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Polymer science team develops additive that can 'upcycle' a wide range of plastics

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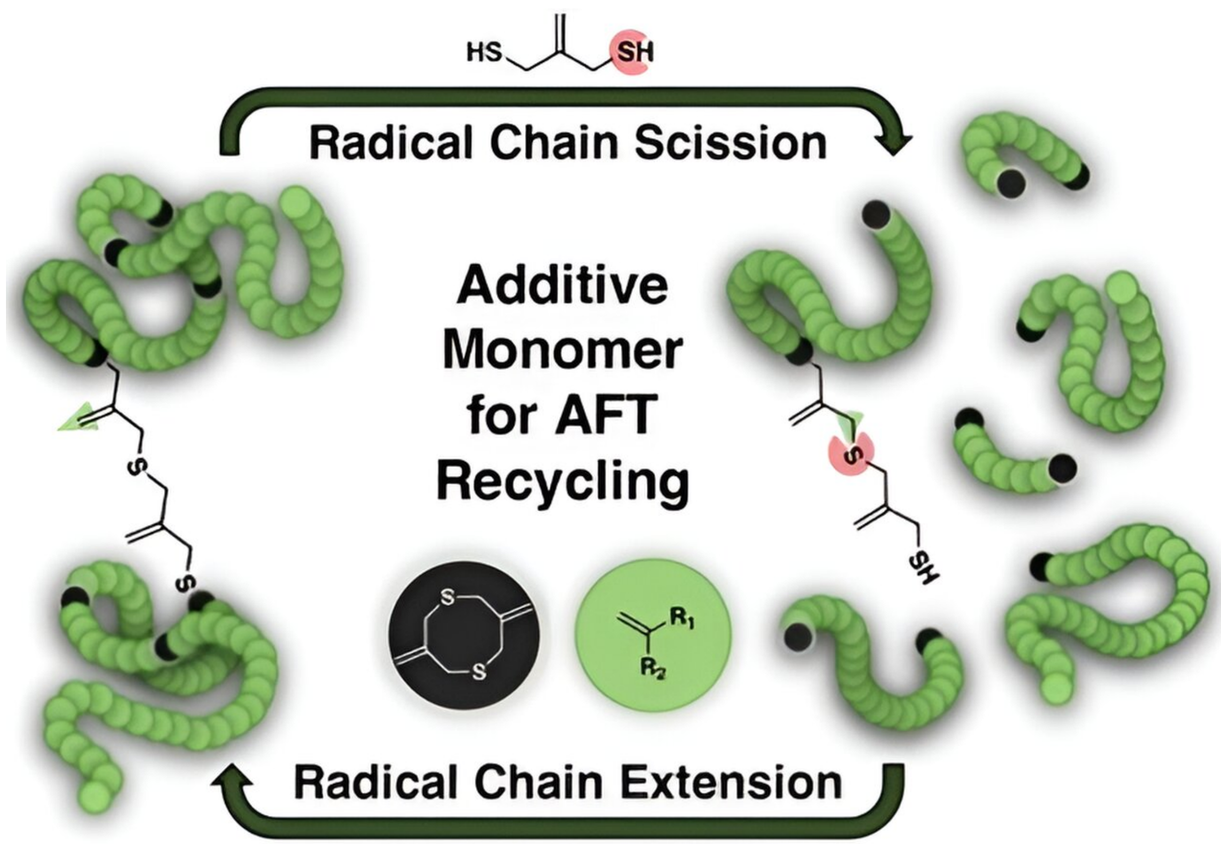

Credit: *Angewandte Chemie International Edition* (2023). DOI: 10.1002/anie.202316248

One doesn't need to be reminded that plastic production, and plastic pollution, have steadily increased over the years—the evidence is all around us. What if we were able to recycle plastic in a way that is truly sustainable?

That very question is being raised by Reika Katsumata, assistant professor, and Ph.D. student Autumn Mineo of the Polymer Science and Engineering (PSE) Department in the College of Natural Sciences, who are experimenting with polymer recycling to identify new, environmentally conscious chemistry and technologies for polymer reprocessing.

Their research is published in the journal *Angewandte Chemie International Edition*.

The realities of recycling

We would all love to think that, despite our best efforts to avoid non-recyclable items, the occasional styrofoam cup we throw in the trash could eventually be reconstituted into a brand-new cup with little or no environmental impact, but the process of recycling is more complicated than that.

Mechanical recycling relies on harsh temperatures and processing conditions to reinvent select streams of post-consumer waste as new products. Repeated exposure to these conditions results in the material breaking down over time and a corresponding worsening of material properties—an outcome often referred to as "downcycling."

Alternatively, certain polymers can be chemically broken down and reformed, leading to improved cycling longevity and material robustness. However, chemical recycling is not possible for many of the commodity polymers used today.

Upcycling through chemistry

Katsumata and her team sought to create a more sustainable process for recycling and reprocessing polymers through what is known as addition-fragmentation-transfer (AFT) chemistry, a field that is focused on radical-based bond exchange reactions. "Everyday plastics are large molecules called polymers, comprised of repeat units, or 'monomers,'" Katsumata explained. "Many polymers are not able to be chemically broken down and reformed, because the carbon-carbon single bonds holding monomers together are relatively stable."

To address this stability issue, PSE researchers developed an additive that copolymerizes with conventional monomers and generates main-chain units that possess the ability to exchange through AFT chemistry.

"This dynamic linkage can foster both polymer scission (or severing) and polymer extension to complete closed-loop recycling," said Katsumata. "Furthermore, the dynamic nature of our additive facilitates other chemical modifications with the potential to 'upcycle,' or increase product value, by taking commodity plastic waste and forming new types of specialized polymers, such as block copolymer adhesives."

This work identified a new monomer compatible with existing methods of synthesizing polymers, which creates a dynamic bond between monomer units that can be leveraged to break down the plastic after use. These smaller fragments of polymers, called oligomers, remain reactive and can serve as starting points from which new polymers can grow.

The team found that the cycle of breaking polymers down (chain scission) and regrowing them (chain extension) can be repeated and modified to change the extent of scission and extension.

Building awareness

A key driver behind this research was an eagerness to spur innovation. "Our research has advanced the fundamental knowledge of AFT chemistry by revealing latent reactivity after polymerization," Katsumata stated. "Additionally, we hope our work has inspired polymer industries to invest in copolymerization strategies and other recycling technology, particularly as it applies to polyolefin products."

Katsumata and the PSE team feel that this research can act as a foundation for new recycling methods and the identification of environmentally friendly chemistry and techniques—providing a glimpse of a future in which plastic and other challenging materials are more sustainably managed.

More information: Autumn M. Mineo et al, A Versatile Comonomer Additive for Radically Recyclable Vinyl-derived Polymers, *Angewandte Chemie International Edition* (2023). DOI: 10.1002/anie.202316248

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