



Full Length Article

Catalytic upgrading of polyethylene plastic waste using GMOF catalyst: Morphology, pyrolysis, and product analysis

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ABSTRACT

Since 2000, global plastic waste production and consumption have doubled, escalating from 250 to 500 million tonnes. Merely 9 % of plastic waste undergoes global recycling, leaving the majority either in landfills or poorly managed. This research introduces a new catalyst, GMOF, created by growing Metal-Organic Framework (MOFs) rods on the flaked, carpet-like structure of Graphene Oxide (GO) nanosheets. The aim is to enhance the quality of pyrolysis products derived from high-density polyethylene (HDPE) and low-density polyethylene (LDPE) waste using this GMOF catalyst. HDPE and LDPE, sourced from post-consumer plastic packaging, underwent specific treatment involving cleaning, drying, and shredding. Morphological and property evaluations of GO nanosheets before and after MOF decoration employed techniques including Field-Emission Scanning Electron Microscopy (FE-SEM), Energy-Dispersive X-ray Spectroscopy (EDS), and Fourier Transform Infrared Spectroscopy (FTIR). Flash pyrolysis at 500 °C for 1 min using a sample-to-catalyst ratio of 4:1 in a Quartz Wool Matrix (QWM) reactor was conducted via a Thermogravimetric Analyzer (TGA) and Frontier LAB pyrolyzers. Thermal stability and characteristics of feedstocks and catalysts were assessed using TGA. Gas Chromatography-Mass Spectrometry (GC-MS) analyzed and quantified pyrolysis product compounds, while a Micro GC Fusion system determined non-condensable pyrolyzate permanent gas distribution. Results showcased that the GMOF catalyst's unique morphology efficiently captured smaller radicals on its surface, providing increased surface area for effective radical-radical interactions during pyrolysis. In HDPE pyrolysis, the GMOF catalyst notably decreased selectivity of C21-C40 and C40 + wax fractions to 49.07 % and 7.73 %, respectively, while boosting C1-C20 olefin production by 2.54 %. Conversely, LDPE pyrolysis with the GMOF catalyst notably amplified the CO₂ peak intensity by 3.17 %, signifying a gasification phase. Primary gases produced were C3 aliphatic hydrocarbons, propane, and propylene, yielding 79.46 % collectively.

1. Introduction

The surge in plastic production and subsequent waste since the onset of industrial manufacturing in the 1950 s has been substantial [1]. Plastics, owing to their cost-effectiveness, lightweight nature, design flexibility, and resistance to corrosion, are extensively utilized in various

sectors, leading to daily production and an expected ongoing annual rise in their production rate [2–4]. However, despite these benefits, the nonbiodegradable nature of plastics results in only 9 % being recycled, 12 % incinerated, and a staggering 79 % accumulating in the natural environment, contributing significantly to solid waste generation [2].

The accumulation of plastic waste adversely affects the environment

Abbreviations: DTG, Derivative Thermogravimetry; FTIR, Fourier Transform Infrared Spectroscopy; GC-MS, Gas Chromatography-Mass Spectrometry; GMOF, Graphene Metal Organic Framework Composite; GO, Graphene Oxide; HDPE, High-density polyethylene; LDPE, Low-density polyethylene; HDPE-CA, Catalytic pyrolysis of high-density polyethylene; HDPE-NC, Non-catalytic pyrolysis of high-density polyethylene; LDPE-CA, Catalytic pyrolysis of low-density polyethylene; LDPE-NC, Non-catalytic pyrolysis of low-density polyethylene; PET, Polyethylene terephthalate; PE, Polyethylene; PS, Polystyrene; QWM, Quartz Wool Matrix; SEM, Scanning Electron Microscopy; TGA, Thermogravimetric Analysis.

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