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革新的CO2分離膜モジュールによる効率的CO2分離回収プロセスの実用化検討

団体名：国立大学法人京都工芸繊維大学、東ソー株式会社、国立大学法人東京科学大学

Introduction

The increase in atmospheric CO_2 concentration leading to the Global Warming and Climate Change is one of the serious issues, and the urgent transition to a decarbonized society is a global challenge. To achieve this, CO_2 capture is now required from all sources of CO_2 emissions. The chemical absorption with aqueous amines has been employed for CO_2 capture in large-scale CO_2 emission sources, such as thermal power stations, and that requires significant energy. In addition, the technology is not suitable for the medium- and small-scale emission sources. Therefore, membrane separation is being recognized as an effective alternative CO_2 capture technology.

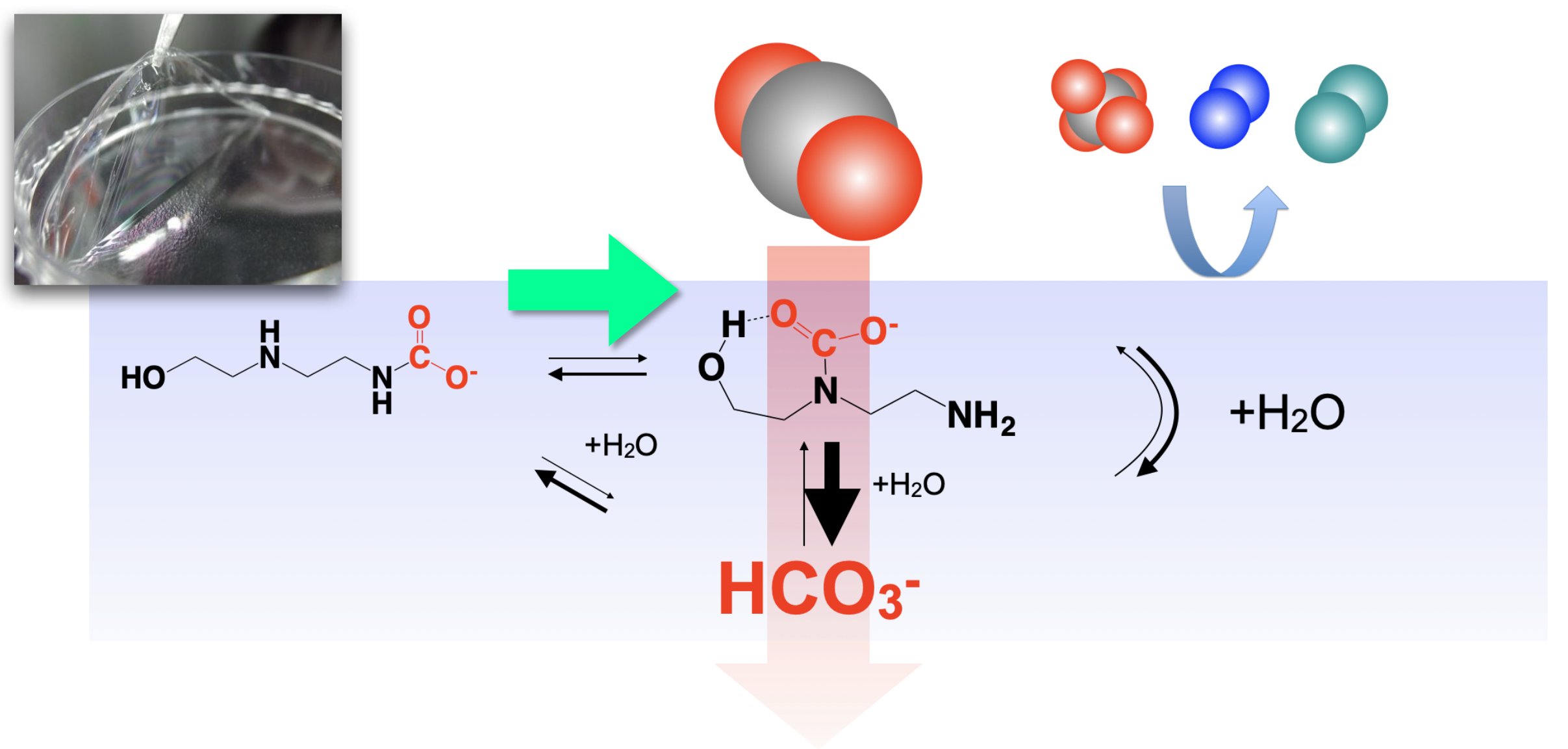
In this research group, amine-containing polymeric membranes have been investigated for CO_2 capture, where amines are physically immobilized in a polymer matrix. The obtained membranes demonstrated excellent CO_2 separation performance. The mechanism of preferential CO_2 permeation was also elucidated at the molecular level.

However, it is essential to further improve CO_2 permeability. One strategy is to reduce the gas permeation resistance, i.e., by making the membrane thinner, while that often results in the loss of its self-standing properties. To address this issue, a thin-film composite (TFC) membrane has been developed by laminating the CO_2 separation membranes (a CO_2-selective layer) onto porous supports. However, large-scale production of membranes or membrane module preparation has remained challenge. Herein, facile membrane preparation is introducing by passing through membrane material solutions into a commercial hollow-membrane modules. This method is also suitable for mass production and scale-up, and is expected to significantly reduce the cost of CO_2 capture.

The resulting membrane module exhibits extremely excellent CO_2 separation performance, and is being considered for application to CO_2 capture from post-combustion flue gas of coal-fired thermal power generation with the support of the NEDO Carbon Recycling Project. Here, we also report our recent results.

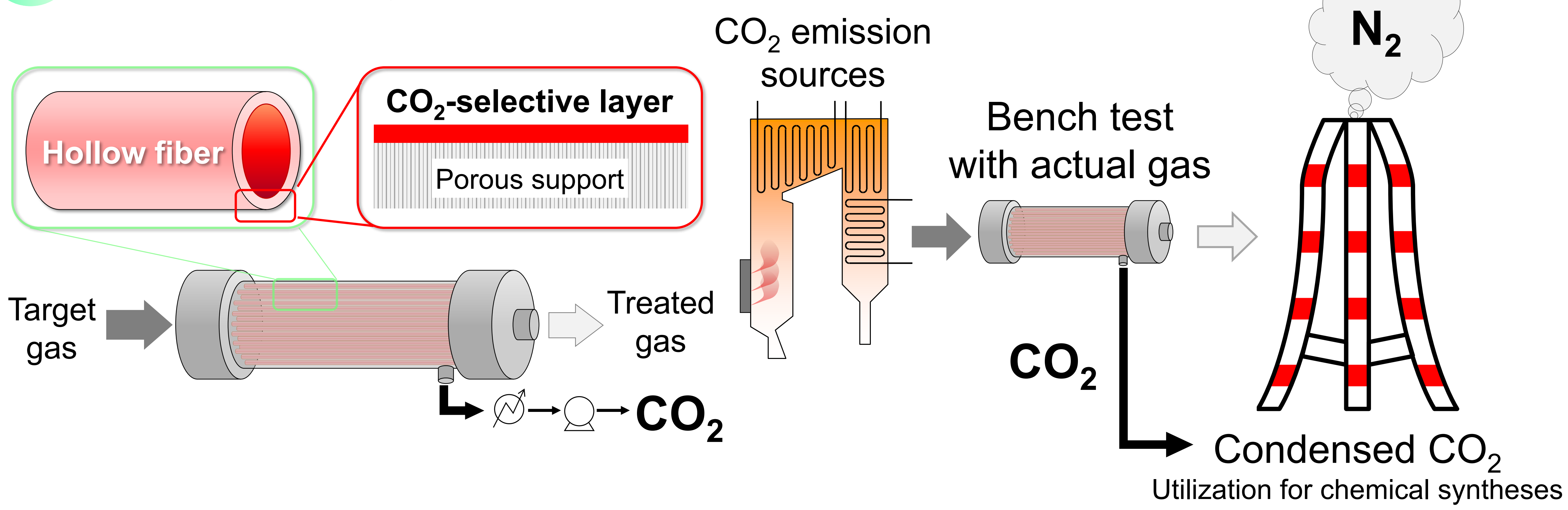
Preferential CO_2 permeation

Mechanism of gas transportation across amin-containing polymeric membranes



- CO_2 interacts to AEAE with the formation of carbamates.
- Hydroxyl group stabilizes the carbamate on secondary amine.
- Bicarbonate ion is released upon hydrolysis of the carbamate.
- Other gas permeation is suppressed by salting-out to give high CO_2 selectivity

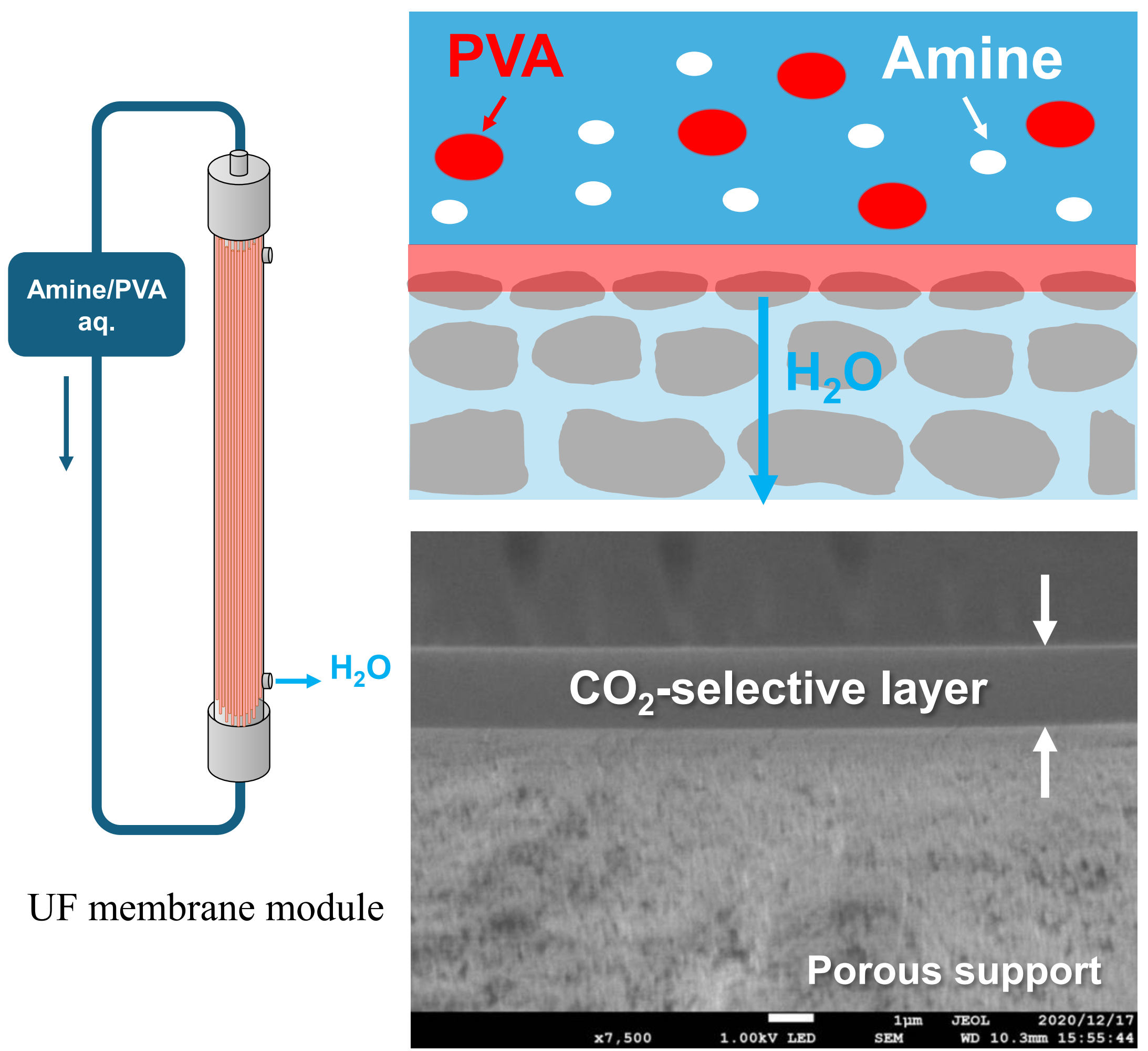
Outline of the project



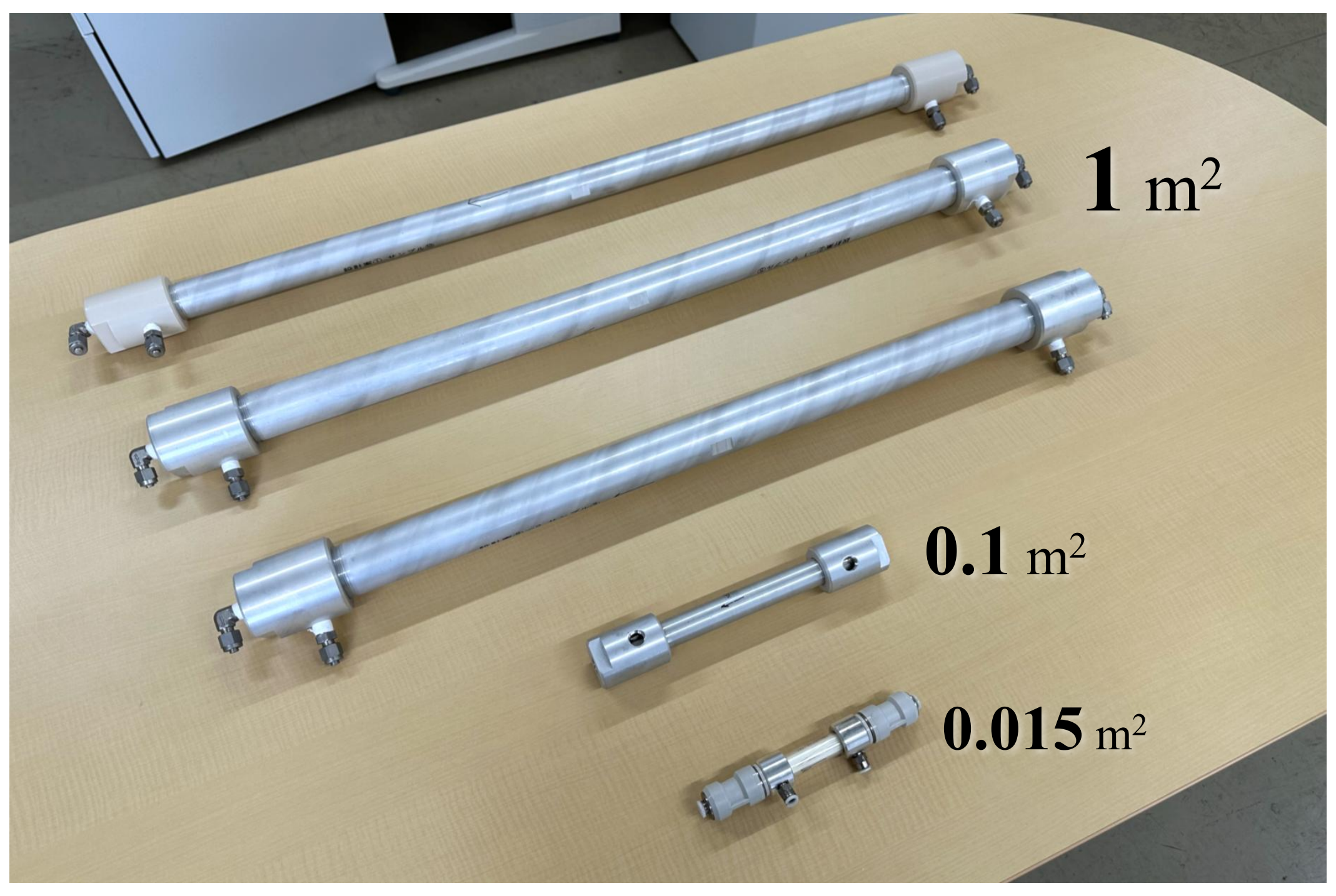
[1] **Preparation of CO_2 separation membrane modules**
[2] Bench-scale demonstration
[3] Optimization of membrane separation process

Capture cost: ≦\$10/t-CO_2

Membrane module preparation



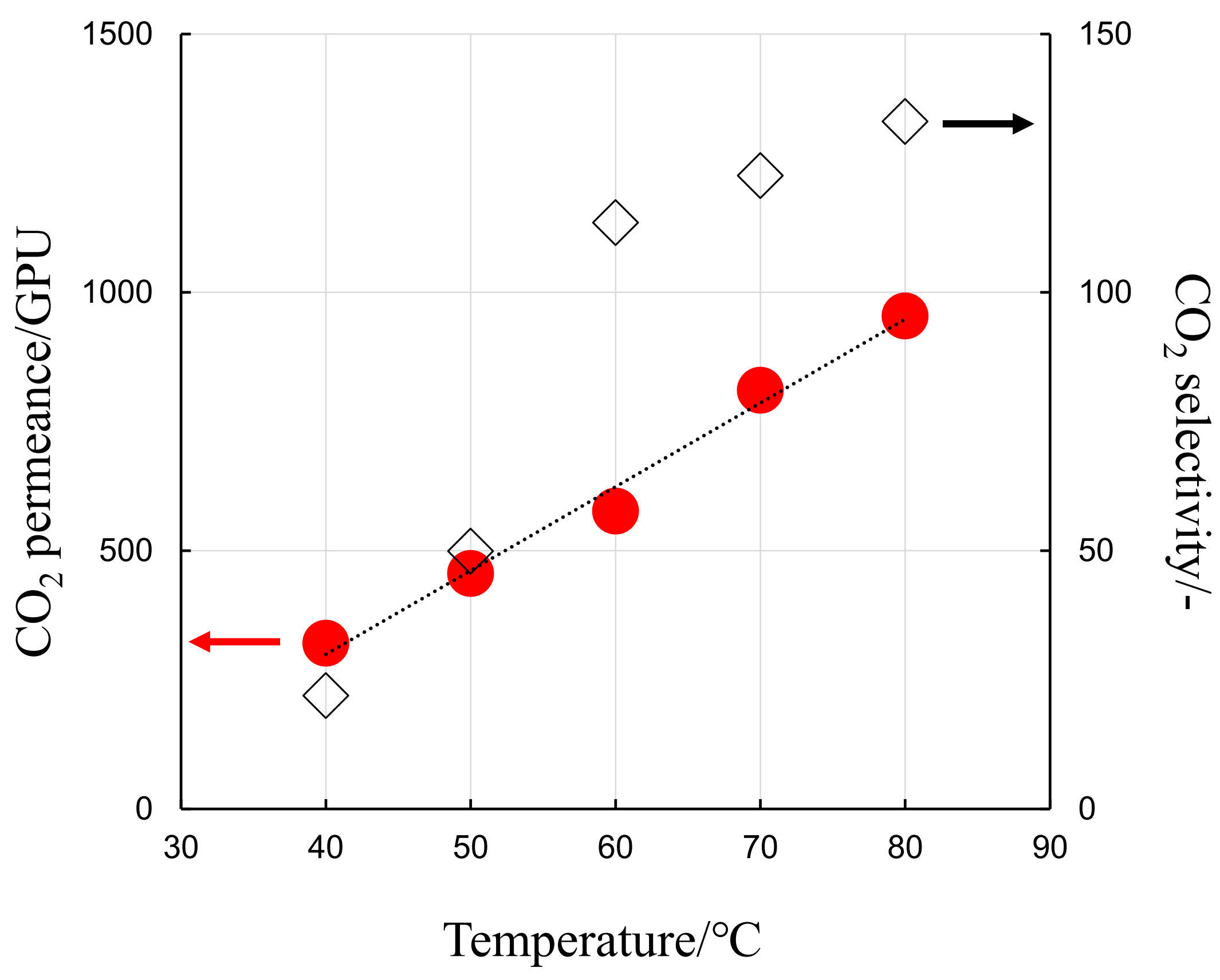
Membrane modules prepared



Significant cost reductions in CO_2 capture

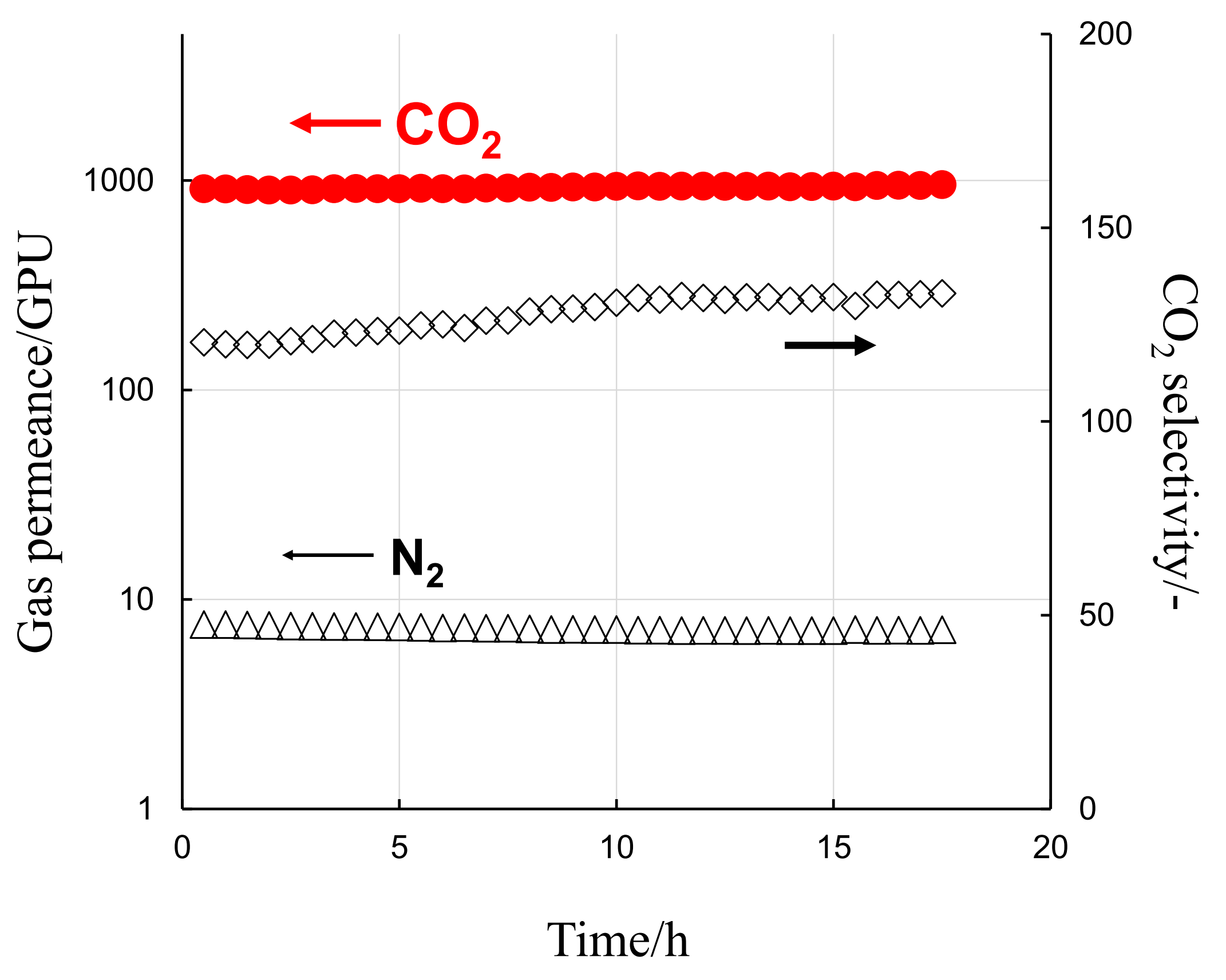
- Extremely simple preparation
- Easy mass production
- Convenient large-area production

Effect of temperature



Membrane area: 150 cm^2; Feed gas: CO_2/N_2=10/90 vol%; Relative humidity: 90 %

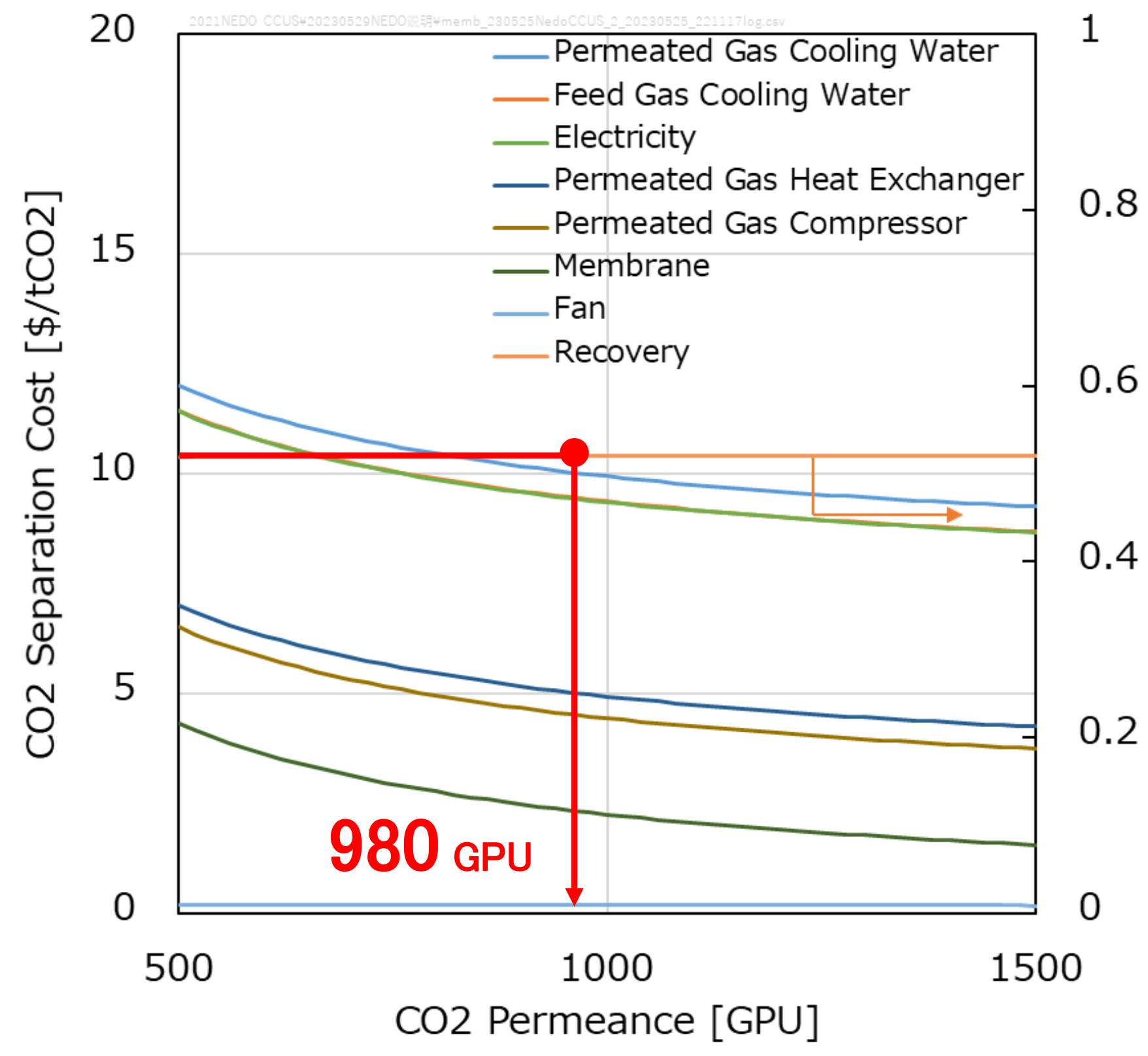
Time course



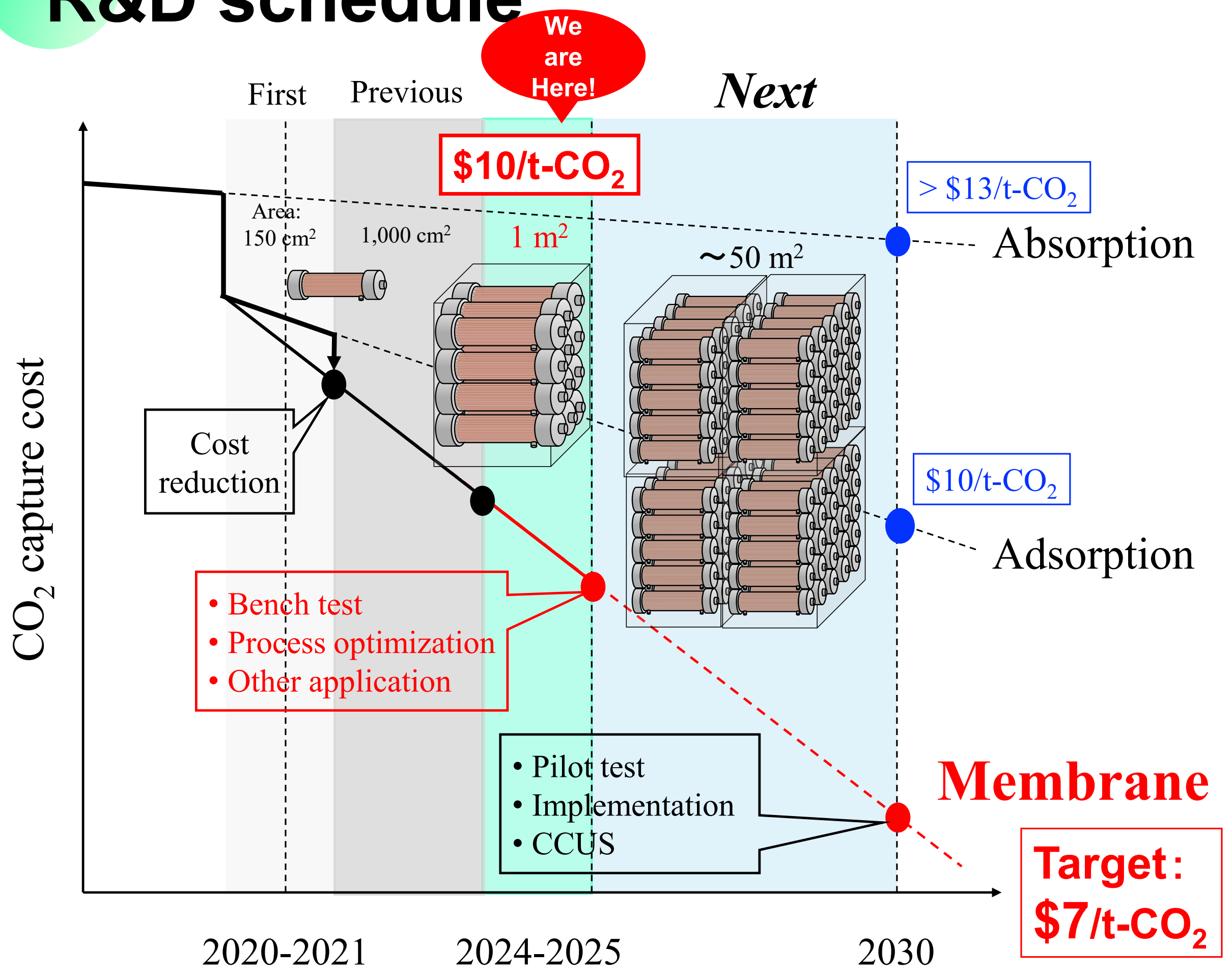
Membrane area: 150 cm^2; Feed gas: CO_2/N_2=10/90 vol%; Relative humidity: 90 % at 80°C

Cost analysis

CO_2 purity: >90 %



R&D schedule



Summary & future perspectives

The results of process simulation showed that the developed hollow fiber membrane module with a membrane area of 150 cm^2 has excellent CO_2 separation performance, and that the CO_2 separation and recovery cost is \$10/t-CO_2 through a bench test using actual exhaust gas. The membrane area was increased to 1 m^2 (20 cm^2).

A bench test with a scaled-up membrane area of 1 m^2 (20 kg-CO_2/day) is currently under consideration, and the membrane area will be further expanded to 50 m^2 in the next pilot test. The next pilot test will further increase the membrane area to 50 m^2, with the aim of commercialization in 2030.

Given the membrane's proven efficacy, its implementation in other CO₂ emission sources, such as steel and cement facilities, is being contemplated.

連絡先：国立大学法人京都工芸繊維大学 谷口育雄
MAIL：ikuot@kit.ac.jp