Center for Plastics Innovation (CPI)
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Lead Institution: University of Delaware
Class: 2020 – 2024

Mission Statement*: To: (1) Develop catalytic and functionalization approaches and fundamental tools applicable to the upcycling, upgrading, and recycling of real polymer plastics waste (PPW) with a strategic focus on enabling mixed-stream transformations in varied material forms (i.e., solutions, melts, and surfaces); (2) Educate the future U.S. workforce for relevant industries; and (3) Enable PPW upcycling innovations via technology transfer, licensing, and start-up formation.*

The ***Center for Plastics Innovation (CPI)*** was launched in August 2020. Led by the University of Delaware (UD), *CPI* brings together researchers from UD; the University of Chicago; the University of Massachusetts, Amherst; the University of Pennsylvania; and Oak Ridge National Laboratory (ORNL) to address the global challenge of transforming polymer plastics waste (PPW) into valuable products. Specific to our approach is the integration of multiscale considerations of evolving materials complexity during upcycling, predictive strategies to accelerate discovery, and less energy-intensive processing considerations. *CPI* is organized into three synergistic thrust areas (**Figure 1**). *Thrust 1: PPW Deconstruction* focuses on converting PPW into fuels, lubricants, precision macromolecules, and monomers *via* tunable heterogeneous catalysis with a focus on selectivity, scalable, and lower-energy approaches. *Thrust 2: PPW Upcycling* develops functionalization and upcycling strategies using plasma-assisted catalysis and surface treatment, photo-redox catalysis, enzymatic and microbial routes to generate high-value monomers and polymers. *Thrust 3: Cross-cutting Tools* enables *CPI's* recycling/upcycling/upgrading advances *via* artificial intelligence (AI) strategies, computational modeling activities, additive manufacturing approaches, and macromolecular characterization.

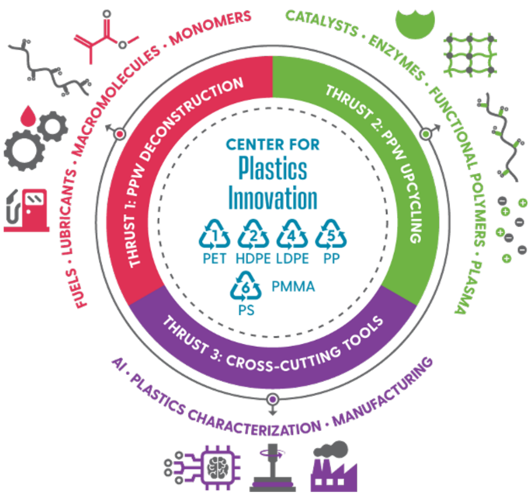

Figure 1. *CPI research thrusts.*

Background and Knowledge Gaps: Plastics play an indispensable role in every aspect of modern life. Globally, the manufacture of plastic products was ~311 million tons in 2014, and that number is estimated to double by 2034. Increased plastics production also exacerbates the projected environmental impacts (*e.g.,* landfill usage, aquatic pollution, degradation byproducts), as in the U.S. less than 10% of polymer plastics waste (PPW) is actually collected for recycling. The increasing demands for lightweight and resilient materials, along with the significant environmental threats from plastics waste and pollution, particularly from single-use plastics, require a new paradigm in end-of-life plastics management. We will leverage our expertise in catalysis (synthetic, biological), macromolecular science and engineering, additive manufacturing, data science and AI, systems engineering, and computation to address three distinct thrusts: (1) tunable heterogeneous catalysts and microwave (MW) energy for the conversion of PPW into fuels, lubricants, precision macromolecules, and monomers, (2) functionalization and upcycling using *a)* plasma-assisted, catalysis and surface treatment, *b)* photoredox-catalyzed decarboxylation, and *c)* enzymatic routes to generate high-value monomers and polymers, and (3) new cross-cutting tools driven by AI, macromolecular characterization, and additive manufacturing to enable scientific advances. *CPI* will overcome distinct challenges related to PPW upcycling, including *PPW diversity and heterogeneity*;

optimization of macromolecule/catalyst interactions in melt; *selectivity control*; and *development of correlations between plastics manufacturing, chemical recycling, and macromolecular physical properties.*

Impact: We will transform the current high-energy/low-value landscape of polymer recycling towards highly efficient polymer upcycling strategies. Mechanistic insights in low-temperature catalysis for polymer deconstruction in the melt, plasma-assisted functionalization approaches, photoredox strategies for chemical transformation, and enzyme engineering to valorize PPW will provide immense fundamental knowledge. Cross-cutting experimental, computational modeling, and data science tools and processes will impart long-lasting impact on science and technology. Furthermore, our systems-level approach will tackle real-life PPW to define new frontiers in research and educational training with direct impact on polymer upcycling, chemistry, manufacturing, catalysis, and data science.

Overarching Goals and Objectives: The complexity of converting PPW presents numerous opportunities for scientific discovery and technological innovation in catalysis, polymers, materials, modeling, and AI science. Our comprehensive program has the **overarching goal** to overcome the fundamental knowledge barriers described above toward advancing PPW chemical recycling and upcycling strategies. The **goals** are to: (1) Develop design principles for catalysts that deconstruct mixed PPW at low temperatures, avoid coking, are resilient to impurities, and produce tunable distributions of products; (2) Design hierarchical, multiscale catalysts to enable fast heat and mass transfer and methods to disperse catalysts in plastics to increase energy efficiency during deconstruction processes; (3) Develop multiscale methods and experimental methods to predict and measure physical property data for polymer processing; (4) Reveal and predict interactions and chemical transformations of macromolecules in the melt, on catalyst surfaces, and in confined spaces; (5) Develop functionalization methods of PPW-deconstruction products through plasma-catalyst interactions, photoredox-catalyzed reactions, and biocatalysis to enable upcycling and recycling; (6) Synthesize and characterize reprocessable, high-performance network polymers; (7) Develop enabling tools, such as AI, multiscale models, 3D-printing and additive manufacturing capability, and an integrated molecular-systems analysis framework to enable catalyst discovery, efficient chemical recycling, and plastics upcycling; (8) Educate the U.S. workforce; and (9) Enable technology transfer.

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