No. A-5-1E

PJ: Development of Global CO_2 Recycling Technology towards "Beyond-Zero" Emission

Organization: Kyushu University
Contact: Shigenori FUJIKAWA (fujikawa.shigenori.137@m.kyushu-u.ac.jp)

Toward a Beyond Zero Society through Ubiquitous Carbon Capture and Utilization (CCU)

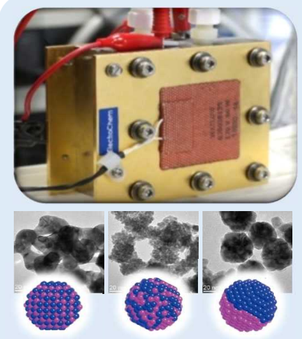
■ CO_2 separation nanomembranes with overwhelming high CO_2 permeability

- Kyushu University has developed a nanomembrane that is only 1/2500 as thin as the diameter of a hair.
- Developed nanomembranes show highest CO_2 permeance , which is 20 times higher than conventional membranes

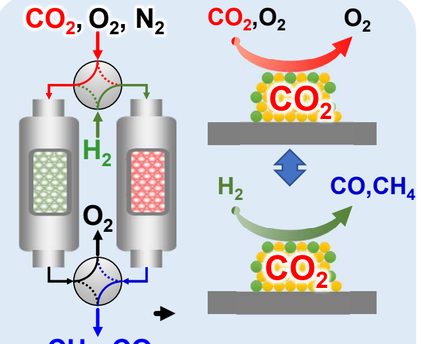
CO_2 separation nanomembrane

■ Catalyst technology for CO_2 conversion and small conversion system

- Nanocatalysts and electrochemical process system for highly efficient conversion of CO_2 to useful substances
- Novel thermochemical catalysts and processes for simultaneous O_2 removal and CO_2 conversion



Electrochemical process

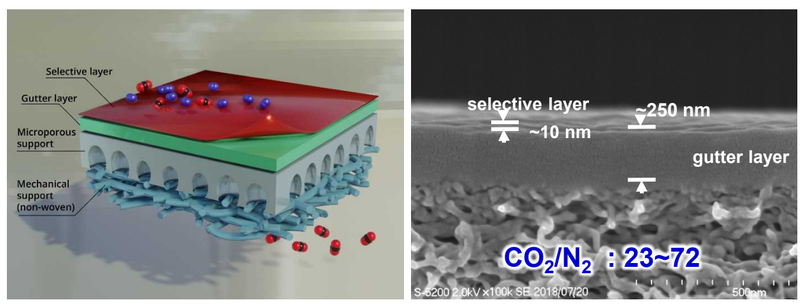


Thermochemical process

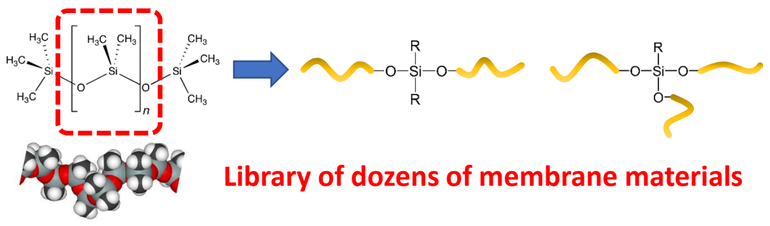
Goals of the Project

Compact, Scalable, Distributed Deployable Direct Air Capture-Utilization (DAC-U) System

Enhancement of CO_2 selectivity

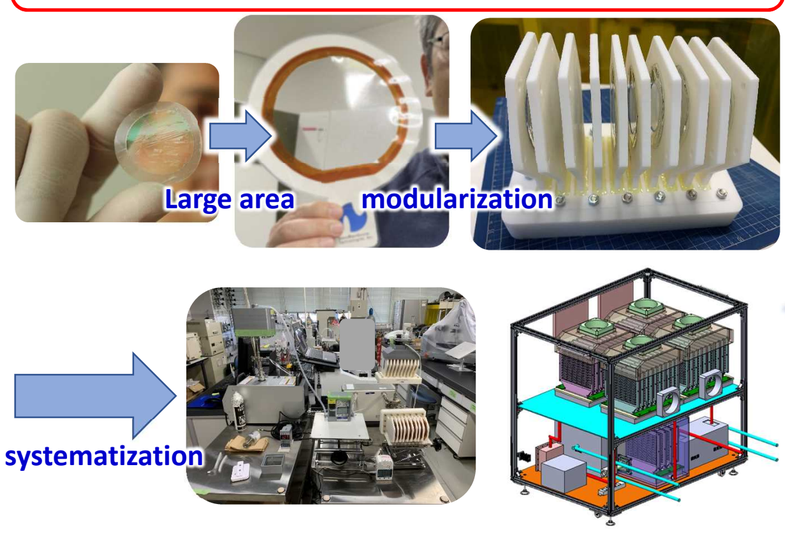


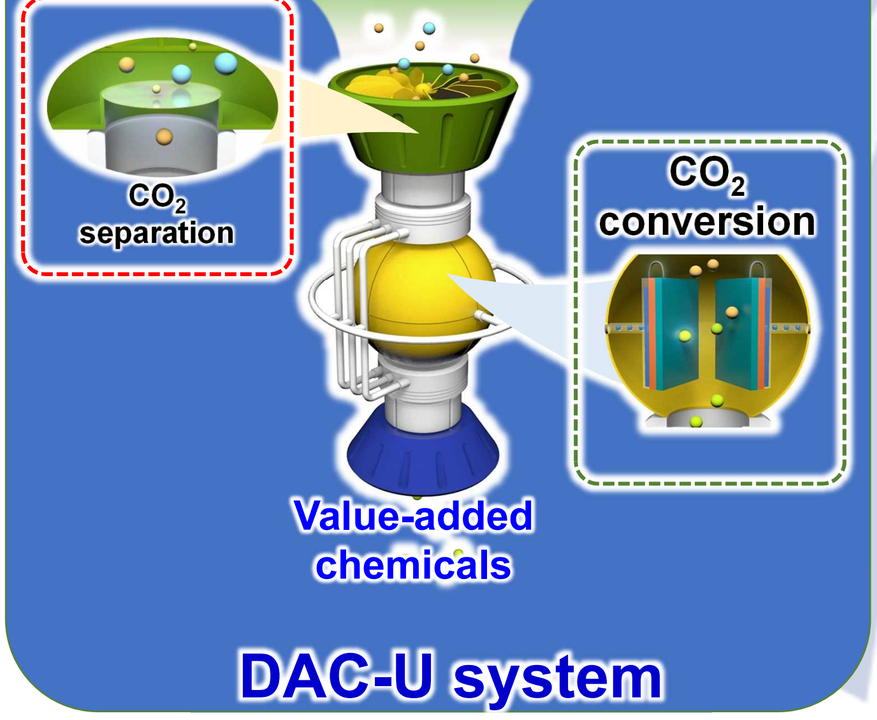
Development of membrane materials



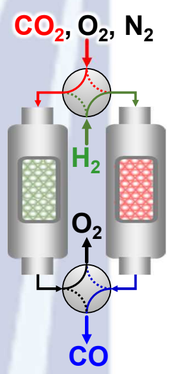
Library of dozens of membrane materials

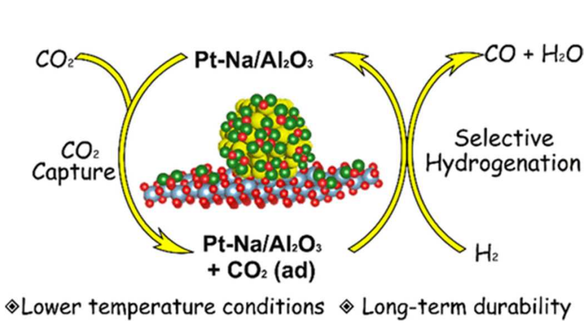
Large area and modularization of nanomembranes





CO_2 absorption and thermochemical CO_2 conversion

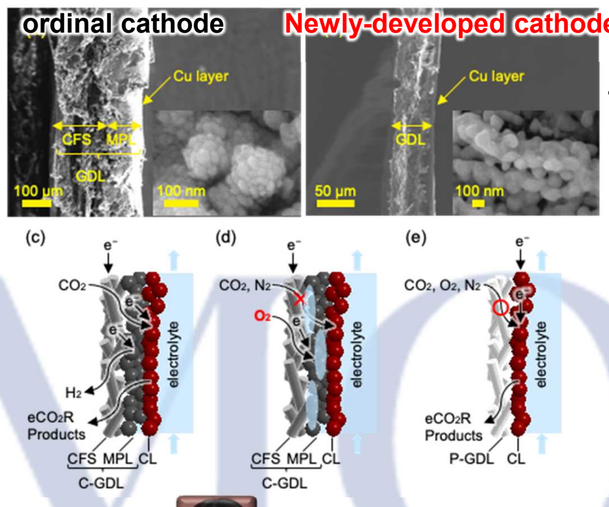


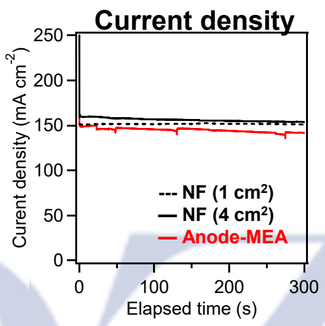


ACS Catal. 2022, 12, 4, 2639−2650

Prof. Ken-ichi SHIMIZU (Hokkaido Univ.)

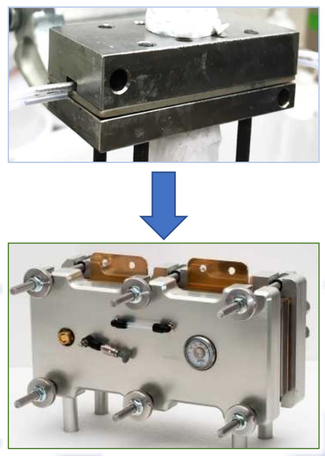
New electrodes for electrochemical CO_2 conversion



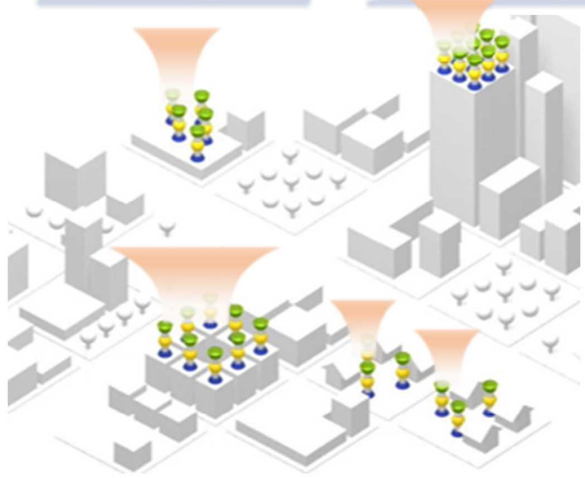


Prof. Miho YAMAUCHI (Kyushu Univ.)

Development of high-performance electrochemical cells



Univ. Illinois at Urbana Champaign
Prof. Paul KENIS



Carbon resource recycling society with decentralized deployment of DAC-U systems

No. A-5-2E

PJ : Development of Global CO_2 Recycling Technology towards “Beyond-Zero” Emission

Theme: Development of electrochemical production system using Air-CO_2

Organization: Kyushu University

Contact: Miho YAMAUCHI (yamauchi@ms.ifoc.kyushu-u.ac.jp)

Electrochemical CO_2 reduction using 60% air mixed 40% CO_2 gas (Air-CO_2)

目標：[Air-CO_2] + H_2O → CO, CH_4, C_2H_4 or α

Method A

$40CO_2$, $12\%O_2$, $48\%N_2$ → Products

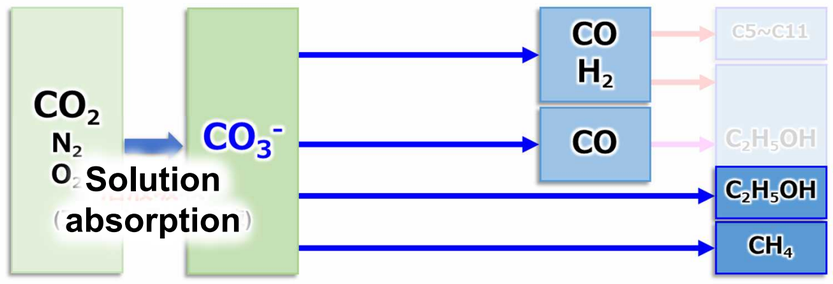
○simple system

×few reports

× N_2, O_2 separation

Method B

electrolyte



○no N_2, O_2 separation

×few reports

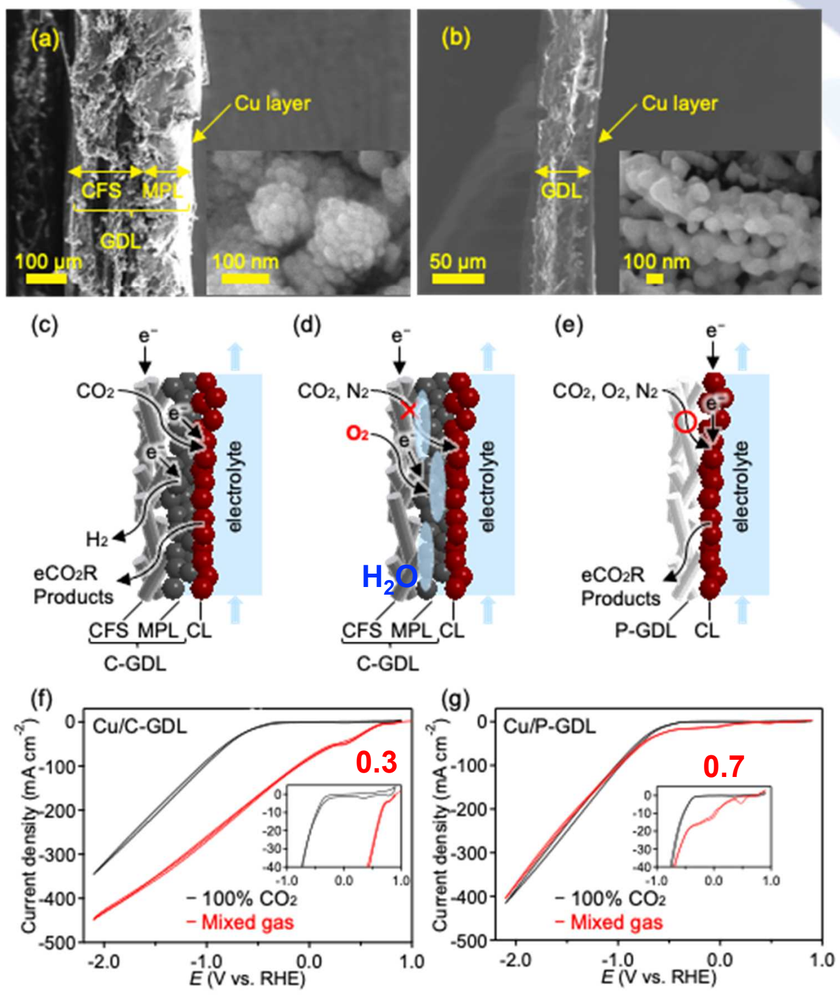
×predominant HER

×dissolving Air-CO_2

Method A

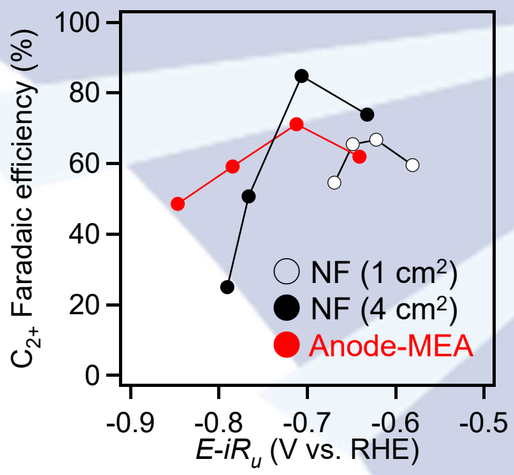
Direct eCO_2R using Air-CO_2

Conventional cathode Novel cathode

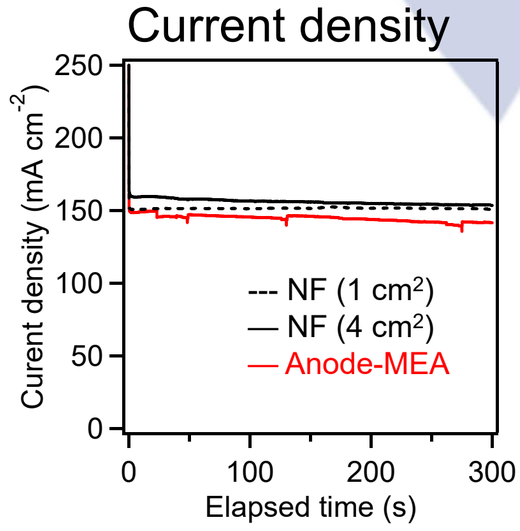


Chem. Comm., 59, 11188-11191 (2023)

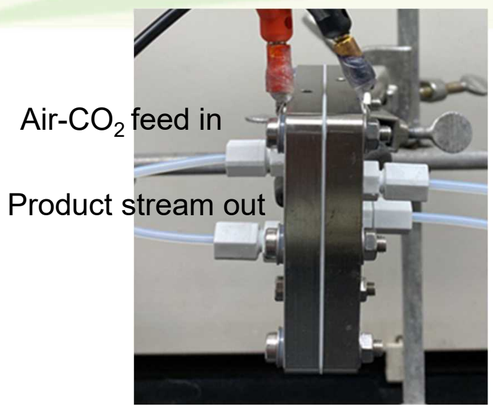
Faradaic efficiency

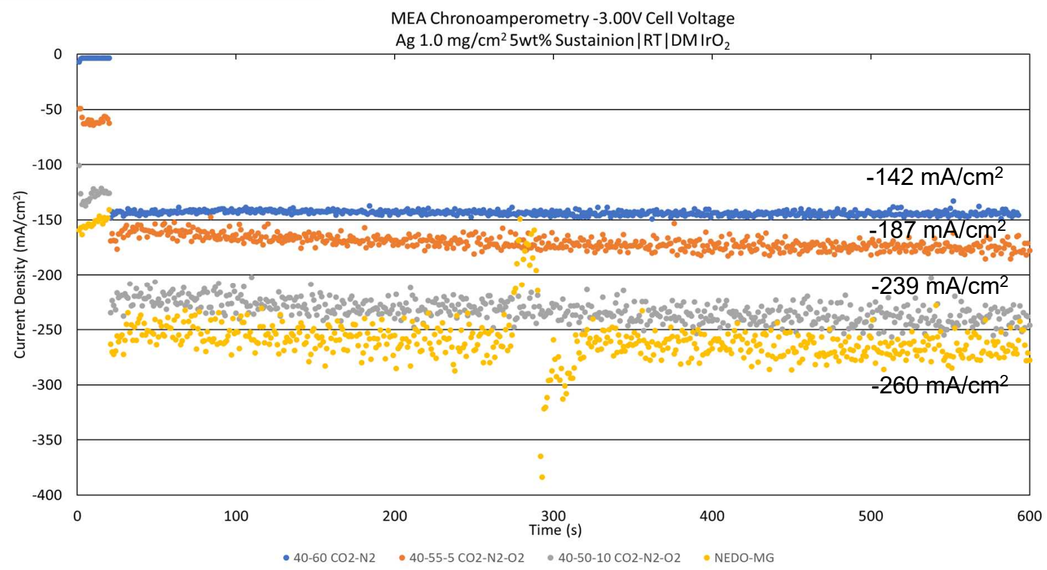


Current density



Prof. Kenis (UIUC)

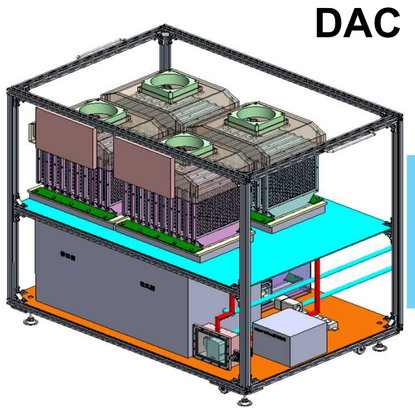




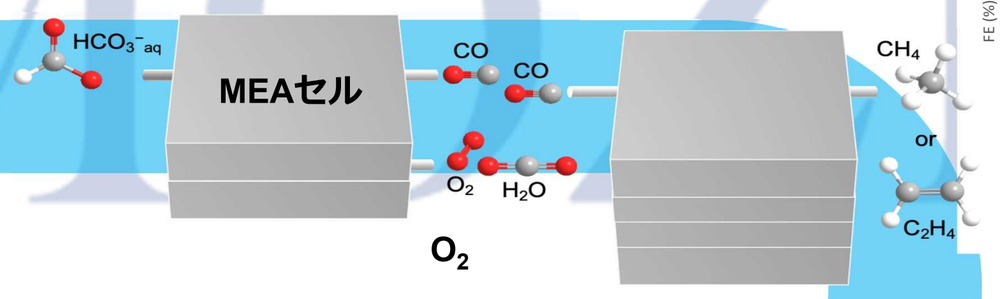
Method B

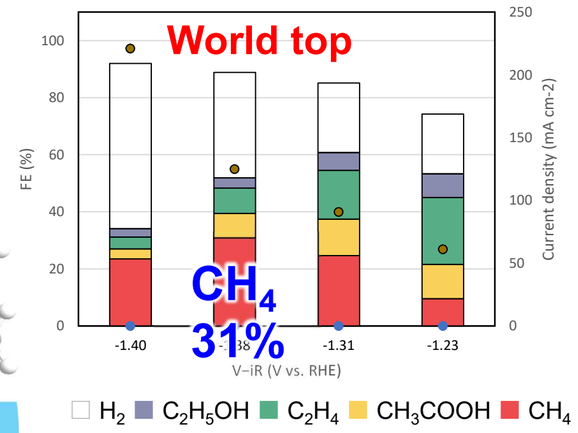
Production of O_2-N_2 free resources by eCO_2R from Air-CO_2

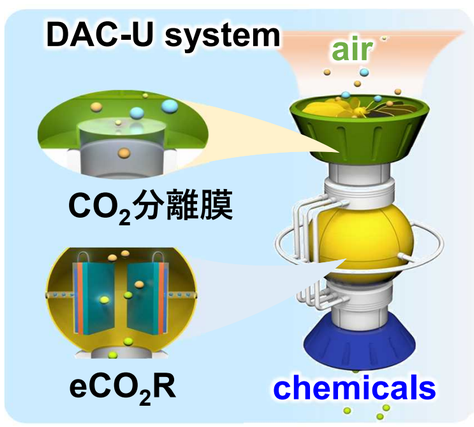
DAC CO_2 dissolution HCO_3^- conversion CO conversion



Captured gas → HCO_3^-







Electricity used to create CH_4 from 2.0 kg CO_2 (current)

CO_2 conv. rate：45.4 mol day^{-1} (CO_2)

CH_4 prod. rate：1.29 mol day^{-1} (CH_4)

(Wh) = P (W) × t (h)より

1st step : 0.6 kWh

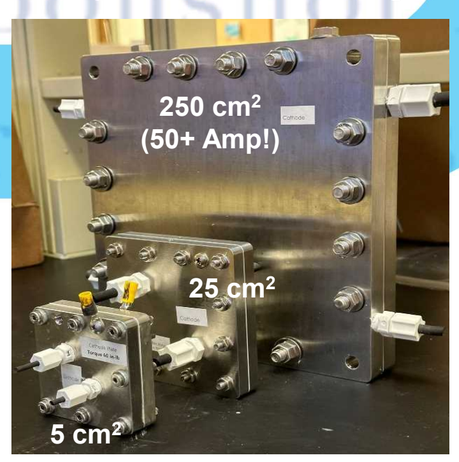
2nd step : 1.0 kWh

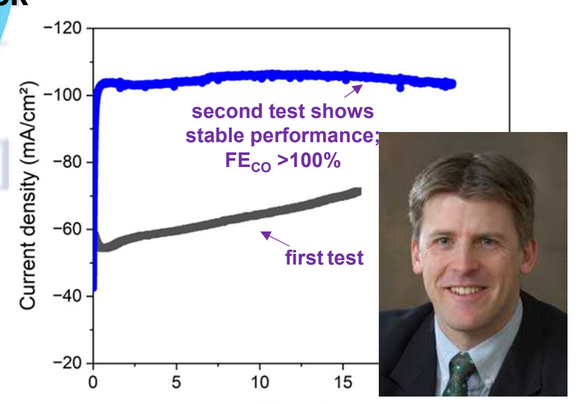
→ **1.6 kWh**

10円/kWh → 16 円 (eCO_2R)

If electricity bill were reduced to 1/10....

Large area, Stack





Prof. Kenis (UIUC)

No. A-5-3E

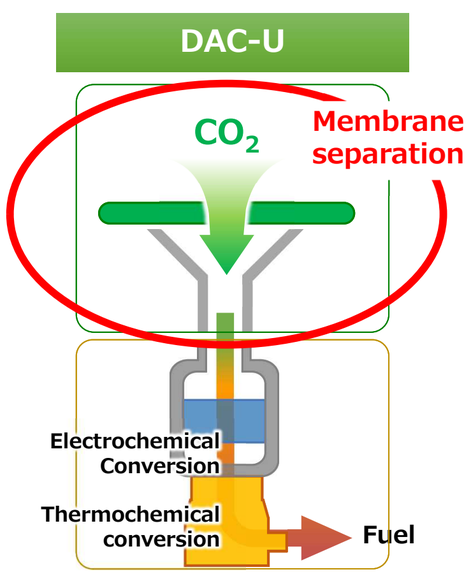
PJ : Development of Global CO_2 Recycling Technology towards "Beyond-Zero" Emission

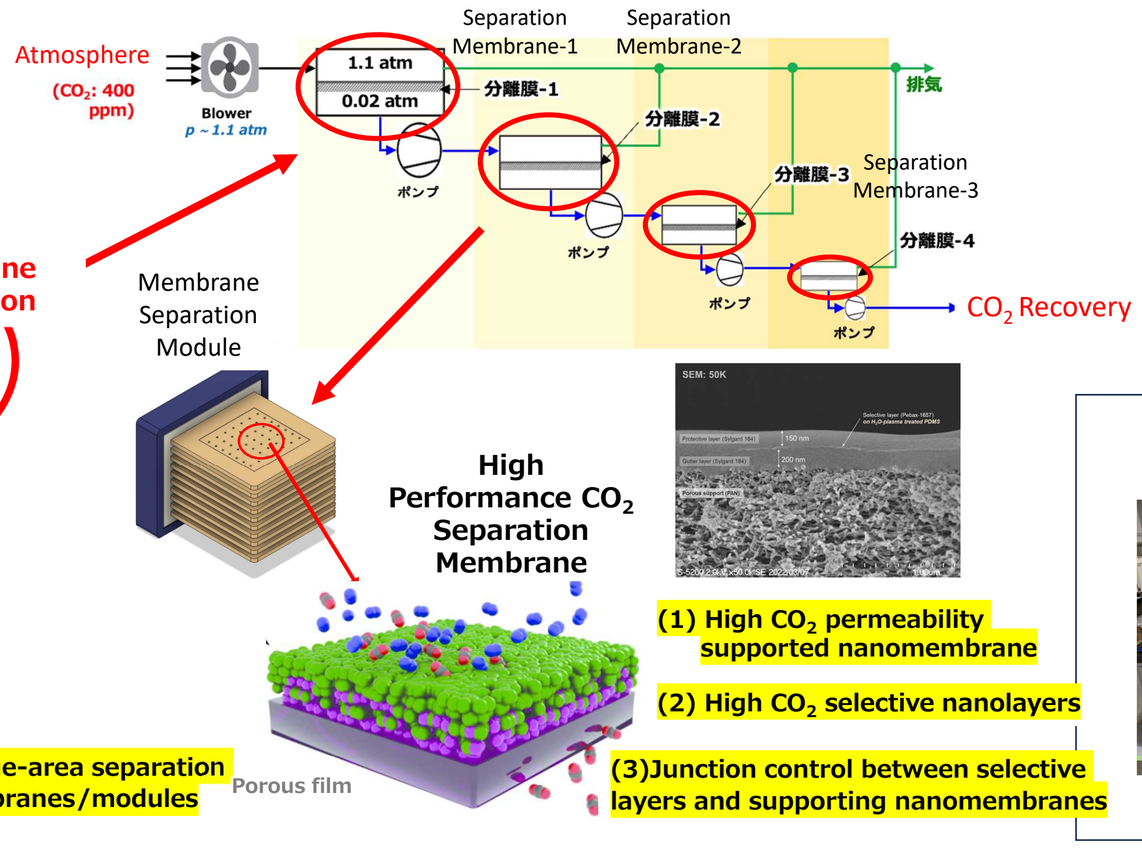
Theme: Development of High-Performance CO_2 Separation Membranes for DAC

Organization: Kumamoto University

Contact: Masashi KUNITAKE (kunitake@kumamoto-u.ac.jp)

CO_2 Capture Membrane Separation System





(1) High CO_2 permeability supported nanomembrane

(2) High CO_2 selective nanolayers

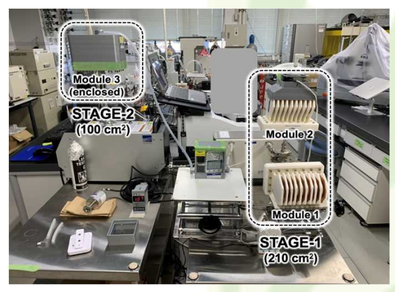
(3)Junction control between selective layers and supporting nanomembranes

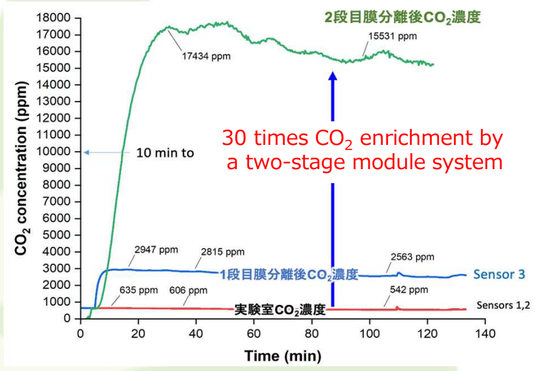
(4) Large-area separation membranes/modules

CO_2 Capture Membrane R&D Unit

Shigenori Fujikawa (Kyushu University, PM)
Masashi Kunitake (Kumamoto University, UL)
Tomoyasu Hirai (Osaka Institute of Technology)
Yoshiro Kaneko (Kagoshima University)
Shinichiro Noro (Hokkaido University)
Toyoki Kunitake (NanoMembrane Technologies, Inc.)

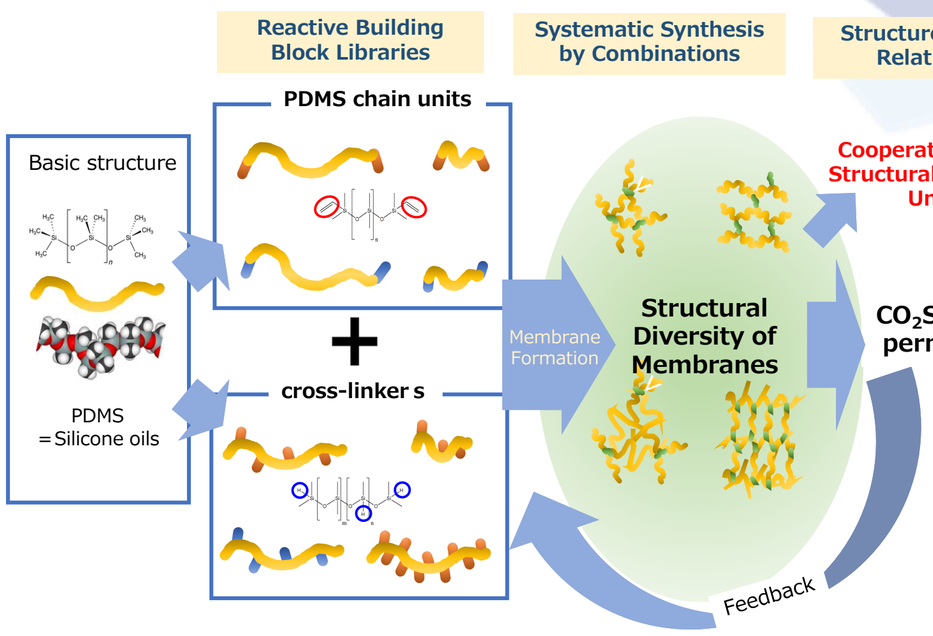
Demonstration of a two-stage separation prototype system



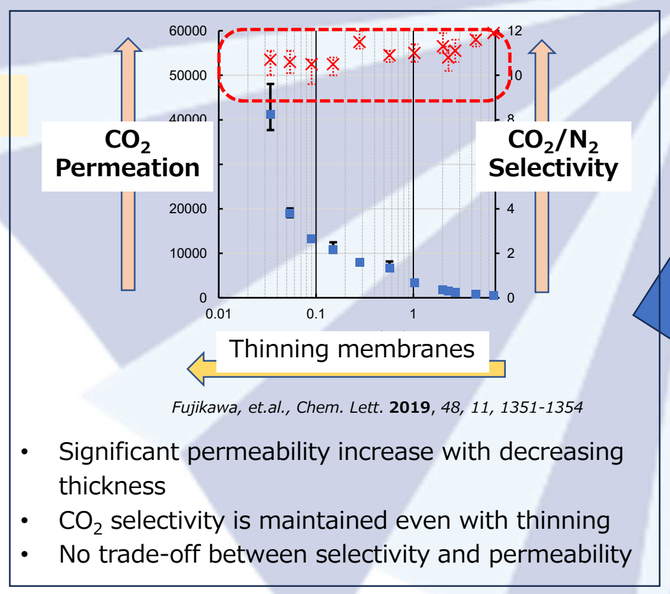


Supported Membranes with High CO_2 Permeability

Reactive Building Block Libraries | Systematic Synthesis by Combinations | Structure-Function Relationship

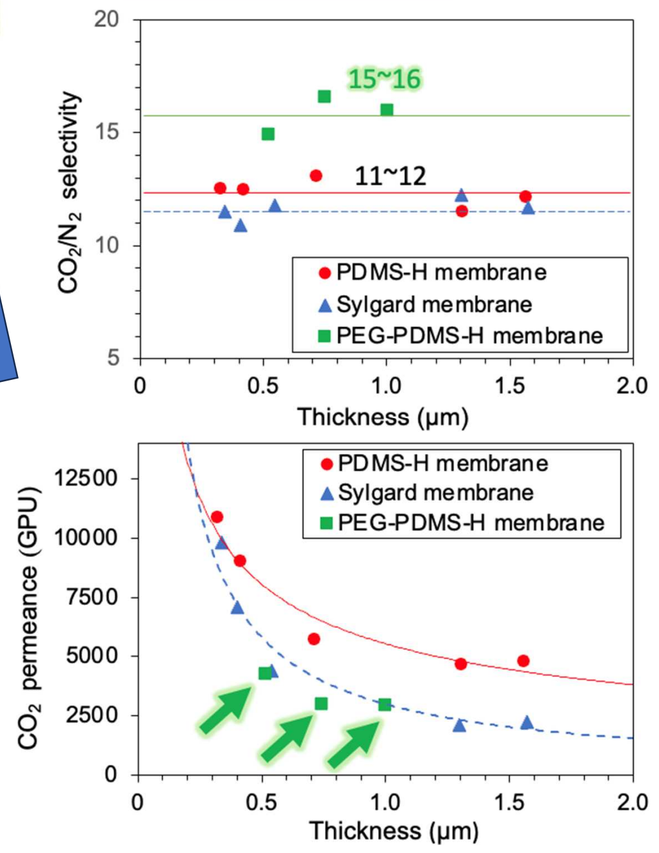


SYLGARD™ 184 Silicone Elastomer (Dow Chemical Company)
- Commercial PDMS cross-linker
- Defect standard for CO_2 selective permeable membranes.
- Structural details are unknown.



Fujikawa, et.al., Chem. Lett. **2019**, *48, 11, 1351-1354*

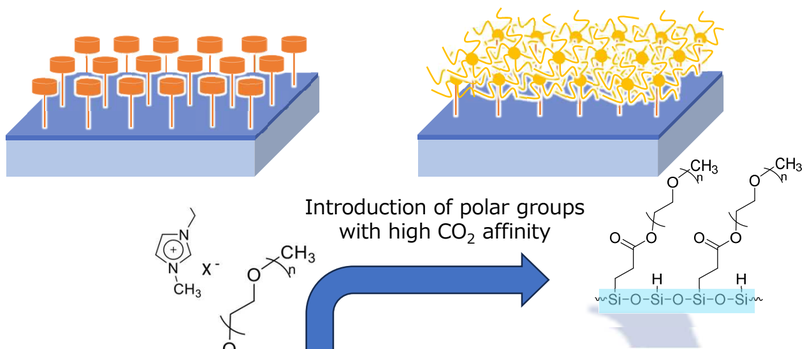
- Significant permeability increase with decreasing thickness
- CO_2 selectivity is maintained even with thinning
- No trade-off between selectivity and permeability



Development of siloxane products for permeation membranes to replace structure-unknown commercial materials

We have successfully developed several membrane material systems with CO_2 selective permeability equivalent to or superior to Sylgard, based on PDMS crosslinking reaction systems that can be hierarchically structured and have a well-defined chemical structure.In each system, we reconfirmed the improvement of permeability by thinning while maintaining the selective permeability.

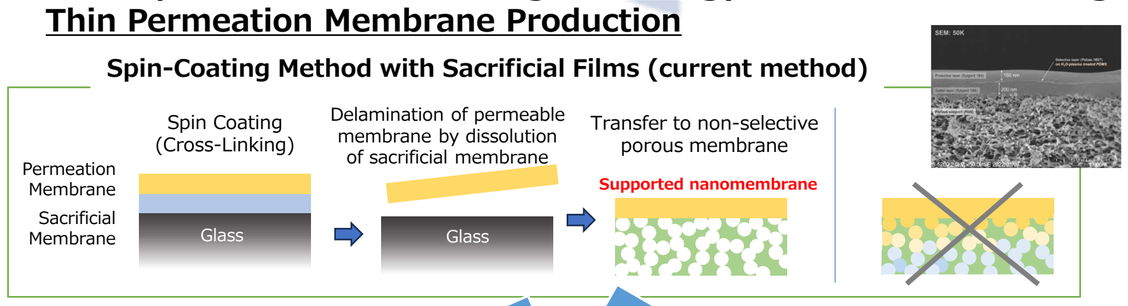
Exploration of Selective Layers, and Junction Control to Supporting Membranes



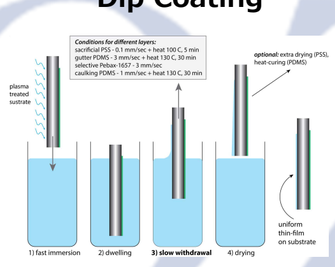
We have developed a technology for selectively introducing reactive units such as vinyl groups and hydrosilyl groups to PDMS film surfaces. This has made it possible to introduce various polar units to the non-polar PDMS film surface.

Development of Manufacturing Technology to Industrialize a Large-Scale Thin Permeation Membrane Production

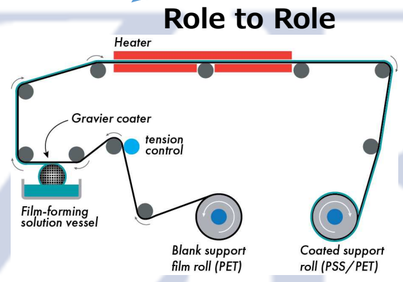
Spin-Coating Method with Sacrificial Films (current method)



Dip Coating



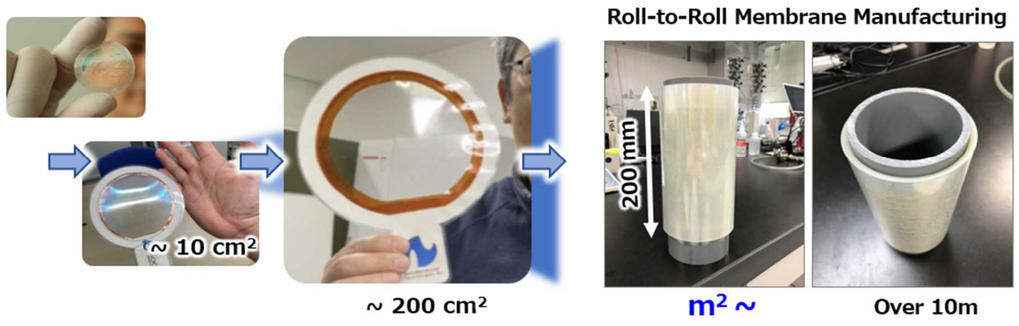
Role to Role

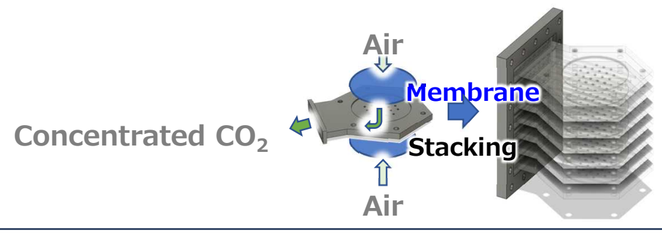


Penetration into a support porous membrane have to stop for thinning to improve selective permeability.

Development of technology for construction and transfer of selectively permeable membranes without a sacrificial membrane

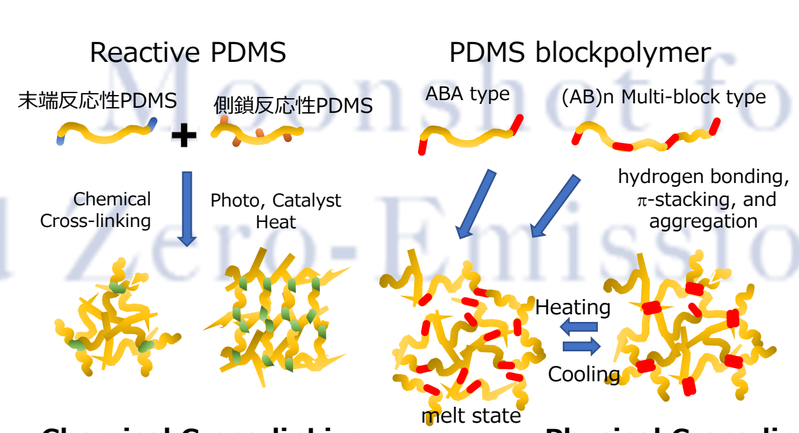
Large-Area/Modular Separation Membrane System



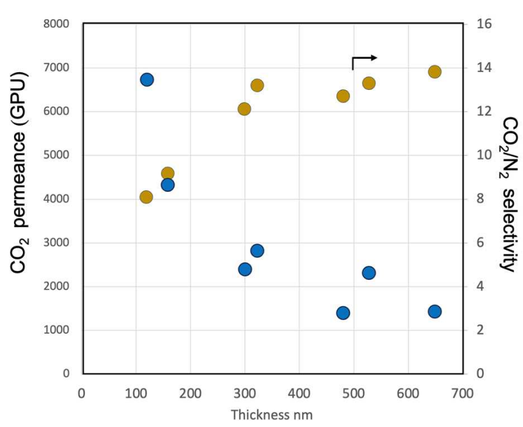


We have developed a technology for selectively introducing reactive units such as vinyl groups and hydrosilyl groups to PDMS film surfaces. This has made it possible to introduce various polar units to the non-polar PDMS film surface.

Development of Membrane Materials that do not Require Chemical Cross-Linking



Chemical Cross-linking **Physical Cross-linking**



A CO_2 selective permeable membrane equivalent to Sylgard has been successfully developed using a physically cross-linked PDMS elastomer that does not require chemical cross-linking. This leads to simplification of membrane production.