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Topic Insights

Green Chemical Engineering

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1. Introduction

Green chemical engineering is regarded as one of the most efficient means of achieving sustainable development in chemical industrial processes. It can be divided into two main categories:

- **Green product engineering.** Examples include the development of new catalysts and the development and use of renewable resources (e.g., solar energy and biomass).
- **Green process engineering.** This category includes process intensification, new reaction media, energy conservation, CO_2 emission reduction, novel reactors, new separation techniques, and so forth.

Promising approaches toward cleaner, more energy-efficient, and more cost-effective processes, including catalysts, reaction media, reactors, and separators, have been developed to meet the increasing needs of both society and the environment. This special issue on green chemical engineering covers the latest developments in green product engineering and green process engineering. The aim of this issue is to assist in proposing strategies to address the needs of the green chemical industries and in conducting further studies on new technologies and processes.

2. Green product engineering

Green product engineering refers to the engineering design, development, and transition to manufacturing of green chemical products, or to the manufacturing of products through green production manufacturing processes. Green product engineering usually entails dealing with issues related to cost, producibility, quality, performance, reliability, serviceability, intended lifespan, and user features.

For example, carbon dioxide (CO_2) emissions from human activities have continuously risen in recent years, and the hydrogenation of CO_2 is considered to be a promising route for the conversion of CO_2 into valuable chemicals and fuel. Current research focusing on high-performance catalysts for this process is reported in the article titled “Effects of potassium and manganese promoters on nitrogen-doped carbon nanotube-supported iron catalysts for CO_2 hydrogenation” by Kangvansura et al. Solar-powered CO_2-to-fuel conversion is another attractive method for mitigating CO_2 emissions and meeting the growing global energy demand; this process is addressed in “Harnessing the beneficial attributes of ceria and titania in a mixed-oxide support for nickel-catalyzed photothermal CO_2 methanation” by Kho et al.

Solar energy, as a clean, renewable, and abundant energy resource, is one of the most promising candidates to substitute for fossil fuels. Photocatalytic water splitting, which directly converts solar energy into hydrogen, is one of the most desirable solar-energy-conversion approaches. The article titled “Tantalum (oxy)nitride: Narrow bandgap photocatalysts for solar hydrogen generation” by Xiao et al. reviews the use of tantalum (oxy)nitride-based photocatalysts for photocatalytic water splitting, and describes how to better design these materials to further improve their water-reduction capability. Dang et al. present another example of a photocatalytic solar-to-fuel device in their article titled “Improved oxygen evolution kinetics and surface states passivation of Ni-B_i co-catalyst for a hematite photoanode.” This work describes the combinational surface kinetics enhancement and surface states passivation of a nickel-borate (Ni-B_i) co-catalyst for an Fe_2O_3 photoanode.

As the most important nanoporous materials, zeolites with intricate micropores have been widely applied in industrial catalytic processes. The use of organic templates in the hydrothermal synthesis of zeolites is environmentally unfriendly and costly, due to the formation of harmful gases and the pollution of water.

Research efforts into the production of alternative fuels from bioresources are underway, driven by the current irrational use of fossil fuels and the effects of greenhouse gases on the environment. In “A technological overview of biogas production from biowaste,” Achinas et al. review the issues of biogas production from lignocellulosic biowaste, the current problems and barriers affecting the different pathways, and potential issues and trends in biotechnological conversion performance.

Cadaverine is becoming an important industrial chemical, and exhibits broad prospects for various applications. In particular, it serves as a key monomer for bio-based polyamides. In “Advances in cadaverine bacterial production and its applications,” Ma et al. summarize recent findings on the biosynthesis, metabolism, and physiological function of cadaverine in bacteria; recent advances in cadaverine production; and the application of cadaverine in the synthesis of bio-based polyamides.

In another article, Wang et al. report on the “Facile and scalable preparation of fluorescent carbon dots for multifunctional applications.” Fluorescent carbon dots that are obtained via a one-pot reaction have been successfully used as internalized fluorescent probes for bioimaging and patterning, and exhibit a good prospect

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for solid-state fluorescent sensing, security labeling, and wearable optoelectronics.

3. Green process engineering

Green process engineering focuses on the design, operation, control, optimization, and intensification of chemical, physical, and biological processes for sustainable development. Researchers in this field strive to solve key scientific problems in resource-efficient conversion and process upgrades in order to create innovative and original technology platforms for the development of clean industrial processes.

Caprolactam, the monomer for the nylon-6 fiber and for engineering plastics, is an important basic organic chemical. A green caprolactam production technology has been successfully developed in China, and has a global market share that exceeds 50%. Zong et al. present a review of this technology in "Green production technology of the monomer of nylon-6: Caprolactam."

Photosynthetic microorganisms are important bioresources for the production of desirable and environmentally benign products, and photobioreactors play an important role in these processes. The article titled "Design of photobioreactors for mass cultivation of photosynthetic organisms" by Huang et al. presents a critical overview of the key parameters in photobioreactor design, which include light, mixing, mass transfer, temperature, pH, capital, and operating costs. Bioreactor lifespan and the costs of cleaning and temperature control are also analyzed in terms of commercial exploitation.

Wastewater treatment is a process that is vital for the protection of both the environment and human health. In "Fluidized-bed bioreactor applications for biological wastewater treatment: A review of research and developments," Nelson et al. summarize the circulating fluidized-bed bioreactor technology for treating wastewater. The excellent mixing and mass transfer characteristics that are inherent to fluidization make this process very effective in treating both municipal and industrial wastewater. In "Optimization, kinetics, and equilibrium studies on the removal of lead(II) from an aqueous solution using banana pseudostem as an adsorbent," Bagali et al. attempt to utilize banana pseudostem powder as an adsorbent material to remove lead(II) from an aqueous solution in a batch mode.

Municipal solid waste (MSW) has become a major environmental concern across the globe due to its huge volume and severe environmental pollution. The study titled "Thermodynamic analysis of the gasification of municipal solid waste" by Xu et al. reports the gasification performance of MSW by thermodynamic analysis for different types of MSWs across a large range of temperature and steam-to-MSW ratio.

Improving the efficiency of reaction and separation processes and reducing the energy consumption of such processes are essential to easing energy, resource, and environmental problems. In "Membrane engineering for green process engineering," Macedonio and Drioli present an overview of membrane applications and their perspectives in strategic industrial sectors such as water treatment, energy production, and raw materials extraction. Regarding more traditional crystallization processes, in "Recent developments in the crystallization process: Toward the pharmaceutical industry," Gao et al. review crystal engineering and crystallization process design and control, and present an overview of new types of crystals such as co-crystals, polymorphs, and solvates. Finally, in the review titled "Progress of pharmaceutical continuous crystallization," Zhang et al. thoroughly summarize the advantages and disadvantages of different types of continuous crystallization processes.