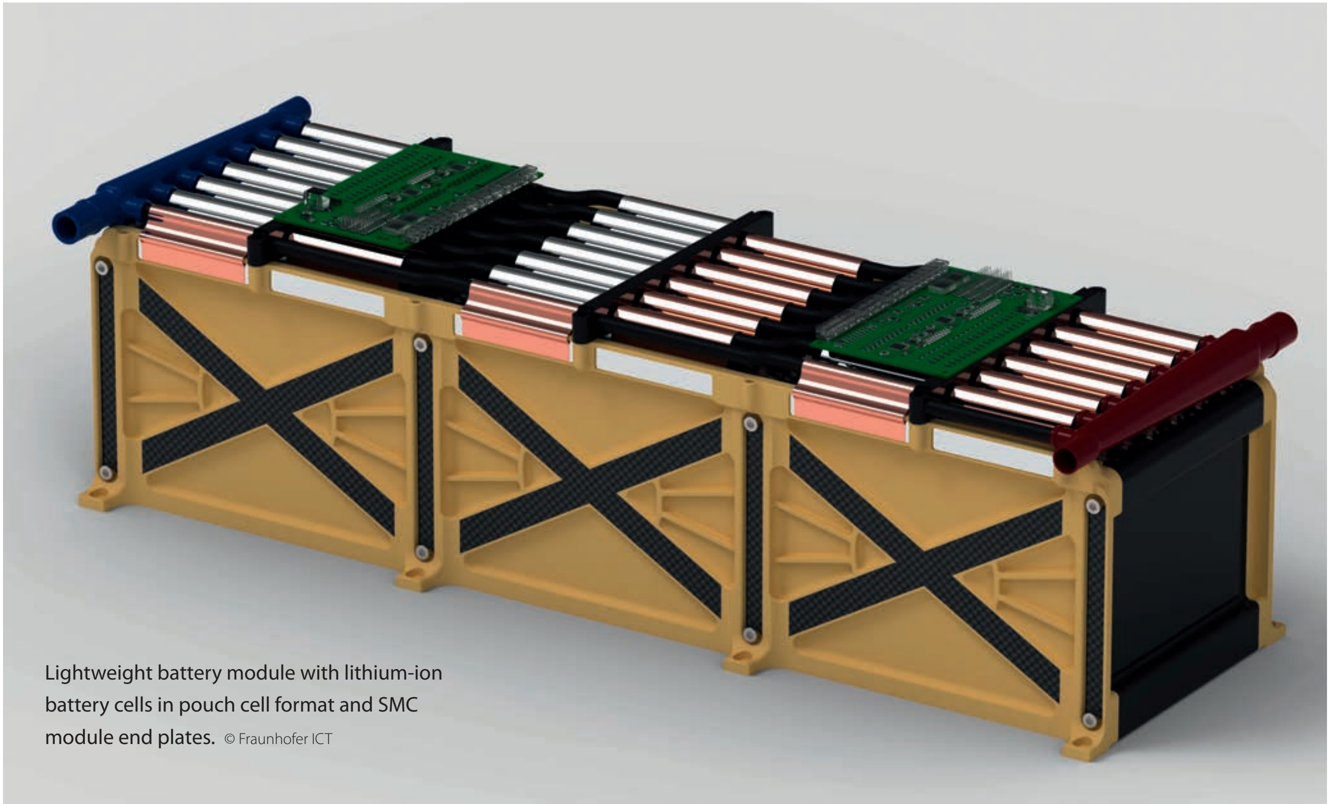
Lightweight Traction Battery System for Electromobility

Lightweight Construction for Heavyweights

The battery system is one of the heaviest components in the powertrain of an electric vehicle. The use of lightweight materials and high-volume production processes according to requirements and functionality offers significant potential to reduce weight without compromising on safety or performance. A new technology concept shows the particular advantages of using a modified direct process with a tailored material selection.



Lightweight battery module with lithium-ion battery cells in pouch cell format and SMC module end plates. © Fraunhofer ICT

Developing sustainable mobility solutions: with this task in mind, important players from science, applied research and industry are networking through the interdisciplinary "High-Performance Center for Mobility Research, Karlsruhe" (**Info box p. 48**). The individual research and development projects highlight different facets of mobility. This article is about new concepts and possible solutions to reduce the weight of the battery system [1]. This is achieved through the use of lightweight materials and large-scale production processes, which are used in or for the battery module according to requirements and functionality. The high demands placed on system safety and the efficiency of the thermal management system are also taken into account. This article focuses on the concept of a newly developed battery system and technical solutions for lightweight design and manufacturing processes, as well as presenting a new direct process.

The aim of this project was to evaluate and demonstrate how thermal performance, safety and lightweight construction can be combined in a battery system. These properties are increasingly in demand for conventional, ground-based mobility applications. In other mobility sectors, such as urban air mobility (UAM) applications, demand is also growing for measures to increase power and energy density in relation to weight. In addition, the concept was designed with large-scale production in mind,

Fig. 1. Cutaway model of the entire battery system. © Fraunhofer ICT

which is reflected in the choice of materials and in the manufacturing and assembly processes.

Lightweight Structural Module Concept with Integrated Functions

The basis for the battery module (**Title figure**) is a lithium-ion battery cell in pouch cell format, which has been established for some years as one of the most important cell formats for battery systems for mobility. A cell with a capacity of 20 Ah was selected for the concept, which originates from the research production of the project partner Institute for Applied Materials – Energy Storage Systems (IAM-ESS) at the Karlsruhe Institute of Technology (KIT), Germany.

The individual cells are mechanically combined in a module and electrically connected: twelve cells in series and six in parallel. Three cells at a time are supported by a holding frame and stacked together to form the module. The holding frames can be manufactured by injection molding. The cells are cooled via their current conductors. Structural end plates with integrated functions close off the module on both sides and ensure that the cell stack receives the required pretension via the screw connection.

Battery Pack in Hybrid Design

The individual modules are then combined to form a complete system (**Fig. 1**), based on a hybrid design. In line with current developments in the automotive industry, the frame of the overall system was designed to serve as a structural, load-bearing component of the complete vehicle. It is made of extruded aluminum profiles and is supplemented on the inside by further profiles that increase rigidity. Both the lid and the base of the system are constructed using plastics. In particular, the the base plate is designed as an innovative sandwich structure with the possibility to integrate functionalities. For example, beads help increase stiffness while providing space for cooling structures. It is manufactured using a newly developed manufacturing process called direct sandwich composite molding (D-SCM).

SMC Module End Plates with Integrated Functions

Electromagnetic shielding and flame retardancy are two of the most important safety features of battery housing components. The SMC (sheet molding compound) process is well suited to the »

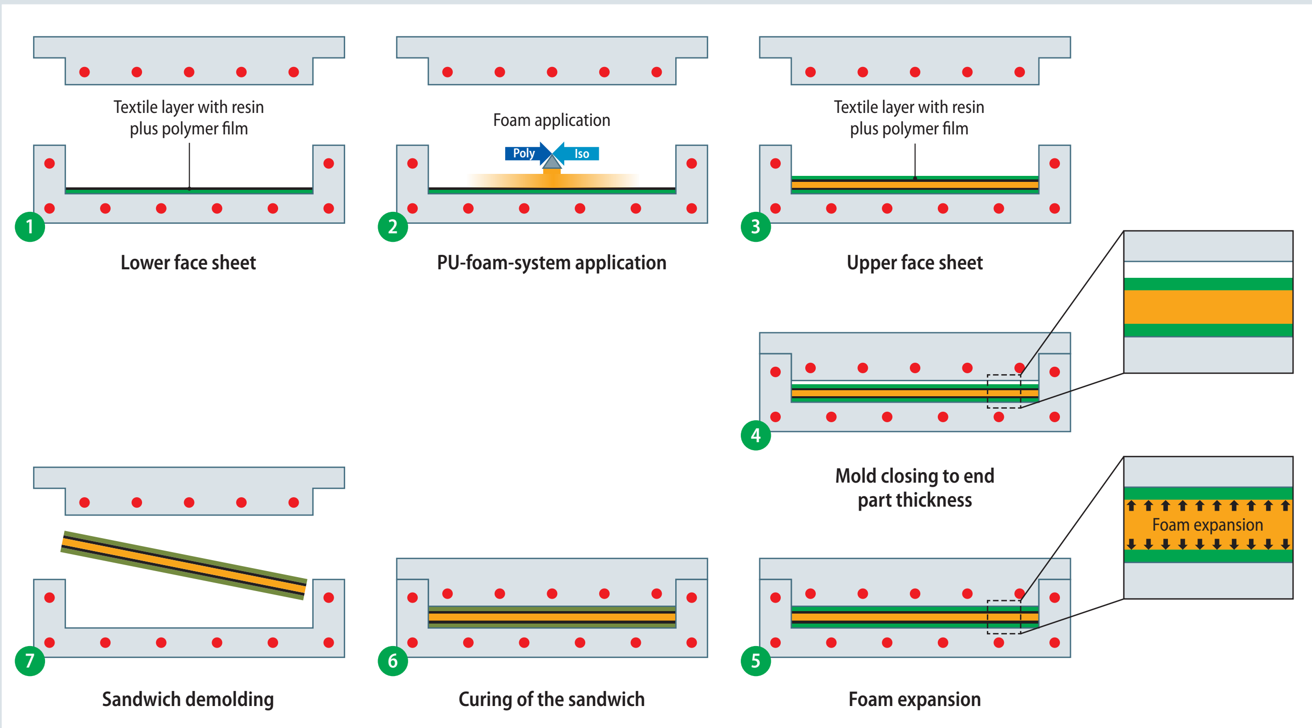


Fig. 2. Schematic for the simple and efficient production of lightweight, highly rigid sandwich structures using the D-SCM process. Source: Fraunhofer ICT; graphic © Hanser

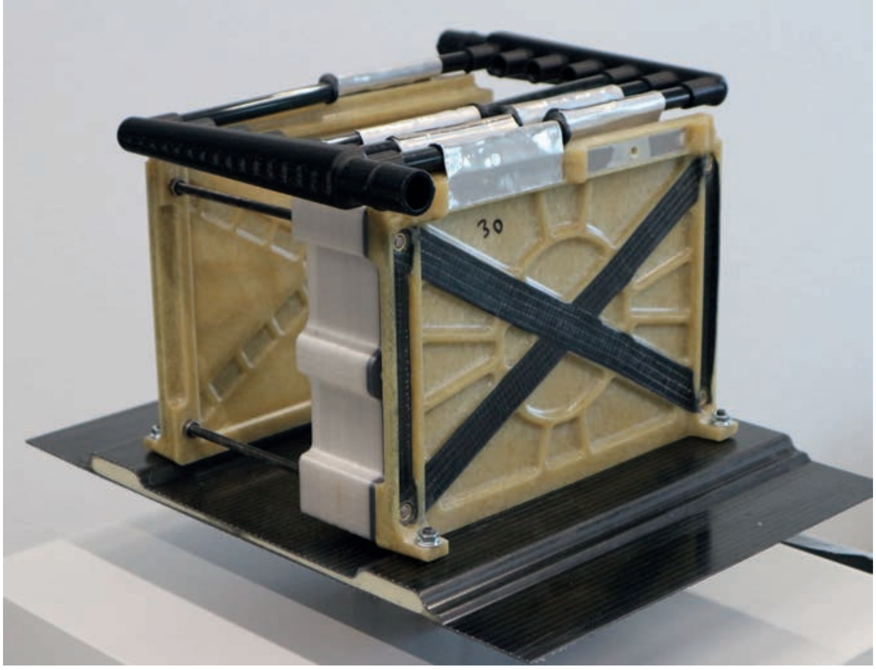


Fig. 3. Partial section of the battery module as a technology demonstrator with the functionally integrated SMC module end plates and the base plate manufactured using the D-SCM process.
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production of these components due to its cost efficiency, and due to the compound's mechanical performance and formability into complex structures. However, both electromagnetic shielding and flame retardancy require specific material modifications. The research and development work in this project focused on the electromagnetic shielding properties and flame retardancy of unsaturated polyester-polyurethane hybrid (UPPH) resins with glass fiber and carbon fiber-reinforcement. By adapting the formulation, this resin system is suitable for the production of both SMC and prepreg semi-finished products. The combination of these semi-finished products in a co-molding process offers high lightweight potential for structural applications [2].

The aim of the EMC investigations (EMC: electromagnetic compatibility) was to achieve the best possible electrical conductivity in the fiber-reinforced UPPH composite without the need for a downstream process step. A continuous electrically conductive network can be formed by introducing additive particles. Exceeding the percolation threshold, the influence on the curing reaction, and the viscosity increase due to the additive content in the resin system, are important factors here.

The developments towards ever higher battery capacities mean that the requirements and standards for battery housing are constantly being adapted and updated. Protecting a fully equipped rechargeable energy storage system (REESS), including battery, housing, control electronics, etc., from a fuel fire is complex and costly. A newly developed approach at the Fraunhofer Institute for Chemical Technology (ICT), in which a laboratory-scale fire test simulates the fire treatment of UNECE-R100–8E (United Nations Economic Commission for Europe Regulation No. 100, Annex 8E – Fire Resistance) at the component level was used to characterize the composites [3].

Glass fiber-reinforced SMC does not exhibit sufficient shielding against electric fields and high-frequency magnetic fields, even with appropriate additives. Carbon fibers, on the other hand, have the potential to be used in battery housing as a replacement for aluminum. The addition of fillers further increases the shielding effect. The additives used can also have a positive effect on combustion behavior. In addition to EMC requirements, the material systems optimized for the application also met the fire criteria of self-extinguishment, ignition of the reverse side, and structural integrity.

Production of the Sandwich Base Plate with the D-SCM Process

Current traction battery housings for electric vehicles are usually constructed with comparatively heavy metal-based materials. In particular, the use of ultralight,

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Project Partners and Competence

The project was carried out within the framework of the "High-Performance Center for Mobility Research, Karlsruhe". In addition to the Applied Electrochemistry, New Drive Systems and Polymer Engineering Departments of the Fraunhofer Institute for Chemical Technology (ICT), various institutes of the Karlsruhe Institute of Technology (KIT) were involved [1].
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References & Digital Version

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highly rigid fiber-composite-based sandwich structures allows their weight to be significantly reduced. However, complex processing and rising part numbers require improved, robust manufacturing processes with short cycle times.

The base plate of battery boxes usually has a low geometric complexity. This means that the wet pressing process is particularly well suited, as it allows high part numbers to be achieved. Additional stiffness can be achieved by geometric embossing and sandwich construction. However, the latter is not yet state of the art in wet pressing.

If the classic sandwich construction method were combined with wet pressing, this would require significant effort in handling the layer structure and foam core. The top layers would be wetted separately with a reactive matrix, and the prefabricated foam core would have to be inserted precisely. If the foam core did not have a constant thickness, it would have to be produced in advance in a foaming tool, or mechanically processed. Closing the mold could also damage the core, especially if embossments were introduced or if the pressure of the matrix exceeded the core strength during during fiber impregnation.

For simple and more efficient production, a new direct process has therefore been developed at Fraunhofer ICT which enables lightweight, highly rigid sandwich structures to be manufactured in a single process step. The scientists named the process direct sandwich composite molding (D-SCM, **Fig. 2**) [4]. First, the lower CF-reinforced textile layer is pre-wetted with resin and placed in the mold (1). A polyurethane foam is applied to a thin TPU film as an intermediate layer (2). A second intermediate TPU layer is followed by the application of the pre-impregnated top layer (3) and the closing of the mold (4). Accelerated by the heat of the temperature-controlled mold, the polyurethane foam expands to form the sandwich layer. At the same time, the foaming polyurethane builds up cavity pressure, to completely impregnate the surface layers and press them against the mold contour (5). The foam and the matrix of the top layers are matched in terms of chemical reactivity so that the curing time is the same (6). After curing, the finished part can be demolded (7).

Conclusion

The base plate produced by the D-SCM process in the project has thin outer layers with carbon fibers. The foamed polyurethane-based intermediate layer has a variable thickness and a defined foam density (**Fig. 3**). Thus, as a result of this subproject, the researchers were able to demonstrate that innovative processes enable the efficient, single-stage production of high-performance sandwich structures. The intrinsic shaping of the sandwich foam is of particular interest here, as this no longer requires any prefabrication. ■