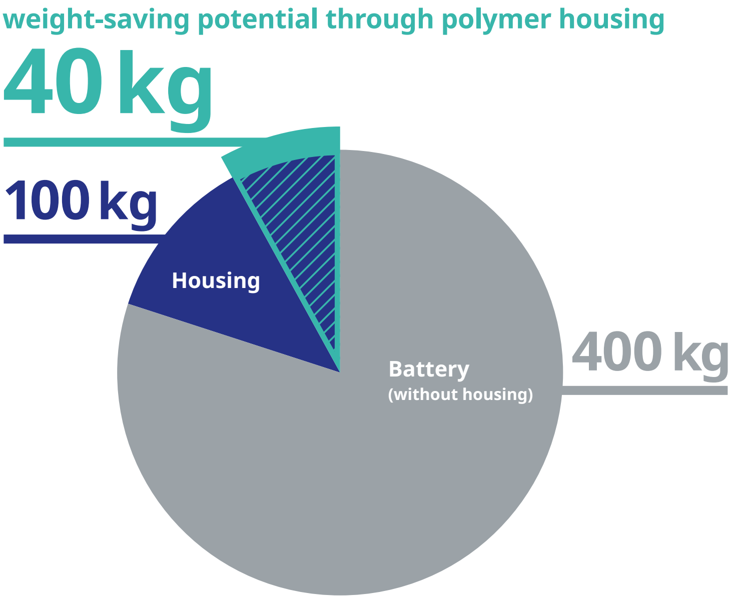
Savings potential of a plastic battery housing

The battery is one of the core components of an electric car. Every kilogram of weight saved extends the car's range and the battery's efficiency. Fibre-reinforced plastics can help to reduce weight, especially that of the battery case.

Model calculation:

- Weight of a typical battery pack:
  400 kg battery + 100 kg case (aluminium)[24]
- Potential savings, depending upon the concept:
  Up to 40 % by the use of plastic instead of aluminium[25] – in this example, this equates to a weight saving of up to 40 kg

The low density of plastics and their potential for lightweight design deliver significantly lighter battery cases. This also extends the range of the electric vehicles.



5. Integration of functions

Integrating as many functions as possible into one battery component enables material, weight, costs and installation space to be reduced in line with the objective and concept. The performance can also be increased and system assembly made easier.

Plastics offer a high degree of design freedom and thus present considerable potential for integrating functions. Some examples:

- Pigmented plastics eliminate the need for subsequent painting/anodizing, for example of high-voltage components in signal orange
- Components that are thermally conductive whilst also having an electrical insulating or electromagnetic shielding function reduce the number of components/process steps
- Integral fastening elements (e.g. clip action) in place of threaded connections reduce weight and eliminate the need for additional bonding process steps
- Integration of cooling channels or screw channels into case components

6. Sustainability: Design for Circularity

The targets of the Paris Agreement for CO2 emissions to be cut by 55 % by 2030 and climate neutrality attained by 2050 are forcing battery manufacturers to review the carbon footprint of their products andoptimize them continually.

“Batteries placed on the EU market should become sustainable, high-performing and safe all along their entire life cycle.” – European Green Deal[26]

Ecological requirements are growing in importance

Surveys of experts, such as the FOREL study[27], show clearly that across all sectors, ecology and in particular recycling will acquire crucial importance in the development of components in the coming 10 to 15 years. 90 % of those questioned rank the importance of ecological requirements for components as clearly increasing or increasing rather than decreasing.

Reuse and recycling

High-voltage batteries for electric vehicles have a life of 1,500 to 2,500 charging cycles over a period of eight to ten years. At the end of the battery’s useful life, its charge capacity is still 70 % to 80 % of the value when new.[28]

The useful life of batteries can be extended by a further 10 to 12 years by a second life in other applications, such as buffer storage for renewable energies, as well as by re-use in vehicles.

The use of engineering plastics in the manufacture of structural components can contribute significantly to the responsible use of resources and the design of high-voltage batteries for recycling:

- **Reversible joining** techniques such as click and plug-in connections instead of threaded, bonded or welded joints simplify repair, disassembly and recycling.
- **Material savings** by the integration of as many functions as possible, such as thermal conduction, insulation and fixing, into discrete plastic components

Examples of battery concepts with a focus on sustainability.

End-of-life recycling is an important element in the quest for more sustainable battery systems. However, to attain the highest possible sustainability over the full life cycle of an HV battery, consideration must be given to the cycle from the outset, i.e. at the product development stage. Many projects in industry and research follow the principle of Design for Circularity:

- New battery concepts, like those of the specialist engineering company IAV, have the potential to reduce the number of threaded connections by two thirds. Bonding and welding should also be significantly reduced. The objective: recyclers should be able to disassemble different battery systems and types more easily and quickly, and by means of automated processes.[29]
- The “ReDesign” project at TU Braunschweig technical university: development of guidelines for battery systems design conducive to recycling, as a part of the circular economy.[30]
- “PolyCE” is a project supported by the EU for promoting circular value chains for plastics in electronics applications. As part of this project, a guideline for sustainable design of electronic components conducive to recycling has been developed.
  The guideline is intended to assist designers and manufacturers in integrating life cycle thinking into the design of electronic products.[31]

> **„Over 80 % of a product’s environmental impact is determined at the design stage.”**
>
> *Design for Recycling – Design from Recycling; Practical guidelines for designers; created by the partners of the Horizon 2020 EU-funded PolyCE project*

Circular design tips for plastic components

- Use click/snap solutions to fix batteries in a product. Avoid permanent fixing such as bonded, welded and enclosed solutions.
- Avoid 2K processes (combining two materials through the same injection moulding/extrusion die).
- Avoid the use of foam. When foam is necessary, use thermoplastic foam. Do not use elastomers or thermosets for foam.

Point to remember: when fibre-reinforced plastics are used, variants with a thermoplastic matrix (e.g. PA or PBT) are more sustainable, as they are significantly more amenable to recycling than thermosets.

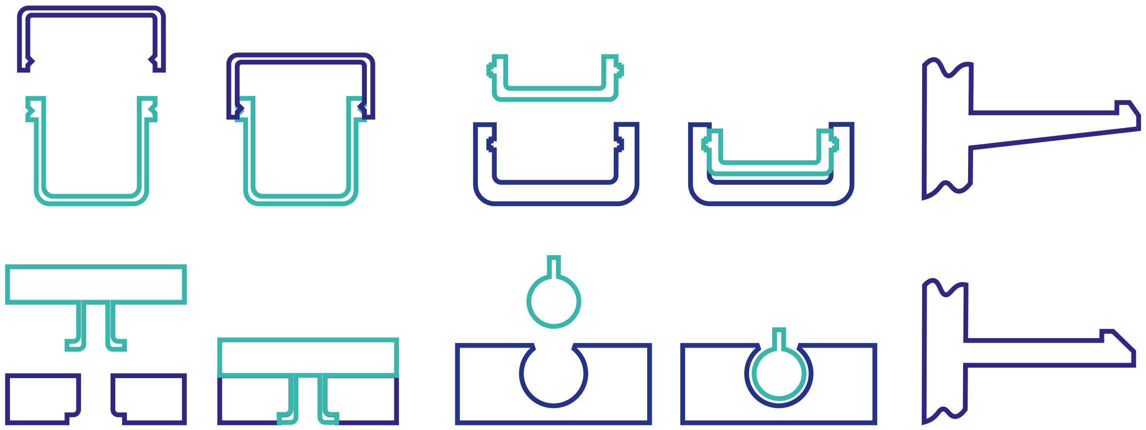
Joining techniques

Battery recycling that is both ecological and economical, is dependent on the right joining techniques. In many cases, reversible joining techniques such as snap or click connections are a viable substitute for threaded connections, bonding and welding.

- Threaded joining techniques are costly and the drilled holes necessitated by them can weaken the component
- Bonded connections are time-consuming in assembly (curing) and laborious in disassembly
- Welding is time-consuming both in assembly and disassembly

In many applications, plastic snap and clip connections represent a high-performance and recyclable alternative to conventional joining techniques. Such connections require precision profile geometries and suitable types of plastic. As a rule, they consist of an elastic spring element and a detent device (undercut). The requirements to be met by the material include high strength, elasticity and resilience combined with high creep resistance.

Standard design concepts for snap connections[32]



Snap and clip connections are a simple, low-cost and sustainable joining technique and thus offer high potential for solutions for the circular design of battery systems.

7. Summary

Thermoplastics for safe and sustainable high-power batteries

Engineering plastics have inherent electrical, thermal and mechanical properties that make them ideally suited for use in high-voltage batteries. Unlike metals, thermoplastics can be modified flexibly by additives and thus offer maximum design freedom. They deliver benefits in terms of cost reduction, integration of functions, flame retardancy, thermal conductivity and lightweight design.

Thermoplastics can be used to improve the safety, performance and sustainability of electric cars.
The challenge lies in designing the plastic such that it satisfies all individual requirements in combination.
This is where Technoform’s plastics experts can provide support.

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Power generation

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Water

Marine

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and facades

Technoform – tailored engineering plastics solutions

Technoform is a family-owned company with over 45 production and sales locations worldwide.
We are a manufacturer of plastic profiles with a global presence and over 1,600 employees. With our numerous locations, we are always on hand right where our expertise is needed. We can also build on a flexible, global network in which we share our knowledge and many years of experience in the use of high-performance and engineering plastics. This enables us to offer a wide range of custom solutions and standard plastic applications – throughout the world and for numerous industries.

The automotive and electrical engineering sectors are important areas for us. To date, we have supplied over 30 million metres of profile for 20 vehicle models from 10 major manufacturers.
Our customers in electrical engineering also value our experience in processing fibre-reinforced and flame-retardant engineering plastics – a safe and reliable solution for high-voltage applications.

We offer solutions for both worlds. Let’s bring automotive and electrical engineering together. We’re there to help you optimize your battery systems.

Contact
Petra Greiner-Stroehl
Business Development E-Mobility
Tel. +49 561 95839-64
Email petra.greiner@technoform.com

TECHNOFORM

Technoform Kunststoffprofile GmbH
Otto-Hahn-Strasse 34
34253 Lohfelden
Germany

T +49 561 95839-00
F +49 561 95839-21
Email info.otsde@technoform.com

I www.technoform.com