

# CURRENT DEPOLYMERIZATION METHODS FOR POST-CONSUMER POLYETHYLENE

Report by Enleyona Weir

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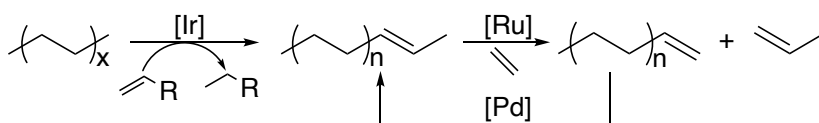
## INTRODUCTION

Plastic is a non-biodegradable material that has outgrown most manufactured products. As a result, plastics accumulate, rather than decompose, in landfills or the natural environment.<sup>1</sup> This is due to the mechanical durability and chemical inertness of commercial plastics. Polyolefins account for 36% of global plastic production, and only a small proportion of polyethylene (PE) waste is recovered by recycling (~14% in 2015).<sup>2</sup> Most PEs are single-use applications, such as packaging films and containers. Considerable efforts over the years have focused on developing technologies such as pyrolysis, gasification, and hydrogenolysis to convert waste polyolefins to monomers or chemical feedstocks. These processes form complex mixtures of different hydrocarbons that are usually difficult to separate. Hence, development is needed by which PE can undergo depolymerization to form single products.

## CHEMICAL RECYCLING OF POLYETHYLENE TO VALUABLE FEEDSTOCK

Recently, Conk et al. have developed a set of catalytic processes that occur simultaneously, resulting in the production of propylene, the second largest demand commodity of plastics used in plastic packaging, plastic parts for machinery and equipment, and even fibers and textile. Dehydrogenation occurs by either homogeneous or heterogeneous catalysts (iridium-pincer complex or platinum/zinc supported on silica) introducing unsaturation into the chain of PE. This is used to enable subsequent C–C bond cleavage with the combination of isomerizing ethenolysis (I/E).<sup>3</sup> This dehydrogenation and isomerizing ethenolysis (DIE) process was

conducted on virgin High-Density Polyethylene (HDPE) and samples of post-consumer PE, propylene yields were detected in all cases. These results show that post-consumer products comprising of

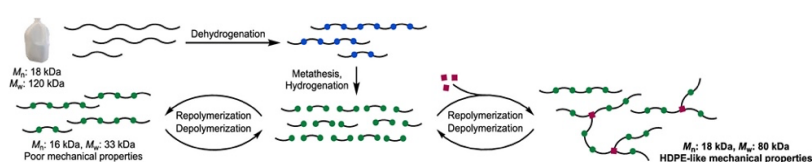


**Figure 1.** Catalytically deconstructed polyethylene through transfer dehydrogenation, isomerization, and metathesis into propylene.

HDPE or Low-Density Polyethylene (LDPE) can be converted to propylene by this DIE process. Wang et al. accomplished a similar transformation using a recently proposed tandem catalysis strategy, which uses ethylene to convert PE to propylene. The tandem process requires an initial

dehydrogenation step into the polymer backbone. The tandem ethenolysis/isomerization is catalyzed by methyltrioxorhenium supported on and activated by chlorinated alumina (MTO/Cl–Al<sub>2</sub>O<sub>3</sub>), providing highly selective access to propylene (≥94%).<sup>4</sup> Post-consumer PE has not been used for this strategy; however, the conversion seems promising.<sup>4</sup> Both strategies catalytically deconstructed polyethylene into propylene through transfer dehydrogenation, isomerization, and metathesis (**Figure 1**).

Additionally, Arroyave et al. reported catalytic chemistry to recycle waste-dehydrogenated HDPE into polyethylene-like material with comparable thermal and mechanical properties to the original post-consumer waste HDPE. This method used similarly an iridium pincer (Ir-POCOP) catalyst for the dehydrogenation of polyethylene, then followed by cross-metathesis with 2-hydroxyethyl acrylate and



**Figure 2.** Chemical recycling of post-consumer waste HDPE into polyethylene-like material.

hydrogenation to transform the partially unsaturated HDPE into telechelic macromonomers.<sup>5</sup> To increase functionalities of the repolymerized product, aminolysis was done on the telechelic macromonomers resulting in a product with polyethylene-like material (**Figure 2**).<sup>5</sup>

## OUTLOOK AND CONCLUSION

A significant improvement in the catalytic lifetime is one of the major remaining challenges for using chemical recycling of PE into valuable hydrocarbon feedstocks. Once this improvement is resolved, the methods described above would provide practical strategies to decrease the amount of discarded plastic globally and serve as a viable method for process scale.

## REFERENCE

1. Geyer, R., et al. *Sci. Adv.* **2017**, 3, e1700782.
2. Coates, G. W., et al. *Nat. Rev. Mater.* **2020**, 5, 501–516.
3. Conk, R. J., et al. *Science*. **2022**, 377, 1561–1566.
4. Wang, N. M., et al. *J. Am. Chem. Soc.* **2022**, 144, 18526–18531.
5. Arroyave, A., et al. *J. Am. Chem. Soc.* **2022**, 144, 23280–23285.