The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Mathijs Born**

The public defense will take place on **Monday 31st August 2026 at 6pm** in room **D.0.08** (Building D, VUB Main Campus)

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INTENSIFICATION OF ADSORPTION-BASED CARBON DIOXIDE CAPTURE: STRUCTURED ADSORBENTS, ELECTRIFICATION AND PROCESS OPTIMIZATION

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Abstract of the PhD research

The continuously growing global population and energy demand have driven carbon dioxide (CO_2) emissions to unprecedented levels. To mitigate global warming, a transition from fossil fuels towards sustainable energy sources is urgently needed. Furthermore, carbon capture and storage or utilization may play an important role in reducing CO_2 emissions. Adsorption has emerged as a promising technology for separation of CO_2 from industrial gas streams prior to storage or utilization. However, adsorption-based CO_2 separation processes must be further improved to enhance their energy efficiency and overall performance.

This doctoral thesis aims to advance adsorption processes for CO_2 capture from two point sources: post-combustion flue gases and CO_2/O_2 mixtures emerging from electrochemical processes for CO_2 capture and conversion. First, adsorbent materials and processes were evaluated for CO_2 separation from dry and humid gas mixtures, as the point source gas streams are typically saturated with water vapor. Experiments and simulations of adsorption processes demonstrate that a hydrophobic zeolite adsorbent can be used for efficient CO_2 separation without prior feed gas drying. Next, structured adsorbent laminates were explored as an alternative to pellets typically used in gas separations. Several advantages of such laminates were revealed, including a higher volumetric efficiency. Finally, desorption of CO_2 via electromagnetic induction heating of steel fibers embedded in structured adsorbents was investigated. The steel fiber-zeolite adsorbent composite material heats up rapidly, leading to extremely fast CO_2 desorption. The potential of this material was further highlighted by optimization of electrified adsorption processes.

Overall, this work studies intensification of adsorption-based CO_2 separation through process development, adsorbent structuring, and electrically driven desorption, supported by extensive experimental work, mathematical modeling, and process optimization to gain insight into the feasibility and performance limits of adsorption processes.