IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Modelling the design of dual functional adsorbents for inductively heated CO_2 TSA

Oliver Stratil*, Rafael Gonzalez-Olmos, Javier Fernandez-Garcia

Instituto Químico de Sarriá, Via Augusta 390, 08017 Barcelona, Spain

Abstract

The decarbonization of industrial processes requires efficient and sustainable carbon capture technologies. While post-combustion carbon capture with adsorption-based technologies is a well-established approach, its widespread implementation is hindered by the high energy demand for adsorbent regeneration [1]. Conventional thermal regeneration methods, often reliant on steam or externally supplied heat, pose challenges for integrating carbon capture with renewable energy sources. To address this, electrification of carbon capture adsorption processes has emerged as a promising strategy, enabling direct coupling with renewable electricity and allowing for more precise, rapid, and efficient energy delivery [2].

Among electrified regeneration methods, Induction-Heated Temperature Swing Adsorption (IH-TSA) offers a faster alternative to conventional TSA by generating heat directly within the adsorbent bed. This is achieved by creating Dual Functional Materials (DFMs), which serve then both as CO_2 adsorbents and induction heat susceptors. However, the introduction of a non-adsorbing magnetic susceptor, such as Fe_3O_4, reduces the effective adsorbent capacity, making DFM design a critical factor in optimizing performance.

To understand the impact of DFM design on adsorption and desorption performance, a mathematical model for CO_2 capture using zeolite 13X as the adsorbent and Fe_3O_4 as the magnetic susceptor was developed. Two DFM configurations were compared with identical bead radius, mass fractions, and energy input during desorption: (1) a homogeneous DFM (H-DFM) where zeolite 13X and Fe_3O_4 are uniformly mixed, and (2) a core-shell DFM (CS-DFM) where an Fe_3O_4 core is surrounded by a zeolite 13X shell.

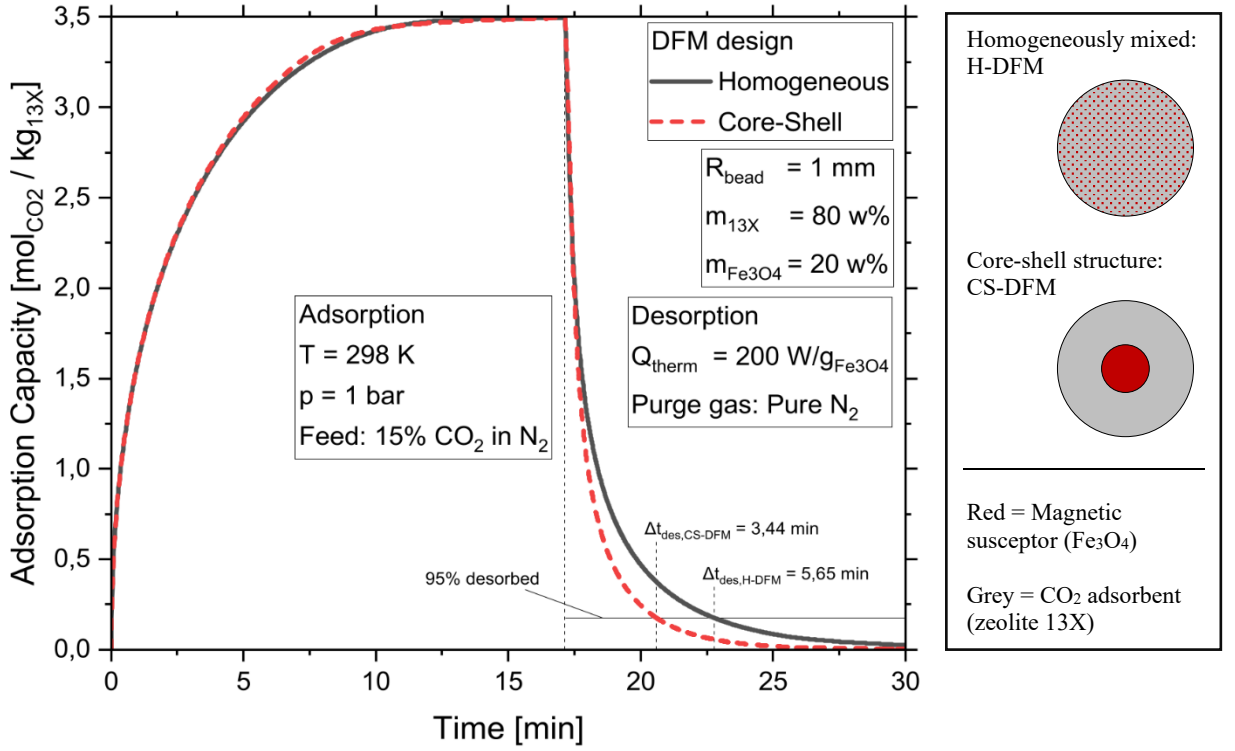

Figure 1: Modelled adsorption and desorption of a single bead of dual functional material (DFM) for induction heated CO_2 temperature swing adsorption. Two DFM designs are compared where the same masses of adsorbent (zeolite 13X) and the magnetic susceptor (Fe_3O_4) are either homogeneously distributed among each other (H-DFM) or separated in core-shell structure (CS-DFM) with a heating core and an adsorbing shell.

The results show that both configurations exhibit the same CO_2 adsorption time. This finding is based on the assumption that Fe_3O_4 does not interfere with zeolite 13X through pore blockage or similar, making the longer penetration depth in the H-DFM compared to CS-DFM a not-critical factor. However, during desorption, the CS-DFM achieves 95% desorption in just 3,44 minutes, whereas the H-DFM requires 5,65 minutes to reach the same level.

References:

[1] I. Campello Gómez, C. Gutiérrez, Desorption strategies in CO_2 capture technologies: Novel approaches and future perspectives, J Environ Chem Eng 13 (2025) 116109. https://doi.org/10.1016/j.jece.2025.116109.

[2] B. Verougstraete, M. Gholami, Y. Gomez-Rueda, E. Pérez-Botella, M. Schoukens, T.R.C. Van Assche, J.F.M. Denayer, Advancements and challenges in electric heating for enhanced temperature swing adsorption processes, Sep Purif Technol 353 (2025) 128522. https://doi.org/10.1016/j.seppur.2024.128522.

Keywords: Induction Heating; Temperature Swing Adsorption; Dual Functional Material; Material Design, Modelling