IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Low-grade Heat Driven Rapid Thermal and Pressure Swing Adsorption Gas Separation

Bruno Michel[a*], Paul Gantenbein[b], Dario van Oerle[b], ,
Ilia I. Sadykov[c], Sandra Galmarini[c], Xavier Daguenet[b†]

[a]IBM Research Zurich, 8803 Rüschlikon, Switzerland
[b]Ostschweizer Fachhochschule (OST), 8640 Rapperswil, Switzerland
[c]Empa, Dübendorf, 8600, ZH, Switzerland

Abstract

A post combustion capture rapid thermal and pressure swing adsorption column with coated finned tube heat and mass exchanger stacks is demonstrated. Temperature cycling driven by low-grade heat <95°C combined with pump down during desorption maximizes rates and energy efficiency of CO_2 capture from flue gas. Low temperature of desorption enables the utilization of the waste heat and significantly reduces the final cost of post combustion CO_2 capture. A small-scale temperature jump system was used for materials characterization, and several columns with increasing dimensions reaching kg scale were built and characterized.

Keywords: gas separation, rapid thermal swing, vacuum / sub-atmospheric swing, solid sorbents, heat exchangers, heat transfer, mass transfer.

Carbon Capture and Storage (CCS) is a key task for reducing greenhouse gas emissions by capturing carbon dioxide (CO_2) from point sources like power plants before it reaches the atmosphere. Scaleup of CCS technologies is hampered by high operational costs due to the significant energy required for steam to regenerate liquid amines and solid sorbents while the plant rejects lower-grade waste heat. A system capable of replacing steam with this waste heat could thus substantially reduce CO_2 capture costs. Use of low-grade heat for rapid thermal swing adsorption (RTSA) was successfully demonstrated for heat driven heat pumps and more recently also for carbon capture [1]. Reduced mass transport and thermal resistance and combining fast temperature and pressure swings - called rapid temperature pressure swing adsorption (RTPSA) - increased cyclic sorption capacity. Solid sorbents are promising for gas separation, but packed bed configurations suffer from high pressure drop and low thermal efficiency.

These challenges are addressed by post-combustion capture columns based on Aluminum finned tube heat and mass exchanger (HEX-MEX) coated with e.g. zeolite layers, enhancing thermal and mass transport performance and overall system efficiency. The study explores the integration of HEX-MEX Columns to enhance the thermal performance and cycle efficiency of rapid thermal and pressure swing (RTPSA) processes. The combined RTPSA system enlarges cycled mass (Mc) and speeds up the kinetics to values inaccessible by systems with pressure or temperature swing alone. The modular HEX-MEX stacks integrated in a gas separation measurement setup (Fig. 1) can run on waste heat while using pump-down of pure product CO_2 and are optimized for high gas flow rates, and

* E-mail address: bruno.michel.bmi@bluewin.ch (Bruno Michel)
† E-Mail address: xavier.daguenet@ost.ch (Xavier Daguenet)

short cycles on minutes scale.

Figure 1. Flue gas separation column with inlet/outlet header flanges.

The columns with zeolite sorbent-coated fins demonstrate a very good selectivity to CO_2 (out of dry N_2 + CO_2 mixtures, Fig. 2) and allow significant improvements in energy efficiency and adsorption capacity compared to conventional packed bed or liquid amine systems. This research presents a promising pathway for optimizing industrial gas separation, CO_2 capture, and other energy-intensive applications.

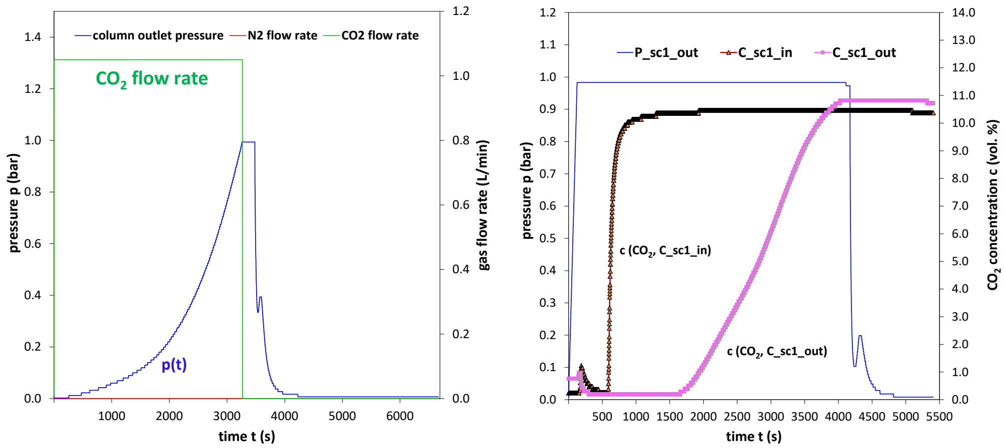

Figure 2. CO_2 single gas adsorption curve – column pressure as a function of time – for selectivity tests in the column B (left) and CO_2 breakthrough curve – CO_2 concentration as a function of time at the OUTLET (C_sc1_out) – in a mixed gas measurement of the column B (right). The mixed gas INLET flow rate in column B was 5 L/min, the gas composition N_2 + 10 vol.% CO_2 and the pressure was 1 bar (constant).

References:

[1] Piccoli, E. and Gantenbein, P. and Galmarini, S. and Ruch, P. and Michel, B., "Low-Grade Heat Driven Rapid Thermal Swing Adsorption Gas Separation" (Nov. 10, 2022). Proc. of the 16th Greenhouse Gas Control Technologies Conference (GHGT-16) 23-24 Oct 2022; http://dx.doi.org/10.2139/ssrn.4274156.