Advancements in Metal-Organic Frameworks for Gas Separation and Storage

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Description

In the quest for sustainable energy and environmental protection, the efficient separation and storage of gases play a pivotal role. Metal-organic Frameworks (MOFs), a class of porous materials composed of metal ions or clusters coordinated to organic ligands, have emerged as promising candidates for gas separation and storage applications. Recent developments in MOF design and synthesis have propelled their performance to new heights, offering solutions to pressing challenges in energy, industry, and environmental sustainability. One of the key advantages of MOFs lies in their high surface area and tenable pore structures, which enable exceptional gas adsorption capacities. Through rational design and functionalization, researchers have achieved remarkable improvements in gas uptake, surpassing the capabilities of traditional porous materials. For example, MOFs with open metal sites or specific functional groups exhibit enhanced affinity for gases such as hydrogen, methane, carbon dioxide, and volatile organic compounds, making them ideal candidates for gas storage and separation applications. MOFs also offer unparalleled selectivity in gas separation, allowing the efficient capture and purification of target gases from complex mixtures. By tailoring pore sizes, shapes, and surface chemistries, researchers can customize MOFs to preferentially adsorb specific gases while excluding others. This selective adsorption behaviour is exploited in processes such as natural gas purification, carbon capture and storage, and air separation, where MOFs demonstrate superior performance compared to traditional separation techniques. Recent advances in understanding the dynamic behaviour of MOFs have further expanded their utility in gas storage and separation. By harnessing concepts from supramolecular chemistry and host-guest interactions, researchers have developed stimuli-responsive MOFs capable of undergoing structural changes in response to external stimuli such as temperature, pressure, or chemical exposure. These "breathing" MOFs exhibit reversible phase transitions or pore opening/closure mechanisms, enabling dynamic control over gas sorption and release kinetics, with implications for gas storage, sensing, and controlled release applications. While the synthesis of MOFs with tailored properties has traditionally been conducted on a laboratory scale, recent advancements in scalable synthesis techniques and process optimization have paved the way for industrial-scale production. Continuous-flow synthesis, microwave-assisted methods, and post-synthetic modification strategies have enabled the rapid and cost-effective fabrication of MOFs with consistent quality and reproducibility. Moreover, advancements in characterization techniques and computational modelling have facilitated the rational design of MOFs optimized for specific industrial applications, accelerating their translation from the laboratory to commercialization. Despite the significant progress in MOF research for gas separation and storage, several challenges remain to be addressed. Issues such as MOF stability under operating conditions, scalability of synthesis methods, and economic viability pose hurdles to widespread adoption in industrial applications. Additionally, the development of MOFs with enhanced selectivity, durability, and recyclability is critical for addressing specific challenges in gas separation and storage, such as the removal of trace contaminants from industrial gas streams or the efficient storage of renewable energy sources like hydrogen and methane. Recent advancements in metal-organic frameworks have revolutionized the landscape of gas separation and storage, offering unprecedented opportunities for energy efficiency, environmental sustainability, and industrial innovation. Through strategic design, synthesis, and characterization, MOFs with tailored properties can address complex challenges in gas purification, carbon capture, and renewable energy storage. As research in this field continues to progress, the potential applications of MOFs in gas separation and storage are boundless, promising transformative solutions to global energy and environmental challenges. Title: Advancements in Gas Separation Frameworks Gas separation frameworks represent a cutting-edge solution to the pressing need for efficient gas purification and storage. These frameworks, exemplified by Metal-organic Frameworks (MOFs), offer customizable pore structures and surface chemistries that enable selective gas adsorption and separation.

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Conflict of Interest

We have no conflict of interests to disclose and the manuscript has been read and approved by all named authors.