Plastic Concepts. It is well known that engineering plastics today have vital functions to fulfill, especially in the areas of weight reduction, performance and safety. These are precisely the requirements that are important in the development of vehicles with alternative drive systems, because the main problems with the first battery-powered cars – electric cars – are the short range and high weight of the batteries and higher safety requirements in operation. New sophisticated engineering plastics can make a valuable contribution to these aspects.


Thermoplastic polyurethanes (TPU) are suitable for encapsulating charging cables for electric vehicles (photo: Gettyimages/BASF)

Electric Cars: Lightweight Construction and More

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While lightweight construction is a well-known concept involving the whole vehicle with all its components (**Fig. 1**), drive batteries and their peripheral units are an entirely new part of the car, posing many new challenges, not only with regard to their electrochemical capability but also in terms of the frame, housing, plug, cable and integration in the vehicle. Because of these multiple fields of development and the as yet partially unsolved problems, electric cars will only gradually become established in the market.

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One of the greatest challenges for the all-electric vehicle is the inadequate energy density of the battery as compared with conventional energy sources. This results in a limited range and high weight. Using so-called range extenders, the limited range – at present about 150 km – of wholly battery-powered vehicles can be significantly increased, with the range extender, e. g. a fuel cell, fulfilling the function of a generator for electricity generation.

Today, above all, it is hybrid drive concepts that represent the first step towards electrically powered vehicles. According to analyses by JD Power, the market share of hybrid vehicles is growing at 20 % per year but over the next few years this is still from a very low base.

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Battery: Electrochemistry and Lightweight Construction

To jointly develop new products and solutions for electromobility, BASF is co-operating closely with customers and partners. The electrochemists are at present intensively involved in the HE-Lion cross-industry project to further develop the lithium-ion battery with the aim of increasing energy density and safety →

and reducing battery charging time. In this connection, the company is working on new metal oxides for the cathode of the lithium-ion battery, which will be produced on an industrial scale from 2012 in a new plant in the USA. In addition to this, the electrochemistry and batteries academic research network was established in August 2010. Together with experts from universities and institutes in Germany, Switzerland and Israel, BASF researchers will be pursuing innovative concepts such as lithium-sulfur and lithium-air batteries.

On the other hand, the housing, peripheral functions and connecting elements of the battery must be as lightweight as possible to increase its efficiency. At the present time, the extra weight that a battery adds to a vehicle amounts to between 150 and 450 kg, depending on the model and concept. Through the use of plastics, not only the weight of the battery can be reduced but also that of the total vehicle. The lightweight construction developments of recent decades must therefore be continued in electric vehicles.

Besides electrochemical developments inside the battery, the feasibility of production-line electric and hybrid vehicles will also depend on how the battery and associated units can be safely and efficiently integrated into the vehicle assembly as a whole. For example, plastics coming into direct contact with the battery must be resistant to aggressive electrolytes and their decomposition products in case there is a leak from the battery. And although battery operating temperatures are low, high temperatures, currents and sparks can suddenly occur in the event of a fault. For this reason, strict requirements are specified in relation to fire safety, heat stability and tracking resistance.

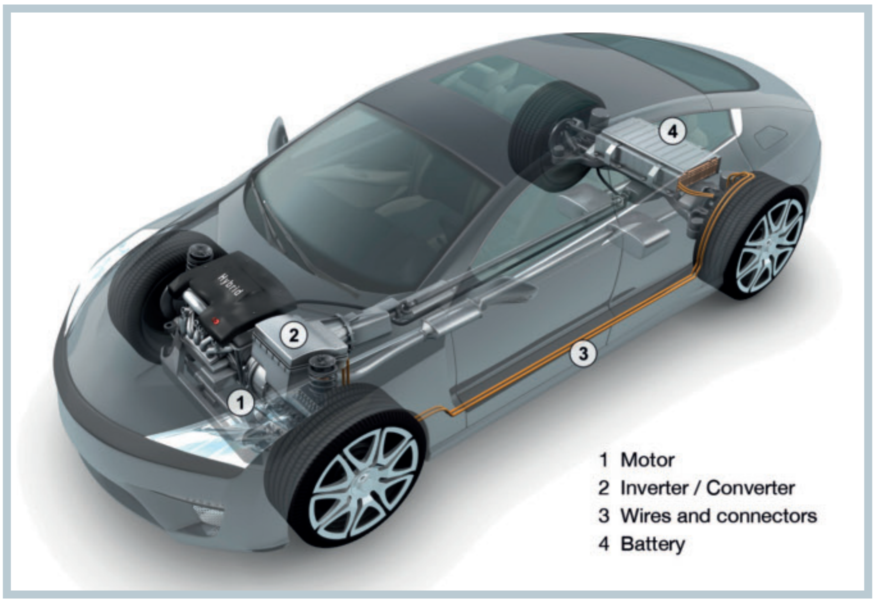

Fig. 1. In both electric and hybrid vehicles, the inner workings will differ significantly from those of conventional cars with combustion engine (photo: BASF)

Weight, Performance, Safety: Units and Requirements

The heart of a battery is the pack of individual battery cells. In addition, the energy storage unit of an electric vehicle consists of components such as the charging system, cooling system, housing/cover, control system and high-voltage connecting system **(Fig. 2)**.

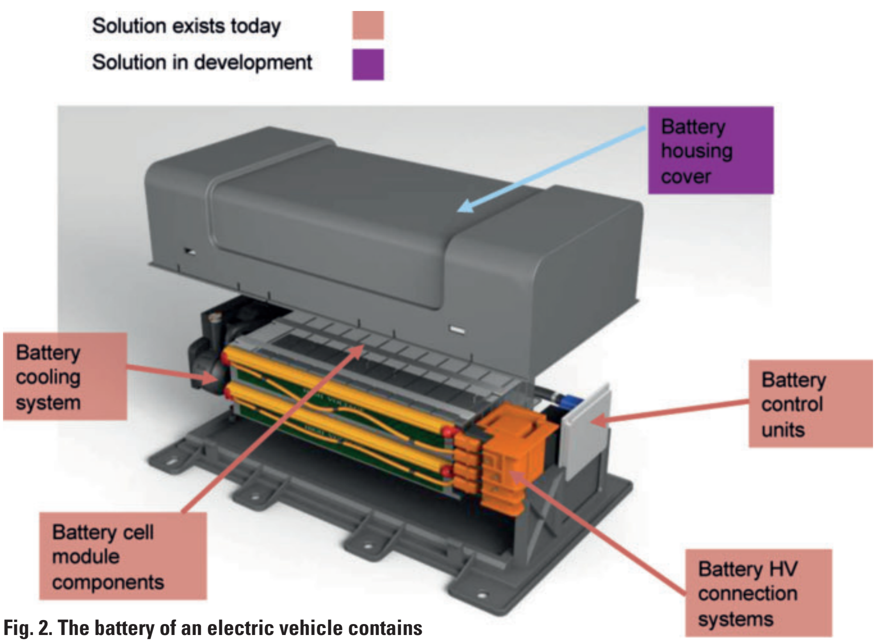

Fig. 2. The battery of an electric vehicle contains units that give rise to new, highly diverse requirements (photo: BASF)

For the battery pack **(Fig. 3)**, it is not only the obvious criteria that are crucial, such as weight, halogen-free flame retardancy to flammability standard UL94-V0 and resistance to high temperature, water and coolant. Great importance is also attached to warpage-free components, good leaktightness and creep resistance. When it comes to the charging system, on the other hand, besides flame resistance, the requirements include impact strength and long-term electrical insulating properties along with tracking resistance and good shielding of cables and plugs. For both charging systems and high-voltage connecting systems, the color stability of the colored plastic used is important, because in the sensitive high-voltage field, color coding of the individual connectors, leads and cables is necessary **(Fig. 4)**.

For the thermally stressed parts of the battery, which must be cooled, coolant resistance and dimensional stability are required but maximum design flexibility is also needed – a well-known intrinsic property of thermoplastics. Crash resistance, i. e. high mechanical capability, approaching that of metal, is a necessary condition for virtually all of these components. Around the battery, in particular, safety requirements can often only be met by crash-optimized plastics and components.

This complex system of property combinations for the different units, which goes way beyond conventional requirements for heat and chemical resistance, flame retardancy and dimensional stability, is summarized in **Table 1.** To enable electric cars to have as smooth a market launch as possible, it is absolutely essen-

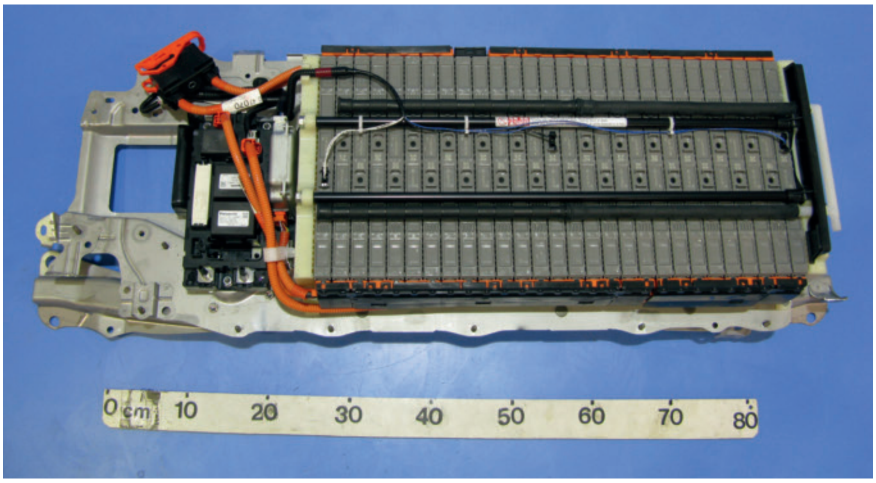

Fig. 3. For the battery pack, hydrolytic stability, coolant resistance, halogen-free flame retardancy and light weight are key criteria (photo: Mavel/Autobench)

tial to keep this complete property spectrum in mind and use it as a guide for component design. The aim of BASF, as a globally active plastics manufacturer, is therefore to provide tailormade plastics for the development of systems suitable for production-line manufacture. In the first place, specialty plastics already in the portfolio can be used for this purpose. But success will not be achieved entirely without developing new special material grades. In any case, plastics producers, OEM and the other partners along the value chain must act decisively and in close collaboration to develop new component concepts, so that electric vehicles can make a broad market entry as quickly as possible.

Suitable Plastics

In **Table 2**, some BASF engineering plastics are matched to the required property profiles. Here, for example, the new Ultradur B4330 HR grades (PBT) stand out as being suitable for applications requiring high resistance to hydrolysis and corrosion. Flame-retardant Ultradur is of particular interest for plugs. The high-temperature plastic Ultrason (PESU) is an excellent choice for units requiring high material performance in many properties at the same time.

Among new product developments from BASF in 2010 are the highly chemical-resistant Ultramid Balance PA610 grades, which can be used to full advantage in sensors and electrical and electronic components around the battery. And for as long as the combustion engine remains in the vehicle, turbocharging temperatures will continue to rise and so new Ultramid Endure, with a continuous service temperature of 220 °C, can make its contribution here.

New Ultramid Structure, a long-glass-fiber-reinforced polyamide with enhanced mechanical capabilities, high dimensional stability and heat resistance, also covers the new requirement profiles. For example, it can be used in crash-relevant components such as battery housings or mountings. For crash-relevant components, in particular, choosing suitable CAE methods like Ultrasim for the material is essential. Precise virtual design →

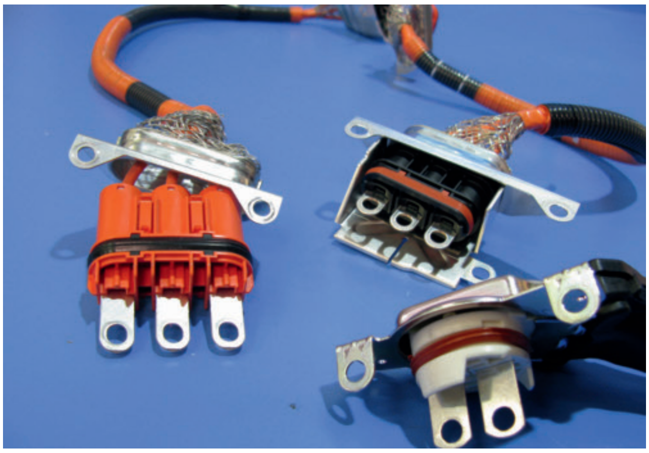

Fig. 4. Metal overmolding that ensures an effective seal, low warpage, good flowability and high flame retardancy are the central requirements for cables and plugs in electric and hybrid vehicles (photo: Mavel/Autobench)

Requirements	Flame retardancy	Chemical resistance	Dimensional stability/ low warpage	Leak-tightness	Heat resistance	Design freedom	Creep resistance	Color stability/ colorability	Crash resistance	Electrical insulating property/ dielectric strength	Electromagnetic shielding
Components											
Battery pack	x	x	x		x	x	x		x	x	
Battery housing	x	x		x	x	x			x	x	x
Charging system	x						x	x	x	x	x
High-voltage connectors	x		x				x	x		x	x
Sealed mechatronic components		x	x	x						x	
Cooling units		x	x			x			x		

Table 1. Material requirements for components used in lithium-ion, high-voltage batteries

Trade name of BASF plastic	Material	Flame retardancy		Dimensional stability	Hydrolytic resistance	Strength/ stiffness/heat resistance
		UL 94	halogen-free			
Ultramid A3X2G5 to G10	PA66, 25–50 % GF	V0	x	–	x	x
Ultramid C3U	PA66/6	V0	x	–	x	x
Ultradur B4406G6	PBT, 30 % GF	V0	–	x	–	x
Ultradur FRee B4450G5	PBT, 25 % GF, suitable for coloration in light shade	V0	x	x	–	x
Ultradur B4330G6 HR	PBT, 30 % GF, hydrolysis-resistant	HB	x	x	x	x
Ultrason E 2010G6	PESU, 30 % GF	V0	x	x	x	x

Table 2. Some typical BASF materials with the basic properties for battery components

at an early stage of the development process is the key to meeting high crash requirements without losing sight of weight and costs.

To seal plug contacts before overmolding with the housing material, Ultramid Seal Fit is suitable. For many plug connectors and plugs, it is not only flame retardancy that is important but also the possibility of color differentiation between cables and plugs, allowing the use of standardized color codes (usually light-colored shades). For this application, among others, BASF introduced the new Ultramid and Ultradur FRee grades in 2010. These not only offer halogen-free flame retardancy but can also be colored in light shades.

Lightweight Construction Remains an Important Theme

Conventional lightweight construction outside the battery zone is the second large area generating product innovations. Intake manifolds, cylinder head covers and oil sumps made from plastics are now state of the art. In the same way, safety components such as lower bumper stiffeners and crash absorbers **(Fig. 5)** as well as highly stressed structural parts, such as engine mountings, stabilizer links and transmission cross beam **(Fig. 6)**, which were previously made of metal, can in future be produced in lightweight construction from plastics. Weight reductions of up to 50 % per component are achievable. And here once again, the use of CAE is indispensable.

In car seats, comfort, safety, weight and cost aspects are all involved, so that here all the advantages of plastics as lightweight construction materials can be exploited at the same time. The new production-line seat in the Opel Insignia OPC as well as the prototype from Faurecia **(Fig. 7)** show that, with seats, it is possible to dispense almost entirely with metal and so save considerable weight without compromising safety. The plastics used are special polyamides characterized by high energy absorption capacity and high elongation at break and may be part of innovative hybrid structures consisting of overmolded continuous-filament composites.

Outlook: Cooperation, Standardization, Political Framework

Everyone is now talking about hybrid and electric vehicles. The concepts are there and the need to switch mobility in the long term to non-fossil energy forms is recognized. But the transition to large-scale production – with few exceptions – is a long time coming, because some developments are taking place in secret. This is understandable given that individual, highly innovative know-how is involved, which developers want to protect. But it

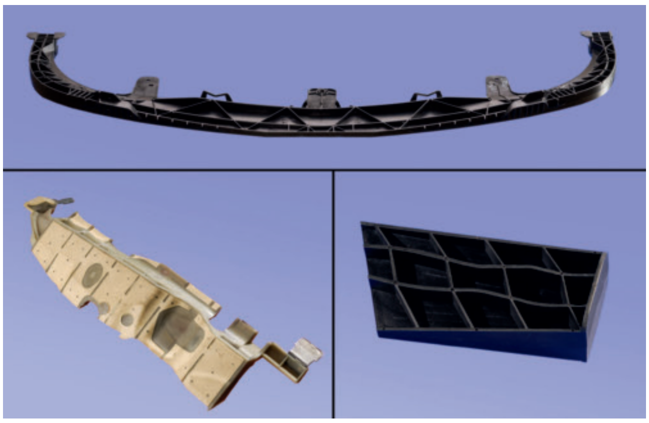

Fig. 5. At Opel, many new models have now been fitted with a lower bumper stiffener for pedestrian protection (top; material: Ultramid B3WG6 CR). Similarly, crash absorbers (right; material: long-fiber-reinforced Ultramid Structure LF) and hybrid components like the structural insert in the Peugeot 308 (left; material: Ultramid A3WG10 CR) are also crash-optimized, lightweight plastic body parts (photo: BASF)

Fig. 6. In the case of the new Opel engine mounting (left, below), the stabilizer link in a Porsche (right) and the transmission cross beam in a BMW (top), highly sophisticated metal parts from the engine and transmission area have been replaced within the last two years by equally effective but considerably lighter-weight components produced from special polyamides (photo: BASF)

Fig. 7. A plastic seat is far lighter than its conventional predecessor. Top: the front seat of the Opel Insignia OPC, without a steel frame but with a seat shell, backrest shell and transverse member, is produced from two PA grades (Ultramid B3ZG8/Ultramid B3G10 SI) and polypropylene foam (EPP: Neopolen). Below: the material used for the seat prototype developed by Faurecia and BASF is the new Ultramid CompoSIT specially optimized for this application

(photo: BASF/Faurecia)

makes it difficult for the broad spectrum of possible cooperation partners to share what they know and have to offer at an early stage.

Since 2009, there have been various initiatives to give impetus to the development of electric vehicles, for example the eNova electromobility strategy group, an alliance of relevant industrial companies from the key automotive, battery, semiconductor and plastics sectors. The German Federal Government is supporting the development of alternative vehicle concepts and creating a suitable political framework through the National Electromobility Platform (NPE), in which BASF is also involved.

International competitive pressure is enormous and existing world market positions are being challenged. German and European industry must act quickly in concert with the worlds of politics, science and society as a whole in order not to lose out on the opportunity to Asia and the United States. Governments in those regions are investing large sums in this sector.

Mandatory standards are also very important for the future of electric vehicles, because only with established standards can new product developments be initiated with adequate confidence.

Only by working closely together can all members of the value chain overcome the new challenges and help ensure that, with the development of electric cars, an important lever is set in motion for the use of non-fossil energy sources in the area of mobility. ■

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! About eNOVA

The eNova strategy group is an alliance of relevant industrial companies from the following key sectors: automotive, batteries, semi-conductor components and materials for lightweight construction. Member companies include Audi, BMW Group, Daimler, Porsche, Bosch, Continental, Hella, ZF, li-Tec, Infineon, Elmos, BASF, Siemens and ThyssenKrupp.

The aim of the alliance is to create and establish a platform to help the German automotive industry become the international leader in the area of electromobility.