Upcycling of Plastic Waste into High-Value Chemicals and Materials

Guoliang (Greg) Liu

Department of Chemistry, Department of Chemical Engineering, Materials Science and Engineering, Macromolecules Innovation Institute, and Academy of Integrated Science-Nanoscience

Virginia Tech, Blacksburg, VA 24061

gliu1@vt.edu

Each year, over 400 million metric tons of plastic are produced and used worldwide, yet less than 10% of the plastic is recycled or reused. To address the global plastic waste crisis, we propose converting plastic waste into high-value chemicals and materials, thereby creating strong financial incentives for plastic recyclers. This approach offers a range of benefits: 1) opening new opportunities for profitable plastic waste recycling, 2) reinforcing the chemical and materials supply chain by providing alternative feedstocks, and 3) fostering global sustainability and social responsibility. Importantly, we focus on low-cost, high-value, and industrially scalable chemical approaches.

In this presentation, we focus on the two highest-volume polyolefins, polyethylene and polypropylene, which are particularly challenging to decompose into their original monomers. Instead of reverting these polyolefins completely to monomers, converting them into oligomeric olefins offers a promising method for upcycling into high-value chemicals and materials. Our research demonstrates that, through our newly invented temperature gradient thermolysis (TGT) process, polyethylene and polypropylene can be broken down into olefin-rich waxes and oils, depending on the temperature profile within the reactors. These products can subsequently be oxidized over manganese catalysts to produce fatty acids or react with sulfuric acid to generate sulfates. Both fatty acids and sulfates serve as high-value surfactants with applications in household and industrial settings. This tandem degradation-upcycling strategy enables the extraction of high-value chemicals from polyethylene and polypropylene with high selectivity. This approach is resilient to impurities and economically more viable than conventional chemical recycling processes, offering a low-value-input, high-value-output model for plastic upcycling.

Brief Bio: Liu earned a bachelor's degree in chemical engineering from Zhejiang University (China) in 2005. After completing his doctorate in 2011, he conducted postdoctoral research at Northwestern University, where he was named an Outstanding Researcher in the International Institute for Nanotechnology. He joined the Department of Chemistry at Virginia Tech in 2014. He is affiliated with the Department of Chemical Engineering and the Department of Materials Science and Engineering. Liu holds about twenty patents. Among them, over ten are licensed or assigned to companies, including Intel®, Western Digital®, Ford Motor Company, SABIC, and Waves Audio (Israel). Liu is a recipient of the VT Junior Faculty Award, NSF CAREER award, Air Force Young Investigator Program (YIP) Award, ACS PRF Doctoral New Investigator (DNI) award, ACS PMSE Young Investigator award, John C. Schug Research Award, and CAPA Distinguished Professor Award. He is also recognized as a Young Talent or Emerging Investigator by several journals, including Macromolecular Rapid Communications, Polymer Chemistry, Journal of Materials Chemistry, Molecular Systems Design & Engineering, and ACS Applied Polymer Materials. He chairs the Blackwood Jr. Faculty Fellow of the College of Science at Virginia Tech. In 2025, he was inducted into the National Academy of Inventors as a Senior Elite Member.