Regenerative Energy-Efficient Manufacturing of Thermoset Polymeric Materials (REMAT)
EFRC Director: Nancy Sottos
Lead Institution: University of Illinois Urbana-Champaign
Class: 2022 – 2026

Mission Statement: *To advance the science of thermochemical reaction-diffusion processes in additive and morphogenic manufacturing and accelerate a transformative, circular strategy for thermoset polymeric and composite materials with programmed end-of-life.*

The Center for Regenerative Energy-Efficient Manufacturing of Thermoset Polymeric Materials (REMAT), a DOE BES Energy Frontier Research Center (EFRC) at the University of Illinois at Urbana-Champaign (UIUC) (lead) and its partner institutions: Sandia National Laboratories (SNL), Massachusetts Institute of Technology (MIT), Harvard University, Stanford University, and the University of Utah addresses fundamental scientific challenges required to overcome barriers for energy efficient manufacturing of thermoset polymers and composites with realistic end-of-life strategies. Thermoset polymers and composites possess the necessary chemical and mechanical properties critical for achieving lightweight, durable structures in the energy, aerospace, and transportation industries, but the vast energy input required for initial manufacture (Gigajoules), long cure times to develop desired structural properties (hrs), and lack of end-of-life strategies render these materials unsustainable. The development of thermoset materials manufactured with a far lower energetic and environmental footprint is critically important to a carbon-neutral economy. The Center seeks to discover thermoset resin formulations that enable (i) closed-loop controlled, energy-efficient additive manufacturing, (ii) moving beyond additive to nascent morphogenic manufacturing strategies, (iii) programmed end-of-life upcycling, and (iv) precise understanding of the chemistry and physics that control properties, performance, and multifunctionality for (re)use in structural materials.

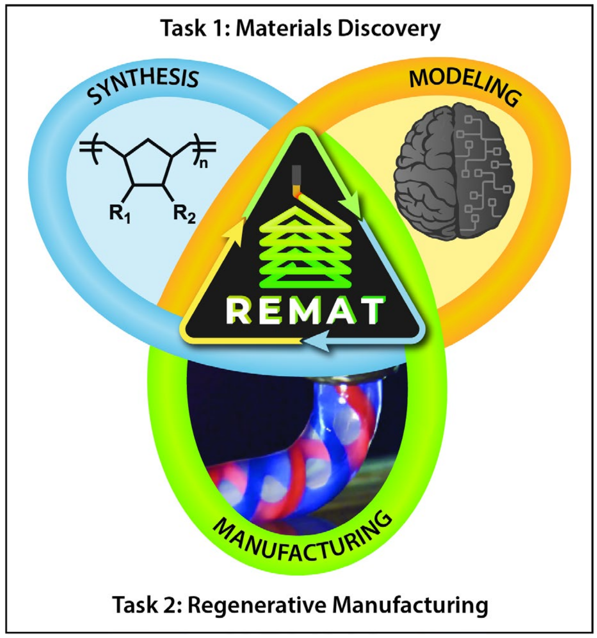

Fig. 1: Organization of the EFRC for Regenerative Energy-Efficient Manufacturing of Thermoset Polymeric Materials (REMAT).

The REMAT EFRC is addressing these multi-faceted scientific challenges through two highly collaborative and integrated Research Tasks (Fig. 1) that bring together synthesis, modeling, high throughput (HTP) experimentation, characterization, and machine learning (ML) to develop transformative manufacturing platforms that harnesses energy-efficient frontal polymerization for sustainable manufacture of thermoset structures. REMAT's four-year goals and outcomes are distilled into two Level 1 (L1) Milestones:

- ***L1.1*** Develop materials, methods, and models to achieve regenerative thermoset polymers with generation-invariant thermomechanical properties over three lifecycles.
- ***L1.2*** Develop thermo- and photochemical reaction-diffusion processes for regenerative thermoset polymers with fabrication rates, energy consumption, and materials performance that equal or exceed state-of-the-art additive manufacturing methods.

These goals - the Level 1 Milestones - direct our bottom-up approach to achieving breakthroughs in regenerative thermoset materials. To achieve these goals, REMAT has put in place a highly integrated Task structure around the core competencies of synthesis, modeling, characterization, and processing (Fig. 2). **Task 1, *Materials Discovery for Regenerative Lifecycles (Materials Discovery)***, focuses on highly integrated synthesis, characterization, and modeling to develop machine learning (ML) models that enable predictable formulation of resins with a programmed end of life strategy, the ability to cure efficiently via frontal polymerization and deconstruct and regenerate over multiple cycles, while maintaining properties and performance. **Task 2, *Circular Additive and Morphogenic Manufacturing (Regenerative Manufacturing)***, focuses on sustainable and precise manufacturing of the regenerative resin formulations discovered in Task 1 and control of resulting architecture and material properties. The research flow and subtasks are summarized in Fig. 2. REMAT research progress to date has been greatly accelerated through several synergistic interactions that include activities to promote inclusive and equitable research (PIER). Cross-cutting research interactions have also been enabled by early implementation of cloud accessible, ML ready data management via Clowder, and the development of a unique HTP polymer formulation and characterization facility.

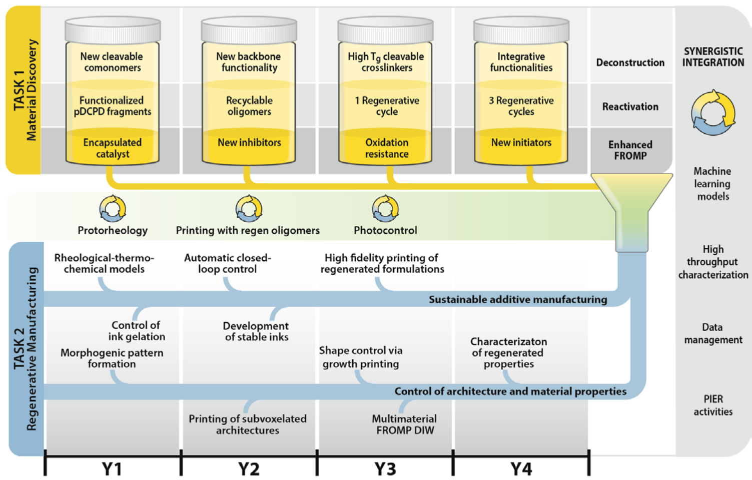

Fig. 2: REMAT roadmap for current and future research.

REMAT research will enhance the US economic competitiveness in industries ranging from lightweight electric vehicles to wind turbine blades. The integration of end-of-life strategies with materials discovery will enable multiple generations of reuse while reducing our dependence on petrochemical resources. The REMAT EFRC will also train the next generation of graduate students and postdoctoral researchers needed to carry out transformational research at the interface between sustainable materials chemistry and energy-efficient manufacturing in an innovative, inclusive, and interdisciplinary team-oriented environment.

Regenerative Energy-Efficient Manufacturing of Thermoset Polymeric Materials (REMAT)	
University of Illinois Urbana-Champaign	Nancy Sottos (Director), Jeffrey Moore (Deputy Director), Jeff Baur, Randy Ewoldt, Philippe Geubelle, Sameh Tawfick
Harvard University	Jennifer Lewis
Massachusetts Institute of Technology	Rafael Gomez-Bombarelli, Jeremiah Johnson
Sandia National Laboratories	Leah Appelhans, Adam Cook, Sam Leguizamon
Stanford University	Yan Xia
University of Utah	Matthew Sigman

Contact: Nancy Sottos, Director, n-sottos@illinois.edu
217-333-1041, https://remat.illinois.edu/