Integrated Electrochemical Systems for Scalable CO_2 Conversion to Chemical Feedstocks

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Implementing organizations : The University of Tokyo, Osaka University, Institute of Physical and Chemical Research (RIKEN), Ube Industries, Ltd., Shimizu Corporation, Chiyoda Corporation, Furukawa Electric Co., Ltd.

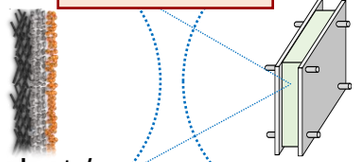
Project organization and goals

Larger electrode area
Stacking of electrodes

System development

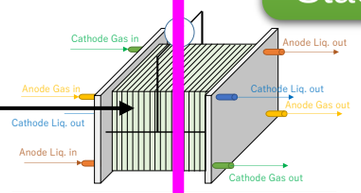
CO_2 electrolysis reactor

Osaka Univ.
Electrode



Catalyst / Electrode

CO_2 electrolysis reactor



Scale up/ stacking

Furukawa Electric Co., Ltd.
Cu-based substrates

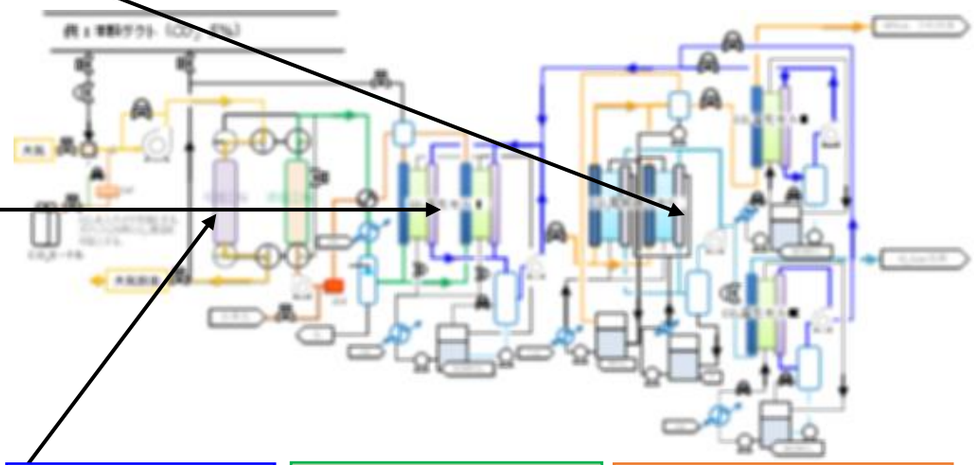
Ube Industries, Ltd.
Acid-tolerant catalysts

RIKEN
Reactor

The Univ. of Tokyo Chiyoda Corp.
Process integration

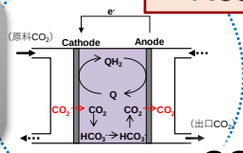
The Univ. of Tokyo・Chiyoda Corp.
Process integration / system control / characterization

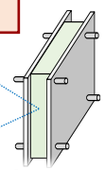
The Univ. of Tokyo
LCA analysis



CO_2 enrichment reactor

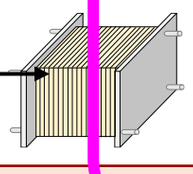
Osaka Univ.
Reactor





CO_2 enrichment reactor

Electrochemical reaction system



Scale up/ stacking

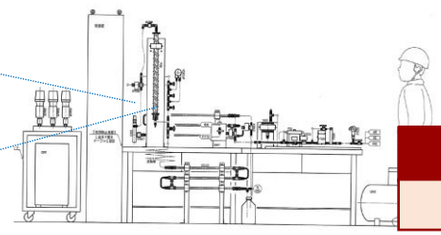
CO_2 Capture

CO_2 Enrichment

CO_2 Electrolysis

Physical CO_2 capture

Adsorption / desorption material



Adsorption / Desorption system

Shimizu Corp.
Prototyping

Shimizu Corp.
Process concept

Ube Industries, Ltd.
Provisional pilot field /
Social implementation scenario

Goals

- Development of an integrated system that electrochemically converts CO_2 captured from an atmospheric air to valuable chemical substances
- Conducting a life cycle assessment on a pilot-scale plant to evaluate the effectiveness as a measure against global warming

Role of the University of Tokyo

- **R&D items**

  Analysis and control of the integrated system
  Life-cycle assessment (LCA)

- **Major results so far**

  1) Development of on-line analysis system for CO_2 electrolysis
  ➔Product analysis over days with a time resolution of minutes

  2) Precise potential measurement of a gas-diffusion electrode (GDE)
  ➔Precise evaluation of the overpotential for CO_2 electrolysis

  3) LCA for CO_2 footprint on the product C_2H_4
  ➔Clarification of the blanching point for a carbon-negative process

Objectives

☐FY 24

Theoretical design of the operation of DAC, electrochemical CO_2 enrichment, and CO_2 electroreduction in series connection is completed.

Verify the feasibility of a lab-scale system consisting of an electrochemical CO_2 enrichment device and a CO_2 electroreduction device connected in series.
(Target continuous operation time: 1,000 hours, current density: 200 mA/cm^2, a current utilization efficiency : 50%)

LCA evaluation considering a wide range of process conditions.

☐FY 27

Prospects for 5,000 hours of continuous operation on a laboratory scale at a current density of 200 mA/cm^2 and a current utilization efficiency of 80% for the product will be determined. Also, obtain the necessary specifications for the pilot design.

LCA evaluation based on the pilot plant design is completed.

1) Development of on-line analysis system for CO_2 electrolysis

- Current: up to 2 A
- Electrolyte flow: 0～100 mL/min
- CO_2 flow: 0～100 mL/min
- Reaction temperature: 0～80℃

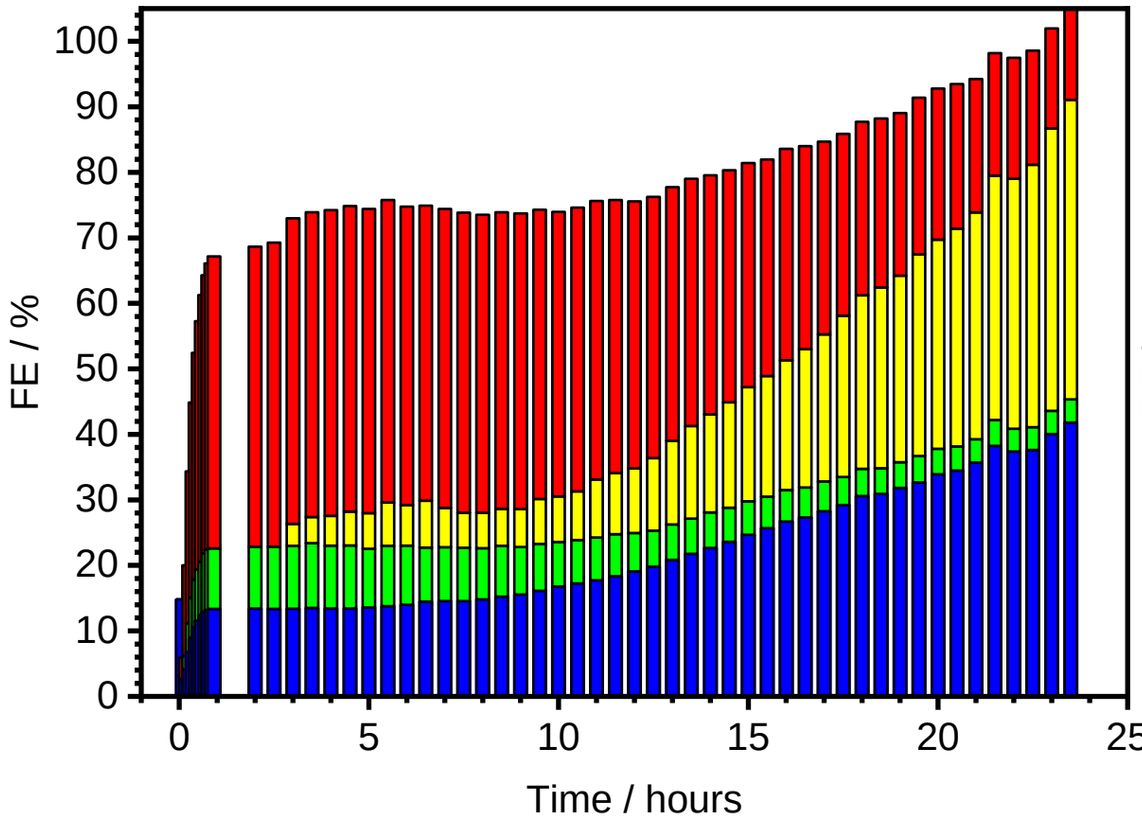
Agilent 490 Micro GC

- 2 channels
  Ch1: Ar, MS5A + Buckflush
  Ch2: He, Pora Plot Q
  Detectors:　MicroTCD

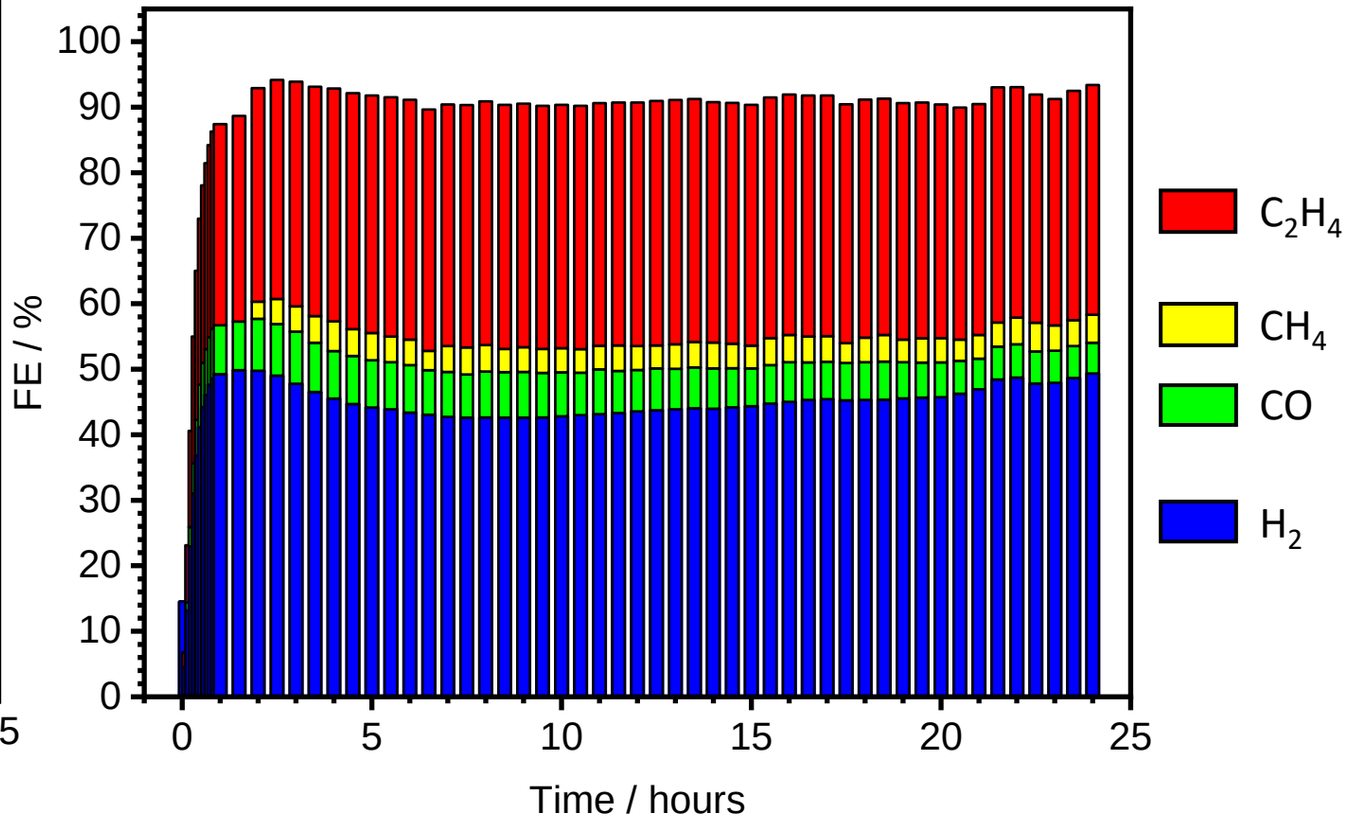
Gas product analysis:
- **2 minutes/analysis**
- **1 ppm～100%**

Ex) CO_2 reduction using electrodeposited Cu_2O electrode

1 cycle electrodeposition



12 cycles electrodeposition



Deposition amount:

Small ➔ High initial FE_{C2H4} , poor durability

Large ➔ Low initial FE_{C2H4} , better durability

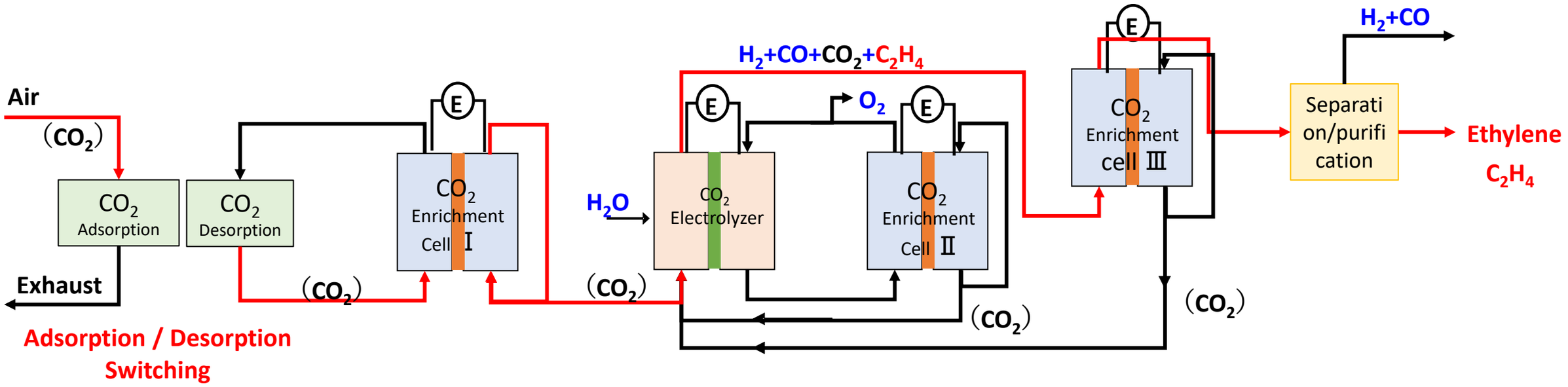
Development of electrodes for both initial performance and durability.

➢ **Necessity for novel analysis and materials**

3) Integrated system design

Collaborative work with Chiyada corporation

①-1 CO_2 Capture	①-2 CO_2 Enrichment	② CO_2 Electrolysis	Separation/purification



- Design of a system flow that integrates the elemental processes under development, from CO_2 capture to ethylene production.
- Material balance and heat balance are examined.
- Basic Study of LCA

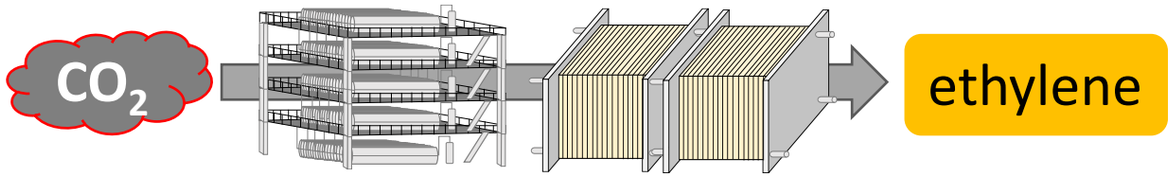
3) LCA

Integrated assessment of the environmental impact from production to disposal.

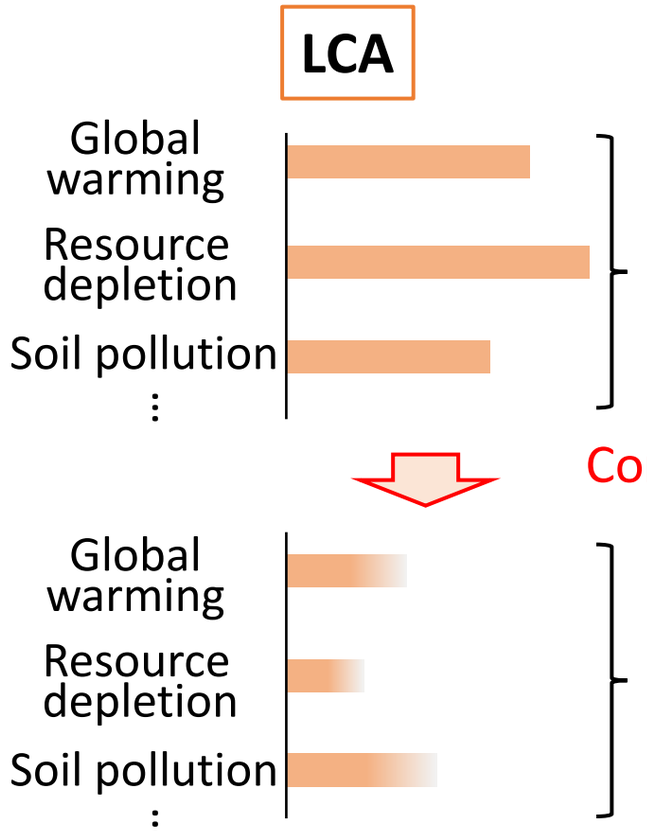
Existing technologies

CO_2 capture & storage　　Oil refinement

This project



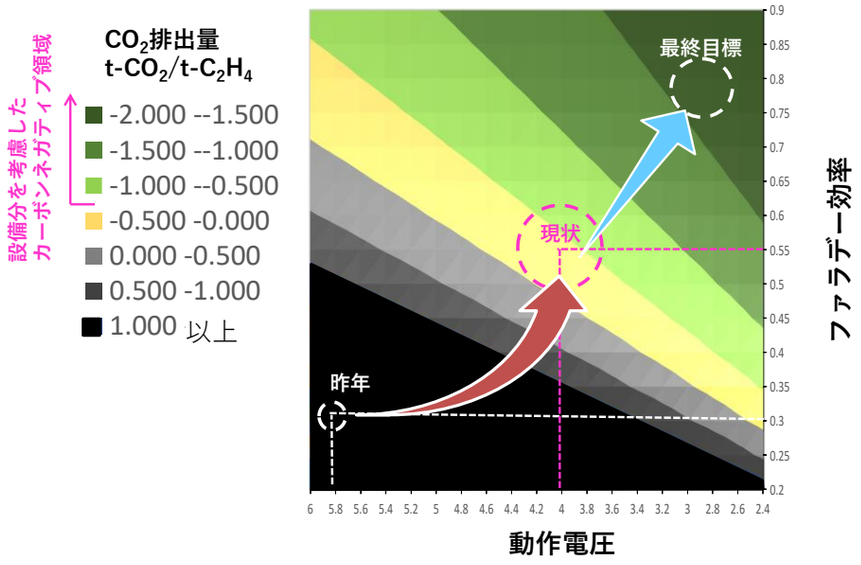
CO_2 capture　　Electrochemical reduction



Compare environmental impact with existing technologies

Current results

- Confirmed that the electrochemical reduction process has the greatest impact of all processes.
- Clarify the operating conditions necessary to achieve carbon negativity (CO_2 emissions < CO_2 fixation)



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