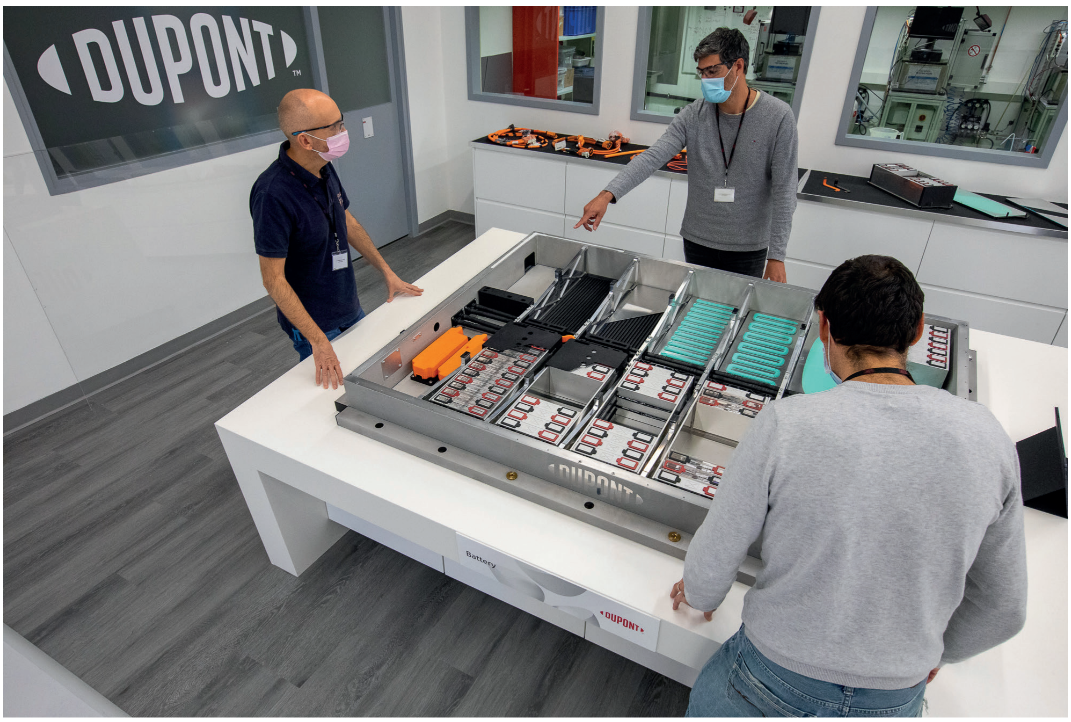
Improving the Performance of Electric Vehicles with the Right Materials

Electric, Environmentally Friendly, Thermoplastic

Electric-vehicle makers looking for fresh impetus are turning to thermoplastics, as these can be used to improve the safety, performance and sustainability of the vehicles. Initial application areas for manufacturers can be found in a multitude of components ranging from battery cases to busbars, cooling lines and seals. Things become very interesting when material suppliers offer support in the form of CAE and injection molding analyses.



Thermoplastics play an important role in the batteries of electric vehicles. They help to keep battery temperatures in the optimal range for a long service life and high performance.

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Few materials offer as much scope as thermoplastics for improving the design of electric vehicles. Engineering thermoplastics are increasingly proving to be the best solution to complex issues arising in electromobility, such as safety, rapid charging, durability and sustainability. Their ability to adhere to metal, for example, facilitates overmolding. They offer low coefficients of thermal expansion (CTE), thermal and electrical conductivity, and EMI shielding.

The role played by these plastics in battery systems is important. A long battery life is crucial for gaining the confidence of consumers and boosting their willingness to buy electric vehicles. The majority of drivers still hesitate to buy them because they consider the charging times to be long. This perception has spurred intensive work on the development of ultra-rapid charging systems. The high-energy-density batteries which these require are very challenging in respect of thermal management, especially in the case of compact, powerful electric motors that generate high torque. For a long service life, the operating and charging temperatures should not stray outside the range 15 to 60 °C. High temperatures are harmful to battery health, shorten its service life, and run the risk of thermal runaway and fire.

Protecting Batteries with Hybrid Plastic-Metal Solution

Battery systems also need to be protected against extreme cold, however. Modern cooling plate systems have a metal-on-metal design that easily leads to excessive heat dissipation and thus to excessive battery cooling. This reduces battery performance and shortens the vehicles' range. Some original equipment manufacturers (OEMs) try to prevent this by separating the base plate and battery housing with a 10 mm-thick layer of expanded polypropylene (EPP) foam, but doing so pushes up costs and complicates manufacturing. »

Fig. 1. To achieve greater protection against battery thermal runaway, manufacturers are increasingly using overmolded busbars. The plastics used must withstand large temperature fluctuations and be resistant to hydrolysis and tracking current. © DuPont

One possible alternative is a hybrid cooling plate. This is a more cost-efficient and reliable way of protecting against extreme temperatures. It consists of an aluminum base plate chemically bonded to a channel plate made of injection-molded thermoplastic, with integrated inlet and outlet valves and fluid channels. The strong chemical bond between the plates represents a major advance here. It is achieved by a specialty polyamide (PA) that was recently launched by DuPont, a plastics supplier, and provides effective protection against coolant leakage. The combination of plastic and metal prevents high heat dissipation and thus excessive battery cooling.

Temperature and Cost Advantages

Extensive simulations at DuPont show that, after 12 hours' exposure to -30 °C under no load, the cell temperature has dropped to -22 °C in a metal-on-metal cooling plate, but to just -5 °C in the hybrid version. This 17 °C improvement leads to better performance and a longer life. Auto-makers are also attracted by the shorter assembly times and lower overall system costs of the hybrid cold plate. And, because it can also be injection molded, functional integration of clips, flow guides, quick-fit connectors and other items is possible.

Thermoplastics can also be used to protect other high-voltage components of rapid-charging systems. They are ideal, e.g., for isolating transformers, charging connectors and plugs, wires and cables, as well as for surface protection. Crastin FR684NH1 OR168, an orange-colored polybutylene terephthalate (PBT), was developed for this purpose by DuPont. Its stable dielectric properties across all the usual temperatures encountered in these applications and its resistance to hydrolysis render it ideal for the production of durable high-voltage components.

The Complexity of Busbars

The use of thermoplastics can also open up improvements in the field of busbars. These seemingly simple components, usually made of aluminum, transmit high voltages between battery components. However, manufacturers have identified the need for enhanced protection against thermal runaway.

The usual test requirement for busbars is to withstand five minutes' exposure to heat at 500 °C. In addition, they must also pass shock tests at alternating temperatures of -40 and 150 °C for 1000 hours. Standard thermoplastics are unable to cope with such extreme temperature fluctuations. DuPont has developed special grades, including flame-resistant variants, which can be used for overmolding aluminum parts for enhancing thermal management and can even accommodate such high loads (**Fig. 1**).

Overmolding of Metal Parts: Avoiding Cracks and Loose Coatings

Even under the most favorable conditions, it is difficult to overmold metal parts with thermoplastics and still achieve stable long-term performance. The different coefficients of thermal expansion lead to differential shrinkage, which can give rise to cracks and even detachment of the coating. The overmolding of busbars specifically for electric vehicle batteries and motors present further challenges. The thermoplastics employed need to be highly resistant to both creep and hydrolysis. Weld line strength, too, is critical.

To overcome these challenges, DuPont relies in particular on computer-aided engineering (CAE). This slashes the number of trial-and-error tests needed and uses models to study the influence exerted by the glass fiber alignment on the stiffness and the CTE.

Other applications areas in CAE are
- changes in material properties over the full operating range,
- accurate calculations of mechanical stresses in parts, and
- detailed evaluations of improvements.

For manufacturers developing a product, it is useful to have a materials supplier that invests in its own injection molding processes. DuPont overmolds busbars in-house, for example, to gain a better understanding of what causes cracks (material properties, part design and injection molding parameters). This saves precious time for customers and also allows DuPont to formulate a number of proven solutions that already meet OEM specifications. Both of these help customers to quickly develop and test new solutions should component requirements change (**Fig. 2**).

Centers of Excellence Develop More Sustainable Cooling Lines

The chief driving force behind the spread and development of electric vehicles is the desire for more sustainable mobility. It is estimated that hybrid and electric vehicles will account for more than two-thirds of the global automotive fleet by 2030. Regulators and consumers expect them to be more environmentally friendly than internal combustion vehicles. To meet their sustainability goals,

Info

Authors

Giacomo Parisi is Marketing Director of DuPont Auto Electrification and has been in charge of the Hybrid and Electric Vehicles Division of DuPont since 2017;
giacomo.parisi@dupont.com
Laurent Lefebvre is Global Automotive Marketing Director of DuPont;
laurent.lefebvre@dupont.com

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vehicle manufacturers are increasingly turning to their materials suppliers to validate new concepts more quickly. With this in mind, DuPont recently opened three international Centers of Excellence (COE) for electric mobility.

Engineers at one COE recently came up with a more sustainable design for cooling pipes. While these are fitted to all automobiles, electric vehicles need more of them – as much as up to 15 m. Traditionally made of metal or rubber, the weight of the pipes affects the range of the vehicles. The rubbers used for this purpose are usually so highly vulcanized that they are thermosets and cannot be recycled. The most common thermoplastic currently used for cooling pipes is PA12, which possesses good functional properties, but has a high global warming potential (GWP), i.e. an unfavorable carbon footprint. A five-layer option based on HDPE is more cost-effective, but has an even worse GWP value. DuPont already has developed a single-layer solution for cooling lines based on PA612 from the company's Zytel product family.

New Multi-Layer Structure Based on PA and TPE Lowers GWP

More recently, the OEM specifications served as a basis for designing a sustainable multi-layer solution based on a PA610 and a thermoplastic elastomer (TPE) called Multiflex. In the course of in-house laboratory trials, DuPont succeeded in extruding multi-layer cooling pipes on an industrial scale. These were fitted with laser-welded connections and subjected to performance testing. The multi-layer solution slashes GWP per vehicle and cost per meter of cooling line. The material combination also allows for a more flexible pipe design, without the need for corrugation. Work is currently underway on a two-layer design that would eliminate the need for an intermediate tie layer.

High-Performance EA Seals

Battery electric vehicles (BEV) also require high-performance seals and gaskets. Elastomers are ideal for this purpose because they have very good compressive properties. Their deformability makes them the right choice for use in hoses and pipes. Many OEMs also favor them for the contribution they make to the reduction of noise and vibration.

Ethylene acrylic (EA) elastomer is a versatile material for sealing oil-filler necks on electric motors. Many common elastomers, such as ethylene propylene diene monomer (EPDM), do not possess the necessary resistance to oil. High-quality elastomers such as fluorocarbon rubbers (FKM) and fluorosilicone rubbers (FVMQ) do meet this requirement, but are much more expensive than EA. In its Vamac series, DuPont has introduced an EA that is specified for electric vehicles.

Ethylene Acrylic for Cooling

Similar considerations apply to the cooling of electric vehicles. EPDMs are perfect for vehicles cooled with mixtures of water and glycol, but oil-based coolants are increasingly being used for electric vehicles, as they allow manufacturers to lubricate and cool motors and transmissions via a single circuit, and thus to save costs. For electric motors and high-performance batteries, it is envisaged that cooling will be done with dielectric oils. Here, too, solutions based on Vamac EA meet OEM requirements, such as VW TL52717.

EAs compounded with non-halogenated flame retardants offer effective thermal regulation and pass the demanding UL-94-V0 protocol. They can also be used for thermal management of the battery, rendering it safer and more efficient.

Weight Savings for Axial Flux Motors

Weight savings may no longer be as important to OEMs as they once were, but they are still highly prized for their contribution to performance improvements, cost reductions and range increases. When the right thermoplastics are substituted for metal parts, their lower density combined with parts consolidation very often leads to weight reductions that facilitate component miniaturization.

Lightweighting remains very appealing to manufacturers of heavy components, such as motors. Electric-vehicle makers are showing growing interest in axial flux motors, as evidenced by the recent Mercedes and Renault acquisitions of companies that develop and manufacture them. Axial flux motors not only offer high power and torque but are also compact. As they can weigh more than 20 kg, weight reduction is essential. For this reason, various makers of these motors opt for parts made from DuPont's Zytel HTN polyphthalamide (PPA), instead of aluminum, to optimize weight and performance. This material is designed to prevent the formation of halide ions that could lead to electrolytic corrosion of metal components, and so contributes to their durability and safety.

More than Just a Materials Supplier

It is no exaggeration to say that the conversion of the global vehicle fleet to electric drives can only be achieved with thermoplastics. To develop successful and safe electric vehicles more rapidly and bring them to market, it is important for OEMs and Tier suppliers to have a partner who offers more than just materials. Aside from having the right polymers, it is also increasingly important to collaborate all along the value chain. ■

Fig. 2. Plastics converters reap huge benefits when materials suppliers have production-scale processing machines and all the necessary testing equipment. DuPont, for example, regularly performs its own injection molding analyses so as to identify sources of defects. © DuPont