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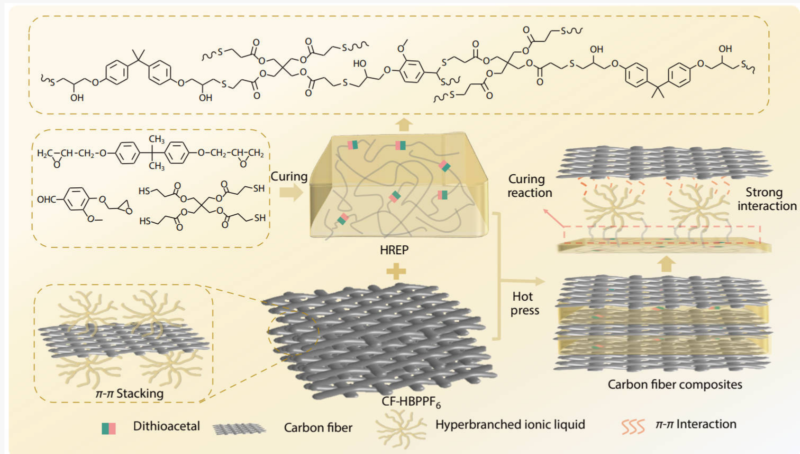
Innovative carbon fiber composites: strength meets sustainability

GA, UNITED STATES, February 13, 2025 /EINPresswire.com/ -- A team of scientists has successfully developed a high-performance, recyclable carbon fiber reinforced epoxy composite (CFRP) that combines exceptional mechanical strength with sustainability. This new material addresses a long-standing challenge in modern industries: the difficulty of recycling traditional CFRPs due to their rigid cross-linked structures. By maintaining both durability and recyclability, the newly developed CFRPs offer a practical solution for sectors such as aerospace, automotive, and construction, where composite materials are widely used. This advancement could help reduce industrial waste and support the transition to a circular economy.



Schematic illustration of the preparation of HREP, HREP20/CF-HBPPF6 and the mechanism of interface strengthening of HREP20/CFHBPPF6.

Carbon fiber reinforced epoxy composites (CFRPs) have been widely adopted for their strength, lightweight properties, and resistance to heat and corrosion. However, their three-dimensional cross-linked structure, while ensuring durability, also makes them difficult to recycle. As a result, most CFRPs end up in landfills at the end of their lifecycle, creating both environmental and economic concerns. With increasing attention on sustainability, researchers have been working toward CFRPs that not only retain high performance but can also be efficiently recycled and reused.

A research team from South-Central Minzu University, Wuhan Textile University, and Hubei University in China has developed a recyclable epoxy resin based on a dynamic dithioacetal covalent adaptive network. Their study (DOI: 10.1007/s10118-024-3191-8), published in the August 2024 issue of the Chinese Journal of Polymer Science, introduces an alternative approach to sustainable composite materials without compromising strength or durability. The newly developed high-strength recyclable epoxy resin (HREP) incorporates a dynamic dithioacetal covalent adaptive network, allowing the material to undergo structural rearrangement at elevated temperatures. The resin is composed of diglycidyl ether bisphenol A (DGEBA), pentaerythritol tetra(3-mercapto-propionate) (PETMP), and vanillin epoxy resin (VEPR). This unique chemical design enables excellent reprocessing capability and strong resistance to solvents.

To further enhance composite performance, the research team modified carbon fibers using hyperbranched ionic liquids (HBP-AMIM$^+$PF$_6^-$). These specially treated fibers (CF-HBPPF$_6$) significantly improved interfacial bonding with the epoxy resin, leading to impressive mechanical properties. The optimized CFRP (HREP20/CF-HBPPF$_6$) exhibited a tensile strength of 1016.1 MPa, an interfacial shear strength (IFSS) of 70.8 MPa, and an interlaminar shear strength (ILSS) of 76.0 MPa. Moreover, the researchers demonstrated that the CFRPs could be fully degraded in DMSO at 140°C within 24 hours, with the recovered carbon fibers retaining their original mechanical properties, making them suitable for reuse.

Prof. Jun-Heng Zhang, one of the leading researchers on the project, emphasized the significance of this development: "Our study provides a solution to the recyclability challenge of CFRPs while also improving their mechanical performance. This dual advantage is essential for the sustainable development of high-performance materials."

The ability to recycle and reprocess CFRPs without compromising strength or durability opens new possibilities for industries reliant on composite materials. By reducing waste and improving resource efficiency, this approach aligns with ongoing efforts to minimize environmental impact while maintaining high-performance applications. As sustainability continues to shape the direction of material science, innovations like this contribute to the development of more responsible and practical solutions for the future.

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