GLOBAL RESEARCH IMMERSION PROGRAM FOR YOUNG SCIENTISTS

Recent advances in catalytic chemical upcycling of polyolefins

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Introduction

Plastic is extensively used in our daily lives due to its affordability and versatility, serving a wide range of functions including containers, food packaging, construction, automotive and electronics[1]. The global recycled plastics market reached $51.70 billion in 2023 and is expected to project at a compound annual growth rate (CAGR) of 9.5% from 2024 to 2030 with the rapid development of utilities and technologies[2] (Figure 1).

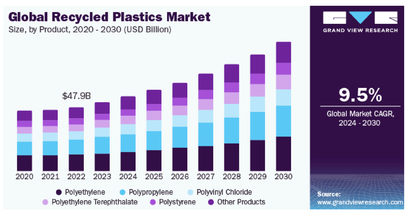

Figure 1: Recycled Plastics Market Size and Segment Forecasts

However, plastic takes roughly 1000 years to naturally decompose, which has a significant impact on both the economy and the environment[3]. Nowadays, upcycling plastic products has become a trend as it helps to improve recycling efficiency and makes the products reusable by transforming plastics into valuable materials and chemical feedstocks[4] (Figure 2).

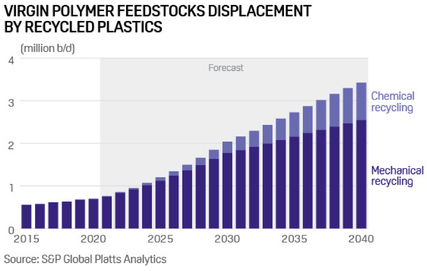

Figure 2: Increase considerations for advancing chemical recycling (upcycling)

This poster will predominantly focus on polyolefins, specifically polyethylene and polypropylene. These polymers are extensively used and present significant challenges for non-mechanical recycling processes[5].

The Different Types Of Recycling

Mechanical recycling is a commonly used method that involves grinding, washing, separating, drying, re-granulating, and compounding plastic waste to create new materials [5]. This process does not change the chemical structure of the plastic but may affect the quality of the final products. In contrast, chemical recycling uses various methods to transform polymers into short-chain molecules, fuels, or virgin plastics that exhibit equivalent or higher performance than the original materials [1]. However, chemical recycling is still under development and may pose challenges related to cost and technical feasibility.

Pyrolysis is the initial chemical recycling process.It involves high temperatures ranging from 300 to 700 °C with catalysts and the absence of oxygen to break down polymers into predominantly liquid hydrocarbons, which can be further used for producing chemicals, various plastics or be used as fuels [6]. Similarly, gasification also requires high temperatures (700 to 1200 °C) but in the presence of oxygen and water. Both processes suffer from high energy requirements, limit recovery of monomers, and generate inorganic residues that may obstruct catalyst pores, thereby reducing efficiency and reusability [1].

Hydroconversion encompasses two distinct pathways: hydrogenolysis and hydrocracking. These methods are employed under moderate temperature conditions (up to 300 °C) which are significantly lower than pyrolysis or gasification. Hydrocracking catalysts typically exhibit bifunctionality, incorporating metallic and acidic sites, and final break down C-C double bonds. In contrast, hydrogenolysis typically involves the use of monofunctional metal catalysts that are dispersed over or applied to various support materials. These catalysts effectively adsorb both H2 and the polyolefin, which leads to formation of C-H bonds at the active sites.

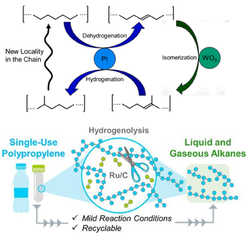

Figure 3: Illustration diagram of both hydrocracking and hydrogenolysis

Photochemical and electrochemical recycling strategies can also be used to save energy and improve efficiency. However, they are still under research due to their limited availability and high cost.

Conclusion:

The high economic cost and environmental problem associated with plastics recycling have drawn people's attention. The poster presented several chemical recycling methods, including pyrolysis, gasification, hydrogenolysis, and hydrocracking, also known as "upcycling". By choosing different processing conditions and materials, the final products can be controlled and further used as lubricants, waxes, or fuels. Although there are still some problems related to cost and reusability, there is an increasing trend in the use of chemical recycling, and researchers have been working to address these issues.

Reference:

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