Vol. 5, No. 1 World Journal of Environmental Science and Engineering March, 2026
第 5 卷第 1 期 环境科学与工程 2026 年 3 月

Chemical Recycling of Polyethylene Terephthalate: A Review

Xiaolan Cai[1, 2], **Wanli Zhang**[3, *]

[1]School of Light Industry and Chemical Engineering, Guangdong University of Technology, Guangzhou 510006, China
[2]Jieyang Center, Guangdong Provincial Laboratory of Chemistry and Fine Chemical Engineering, Jieyang 515200, China
[3]R&D Center, Shanghai Shaanxi Coal Hi-tech Research Institute, Shanghai 201613, China

Abstract: Polyethylene terephthalate (PET) is one of the most widely produced synthetic polymers, extensively used in beverage bottles, food packaging, and textile fibers due to its excellent mechanical strength, transparency, and chemical resistance. However, the massive consumption of PET has generated an escalating global plastic waste crisis. Mechanical recycling remains the dominant strategy for PET waste management, yet it suffers from polymer degradation, contamination sensitivity, and limited recyclability. Chemical recycling has therefore emerged as a promising approach to close the carbon loop by converting PET waste into its constituent monomers or other high-value chemicals. In recent years, significant progress has been achieved in catalytic depolymerization strategies including glycolysis, methanolysis, hydrolysis, aminolysis, and hydrogenolysis. In addition, emerging approaches such as enzymatic depolymerization, solvent-assisted recycling, and tandem catalytic upgrading have further expanded the valorization potential of PET waste. This review provides a comprehensive overview of recent advances in PET chemical recycling, focusing on reaction mechanisms, catalytic systems, process intensification strategies, and product upgrading pathways. Special emphasis is placed on heterogeneous catalysis, green solvents, and integrated catalytic systems for converting PET into monomers such as terephthalic acid and ethylene glycol or into value-added chemicals including fuels, polymers, and aromatic compounds. Finally, current challenges and future research directions are discussed, highlighting opportunities for designing sustainable catalytic systems and scalable industrial processes for circular plastic economy.

Keywords: Polyethylene Terephthalate; Chemical Recycling; Depolymerization; Catalysis; Circular Plastics Economy; Sustainable Polymers

DOI: 10.57237/j.wjese.2026.01.002

1 Introduction

The rapid expansion of plastic production has become a defining feature of the modern materials economy [1, 2]. Among commodity polymers, polyethylene terephthalate (PET) occupies a particularly prominent position due to its widespread use in packaging, textiles, and engineering materials [3]. Global PET production has exceeded 80 million tons annually, with beverage bottles and polyester fibers accounting for the majority of consumption [4, 5]. While PET offers excellent material properties such as high tensile strength, thermal stability, and chemical resistance, its durability also contributes to long-term environmental persistence once discarded [6].

The accumulation of PET waste has therefore become a major environmental challenge [7]. Large quantities of post-consumer PET are either landfilled [8], incinerated [9], or leaked into ecosystems [10], contributing to microplastic

---

[*]Corresponding author: Wanli Zhang, boluomixqz@foxmail.com

Received: 6 March 2026; Accepted: 23 March 2026; Published Online: 24 March 2026

pollution [11] and carbon emissions [12]. Mechanical recycling is currently the dominant recycling strategy and involves reprocessing PET waste through melting and remolding [13]. Although this approach is economically attractive, it is fundamentally limited by polymer chain degradation, contamination, and deterioration of material properties after multiple recycling cycles [14]. As a result, mechanically recycled PET often experiences “downcycling,” restricting its reuse in high-performance applications such as food-grade packaging [15, 16].

Chemical recycling has emerged as a promising alternative strategy that enables the depolymerization of PET into monomers or other valuable chemicals [17]. Unlike mechanical recycling, chemical recycling breaks the ester bonds within PET, regenerating building blocks such as terephthalic acid (TPA), dimethyl terephthalate (DMT), and ethylene glycol (EG) [18]. These monomers can subsequently be repolymerized to produce virgin-quality PET, thus enabling a closed-loop recycling system. Furthermore, PET can also be transformed into other value-added chemicals such as aromatic compounds, polyols, and fuels, expanding the economic potential of plastic waste valorization [19].

Over the past decade, advances in catalysis, reaction engineering, and solvent design have significantly improved the efficiency and selectivity of PET chemical recycling processes [20]. Conventional depolymerization strategies include glycolysis, methanolysis, hydrolysis, and aminolysis, each producing distinct chemical intermediates. In addition, emerging technologies such as hydrogenolysis, enzymatic degradation, and tandem catalytic upgrading are opening new pathways for transforming PET waste into high-value chemicals under milder conditions.

Despite these advances, several challenges remain for the large-scale deployment of PET chemical recycling technologies. These challenges include catalyst stability [21], energy efficiency [22, 23], solvent recovery, product purification, and the handling of mixed plastic waste streams [24]. Addressing these issues requires a deeper understanding of reaction mechanisms, catalyst–substrate interactions, and process integration strategies.

This review provides a comprehensive overview of recent developments in PET chemical recycling, focusing on catalytic depolymerization pathways, catalyst design, and process intensification. Particular attention is given to heterogeneous catalytic systems and integrated catalytic processes that enable the efficient transformation of PET waste into monomers and other valuable chemicals. By highlighting recent progress and identifying remaining challenges, this review aims to provide guidance for the development of sustainable and economically viable PET recycling technologies.

2 Structure and Properties of PET Relevant to Chemical Recycling

Polyethylene terephthalate is a thermoplastic polyester synthesized through the polycondensation of terephthalic acid (TPA) or dimethyl terephthalate (DMT) with ethylene glycol (EG). The polymer structure consists of repeating ester linkages connecting aromatic terephthalate units with ethylene glycol segments. This unique combination of aromatic rigidity and flexible aliphatic segments gives PET its desirable mechanical strength, thermal stability, and barrier properties.

The chemical structure of PET plays a crucial role in determining its depolymerization behavior. The ester bonds within PET chains are susceptible to nucleophilic attack by alcohols, water, amines, or hydrogen in the presence of suitable catalysts [25, 26]. As a result, PET can be depolymerized through several chemical pathways depending on the reacting nucleophile. For instance, glycolysis involves the transesterification of PET with glycols [27], while methanolysis uses methanol to generate dimethyl terephthalate [3, 28].

Another important factor influencing PET recycling is its semi-crystalline structure. PET typically exhibits both amorphous and crystalline domains, with crystallinity ranging from 20% to 50% depending on processing conditions [29]. Crystalline regions are more resistant to chemical attack because of strong intermolecular interactions and dense chain packing. Consequently, depolymerization reactions often occur preferentially in amorphous regions before gradually penetrating crystalline domains [30].

Additives and contaminants present in post-consumer PET waste also affect chemical recycling processes [31, 32]. Plasticizers [33], colorants [34], multilayer packaging components [35], and residual food contaminants may interfere with catalytic reactions or complicate product purification [36]. Therefore, pretreatment steps such as washing, sorting, and particle size reduction are often necessary to improve recycling efficiency.

Understanding these structural characteristics is essential for designing efficient catalytic systems and reaction conditions for PET depolymerization. Advances in catalyst design and solvent engineering have increasingly focused on improving polymer accessibility and facilitating ester bond cleavage under mild conditions.

3 Chemical Recycling of PET

3.1 Glycolysis of PET

Glycolysis is one of the most widely studied chemical recycling methods for PET [37]. In this process, PET undergoes transesterification with glycols—typically ethylene glycol—resulting in the formation of bis(2-hydroxyethyl) terephthalate (BHET), which can be repolymerized into PET or used as a precursor for other polymers [38].

The reaction mechanism involves nucleophilic attack of the glycol hydroxyl group on the ester carbonyl carbon of PET, leading to cleavage of the ester linkage and formation of BHET. Because PET is solid and relatively inert, catalysts are usually required to accelerate the reaction and improve selectivity.

Traditional catalysts for PET glycolysis include metal acetates such as zinc acetate, manganese acetate, and cobalt acetate [37]. Among these, zinc acetate has been widely used due to its high catalytic activity and relatively low cost [27, 39, 40]. However, homogeneous catalysts present challenges in catalyst recovery and product purification.

To overcome these limitations, heterogeneous catalysts have been increasingly explored [41, 42]. Solid catalysts such as metal oxides, layered double hydroxides, and zeolites have demonstrated promising catalytic performance [21, 43–48]. For example, metal–organic frameworks (MOFs) and functionalized carbon materials have been shown to provide high catalytic activity and improved recyclability.

Process intensification strategies have also been investigated to enhance glycolysis efficiency. Microwave-assisted heating, ultrasonic irradiation, and supercritical glycolysis have significantly reduced reaction times and improved BHET yields [49–51]. These approaches enhance mass transfer and polymer accessibility, enabling more efficient depolymerization.

Despite these advances, challenges remain in optimizing catalyst stability, minimizing side reactions, and improving product separation processes [52, 53]. Continued research into advanced catalytic materials and reactor designs is therefore crucial for scaling up glycolysis-based recycling technologies [54].

3.2 Methanolysis of PET

Methanolysis is another important chemical recycling pathway that converts PET into dimethyl terephthalate (DMT) and ethylene glycol [39, 55–61]. This process typically occurs in the presence of methanol at elevated temperatures and pressures, often using metal-based catalysts [62].

Historically, methanolysis was widely used in early PET production processes because DMT could be purified through distillation and reused for polymer synthesis [58, 63–65]. The reaction involves nucleophilic attack of methanol on PET ester bonds, forming DMT as the primary aromatic product [3, 66].

Industrial methanolysis processes often employ catalysts such as zinc acetate, cobalt acetate, or manganese acetate [67]. However, high reaction temperatures and pressures are typically required to achieve high conversion rates [68].

Recent research has focused on developing heterogeneous catalysts capable of promoting methanolysis under milder conditions [69]. Catalysts based on metal oxides, and supported metals have shown promising results [70, 71]. Additionally, supercritical methanol has been explored as a solvent and reactant to enhance depolymerization efficiency [68].

3.3 Hydrolysis of PET

Hydrolysis involves the reaction of PET with water to produce terephthalic acid (TPA) and ethylene glycol [72]. Depending on the reaction conditions, hydrolysis can be classified into acidic, alkaline, or neutral hydrolysis.

Alkaline hydrolysis is one of the most commonly studied methods because it proceeds relatively rapidly and produces terephthalate salts that can be converted into high-purity TPA after acidification [73–75]. However, large amounts of inorganic salts are generated as by-products, posing environmental and economic challenges.

Acidic hydrolysis uses strong acids such as sulfuric acid to depolymerize PET [65, 72, 76–78]. While this method can achieve high conversion rates, the use of concentrated acids raises issues related to corrosion and waste management.

Neutral hydrolysis, typically conducted under high-temperature steam conditions, avoids the use of strong acids or bases but often requires more severe reaction conditions [79].

3.4 Emerging Approaches: Hydrogenolysis and Enzymatic Recycling

Beyond conventional depolymerization methods, emerging catalytic technologies have opened new pathways for PET chemical recycling.

Hydrogenolysis involves the catalytic cleavage of PET ester bonds in the presence of hydrogen [80], producing aromatic compounds such as terephthalic acid derivatives or aromatic hydrocarbons [81]. Noble metal catalysts such as Ru, Pd, and Pt have demonstrated promising activity for PET hydrogenolysis.

Another rapidly developing field is enzymatic PET recycling [82]. Enzymes such as PETase and MHETase have been discovered to selectively depolymerize PET into its monomers under mild conditions [82]. Advances in protein engineering have significantly improved enzyme stability and catalytic efficiency, making enzymatic recycling a promising sustainable alternative.

3.5 Upgrading of PET-Derived Intermediates

Chemical recycling not only regenerates PET monomers but also enables the production of value-added chemicals.

For example, terephthalic acid can be converted into aromatic hydrocarbons, benzene derivatives, and polymer intermediates [83]. Ethylene glycol can be upgraded to fuels, solvents, or polyols [84]. BHET and other oligomers can serve as building blocks for polyurethanes and specialty polymers.

These upgrading strategies expand the economic value of PET recycling and integrate plastic waste into broader biorefinery and chemical manufacturing systems.

4 Conclusion and Outlook

Chemical recycling has emerged as a promising strategy for addressing the growing accumulation of polyethylene terephthalate (PET) waste and enabling a circular plastics economy. Unlike mechanical recycling, chemical recycling breaks the ester bonds in PET and regenerates valuable monomers such as terephthalic acid, dimethyl terephthalate, and ethylene glycol, which can be reused to produce virgin-quality polymers or other high-value chemicals. Significant progress has been achieved in recent years in developing depolymerization pathways including glycolysis, methanolysis, hydrolysis, and aminolysis, as well as emerging approaches such as hydrogenolysis and enzymatic degradation. Advances in catalyst design—particularly heterogeneous catalysts, ionic liquids, and porous materials—have improved reaction efficiency, selectivity, and catalyst recyclability.

Despite these advances, several challenges remain for large-scale implementation, including catalyst stability, high energy consumption, and the complexity of mixed plastic waste streams. Future research should focus on developing robust and cost-effective catalytic systems [85], improving energy efficiency through process intensification, and integrating depolymerization with downstream upgrading processes. With continued advances in catalysis, reaction engineering, and waste management infrastructure, chemical recycling is expected to play a critical role in transforming PET waste into valuable resources and advancing a sustainable circular plastics economy.

References

[1] Hopewell J, Dvorak R, Kosior E. Plastics recycling: Challenges and opportunities. Philos Trans R Soc B Biol Sci 2009; 364: 2115–26. https://doi.org/10.1098/rstb.2008.0311

[2] Ivanova B. Structural Analysis of Polylactic Acid in Composite Starch Biopolymers – A Stochastic Dynamics Mass Spectrometric Approach. Innov Discov 2024; 1: 26. https://doi.org/10.53964/ID.2024026

[3] Xie S, Wang C, Hu W, Hu JZ, Wang Y, Dong Z, et al. Chemical recycling of post-consumer polyester wastes using a tertiary amine organocatalyst. Cell Reports Phys Sci 2024; 5. https://doi.org/10.1016/j.xcrp.2024.102145

[4] Welle F. Twenty years of PET bottle to bottle recycling - An overview. Resour Conserv Recycl 2011; 55: 865–75. https://doi.org/10.1016/j.resconrec.2011.04.009

[5] Peterson A, Wallinder J, Bengtsson J, Idström A, Bialik M, Jedvert K, et al. Chemical Recycling of a Textile Blend from Polyester and Viscose, Part I: Process Description, Characterization, and Utilization of the Recycled Cellulose. Sustain 2022; 14. https://doi.org/10.3390/su14127272

[6] Pan D, Su F, Liu C, Guo Z. Research progress for plastic waste management and manufacture of value-added products. Adv Compos Hybrid Mater 2020; 3: 443–61. https://doi.org/10.1007/s42114-020-00190-0

[7] Lönnstedt OM, Eklöv P. Environmentally relevant concentrations of microplastic particles influence larval fish ecology. Science (80-) 2016; 352: 1213–6. https://doi.org/10.1126/science.aad8828

[8] Gracida-Alvarez UR, Winjobi O, Sacramento-Rivero JC, Shonnard DR. System Analyses of High-Value Chemicals and Fuels from a Waste High-Density Polyethylene Refinery. Part 2: Carbon Footprint Analysis and Regional Electricity Effects. ACS Sustain Chem Eng 2019; 7: 18267–78. https://doi.org/10.1021/acssuschemeng.9b04764

[9] Eriksson O, Finnveden G. Plastic waste as a fuel - CO_2-neutral or not? Energy Environ Sci 2009; 2: 907–14. https://doi.org/10.1039/b908135f

[10] Gracida-Alvarez UR, Winjobi O, Sacramento-Rivero JC, Shonnard DR. System Analyses of High-Value Chemicals and Fuels from a Waste High-Density Polyethylene Refinery. Part 1: Conceptual Design and Techno-Economic Assessment. ACS Sustain Chem Eng 2019; 7: 18254–66. https://doi.org/10.1021/acssuschemeng.9b04763

[11] Gohla J, Bračun S, Gretschel G, Koblmüller S, Wagner M, Pacher C. Potassium carbonate (K_2CO_3) – A cheap, non-toxic and high-density floating solution for microplastic isolation from beach sediments. Mar Pollut Bull 2021; 170. https://doi.org/10.1016/j.marpolbul.2021.112618

[12] Nematov DD. Titanium Dioxide and Photocatalytic CO_2 Reduction: A Detailed Review of the Current Status and Future Prospects. Innov Discov 2025; 2: 5. https://doi.org/10.53964/ID.2025005

[13] Perugini F, Mastellone ML, Arena U. A life cycle assessment of mechanical and feedstock recycling options for management of plastic packaging wastes. Environ Prog 2005; 24: 137–54. https://doi.org/10.1002/ep.10078

[14] Jie H, Ke H, Wenjie Q, Zibin Z. Process analysis of depolymerization polybutylene terephthalate in supercritical methanol. Polym Degrad Stab 2006; 91: 2527–31. https://doi.org/10.1016/j.polymdegradstab.2006.01.014

[15] Arrieta MP, Fortunati E, Dominici F, López J, Kenny JM. Bionanocomposite films based on plasticized PLA-PHB/cellulose nanocrystal blends. Carbohydr Polym 2015; 121: 265–75. https://doi.org/10.1016/j.carbpol.2014.12.056

[16] Kaiser K, Schmid M, Schlummer M. Recycling of polymer-based multilayer packaging: A review. Recycling 2018. https://doi.org/10.3390/recycling3010001

[17] Liu J, Peng X. Interface-engineering of the Catalysts for Efficient Electrocatalytic Upcycling of Polyethylene Terephthalate Waste. Innov Discov 2024; 1: 1. https://doi.org/10.53964/ID.2024001

[18] Scremin DM, Miyazaki DY, Lunelli CE, Silva SA, Zawadzki SF. PET Recycling by Alcoholysis Using a New Heterogeneous Catalyst: Study and its Use in Polyurethane Adhesives Preparation. Macromol Symp 2019; 383. https://doi.org/10.1002/masy.201800027

[19] Wei L, Yan N, Chen Q. Converting Poly(ethylene terephthalate) waste into carbon microspheres in a supercritical CO_2 system. Environ Sci Technol 2011; 45: 534–9. https://doi.org/10.1021/es102431e

[20] Barbieri M, Terreni E, Tollini F, Storti G, Moscatelli D. A novel process for recovery and exploitation of polyesters and polyamides from waste polymeric artifacts. Invent Discl 2024; 4: 100026. https://doi.org/10.1016/J.INV.2024.100026

[21] Imran M, Kim DH, Al-Masry WA, Mahmood A, Hassan A, Haider S, et al. Manganese-, cobalt-, and zinc-based mixed-oxide spinels as novel catalysts for the chemical recycling of poly(ethylene terephthalate) via glycolysis. Polym Degrad Stab 2013. https://doi.org/10.1016/j.polymdegradstab.2013.01.007

[22] Albrahee I, Li Y, Xing G. Carbon-based Perovskite Solar Cells: From Current Fabrication Methodologies to Their Future Commercialization at Low Cost. Innov Discov 2025; 2: 1. https://doi.org/10.53964/id.2025001

[23] Wang L, Wang Y, Wu L, Wei G. Fabrication, properties, performances, and separation application of polymeric pervaporation membranes: A review. Polymers (Basel) 2020; 12: 1466. https://doi.org/10.3390/polym12071466

[24] Katibi KK, Shitu IG, Mutalovich AA, Abba MU, Zakar MN. Application of Nanocomposite Membrane Fibre Blended with $CoFe_2O_4$ Nanoparticles for the Sequestration of Bisphenol S from Aqueous Solution: Fouling and Permeability Studies. Innov Discov 2025; 2: 19. https://doi.org/10.53964/id.2025019

[25] Niaounakis M. Recycling of biopolymers – The patent perspective. Eur Polym J 2019; 114: 464–75. https://doi.org/10.1016/j.eurpolymj.2019.02.027

[26] Han Z, Xue Q, Hu X, Guo T, Ma J, Guo Q. A Comprehensive Review of Chemical Looping Ammonia Synthesis. Innov Discov 2024; 1: 9. https://doi.org/10.53964/id.2024009

[27] López-Fonseca R, Duque-Ingunza I, de Rivas B, Arnaiz S, Gutiérrez-Ortiz JI. Chemical recycling of post-consumer PET wastes by glycolysis in the presence of metal salts. Polym Degrad Stab 2010; 95: 1022–8. https://doi.org/10.1016/j.polymdegradstab.2010.03.007

[28] Song X, Zhang X, Wang H, Liu F, Yu S, Liu S. Methanolysis of poly(lactic acid) (PLA) catalyzed by ionic liquids. Polym Degrad Stab 2013; 98: 2760–4. https://doi.org/10.1016/j.polymdegradstab.2013.10.012

[29] Mittal A, Soni RK, Dutt K, Singh S. Scanning electron microscopic study of hazardous waste flakes of polyethylene terephthalate (PET) by aminolysis and ammonolysis. J Hazard Mater 2010; 178: 390–6. https://doi.org/10.1016/j.jhazmat.2010.01.092

[30] Xie S, Sun Z, Liu T, Zhang J, Li T, Ouyang X, et al. Beyond biodegradation: Chemical upcycling of poly(lactic acid) plastic waste to methyl lactate catalyzed by quaternary ammonium fluoride. J Catal 2021; 402: 61–71. https://doi.org/10.1016/j.jcat.2021.08.032

[31] Leng Z, Padhan RK, Sreeram A. Production of a sustainable paving material through chemical recycling of waste PET into crumb rubber modified asphalt. J Clean Prod 2018; 180: 682–8. https://doi.org/10.1016/j.jclepro.2018.01.171

[32] Koo HJ, Chang GS, Kim SH, Hahm WG, Park SY. Effects of recycling processes on physical, mechanical and degradation properties of PET yarns. Fibers Polym 2013; 14: 2083–7. https://doi.org/10.1007/s12221-013-2083-2

[33] Hansen E, Nilsson NH, Lithner D, Lassen C. Hazardous substances in plastic materials. Hazard Subst Plast Mater 2013: 148. https://www.byggemiljo.no/wp-content/uploads/2014/10/72_ta3017.pdf

[34] Zhou X, Yang L, Shao Y, Feng S, Deng J, Hu J, et al. Highly efficient depolymerization of waste polyethylene terephthalate for upcycling in colorful pigments and coatings. J Mater Sci Technol 2026; 251: 59–70. https://doi.org/10.1016/j.jmst.2025.06.034.

[35] Ügdüler S, Van Geem KM, Denolf R, Roosen M, Mys N, Ragaert K, et al. Towards closed-loop recycling of multilayer and coloured PET plastic waste by alkaline hydrolysis. Green Chem 2020; 22: 5376–94. https://doi.org/10.1039/d0gc00894j

[36] Cruz SA, Zanin M, Nerin C, De Moraes MAB. Study of barrier properties and chemical resistance of recycled PET coated with amorphous carbon through a plasma enhanced chemical vapour deposition (PECVD) process. Food Addit Contam 2006; 23: 100–6. https://doi.org/10.1080/02652030500384064

[37] Fukushima K, Coulembier O, Lecuyer JM, Almegren HA, Alabdulrahman AM, Alsewailem FD, et al. Organocatalytic depolymerization of poly(ethylene terephthalate). J Polym Sci Part A Polym Chem 2011; 49: 1273–81. https://doi.org/10.1002/pola.24551

[38] Chen F, Wang G, Li W, Yang F. Glycolysis of poly(ethylene terephthalate) over Mg-Al mixed oxides catalysts derived from hydrotalcites. Ind Eng Chem Res 2013; 52: 565–71. https://doi.org/10.1021/ie302091j

[39] Mishra S, Goje AS. Kinetic and thermodynamic study of methanolysis of poly(ethylene terephthalate) waste powder. Polym Int 2003; 52: 337–42. https://doi.org/10.1002/pi.1147

[40] Khoonkari M, Haghighi AH, Sefidbakht Y, Shekoohi K, Ghaderian A. Chemical Recycling of PET Wastes with Different Catalysts. Int J Polym Sci 2015; 2015: 1–11. https://doi.org/10.1155/2015/124524

[41] Chen F, Yang F, Wang G, Li W. Calcined Zn/Al hydrotalcites as solid base catalysts for glycolysis of poly(ethylene terephthalate). J Appl Polym Sci 2014; 131. https://doi.org/10.1002/app.41053

[42] Kalita H, Patowary M. Magnetite Nanoparticles: A Potent Magnetic Perspective for Environmental and Biomedical Applications. Innov Discov 2026; 3: 3. https://doi.org/10.53964/id.2026003

[43] Yang G, Wu H, Huang K, Ma Y, Chen Q, Chen Y, et al. The Recyclable Dual-Functional Zeolite Nanocrystals Promoting the High Efficiency Glycolysis of PET. J Polym Environ 2024 3210 2024; 32: 5071–85. https://doi.org/10.1007/s10924-024-03298-2

[44] Imran M, Lee KG, Imtiaz Q, Kim BK, Han M, Cho BG, et al. Metal-Oxide-Doped Silica Nanoparticles for the Catalytic Glycolysis of Polyethylene Terephthalate. J Nanosci Nanotechnol 2011; 11: 824–8. https://doi.org/10.1166/jnn.2011.3201

[45] Cano I, Martin C, Fernandes JA, Lodge RW, Dupont J, Casado-Carmona FA, et al. Paramagnetic ionic liquid-coated $SiO_2@Fe_3O_4$ nanoparticles—The next generation of magnetically recoverable nanocatalysts applied in the glycolysis of PET. Appl Catal B Environ 2020; 260: 118110. https://doi.org/10.1016/j.apcatb.2019.118110

[46] Shukla SR, Palekar V, Pingale N. Zeolite catalyzed glycolysis of polyethylene terephthalate bottle waste. J Appl Polym Sci 2008. https://doi.org/10.1002/app.28656

[47] Al-Sabagh AM, Yehia FZ, Harding DRK, Eshaq G, ElMetwally AE. Fe_3O_4-boosted MWCNT as an efficient sustainable catalyst for PET glycolysis. Green Chem 2016. https://doi.org/10.1039/c6gc00534a

[48] Kaseem M, Fattah-alhosseini A. Enhanced the Electrochemical Stability of Al-Zn-Mg Alloy Through the Dual Incorporation of ZrO_2 and V_2O_5 into the Alumina Layer. Innov Discov 2024; 1: 2. https://doi.org/10.53964/id.2024002

[49] Chen F, Wang G, Shi C, Zhang Y, Zhang L, Li W, et al. Kinetics of glycolysis of poly(ethylene terephthalate) under microwave irradiation. J Appl Polym Sci 2013; 127: 2809–15. https://doi.org/10.1002/app.37608

[50] Achilias DS, Redhwi HH, Siddiqui MN, Nikolaidis AK, Bikiaris DN, Karayannidis GP. Glycolytic depolymerization of PET waste in a microwave reactor. J Appl Polym Sci 2010; 118: 3066–73. https://doi.org/10.1002/app.32737

[51] Srithongpusakul MA, Romero-Zerón DL, Kongvarhodom DC, Rogers DK. Polyester (PET) Degradation in Mild-Alkaline Solutions Assisted by Ultrasonication and UV-Activated Metal Oxides 2025. https://doi.org/10.26434/chemrxiv-2025-m1m39

[52] Xie S, Sun Z, Tan J, Zhang W, Cai X, Fang Y. Emerging Micromolecule-based Aqueous Two-phase Systems and Their Application in Biofuels. Innov Discov 2024; 1: 30. https://doi.org/10.53964/id.2024030

[53] Bhattacharjee J, Roy S. Advanced Techniques Using Ionic Liquids for Efficient Separation of Sugar Alcohols. Innov Discov 2025; 2: 3. https://doi.org/10.53964/ID.2025003

[54] Daengpradab B, Rattanaphanee P. Process Intensification for Production of Ethyl Lactate from Fermentation-Derived Magnesium Lactate: A Preliminary Design. Int J Chem React Eng 2015; 13: 407–12. https://doi.org/10.1515/ijcre-2014-0133

[55] Sinha V, Patel MR, Patel J V. Pet waste management by chemical recycling: A review. J Polym Environ 2010; 18: 8–25. https://doi.org/10.1007/s10924-008-0106-7

[56] Kurokawa H, Ohshima MA, Sugiyama K, Miura H. Methanolysis of polyethylene terephthalate (PET) in the presence of aluminium tiisopropoxide catalyst to form dimethyl terephthalate and ethylene glycol. Polym Degrad Stab 2003; 79: 529–33. https://doi.org/10.1016/S0141-3910(02)00370-1

[57] Viante MF, Zanela TMP, Stoski A, Muniz EC, Almeida CAP. Magnetic microspheres composite from poly(ethylene terephthalate) (PET) waste: Synthesis and characterization. J Clean Prod 2018; 198: 979–86. https://doi.org/10.1016/j.jclepro.2018.07.101

[58] Nikles DE, Farahat MS. New motivation for the depolymerization products derived from poly(ethylene terephthalate) (PET) waste: A review. Macromol Mater Eng 2005; 290: 13–30. https://doi.org/10.1002/mame.200400186

[59] Shibata M, Masuda T, Yosomiya R, Ling-Hui M. Depolymerization of poly(butylene terephthalate) using high-temperature and high-pressure methanol. J Appl Polym Sci 2000; 77: 3228–33. https://doi.org/10.1002/1097-4628(20000929)77:14<3228::AID-APP260>3.0.CO;2-G

[60] Nunes CS, Vieira Da Silva MJ, Cristina Da Silva D, Freitas ADR, Rosa FA, Rubira AF, et al. PET depolymerisation in supercritical ethanol catalysed by [Bmim] [BF 4]. RSC Adv 2014; 4: 20308–16. https://doi.org/10.1039/c4ra00262h

[61] Bartolome L, Imran M, Gyoo B, A. W, Hyun D. Recent Developments in the Chemical Recycling of PET. Mater. Recycl. - Trends Perspect., 2012. https://doi.org/10.5772/33800

[62] Goto M, Koyamoto H, Kodama A, Hirose T, Nagaoka S, McCoy BJ. Degradation kinetics of polyethylene terephthalate in supercritical methanol. AIChE J 2002; 48: 136–44. https://doi.org/10.1002/aic.690480114

[63] Lorenzetti C, Manaresi P, Berti C, Barbiroli G. Chemical recovery of useful chemicals from polyester (PET) waste for resource conservation: A survey of state of the art. J Polym Environ 2006; 14: 89–101. https://doi.org/10.1007/s10924-005-8711-1

[64] Sabu Thomas,, Ajay Vasudeo Rane,, Krishnan Kanny,, V. K. Abitha, and MGT. Table of Content Section Recycling of Polyethylene Terephthalate Bottles. n.d.

[65] De Winter W, Mariën A, Heirbaut W, Verheijen J. Recycling of poly(ethylene terephthalate) (PET). vol. 57. Norwich, United States: 1992. https://doi.org/10.1002/masy.19920570123

[66] Sanghavi R, Intan NN, Xie S, Lin H, Pfaendtner J. Reaction Pathway Analysis of PET Deconstruction via Methanolysis and Tertiary Amine Catalysts. J Phys Chem A 2024; 128: 5883–91. https://doi.org/10.1021/acs.jpca.4c02276

[67] Hofmann M, Sundermeier J, Alberti C, Enthaler S. Zinc(II) acetate Catalyzed Depolymerization of Poly(ethylene terephthalate). ChemistrySelect 2020; 5: 10010–4. https://doi.org/10.1002/slct.202002260

[68] Huang J, Qi WJ, Huang K, Wu YQ, Zhu Z Bin. The depolymerization mechanism of polybutylene terephthalate in supercritical methanol. Gao Xiao Hua Xue Gong Cheng Xue Bao/Journal Chem Eng Chinese Univ 2007; 21: 48–53.

[69] Lin TM, Anggo Krisbiantoro P, Sato M, Chang YC, Atayde EC, Liao W, et al. Potassium Carbonate as a Low-Cost and Highly Active Solid Base Catalyst for Low-Temperature Methanolysis of Polycarbonate. ChemSusChem 2025; 18. https://doi.org/10.1002/cssc.202401676

[70] Laldinpuii ZT, Khiangte V, Lalhmangaihzuala S, Lalmuanpuia C, Pachuau Z, Lalhriatpuia C, et al. Methanolysis of PET Waste Using Heterogeneous Catalyst of Bio-waste Origin. J Polym Environ 2021 304 2021; 30: 1600–14. https://doi.org/10.1007/s10924-021-02305-0

[71] Lalhmangaihzuala S, Laldinpuii ZT, Khiangte V, Lallawmzuali G, Thanhmingliana, Vanlaldinpuia K. Orange peel ash coated Fe_3O_4 nanoparticles as a magnetically retrievable catalyst for glycolysis and methanolysis of PET waste. Adv Powder Technol 2023; 34: 104076. https://doi.org/10.1016/j.apt.2023.104076

[72] Yoshioka T, Okayama N, Okuwaki A. Kinetics of Hydrolysis of PET Powder in Nitric Acid by a Modified Shrinking-Core Model. Ind Eng Chem Res 1998; 37: 336–40. https://doi.org/10.1021/ie970459a

[73] Kao CY, Cheng WH, Wan BZ. Investigation of alkaline hydrolysis of polyethylene terephthalate by differential scanning calorimetry and thermogravimetric analysis. J Appl Polym Sci 1998; 70: 1939–45. https://doi.org/10.1002/(SICI)1097-4628(19981205)70:10<1939::AID-APP8>3.0.CO;2-G

[74] Achilias DS, Karayannidis GP. The chemical recycling of PET in the framework of sustainable development. Water, Air, Soil Pollut Focus 2004; 4: 385–96. https://doi.org/10.1023/B:WAFO.0000044812.47185.0f

[75] Paul Daniel Berger SL, Berger T (US); CH, Sugar Land T (US). Cess for Oil Recovery Using Mixed Surfactant Composition, 2007.

[76] Karayannidis GP, Achilias DS. Chemical recycling of poly(ethylene terephthalate). Macromol Mater Eng 2007; 292: 128–46. https://doi.org/10.1002/mame.200600341

[77] Yoshioka T, Sato T, Okuwaki A. Hydrolysis of waste PET by sulfuric acid at 150 ℃ for a chemical recycling. J Appl Polym Sci 1994; 52: 1353–5. https://doi.org/10.1002/app.1994.070520919

[78] George E. Brown, Jr., Cincinnati; Richard C. O'Brien, Dayton both of, Ohio. Method for recovering terephthalic acid and ethylene glycol from polyester materials. US39520053A, 1974.

[79] Carta D, Cao G, D'Angeli C. Chemical Recycling of Poly(ethylene terephthalate) (PET) by Hydrolysis and Glycolysis. Environ Sci Pollut Res 2003; 10: 390–4. https://doi.org/10.1065/espr2001.12.104.8

[80] Xie S, Dong H, Peng X, Chu PK. Non-precious Electrocatalysts for the Hydrogen Evolution Reaction. Innov Discov 2024; 1: 11. https://doi.org/10.53964/ID.2024011

[81] Zhao X, Li C, Wen J, Qiang Q, Shen Z, Yu H, et al. Catalytic refining lignin into toluene over atomically dispersed Cu/Ni dual sites. Nat Commun 2025; 16: 7967. https://doi.org/10.1038/s41467-025-63286-5

[82] Tamoor M, Samak NA, Jia Y, Mushtaq MU, Sher H, Bibi M, et al. Potential Use of Microbial Enzymes for the Conversion of Plastic Waste Into Value-Added Products: A Viable Solution. Front Microbiol 2021; 12. https://doi.org/10.3389/fmicb.2021.777727

[83] Mishra S, Goje AS, Zope VS. Chemical recycling, kinetics, and thermodynamics of poly (ethylene terephthalate) (PET) waste powder by nitric acid hydrolysis. Polym React Eng 2003; 11: 79–99. https://doi.org/10.1081/PRE-120018586

[84] Xi J, Ding D, Shao Y, Liu X, Lu G, Wang Y. Production of ethylene glycol and its monoether derivative from cellulose. ACS Sustain Chem Eng 2014; 2: 2355–62. https://doi.org/10.1021/SC500380C/SUPPL_FILE/SC500380C_SI_001.PDF

[85] Yang H, Hu P, Li Z, Hu C. Catalytic Conversion of Complex Reactant Systems Makes the World Greener, More Sustainable and Hopeful: Where and How to Go? Innov Discov 2024; 1: 8. https://doi.org/10.53964/ID.2024008