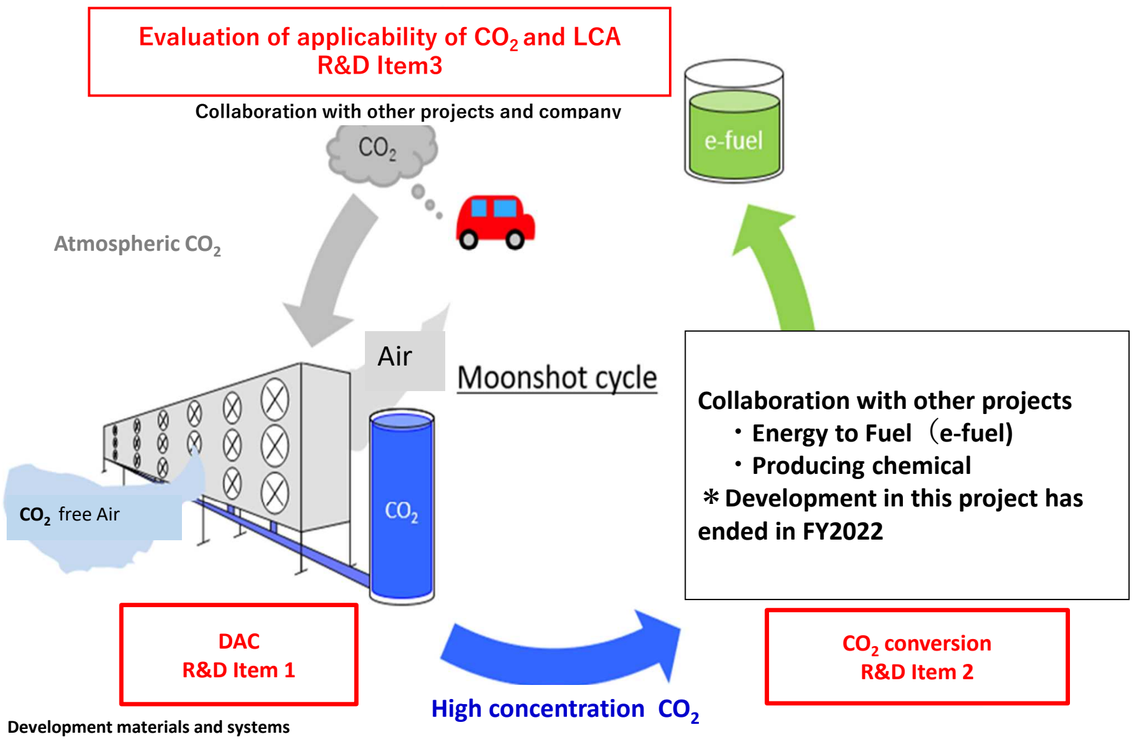
No. : A-1-1E
PJ: Development of Highly Efficient Direct Air Capture (DAC) and Carbon Recycling Technologies
Theme: For realization of Carbon recycling society
Organization: Kanazawa University/RITE
Contact: Kanazawa University (akodama@se.kanazawa-u.ac.jp) /RITE (yogo@rite.or.jp)

【Duration】 FY2020～FY2029
【R&D Items】
1. Development of high-efficient CO2 Direct Air Capture technology from the atmosphere
→Applying RITE Sorbent
3. Evaluation of applicability of CO2 and LCA → Collaboration with other projects and company
* Item 2. Development of CO2 conversion technology for carbon recycling into valuable resources has been ended in FY2022

【Overview of R&D】

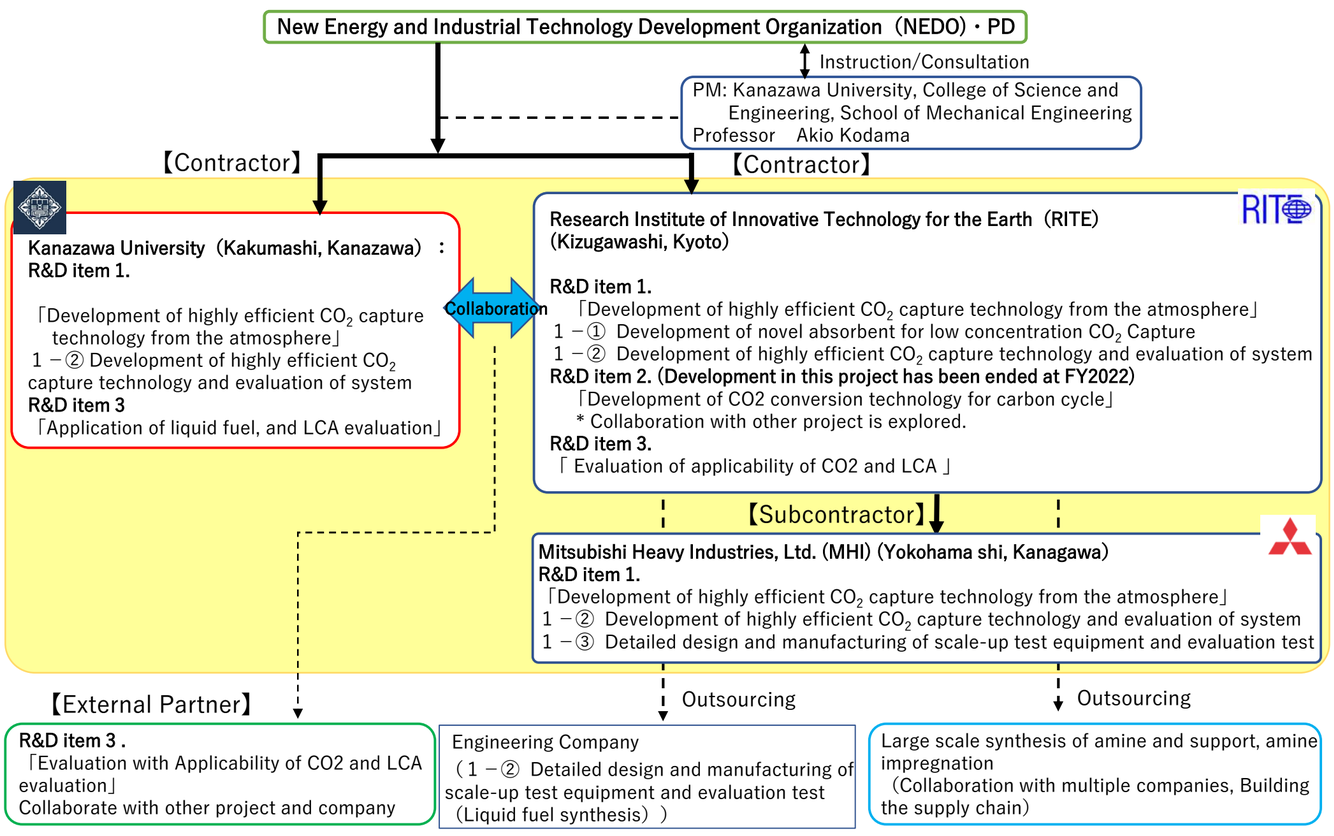


【Schedule】

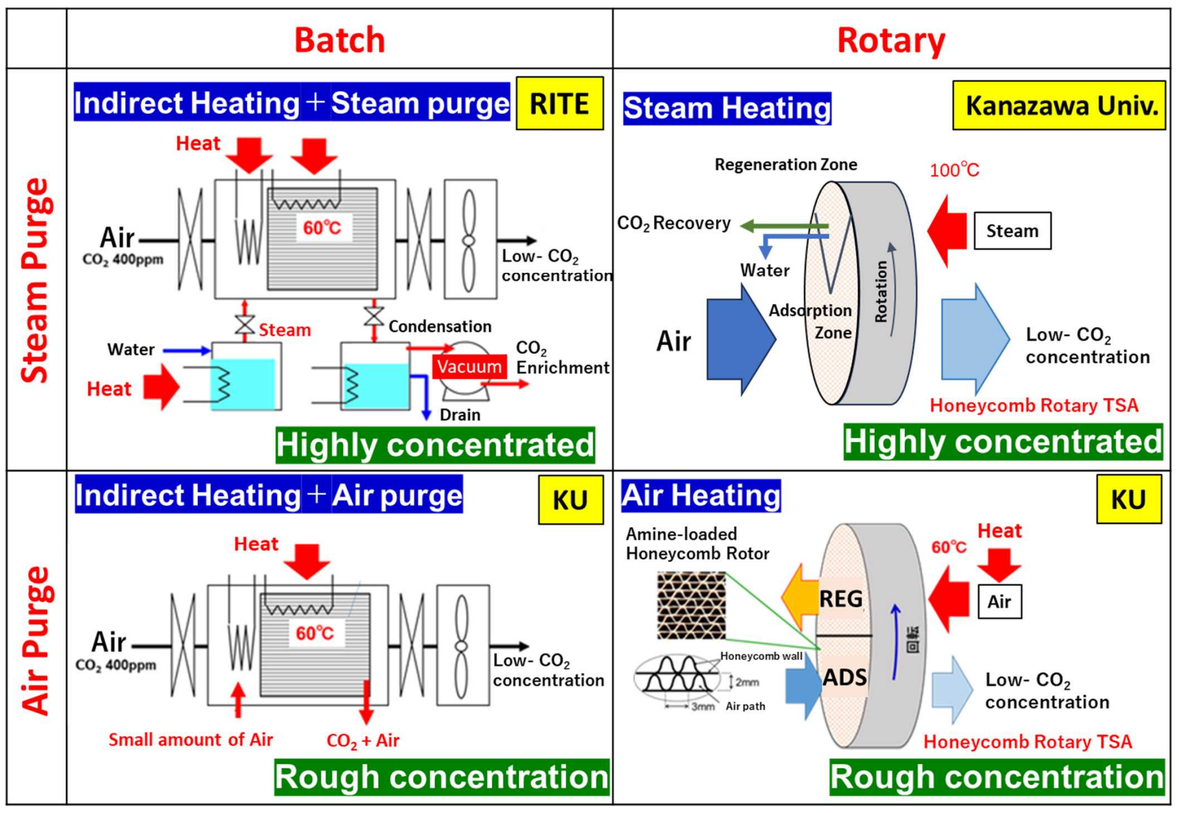
Upper: DAC Technology
Lower: Evaluation of Applicability of CO_2 and LCA

Item \ Fiscal year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Material development・Simulation for DAC (RITE)	New material screening・Lab test		Optimization of preparation method			Improvement of material, production method, and performance (Development of a highly durable material for the air-recovery)				
	Development of simulator (Proposing optimized processes)			Modification of simulator (Improving accuracy)		Simulation（optimization of operation condition）				
Process development (Air-purge) (Honeycomb Rotary with Steam purge) Kanazawa Univ.	Development of air-purge type DAC (Indirect heating, Honeycomb rotary)					Development of an effective DAC system based on LCA evaluation (Air regeneration and indirect heating type applied for air conditioning, improvement of steam regeneration honeycomb rotary type)				
				Honeycomb Rotary with steam purge						
				Design & Test		Improvement	Scale-up test		long-term demonstration	
Process examination (Steam-recovery) Test equipment at RITE	reorganization	design・manufacturing	Performance confirmation	Improvement・design						
Bench scale test					Manufacturing construction	Demonstration	Relocation			
Pilot scale test							Improvement・design	Manufacturing construction	Long-term demonstration	Disassembly
Evaluation of Applicability of CO2 and LCA			preparation	LCA evaluation					Evaluation of Applicability of CO2 and LCA	
Development of membranes and membrane reactors (RITE) ＊Development has been ended in FY2022	Membrane synthesis									
	Manufacturing MR (Lab)	Lab test		Collaboration with other projects is explored						

【System of research and development】

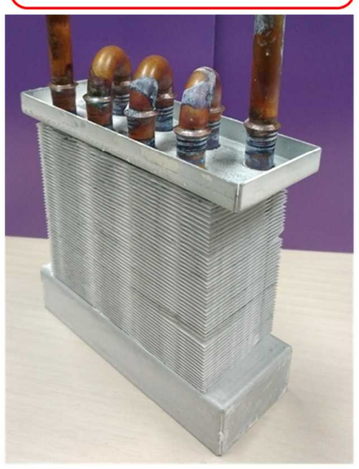


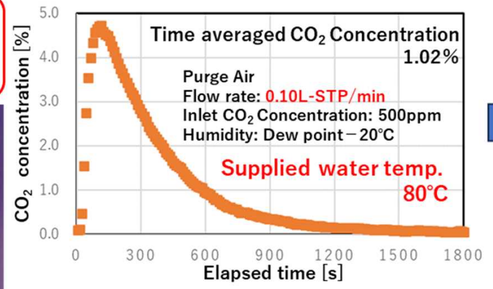
【 “Batch or Rotary Cycle” x “Steam or Air Purge”】



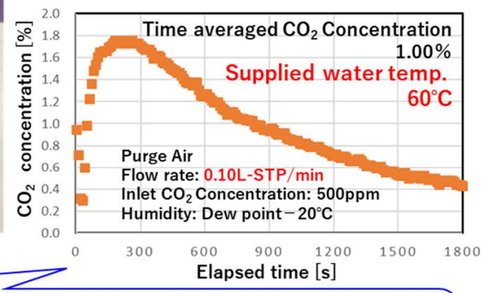
【Indirect Heating with Air purge(Kanazawa University)】

Amine coated Heat Exchanger



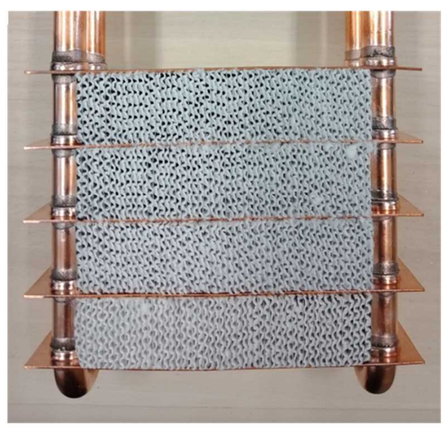


Regeneration outlet CO_2 concentration



Test at a requested air flow rate in actual use

An indirect heating adsorption unit as an alternative to "coating"

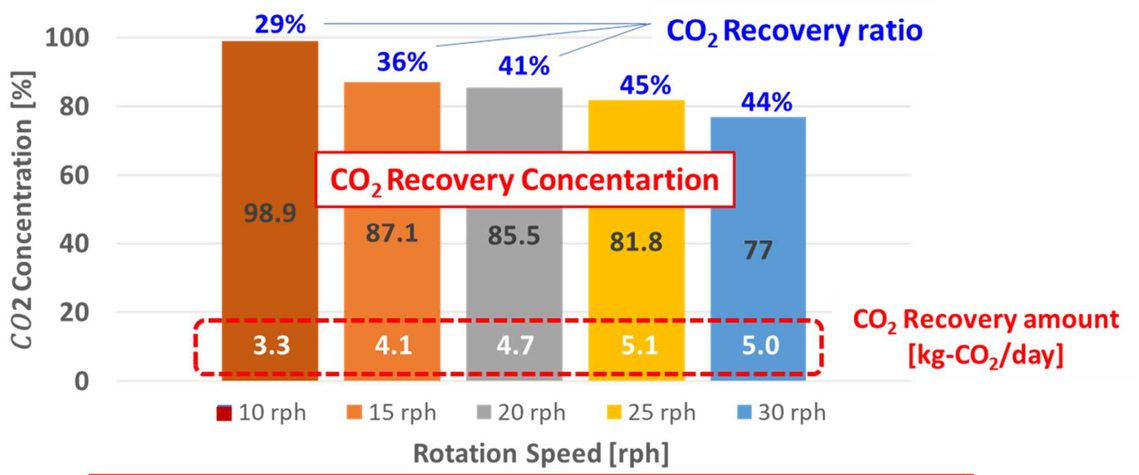


CO_2 concentration averages about 1% (20x enrichment) at regeneration temperatures of 60°C to 80°C, reaching 5% momentarily at 80°C regeneration.

【Honeycomb Rotary + Steam(Kanazawa University)】

【Experimental condition】
Air flow rate = 600m³/h
(superficial air velocity = 2.6m/s)
Air temperature, humidity, CO2 concentration and Steam supply = Not controlled

【Amine loaded Honeycomb Rotor】
diameter 320mm x thickness 50mm
(Effective diameter: 300mm)



Optimization of equipment and operation
⇒ Both CO_2 recovery concentration and recovery ratio at high values

Demonstrated that CO_2 in air can be highly concentrated with a relatively simple equipment configuration, although 100°C steam is required.

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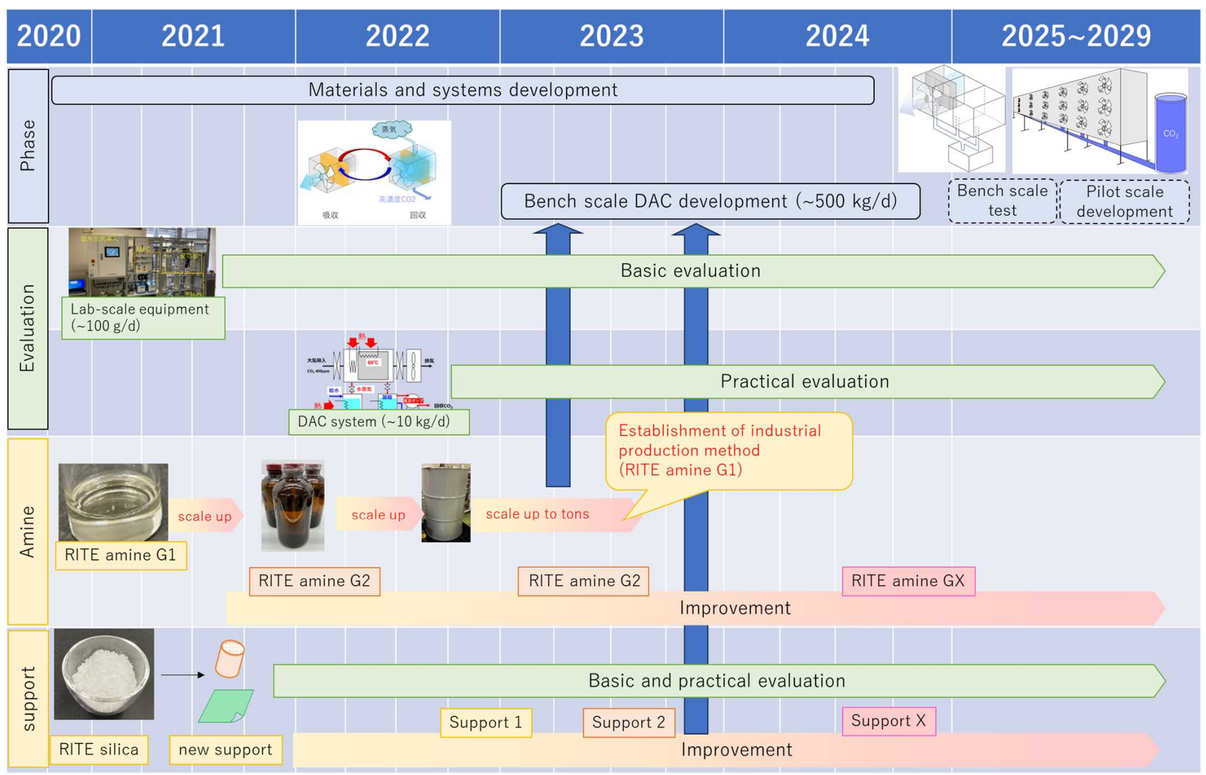
•DAC(Direct Air Capture) technology development: We are conducting development of a new solid sorbent materials consisting of new amine and support structure for low-concentration CO2 capture from the air and developing high-efficient process with low energy.
•In order to conduct a demonstration test using our bench-scale DAC (max 500 kg/d) at the Expo 2025 Osaka, we are promoting the design and fabrication of the machine and developing RITE-amine impregnated solid sorbent. The basic design of the demonstration machine is being conducted by Mitsubishi Heavy Industries, Ltd.

【Development of new amines and porous supports】

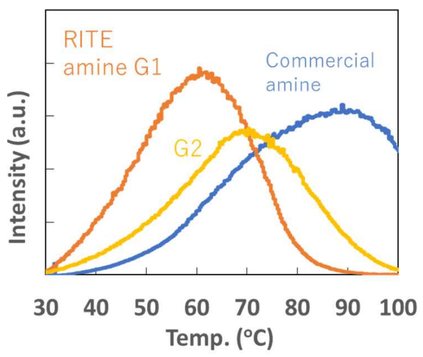


【Feature of RITE amines】

Comparison of commercial and RITE amines

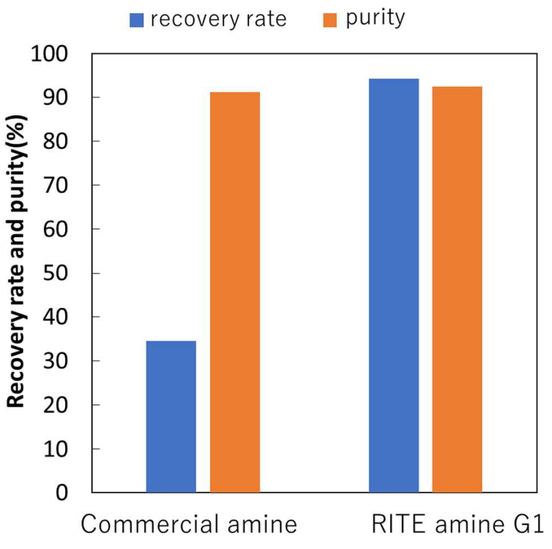
	Commercial amine	RITE amine G1	RITE amine G2
Desorption temp.	90°C	60°C	70°C
Absorption amount	high	low	middle
Oxidative degradation resistance	×	○	◎

Desorption peak of each amines



Oxidative resistance

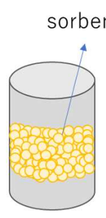
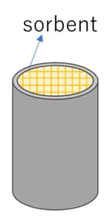
Desorption performance using low pressure steam (60°C)



RITE amine G1 : CO_2 can be desorbed at 60°C, under optimization
RITE amine G2~ : New amines improving each performance, under development

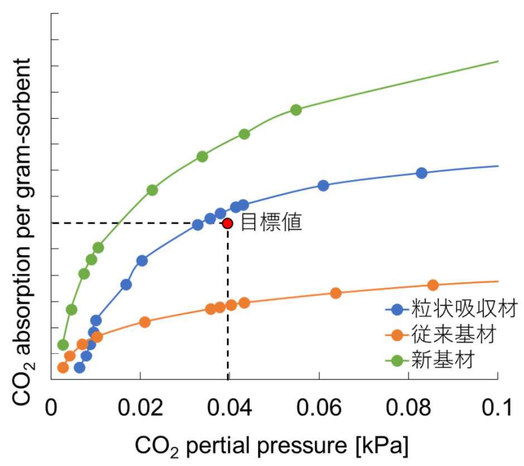
【Evaluation of RITE amine G1 impregnated sorbents】

Structures and features

Beads	Honeycomb	New structure
		Completely different shape and material
・Highly packing ・Large capacity for CO_2 absorption ・High pressure drop	・Superior CO2-amine contact ・Low pressure drop ・Small absorption amount	・Highly packing ・Large capacity for CO_2 absorption ・Low pressure drop (depend on structure)

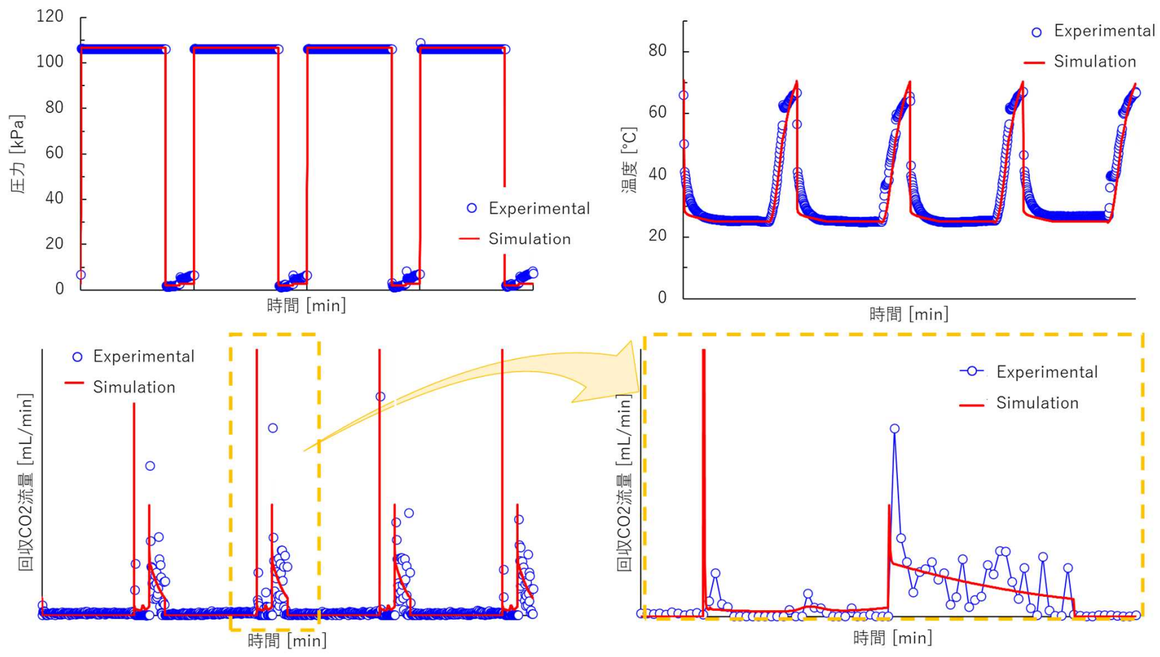
・ Under development of porous supports with different materials and structures

CO2 absorption isotherm
Temp. : 20°C



・New structured sorbent is shown the performance far exceeds target values

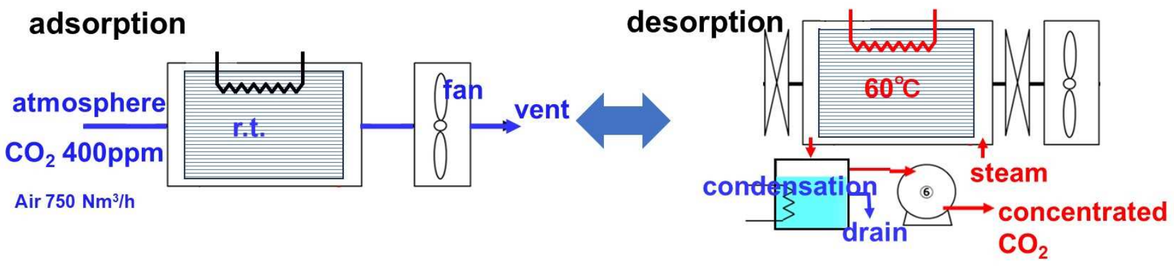
【Prediction of cyclic behavior using simulation】

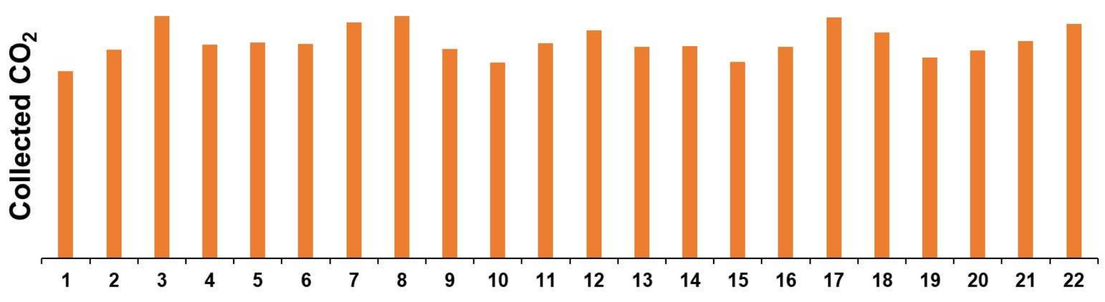


RITE simulation can accurately predict the cyclic behavior of the new structured sorbent.

【Cycle test in DAC experimental facility equipment】

Cycle tests using RITE amine-loaded conventional honeycomb



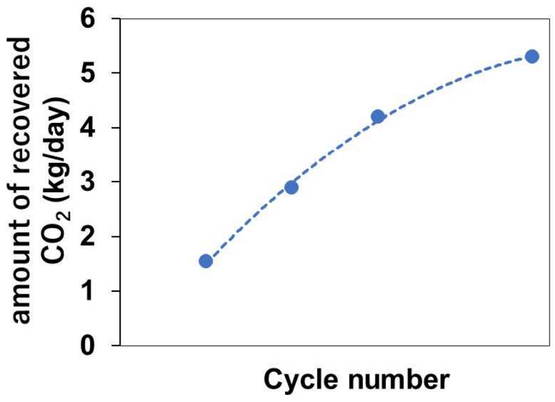


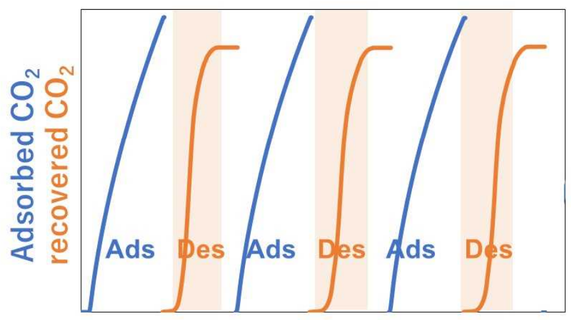
・ CO_2 concentration > 95%
・ amount of CO_2 collected ~ av. 3 kg/day

【Improvement of substrate for faster cycles】

Improvement of adsorbent substrate

①Increasing adsorption capacity
②Improving heat conductivity
③Increasing adsorption rate
⇒Increase in the number of cycles and the amount of recovered CO_2 per day





By improving adsorbent substrate, amount of recovered CO_2 increased up to 5 kg/day.