

Carbon Capture, Utilisation and Storage:
Opportunities, challenges and pathways to Net Zero

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**Advanced materials for Carbon Capture: Progress, challenges
and future directions towards industrial deployment**

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In the context of increasingly urgent climate challenges, carbon capture is widely recognised as a key enabling technology for achieving climate neutrality and supporting the decarbonisation of hard-to-abate industrial sectors. Over the last two decades, thousands of advanced porous materials have been developed for CO₂ capture. While these efforts have significantly expanded our understanding of structure-property relationships, large-scale deployment of carbon capture technologies based on advanced sorbents continues to face significant challenges. Beyond achieving high CO₂ uptake under ideal laboratory conditions, practical implementation requires addressing issues related to material stability, regeneration energy demand, resistance to contaminants, manufacturing scalability, cost effectiveness and environmental sustainability throughout the material life cycle. Increasingly, performance indicators such as working capacity under realistic operating conditions, adsorption kinetics, cyclic stability, tolerance to moisture and impurities, volumetric productivity, specific energy consumption for regeneration and overall capture costs are emerging as more relevant benchmarks than equilibrium adsorption capacity alone. At the same time, the growing number of newly reported adsorbents raises important questions regarding the balance between the discovery of novel materials and the optimisation and industrial translation of existing technologies. This contribution provides a critical overview of the current role of advanced materials across the carbon capture value chain, highlighting recent scientific and technological developments while discussing the major barriers that still hinder commercial deployment. Particular attention will be devoted to the evolving research priorities in the field and to the question of whether continued synthesis of increasingly complex materials alone is sufficient to accelerate CCUS implementation. The presentation will argue that future progress will increasingly depend on integrating materials innovation with process design, techno-economic assessment and sustainability considerations, thereby enabling a more effective transition from laboratory-scale discoveries to impactful carbon capture solutions.

Keywords: *CO₂ capture, advanced materials, process integration, industrial deployment*

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