Integrated Electrochemical Systems for Scalable CO_2 Conversion to Chemical Feedstocks

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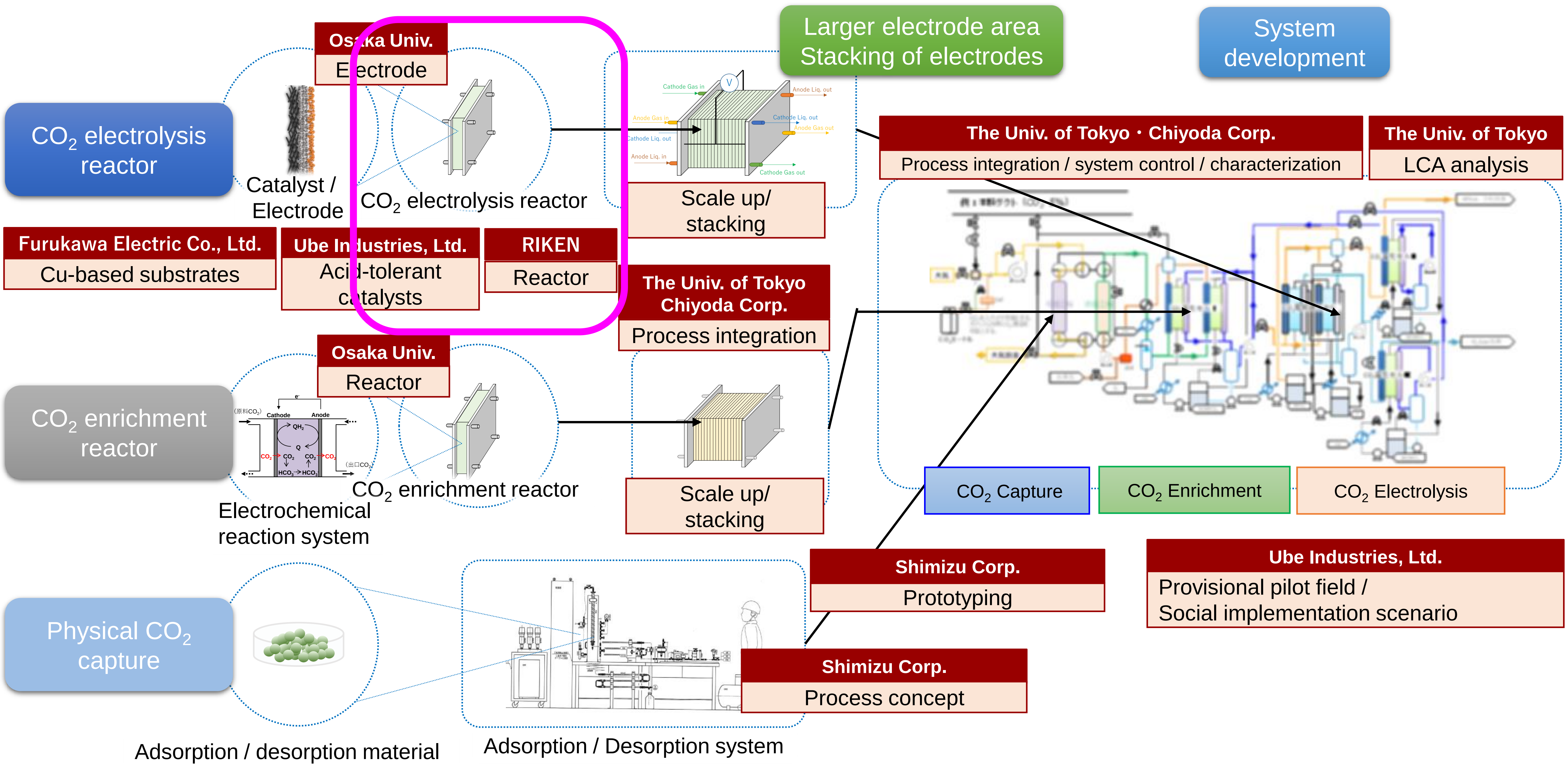
Project organization and goals



Goals

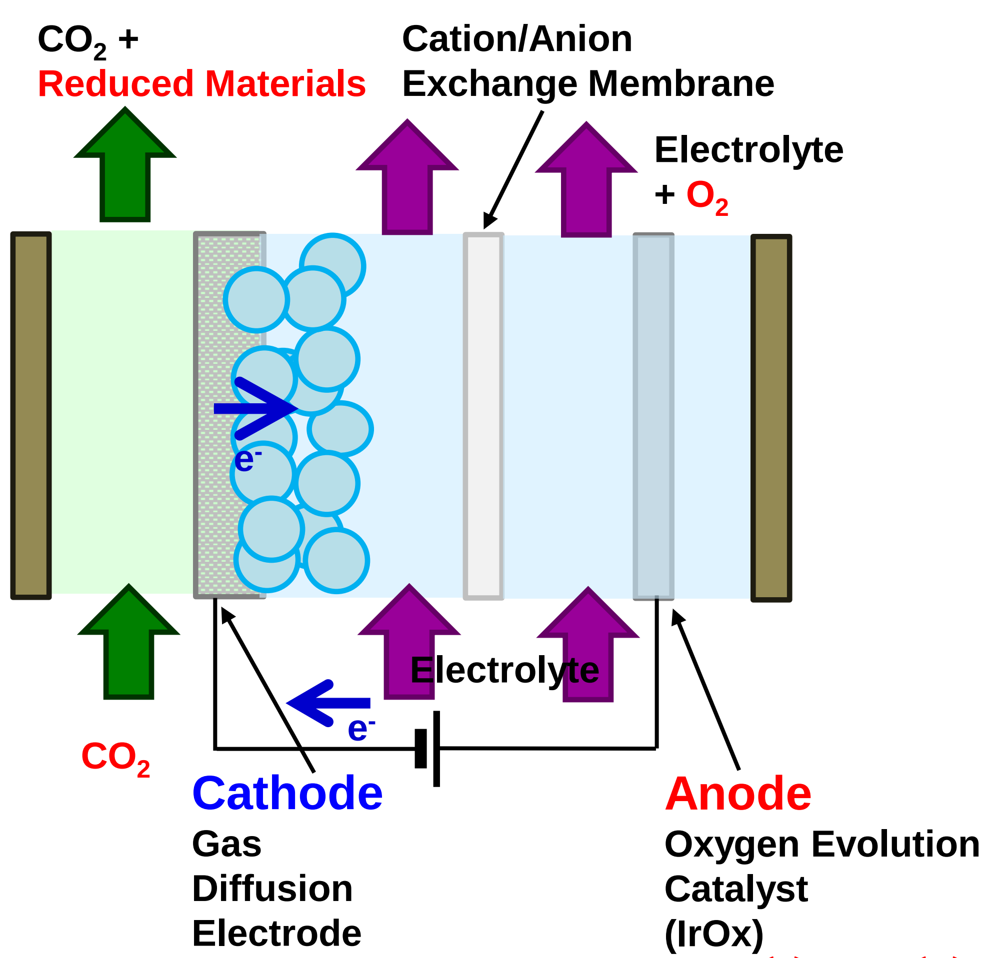
- Development of an integrated system that electrochemically converts CO_2 captured from an atmospheric air to valuable chemical substances
- Conducting a life cycle assessment on a pilot-scale plant to evaluate the effectiveness as a measure against global warming

RIKEN Research Items

- Reduction from CO2 to C2H4 requires not only a catalyst but also an electrochemical reactor.
- The presence of thick electrolyte limit the reduction in operating voltage of GDE-type reactors.
- **Providing "Zero Gap Reactor" as the ultimate reactor.**

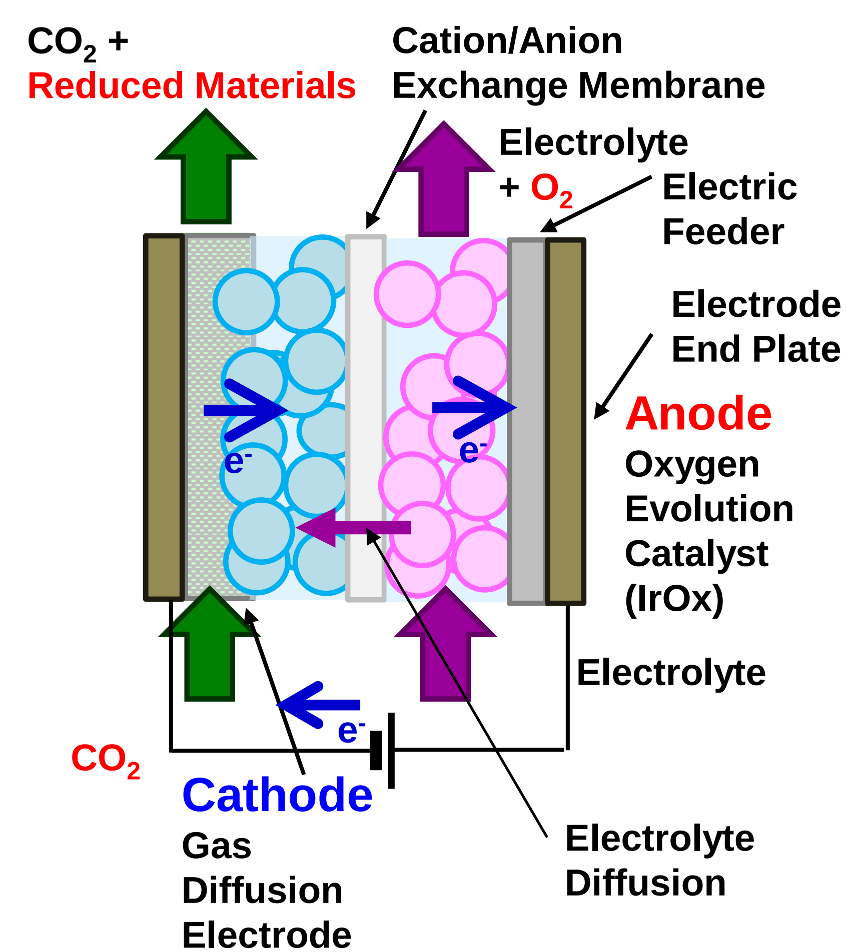
Industrially usable "Zero Gap Reactor" is developed using "Membrane Electrode Assembly (MEA)" with polymer electrolyte, applying the research results of the electrochemical catalyst from CO_2 to C_2H_4, and the mesoporous structure for "Gas Diffusion Electrode (GDE)".

Gas Diffusion Electrode



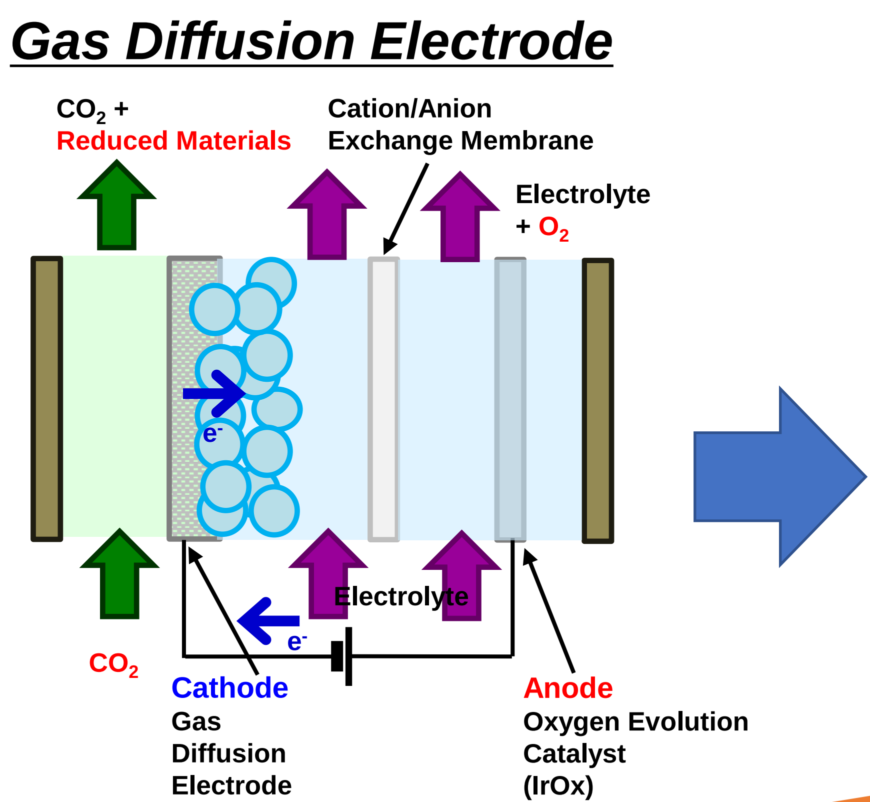
$$2H_2O\,(\ell) = O_2(g) + 4H^+ + 4e^-$$

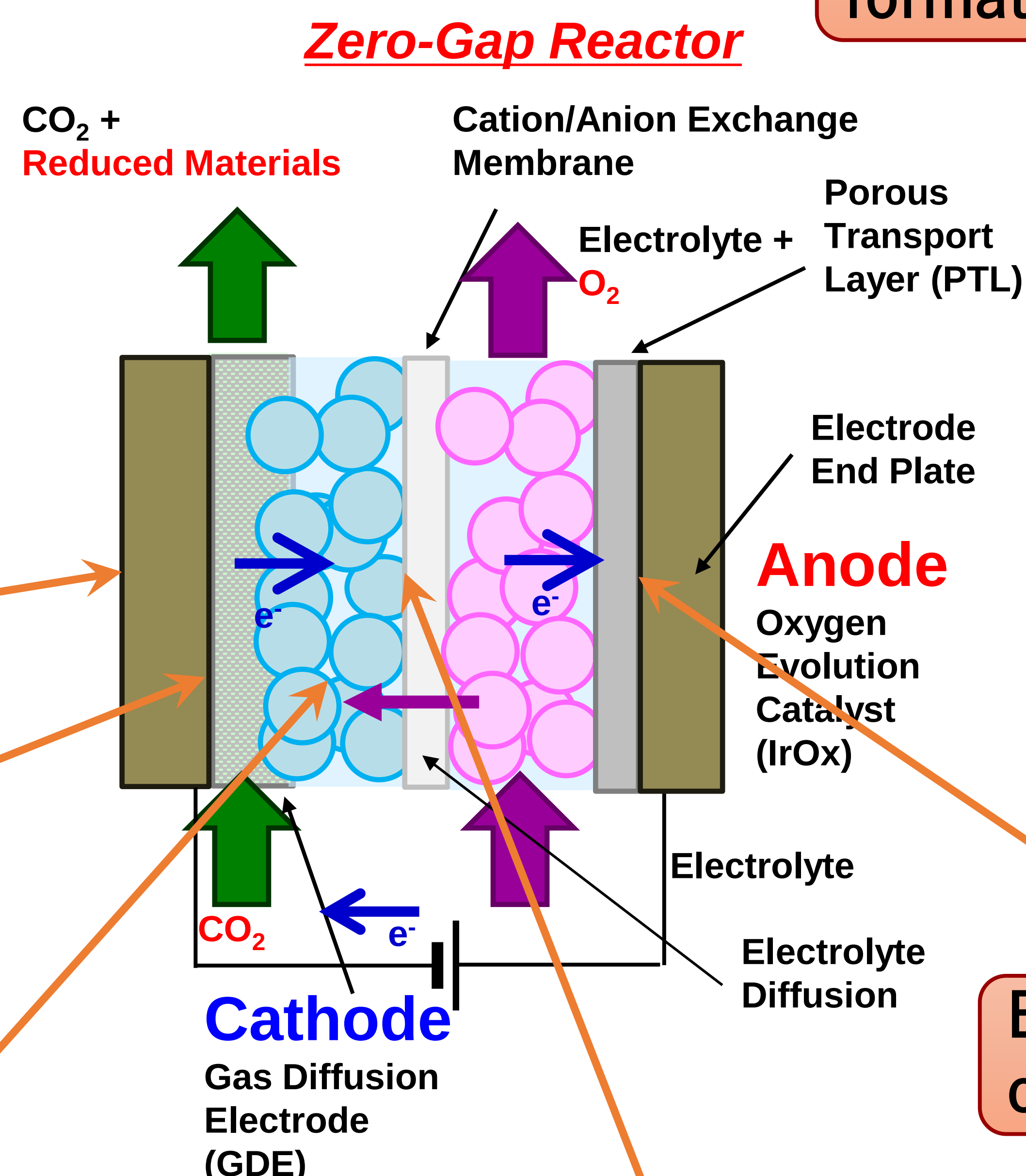
Zero-Gap Reactor



>> Since voltage difference exists at hetero-interfaces, **Small Gap** Reactor and **Zero Gap** Reactor are essentially different.

Challenges for the realization for Zero-Gap Reactor





F. Parameters for ethylene formation selectivity

Parameters affected by reactor structure

- Position of CO_2-electrolyte interface
- Local CO and H_2 concentration
- Local electric field
- Local pH
- Local metal ion distribution, etc

A. Simultaneous CO_2 and electric current supply

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B. Prevent energy loss due to hydrogen evolution

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C. Prevent salt crystallization

D. Contact of cathode catalyst

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E. Uniformity of anode region

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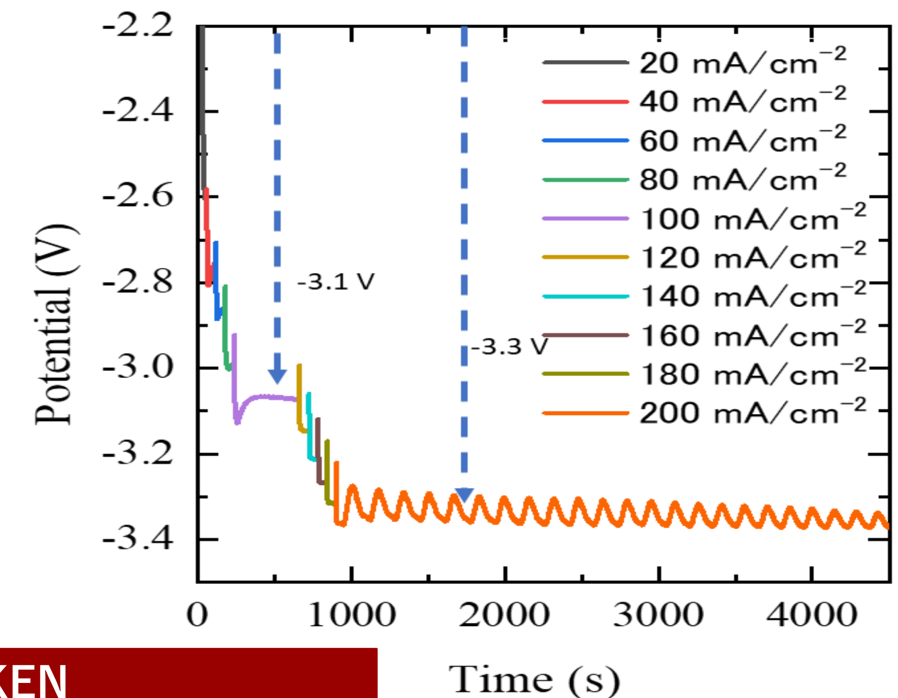
Target

☐2024

Realization of (1) voltage: 2.5 V, (2) current density > 200 mA/cm^2, (3) faradaic efficiency for CO_2 reduction > 50%, using non-precious metal anode catalyst.



RIKEN
3.3V(Cell) & 200mA/cm^2

☐2027

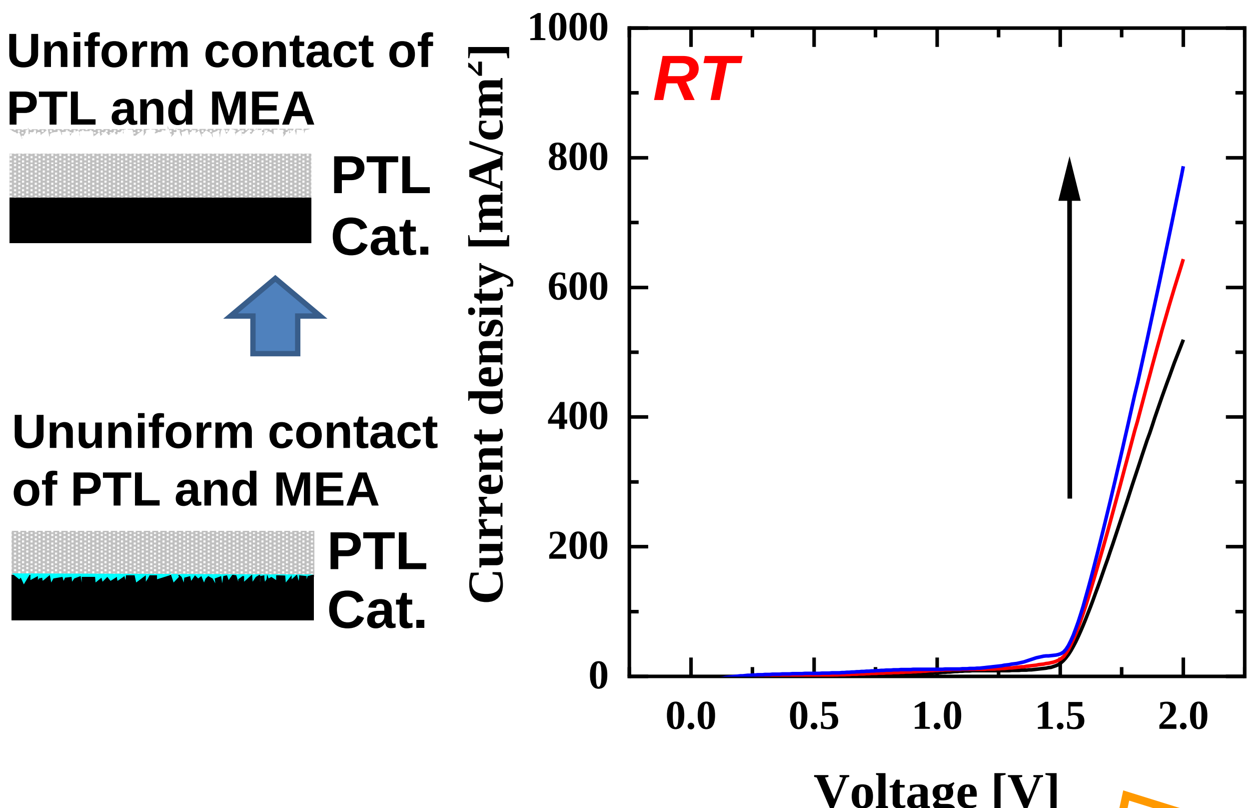
Realization of (1) voltage: 2.5 V, (2) current density: 200 mA/cm^2, (3) faradaic efficiency for C_2H_4: 80%, under the hybridization of CO_2 enrichment devices and CO_2 reduction reactors.
Find the guideline for the lifetime of electrode over 1000 hrs.

Results

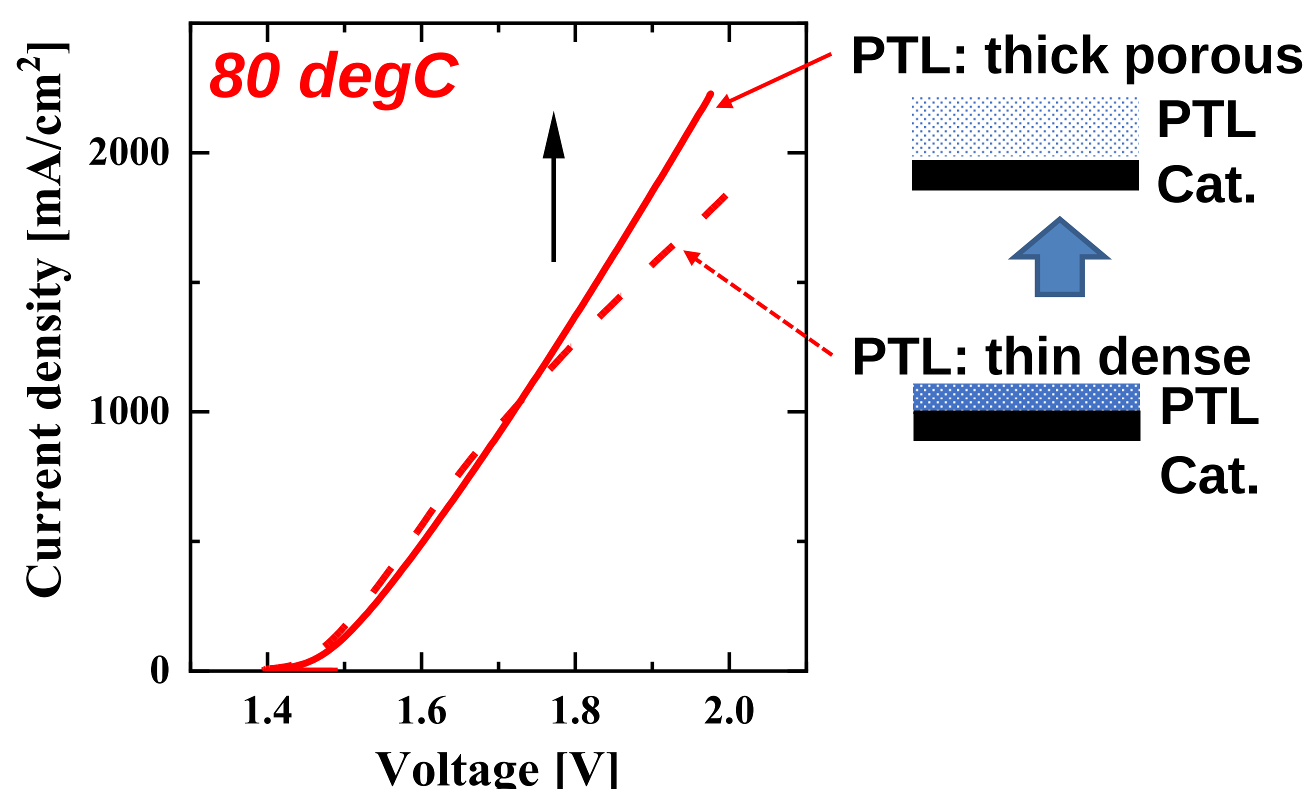
□Using the findings of high-speed water electrolysis (ca. 2 A/cm²)

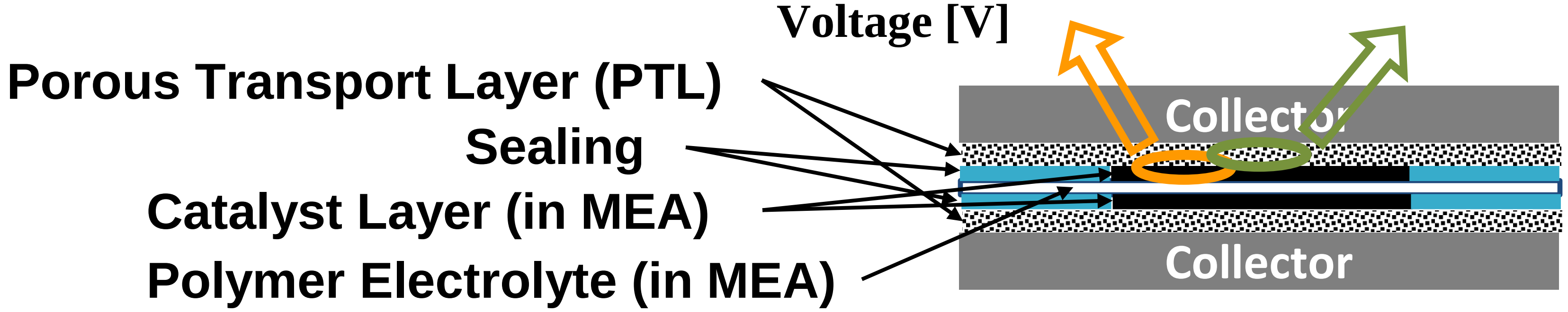
- Minimize the contact electric resistance
- Structure for the rapid supply of precursor and removal of reactant at reaction site
- Structure to realize uniform reaction condition over the electrode surface

Contact pressure dependence for current density



Structure dependence of porous transport layer (PTL) for current density





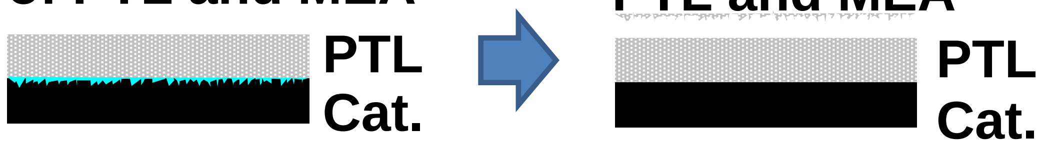
水素利用等先導研究開発事業／
水電解水素製造技術高度化のための基盤技術研究開発／
非貴金属触媒を利用した固体高分子型水電解の
変動電源に対する劣化解析と安定性向上の研究開発

Results

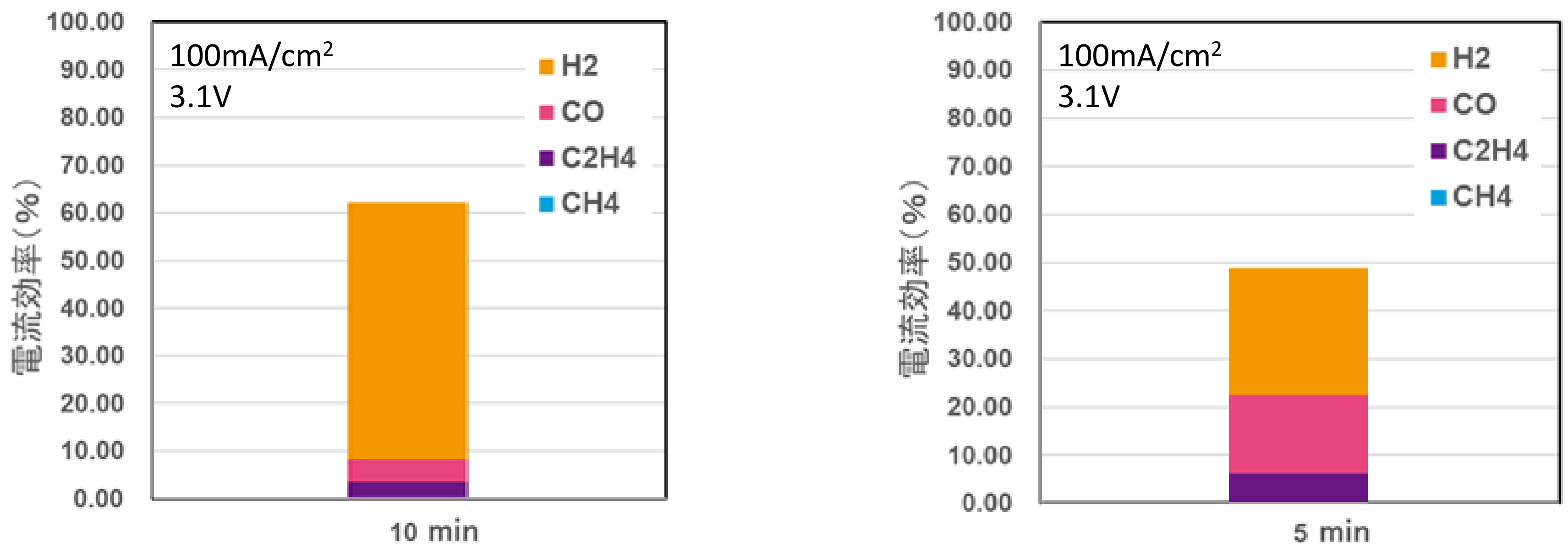
□Current density dependence of contact pressure

Change in electrode structure ➔ Change in Faradaic efficiency

Non-uniform contact of PTL and MEA | **Uniform contact of PTL and MEA**



Membrane: Anion xxchange
Catode: Cu_2O NP Catalyst
Anode: IrOx Catalyst



When the contacts among collecting plate, PTL, electrode, and membrane are ununiform, large over-voltage was observed at the beginning of the reaction even at the low current density conditions.

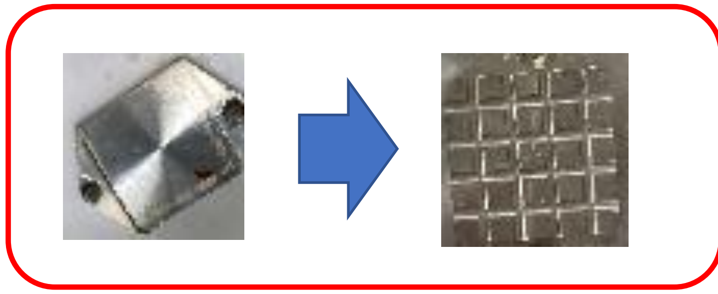
⇒ Not only large overpotential, but **low faradaic efficiency of CO_2 was observed**.

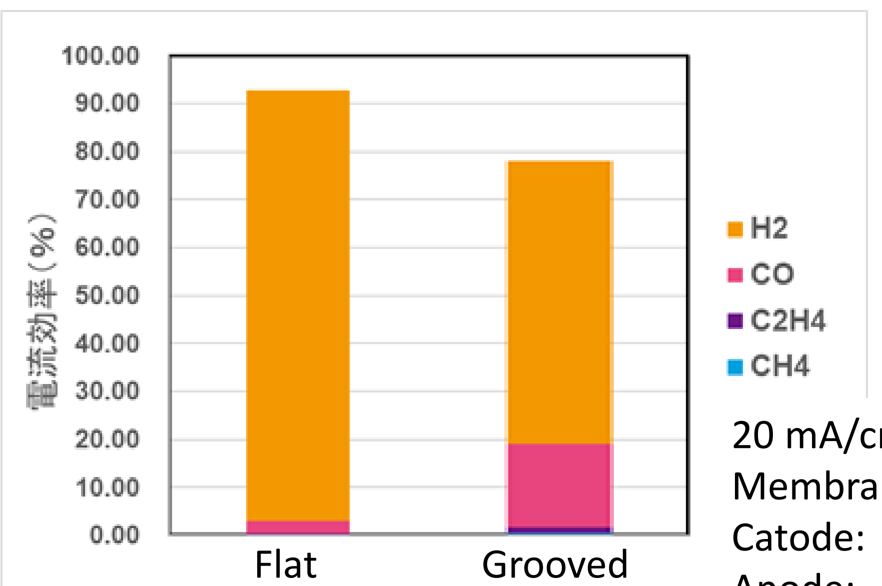
The problem never exists in water electrolysis.

Results

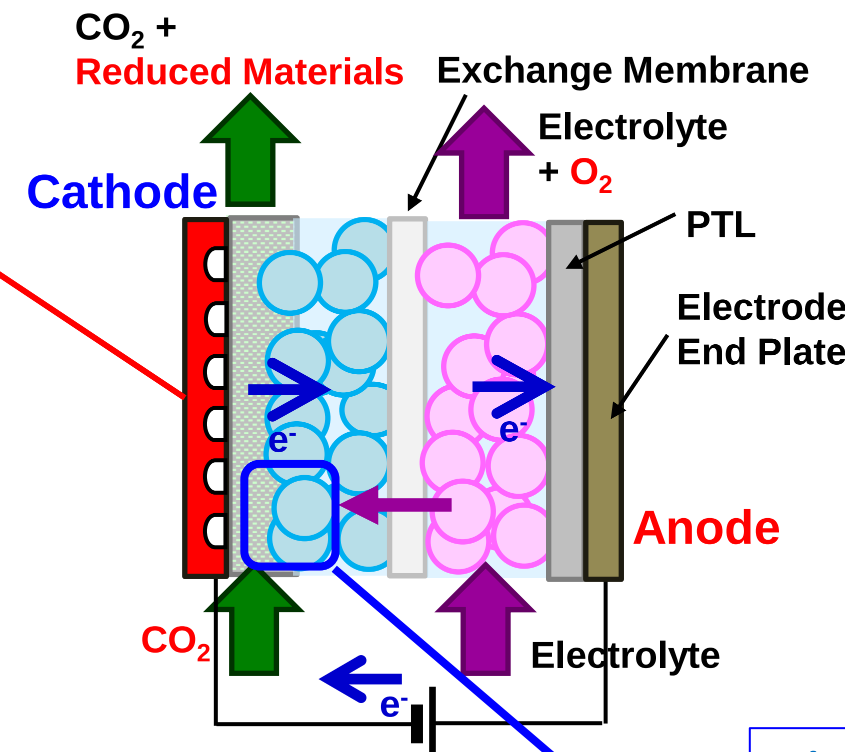
☐Porous Transport Layer (PTL) dependence for current density

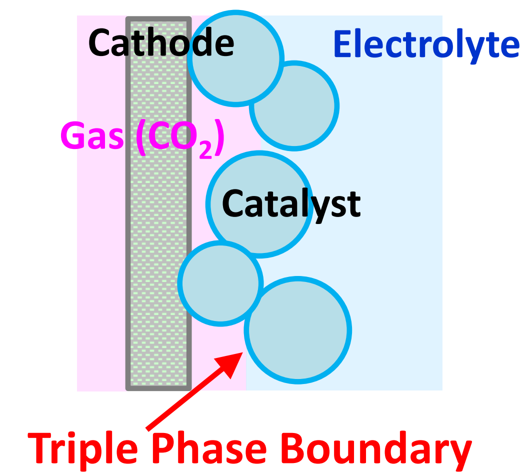
➔ Importance of CO_2 gas supply channel





20 mA/cm²,
Membrane: Anion Exchange
Catode: Ag NP Catalyst
Anode: IrOx Catalyst





Triple phase boundary at local CO and H_2 pressure, which affects the production selectivity of C2H4, is influenced by the structure of gas supply channel.

Since water electrolyzer has no gas supply for the cathode, fast removal of product H_2 is enough for the high performance of H_2 formation.

⇒ For CO_2 reduction, **CO_2 supply from the back surface of the cathode affects the faradaic efficiency of CO_2 reduction**.

Since trench at the electric plate cannot supply electricity to the reaction field, effective reaction area decreases with the increase in trench area.

⇒ **Trade-off between electron supply and CO_2 supply ⇒ Optimization is mandatory.**

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