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NTU scientists chemically recycle polyolefins at room temperature

The new method paves the way to solar-powered chemical recycling of HDPE, LDPE, PVC, PP, PS PVA, EVA

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A close-up of the continuous flow set-up, where the dissolved plastic and vanadium catalyst solution is exposed to light from LEDs and transformed into acids that are useful to make fuel cells or hydrogen energy storage

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Researchers from the **Nanyang Technological University** (NTU) in Singapore have developed a method to recycle HDPE, LDPE, PVC, PP, PS PVA, EVA into formic acid and benzoic acid, which can be used to make other chemicals employed in fuel cells and liquid organic hydrogen carriers (LOHCs).

The new process uses light-emitting diodes (LEDs) to activate and break down the inert carbon-carbon bonds in polyolefins with the help of a commercially available vanadium catalyst, all at room temperature. Unlike other photochemical technologies that chemically recycle plastic near ambient temperatures, however, this approach is not restricted to polystyrene, but is also suitable for materials such as polypropylene, polyethylene, polyvinyl chloride, and polyvinyl acetate.

The NTU team dissolved the plastics in an organic solvent known as dichloromethane, which is used to disperse the polymer chains, making them more accessible to the photocatalyst. They then mixed the solution with the catalyst and directed it through a series of transparent tubes with LED light shining on it. With the help of the vanadium catalyst, the light provides the initial energy to break the carbon-carbon bonds in a two-step process called tandem carbon–hydrogen bond oxidation/carbon–carbon bond cleavage reaction. The carbon-hydrogen bonds in the plastics are oxidised – making the bonds less stable and more reactive – after which the carbon-carbon bonds are broken down.

Results show carbon recoveries of up to 77% and selective formation of valuable, isolable acids that can be used to produce LOHCs, for example, a resource much discussed in the clean energy transportation fuel sector, given their ability to store and transport hydrogen gas more safely.

In particular, results showed that PVC, HDPE, and LDPE produced formic acid as the main product but showed lower carbon recoveries compared to PS 'because of their higher 'C–H and C–C [bond dissociation energies] and poorer solubilities', the scientists said. PP, PVA, and EVA generated both formic and acetic acids, with PP working particularly well compared to HDPE or LDPE, with a carbon recovery of 32.3%, a formic acid yield of 41.8%, and an acetic acid yield of 27.5%. The scientists also successfully applied the method on multi-layered packaging from a local supermarket.

The discovery paves the way to solar-powered **chemical recycling** of polyolefins. As the method doesn't require high temperatures, unlike pyrolysis and hydrogenolysis, it can easily use sunlight or LEDs powered by renewable electricity to break the carbon bonds. While using solar or other renewable sources to power pyrolysis isn't technically impossible, achieving 200 C temperatures or higher without burning fuels is very difficult to achieve. The new method thus show promise to recycle polyolefins without generating large amounts of greenhouse emissions and having high energy costs.

The researchers concluded that ‘detailed technoeconomic analyses will also be needed to examine how our process can offer a sustainable and economically viable route to ‘‘mine’’ plastic waste as replacements for fossil fuels’. They shared their work in ‘**Upcycling of non-biodegradable plastics by base metal photocatalysis’**, recently published in *Chem*.

Inline Play

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