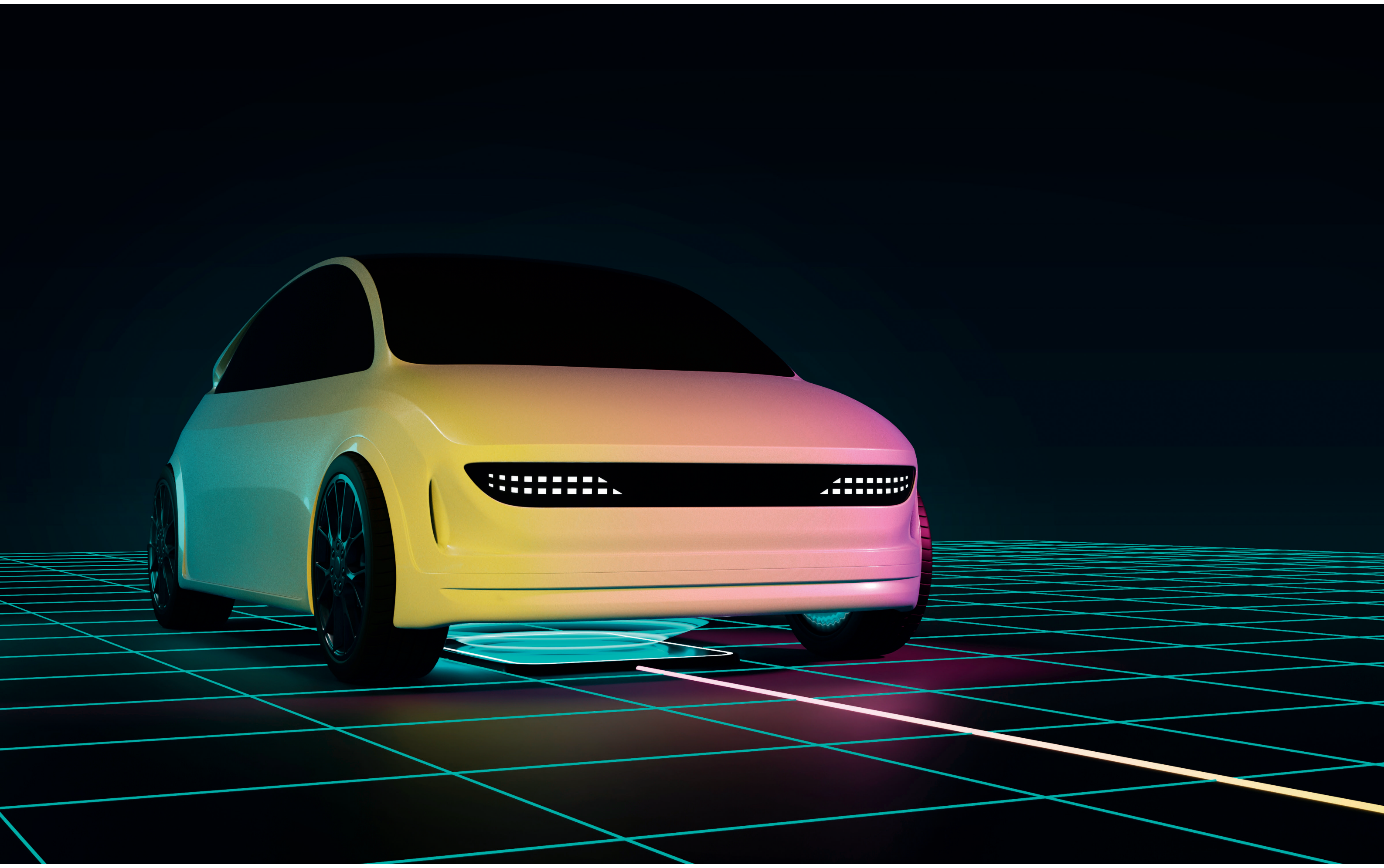

Wireless charging could increase the range, and therefore the acceptance of electromobility. © Adobe Stock; Lee

Flame Retardant Polyamide for Inductive Charging Systems

No Cable thanks to Suitable Compounds

Electric vehicles can be charged not only at charging stations, but also wirelessly. Here, the energy exchange takes place between an induction coil positioned in the ground and a receiver coil mounted in the e-car. For the system to function reliably, the coils must be protected from damage. Glass fiber-reinforced and flame-retardant PA66 is particularly suitable for this, as the example of a current wireless charging system shows.

As electric mobility gains in popularity, electric vehicle charging stations are popping up in many places. Electromagnetic induction charging systems for electric cars are a viable alternative to conventional cable systems. Wireless charging systems can help solve the problem of so-called "range anxiety" by allowing vehicles to recharge simply by parking them over charging plates. In the case of taxis, for instance, the vehicles could be charged while waiting for passengers. In addition, these systems will eventually allow for dynamic wireless charging while driving. This technology is enjoying considerable success, especially in Europe and China. Globally, according to different market research companies an average annual growth rate (CAGR) of more than 30 % for the technology is expected for the next five years.

Wireless charging is based on the principle of electromagnetic induction. When electric current passes through a coil, it creates a magnetic field. This, in turn, generates an electric current in a coil at a certain distance. This way electricity can be transferred from one device to another without physical contact (**Fig. 1**). These applications require proximity between the transmitting and receiving devices (a near field). This article refers to a static charging system with the vehicle being charged while standing still in a car park or garage, for example, where the charging system is installed.

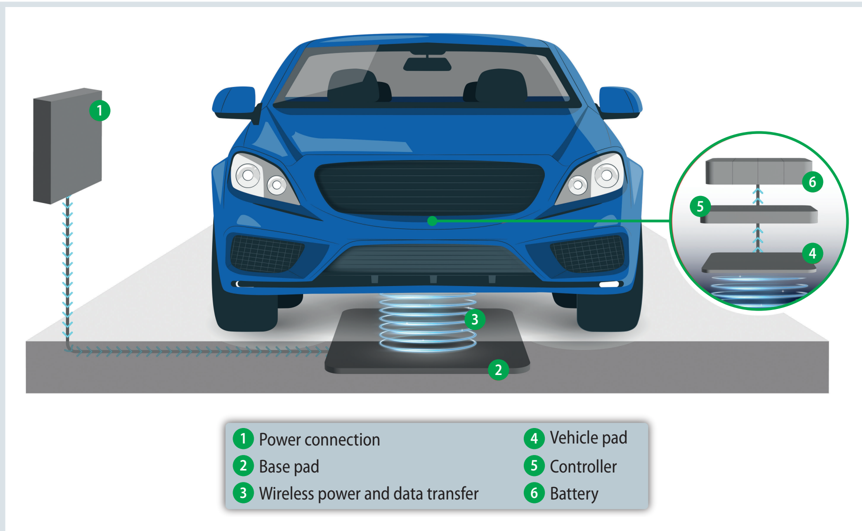

Fig. 1. Functional principle of the wireless charging system for electric vehicles: among other things, the system can save scarce space, for example in city centers. Source: RadiciGroup; graphic: © Hanser

The transmitter is installed underground and the receiver is located on the underside of the vehicle. For efficient charging, the transmitter and receiver must be aligned. The characteristics relating to the performance and safety of the system are described in detail in the SAE J2954 standard (updated in 2020) and in the GB/T 38775 standard for the Chinese market.

Metal Alternatives

In the design of some components in the emitting and receiving systems, the producer Shanghai Wanji Electronic Technology considered the use of engineering polymers, as they could offer significant advantages compared to metals.

For this application, the most important characteristics that favor the engineering polymer option are:

- The ability to produce complex shapes.
- Weight reduction and better "handling" of the components, as in the assembly phase.
- High productivity with lower environmental impact, thanks to less energy expenditure during the processing phase.

To achieve the objectives of rigidity and mechanical resistance, an optimized design was carried out considering the specific characteristics of the chosen material (**Fig. 2** shows the buildup of the modules).

Material Selection Criteria

The focus was on two components in particular: the covers of the receiving system (transmitter pad) and the receiver pad. As for the transmitter pad, the technical specifications required the pass- »

Info

Text

Erico Spini is global marketing manager at the business unit high performance polymers of the RadiciGroup; erico.spini@radicigroup.com
David Qi is business development manager for Southeast Asia at the business unit high performance polymers of the RadiciGroup; david.qi@radicigroup.com

Company Profile

Shanghai Wanji Electronic Technology is a global Tier 1 supplier producing products and solutions for the automotive industry. Among them are wireless charging systems for electric vehicles. The company's inductive charging technology enables electric vehicles to be charged wirelessly.

Contact

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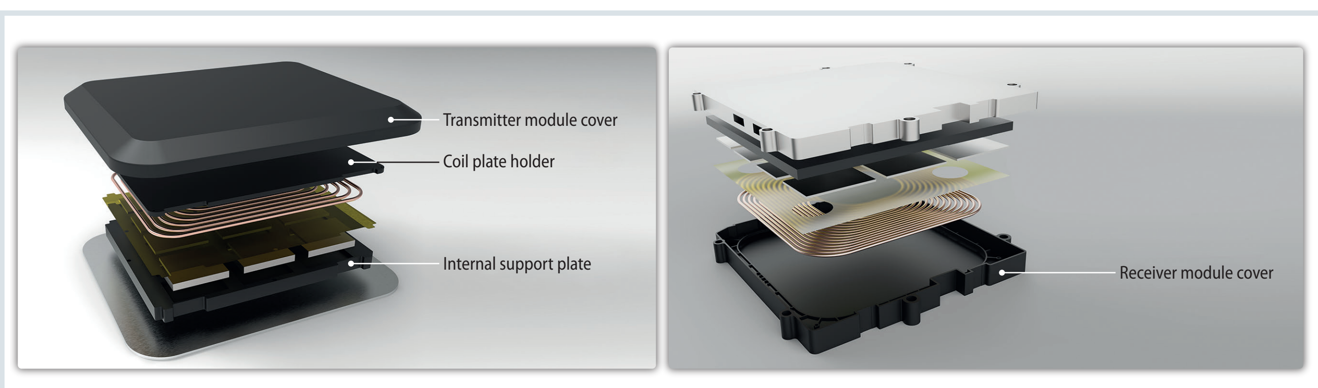

Fig. 2. Components of the transmitting (left) and receiving (right) modules of the inductive charging system: the covers must protect the electronics from damage and have flame-retardant properties. © RadiciGroup

Tensile modulus [MPa]		Tensile stress at break [MPa]		Elongation at break [%]		
23 °C (dry)	23 °C (conditioned)	23 °C (dry)	23 °C (conditioned)	23 °C (dry)	23 °C (conditioned)	
10,200	8800	160	120	2.8	3	
Flexural modulus [MPa]		**Flexural strength [MPa]**		**Charpy notched impact strength [KJ/m²]**		
23 °C (dry)	23 °C (conditioned)	23 °C (dry)	23 °C (conditioned)	-40 °C	23 °C (dry)	23 °C (conditioned)
10,000	6500	240	160	6	10	12

Table 1. Mechanical properties of the PA66 Radiflam A RV300HF. Source: RadiciGroup

Table 2. Thermal properties of the PA66 Radiflam A RV300HF. Source: RadiciGroup

Property	Value
Coefficient of thermal expansion	$0.2\text{-}0.7 \cdot 10^{-4}$/K
Thermal conductivity	0.25 W/m·K
Specific heat capacity	1700 J/kg·K

Dielectric constant (IEC 60250)				Dissipation factor (IEC 60250)			
At 23 °C, 100 Hz		At 23 °C, 1 MHz		At 23 °C, 100 Hz		At 23 °C, 1 MHz	
Dry	Conditioned	Dry	Conditioned	Dry	Conditioned	Dry	Conditioned
4	7.3	3.4	3.9	0.02	0.11	0.018	0.056

Table 3. Electrical properties of the PA66 Radiflam A RV300HF. Source: RadiciGroup

ing of severe mechanical tests and the use of materials with good chemical resistance, flame-retardant properties and excellent processability for injection molding with very low warpage.

The technical specifications in detail are:

- Passing a test simulating the passage of a vehicle (tire rolling test).
- Cone drop and ball drop test (IEC61439–5:2014) with a cone weight of 5 kg, a drop height of 0.4 m and an impact energy of 20 J.
- Chemical resistance: testing the effect that accidental contact with organic solvents, such as oils, may have on product performance and material integrity.
- Hydrolysis resistance: in order to prevent accidents related to the installation on the ground, the material should be soaked in water for two days without any problems arising.
- Flame retardancy: UL-94 V0 classification requested for part wall thickness.
- Low coefficient of linear thermal expansion (CLTE).
- Maintaining the integrity of the system's electro-magnetic signal.
- UV resistance in case of direct light exposure.
- Working temperature: in ordinary conditions, operating temperatures ranging from –40 °C to +55 °C are foreseen. In some cases, for example, in the presence of misalignment during charging, the temperature can rise up to 105 °C. Considering the need for a safety margin, structural analyses were carried out using a temperature of 125 °C.

As regards the receiver pad, some specific requirements were defined:

- Impact resistance, in case of accidental contact with objects (typically stones) that may hit the component while driving.
- Expected temperature range between –40 °C and 150 °C.
- Finally, excellent processability and flatness.

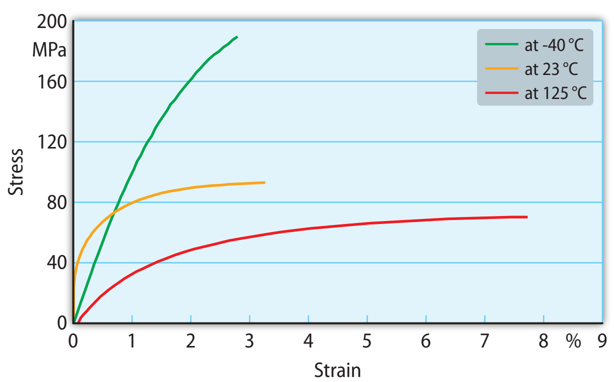

Fig. 3. Stress-strain diagram of the PA66 Radiflam A RV300HF at different temperatures: the material achieves the necessary values for use in the charging modules. Source: RadiciGroup; graphic: © Hanser

Flowability of the Material Is Decisive

Taking into account the required properties listed in the above section, various alternative materials were analyzed, including semi-crystalline polymers and amorphous polymers. The choice fell on semi-crystalline polyamide polymers for several reasons, among which: greater mechanical strength even for long-term properties such as creep, greater fluidity (very important in injection molding given the large size of the objects considered), superior chemical resistance and good UV resistance.

Two PA66 products were successfully tested, one classified UL 94-V0 at 0.8 mm and the other customized to guarantee excellent FR properties (UL 94-V0) at 1.6 mm. Tests are also underway to evaluate PA6-FR, loaded with glass-fiber and free of halogen and red phosphorus, as an additional potential choice for these applications.

The technical data shown in this article refer to the PA66 Radiflam A RV300HF produced and marketed by RadiciGroup High Performance Polymers. It is 30 % glass-fiber filled, flame re-

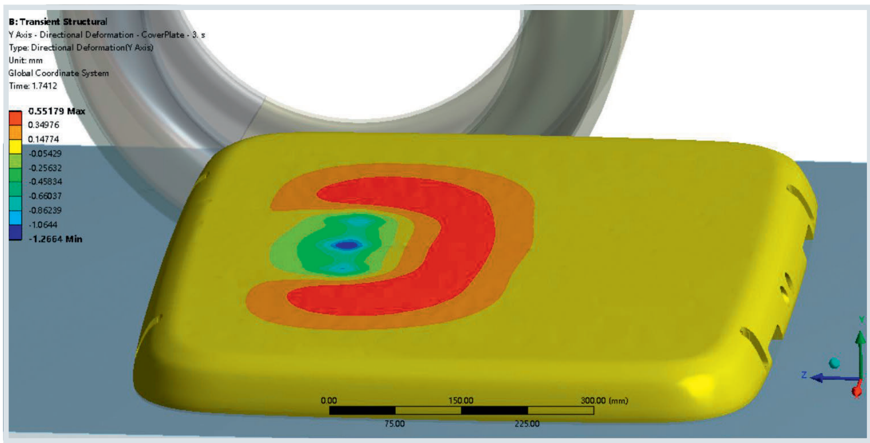

Fig. 4. Deformation of the charging pad in the y-direction during the traverse test: to achieve the required performance, the gating system and the injection molding parameters were optimized. © RadiciGroup

tardant, classified UL 94-V0 at 0.8 mm. This material, which is already used in various applications in the electrical sector, offers a good compromise among the various technical requirements, including good mechanical properties (**Fig. 3, Tables 1–3**).

The material is also certified UL-94 V0 at 0.75 mm (Relative Thermal Index, RTI) values: RTI Elec (electrical) 140 °C, RTI Imp (mechanical impact) 115 °C, and RTI Str (mechanical strength) 130 °C). That is why it is even suitable for use in the presence of high temperatures.

Support for Simulation and Design

Radici also supported Shanghai Wanji Electronic Technology in the component design for the transmitter pad and the receiver pad. For the transmitter pad, given the considerable size of the component, a mold filling analysis was carried out and the injection points were chosen after comparing trials with different configurations. Proper mold filling, compactness and gating lay-out optimization were essential parameters to obtain the expected mechanical characteristics and to minimize part warpage.

Another very important test involved the simulation of the passage of a vehicle over the pad (tire rolling test). **Figure 4** shows pad displacement in the y direction after optimization of the part design, injection gating system and molding parameters. As for the pad receiver, a key aspect was the integrity of the component after the impact of a stone weighing 22 g at a speed of 140 km/h. An accurate material characterization, including high speed impact properties, has been provided from Radici in order to perform a reliable simulation.

Conclusion

Components made of Radiflam A RV300HF passed all the required tests and are now mass-produced for this application (**Fig. 5**). The construction and design of these components required a detailed multi-functional analysis which was necessary to take into account the multiple, sometimes conflicting, technical specifications. Other decisive aspects in achieving the positive result were the characterization of the material, which involved extensive use of the most sophisticated calculation programs, and the optimization of the geometry already at the virtual model level. ■

Fig. 5. The transmitter module and receiver module are now in mass production. © Shanghai Wanji Electronic Technology

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