CENTER FOR PLASTICS INNOVATION at the UNIVERSITY OF DELAWARE

THRUST 1

CPI develops technologies and processes to accelerate the discovery of solutions to the global problem of plastics waste. Our innovative approaches bring us closer to balancing demand for lightweight, resilient materials and thwarting the environmental threats of plastics waste and pollution.

FEEDSTOCK

At CPI, we are working to tackle the plastics waste problem without neglecting the inherent complexity of waste feedstock. Multiple additives and formulation components are treated.

POLYETHYLENE & POLYPROPYLENE

Nearly 60% of all plastics are comprised of polyethylene and polypropylene.

POLYETHYLENE TEREPHTHLATE

From single-use bottles to packaging to textiles, PET is one of the largest sources of plastics waste.

POLYSTYRENE PLASTICS

Polystyrene is widely used but the challenging material is rarely recycled by consumers.

PRISTINE MATERIALS

Pure feedstock studies enable key insights into catalytic chemistry of polymers.

CONSUMER PRODUCTS

We also utilize bags, bottles, and other post-consumer products in our research.

Future Goals: Adapt catalytic technologies and deconstruction strategies to real-world complexities of waste additives and impurities with multivector approaches and processes.

PRODUCTS

Our innovative catalytic technologies convert plastics into fuels, chemicals, and other useful products.

JET and DIESEL FUELS

Fuel created from plastics waste is high-quality and amenable to direct blending with existing fuel.

LUBRICANTS

Consumers and the environment benefit from the conversion of plastics waste to lubricant oils.

OLEFINS

These building blocks are used to make cosmetics, surfactants, and many other consumer products.

ISOMERIZED and FUNCTIONALIZED POLYOLEFINS

Directly converting plastics into other plastics opens new possibilities.

MONOMERS

Recycling back to building blocks enables full circularity.

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Future Goals: As we continue our work to perfect scientific pathways for the development of sustainable, commercially viable products, we see endless potential. Transitioning laboratory success to commercial products requires the development of several steps. Sustainable, cost-effective manufacturing is essential to addressing plastics waste.

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CATALYSTS AND PROCESSES

We have developed several catalytic strategies to valorize plastic waste for diverse products and applications.

OUR INNOVATIVE TECHNOLOGIES:

- robustly manage single and multi-component polymer streams
- utilize active, selective, & tunable catalysts for conversion to a diverse product slate
- allow rapid processing
- result in high liquid and low gas yields
- enable electrified recycling
- are tunable by modifying catalyst pores and surface polymer interactions
- are enabled by multiscale modeling

The inherent heterogeneity and complexity of plastics waste streams raises barriers to catalytic deconstruction. Identification, characterization, and removal of chemical contaminants that can poison catalytic activity are essential. Managing slow heat and mass transfer of viscous streams, long processing times, and high selectivity to methane require further research and development.

HYDROCRACKING: DUAL CATALYSTS

$PtWO_x/ZrO_2$ HY Zeolite

$Pt/WO_3/ZrO_2$ blended with HY zeolite produces up to 85% of fuel-range hydrocarbons at mild reaction conditions. Catalyst acid sites impart branching essential for products. Metal sites initiate the chemistry and stabilize the product.

HYDROISOMERIZATION CATALYSTS

XYO_x/ZrO_2

$PtWO_x/ZrO_2$ facilitates solid-solid transformations to branched polyolefins and products. The relative density of metal and acid sites can tune the degree of branching.

EARTH ABUNDANT, NON-NOBLE METAL CATALYSTS

Mn · Fe ·Cu Ni · Co

Development of Pt and Ru-free alternative catalysts will strongly increase economic feasibility of the hydroconversion process.

TARGETING LUBRICANTS

Ru/TiO_2

Conversion of plastics waste to lubricants is a long-term sustainable solution to curb greenhouse emissions. Ru/TiO_2 catalyst is capable of breaking waste polypropylene down to an oil base with good lubricating properties.

ALKANE METATHESIS

WO_x/SiO_2 Zeolite 4 A

WO_x/SiO_2 is an effective metathesis catalyst for the molecular redistribution of olefin/alkane feedstocks. Addition of a zeolite 4 A prevents catalyst poisoning. This approach shows excellent potential for polyethylene upgrading.

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MANUFACTURING

GREEN ENERGY

Powered by electricity from sustainable sources - like wind, solar, and hydrothermal - microwave technology dramatically reduces greenhouse gases produced in traditional recycling.

REDUCING CO_2 PRODUCTION

Catalytic conversion of plastics using hydrogen produces significant amounts of CO_2. Non-H_2 based processes result in greener manufacturing.

Our multiple state-of-the-art microwave applicators (Discover CEM, Anton Paar, ITACA, SAIREM-Malachite) offer a wide range of processing capabilities, in batch and flow modes, for the chemical conversion of plastics waste. The rapid and volumetric heating by microwaves enhances heat transfer and reduces processing times. Combined with our efficient catalysts, microwave technology demonstrates tremendous promise toward energy-efficient and modular upcycling of plastics waste.

LOW TEMPERATURE

Microwave energy deposits heat directly onto materials, eliminating heat transfer limitations and reducing both operation temperature and energy use.

RAPID, MODULAR DECONSTRUCTION

Combining microwave technology with chemical catalysts enables rapid and portable manufacturing. Ultrafast microwave irradiation reduces the deconstruction time from days to seconds. Small modular units favor consumer and community use.

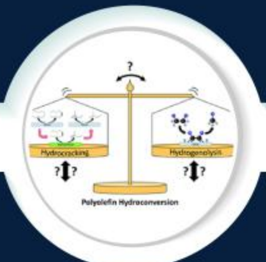
Challenges:

- Temperature inhomogeneities (hotspots) are quite common in microwave heating, especially with solid materials.
- The high viscosity of polymers challenges processing.
- Plastics waste feeding and design strategies are lacking.

Future Goal: Develop continuous processes that address the challenges above to provide high reactor output.

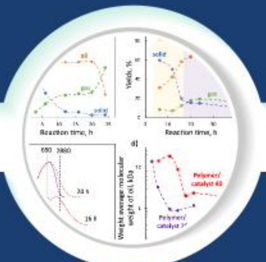
PUBLICATION
HIGHLIGHTS

Reaction Chemistry and Engineering (2022)



POLYOLEFIN PLASTIC WASTE **HYDROCONVERSION** TO FUELS, LUBRICANTS, AND WAXES: A COMPARATIVE STUDY

ACS Catalysis (2021)



POLYPROPYLENE PLASTIC WASTE CONVERSION TO **LUBRICANTS** OVER Ru/TiO_2 CATALYSTS

JACS Au (2021)

POLYETHLYENE **HYDROGENOLYSIS** AT MILD CONDITIONS OVER RUTHENIUM ON TUNGSTATED ZIRCONIA

Applied Catalysis B Environmental (2021)

SINGLE POT CATALYST STRATEGY TO BRANCHED PRODUCTS VIA ADHESIVE **ISOMERIZATION** & **HYDROCRACKING** OF POLYETHYLENE OVER Pt-WZR

Science Advances (2021)

PLASTIC WASTE TO **FUELS** BY HYDROCRACKING AT MILD CONDITIONS

for a full listing of publications, please visit our website at cpi.udel.edu/research/publications

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