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Carbon Capture and Storage Using Porous-Based Aerogel Materials

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Abstract : The global energy landscape heavily relies on the oil and gas industry, which faces the critical challenge of reducing its carbon footprint. To address this issue, the integration of advanced materials like aerogels has emerged as a promising solution to enhance sustainability and environmental performance within the industry. This study thoroughly examines the application of aerogel-based technologies in the oil and gas sector, focusing particularly on their role in carbon capture and storage (CCS) initiatives. Aerogels, known for their exceptional properties, such as high surface area, low density, and customizable pore structure, have garnered attention for their potential in various CCS strategies. The review delves into various fabrication techniques utilized in producing aerogel materials, including sol-gel, supercritical drying, and freeze-drying methods, to assess their suitability for specific industry applications. Beyond fabrication, the practicality of aerogel materials in critical areas such as flow assurance, enhanced oil recovery, and thermal insulation is explored. The analysis spans a wide range of applications, from potential use in pipelines and equipment to subsea installations, offering valuable insights into the real-world implementation of aerogels in the oil and gas sector. The paper also investigates the adsorption and storage capabilities of aerogel-based sorbents, showcasing their effectiveness in capturing and storing carbon dioxide (CO_2) molecules. Optimization of pore size distribution and surface chemistry is examined to enhance the affinity and selectivity of aerogels towards CO_2, thereby improving the efficiency and capacity of CCS systems. Additionally, the study explores the potential of aerogel-based membranes for separating and purifying CO_2 from oil and gas streams, emphasizing their role in the carbon capture and utilization (CCU) value chain in the industry. Emerging trends and future perspectives in integrating aerogel-based technologies within the oil and gas sector are also discussed, including the development of hybrid aerogel composites and advanced functional components to further enhance material performance and versatility. By synthesizing the latest advancements and future directions in aerogel used for CCS applications in the oil and gas industry, this review offers a comprehensive understanding of how these innovative materials can aid in transitioning towards a more sustainable and environmentally conscious energy landscape. The insights provided can assist in strategic decision-making, drive technology development, and foster collaborations among academia, industry, and policymakers to promote the widespread adoption of aerogel-based solutions in the oil and gas sector.

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