



How advanced fluoromaterials are transforming EV wiring and cable systems

By Sarah Blosch, Ph.D., Product and Development Engineer | AGC Chemicals Americas, Inc. | January 6, 2026



Electric vehicles (EVs) are reshaping mobility through cleaner energy and higher efficiency. However, achieving the potential of EV technology depends on continuous innovation in materials, especially those used in high-voltage wire and cable systems.

EV wire and cable must transmit high levels of electricity safely and efficiently while withstanding extreme thermal and chemical conditions. As voltage levels rise from 400 to 800 volts and beyond, insulation materials must maintain electrical integrity within increasingly compact and demanding system designs.

Fluororesins, fluoroelastomers, and fluoropolymer compounds are emerging as key components of this next generation of EVs. These fluoromaterials provide lightweight, high-strength insulation and coating solutions that outperform traditional materials.

The challenge: High voltage, limited space

EV manufacturers are working to increase motor output density and optimize space utilization. In particular, motor stators and wiring harnesses must accommodate more conductive material within tighter spaces to handle higher voltages.

Within EV motor stators, traditional round wire designs achieve only 78 to 88% occupancy. In contrast, flat wire geometries can reach up to 96% occupancy. Improving packing efficiency supports higher power density and more efficient motor operation.

However, maximizing voltage and density also exposes weaknesses in conventional insulation materials. Many materials traditionally used in this application suffer when accommodating the flat wire geometries. Common issues are pinhole defects, thinning at the flat wire corners, poor adhesion to the conductor, and limited flexibility.

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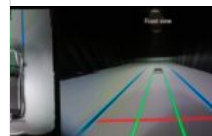
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Limitations of conventional insulation materials in EV motor stators

Conventional wire insulation materials used in an EV motor present performance tradeoffs:

- **Polyimide (PI) and polyamide-imide (PAI):** These materials, when used as the enamel layer, can be too thick to achieve efficient space utilization, and their coatings are prone to pinhole defects that compromise reliability at high voltage.
- **Polyetheretherketone (PEEK) and polyphenylene sulfide (PPS):** When used as the polymer layer in extrusion processes, they suffer from poor adhesion and cracking when subjected to bending, vibration, or prolonged heat exposure.

These deficiencies can cause insulation breakdown and partial discharge, leading to reduced voltage endurance and reliability in EV motor and cable systems.

Fluoropolymer resins and compounds: Enabling high-density flat magnet wire systems

To further improve performance, new fluoropolymer compounds have been developed for flat magnet wire insulation to maximize the packing efficiency in a limited space and allow for higher voltage levels.

Fluoropolymers provide exceptional electrical insulation and maintain stability under a wide range of thermal and chemical conditions. Unlike PI, PAI, or PEEK coatings, fluoropolymer compounds maintain excellent adhesion to both copper (Cu) and polyimide (PI) substrates, preventing cracking and delamination.

These fluoropolymer compounds, including adhesive ETFE and PFA-based compounds, show superior adhesion and flexibility in dispersion/powder coatings and extrusion processes:

- **Dispersion coatings:** Dispersible fluoropolymer additives can be added to typical PI and PAI varnishes to provide stronger bonding to copper, better electrical insulation, and greater resistance to pinholes compared to PI enamel alone.
- **Extrusion coatings:** ETFE and PFA-based compounds adhere to copper and aluminum while maintaining flexibility and preventing cracking during bending.

These materials maintain the insulation performance of neat ETFE and PFA while offering superior manufacturability and electrical resistance. One method for determining electrical performance is partial discharge inception voltage (PDIV), which is a commonly used for determining a material's propensity for eventual electrical breakdown.

Figure 1 provides comparison between ETFE, PFA, PEEK, and ETFE- and PFA-based compounds based on their allowable PDIV at increasing temperatures.



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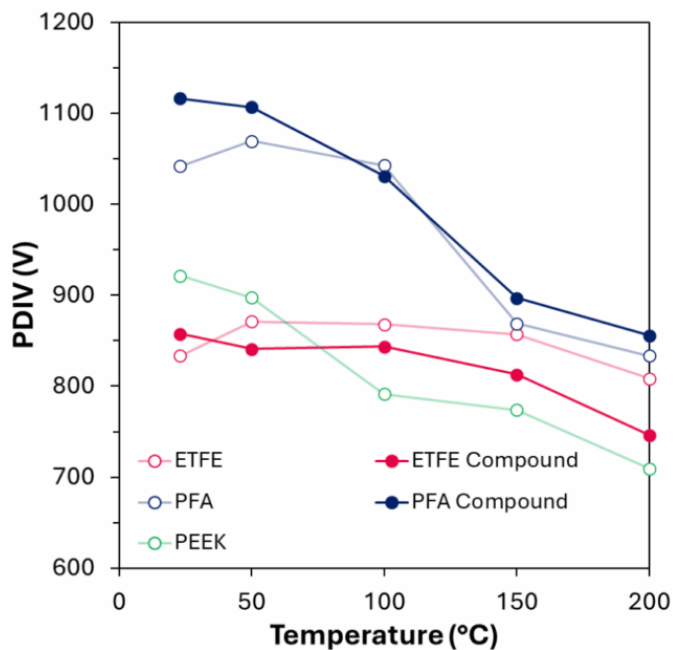


Figure 1. Partial discharge inception voltage (PDIV) as a function of temperature for ETFE, PFA, PEEK, and ETFE and PFA-based compounds.

Fluoroelastomers: Lightweight, durable & electrically robust

Within EV applications outside of motor stators, fluoroelastomers represent a significant leap forward in cable insulation technology. They combine excellent thermal and chemical resistance with reduced weight and enhanced flexibility.

Table 1 compares the physical, electrical, thermal, and chemical properties of FEPM fluoroelastomers compared with other fluorinated elastomers, silicone rubber, and cross-linked polyethylene used in EV wire and cable insulation.

	TFE/P	Other Fluoroelastomers	Silicone Rubber	Crosslink Polyethylene
	FEPM	FKM	Q as compound	XL-PE as compound
Specific Gravity	1.55	1.8	1.2	1.3
Dielectric Breakdown (kV/mm)	23	20	25	35
Volume Resistivity ($\Omega \cdot \text{cm}$)	10^{16}	10^{13}	10^{16}	10^{16}
Dielectric Constant (1 kHz)	2.8	17	3–4	2.3
Flexibility	Excellent	Excellent	Excellent	Applicable
Flame Resistance	Excellent	Excellent	Good	Applicable (with fillers)
Heat Resistance (max. operating temp)	200 °C	200 °C	180 °C	150 °C
Oil Resistance	Excellent	Excellent	Not Recommended	Good
Hot Water & Steam Resistance	Excellent	Applicable	Applicable	Good

Excellent

Good

Applicable

Not Recommended

Table 1. Comparison of key physical, electrical, thermal, and chemical properties of FEPM fluoroelastomers with other fluorinated elastomers, silicone rubber, and cross-linked polyethylene compounds. The table highlights differences in dielectric performance, heat resistance, flexibility, and environmental durability relevant to high-voltage EV wire and cable applications.



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Compared to cross-linked polyethylene (XLPE) insulated wire, fluoroelastomer insulation enables smaller cable diameters and lighter assemblies while maintaining high dielectric strength.

FEPM fluoroelastomers are copolymers formulated for demanding automotive conditions. They provide several key advantages over conventional FKM-type fluoroelastomers and XLPE insulation:

- Superior chemical resistance
- Outstanding heat and steam resistance, unaffected by continuous 200 °C exposure
- Unmatched electrical resistivity for high-voltage insulation
- Excellent vibration resistance
- Reduced cable weight and enhanced flexibility for compact routing

FEPM fluoroelastomers are well suited for hybrid and electric powertrains requiring long-term durability and reduced mass in high-temperature environments.

Table 2 compares cable weight reduction properties of materials used in EV wire insulation.

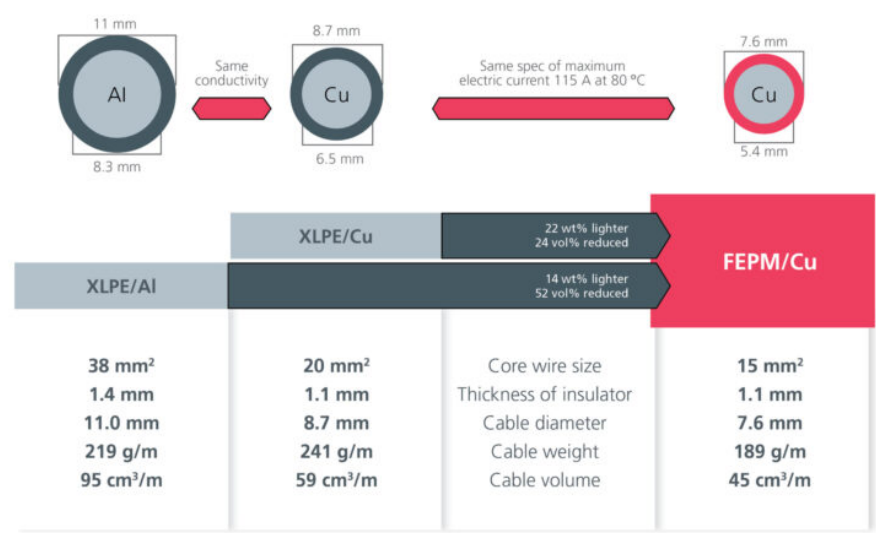


Table 2. Comparison of cable cross-section, diameter, weight, and volume for aluminum and copper conductors using XLPE and FEPM insulation at the same maximum current rating (115 A at 80° C). The figure illustrates how FEPM insulation enables reduced cable size, weight, and volume while maintaining equivalent electrical performance.

Conclusion

As electric vehicles advance toward higher voltages and increased power density, innovation in material science is becoming critical. Fluororesins, fluoroelastomers, and fluoropolymer compounds are setting new performance benchmarks for EV wiring and cable systems.

The combination of low weight, high electrical performance, and strong chemical resistance supports the development of safer and more efficient high-voltage architectures, forming the foundation of next-generation electric mobility.

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