SUMMARY FOR PUBLIC RELEASE

Full Application Title: Highly Recyclable Thermosets for Lightweight Composites
Control Number: 2245-1683
Name of Applicant: University of Akron
Project Director/Principal Investigators: Junpeng Wang
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The project will show thermoset composites can be produced from >50 wt. % bio-based carbon sources (CO_2 and biomass) with chemical and thermal recyclability. We aim to develop novel highly recyclable thermoset materials, termed vitrimers, that combine mechanical advantages of thermosets with the recyclability of thermoplastics. The enabling technology will replace the permanent cross-links in conventional thermosets with dynamic bonds that can be thermally triggered to undergo bond exchange to change the network topology. At service temperature, vitrimers are rigid like conventional thermoset polymers. At temperatures above the vitrimer transition temperature T_v, vitrimers flow and behave as viscous liquid thermoplastic polymers. We will target carbon fiber reinforced plastics (CFRP) as a good candidate application for developing the vitrimer system. The enabling technology of vitrimers will improve the recovery of the energy intensive carbon fibers and the thermoset material and provide end-of-life value for the composites. Our technology will also create an avenue for bio-based carbon sources to be used in high-volume production for products with long service life and performance comparable to that of conventional fossil fuel-based materials.

The recyclable thermoset material (vitrimer) will can undergo β-hydroxyl ester-based transesterification that is not catalyzed by external catalysts, but rather enabled by the proximity of the hydroxyl to the ester group. This approach has been extensively employed in the catalysis of organic reactions, but less explored in materials development. Viscosity and vitrimeric transition temperature (the temperature above which reformability is gained) are important molecular design parameters for new vitrimer chemistry. Widespread use of a successful vitrimer system in CFRP will support the U.S. lightweighting strategy in industrial applications such as aviation and vehicles, which is a critical source of end-user energy savings. It is estimated that manufacture of the next generation of recyclable CFRP will have huge market growth opportunities covering aviation (commercial & military), transport sectors, wind turbines, and compressed gas storage tanks for natural gas vehicles and fuel cell vehicles, among others. We will make CFRP prototype parts for testing to evaluate mechanical performance and durability for comparison with the baseline technology – non-recyclable carbon fiber/epoxy thermoset systems. The product will be optimized by tuning polymer chemistry for product processing towards higher requirements and improved sustainability for intended uses.

This highly collaborative project brings together expertise from top U.S. academics (the University of Akron, Akron, OH), industry (Raytheon Technologies Corporation, Farmington, CT) and DOE's national laboratory (Pacific Northwest National Laboratory, Richland, WA). The University of Akron has long-standing research strengths in polymer synthesis and polymer physics, in addition to extensive characterization and manufacturing facilities such as the National Polymer Invention Center and Materials Development Center. Raytheon Technologies Corporation, as a global aerospace conglomerate, conducts edge-cutting interdisciplinary research in state-of-the-art laboratories for materials characterization with key staff leading the disciplines of probabilistic risk assessment, life cycle assessment, techno-economic analysis, and reliability engineering. Pacific Northwest National Laboratory (PNNL) offers competitive research resources and capabilities in polymer chemistry, polymer processing and composite testing by leveraging PNNL's Environmental Molecular Sciences Laboratory, Polymer Analysis Laboratories and Applied Processing and Engineering Facility. The project outcome will have both economic and environmental benefits in alignment with the interests of U.S. DOE's Bioenergy Technologies Office and Advanced Manufacturing Office.