RECYCLING

Cheap catalysts recycle polystyrene into valuable products

2 groups report upcycling the plastic into benzoic acid using light and oxygen

Polystyrene, the polymer commonly used to make foam packaging, insulation, and food containers, is notoriously difficult to recycle. Instead of turning the material into new polystyrene products, breaking it down chemically into more valuable substances could be a more cost-effective alternative. So far, though, chemical recycling has been energy intensive and expensive. Two groups of researchers have now independently come up with simple, low-cost processes that employ light to drive the catalytic breakdown of polystyrene into commodity chemicals.

One group uses an acid as a catalyst and violet-blue light to cleave the strong carbon-carbon and carbon-hydrogen bonds in polystyrene (*J. Am. Chem. Soc.* 2022, DOI: 10.1021/jacs.2c01410). The other uses white light to trigger an iron chloride catalyst to break the bonds (*J. Am. Chem. Soc.* 2022, DOI: 10.1021/jacs.2c01411).

Older methods of chemically cracking polystyrene's bonds tend to be complex, use harsh chemicals and high temperatures, and "almost inevitably produce a soup of many compounds that are difficult to separate, so the value is decreased," says Jianliang Xiao, a chemist at the University of Liverpool who led the acid catalyst study.

The two teams set out to create simple processes that generate just a few products that can be easily harvested from the reaction mixture. Both reactions use oxygen, light-emitting diodes (LEDs), and readily available catalysts to generate benzoic acid—which can be worth about twice as much as polystyrene by weight, according to market research firm ChemAnalyst.

Xiao says his graduate student Zhiliang Huang made the "surprising discovery" that acids work better than previously studied metal catalysts to cleave bonds in polystyrene. When irradiated with a high-power violet-blue LED, the acid and the polystyrene react to form reactive oxygen species, which then cause a chain reaction that breaks up polystyrene's strong bonds. The resulting formic acid and benzoic acid were easy to separate from the reaction mixture.

Meanwhile, Cornell University chemist Erin E. Stache and her graduate student Sewon Oh chose iron chloride as a catalyst, because chlorine radicals are known to break strong C–H bonds. Under white-light irradiation and oxygen-rich air, those broken C–H bonds created peroxy radicals, which in turn cleaved C–C bonds, degraded the polymer, and made benzoic acid.

Although the processes are similar, each has particular advantages. The acid-catalyzed process gives a benzoic acid yield of about 50% and even higher yields of formic acid as a side product, while the iron catalyst achieves 23% benzoic acid yield. But the acid catalyst is double the price of the iron chloride, Stache says. Xiao adds that using white light, as the Stache team did, might reduce costs and energy use.

The techniques' downside is their use of light, which could make them more difficult to scale up than processes that employ heat, according to Frank Leibfarth, a chemist at the University of North Carolina at Chapel Hill. Still, he says, the upcycling of polystyrene into defined products with a clear market using inexpensive, earth-abundant catalysts is an important advance. Tackling the challenge of plastic waste will require many technologies, Leibfarth adds, and these approaches to turn polystyrene into benzoic acid "could be one piece of that puzzle."—PRACHI PATEL, special to C&EN