The potential of epoxy SMC in electro-mobility battery systems




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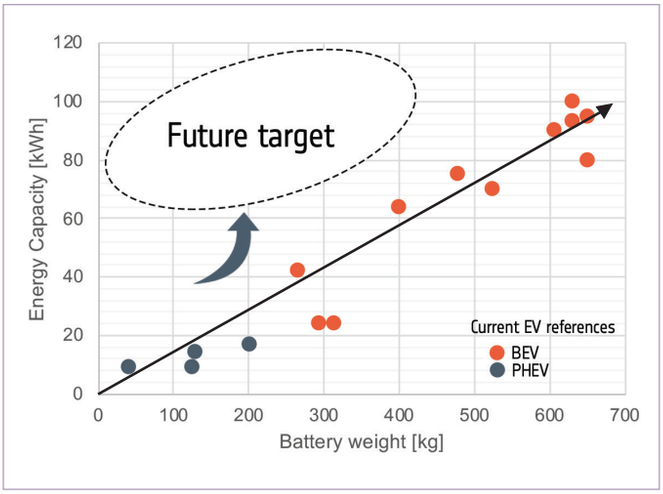
Evonik's new curing agent for epoxy SMC – VESTALITE® S – makes it possible to use SMC technology in structural automotive applications. As part of a case study, Evonik's joint venture Vestaro is developing an enclosure concept for a holistic battery system based on this high-performance material, together with different partners.

In times of growing attention to climate change, electro-mobility is an omnipresent topic in our society. The development of electric vehicle (EV) technologies is accelerating significantly, including new material developments to meet the growing demand for efficient mobility. Improving energy density without compromising safety is a huge challenge that all battery electric vehicle (BEV) or plug-in hybrid electric vehicle (PHEV) manufacturers and battery system developers are facing, independently of car and battery sizes. Current approaches target improvements in the cell's active material, increasing the cell packaging density in modules and lowering the total weight of the battery system through lightweight design and high-performance materials. Future battery system concepts need to consider cost-efficient processing and system modularity for increased gravimetric energy density (kWh/kg) and lower total cost per energy (€/kWh).

Battery system requirements

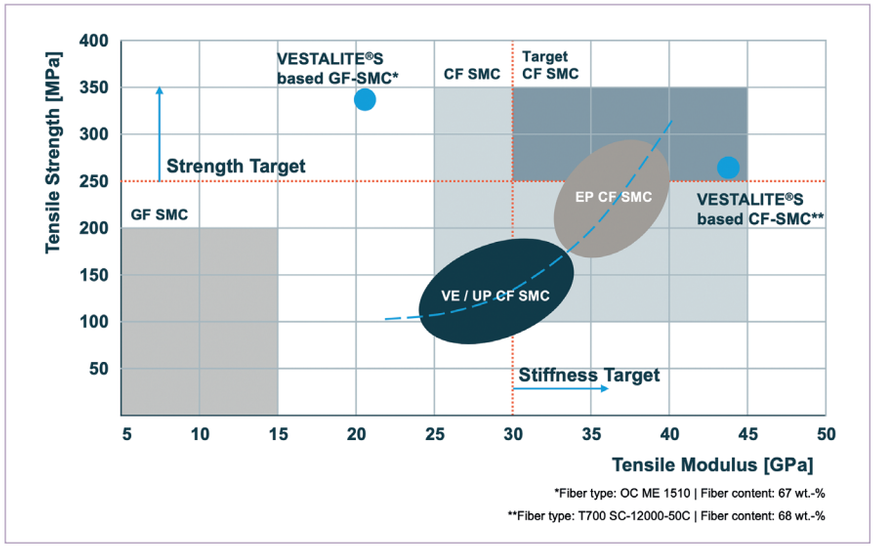
Current battery systems consist of different battery module solutions based on prismatic, pouch or cylindrical cell formats. Thermal management, voltage and temperature sensing concepts depend on the battery system manufacturer and the cell technology used. To achieve the required capacity, a certain number of battery cells are connected within modules to form a battery system. These modules are packaged into a battery enclosure, which protects the battery cells from external impacts and the passengers from excessive temperatures and gases during thermal runaway scenarios. Aside from these worst-case safety scenarios, the battery enclosure makes it possible to minimize cell displacement during crash scenarios, control loads on cells during operation and meet requirements for electrical isolation and electromagnetic compatibility. Current solutions generally rely on metal-based structures. Nevertheless, to achieve the high mechanical, thermal and electrical requirements and simultaneously reduce weight and cost, alternative designs and materials need to be considered.



Energy density of new battery systems can be increased by lower battery system weight

Cost-efficient lightweight materials

Plastic or composite materials can be used to reduce weight and to integrate more functions into the battery enclosure. In higher price segments, carbon fibre-reinforced plastic



Mechanical properties of VESTALITE®S based SMC materials compared to other SMC systems

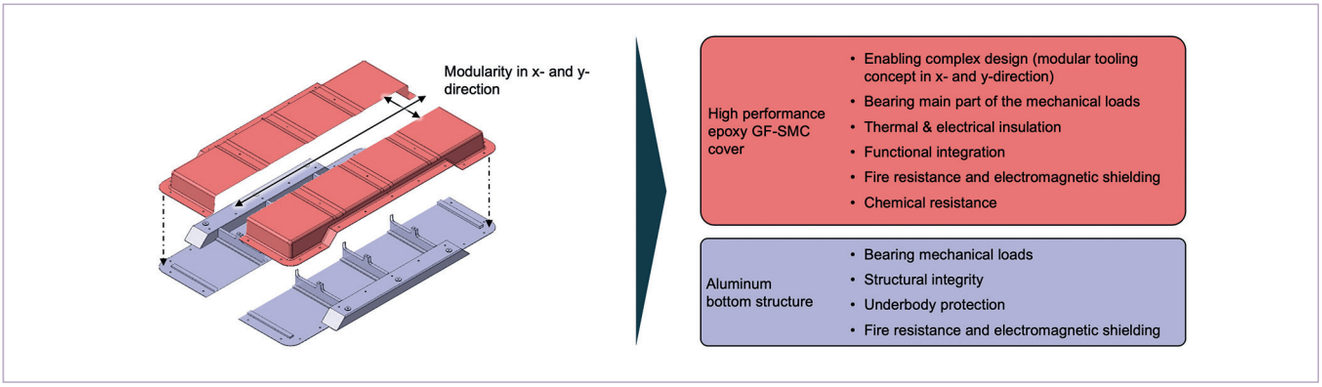
Schematically illustration of LION Smart's modular LIGHT Battery concept

(CFRP) materials are already in use for battery enclosures. Due to economic reasons, established and cost-efficient composite technologies such as Sheet Moulding Compound (SMC) technology are getting more and more relevant. SMC formulations based on glass fibre can provide both a cost-efficient and lightweight solution. New high-performance SMC materials can match the requirements of EV battery systems, such as mechanical strength and robustness, electrical and heat/flame resistance as well as processability. Evonik is offering the new epoxy curing agent VESTALITE® S, which uses amine-based EP SMC materials to compete with lightweight materials such as aluminium. When used in a compound, this curing agent opens up new fields of application for SMC technology in the automotive industry. With its low viscosity, VESTALITE® S contributes to excellent mould behaviour for complex part geometries with a high fibre volume content, as SMC formulations developed by compounders show excellent fibre flow during the moulding process. Like all epoxy systems, there are no styrene and practically no volatile organic compound (VOC) emissions during processing and in the final part.

Holistic battery system solution

As part of a showcase project, a consortium formed by Vestaro, Forward Engineering, LION Smart and Lorenz Kunststofftechnik is developing a holistic solution for an EV battery system. To achieve a comprehensive system solution, LION Smart's innovative LIGHT Battery concept is integrated into a functionally-integrated battery enclosure developed by Vestaro (material, design and process) and Forward Engineering (CAE engineering). The main part of the design is based on an epoxy SMC material, which is used for the complex-shaped cover of the battery enclosure. The design takes all regulatory requirements into account while seamlessly integrating LION Smart's modules into the pack structure. Therefore, Lorenz Kunststofftechnik conducted extensive processing trials for the use of VESTALITE® S in an epoxy SMC compound suitable for EV battery enclosures. In addition to its mechanical performance, the material exhibits a high flame resistance to ensure the required safety in case of battery cell venting or external flame impact. Within this integrated approach, all regulatory requirements, a high level of functional integration and the modularity for various battery system sizes are considered to enable a cost-efficient implementation within a broad range of vehicle sizes.

The LIGHT Battery concept is based on multiple supercells, each consisting of standardized cylindrical lithium-ion cells electrically connected in parallel, which results in a behaviour similar to a single large battery cell. The cylindrical format combines excellent cost efficiency, high mechanical stability and superior safety behaviour at high energy densities. A direct cooling concept based on a dielectric, non-flammable coolant is combined with a highly modular packaging approach. This cooling method ensures a homogenous temperature distribution between the cells and reduces cell ageing caused by large temperature gradients during fast charging. The module size can easily be adjusted by interconnecting supercells in series to meet the required voltage level and to efficiently use the available design space. To reduce the assembly effort, a modular sensing system based on flexible printed circuits (FPC) is used in each supercell, making it possible not



Battery enclosure platform for different layouts

only to monitor the voltage and temperature distribution within the highly parallelized thermal management system, but also to feature an online electrochemical impedance spectroscopy (EIS) system.

Although the volumetric and gravimetric energy density of the LIGHT Battery concept is remarkably high, the total weight of the entire battery system is increased due to the direct cooling fluid. To compensate for the total weight of the battery system, Vestaro and Forward Engineering are currently developing an appropriate multi-material design for the battery enclosure. The design consists of a glass fibre-reinforced epoxy SMC battery case cover, which carries most of the mechanical loads. Through the flow moulding process, complex geometries can be designed, thus reducing the enclosure's assembly cost. Moreover, stiffening ribs and different functions such as inserts, local carbon fibre reinforcements and sealing grooves are integrated into the concept. The additional usage of specific fire, smoke and toxicity (FST) retardant fillers can increase the fire resistance properties of the material. The percentage of FST fillers in the Lorenz Kunststofftechnik compound is balanced to meet both mechanical and thermal requirements. Additionally, the integration of an electromagnetic shielding layer within the flow moulding process of the SMC material is part of the Lorenz Kunststofftechnik processing concept. In addition to the chemical resistance ensuring media compatibility with several liquids or gases, the material's thermal insulation properties can help increase the temperature management efficiency inside the battery case. Unidirectional carbon fibre strips can be applied locally to reinforce the SMC cover in the required areas. A flat aluminium plate with attached impact structure and supporting elements is used at the bottom of the battery enclosure. In addition to supporting the mechanical loads and ensuring electromagnetic compatibility, the bottom structure also protects the cells against underside impacts and controls hot gas flow during thermal runaway scenarios.

Within the holistic approach of the consortium project, two concepts were combined by implementing the LIGHT Battery modules into the enclosure concept. Therefore, the structural integration of the modules into the battery enclosure was considered in the concept. This innovative approach results in a comprehensive battery system solution with outstanding energy and power density. To provide a cost-efficient solution, the modularity of the LIGHT Battery concept was combined with a modular battery enclosure. Therefore, a specific tooling concept will be used by Lorenz Kunststofftechnik to enable flexible enclosure lengths and widths. Depending on the required amount of serial connected supercells, several battery enclosure sizes for all relevant energy capacity levels (see Figure 1) can be produced within only one tool. This results in a highly integrated battery system with reduced tooling and processing cost to support multiple vehicle architectures.

Current project status and outlook

The initial evaluations of the LIGHT Battery concept showed that this technology has the potential to increase the energy and power density by up to 30%. The goal of this project is to demonstrate the combined potential of the battery module and the battery enclosure concepts. Therefore, a comprehensive process and cost assessment considering different production scenarios for the virtual showcase is currently performed. Lorenz Kunststofftechnik conducted extensive small-scale testing in order to find the optimal compound for meeting regulatory flammability and fire resistance requirements.

To avoid the duplication of structural elements, the structural integration of the battery system into the body in white (BiW) will become more and more important in future battery enclosure designs. High-performance materials such as epoxy-based SMC can help to exploit this seldom used potential and therefore enable more cost efficient and lightweight solutions considering the entire vehicle. As the current concept already provides solutions to introduce the mechanical loads from the BiW into the battery enclosure, the approach will be extended in future projects with OEMs. □

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Focus

Combining chemical and engineering know-how

Evonik is one of the world's leading specialty chemicals companies. Together with Forward Engineering, they founded the Vestaro joint venture to combine chemical and engineering know-how. Vestaro is supporting case studies for Evonik's customers to support the VESTALITE® S based product for automotive applications. In the battery case study mentioned in this paper, an epoxy SMC battery enclosure concept is developed as part of a consortium with LION Smart (LIGHT Battery concept) and Lorenz Kunststofftechnik (SMC compounder).