Center for Plastics Innovation (CPI)
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Lead Institution: University of Delaware
Class: 2020 – 2028

Mission Statement*: To develop energy-efficient, selective, and tolerant chemo- and bio-catalytic and synthetic pathways to valorize diverse plastics waste streams and dramatically increase circularity.*

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 Florida; the University of North Carolina at Chapel Hill; the University of Pennsylvania; and Oak Ridge National Laboratory (ORNL) to shift the landscape of the plastics life cycle from linear (*i.e.,* "make, use, and dispose") to circular (*i.e.,* "reuse, redesign, and repair") *via* a new frontier of valorization and synthetic approaches. We build upon our previously developed foundational, mechanistic knowledge and leverage a cross-cutting core to advance sustainability in the plastics lifecycle. Our research is organized into three distinct, yet synergistic thrusts (**Figure 1**), each targeting a key challenge in plastics circularity. *Thrust 1 targets deconstruction strategies for existing, commodity, non-polyolefin waste* [*e.g.*, poly(methyl methacrylate) (PMMA) and polyamides (PAs)] by developing novel, efficient, robust, and scalable valorization approaches. *Thrust 2* facilitates the *deconstruction of complex, heterogeneous, plastics waste streams* including consumer products that contain additives or multiple layers of diverse polymers. *Thrust 3* moves beyond existing waste streams to design new*, inherently circular polymers* benchmarked against commodity plastics.

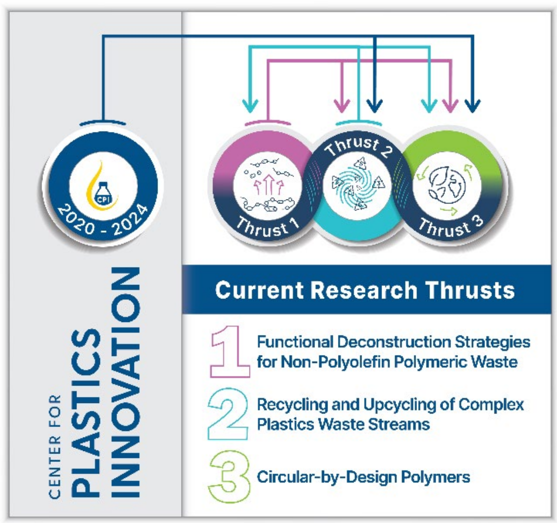

Figure 1. *CPI research thrusts.*

Background and Knowledge Gaps: Plastics manufacturing is a cornerstone of innovation across multiple sectors, including infrastructure, food and medical packaging, aerospace, and energy conversion and storage, enabled by the durability, versatility, low thermal conductivity, high strength-to-weight ratio, and barrier properties of polymers. These technological advances are driving increased demand for plastics production (~1,230 Mt/year by 2060 - OECD *Global Plastics Outlook*; 2022), while introducing higher levels of complexity (*e.g.,* additives, fillers, blends, multilayers) within the manufacturing cycle. There is a pressing need for *fundamental approaches that address the entire plastics life cycle*, from polymers designed for circularity to end-of-life treatment (*e.g.,* deconstruction/reprocessing) of complex polymer waste streams, to mitigate environmental and health impacts worldwide. It is imperative that scientific breakthroughs are realized both downstream (*i.e.,* complex, multicomponent, plastics waste streams after use) and upstream (*i.e.,* pre-manufacture, readily-recyclable, polymeric feedstocks). To unlock these innovations, scientific challenges related to bond energetics, low thermal conductivity, high viscosity, and multicomponent formulations must be recognized and addressed in an interdisciplinary framework. *CPI* is uniquely positioned to deliver *disruptive*, *transformative*, and *robust* solutions to realize sustainable plastics manufacturing, integrating a systems-based and data-driven approach with molecular-level understanding; selective and efficient catalytic pathways; advanced synthetic methodologies; high-throughput screening; and comprehensive, multiscale experimental and computational characterization.

Impact: Transforming the landscape of plastics manufacturing towards circularity requires fundamental strategies that address the complexity of plastics waste streams, emphasize product performance, and enable polymer redesign. We explore deconstruction routes that synergize chemical and enzymatic approaches to produce building blocks from heteroatomic polymers; define pathways to enable tailored deconstruction of waste streams with compositional complexity; and employ methods to impart selective sites for degradation, all to nucleate a paradigm shift in the plastics life cycle *via* detailed mechanistic understanding. Additionally, we develop cross-cutting platforms and tools to enable plastics circularity that will have long-lasting influence on plastics design, manufacturing, processing, and (re)use. Moreover, the coupling of experiments, modeling, artificial intelligence (AI), polymer chemistry/engineering, and life-cycle assessment (LCA)/technoeconomic analysis (TEA) in *CPI* will define new frontiers in trainee development with direct impacts on sustainable manufacturing. Furthermore, these research innovations will provide a platform to foster *belonging*, *leadership*, *access*, and *inclusivity* through community-building activities, active mentoring and outreach, and professional development programming.

Overarching Goals and Objectives: *CPI* addresses the plastics life cycle through three **overarching research goals** in three synergistic research thrusts: 1) develop novel synthetic approaches to valorize major plastics and polymer systems [including thermosets and composites], beyond polyolefins; 2) design strategies to tackle the complex plastics mixtures that are prevalent in 'real waste streams' and mitigate the effects of additives in polymer formulations; and 3) create readily-recyclable polymers with targeted properties as circular alternatives to current materials. These goals will be achieved *via* six targeted **objectives**: 1) design a suite of valorization approaches to enable *low-energy, controlled deconstruction* of non-PO waste streams to monomer and other functional, small-molecule products; 2) develop chemical recycling design principles to address the *compositional complexity of 'real' polymer waste*; 3) design *hierarchical, multiscale catalysts* with tailored and selective catalyst-polymer interactions to facilitate deconstruction of complex and varied waste streams; 4) develop *advanced computational models, theoretical frameworks, and characterization methods* to enable prediction and analysis of deconstruction products, polymer properties, and macromolecular transformations; 5) generate new *structure-property paradigms for circular-by-design polymers via* innovative synthetic schemes with a focus on property enhancement; and 6) employ *systems analyses* to inform strategic decision making to enable circularity.

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