Lightweight and Safe Composite Battery Housings

Cost-effective lightweight design is paramount in contemporary and future automotive engineering, where it is all about developing efficient and cutting-edge vehicles. For electric vehicles, SGL Carbon is developing fiber composite battery housings that despite their low weight meet all safety, stiffness and thermal management demands.

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Automotive manufacturers are intensively working on developing new drive types for large-scale production and making them conveniently accessible to customers to meet statutory stipulations regulating a reduction of vehicle emissions. The electrification of the drive train is of great importance in this process. In addition to concepts such as fuel cell propulsion, hybrid, plug-in hybrid or purely electric vehicles will play an increasingly important role in the automotive market over the next few years [1].

At present, however, the electric vehicle in particular has not yet reached a range comparable to that of gasoline or diesel-powered vehicles. There are various ways of boosting the range. One option would be to install a significantly larger energy storage unit. However, this would have a negative effect on the vehicle's weight. Another possibility would be to boost the energy density within the storage unit. Unfortunately it is currently not possible to say whether or not and when batteries' specific energy capacity will be comparable to values generated by conventional fuels, such as gasoline and diesel.

A further possibility to extend the radius of action of a vehicle is to increase the overall efficiency of the vehicle and thus reduce consumption. In addition to optimization measures in the powertrain, the driving resis-

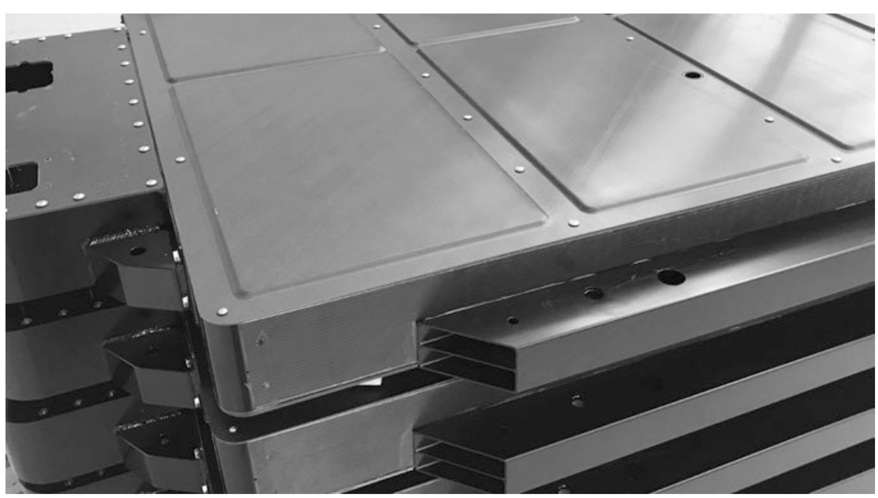

Figure 1 Battery housing made of fiber-reinforced plastic (© SGL Carbon)

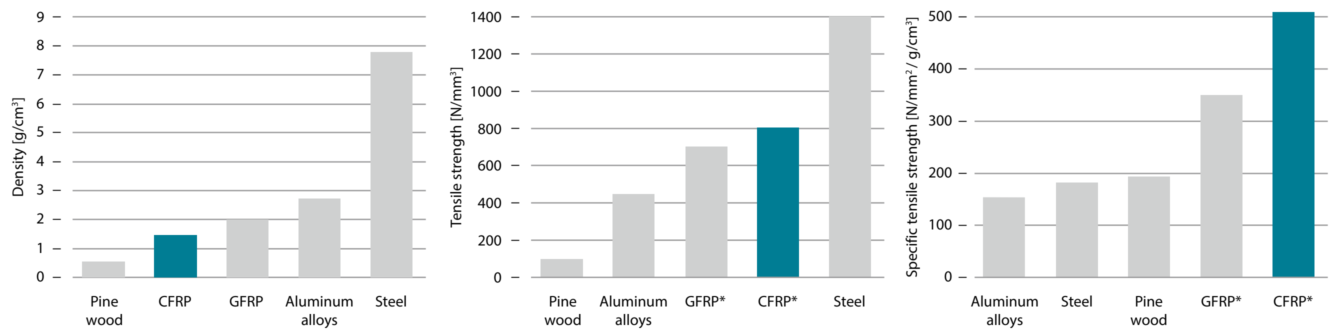

Figure 2 Properties of fiber-reinforced plastics compared to steel, aluminum and wood (* fiber orientation 0°/±45° = 1/1) (© SGL Carbon)

tances must also be reduced – the weight of a vehicle plays a major role here. Lightweight design is therefore important not only for electrified vehicles, but also for conventionally powered cars with combustion engines in order to increase efficiency. A weight saving of 100 kg reduces CO_2 emissions by about 10 g/km and consumption by up to 0.45 l/100 km. As a result of secondary effects, the weight of additional components and assembly parts can be reduced by up to 37 kg and the weight spiral reversed. This effect is called downsizing. In the case of electric vehicles, battery costs are also expected to be reduced by about 5 % [2]. Furthermore, low weight also has a positive effect on driving dynamics.

In terms of electric vehicles, the heavy battery and required protection housing can be compensated partly by lightweight design to make vehicles efficient and provide drivers with the maximum possible range. In this process, it is not enough to just make the housing lightweight. In addition the corresponding concept must be as reliable and safe as possible in the long term. For instance, this includes elements, such as fire safety, rigidity, integrity, thermal management, electromagnetic compatibility and anticorrosion properties.

Customized Housing thanks to Modular Design

Battery enclosures for electric cars are currently mainly made of aluminum and steel. By comparison, a composite design battery case, Figure 1, is up to 40 % lighter while demonstrating similar mechanical properties, Figure 2.

Most of all the design of the base panel and lid are crucial for the good properties of composite housings: it combines a sandwich core – e. g. made of PET, EPDM or aluminum foam and similar materials – with several layers of carbon fiber and/or glass fiber fabric. Mats, fabric or fiber webs can be used for this purpose, depending on demands, Figure 5. The processing is carried out in an automated pressing process using fast curing duroplastic resins. This allows high quantities to be produced in high quality, Figure 3.

Materials can be flexibly combined with each other to match the requirements of the corresponding application. The special stability of textile layers positioned in the tensile direction of fibers can be applied particularly easily to design components in which layers have been oriented so that they withstand the developing forces, leading to a particularly efficient material utilization.

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Battery Housings for Electric Vehicles

The stiffness of the components is strongly dependent on the sandwich structure used. As a rule, aluminum components can be substituted by CFRP components in a space-neutral manner. In this case, too, the design can often be neutral in terms of installation space. This stiffness of the battery housing is

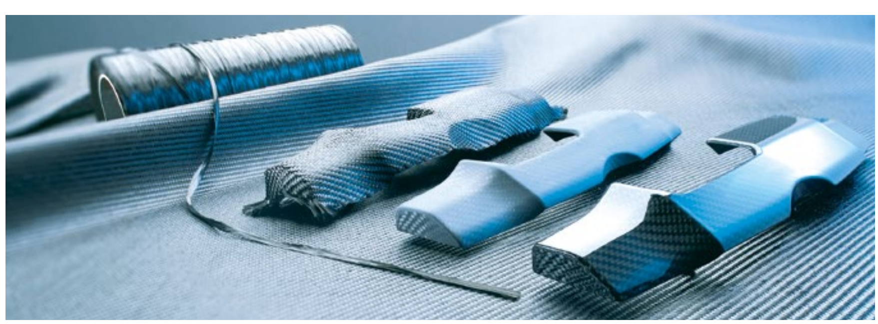

Figure 3 The SGL Carbon value chain extends from the fiber to the prepreg to the finished component (© SGL Carbon)

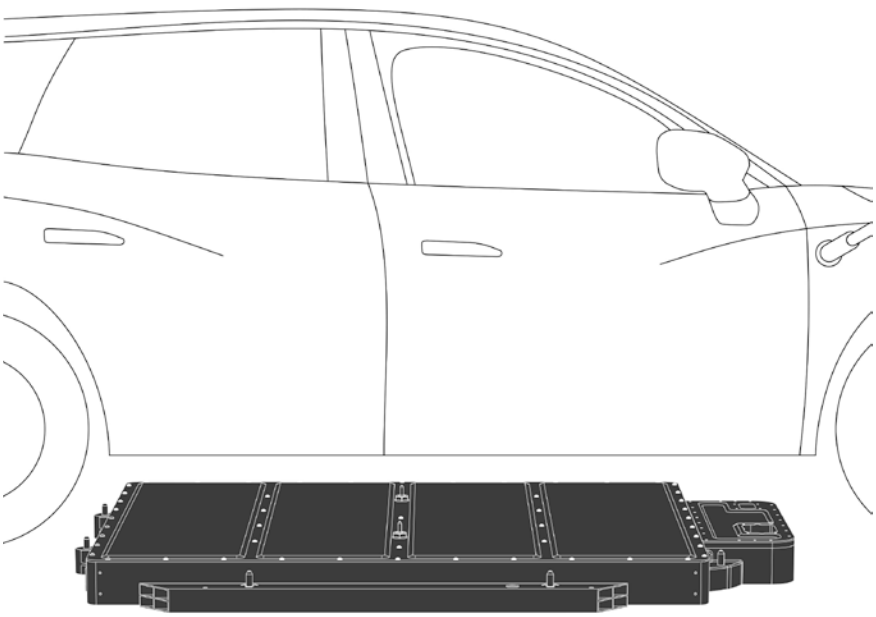

Figure 4 Most battery cases in fully electric vehicles feature a slim design; they serve to house battery modules and make the body more rigid (© SGL Carbon)

particularly important because in the majority of electric cars the battery housing makes an important contribution to the overall stiffness of the body-in-white and is a supporting element of the vehicle structure, Figure 4.

In conjunction with a corresponding integration into the respective vehicle and, for instance, in combination with aluminum hollow chamber profiles, the concept also meets conventional crash test requirements. The battery housing consequently withstands the stress caused by the usual head-on or rear-end collision tests as well as absolutely critical side-impact scenarios.

In addition, the high specific stiffness of the fiber-reinforced components combined with low weight and good damping properties has a positive influence on the Noise, Vibration, Harshness (NVH) behavior of the vehicle.

Thermal Management and Fire Safety

A further advantage is the low thermal conductivity of fiber-reinforced plastics – compared to aluminum, it is about 200 times lower with carbon fiber-reinforced plastics –, which often makes additional battery insulation superfluous and provides better protection against cold and heat than classic metallic housing concepts. The ideal operating temperature of lithium-ion cells commonly used today is between 10 and 40 °C, so that in many situations it is necessary to actively heat or cool batteries. When using composite materials, less energy is necessary for thermal regulation compared with other concepts as a result of the material's insulating effect. This further increases the vehicle's efficiency and lowers the overall power consumption.

In addition to the positive effects on thermal management, low levels of thermal conductivity are also excellent prerequisites for effective fire safety. This factor can be boosted further by additives and consequently, test requirements like for instance UL94-V-0 and UL94-5VB are met with ease. Internal comparative tests on sample panel material were also run within this context: Using a Bunsen burner with a flame temperature of around 800 °C the front of the panel is selectively exposed to the flame at a distance of only a few centimeters while simultaneously measuring the temperature developing on the side of the panel that is not exposed to the flame. This test was carried out on samples of steel, standard thermoset resin composite and sandwich material with supplementary additives for fire protection

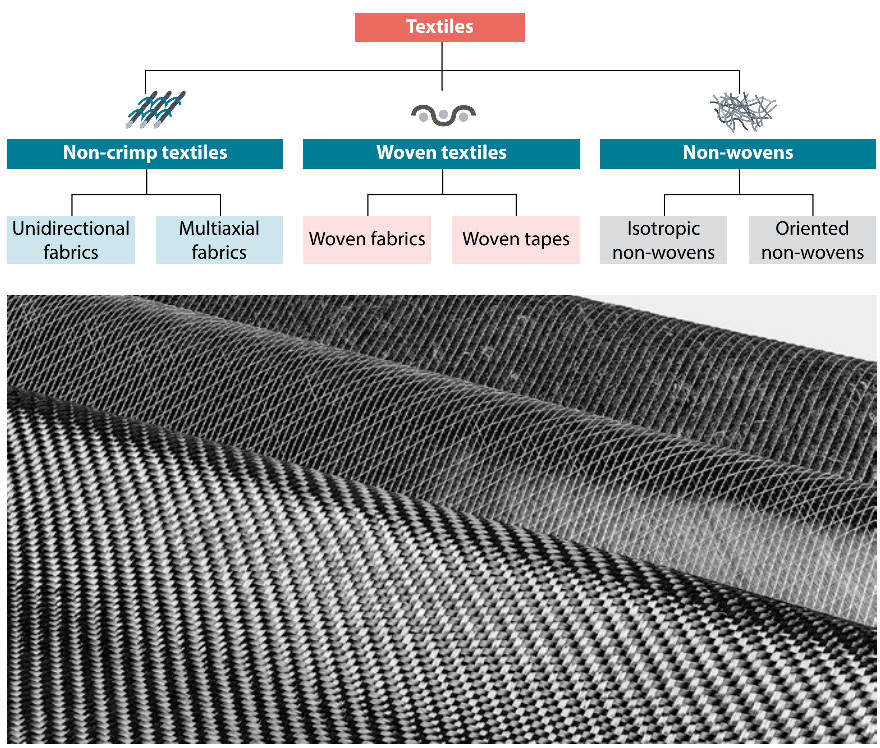

Figure 5 Textile semi-finished products for battery case production (© SGL Carbon)

Benefits of a Composite Battery Housing

- Saves weight
- Frees up design space or boosts safety
- Increased fire safety
- Improved thermal management
- No corrosion
- High Electromagnetic Compatibility (EMC)
- Automated production: series production to meet automotive production qualities and quantities
- Attractive lightweight costs

measures. Aluminum was not taken into account in this test as the material already reaches its melting point at a temperature of 660 °C.

The following temperatures developed on the side that was not exposed to the flame:

- steel: approximately 750 °C after 30 s
- standard thermoset resin epoxy composite: approximately 550 °C after 60 s
- sandwich structure with additives: around 350 °C after 180 s, Figure 6.

These results show that the use of fiber-reinforced plastics for battery cases is also possible with regard to fire protection. The material is self-extinguishing, inhibits the progress of fires and only transmits the extreme heat developing as a result of a burning battery cell to adjacent components and the inside of the vehicle to a restricted extent so that passengers and emergency service staff gain valuable time in the event of an emergency.

Fulfillment of Further Demands

The sandwich design battery housing concept by SGL Carbon also meets other demands. As is typical for plastics, corrosion resistance requirements are well met. Possibly critical areas in this respect can also be mitigated by the use of glass fiber layers and appropriate seals.

Using carbon fiber web or an adequate number of layers as well as considering their fiber volume content are methods to guarantee fundamental electromagnetic shielding for critical areas to adapt to the corresponding demands of the respective application [3].

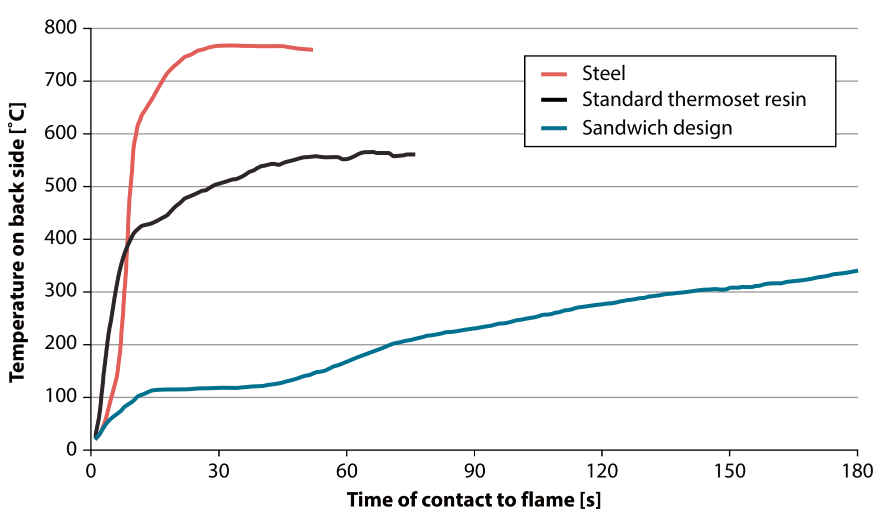

Figure 6 Thermal conductivity in flame test (© SGL Carbon)

Furthermore, fiber compound materials also offer an opportunity for functional integration. This means that, for instance, individual areas within a component can be reinforced, attachment or connecting elements can be installed or sensors can be integrated.

Summary

The right material in the right place – with this guiding principle in mind, and depending on customer concepts or project requirements, a modular concept can be applied to develop and produce a customized solution for the specific use case. Using composite materials in electric vehicles leads to high levels of product and system efficiency. In particular the use of high-performance carbon fibers in battery housing systems helps vehicles develop improved dynamic driving performance and boosts their range.

Chinese automotive manufacturer Nio has already developed prototypes of carbon fiber-reinforced plastic battery enclosures for high-performance electric vehicles in collaboration with SGL Carbon. In addition, SGL Carbon is working with various partners on the further development of various composite battery housings that will be scalable for batteries in electric cars of different sizes and designs in the future.

References

[1] Index Elektromobilität 2018. Roland Berger – Automotive Competence Center & Forschungsgesellschaft Kraftfahrwesen mbH Aachen. Online: https://www.fka.de/images/publikationen/2018/Roland_Berger_E-Mobility-Index_2018_D_final.pdf, access: October 23, 2019

[2] Trautwein, T.; Henn, S.; Rother, K.: Weight Spiral – Adjusting Lever in Vehicle Engineering. In: ATZ worldwide 05/2011, pp. 30-35

[3] Lu, L.; Xing, D. ; Teh, K. S. ; Liu, H. ; Xie, Y. ; Liu, X. ; Tang, Y.: Structural effects in a composite nonwoven fabric on EMI shielding. In: Materials & Design, 120 (2017), pp. 354-362