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TECHNICAL PAPER

HIGH VOLTAGE E-MOTOR PEEK MAGNET WIRE INSULATION & EPOXY SECONDARY INSULATION

Introducing Epic Resins' New ProPreg E240 Secondary Insulation for E-Motors

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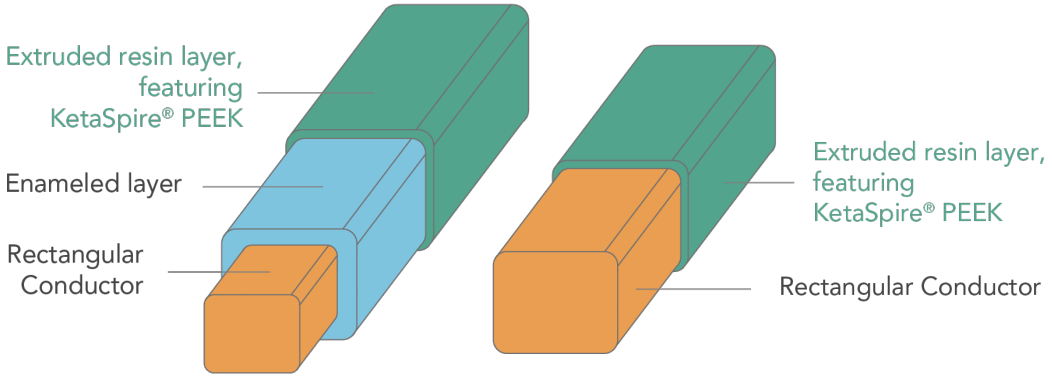
Epic Resins & Solvay Specialty Polymers

In an effort to increase battery electric vehicle range and decrease the battery charging time, automotive OEMs and tier suppliers have begun to adopt high voltage systems ranging from 800 to 1200 Volts. Solvay has been commercially successful with their KetaSpire® PEEK in magnet wire insulation for over five years and has seen greater adoption as OEMs have increased the system voltage from 400 to 800 Volts or higher.

The key drivers for using PEEK-insulated magnet wire are the material's ability to withstand high voltage environments (partial discharge inception voltage values ~1600-1700 V @ 150 microns typical) with great reliability due to the reduced level of defects (vs. pure enamel solutions). Utilizing these new extrusion-based PEEK materials with hairpin technology, OEMs have been able to increase their copper slot fill by over 10%. This is achieved by optimizing the thickness using the various constructions as seen below in Figure 1.

▼ Figure 1: Multi-layer & Mono-layer PEEK magnet wire constructions



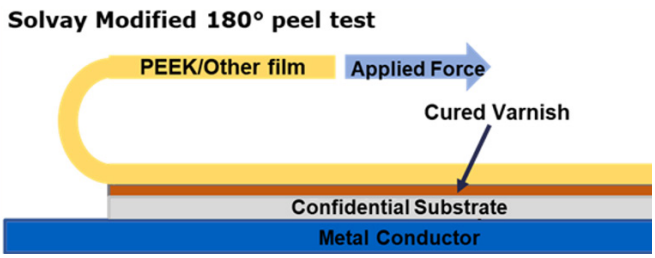
A remaining challenge for e-Motor designers has been to identify secondary insulations designed to have excellent adhesion with these newer PEEK magnet wire and PEEK slot liner insulation materials.

Epic Resins developed ProPreg E240, a single component epoxy secondary insulation. It was designed to increase the adhesion to PEEK while also being compatible with other common insulation materials such as polyamideimide (PAI). ProPreg E240 has achieved the highest industry adhesion in a variety of applications including: wire to wire, wire to aramid paper, aramid-paper to steel, and wire to Ajedium™ PEEK slot liners. All of this has led to an epoxy that can penetrate and wick between tight spacing conductors utilizing low energy polymers in high copper slot fill applications. Currently 5000 hour thermal testing is underway to attain a temperature rating targeting 240 °C, to match the thermal rating of the PEEK itself.

One of the first steps in designing ProPreg E240 was to match the thermal mechanical properties with PEEK such as KetaSpire® KT-880 and Ajedium™ Slot liner XZY. By matching the thermal transitional properties, Epic was able to minimize differences in coefficient of thermal expansion mismatch that contributed to failures of brittle polyester resins used in the market today. Another key achievement was to ensure that the epoxy could be used in existing trickle processing equipment with minimal changes. The material also has the potential to improve cure time and shorten process time.

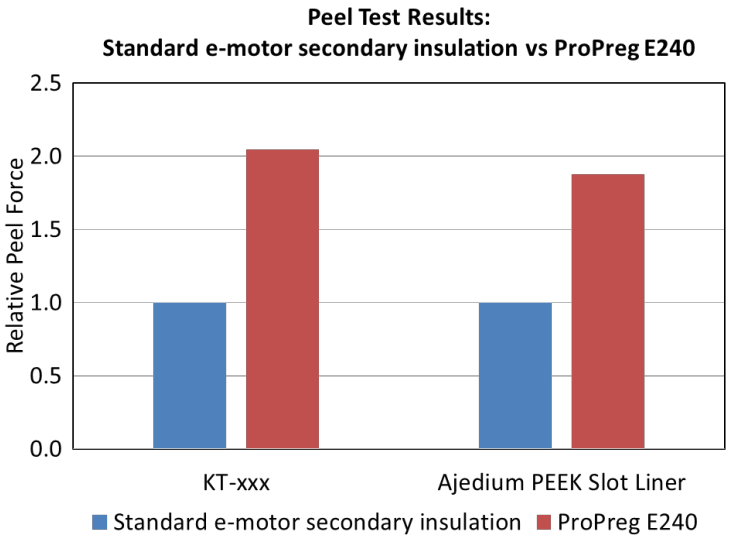
Once the ProPreg E240 was formulated, Epic Resins worked together with Solvay to generate adhesion and compatibility data. To determine the adhesion strength between the ProPreg E240 epoxy and KetaSpire® PEEK, Solvay developed a 180-degree peel test method. Figure 2 below shows this in detail, where the metal conductor represents the copper magnet wire from which a proprietary substrate is applied followed by the cured epoxy then finally KetaSpire® PEEK film.

▼ Figure 2: Solvay Adhesion Test Method for PEEK films & epoxy resins



The peel test benchmarked a standard e-motor polyester secondary insulation alongside Epic Resins' ProPreg E240 epoxy. Two different tests were performed. One using a KetaSpire® PEEK magnet wire grade and the other on Solvay's Ajedium™ PEEK slot liners. In both cases, a significant increase in adhesion was observed. Figure 3 below shows the relative peel force between KetaSpire® PEEK and ProgPreg was two times higher than the adhesion between PEEK and the standard e-motor polyester. Similarly, adhesion between the epoxy and slot liner showed great improvement.

▼ Figure 3: PEEK & Epoxy Adhesion Results



In addition to adhesion between the PEEK and ProgPreg E240 secondary insulation compatibility data is being developed on the adhesion of PEEK coated wire and ProgPreg E240 after 2000 hours exposure to automatic transmission fluid (ATF) at 150˚C, both submerged and in vapor. ATF is commonly used as a fluid to cool the e-motor windings. As shown below in Figure 4, after 2000 hours of ATF exposure the PEEK and ProgPreg E240 maintained their adhesion strength. In all the cases so far, separation took place between polymer coatings and copper wire while the bond between the epoxy and polymer remained intact. The results indicate that the ProPreg E240 bond strength was greater than the polymer coat tensile strength and the polymer copper bond strength.

▼ Figure 4: PEEK and ProgPreg E240 adhesion strength after 2000 hr ATF exposure at 150˚C

Test Method: IEC 60133 provided by Eltek International Laboratories

	Pull Force, max. (N)	
Hours / ATF	**Mean**	**Std. Dev.**
500 hrs / Immersed	413	18
500 hrs / Vapor Exposed	442	30
1000 hrs / Immersed	351	24
1000 hrs / Vapor Exposed	384	17
1500 hrs / Immersed	398	31
1500 hrs / Vapor Exposed	439	31
2000 hrs / Immersed	415	47
2000 hrs / Vapor Exposed	444	10

Adapting to meet the changing needs of electric vehicle OEMs is where innovation and collaboration becomes a game changer. This case study from Epic Resins and Solvay's partnership highlights how this is made a reality. Epic Resins' new ProPreg E240 secondary insulation and Solvay KetaSpire® PEEK magnet wire grade and Ajedium™ PEEK slot liners show significant improvement in adhesion over the standard e-motor secondary insulations used today. The completed test results show that after 2000 hours of testing and ATF exposure at 150˚C, superior adhesion to Solvay KetaSpire® PEEK magnet wire grade was achieved. This allows motor manufacturers a confident choice for secondary insulation when designing with Solvay KetaSpire® PEEK magnet wire grade.

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