Journal of Environmental Chemical Engineering 12 (2024) 111799

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

Bifunctional materials for integrated CO_2 capture and conversion: review on adsorbent and catalyst types, recent advances, and challenges

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A R T I C L E I N F O

Editor: Dong Yeun Koh

Keywords:
Carbon capture
Adsorption cycle
Solid adsorbents
Catalyst
Bifunctional materials
Adsorption selectivity

A B S T R A C T

In recent years, there has been a significant surge in the development of carbon dioxide (CO_2) emission reduction technologies aimed at mitigating the excessive release of CO_2 into the atmosphere. In this context, the adoption of integrated CO_2 capture and conversion (ICCC) technology stands out as one of the most promising approaches. This approach offers significant advantages in terms of energy savings and cost reduction with respect to the conventional carbon capture, utilization, and storage (CCUS) technology. The aim of this study is to present a comprehensive review of the various types of adsorbents and catalysts utilized in the synthesize of bifunctional materials (BFMs) tailored for high-performance ICCC processes. The first and second part analyze the various adsorbents and catalysts employed in CO_2 capture and conversion, respectively, focusing on their efficacy and the practical constraints arising from factors such as cost and regeneration ability of industrial implementation. Additionally, the detailed review of adsorbent and catalyst selection for the development of BFMs also has been conducted, as it has a significant impact on the performance of BFMs, including the efficiency of adsorption and catalytic activity. In the third section, the application of BFMs in various ICCC processes, highlighting their strengths and limitations have been reviewed comprehensively. Finally, the last section provides a review on the challenges and prospects of BFMs for ICCC. The review concludes with a comprehensive summary, accompanied by valuable recommendations to guide future research endeavors that focus on the advancement of BFMs within the context of ICCC.

1. Introduction

The global community is currently facing an urgent and challenging environmental issue concerning the reduction of atmospheric carbon dioxide (CO_2) concentrations, which is widely recognized as the primary anthropogenic greenhouse gas responsible for global warming and climate change. In the year 2021, the total amount of CO_2 emitted into the atmosphere is estimated to be around 36.3 gigatons (Gt), resulting in an atmospheric concentration of CO_2 of approximately 416 parts per million (ppm) [1,2]. The present concentration level demonstrates a relative rise of around 145% in comparison to the reported CO_2 concentration in the year 1850. The primary sources of greenhouse gas emissions include industry, transportation, electricity production, commercial and residential, agriculture, land use, and forestry. The Paris Agreement 2015, a legally binding international agreement on climate change, receives commitments from a total of 196 countries to take measures to reduce their greenhouse gas emissions [3]. The primary purpose of the Paris Agreement, which is the most significant global climate agreement to date, is to prevent the global average temperature from rising 2 °C above preindustrial levels and pursue efforts to keep it below 1.5 °C. To effectively mitigate this phenomenon and align with the climate objectives outlined in the Paris Agreement, it is necessary to take specific initiatives aimed at reforming the energy management system. By applying the best strategies like renewable fuel, energy efficiency, clinker substitution, and carbon capture and utilization (CCU), CO_2 emissions can be reduced.

CCU is a promising technique for reducing CO_2 emissions, as it offers practical advantages such as efficient CO_2 recycling and economic

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https://doi.org/10.1016/j.jece.2023.111799
Received 12 July 2023; Received in revised form 5 October 2023; Accepted 22 December 2023
Available online 29 December 2023