Chemical Research Group

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Challenges Associated with Advancing the Industrialization of CO_2 Capture and Utilization Technologies

1. Introduction

RITE is working towards achieving the technical breakthroughs needed for the practical application and industrialization of various technologies related to CO_2 capture and utilization (CCU) at an early-stage. The current research topics of RITE are described below.

2. Technologies for CO_2 capture and utilization

In October 2020, Japan declared that it aims to achieve carbon neutrality by 2050, and in December 2020 (with detailed planning in June 2021), it formulated the “Green Growth Strategy through Achieving Carbon Neutrality in 2050,” and various initiatives to combat global warming are being promoted in multiple sectors. In May 2024, the "Act on Carbon Dioxide Storage Business" (CCS Business Act) was enacted, marking a significant step toward realizing the CCS roadmap, which sets ambitious targets for annual CO_2 storage: 6 to 12 million tons per year by 2030 and 120 to 240 million tons per year by 2050. Under this legislation, nine domestic advanced CCS projects have been selected to spearhead the development of business models encompassing the entire CCS value chain—from CO_2 capture and transportation to storage.

To achieve carbon neutrality, it is essential to implement technologies that can reduce the atmospheric CO_2 concentration—known as negative emission technologies. Of these technologies, Direct Air Capture (DAC), which directly captures CO_2 from the atmosphere, is garnering significant attention. In July 2021, Japan's Ministry of Economy, Trade and Industry revised the "Carbon Recycling Technology Roadmap" to include DAC as a newly advancing technological field. Efforts in carbon management—encompassing Carbon Dioxide Removal (CDR) and Carbon Capture, Utilization, and Storage (CCUS)—are intensifying, with a focus on the recycling and reduction of CO_2. As large-scale DAC projects are progressing overseas, Japan has been conducting various R&D initiatives for DAC technologies since 2020 under the "Moonshot R&D Program." Some of these DAC technologies are being showcased at Expo 2025 Osaka, Kansai.

In 2024, RITE made a significant move in the demonstration of DAC technology at Expo 2025 Osaka, Kansai. Developed under the "Moonshot R&D Program" by the New Energy and Industrial Technology Development Organization (NEDO), a DAC demonstration unit equipped with advanced solid absorbents is actively capturing CO_2 from the atmosphere at Expo 2025 Osaka, Kansai. This exhibition showcases RITE's cutting-edge DAC technology to visitors from Japan and around the world.

Funded by NEDO's program "Establish a common base for evaluating the standards of CO_2 separation materials," RITE Carbon Capture Center (RCCC) was established in February 2025. RCCC is Japan's first actual real gas test center for carbon capture, and it aims to support the acceleration of the development and commercialization of domestic CO_2 capture materials. Furthermore, RITE is the only Japanese member of the International Test Center Network (ITCN), a global coalition dedicated to advancing carbon capture technologies. Through its participation in ITCN, RITE actively works on the construction of an international network and announces to the global Carbon Capture community the activities of the RITE Carbon Capture Center that is contributing to the standardization of CO_2 capture technologies.

RITE is dedicated to developing and commercializing CO_2 capture technologies and providing world-leading R&D results with a special focus on chemical absorption, solid sorbent, and membrane separation. For chemical absorption, high-performance chemical solvent was developed and commercialized under the "COURSE50" project (Environmentally Harmonized Steelmaking Process Technology Development) commissioned by NEDO. The application of chemical absorption is expected to broaden within advanced CCS initiatives. Concurrently, R&D efforts are underway to develop new absorbents based on a mixed solvent system.

For solid sorbent, a pilot-scale CO_2 capture demonstration test using solid sorbents with excellent CO_2 desorption performance at low temperatures, was conducted under a NEDO funded project in collaboration with private companies and using actual flue gas from a coal-fired power plant. Efforts are also underway to apply the solid sorbents to flue gas from natural gas-fired power plants, which contain lower concentrations of CO_2. The R&D is ongoing for solid sorbents that not only allow low-temperature regeneration but also exhibit high resistance to oxidative degradation.

Membrane separation was advanced for processes including high-pressure gas separation (CO_2/H_2), the Integrated Coal Gasification Combined Cycle (IGCC) process and H_2 production plants. Beginning in 2024, a new NEDO-funded project was launched to support a demonstration trial of a compact, medium-pressure hydrogen production system equipped with a membrane-based CO_2 capture process.

Also, RITE is engaged in the R&D of CO_2 utilization technology, for example, using membrane reactors equipped with dehydration membranes to convert CO_2 into methanol. Since 2021, we have been conducting a

NEDO-funded project named "Development of Optimum Systems for Methanol Synthesis Using CO_2" in collaboration with private companies to synthesize methanol by reacting CO_2 from steel plants with hydrogen.

Furthermore, efforts for CO_2 fixation that utilizes the calcium and magnesium contained in industrial waste and similar materials to convert CO_2 from flue gas into high-purity calcium carbonate are underway in collaboration with private companies.

3. Technology for capturing CO_2 from the atmosphere

NEDO's Moonshot R&D Program was launched in FY 2020 as one of the systems to support the action plan of the Environment Innovation Strategy, which aims to establish technologies that enable Beyond Zero by 2050.

RITE is working to develop technologies for high-efficiency CO_2 capture from the atmosphere and carbon circulation in cooperation with Kanazawa University and Mitsubishi Heavy Industries, Ltd., as part of (1) Development of technologies to capture, convert, and detoxify greenhouse gases in Goal 4 "Realization of sustainable resource circulation to recover the global environment by 2050."

The technology for capturing CO_2 directly from the atmosphere is called Direct Air Capture (DAC), and combining it with storage is expected to be one of the negative emission technologies. Six other industrial DAC projects are also underway.

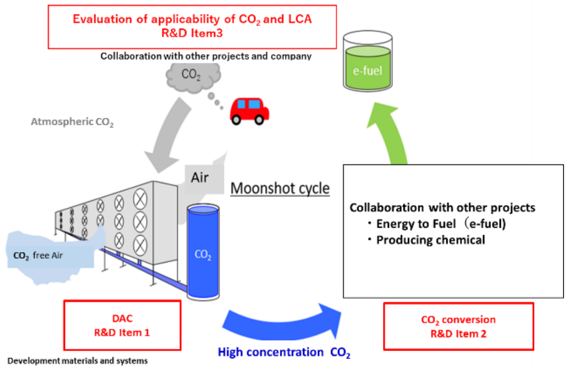


Fig. 1. Development of highly efficient DAC and carbon recycling technologies

RITE is developing new amines suitable for DAC and structured solid sorbents that show low-pressure drops at a high flow rate and low energy consumption in CO_2 desorption. The fundamental properties of both amines and structured sorbents are collected using lab testing equipment (Fig. 2), the CO_2 capture performance of real-sized sorbents is evaluated using DAC system evaluation equipment (Fig. 3, designed by Mitsubishi Heavy Industry Co., Ltd., and built on the RITE premises), and improved sorbent structure and optimized operation conditions are predicted by process simulation. In FY2024, a pilot-scale demonstration test on a scale of up to 0.5 t-CO_2/day was conducted at the Osaka-Kansai Expo site, which opened in April 2025, with the cooperation of Mitsubishi Heavy Industries, Ltd. (Fig. 4).

Fig. 2. Lab test equipment for DAC

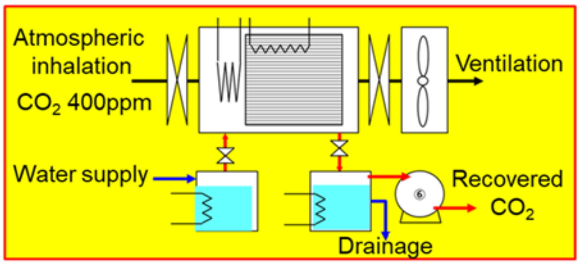


Fig. 3. DAC system evaluation equipment schematic image (upper) and DAC experimental laboratory on the RITE premises (lower)

Fig. 4. Pilot-scale demonstration test equipment installed at the Osaka-Kansai Expo site

The recovered CO_2 will be fed to the methanation facility of Osaka Gas Co. The synthesized methane will be used in the kitchen of guest house. This is the first attempt in Japan to demonstrate effective utilization on such a scale.

4. Common evaluation standard for CO_2 capture materials

In order to move toward decarbonization, fuel and energy sources in both the power and industrial sectors are shifting to renewable energy sources, but a certain amount of fossil-fuel-based thermal power generation remains to meet electricity demand, and CO_2 emissions are inevitable. Therefore, it is necessary to develop low-energy-consumption and low-cost technologies for CO_2 capture from low-pressure and low-concentration mixed gas, for example, a natural gas combustion gas of 10% or less with relatively low CO_2 concentrations.

Since 2022, RITE has been conducting the NEDO Green Innovation Fund Project for the establishment of a common evaluation standard for CO_2 capture materials in collaboration with the National Institute of Advanced Industrial Science and Technology (AIST). Along with the vision of realizing a carbon neutral society, a common base for CO_2 capture materials will be established, and it will support the enhancement of the global share of domestic companies in the expanded CO_2 capture market.

The project is scheduled for the nine years from 2022 to 2030 (the first stage: 2022–2024) and will carry out the following R&D objectives: (a) formulation of standard evaluation methods using actual gas (installation and operation of RCCC), (b) establishment of standard evaluation methods for the development of innovative capture materials, (c) development of durability evaluation methods, and (d) database construction and popularization of the standard evaluation methods.

RITE formulated standard performance evaluation methods using actual gas and developed a test center (RCCC) in the first stage up to FY 2024 in order to evaluate CO_2 capture materials under the flue gas conditions of power plants and boilers. RCCC was constructed at the RITE headquarters site in Kyoto. Three different test facilities for absorption, adsorption, and membrane processes are installed there, and a natural gas combustion boiler is the source of the actual flue gas (Fig. 5). The test facilities for adsorption (PSA) and membrane processes were installed and preparation for evaluating CO_2 capture materials was completed in FY 2024.

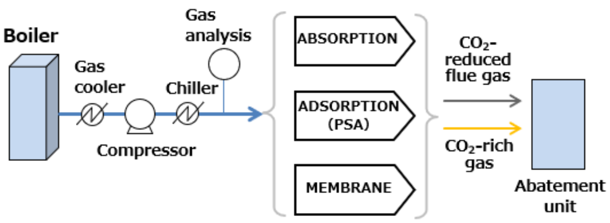


Fig. 5. Overview of RCCC test facilities

(Each unit capacity: –100 kg-CO_2/day)

The second phase that will continue until FY2028 was approved upon recognizing the successful achievements of the previous three years based on the results of the stage gate review in January 2025. The test facility for the absorption process will be installed by June 2025 after which operation will start, and another adsorption process (TSA) and single-membrane test facilities will be planned in the first half of the 2nd phase of the project.

In recent years, in the development of CO_2 capture materials for carbon neutrality, test centers for CO_2 capture technologies have been established throughout the world, but such a test center was not organized in Japan. Through the activities at RCCC, we exchange opinions on a CO_2 capture test center with domestic companies in the project and built cooperative relationships with overseas organizations, especially with the International Test Center Network (ITCN) members. RITE provided the first real gas test center in Japan, and it is used by companies and institutions involved in the development of CO_2 capture materials. The test center will contribute to the promotion of domestic CO_2 capture materials development so that Japan will continue to be the world's top operator of CO_2 capture technologies.

5. Solid sorbent method for CO_2 capture

Unlike a chemical absorbent where amines are dissolved in a solvent, such as water, a solid sorbent is one where the amines are supported on a porous material, such as silica or activated carbon (Fig. 6). In the process of using a solid sorbent, a reduction of the CO_2 capture energy can be expected because the heat of vaporization and sensible heat caused by the solvent can be suppressed.

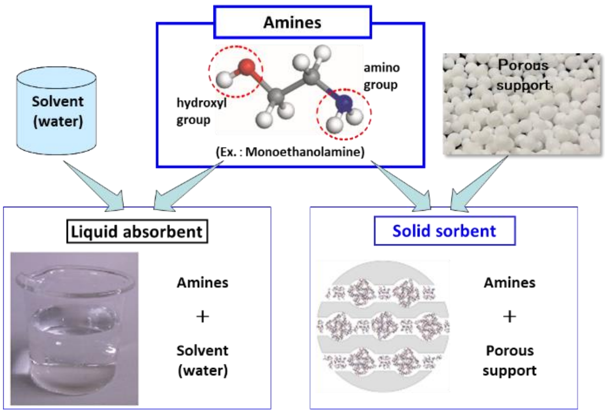


Fig. 6. Liquid absorbent and solid sorbent

1) For coal-fired power plants

RITE has been developing solid sorbent materials since 2010, mainly for CO_2 capture from the combustion exhaust gas of coal-fired power plants.

In the fundamental research phase (FY2010-FY2014), we developed an innovative solid absorbent that can utilize low-temperature exhaust heat of 60°C, and in the practical application research phase (FY2015-FY2019) in which we partnered with Kawasaki Heavy Industries, Ltd. (KHI), scale-up synthesis of solid absorbent (>10 m^3), bench scale testing (>5 t-CO_2/day), and real-gas exposure testing at a coal-fired power plant were conducted.

In the NEDO-commissioned project that began in 2020, KHI constructed the pilot scale test facility (40t-CO2/day scale) at the Maizuru Power Plant in cooperation with Kansai Electric Power Co., Inc. from the second half of 2023, we started CO_2 capture tests from the flue gas of the combustion exhaust gas from coal-fired power plants using solid sorbent supplied by RITE (Fig. 7).

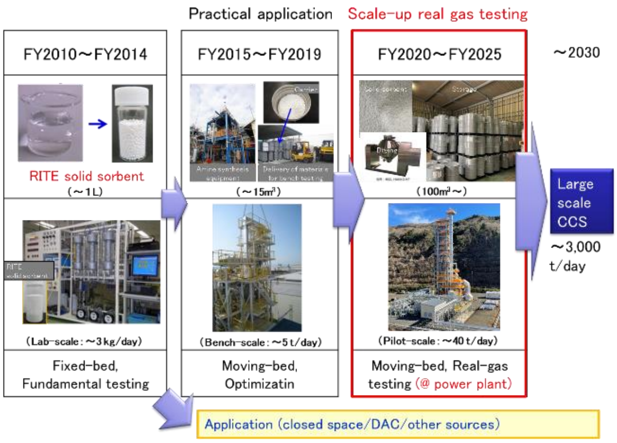


Fig. 7. Development roadmap of the solid sorbent method for CO_2 capture

We are working on elucidating the mechanism of material degradation and developing technologies to prevent degradation, developing technologies to reuse the materials used, and examining handling methods through long-term storage tests, in which we checked the materials periodically for three years after their manufacture and found no abnormalities. Furthermore, we are also working on examining efficient operating conditions using process simulation technology, and have developed a simulator that can predict the amount of CO_2 captured and the energy required for separation and capture with high accuracy in KHI's moving bed system (Fig. 8).

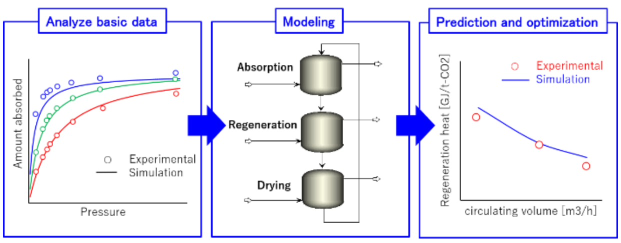


Fig. 8. RITE's simulation technology

In the pilot test, we plan to use this simulation technology to examine optimal operating conditions. Simulations are also useful for understanding the adsorption and desorption behavior inside the equipment, which is difficult to observe in reality, and the calculation results are also being used in material development.

2) For natural gas-fired power plants

In 2022, the Technology Development Project of CO_2 Separation and Capture in the Green Innovation Fund project started jointly with Chiyoda Corporation (organizer company) and JERA in order to commercialize low-cost CO_2 separation and capture processes from natural gas combustion exhaust gas.

The CO_2 concentration contained in natural gas combustion exhaust gas is around 4%, which is lower than the CO_2 concentration in coal combustion exhaust gas (around 13%), and the oxygen concentration is as high as about 10%. Therefore, solid sorbent materials with high CO_2 absorption performance even at low CO_2 concentrations and high durability against oxidation are required. RITE is in charge of the development of amines based on the knowledge and technology accumulated during the R&D histories in this field, in addition to the development of solid sorbent materials composed of developed amines and optimal support.

RITE passed the stage-gate review in the 3Q of FY2024 by developing a new solid sorbent (Fig. 9), which can change the CO_2 absorption amount significantly with slight temperature changes. As a result, our project was going to move forward from the basic research phase to the bench testing phase.

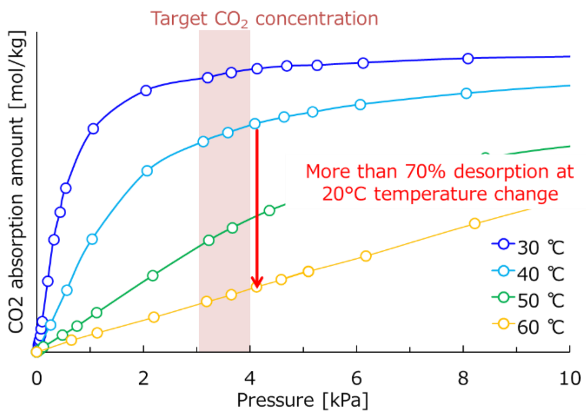


Fig. 9. Absorption isotherms of the developed solid sorbent

The developed new solid sorbent is characterized not only by its ability to be regenerated at low temperatures, but also by its extremely high resistance to oxidative degradation, which makes it applicable to natural gas-fired power plant exhaust gases with relatively high oxygen concentrations. In addition, large scale productivity was confirmed with the aid of chemical manufacturers this year. Further improvements of the solid sorbent will be conducted for bench testing.

6. Chemical absorption method for CO_2 capture

In the absorption method, CO_2 is separated by using the selective dissolution of CO_2 from a mixed gas into a solvent. In particular, the chemical absorption method based on the chemical reaction between amine and CO_2 in a solvent can be applied to gases with a relatively low CO_2 concentration, such as combustion exhaust gas, and the method is one of the most mature CO_2 capture technologies developed.

In the COCS project (METI's Subsidy Project) and the COURSE50 project (NEDO consignment project), RITE has been working to develop a high-performance amine solvent that reduces the cost of CO_2 capture. The chemical absorbent and process created by the COURSE50 project were adopted by the energy-saving CO_2 capture facility ESCAP® of Nippon Steel Engineering Co., Ltd. (Fig. 10).

Fig. 10. Equipment of energy-saving CO_2 absorption process ESCAP® at Niihama Nishi Power Station, Sumitomo Joint Electric Power Co., Ltd.
(This is the second commercial plant and it produces CO_2 for chemical production.)

Although the chemical absorption method for CO_2 capture is mature, in order to accelerate CCUS, we still have to overcome the technological issues of cost reduction and practical implementation. In particular, R&D to decrease the energy consumption in the solvent regeneration process and the enhancement of amine durability for stable long-term operation are required.

In COURSE50, we also demonstrated a new technological concept with the possibility of further reducing energy consumption by using the absorption solvent with an organic compound instead of water (Fig. 11). We call the new technology *mixed solvent*, and it can control the reaction mechanism of CO_2 absorption and the effect of polarization.

Since 2022, we have been working to develop novel compounds and optimal formulations of the mixed solvents for practical use under the NEDO Green Innovation Fund Project for the development of hydrogen reduction technology using blast furnaces. In the first half of 2024, bench-scale plant tests were conducted at the

Kimitsu Steelworks of Nippon Steel Corporation. The new high-performance mixed solvents developed by RITE successfully performed CO_2 capture from actual blast furnace gas.

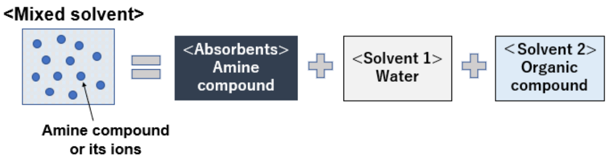
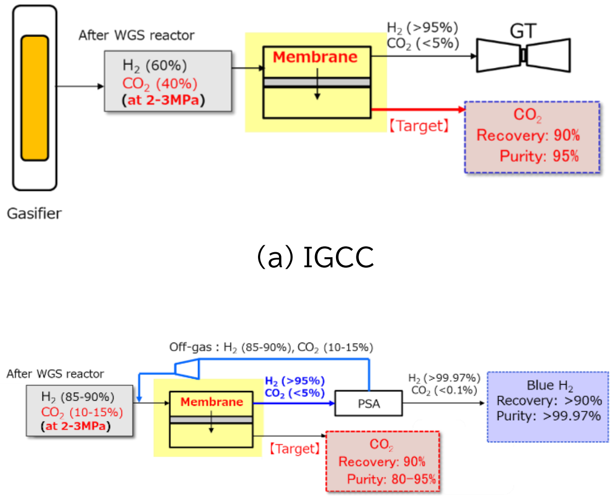


Fig. 11. Concept of mixed solvent

7. Membrane separation

CO_2 separation by membranes involves the selective permeation of CO_2 from the pressure difference between the feed side and the permeate side of the membrane. As such, CO_2 capture at low cost and low energy is expected by applying the membrane processes to pre-combustion (Fig. 12). For this reason, we are currently developing novel CO_2 selective membrane modules that effectively separate CO_2 for precombustion.



(a) IGCC

(b) Hydrogen production plant

Fig. 12. Schematic of the IGCC and hydrogen production plant with CO_2 capture by CO_2 selective membrane modules

We found that novel polymeric membranes composed of dendrimer/polymer hybrid materials (termed molecular gate membranes) exhibited excellent CO_2/H_2 separation performance. Fig. 13 presents a schematic that summarizes the working principles of a molecular gate membrane.

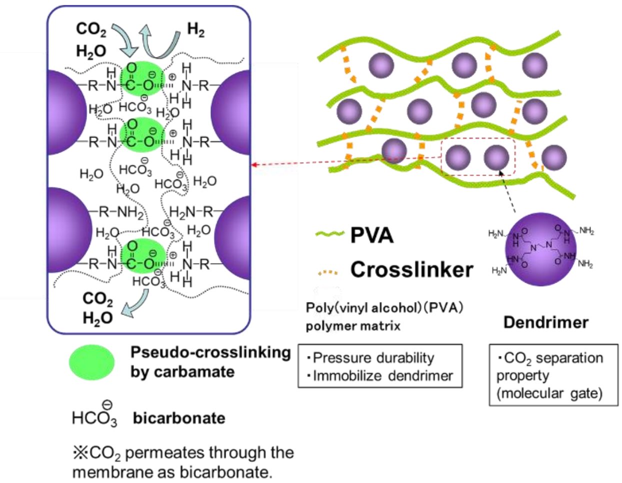


Fig. 13. Schematic illustration of the working principles of the molecular gate membrane

Under humidified conditions, CO_2 reacts with the amino groups in the membrane to form either carbamate or bicarbonate, which then blocks the passage of H_2. Consequently, the amount of H_2 diffusing to the other side of the membrane is greatly reduced, and high concentrations of CO_2 can be obtained. A poly (vinyl alcohol) (PVA) polymer matrix is used for pressure durability and to immobilize the dendrimers.

We developed new types of molecular gate membranes that provide superior separation of the CO_2/H_2 gas mixtures. Based on this work, the Molecular Gate Membrane Module Technology Research Association (MGMTRA consists of the Research Institute of Innovative Technology for the Earth [RITE] and Sumitomo Chemical Co., Ltd.) is conducting research in new membranes, membrane elements, and membrane separation systems.

As for the development of membrane materials, we modified the membrane materials for a new application (small-scale, medium pressure hydrogen production equipment). As a result, separation performance under medium pressure was improved as shown in Fig. 14.

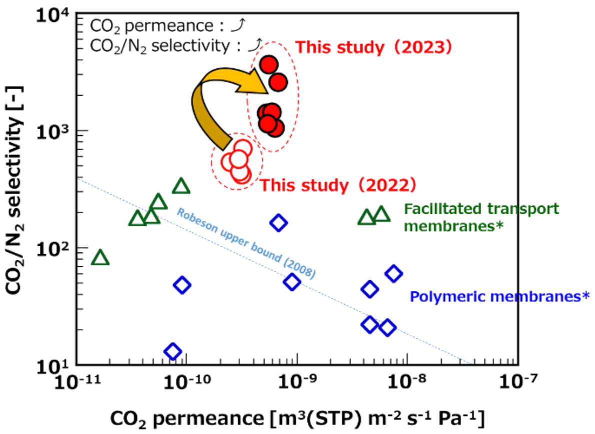


Fig. 14. CO_2/N_2 Separation performance of MGM membranes

Operating conditions of molecular gate membranes: temperature 85°C, total pressure 0.85 MPa, feed gas composition CO_2/N_2=20/80.

*Reference: Kamio et al., *J Chem Eng Jpn* 56 (2023) 2222000.

By modifying membrane materials, both CO_2 permeance and CO_2/N_2 selectivity increased compared with our previous modified membranes (in 2022). The separation performance required to apply the membranes for use with hydrogen production equipment was obtained.

As for the development of the membrane elements, we succeeded in developing commercial-size membrane elements (ϕ = 20 cm, L = 60 cm) (Fig. 15).

As of FY 2024, we have started a project in collaboration with Mitsubishi Kakoki Kaisha, Ltd., a hydrogen production system manufacturer, which aimed to conduct demonstration testing of a hydrogen production system with CO_2 capture, under the NEDO-funded project "Development of Technologies for Carbon Recycling and Next-Generation Thermal Power Generation / R&D of CO_2 separation/capture technologies / R&D for Practical Application of CO_2 Separation Membrane Systems / Study on the Applicability of High-Performance CO_2 Separation Membranes to Hydrogen Production Systems."

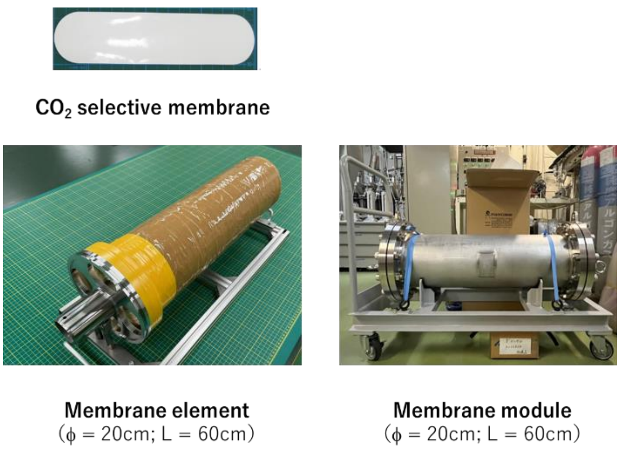


Fig. 15. CO_2 selective membrane, membrane element, and membrane module

Membrane element: Structure with a large membrane area composed of a membrane, support, and spacer

Membrane module: Structure in which the membrane element is placed

8. Effective methanol synthesis from CO_2 hydrogenation

Carbon dioxide (CO_2) is one of the causes of global warming; therefore, significantly reducing it is a critical global challenge and special importance is attached to Carbon Capture and Utilization (CCU) technologies. However, CO_2 hydrogenation as one of the utilization technologies produces water that causes deactivation of the catalyst and decreases the reaction rate. In order to solve this problem, we shed light on methanol synthesis using CO_2 as the raw material using a membrane reactor that combines the membrane and the catalyst.

RITE has successfully developed a dehydration membrane (Si-rich LTA membrane) with high hydrothermal stability and permeation separation performance, and has experimentally demonstrated that a laboratory-scale methanol synthesis membrane reactor using the new dehydration membrane has a CO_2 conversion rate three times higher than that of a conventional catalyst packed bed reactor. We have been experimentally demonstrating that the CO_2 conversion rate of a laboratory-scale methanol synthesis membrane reactor using the new dehydration membrane is three times higher than that of a conventional catalyst-packed layer reactor. Currently, we are studying the possibility of extending the length of the developed dehydration membrane under the NEDO project "Development of Technologies for Carbon Recycling and Next Generation Thermal Power Generation / Development of Technologies for CO_2 Emission Reduction and Effective Utilization / Development of Technologies for CO_2 Utilization in Chemical Products / Development of Optimal Systems for Methanol Synthesis Using CO_2." In this study, we have succeeded in synthesizing a practical-length dehydration membrane with relatively high permeation separation performance and achieved the target values (H_2O permeability: 1 x 10^{-6} mol m^{-2} s^{-1} Pa^{-1}, H_2O/MeOH selectivity: >1,050) in the reaction temperature range for methanol synthesis.

In FY2024, we focused on improving the reproducibility, confirming hydrothermal stability (durability), and further improving the permeation separation performance of dehydration membranes of practical length (1,000 mm), which show high permeation separation performance. In improving reproducibility, we have succeeded in increasing the yield by improving the synthesis method. In addition, the improved synthesis method resulted in a smaller performance distribution in the longitudinal direction, and we were able to establish a high-performance and highly reproducible method for synthesizing long dehydrated membranes. Fig. 16 summarizes the performance distribution of the long-dehydrated membrane in the longitudinal direction. The coefficient of variation on the vertical axis is calculated from the standard deviation and mean of the permeation separation performance of a sample of 1,000 mm long dehydrated membrane cut into 100 mm pieces, and is smaller as the performance distribution is smaller. Durability tests using cut samples (100 mm) of the obtained long dehydration membranes were conducted to confirm the hydrothermal stability of the dehydration membranes before and after the synthesis method improvement. The results showed that the improved membrane maintained its crystallinity for 500 h, suggesting that it has hydrothermal stability. As mentioned above, the synthesis conditions of the dehydration membrane with high performance have been established in a reproducible manner, and the membrane is steadily progressing toward practical application step by step.

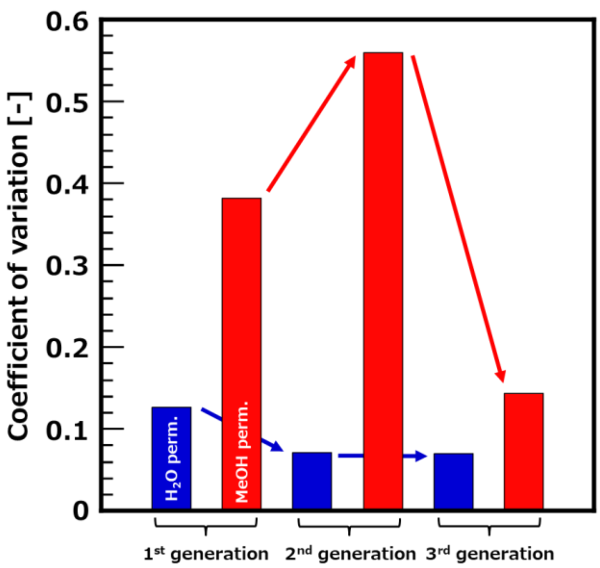


Fig. 16. Performance distribution of long-scale membranes with respect to the longitudinal direction

In the future, we aim to commercialize the developed dehydration membrane with a practical length, and to further improve the permeation separation performance (especially improvement of Si/Al), we will investigate the conditions for synthesizing dehydration membranes on various types of supports.

9. He recovery membrane

RITE has been developing silica membranes for hydrogen separation and has succeeded in producing various silica membranes that can permeate hydrogen produced from a variety of different reactions, including dehydrogenation of methylcyclohexane (MCH), one of the hydrogen carriers. The silica membrane was formed using the counter diffusion chemical vapor deposition (CVD) method (Fig. 17). Oxygen was supplied from inside of the porous support, and a silica source was fed to outside of that. When the pores are filled with silica, the reaction occurs preferentially in the unfilled areas, allowing for the reproducible formation of silica membrane with relatively high performance.

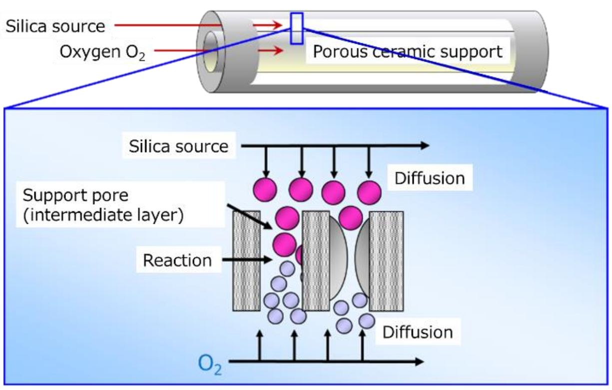


Fig. 17. Schematic diagram of counter-diffusion CVD method

Recently, the global helium crisis has become an issue, and it is important to find a way to secure sources of helium. Considering energy conservation, a method of recovering helium using a membrane separation method that does not involve a phase change is considered the best option. The smallest molecular size of helium is 0.26 nm, and other small molecules are H_2: 0.29 nm, CO_2: 0. 33 nm, N_2: 0.36 nm, and CH_4: 0.38 nm. The silica membranes for hydrogen separation developed at RITE are considered to be sufficiently applicable to helium separation. Currently, we are studying the development of longer silica membranes for helium separation under the NEDO Leading Research Program / Leading Research Program for the Creation of New Industry and Innovative Technology / Development of Highly Efficient Helium Membrane Separation and Recovery Technology in Nonflammable Gas Fields entrusted by the Japan Fine Ceramics Center (JFCC).

10. CO_2 fixation

CO_2 mineralization is an elemental technology of 'enhanced weathering', a negative emission technology in which CO_2 is reacted with alkaline earth metals and immobilized as chemically stable carbonates.

RITE has a proprietary process that has been developed over many years to immobilize CO_2 as carbonate, and since 2020, in collaboration with private companies, RITE has been developing technology to extract alkaline earth metals from steel slag, concrete waste, etc. in a wet process to recover CO_2 emitted from factories, etc. as stable compounds of carbonate (Fig. 18).

Presently, we are working on process optimization of reaction temperature, reaction time, etc., and are currently studying the commercialization of this process, including scaling up.

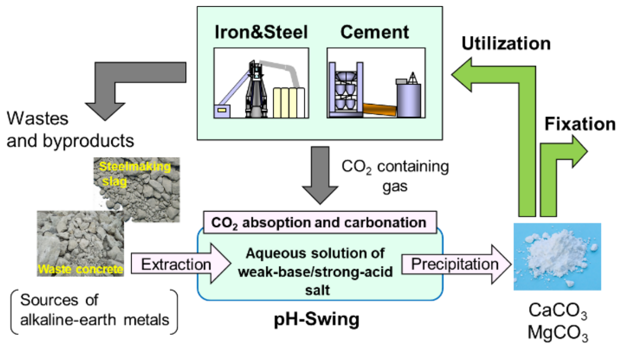


Fig. 18. CO_2 fixation as carbonates

11. Activities and efforts toward commercialization and industrialization

The core of the Industrial Collaboration Division is the Industrialization Strategy Council, which includes a total of 43 private companies (as of April 2025) and the Fine Ceramics Center, Inc., as a special member.

From FY 2023, activities were expanded to promote the following projects with the aim of establishing technologies for CO_2 separation and effective utilization that will contribute to innovative environmental and energy technologies. We are promoting a variety of activities, which include the following:

【General Activities】

(1) Sponsorship of research meetings

(2) Free seminars for members only

(3) Dissemination of information on needs and seeds and hot topics to members

(4) Sponsorship of symposiums

【Individual Activities】

(1) Plans for joint implementation projects funded by the government and NEDO

(2) Acceptance of researchers from council members to the Research Section of the RITE and the implementation of training workshops

(3) Offers for technical guidance from the RITE Advisory Board and Research Section

(4) Hosting of exclusive technology seminars for council members

In FY 2024, two research group activities were launched: the CO_2 Separation and Recovery Research Group and the Membrane Reactor Research Group.

In the CO_2 Separation Study Group, RITE presented the latest trends in CO_2 separation mainly from overseas conferences and survey visits, as well as information on RCCC.

In the Membrane Reactor Group, RITE provided information on effective CO2 utilization using membrane reactors and on supports for separation membranes, and one of the private companies of the research group presented the manufacturing supports for separation membranes. The above two research groups ended in FY 2024, and a new research group has been launched in FY 2025 to broaden the scope to CO2 separation and effective utilization.

The members-only free seminars were held three times at a venue and online. Researchers from universities and private companies gave lectures on the latest R&D trends and case studies on CO_2 capture and effective utilization, and active Q&A sessions took place.

In addition, we conducted patent and literature searches related to the information presented at the lectures and sent out *needs and seeds information* once with comments from RITE researchers, and *hot topics* once with academic conferences and overseas visits by RITE members, thus contributing to the promotion of technological development and improvement of knowledge of the members.

Two member companies participated in poster presentations at the Symposium on Innovative CO_2 Capture and Effective Utilization held in February 2025.

12. Conclusion

RITE will continue to advance the R&D of CO_2 capture technologies targeting various emission sources. We will actively address the challenges within each process/application, and for those technologies that are closer to the commercialization stage, we will focus on scaling up and conducting real-gas tests to demonstrate these technologies at an early stage and facilitate their societal implementation. There is a need to further develop technologies that can also address low-concentration CO_2 emission sources. We will also dedicate efforts to negative emission technologies, such as Direct Air Capture with Carbon Storage (DACCS), which are expected to make significant contributions to sustainable development scenarios aimed at decarbonization. As CO_2 concentrations decrease, the volume of gas that needs to be processed increases, and since the oxygen concentration is higher, the development of low-cost, durable materials and corresponding system designs will become increasingly important. We will accelerate these developments to enable the early societal implementation of CO_2 capture technologies that are more energy-efficient and cost-effective.

The RITE Carbon Capture Center (RCCC) will be operated as a facility capable of acquiring reliable, fair and neutral real-gas testing data. Starting within the duration of the Green Innovation Fund project, the center will begin accepting external materials/samples and providing fair and neutral test data to domestic CO_2 capture material developers. Additionally, to ensure the continuation of the center's operations after the project, the acceptance of external samples will help cultivate the management of RCCC. Meanwhile, through presentations at ITCN and international conferences, RITE will share the test data with international audiences, promoting the global recognition of the standard evaluation methods established by RCCC.

Through these activities, we are committed to contributing to the further advancement of domestic CO_2 capture technologies.