CO_2 Capture by Solid Adsorbents
: Lowering the Energy Input for Social Implementation

Nobutaka Maeda
Center for Energy System Design (CESD)
International Institute for Carbon-Neutral Energy Research (WPI-I2CNER)
Kyushu University
maeda.nobutaka.118@m.kyushu-u.ac.jp

Abstract

Extreme weather events associated with the climate change caution that our descendants will never enjoy the same environment on the Earth as we do now unless any actions are taken. The social implementation of CO_2 capturing technologies is, therefore, the centre of public attention. A major reason why solid adsorbents are not readily put into practical use is its high energy input for material regeneration operated at 85-120 °C.[1] This energy corresponds to ca. 80 % of the entire CO_2 capturing process. Hence, the price of CO_2 captured by direct air capture (DAC) is estimated to be 500-1000 USD per ton. This estimate is tremendously far from the market price (<100 USD per ton).

In this seminar, I will be talking about our recent attempt to lower the regeneration temperature of supported polyethylenimine (PEI) down to 35-70 °C. There are three strategies discovered: (1) combination of PEI with ionic liquid,[2] (2) utilisation of linear PEI with secondary amines,[1] (3) controlling the electron density of nitrogen lone pairs of PEI by functionalisation.[3] The strategy (3) can even control the regeneration temperature between 35-70 °C by the degree of functionalisation and enables the isothermal operation of adsorption and desorption cycles. The low-temperature regeneration is a necessary prerequisite for realising the isothermal operation by exploiting off-gas heat or waste heat available in industries. The newly developed adsorbents together with the isothermal operation has a potential to cut the energy input of CO_2 capturing system by 80 %. I also briefly introduce a collaborative work with the Cologne Business School and a start-up company in Germany for DAC.[4] In general, DAC requires high-powered fans for air to be drawn into a processing facility. In addition to the newly developed adsorbents, we are proposing further reduction of energy input by incorporating DAC into heating, ventilation, and air conditioning (HVAC) systems. The novel concept, HVAC-DAC coupling, utilises existing equipment such as ventilation systems for recirculating indoor air. This concept allows removing CO_2 from indoor air and provides purified air back into building's environments. Our energy analysis suggests a CO_2-separation potential of 26.69 tons/year and an energy saving potential of 23.28 MWh/year. The saved energy by the HVAC-DAC coupling system corresponds to 60 % of the energy demand of separated HVAC and DAC systems.

References

[1] J. Hack, N. Maeda, D. Meier, "Review on CO_2 Capture Using Amine-Functionalized Materials", *ACS Omega*, 7 (2022) 39520-39530

[2] F. Weisshar, A. Gau, J. Hack, N. Maeda, D. Meier, "Toward Carbon Dioxide Capture from the Atmosphere: Lowering the Regeneration Temperature of Polyethylenimine-Based Adsorbents by Ionic Liquid", *Energy & Fuels*, **35** (2021) 9059-9062.

[3] N. Maeda, D. Meier, F. Weisshar, J. Hack, J. Gnehm, A. Elkaz, "Sorbent Materials for Carbon Dioxide Separation", EU Patent, (2023) EP4289503.

[4] L. Baus, S. Nehr, N. Maeda, "Investigation of CO_2-Sorption Characteristics of Readily Available Solid Materials for Indoor Direct Air Capturing", *Indoor Air*, **2023** (2023) Article ID: 8821044.