Navy develops high impact, high integrity polymer for air, sea, and domestic applications

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NRL's proprietary phthalonitrile resins, developed by the Chemistry Division, were measured to have dielectric permittivity and loss tangent characteristics that make them ideally suited for use in radomes. The E-2C Hawkeye aircraft is the U.S. Navy's all-weather, carrier-based tactical battle management airborne early warning, command and control aircraft. The spiral painted on the rotating radome of this Hawkeye is the hallmark of the "Screwtops" of Carrier Airborne Early Warning Squadron 123. Credit: DoD/U.S. Navy

U.S. Naval Research Laboratory Chemistry Division scientists have developed a second generation, cost-effective polyetheretherketone (PEEK)-like phthalonitrile-resin demonstrating superior high temperature and flammability properties for use in numerous marine, aerospace and domestic applications.

The resin can be used to make composite components by established industrial methods such as resin transfer molding (RTM), resin infusion molding (RIM), filament winding, prepreg consolidation, and potentially by automated composite manufacturing techniques such as automated tape laying and automated fiber placement.

Phthalonitrile-based polymers constitute a class of high temperature thermosets that remain strong at temperatures up to 500 degrees Celsius (C), and that are easily processed into shaped fiber reinforced composite components by low-cost non-autoclave techniques. They are also nearly fireproof.

"The NRL-developed phthalonitrile-based polymeric composites exhibit superior flammability, low water absorption and high temperature properties that do not exist in the current marketplace," said, Teddy Keller, Ph.D., head, NRL Advanced Materials Section. "The fully cured phthalonitrile does not exhibit a glass transition temperature and can be used for structural applications in oxidizing and thermally hostile environments."

The many attractive features of the phthalonitriles make these resins excellent candidates for numerous marine, aerospace, and domestic settings. The fire performance of phthalonitrile-carbon and phthalonitrile-glass composites is superior to that of any other thermoset-based composite currently in use for aerospace, ship and submarine applications and opens up many more applications than could be realized for other resin systems.

"Furthermore, a low melt viscosity and a larger processing window exhibited exclusively by the new second generation phthalonitrile technology are useful for fabrication of thick composite sections where the melt has to impregnate into thick fiber preforms," Keller said.

NRL's PEEK-like phthalonitrile resins were also measured to have excellent dielectric permittivity and loss tangent characteristics for potential high temperature radomes and other applications requiring radiofrequency transparency. The ability to cure to a shaped solid or composite below 250 C and the superior physical properties relative to other high temperature polymers such as polyimides enhance the importance of the phthalonitrile system.

Due to their low water absorption, processing temperatures comparable to common epoxy resins, and superior thermo-oxidative stability at temperatures in excess of 375 C, the second-generation PEEK-like phthalonitrile-based polymers can revolutionize the use of composites in applications ranging from lightweight automobiles to fire-resistant building materials.

A notable aspect of this second generation technology is the ability to melt the resin and to control its initial cure to the shaped solid below 200 C. This permits NRL's phthalonitriles to be processed in the same way as ordinary commercial resins, using standard industrial composite manufacturing methods—a vital technological advantage to the aerospace, ship, and other domestic industries.

The oligomeric PEEK-like phthalonitrile is a liquid above 50 C and polymerizes to a thermoset occurring above 150 C, giving it an ample processing temperature window. The rate of polymerization is controlled as a function of temperature and the amount of curing additive, and the fully cured void-free phthalonitrile polymer does not exhibit a glass transition temperature (does not melt or soften) when post-cured to temperatures greater than 375 C. NRL's phthalonitrile resins/prepolymers or resin prepregs have an indefinite shelf life without the need for refrigeration.

Current interest in the PEEK-like phthalonitrile includes aircraft, ship, automotive, and wind blade structural applications; battery casings; fire-resistant textiles and structural composites; robotic and autonomous firefighting; and ammunition casings and storage containers.

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