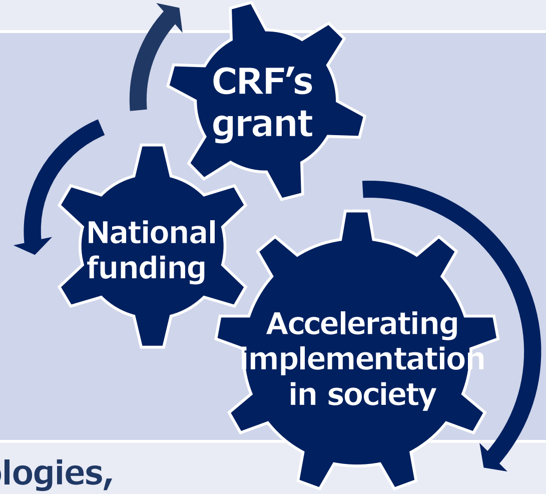
CARBON RECYCLING FUND INSTITUTE

CRF Activities: Research Grant

- Exploring research seeds (ideas, people) and supporting efforts related to carbon recycling through flexible operations that take advantage of private funds.

	Features
Eligibility	Researchers or teams affiliated with companies, universities, etc. A startup support framework established in FY2022
Research targets	Research on carbon recycling that uses CO_2 (or carbon atoms) as a resource, related technologies, and social science to solve social issues
	<Expected Fields> 1. CO_2 fixation by mineralization (materials such as concrete) 2. Conversion to fuels 3. Conversion to chemicals 4. Separation and recovery (including direct-air capture) 5. Social science 6. Utilization of CO_2 sinks (soil, forests, blue carbon, biologics, agriculture, forestry and fisheries) 7. Other (H_2 production, geo-engineering, functional materials, medical fields, etc.)
Evaluation points	Creativity, innovativeness, superiority over conventional technologies, method to determine issues, and social realization potential through collaboration with companies
Grant scale	Up to 10 million yen per project (Up to two years)
Number of applications and accepted cases	FY2020～FY2025：（total）428 applications → 93 accepted FY2024: 78 applications → 13 accepted and 26 applications for startup support → 1 accepted FY2025: 56 applications → 19 accepted and 16 applications for startup support → 3 accepted
Attribution of research results	Research results basically belong to researchers



Research Grant:22 Projects Adopted in FY2025 (1/2)

Field	Study title	Name of Research Representative (Organization)
CO2 separation, capture and storage	Innovative high-purity CO2 purification technology: Development of CO2 separation system using “gate-adsorption-type zeolites”	Shunsuke Tanaka (Kansai University)
	Direct air capture using a combination of zeolite and a liquid-phase desorption system	Kenta IYOKI (Planet Savers)
	Development of a CO_2 Fixation Process Converting Byproducts of Rare Earth Recovery from Coal Ash into Carbonated Granules	Yuko OGAWA (Hiroshima University) Collaborators: University of Wyoming
	Catalytic Conversion of Carbon Dioxide over Hybrid Nanoconfined Catalysts	Daichi Takami (The Univ. of Osaka)
	Development of a Multi-Material, Multi-Use DAC System for Cost Optimization Across CO2 Applications	Kei Kawasaki (CarbonNest Inc.)
Conversion to fuels or chemicals	Development of a water-cooled electrode-type direct methanol synthesis plasma reactor using a DC pulse power with CO2	Nobusuke KOBAYASHI (Gifu University)
	Development of Biomass Plastic Synthesis Utilizing Carbon Dioxide and Non-Edible Sugars	Masanari Kimura (Nagasaki University)
	CO2 Conversion to Useful Chemicals by Si Powder with Metal Cluster Catalysts	Shingo Hasegawa (Yokohama National University)
	Design of Coordination Polymer-Based Catalysts for Fast CO2 Electrolysis Without Resource Limitations	Kazuhiko Maeda (Institute of Science Tokyo)
	High-efficiency methanol conversion of CO2 using tungsten trioxide catalysts.	Hidetoshi Miyazaki (Shimane University)

Research Grant:22 Projects Adopted in FY2025 (2/2)

Field	Study title	Name of Research Representative (Organization)
Social sciences	Designing a voluntary credit system for green carbon ecosystem conservation	Ayu WASHIZU (Waseda University)
	Possibilities and Issues for Realizing Australia - Japan JCM: A Case Study of the CCS/CCUS Project in Australia	Toshi H. Arimura (Waseda University) Collaborators: Australian National University
Circulation of carbon resources	Porous copper-based electrodes for organic electrosynthesis and water hydrolysis	Sho HIDESHIMA (Tokyo City University)
	Development of an Innovative Carbon Recycling Process for Acrylic Resins	Keita Koshiba (Mitsubishi Chemical Corporation Co., Ltd.)
	Development of Recycling Technologies for Highly Stable Plastics	Masanori Shigeno (Tohoku University)
	Catalytic plastic depolymerization and organic waste decomposition into hydrogen	Tadashi Kubo (AC Biode)
Utilization of living organisms	Carbon-negative electricity generation using photosynthetic microorganisms and enzymatic biofuel cells	Tsutomu MIKAWA (RIKEN)
	Bio-PET Circulation: Harnessing CO_2 for Sustainable Growth	Tsutomu Tanaka (Kobe University)
Value Enhancement	Development of an Innovative Conversion Process from Carbon Dioxide to Acrylic Resin Precursors without Hydrogen Consumption	Teruoki Tago (Institute of Science Tokyo)
Utilization of CO2 sinks	Research and Development of a Seaweed Attachment System for Large-Scale Blue Carbon Creation	Nobuko Nishikawa (BLUABLE Co., Ltd.)
	Development of Functional Biochar as the Final Utilization Stage in the Material Flow of Wood-based Resources	Masako SEKI (National Institute of Advanced Industrial Science and Technology “AIST”)
H2 Carrier Usage	Ammonia Cracking at Low Temperature and High Rates with Precious-Metal-Lean Catalysts: From Discovery to Scale-Up	Akira Oda (Institute for Catalysis, Hokkaido University)

Innovative high-purity CO_2 purification technology: Development of CO_2 separation system using "gate-adsorption-type zeolites"

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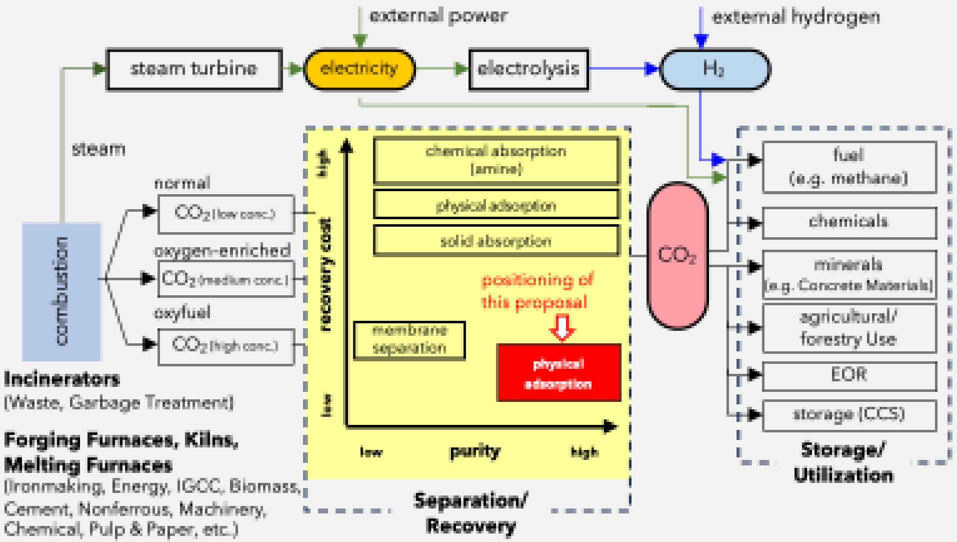
Shunsuke Tanaka（Separation Systems Engineering Lab. @Kansai University)

CO2 separation, capture and storage

Outline : Gate adsorption-type zeolites contribute to the practical application of an energy-saving CO_2 separation and recovery compact system by reducing vacuum pump power and eliminating the need for a dehumidification process.

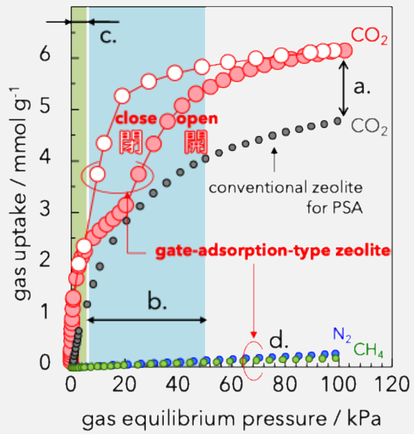
1. Background

- ◆ CO_2 emissions from small and medium-sized industrial furnaces account for 2/3 of CO_2 emissions from the industrial sector, but these emissions remain unaddressed due to issues such as installation locations and recovery costs.
- ◆ Chemical absorption requires large-scale equipment, while membrane separation, which is expected to be the ultimate next-generation technology, faces fundamental challenges such as the difficulty of achieving high-purity purification.



2. Procedure

- ◆ (a) High-capacity CO_2 adsorption
- ◆ (b) Gate adsorption similar to metal-organic frameworks
- ◆ (c) Strong adsorption of CO_2 at low pressures to prevent water adsorption
- ◆ (d) Selective recovery of CO_2



3. Feature of the Research

- ◆ The mechanism underlying the selective CO_2 adsorption of gate-adsorption-type zeolites will be elucidated, thereby overturning conventional concepts of zeolites.

4. Ripple Effect

- ◆ The provision of PSA system that enables the CO_2 separation/recovery from exhaust gases emitted from industrial furnaces; maintaining high-purity purification and achieving energy savings (low cost) using compact equipment, contributes to the goal of recovering 7 billion tons of CO_2 by 2050, as outlined in "Net Zero by 2050."

Direct air capture using a combination of zeolite and a liquid-phase desorption system

Principal Investigator（Affiliated institution）：Kenta IYOKI（Planet Savers）
R&D Organizations : Kyoto University, Shinshu University

CO_2 separation, capture and storage

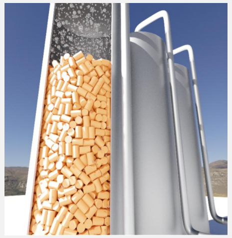
Outline : Direct air capture using a combination of zeolite and a liquid-phase desorption system

1. Background

- Direct Air Capture (DAC) is a key solution for achieving net-zero CO_2 emissions by 2050.
- Recycling CO_2 captured by DAC contributes to producing synthetic fuels that replace fossil fuels and achieving zero emissions.
- It is necessary to selectively adsorb CO_2 at extremely low concentrations while minimizing energy consumption during desorption.
- Current PSADAC systems operate solely in the gas phase. Dilution due to non-CO_2 gas contamination during CO_2 desorption poses a challenge, making concentration above 90% difficult.

2. Procedure

- Dilution by the gas phase poses a problem. Therefore, we aim to resolve these issues by developing desorption technology using the liquid phase (figure below).
- We utilize CO_2 adsorption via physical adsorption, which is expected to facilitate easy desorption.
- To prevent degradation during the adsorption-desorption process, we employ highly durable adsorbents.



3. Feature of the Research

- Compared to existing technologies requiring significant energy input during heating processes and vacuum pumping, this method enables desorption simply by introducing liquid phase, promising substantial energy savings.
- Since no gas dilution is required, it is expected to yield high-concentration CO_2 using a simple mechanism.
- Zeolite, an inorganic porous material, offers high durability and low cost compared to organic compounds such as amines.

4. Ripple Effect

- Given the projected greenhouse gas emissions that cannot be avoided, the International Energy Agency has announced that Direct Air Capture (DAC) will need to be implemented at an annual scale of 1 gigaton (1 billion tons) by 2050.
- This R&D technology is expected to significantly reduce DAC costs.
- Recovered CO_2 can be recycled for industrial applications such as greenhouse cultivation (e.g., tomatoes) and dry ice/liquid carbon dioxide production. Long-term, it can also be used for manufacturing synthetic fuels, olefins, and other chemical products.
- Global investment in DAC is active. Japan must now aim to develop domestically produced technology that can achieve competitive advantage on the world stage.

Development of a CO_2 Fixation Process Converting Byproducts of Rare Earth Recovery from Coal Ash into Carbonated Granules

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Principal Investigator（Affiliated institution）：Yuko OGAWA（Hiroshima University)
R&D Organizations： The Chugoku Electric Power CO., INC., Japan Carbon Frontier Organization

CO2 separation, capture and storage

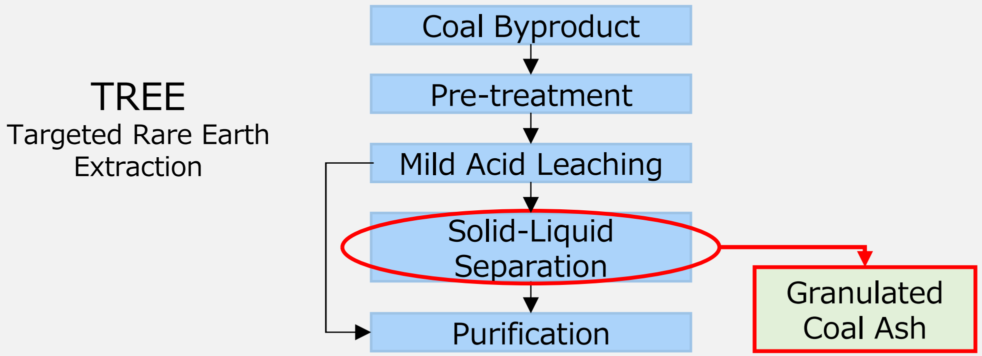
Outline : Developing a CO2 fixation process with carbonated granules from coal ash residue after REE (Rare Earth Element) recovery.

1. Background

- **Carbonation-based CO_2 fixation:** A technology with high expectations for early social implementation.
- **Carbonated granule technology:** Applying carbonation technology to concrete has challenges (e.g., rebar corrosion). Our "carbonated granules" solve this by combining granulation and carbonation, offering a significant advantage with no product limitations.
- **REE recovery technology** (developed by the University of Wyoming) : A key challenge lies in the effective utilization of the recovered residue.

2. Solution

- **Combining two key technologies;**
  (1) REE recovery (University of Wyoming)
  (2) Coal ash granulation (The Chugoku Electric Power Company)
- **Goal:** To develop an efficient CO_2 fixation process with carbonated granules from REE residue.

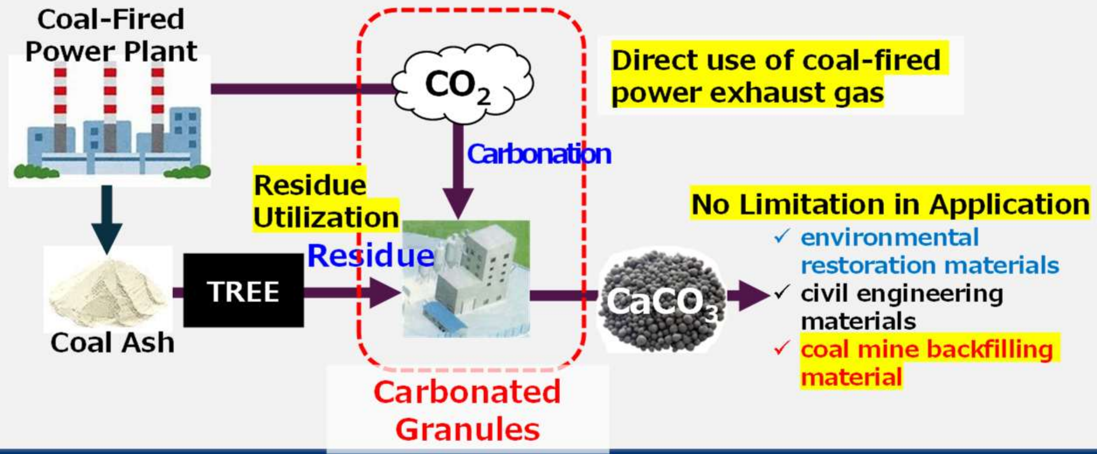


3. Research Feature

- No need for a separate CO2 capture process from flue gas.
- Early practical implementation possible by combining existing technologies.
- An international joint research project with the University of Wyoming.

4. Ripple Effect

- **Product uses:** Environmental purification and backfill material for coal mines (in the U.S. and Southeast Asia).
- **CO_2 reduction:** Potential for a 3.5 million tons/year reduction in Japan and the U.S.
- **Future potential:** Application to biomass and waste incineration ash.



Catalytic Conversion of Carbon Dioxide over Hybrid Nanoconfined Catalysts

Principal Investigator（Affiliated institution）：Daichi Takami（The Univ. of Osaka）

CO2 separation, capture and storage

Outline : Establishing nanospace design in hollow silica to advance catalyst development for CO_2 conversion

1. Background

- Catalysts for CO_2 conversion is highly desired
- A key challenge in catalysis is to integrate the benefits of both homogeneous and heterogeneous systems.

Homogeneous Catalysts
Activity
Selectivity

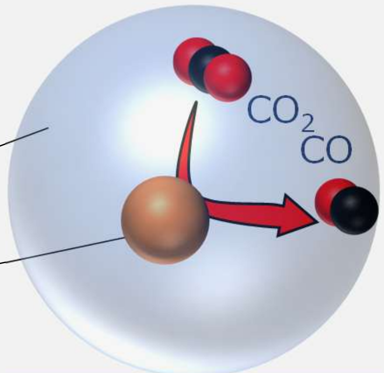
Heterogeneous Catalysts
stability
Recoverability

2. Procedure

- This study seeks to design a hybrid catalyst that combines hollow structures with homogeneous catalysts.

Spherical Silica

Homogeneous catalysts



3. Feature of the Research

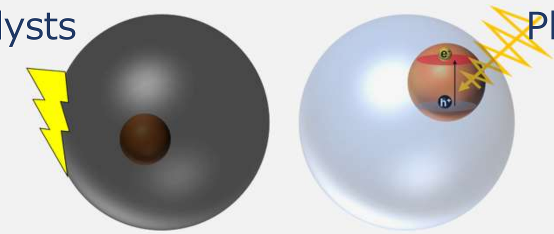
- Encapsulation in hollow structures enables homogeneous catalysis without leaching.
- Prevention of loss of dispersibility or electronic properties caused by immobilization on a support
- Multifunctional nanospace design inside the hollow.

4. Ripple Effect

- High applicability to liquid-phase reactions, lowering barriers for homogeneous catalysts in industry
- Transparent, conductive hollow structures enable photocatalytic and electrocatalytic applications.

Electrocatalysts

Photocatalysts



Development of a Multi-Material, Multi-Use DAC System for Cost Optimization Across CO2 Applications

Principal Investigator（Affiliated institution） : Kei Kawasaki (CarbonNest Inc.)
R&D Organizations : Tokyo University of Science, National Institute of Advanced Industrial Science and Technology (AIST)

CO2 separation, capture and storage

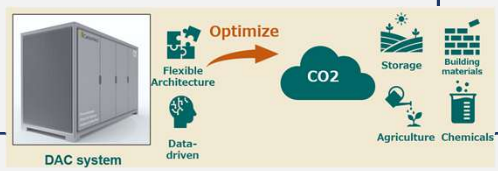
Outline : Develop a multi-material, multi-use DAC system to contribute to the construction of a diverse carbon management framework.

1. Background

- To achieve carbon neutrality, it is essential not only to drastically reduce emissions but also to capture and remove CO2 as part of carbon management.
- Direct Air Capture (DAC) technology is considered highly promising due to its scalability and flexibility.
- However, the current cost of CO2 capture with DAC remains high, especially when compared with nature-based carbon management methods such as forests.

2. Procedure

- By integrating DAC into broader carbon management, we address current issues such as scalability and cost efficiency.
- Instead of a system specialized in only one capture material, we will build a multi-material, multi-use DAC system capable of switching between multiple adsorbents and operational modes to flexibly adapt to different use cases and cost requirements.



3. Feature of the Research

- Unlike conventional DAC systems that specialize in a single CO2 adsorbent, our system optimizes operational parameters across multiple capture materials.
- By adjusting to the intended CO2 application (e.g., storage, synthetic fuels, agricultural chemicals), the system achieves cost minimization tailored to each CO2 use case.

4. Ripple Effect

- The outcomes of this research will reduce the cost burden of standalone DAC and optimize the entire carbon management value chain.
- This will help accelerate the transition to a carbon recycling society, linking DAC with carbon utilization in fuels, building materials, and other industries.
- Ultimately, it will contribute to the development of an integrated CO2 management framework that supports both domestic and global carbon neutrality goals.

Development of a water-cooled electrode-type direct methanol synthesis plasma reactor using a DC pulse power with CO_2

Principal Investigator（Affiliated institution） : Nobusuke KOBAYASHI（Gifu University)
R&D Organizations : Gifu University, Tokyo University of Agriculture and Technology

Conversion to fuels or chemicals

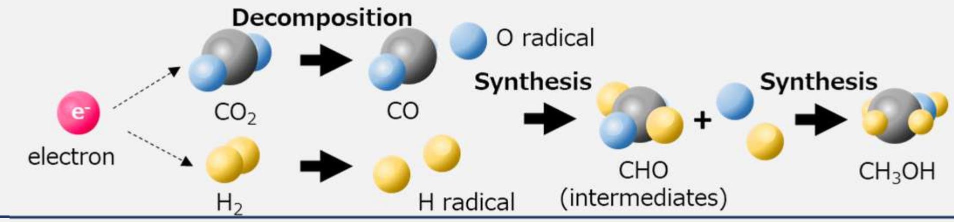
Outline : Establish innovative plasma gas synthesis technology for low-temperature synthesis of methanol from CO_2, and build the foundation for next-generation power-to-methanol processes.

1. Background

- Methanol is produced at high temperatures and pressures using synthetic gas obtained from steam reforming of fossil.
- Methanol synthesis using plasma can be achieved at low temperatures and normal pressure. In theory, it is possible to achieve higher energy efficiency than thermochemical conversion.
- However, the current energy efficiency of plasma methanol synthesis is lower than that of thermochemical conversion.
- A wide variety of substances are synthesized in plasma process, and the selectivity and yield of the methanol are low.

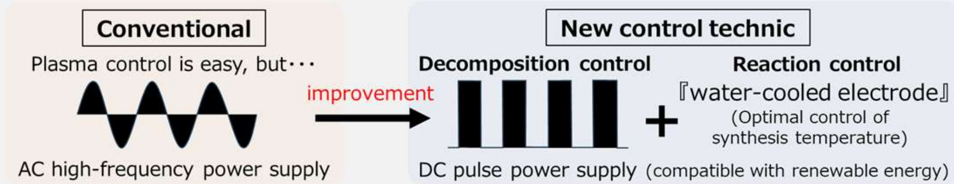
2. Procedure

- In plasma methanol synthesis, the reaction gas (CO_2 and H_2) is decomposed by plasma, and then the decomposed radicals pass through intermediates (such as CHO*) to synthesize methanol.
- In this study, decomposition and synthesis, which had previously been carried out in a single reactor, were divided into two stages, and optimal conditions were controlled to improve the selectivity and yield of methanol.



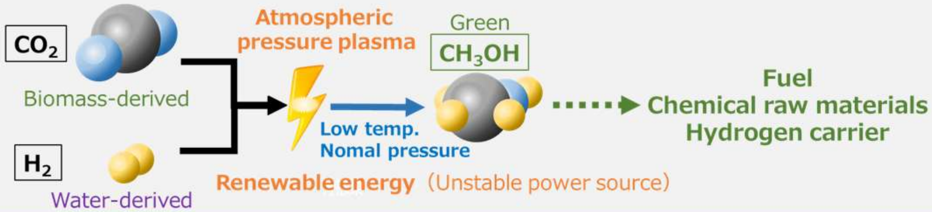
3. Feature of the Research

- Until now, AC power were used for CO_2 decomposition, but DC pulse power are now used to enhance CO_2 decomposition.
- By separating decomposition and synthesis and controlling each according to the synthesis of methanol, plasma decomposition of intermediates, as well as side reactions are suppressed.



4. Ripple Effect

- By utilizing CO_2 and renewable energy in the region, it is possible to synthesize methanol with a switch, contributing to the construction of a decentralized energy system.
- Green methanol is expected to spread to various fields such as transportation, aviation, agriculture, and chemical industry, which will lead to strengthening international competitiveness and energy security.



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Development of Biomass Plastic Synthesis Utilizing Carbon Dioxide and Non-Edible Sugars

Principal Investigator（Affiliated institution） : Masanari Kimura（Nagasaki University）
R&D Organizations :

Conversion to fuels or chemicals

Outline： This study aims to establish a catalytic reaction for the highly selective direct incorporation of CO_2, thereby contributing to the realization of a sustainable, resource-circulating society through the effective utilization of CO_2 and non-edible biomass, which are inexpensive and stably supplied feedstocks.

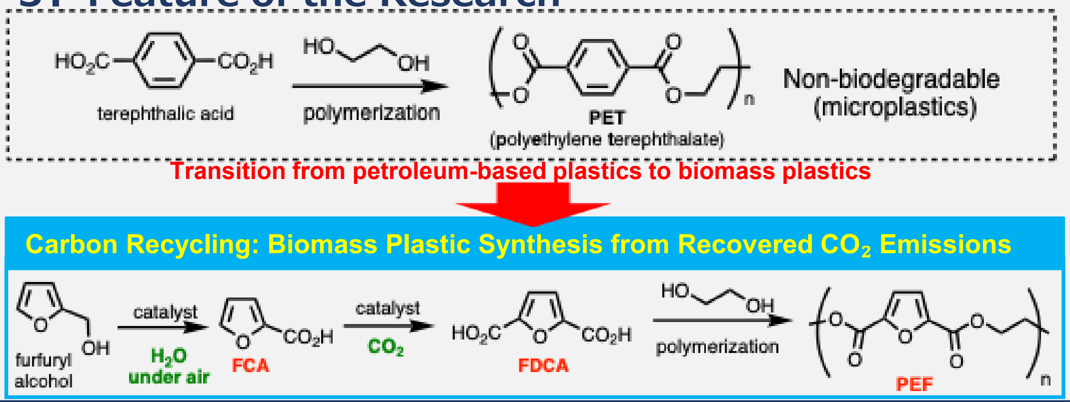
1. Background

Polyethylene furanoate (PEF) has emerged as a promising next-generation polymer to serve as an alternative to petroleum-derived PET. In this study, we aim to develop a novel synthetic method for the selective and efficient production of 2,5-furandicarboxylic acid (FDCA) by directly incorporating CO_2 into 2-furancarboxylic acid (FCA), an inexpensive and readily available non-edible biomass-derived feedstock.

2. Procedure

The present study aims to establish a new synthetic route to FDCA by first synthesizing FCA from furfuryl alcohol via hydrogen transfer oxidation, followed by regioselective carboxylation through direct CO_2 incorporation. This approach utilizes non-edible biomass and CO_2 as feedstocks, thereby overcoming the instability and high cost associated with 5-hydroxymethylfurfural (HMF). This methodology offers a novel and potentially foundational technology for the sustainable production of bio-based plastics such as PEF.

3. Feature of the Research



4. Ripple Effect

By enabling the synthesis of FDCA through the CO_2 insertion reaction into FCA, which can be readily obtained from non-edible monosaccharides such as xylose, this study provides a streamlined and efficient route to PEF. The ability to synthesize plastics from CO_2 and biomass, using monomers derived from renewable rather than depletable resources, has significant implications as an innovation in polymer synthesis. PEF exhibits substantially higher gas barrier properties than conventional PET.

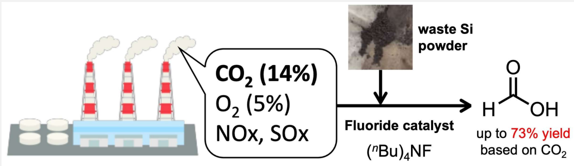
CO_2 Conversion to Useful Chemicals by Si Powder with Metal Cluster Catalysts

Principal Investigator (Affiliated institution) : Shingo Hasegawa (Yokohama National University)
R&D Organizations :

Conversion to fuels or chemicals

Outline : CO and phenol are directly obtained from CO_2 and benzene by using unique reducing ability of Si powder.

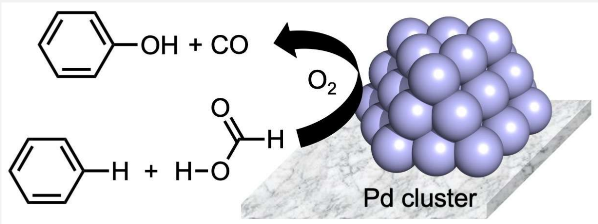
1. Background



ACS Sustainable Resour. Manage. 2025, 2, 1220.

The establishment of the recycling method of wasted silicon recovered from end-of-life solar panels is desired, since it is expected that a large amount of solar panels will be discarded in the future. We have succeeded in converting CO_2 in exhaust gases into formic acid and amides using wasted silicon. The aim of this study is developing novel reaction systems for more diverse CO_2 conversion using silicon.

2. Procedure



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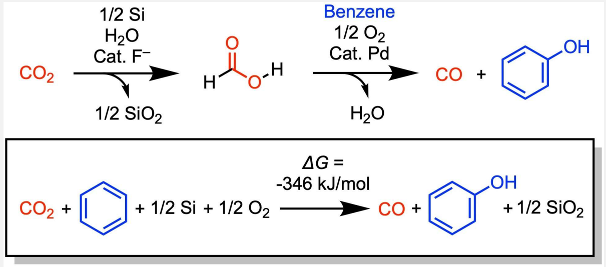
We have developed a catalytic system directly producing phenol and CO from benzene and formic acid using metal cluster catalyst. In this study, we try to combine the CO_2 reduction to formic acid using silicon powder and the reaction of benzene and formic acid on metal cluster catalyst. The one-pot synthesis of phenol and CO from benzene and CO_2 will be achieved by unique reducing ability of silicon and catalysis of metal cluster.

3. Feature of the Research



(*ΔG* = +82 kJ/mol for the reaction without Si)

In this study, the unique reducing ability of silicon powder is used as the thermodynamic driving force for the direct production of phenol and CO from benzene and CO_2.

The reaction including the oxidation process of silicon is thermodynamically favorable because of the negative *ΔG* of -346 kJ/mol. In contrast, *ΔG* of the reaction without silicon is +82 kJ/mol, indicating that the reaction is challenging.

4. Ripple Effect

The amount of waste solar panels in Japan is expected to reach 800,000 tons and the global total is expected to be ~10 times larger than this amount. By using the catalytic system developed in this study, 240,000 tons of waste silicon could be theoretically converted into 480,000 tons of CO and 1,600,000 tons of phenol. Therefore, our technology can achieve large-scale chemical production and CO_2 recycling.

Design of Coordination Polymer-Based Catalysts for Fast CO_2 Electrolysis Without Resource Limitations

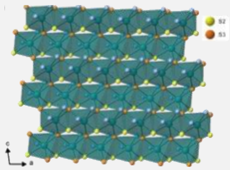
Principal Investigator（Affiliated institution）：Kazuhiko Maeda（Institute of Science Tokyo）
R&D Organizations：Kwansei Gakuin University

Conversion to fuels or chemicals

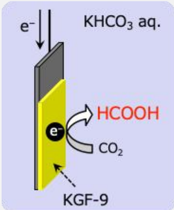
Outline： Development of a CO_2 electrolysis catalyst using a coordination polymer based on abundant and inexpensive lead, achieving highly selective formic acid production at low voltage!

1. Background

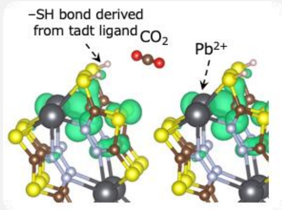
- Pb-based coordination polymers enable rapid, selective CO_2 electrolysis to formic acid, but the high overpotential remains a challenge for practical use.



KGF-9 ([Pb(tadt)])



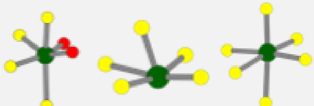
Highly selective CO_2-formic acid conversion even under fast electrolysis conditions



The uneven KGF-9 surface and tadt ligands form the active site for CO_2 reduction reaction!

2. Procedure

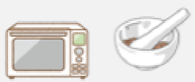
1: Screening of candidate catalysts



Local structure around Pb

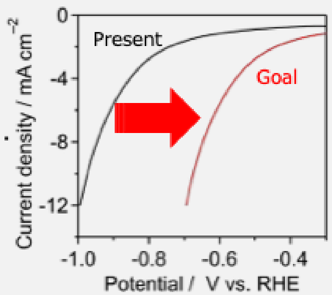
2: Search for new synthetic routes

- Solvothermal
- Microwave
- Solid-state
- ・・・



3: Overpotential decrease by metal doping

…–S–Pb–S–Pb–S–… ⇨ …–S–Pb–S–**M**–S–…



3. Feature of the Research

- Pb-based coordination polymers offer a cost-effective alternative to Ag and Au, achieving near-100% selectivity for formic acid in CO_2 electroreduction.
- Embedding Pb ions creates a unique reaction field that enables catalytic activity.
- Designing metal–anion polyhedra from a solid-state chemistry perspective opens new paths beyond traditional coordination chemistry.

4. Ripple Effect

- Formic acid is a valuable feedstock for chemicals and pharmaceuticals, and its efficient production from CO_2 offers major industrial advantages.
- Using electricity from renewable sources and abundant, low-cost elements like Pb as catalysts can significantly reduce manufacturing costs.
- Pb is inexpensive, price-stable, and already widely used in society, making it a viable catalyst under proper safety management.
- This research also aligns with the SDGs, opening diverse possibilities for future applications.

High-efficiency methanol conversion of CO2 using tungsten trioxide catalysts

CARBON RECYCLING FUND INSTITUTE

Principal Investigator（Affiliated institution） : Hidetoshi Miyazaki（Shimane University）

Conversion to fuels or chemicals

Outline : Ammonium bicarbonate is used to increase the concentration of CO_2 in an aq. solvent, and WO_3 catalyst is used to efficiently convert CO_2 into methanol. Furthermore, the charge transfer efficiency is increased by reducing WO_3, thereby increasing the methanol conversion efficiency.

1. Background

- Over a century, the temperature has risen by 0.7°C. One of the rising temperature is greenhouse gases, particularly CO_2 emitted by industry.
- Greenhouse gas emissions in Japan amounted to approximately 1.17 billion tons in 2021, with CO_2 accounting for about 90% of total emissions.
- Not only CO_2 reduction, but also CO_2 fuelization is necessary.

2. Procedure

- CO_2 reduction technologies are being researched in various fields, and “photoreduction of CO_2 using catalysts” is one of the leading candidates.
- Among the CO_2 photoreduction technologies mentioned above, CO_2 photoreduction using tungsten trioxide (WO_3) catalysts is being actively pursued. This method does not require sacrificial reagents and has been reported to reduce CO_2 (in either the gas phase or aqueous solvent) to methanol solely through light irradiation.

3. Feature of the Research

- We have previously succeeded in efficiently converting CO_2 into methanol using WO_3 photocatalysts after increasing the CO_2 concentration with ammonium bicarbonate in an aqueous solvent system.
- In this reaction, the only byproduct is oxygen, resulting in a significantly low environmental impact.By using WO_{3-x}, which is reduced WO_3, it is possible to greatly increase electron transfer in the WO_3 catalyst.

4. Ripple Effect

- Using WO_3 catalyst, it is possible to convert CO_2 directly into methanol fuel through photoreduction. In other words, this provides a means of recycling CO_2 into fuel with low environmental impact.

$$CO_2 \xrightarrow[\text{NH}_4\text{HCO}_3\text{aq, WO}_3\text{ catalyst}]{\text{Phoro irradiation (Sunlight)}} CH_3OH \text{ (Methanol)}$$

CARBON RECYCLING FUND INSTITUTE

Designing a voluntary credit system for green carbon ecosystem conservation

Principal Investigator（Affiliated institution） : Ayu WASHIZU (Waseda University)
R&D Organizations : Linkhola Inc.

Social sciences

Outline : Designing a voluntary credit system for the use of woody biomass fuel, contributing to the conservation of green carbon ecosystems and carbon neutrality in mountainous regions.

1. Background

To construct carbon-neutral rural areas, it is important to change the social system (regime) to make effective use of ubiquitous local resources within the region. Voluntary credits are one such regime. A feasibility study was conducted to consider the requirements for a voluntary credit system to make effective use of unused wood biomass in mountainous and hilly regions. The results identified the following issues: Accumulating operational know-how, improving facility and thermal utilization rates, and developing aggregators that can manage multiple facilities (projects) together.

3. Research Features

Overcoming the challenges of effectively utilizing unused wood biomass requires fundamental regional development that involves various stakeholders. We will focus on demand-side surveys to design a system that benefits all stakeholders, including credit consumers.

4. Ripple Effect

By incorporating the local environmental value created by carbon credits into the value chain within the region and the entire economy, the effective use of unused woody biomass will be promoted. This will contribute to a smooth transition to a carbon-neutral society (Figure 2).

2. Procedure:

Voluntary credits that monetize the value of the region in addition to the CO_2 value.
Under a general credit price, credit demand ③ will arise. Under a credit price that includes the environmental value of Region A, credit demand ② will arise. The environmental value of Region A is expressed as the credit price difference ①.

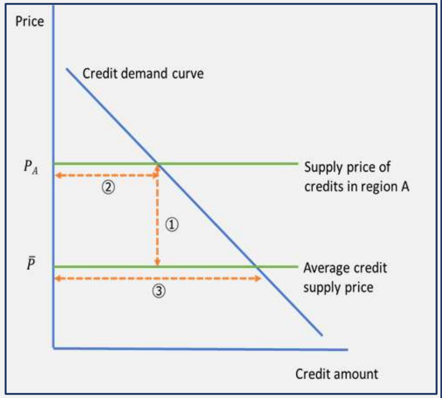


Fig. 1. Theoretical explanation of the voluntary credit system.

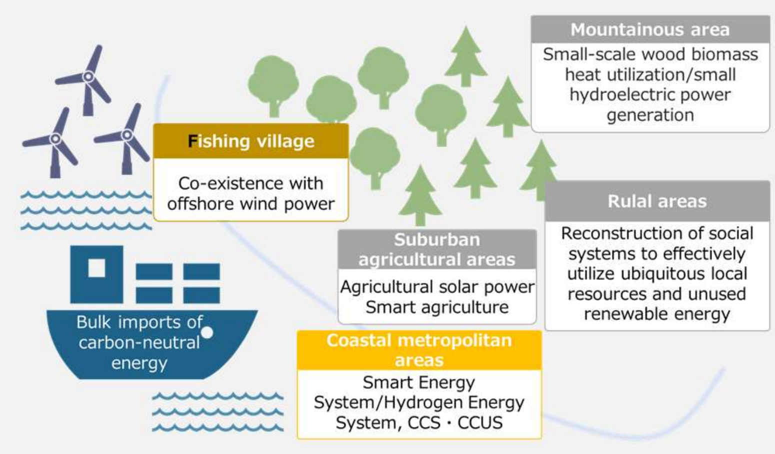


Fig. 2: Blueprint for a carbon-neutral society

Possibilities and Issues for Realizing Australia - Japan JCM: A Case Study of the CCS/CCUS Project in Australia

CARBON RECYCLING FUND INSTITUTE

Principal Investigator（Affiliated institution）：Toshi H. Arimura（Waseda University)
R&D Organizations：Waseda University, Australian National University

Social sciences

Outline: Promoting international CO_2 emissions reduction through identifying issues for the conclusion of a Japan-Australia JCM

1．Background

International cooperation for achieving Japan's NDC targets and carbon neutrality

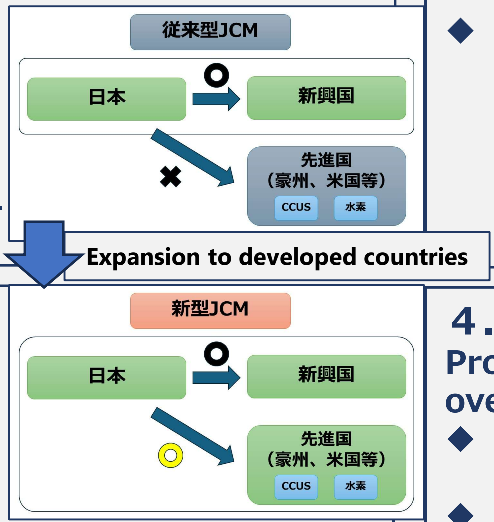
- CCS, CCUS, green hydrogen production, etc.
- Australia is a leading candidate for CCS.

Prospects and issues for JCM

- JCM with 30 countries by 2025.
- Not implemented in developed countries.
  ->**Possibility of expanding JCM**

Research on applying JCM

- No research on JCM in developed countries.
- Measures against greenwashing.



2．Research Methods

Issues for JCM between Japan and Australia

- Requests and issues in Australia
- Target technologies for JCM
- Differences in systems (e.g., MRV).
- Concerns regarding CCS implementation in Australia.

Analysis Methods

- Literature review and interviews with Japanese government agencies and companies.
- Plans to hold a roundtable meeting in Australia.

Design of the Japan-Australia JCM System

- Key requirements for JCM implementation in Australia.
- Emissions reduction and international competitiveness improvement.

3．Feature of the Research

Japan-Australia Collaboration

- **Waseda university (Coordination):**
  Research on expanding JCM target countries and technologies, literature review and interviews.
- **Australian National University:**
  Research on Australian domestic policies

4．Expected Impact

Promoting the international framework for decarbonisation overseas.

- Improving the economic efficiency of Japan's decarbonisation technologies overseas, particularly in developed countries.
- Improvement of international competitiveness and international expansion of CCS/CCUS.

Proposing a system to utilise JCM in developed countries

- Progress in international coordination toward decarbonisation through raising the international profile of JCM.
- Accelerating decarbonisation efforts in Japan and Australia through the introduction of advanced technologies.

Porous copper-based electrodes for organic electrosynthesis and water hydrolysis

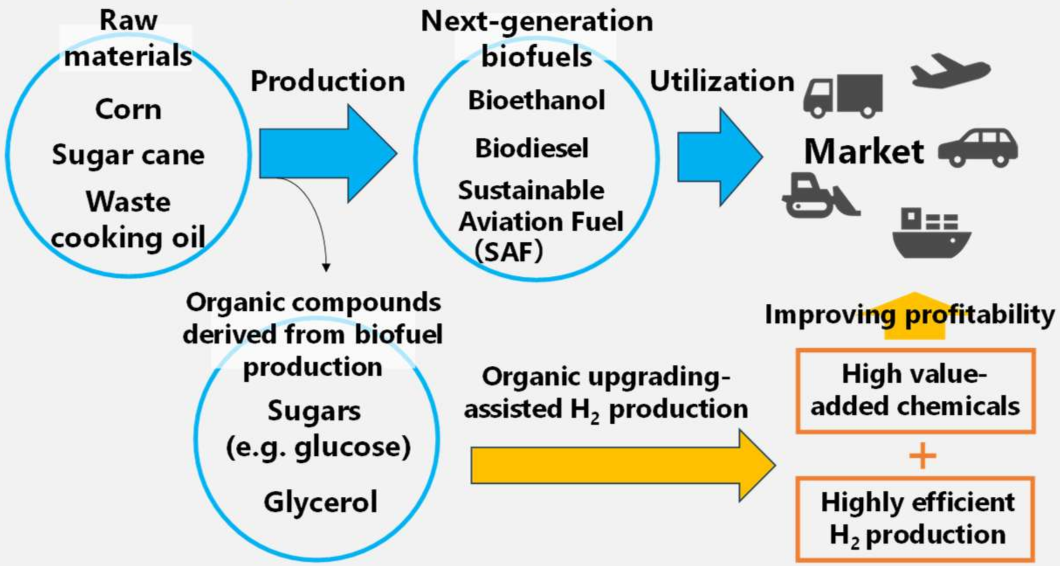
Principal Investigator（Affiliated institution） : Sho HIDESHIMA（Tokyo City University）
R&D Organizations : Idemitsu Kosan Co.,Ltd.

Circulation of carbon resources

Outline : Potentials of nanostructured copper oxide electrodes formed by reducing a layered copper hydroxide for organic electrosynthesis and water hydrolysis would be evaluated.

1. Background

- Technologies for next-generation fuels are gaining attention. For the future, it is essential to reduce the cost of next-generation fuels. Lowering raw material costs and effectively utilizing organic compounds derived from biofuel production can contribute to improving the overall profitability of the business.
- Developed electrodes for such applications have drawbacks in view of electrochemical properties and electrocatalytic activity

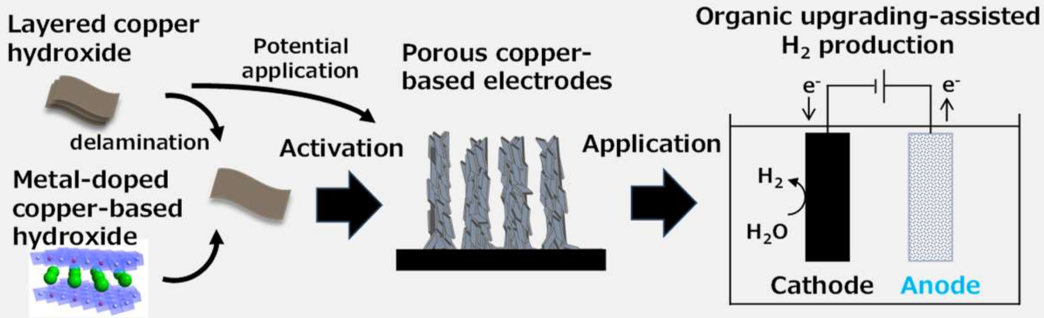


2. Procedure

- Electrodes with microstructure or porous structure useful for organic electrosynthesis and water hydrolysis would be developed.

3. Feature of the Research

- Porous copper-based electrodes prepared based on nanosheet electrode fabrication technique will be developed to enhance the electrochemical properties and electrocatalytic activities.



4. Ripple Effects

- This technology could be useful both in reducing the power consumption of conventional water electrolysis, and in converting organic compounds derived from biofuels to higher-value products.

Development of an Innovative Carbon Recycling Process for Acrylic Resins

CARBON RECYCLING FUND INSTITUTE

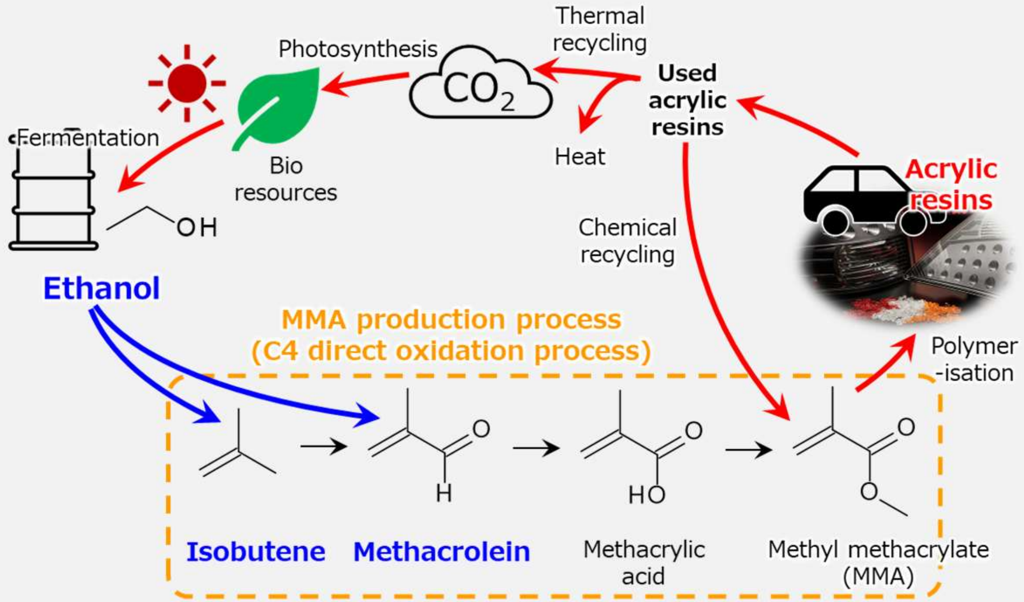
Principal Investigator (Affiliated institution): Keita Koshiba (Mitsubishi Chemical Corporation Co., Ltd.)
R&D Organizations : Hokkaido University, Tohoku University

Circulation of carbon resources

Outline : We will develop reactions from ethanol to raw materials for methyl methacrylate (MMA) monomer with catalysts, and explore the construction of a large-scale carbon recycling cycle for acrylic resins.

1. Background

Acrylic resins are known as the 'queen of plastics' due to their high transparency and durability. They are widely used in applications such as automotive lamp covers. Plastics and plastic waste, including acrylic resins, can fix carbon and retain it through material and chemical recycling processes. However, contamination and processing burdens hinder their use, making thermal recycling—which emits CO_2—the predominant approach. It is necessary to develop recycling methods and carbon fixation techniques that are independent of the condition of waste plastics.



2. Procedure

We propose a large-scale carbon recycling cycle for acrylic resins via ethanol. The final piece of this cycle is the technology to convert **ethanol into raw materials for MMA monomer (i.e. isobutene and methacrolein).** We will develop their reactions and catalysts.

3. Feature of the Research

This carbon recycling cycle enables the production of acrylic resins regardless of the type or state of waste plastics. Acrylic resins are widely used as durable consumer materials, allowing for longer product life cycles (i.e., extending CO_2 fixation periods).

4. Ripple effect

This research focuses on the synthesis of iso-C4 from C2, which has not yet been commercialized. If successful, it could lead to applications beyond acrylic resins, such as additives for gasoline, and reduce dependence on petroleum-based raw materials.

Development of Recycling Technologies for Highly Stable Plastics

CARBON RECYCLING FUND INSTITUTE

Principal Investigator（Affiliated institution）：Masanori Shigeno（Tohoku University）

Circulation of carbon resources

Outline： Development of a chemical recycling technology to depolymerize highly stable plastics into monomers

1．Background

- Super engineering plastics offer excellent heat resistance, flame retardancy, chemical resistance, and low water absorption, making them essential for electronics, communications, and automotive parts.
- Yet, their high stability makes recycling difficult, so they are usually incinerated or landfilled, directly contributing to CO_2 emissions.

2．Procedure

- This study aims to develop a technology for depolymerizing super engineering plastics into reusable monomers under mild conditions.
- The applicant has achieved efficient transformations of stable C–H and C–O bonds using strong Brønsted bases; notably, the organic superbase enables exchange at aromatic C–OMe bonds. This molecular strategy will serve as a platform for advancing chemical recycling of super engineering plastics.

3．Feature of the Research

- We have shown that bulky organic bases enhance anion nucleophilicity by suppressing electrostatic interactions, enabling reactions such as carbon–methoxy bond transformations not possible with conventional bases.
- These insights will underpin the chemical depolymerization of super engineering plastics in this study.

4．Ripple Effect

- Super engineering plastics, exemplified by PEEK, are widely used in electronics and automotive applications, with demand rising through 5G and EV expansion.
- Although costly, they are difficult to recycle, highlighting the need for efficient chemical recycling. This study enables their depolymerization into reusable monomers, contributing to resource circulation, CO_2 reduction, and the broader adoption of carbon recycling.

Catalytic plastic depolymerization and organic waste decomposition into hydrogen

Principal Researcher (Affiliated institution): Tadashi Kubo, Co-Founder & CEO (AC Biode)

Circulation of carbon resources

Outline: Catalytic mixed, multi-layered plastic depolymerization and organic waste decomposition into monomers, hydrogen, CO, and other gases, and sequester carbon by carbonization

1. Problem

- Most of plastic waste are mixed, multi-layered, and dirty. Mechanical (material) recycling cannot treat them. Thermal recycling requires a lot of investment, emits GHG, and is bad to the environment.
- pyrolysis: 1) needs high temperature/pressure, 2) requires a lot of energy, 3) oil applications can be limited due to the quality and requires a lot of energy for oil cracking.
- Depolymerization: 1) requires high temperature/pressure, 2) requires a lot of energy, 3) uses organic solvent, and 4) uses precious metals for catalysts.

2. Solution

- With our patented catalysts, we depolymerize mixed plastic waste such as PVC, polyester, etc. into monomers, H2, CO, methane, alcohol, only at 200-300 degrees C, using industrial water as solvent, and no precious metals are used in the catalysts.
- We can also decompose organic waste such as cellulose, lignin, agriculture waste, sewer sludge, paper sludge etc. into hydrogen and CO, etc.
- At the same time, we aim to sequester carbon into charcoal in the solid phase by carbonization.

3. Feature of the Research

- Compared to pyrolysis: ours is at lower temp/pressure, uses less energy, and no need to oil cracking
- Compared to depolymerization: ours is at lower temp/pressure, uses less energy, no organic solvent is needed, and no precious metals are used for catalysts.
- Compared to methane fermentation: while it takes a few days, ours can within a few hours. We can get different monomers and gases.

4. Ripple Effect

- There are a lot of plastic waste that can be mechanically recycled. Instead of incineration, we can recycle them only 180-200 degrees C, potentially saving 30-70% of GHG.
- Our strategy and R&D fit with the policies of the countries all over the world.
- While the current plastic carbonization requires a lot of energy, our process can do chemical recycling, and the same time carbonize plastic only at 200-300C and sequester carbon into charcoal.

Carbon-negative electricity generation using photosynthetic microorganisms and enzymatic biofuel cells

Principal Investigator（Affiliated institution）：Tsutomu MIKAWA（RIKEN）
R&D Organizations : Cyanology Co., Ltd.

Utilization of living organisms

Outline : We aim to develop a carbon-negative power generation system based on lactic acid derived from photosynthetic microorganisms, integrated with enzymatic biofuel cells.

1. Background

- RIKEN: Efficient power generation from lactic acid using biofuel cells
- Cyanology: Lactic acid production from CO_2 using photosynthetic microorganisms
- By integrating these technologies, we will develop a carbon-negative power generation system.

2. Procedure

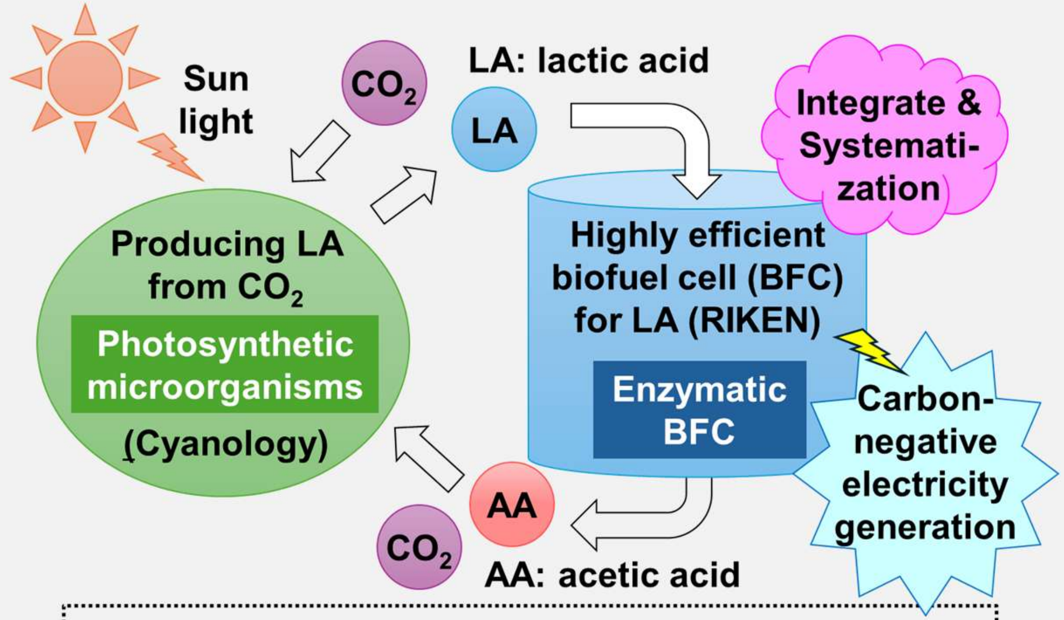
- Development of photosynthetic microorganisms that produce high concentrations of lactic acid from CO_2.
- Development of a biofuel cell that operates with lactic acid containing many impurities.
- Development of high-efficiency biofuel cells based on multi-step enzymatic reactions.

3. Feature of the Research

- Carbon dioxide is used as a fuel to generate electricity with net negative carbon emissions.
- Enzyme fuel cells offer a safe, secure, and sustainable energy solution.

4. Ripple Effect

- If the prototype proves effective, large-scale expansion will be easy due to its cost-effectiveness, making industrial application highly feasible.



Challenges to be solved: Development of

- **Photosynthetic microorganisms producing LA**
- **BFC working even with LA containing impurities**

Bio-PET Circulation: Harnessing CO_2 for Sustainable Growth

CARBON RECYCLING FUND INSTITUTE

Principal Investigator（Affiliated institution）：Tsutomu Tanaka（Kobe University）
R&D Organizations :

Utilization of living organisms

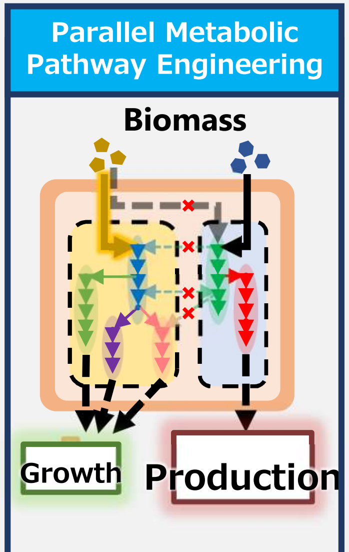
Outline : This project aims to develop microbial chassis strains capable of industrial-scale fermentation to produce PET alternative feedstocks from biomass, thereby enabling a sustainable bio-PET cycle.

1. Background

- Many companies now prioritize carbon neutrality as a central strategy for plastic resource circulation.
- Biomass utilization—capable of capturing CO_2 and substituting for fossil-derived PET feedstocks—offers the most viable pathway to long-term social and economic sustainability.
- Amajor gap remains in producing PET feedstocks directly from biomass.

2. Procedure

- Engineer microbial chassis strains to produce pyridinedicarboxylic acid, a key PET alternative.
- Apply parallel metabolic engineering to decouple growth and production, minimizing trade-offs and maximizing productivity.
- Achieve both efficient biomass utilization and enhanced CO_2 capture capacity.
- Conduct scale-up cultivation studies and precise process evaluations, supported by prototype validation to overcome bottlenecks.



3. Feature of the Research

- Bio-based production yields materials equivalent in quality to petroleum-derived virgin PET.
- Simultaneously achieves growth performance and sustainability.
- Biomass serves as a carbon sink, enabling CO_2 capture beyond PET production.
- Establishes a robust framework for practical-scale troubleshooting through mechanistic insights into production and cultivation.

4. Ripple Effect

- Promotes wider societal acceptance of bio-based production.
- Bio-PET contributes simultaneously to carbon neutrality and economic feasibility.
- Delivers new consumer value by combining environmental responsibility with practical usability.

CARBON RECYCLING FUND INSTITUTE

Development of an Innovative Conversion Process from Carbon Dioxide to Acrylic Resin Precursors without Hydrogen Consumption

Principal Investigator（Affiliated institution）：Teruoki Tago （Institute of Science Tokyo)

Value Enhancement

Outline：We aim to develop an innovative process that converts CO_2 into methacrylic acid without hydrogen consumption, applying our expertise in zeolite-encapsulated metal nanoparticle catalysts to realize an efficient catalytic process.

1. Background

Research Background

CO_2 fixation is key to carbon neutrality, based on carbon cycling.

◆ Convert CO_2 into plastic monomers →fixed as plastics.

Research Challenges

Develop a process to directly convert CO_2 into monomers.

◆ Efficient reaction process with novel catalysts.

Catalyst: "CO_2 activation" + "monomer-formation"

Process: "Low H_2 consumption" + "Novel pathway"

2. Procedure

◆ Convert CO_2 into plastic monomers using novel multifunctional catalysts.

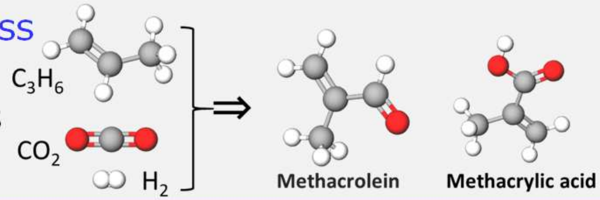
One-step catalytic synthesis of acrylic monomers via CO_2 activation and direct insertion into olefins.

✓ Cu@Zeolite catalyst

✓ CO_2–H_2–olefin reaction system

◆ High-Efficiency Process

Testing CO_2 activation and insertion into olefins



3. Feature of the Research

◆ Cu-catalyst, CO_2 activation and monomer synthesis

Cu nanoparticle catalysts are promising for CO_2 insertion into olefins.

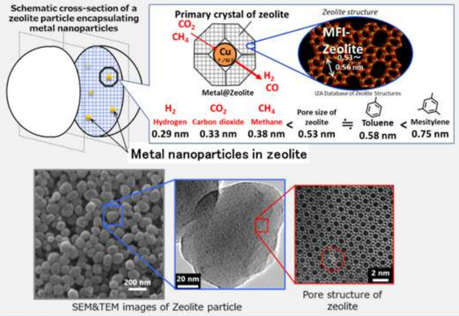
✓ **Cu@Zeolite catalyst**

Suppress Cu sintering

Insert CO_2 into olefins

Carbon chain growth

Direct monomer synthesis



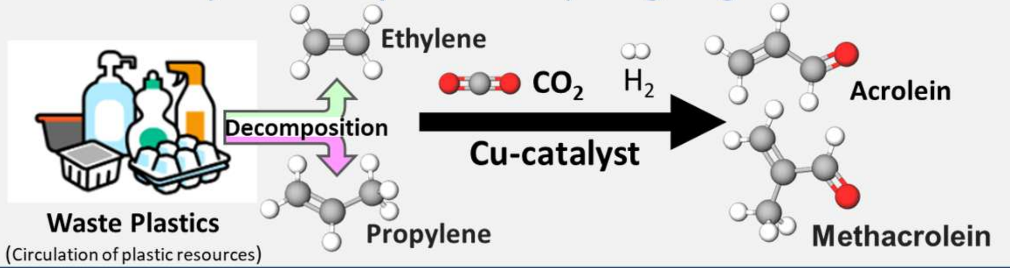
4. Ripple Effect

◆ Direct conversion of CO_2 into plastic monomers

CO_2 fixation through a low-H_2-consumption process

◆ Expand to various substrates → high-value CO_2 utilization

◆ Carbon cycle with plastic recycling & green olefins



Research and Development of a Seaweed Attachment System for Large-Scale Blue Carbon Creation

Principal Investigator（Affiliated institution）：Nobuko Nishikawa (BLUABLE Co., Ltd.)
R&D Organizations：Hokkaido University, Marine Open Innovation Organization

Utilization of CO2 sinks

Outline： Research and development of substrates that promote large-scale seaweed attachment, supporting blue carbon creation.

1．Background

① J-Blue Credit is not profitable

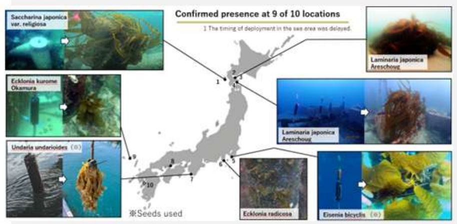
Current seaweed bed creation costs over ¥250,000 per ton of CO_2 removed, but J Blue Credit pays only about ¥80,000, making it unprofitable. As a result, commercialization stalls and many degraded seaweed beds remain unrestored.

② Seaweed attachment substrate

Conventional concrete artificial substrates allow seaweed to attach in the first year, but within a few years, we have observed cases of other seaweed becoming dominant or disappearing.

2．Procedure

The inexpensive resin-based "Klein substrate" reduces substrate costs while significantly reducing installation and maintenance costs. Its high durability and adhesion enable a profitable model even at J Blue Credit unit prices.



3．Feature of the Research

① Elucidation of the basis for the massive and strong adhesion of kelp to Klein substrate

Use genomics and metabolomics to identify why kelp spores settle en masse and why mature pseudorhizoids adhere strongly to Klein substrate.

② Design of an "algae bed creation kit" for large-scale implementation

Develop a scalable kit and validate it via small-scale Antokume restoration trials in Izu, Shizuoka.

4．Ripple Effect

- **Algae bed creation can be a green investment with payback in six years.**

Using the J-Blue Credit system, 1 ha can absorb 5 t-CO_2/year. At the average credit price, the initial cost can be recovered in six years. Restoring 100,000 ha of eroded shores could capture 500,000 t-CO_2..

- **Seaweed beds are the "cradle of the sea" that boost biodiversity.**

Restoration can add up to 200 million invertebrates, 36× more fish, and 48 more diatom species per ha. A 1-ha kelp bed also removes nitrogen and phosphorus equivalent to the water purification of 188 and 63 people, respectively.

CARBON RECYCLING FUND INSTITUTE

Development of Functional Biochar as the Final Utilization Stage in the Material Flow of Wood-based Resources

Principal Investigator（Affiliated institution）：
Masako SEKI（National Institute of Advanced Industrial Science and Technology (AIST)）

Utilization of CO2 sinks

Outline: Developing functional biochar as the final utilization stage in the material flow of wood-based resources. Contributing to achieving negative emissions through functional expression and long-term stabilization in the soil.

1．Background

- To achieve negative emissions through the circular use of wood resources, it is essential to avoid incineration after long-term use as wood products※.
- We propose carbon sequestration in soil using biochar as the final utilization stage of wood materials.

※NEDO Leading Research Program "Development of recycling elemental technologies for accelerating CCUS of waste wood resources" (2022-2023)

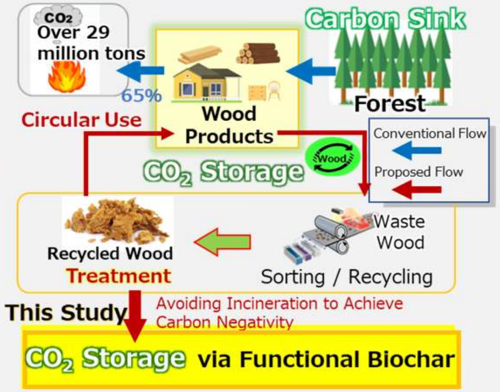


Fig.1 Wood Material Recycling System

2．Procedure

- We aim to enhance functionality from the bottom up by understanding the carbonization phenomena through structural evaluation and analysis before and after carbonization, with multiscale structural control of wood-based materials (Fig. 3).

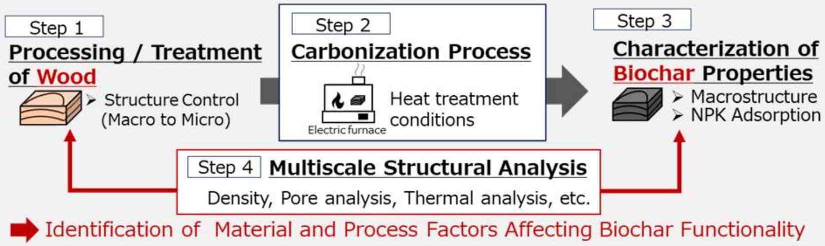


Fig.2 Research Procedure

3．Feature of the Research

- Our focus is on preparing wood-based raw materials with highly controlled micro- to macro-scale (multiscale) structures and deriving optimal carbonization process conditions that leverage these structures.

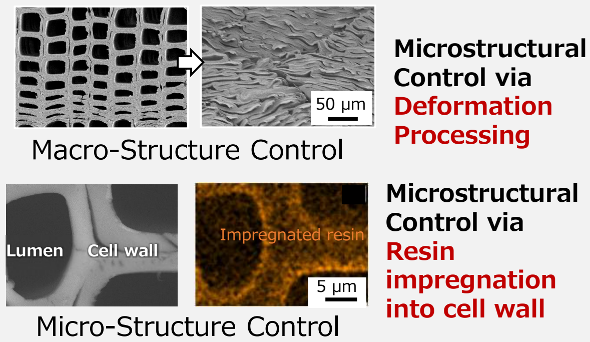


Fig.3 Multiscale Structural Control of Wood

4．Ripple Effect

- Improved functionality of biochar (Fig. 4) will expand its applications, contributing to the development of a biochar industry that includes not only recycled woods but also unused biomass such as forest residues.
- By 2040, the material flow of wood products (Fig. 1) is expected to enable carbon sequestration of 2 million tons of CO_2 per year.

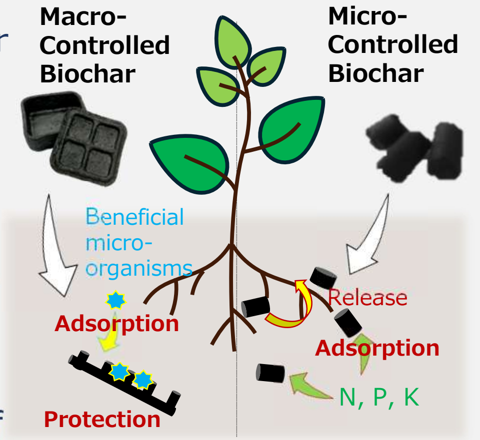


Fig.4 Expectations for Functional Biochar

Ammonia Cracking at Low Temperature and High Rates with Precious-Metal-Lean Catalysts: From Discovery to Scale-Up

Principal Investigator (Affiliated institution) : Akira Oda (Institute for Catalysis, Hokkaido University)

H2 Carrier Usage

Outline : We aim to develop scalable manufacturing methods for catalysts that significantly reduce the thermal energy and associated CO_2 emissions required to extract H_2 from the hydrogen carrier (NH_3), while minimizing precious metal usage.

1. Background

NH_3 is a high-energy-density compound that enables efficient H_2 storage and transport. At the point of use, a catalytic dehydrogenation step is required to release H_2. However, three challenges remain: [Challenge 1] With base-metal catalysts, operation above 700 °C is common. External heat input is unavoidable and leads to substantial CO_2 emissions. This undercuts the benefits of green H_2. [Challenge 2] Designing high-performance, low-temperature catalysts typically requires ~5 wt% Ru or very sophisticated catalyst engineering, both of which entail significant resource risk and cost. [Challenge 3] Even though highly active, precious-metal-lean catalyst designs have been established, they rely on specialized methods and environmental burdens; such routes are ill-suited to large-scale manufacturing and have not led to practical deployment.

2. Procedure

By harnessing spontaneous, self-driven phenomena that do not require esoteric synthesis techniques, we will design the "ideal" catalyst and transition to scalable, large-scale manufacturing.

3. Feature of the Research

By engineering the local structure of surface Ru atoms on the solid catalysts, we will achieve high performance suitable for practical deployment and drastically reduce precious-metal use. We will employ our proprietary "mix-and-calcine" route, which produces diverse, highly-dispersed Ru catalysts simply by blending precursors and calcining, and we will extend this method to large-scale manufacturing. Specifically, we aim to [Goal 1] reduce Ru usage to ≤1/100 of that of conventional catalysts; [Goal 2] surpass benchmark catalysts at 300–400 °C; and [Goal 3] validate a large-scale synthesis process via spray-drying—widely used in the chemical industry—to establish a clear path to implementation.

4. Ripple Effect

We will develop a precious-metal-lean ammonia-cracking catalyst highly active at 300–400 °C, reducing energy consumption and precious-metal demand relative to existing catalysts. Lowering the heat required for H_2 release and the associated CO_2 emissions, accelerating the adoption of carbon recycling. A low-cost, scalable synthesis supports deployment and can extend to other H_2 storage/transport processes.