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Moisture-Stable, Oxidation-Resistant Amino Acid-Based Solid Adsorbents for Direct Air Capture Applications

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Abstract

In the field of direct air capture (DAC) technologies, designed to selectively capture carbon dioxide (CO_2) from atmospheric air, efforts on adsorption-based separation strategies are being pursued worldwide, with early-stage commercialization already in progress. Compared to conventional absorption processes employing liquid-phase sorbents, solid adsorbent systems are generally recognized for their lower thermal energy demands during CO_2 regeneration.[1] To date, adsorption-based DAC systems have primarily employed solid adsorbents comprising polyamines and structurally analogous nitrogen-containing compounds, typically derived from fossil-based precursors and immobilized on porous inorganic supports. However, these amine-functionalized materials exhibit limited oxidative stability and are susceptible to degradation upon prolonged exposure to oxygen-rich gas streams such as ambient air or flue gas, leading to a gradual decline in CO_2 capture performance.

Moreover, growing emphasis on reducing the life cycle carbon footprint of DAC systems, including material production, deployment, recycling, and disposal, has driven increasing interest in adsorbents fabricated from renewable, non-fossil-based feedstocks.[2] Among such candidates, amino acid salts have emerged as promising CO_2-reactive materials.[3] Nonetheless, their high hygroscopicity and tendency to liquefy under humid conditions have precluded their practical application as solid-phase adsorbents. Consequently, these compounds have thus far been deployed primarily as aqueous absorbents in liquid-phase CO_2 capture systems.

In the present study, a series of amino acid-based adsorbents were developed, capable of maintaining their solid state under exposure to humid CO_2. Specifically, coordination polymers with amino acids as ligands were designed as supports, and various basic salts including amino acid alkali metal salts were immobilized onto the supports. Humid gas exposure and CO_2 adsorption tests (dew point: 20 °C, CO_2 concentration: 400 ppm, measurement temperature: 40 °C) revealed that certain amino acid-based coordination polymers prevent liquefaction under humid conditions and function effectively as CO_2 adsorbents. Accelerated degradation tests further demonstrated superior oxidative stability compared to conventional polyamine-based adsorbents.

References
[1]Zhu et al., *Chem. Soc. Rev.*, 2022, **51**, 6574; [2]Quan et al., *J. CO_2 Util.*, 2023, **68**, 102373; [3]Hatta et al., *Energies*, 2022, **15**, 3753.

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