No. A-3-1J

PJ Research and Development Toward Saving Energy for Direct Air Capture With Available Cold Energy

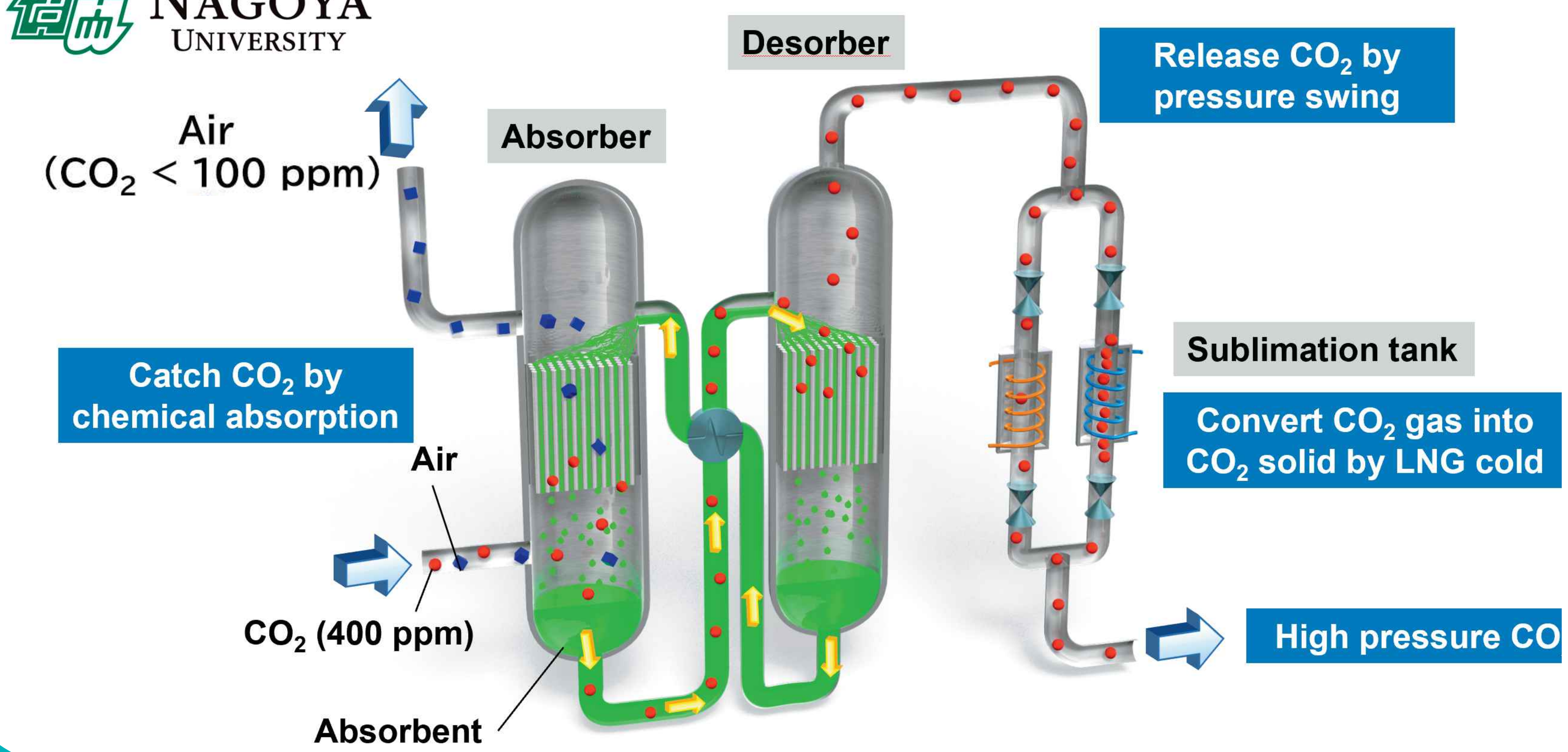
Team Nagoya University, TOHO GAS, Tokyo University of Science JGC, The University of Tokyo, Chukyo University

Contact Institute of Innovation for Future Society, Nagoya Univeristy Koyo NORINAGA (norinaga@nagoya-u.jp)

An alternative DAC with pressure swing amine process driven by cryogenic pumping with LNG cold

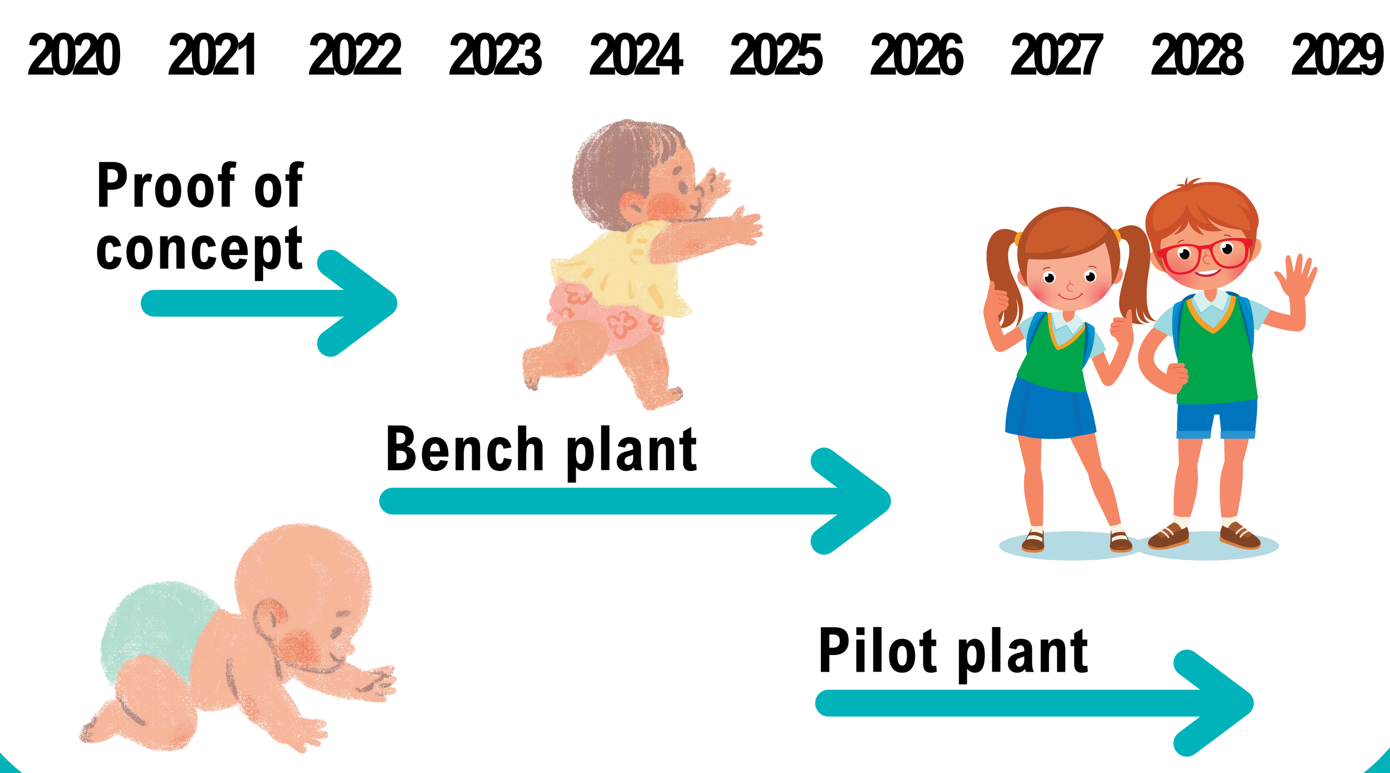
Cryo-DAC®

NAGOYA UNIVERSITY



Roadmap

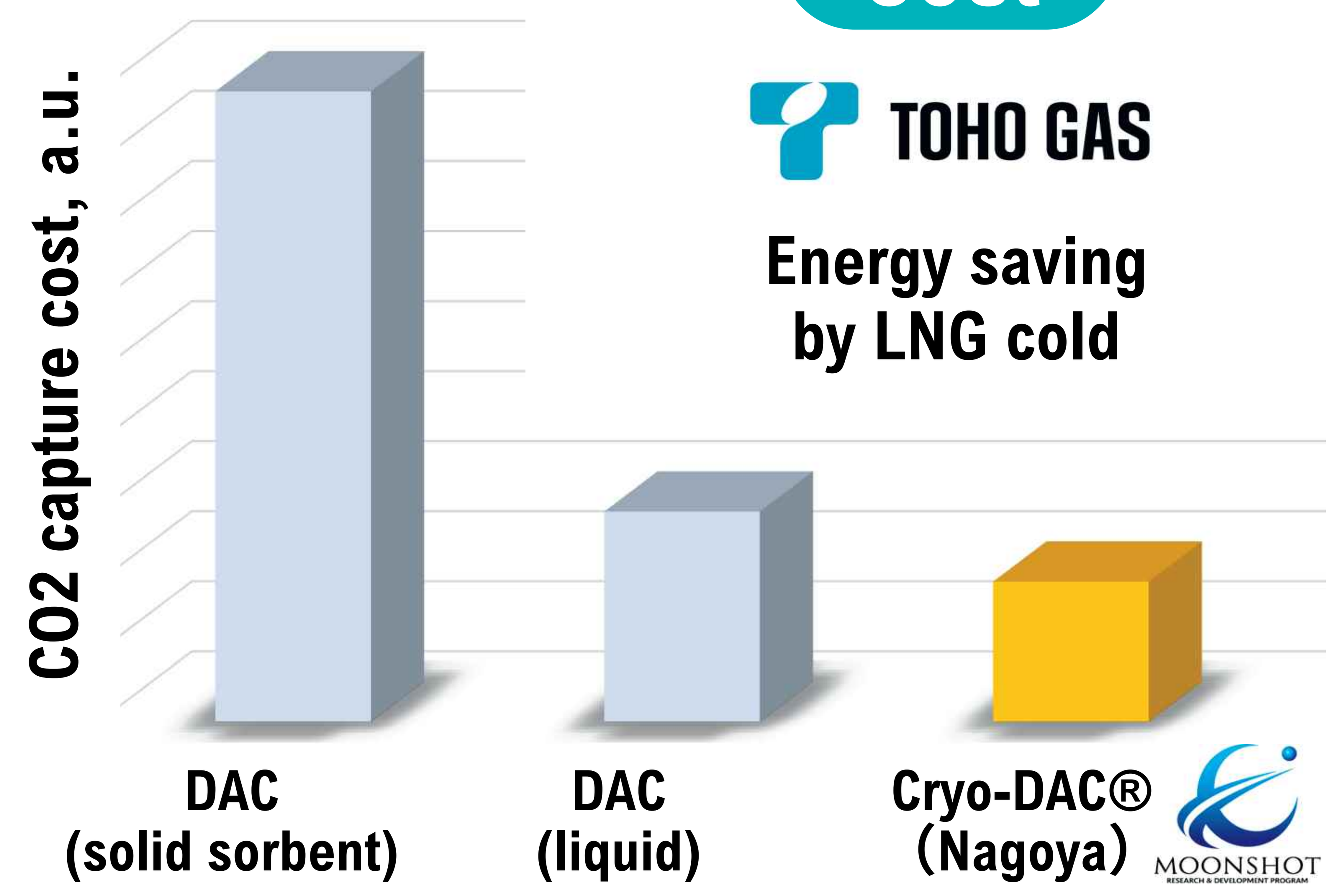
JGC HOLDINGS CORPORATION



Cost

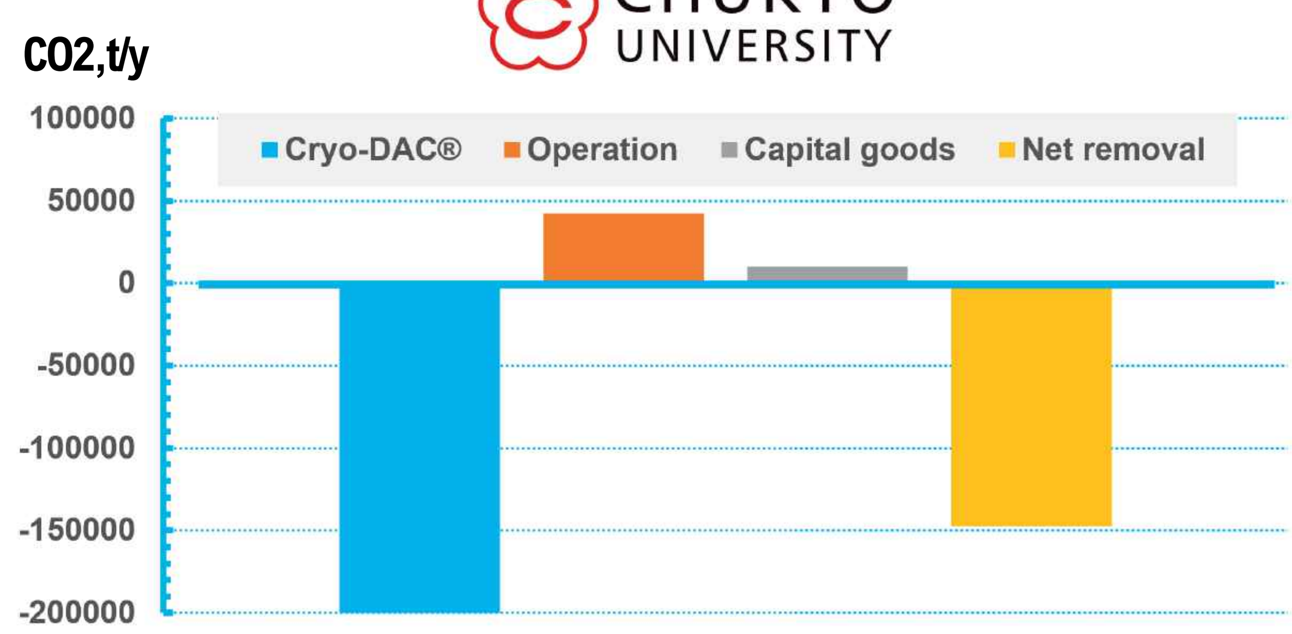
TOHO GAS

Energy saving by LNG cold



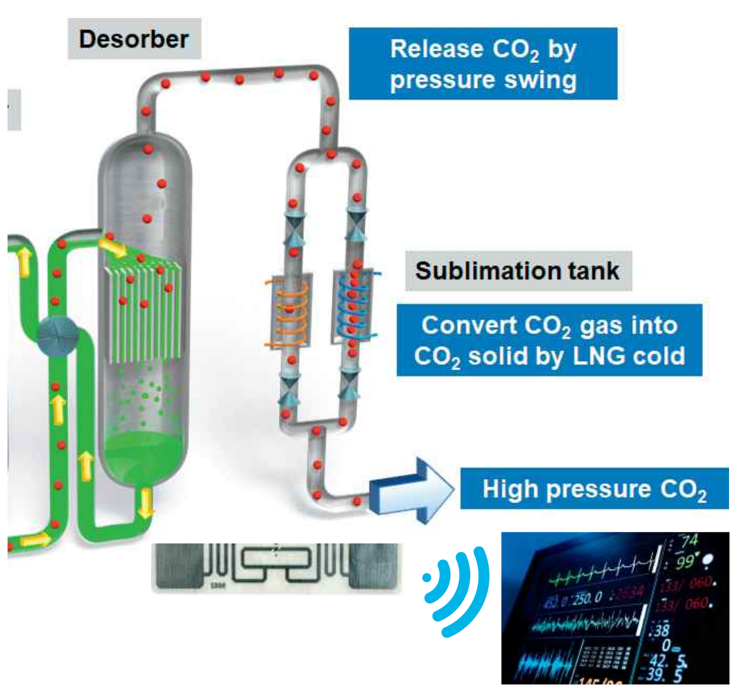
Life cycle assesment

CHUKYO UNIVERSITY



※1 CO2 emission factor :0.506 kg/kWh (2020)
※2 Aspen Economic Analyzer / National Institute for Environmental Studies 3EID database

Sensor



Integrity monitoring with wireless sensor

UTokyo

Material

Fatigue tests (>10 cycles, 25 years operation) in liquid nitrogen proved SUS 304 to be a candidate material for the sublimation tank

TOKYO UNIVERSITY OF SCIENCE

Team

NAGOYA UNIVERSITY
- Cryo-DAC® concept design
- High-performance amine development

TOHO GAS
- Process simulation for cost and energy analysis

UTokyo
- Exergy-based process analysis
- Sensing device for stable operation

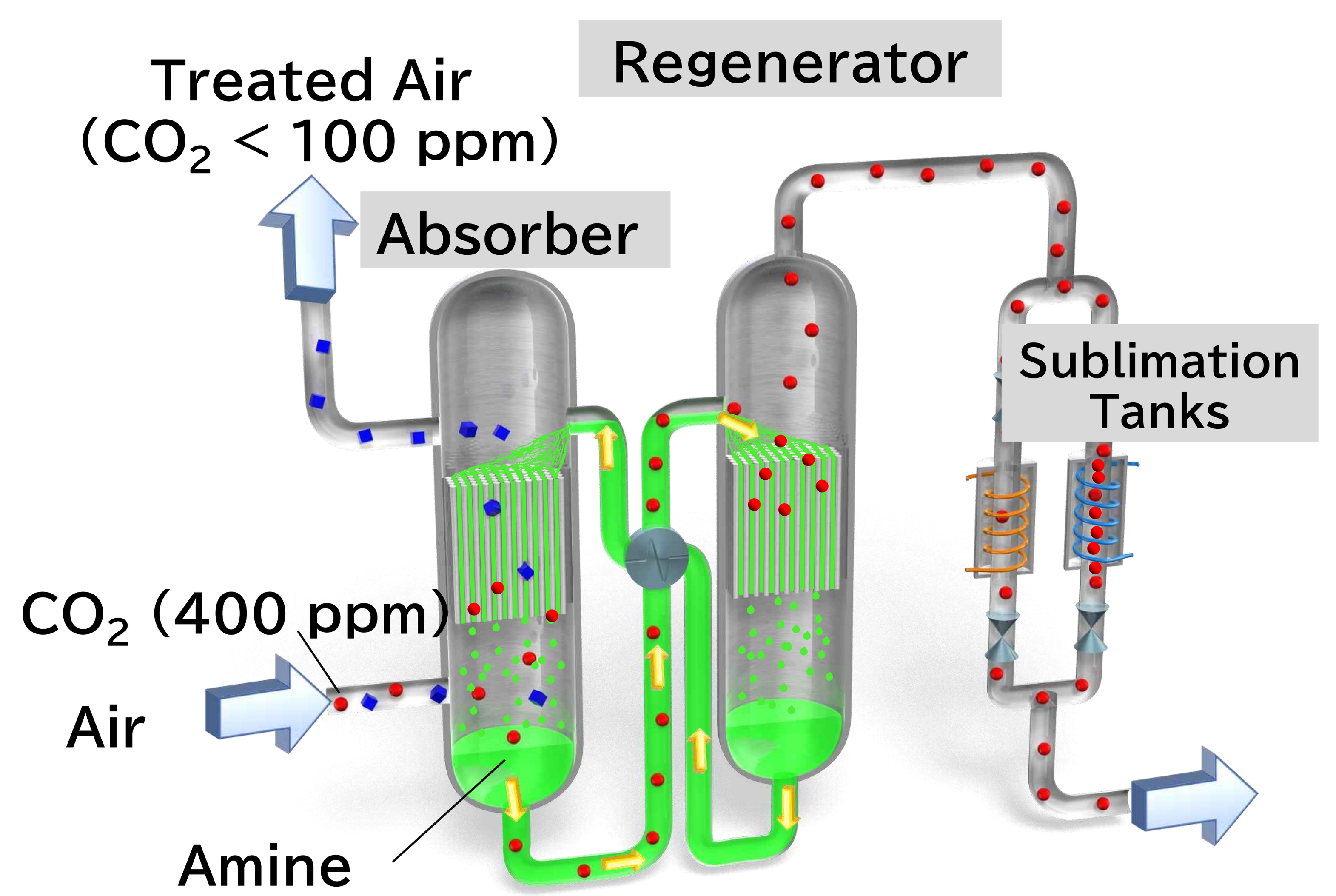
JGC HOLDINGS CORPORATION
- Cryo-DAC plant design and construction

CHUKYO UNIVERSITY
- Environmental and economic analysis

TOKYO UNIVERSITY OF SCIENCE
- Material selection and analysis

No.: A-3-2E
PJ : Research and Development Toward Saving Energy for Direct Air Capture With Available Cold Energy
Theme : Development of Cryo-DAC® process
Organization : Nagoya University
問合せ先 : Institutes of Innovation for Future Society, Koyo NORINAGA (norinaga_at_nagoya-u.jp)

Cryogenic + DAC, Cryo-DAC®

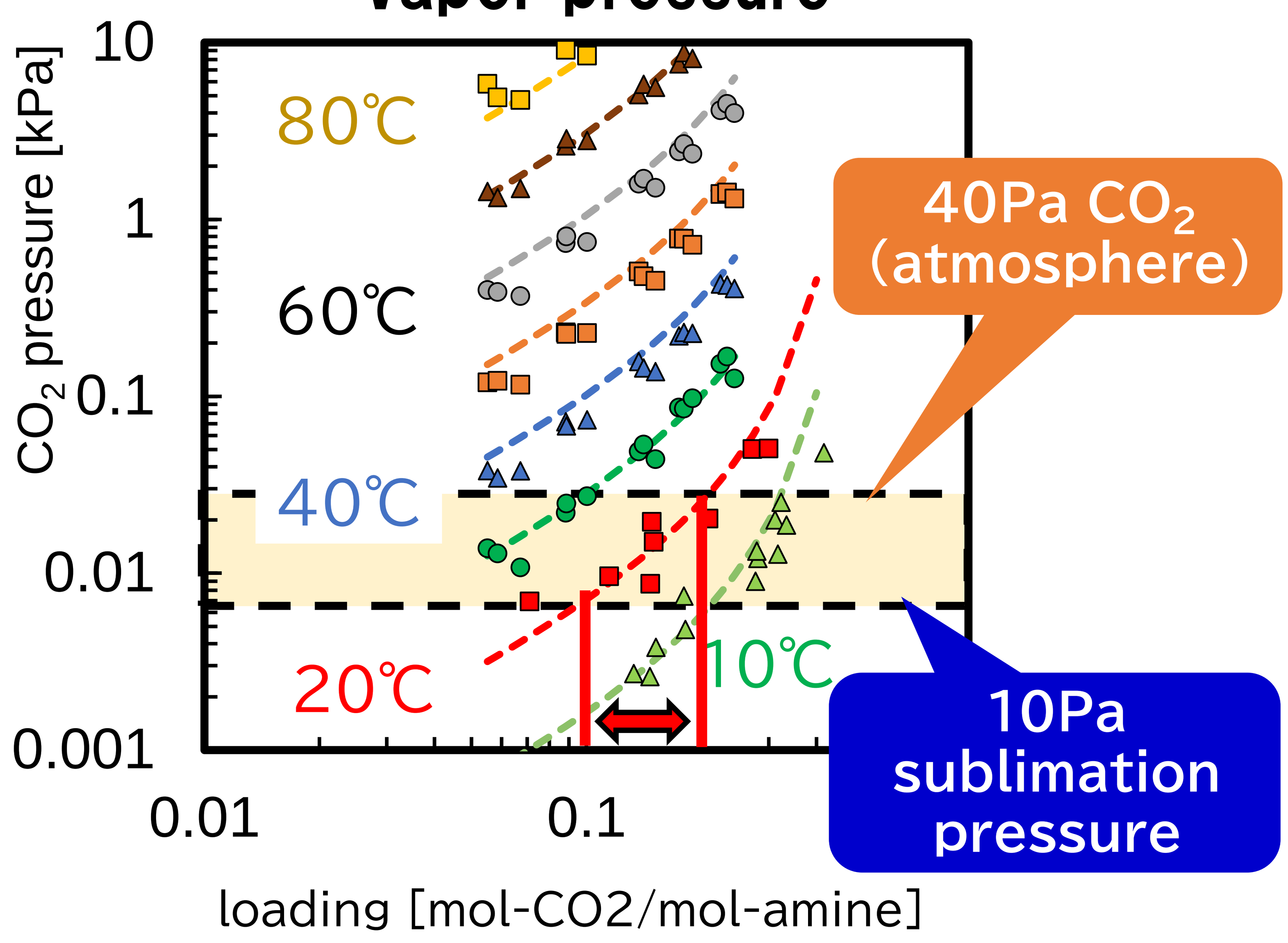


Chemical absorption

- ✓ Pressure Swing
- ✓ Sublimating with LNG

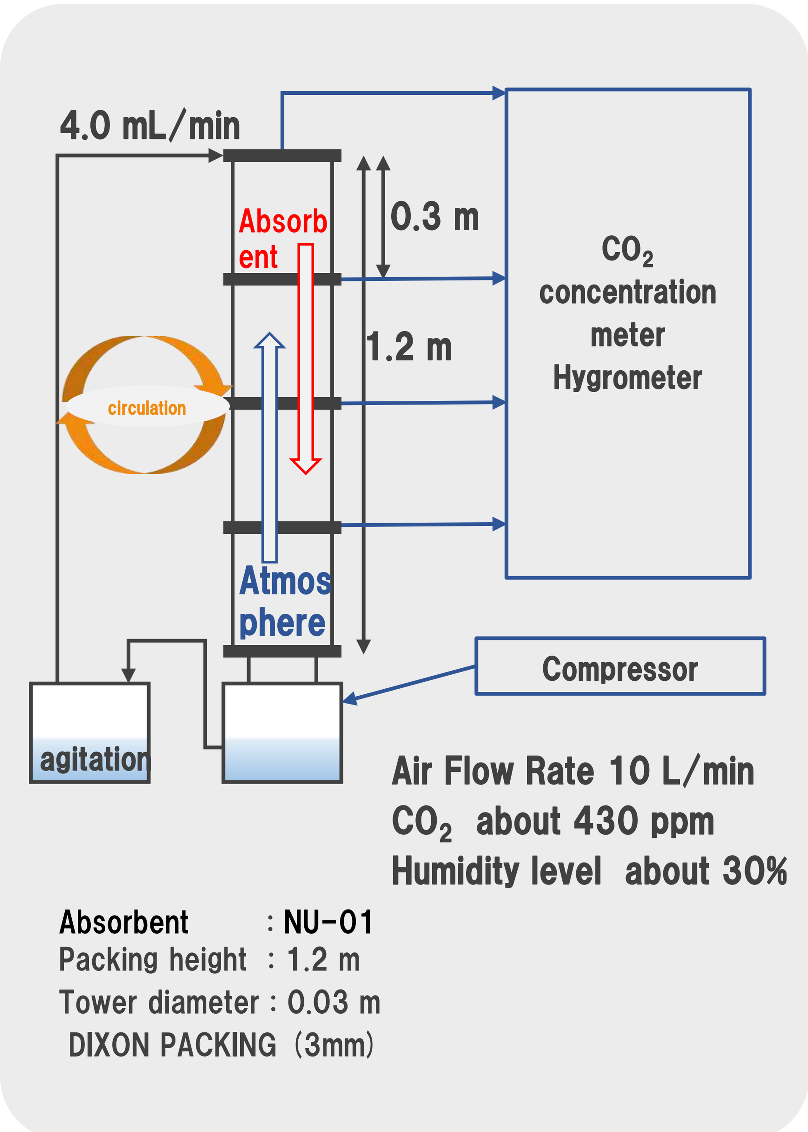
Pressure swing absorption driven by a cryogenic pumping by LNG coldness

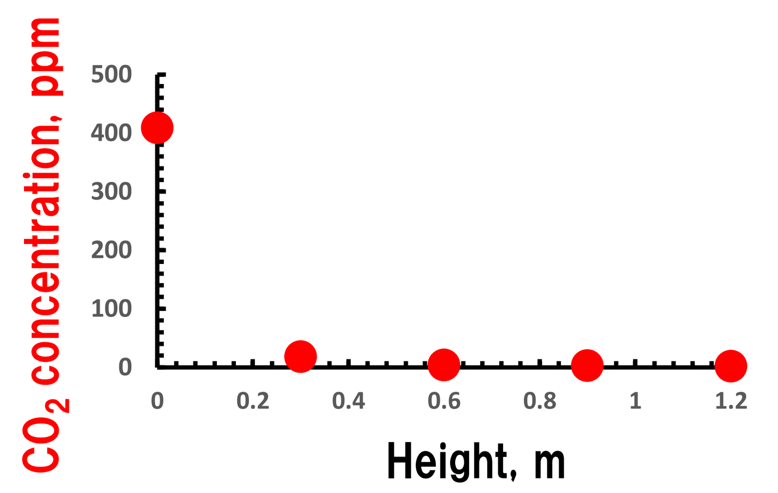
Absorbent liquid with low vapor pressure

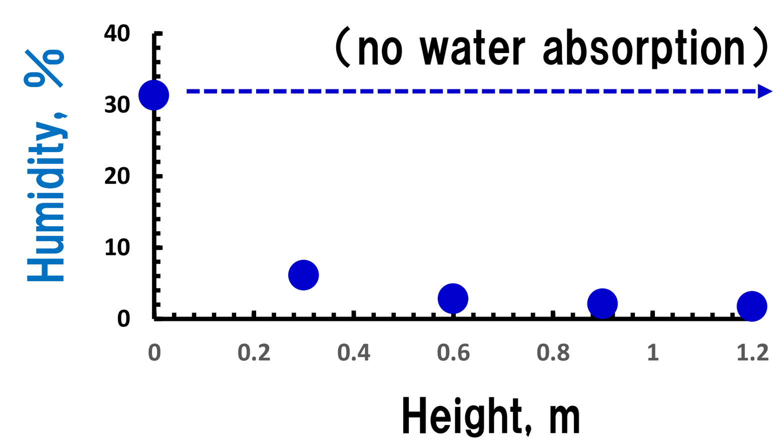


- ✓ Loading difference > 0.1
- ✓ Low vapor pressure < 0.5Pa

Lab scale DAC test with real air

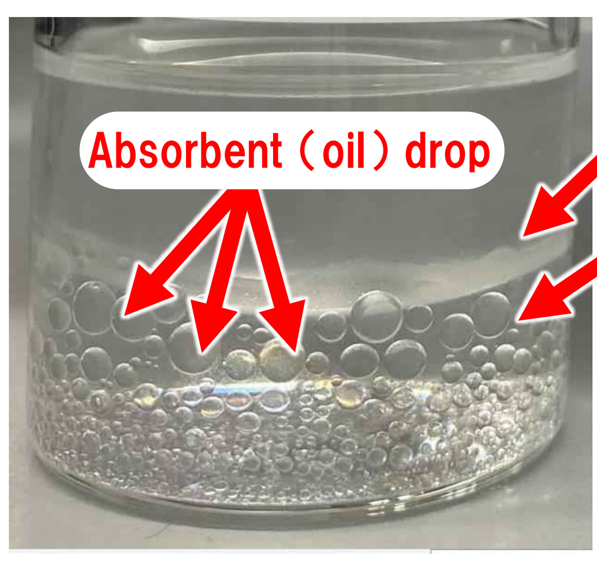






- The candidate absorbent absorbs both CO_2 and water
- Water management need to be addressed

Development of water-repellent absorbent



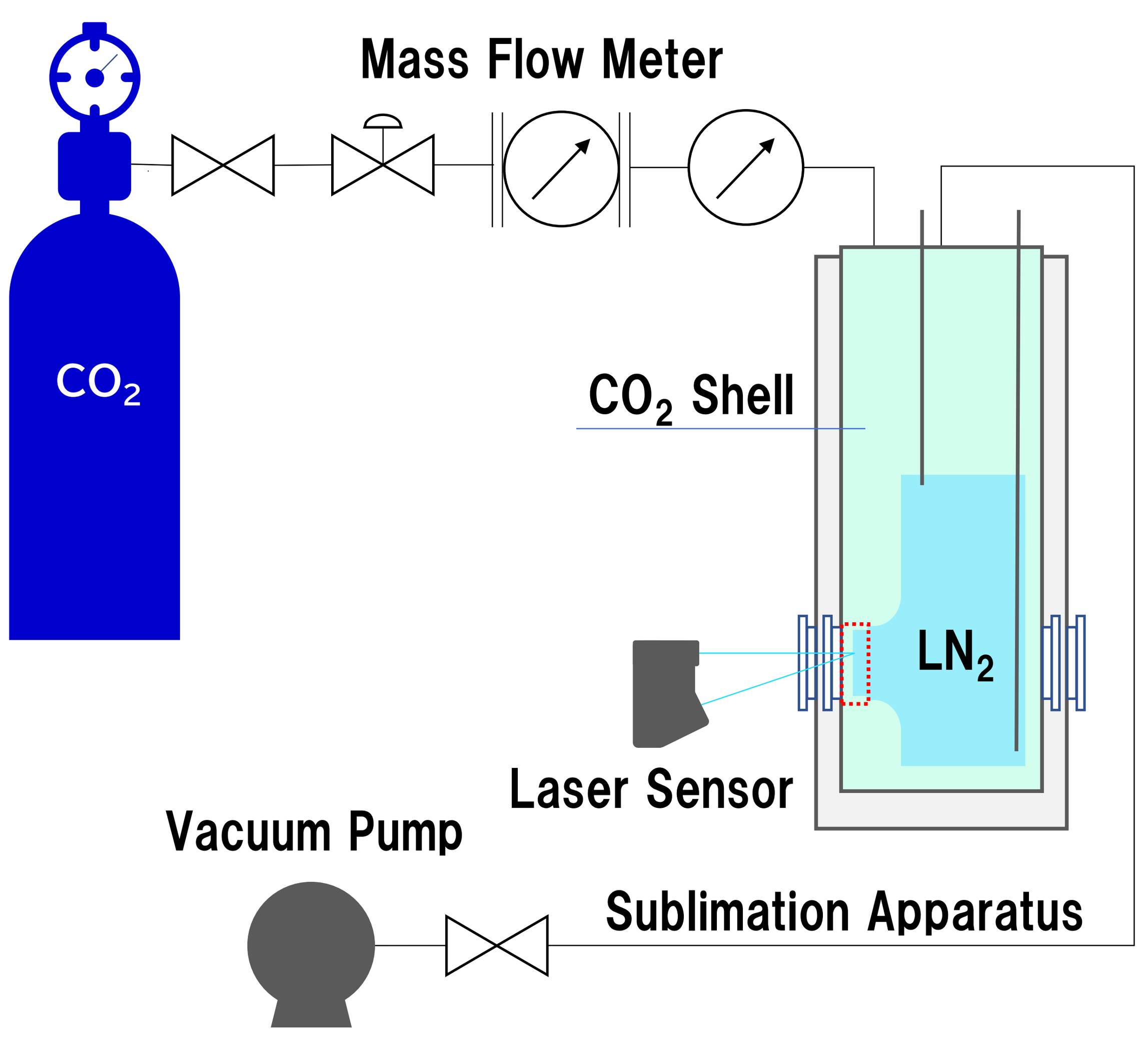
absorbent(oil)phase & aqueous phase liquid-liquid separation

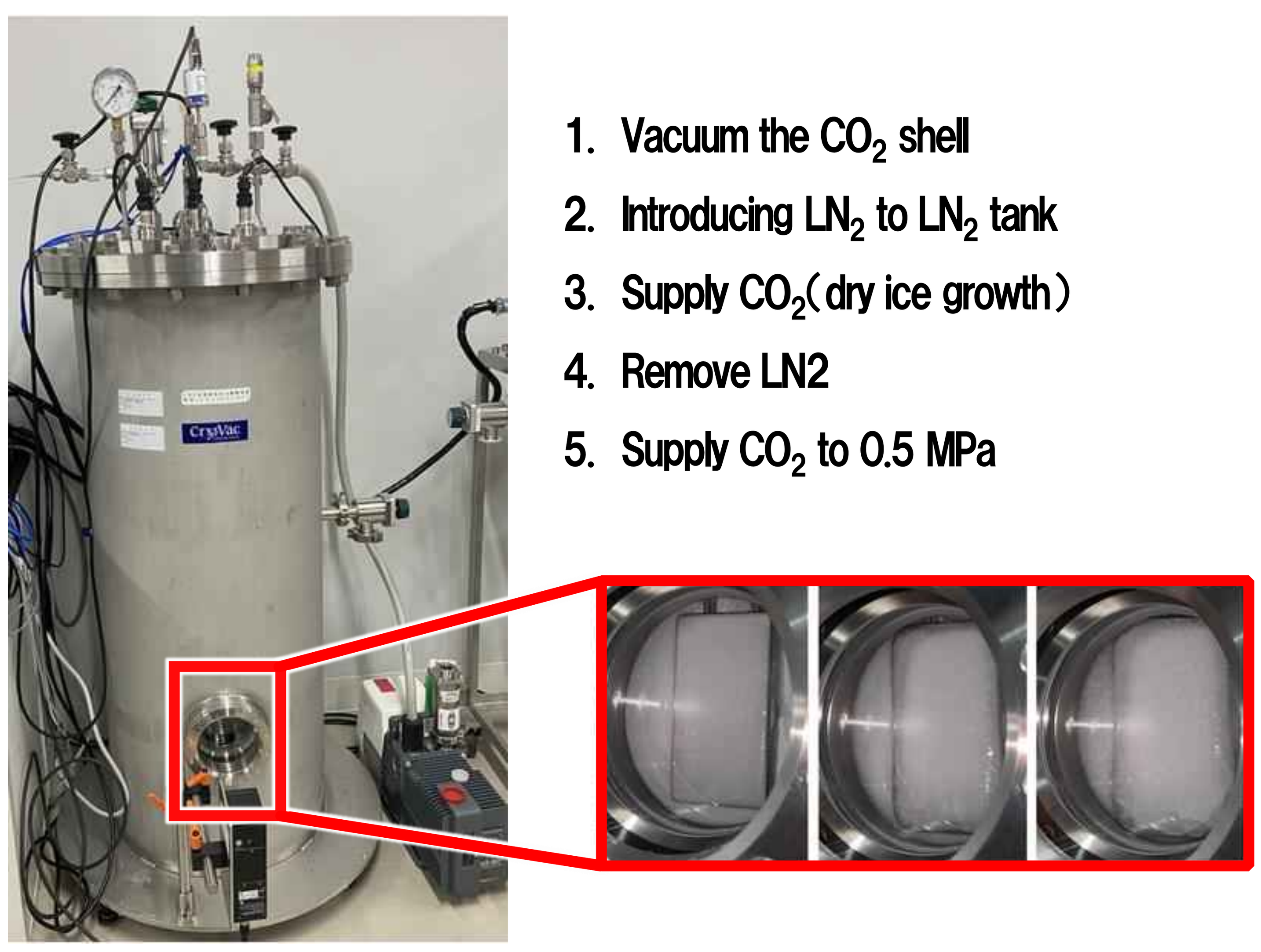
No need for latent heat of evaporation of water during regeneration

⬇

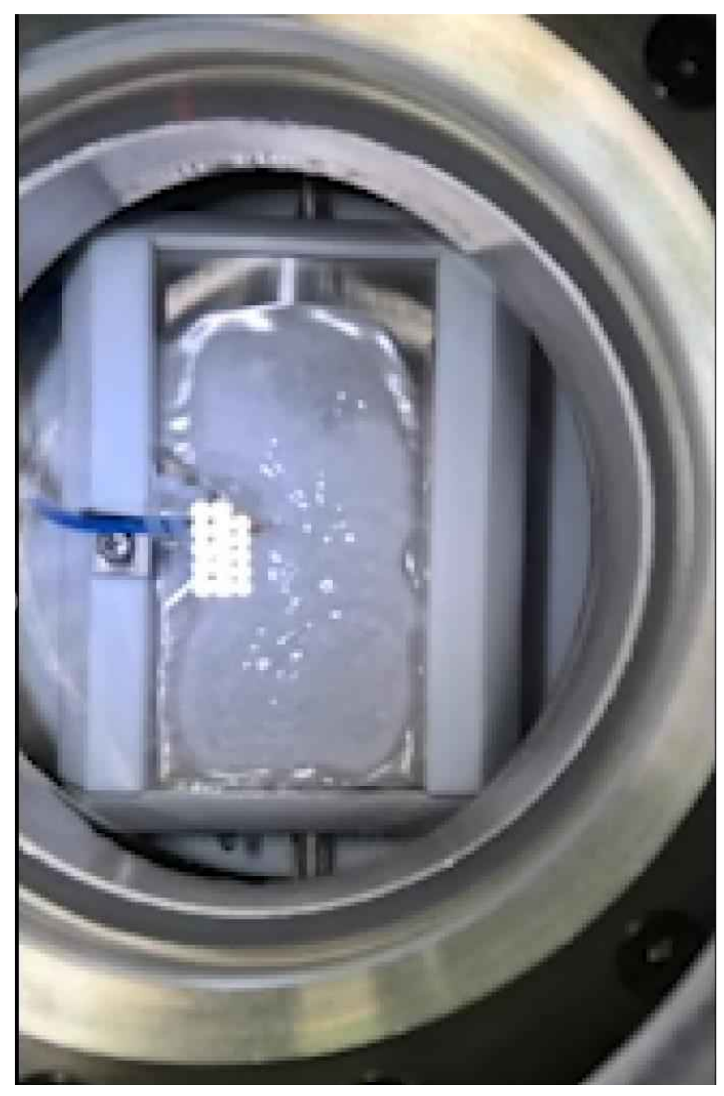
Energy saving !

CO_2 solidification and dry Ice liquefaction





1. Vacuum the CO_2 shell
2. Introducing LN_2 to LN_2 tank
3. Supply CO_2(dry ice growth)
4. Remove LN2
5. Supply CO_2 to 0.5 MPa



No. A-3-3E

PJ : Research and Development Toward Saving Energy for Direct Air Capture With Available Cold Energy

Theme: Evaluation of reliability on structural materials for Cryo-DAC® sublimation tanks

Organization: Tokyo University of Science

Contact: Faculty of Engineering, Tokyo University of Science. Yumi TANAKA (yutanaka@rs.tus.ac.jp)

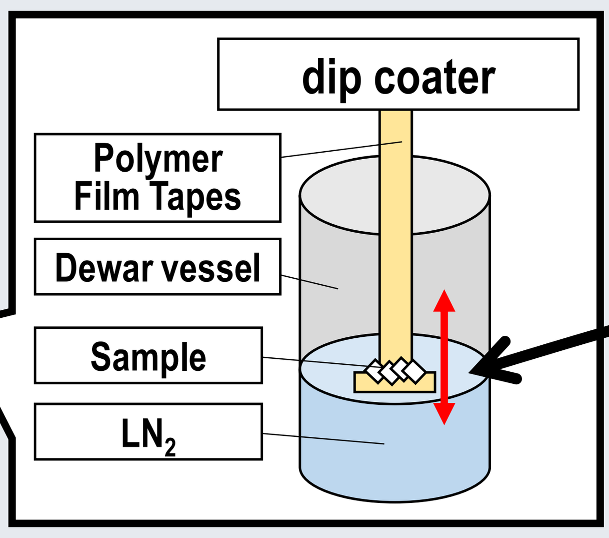
NEDO

MOONSHOT

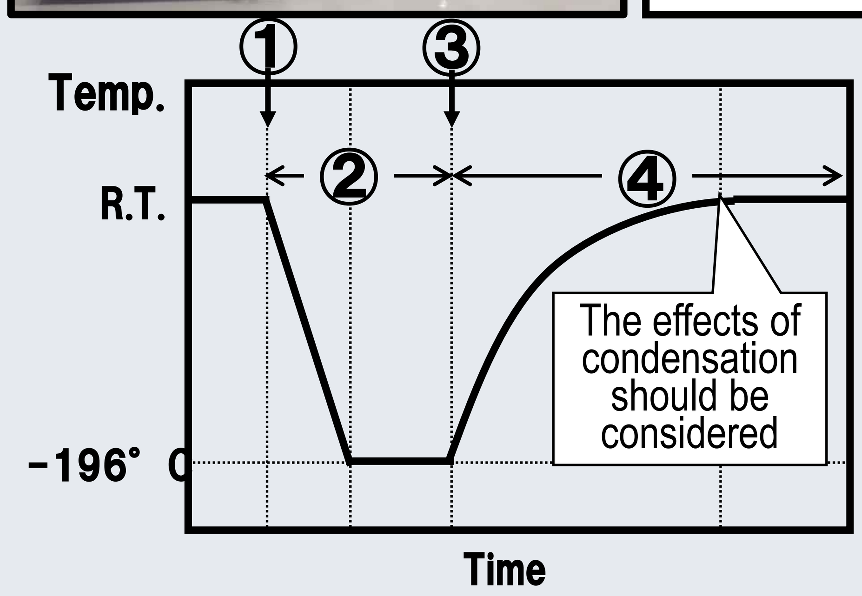
Evaluation of Cold Thermal Shock Durability of Austenitic SUS (~2 x 10^4 cyc.)

Automation and shortening of immersion thermal shock process by using dip coater

⇒ Thermal shock tests conducted up to 2 x 10^4 cyc. by repeating "LN_2 immersion ⇔ return to room temp."



A system that utilizes LN_2 instead of a dip-coating agent and directly reciprocates the sample pieces under air/LN_2



The following sequence of steps is repeated as a cycle:

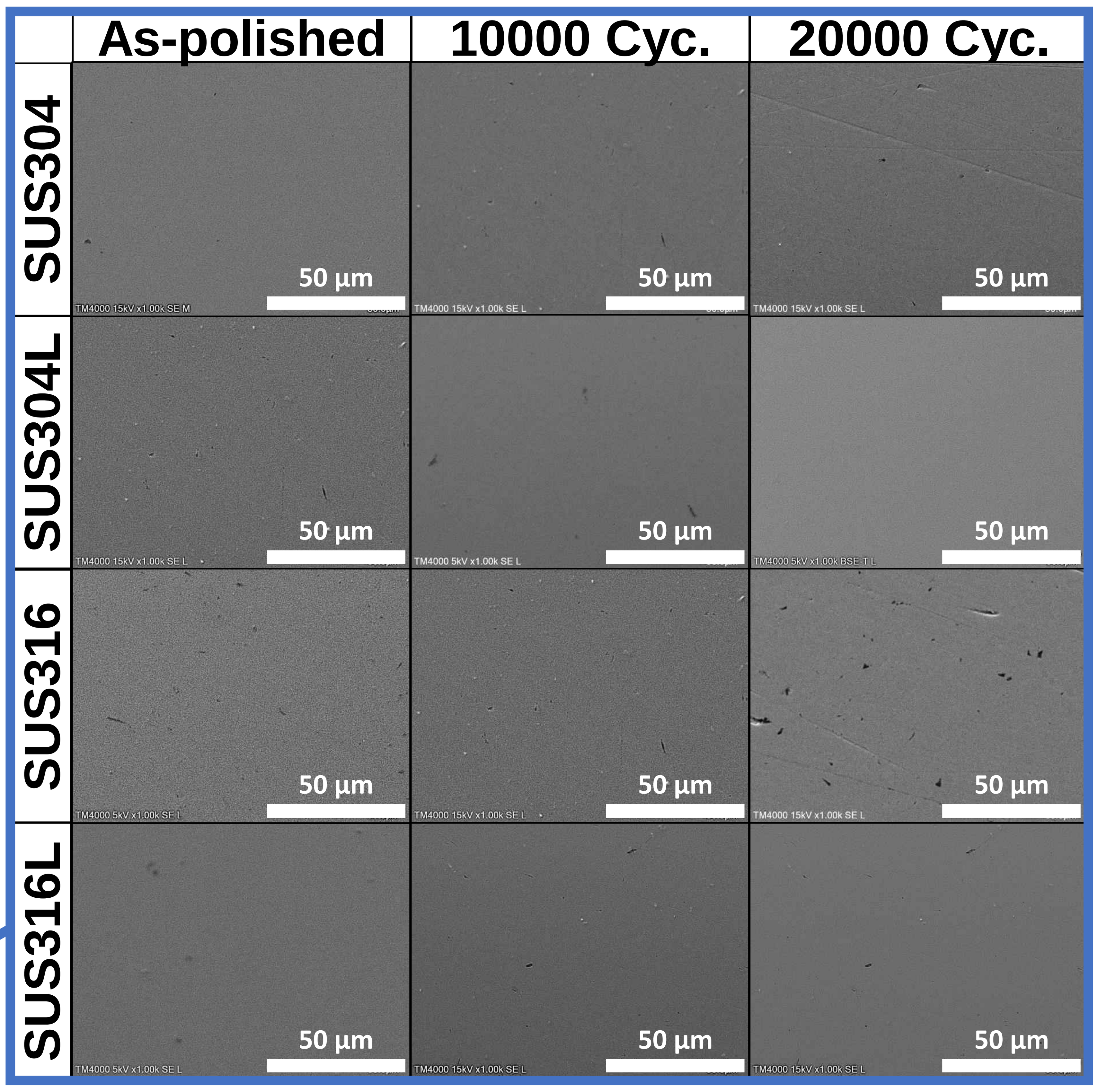
1. Air ⇒ LN_2
2. Holding under LN_2
3. LN_2 ⇒ Air
4. Holding under air

【Samples】

Four austenitic stainless steels resistant to cold temperatures

SUS304, SUS304L, SUS316, SUS316L

(5 mm x 5 mm sized square specimens)

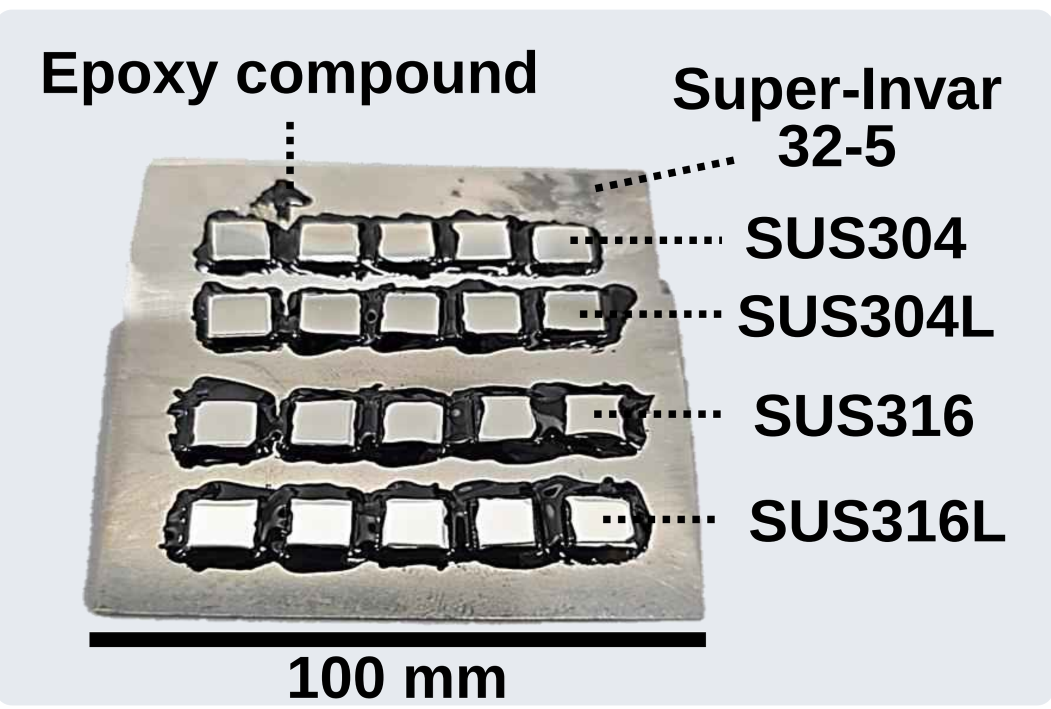


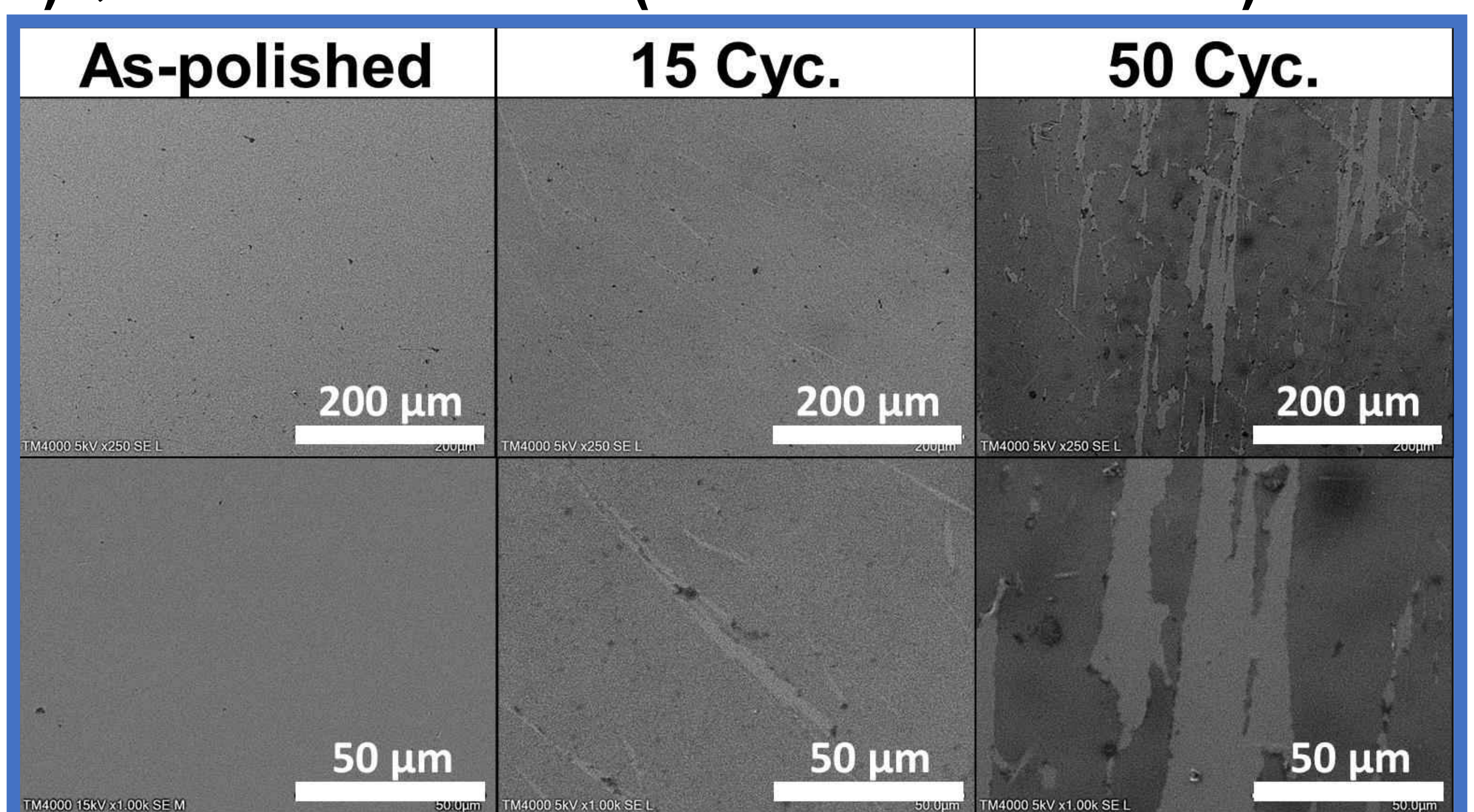
There was no significant difference in surface structure before and after 2 x 10^4 cyclical thermal shock tests

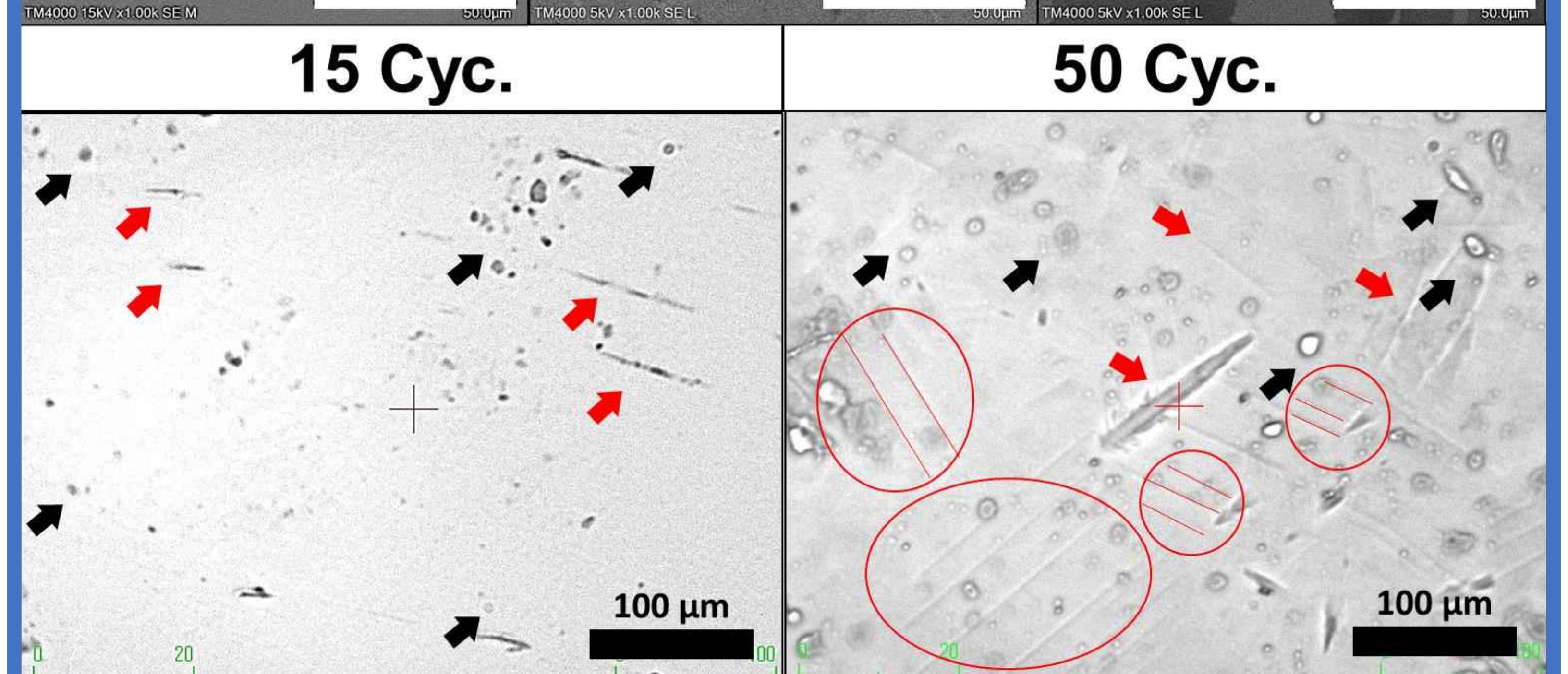
Evaluation of Cold Thermal Shock Durability of Austenitic SUS / Low Expansion Alloy Joints (~50 cyc.)

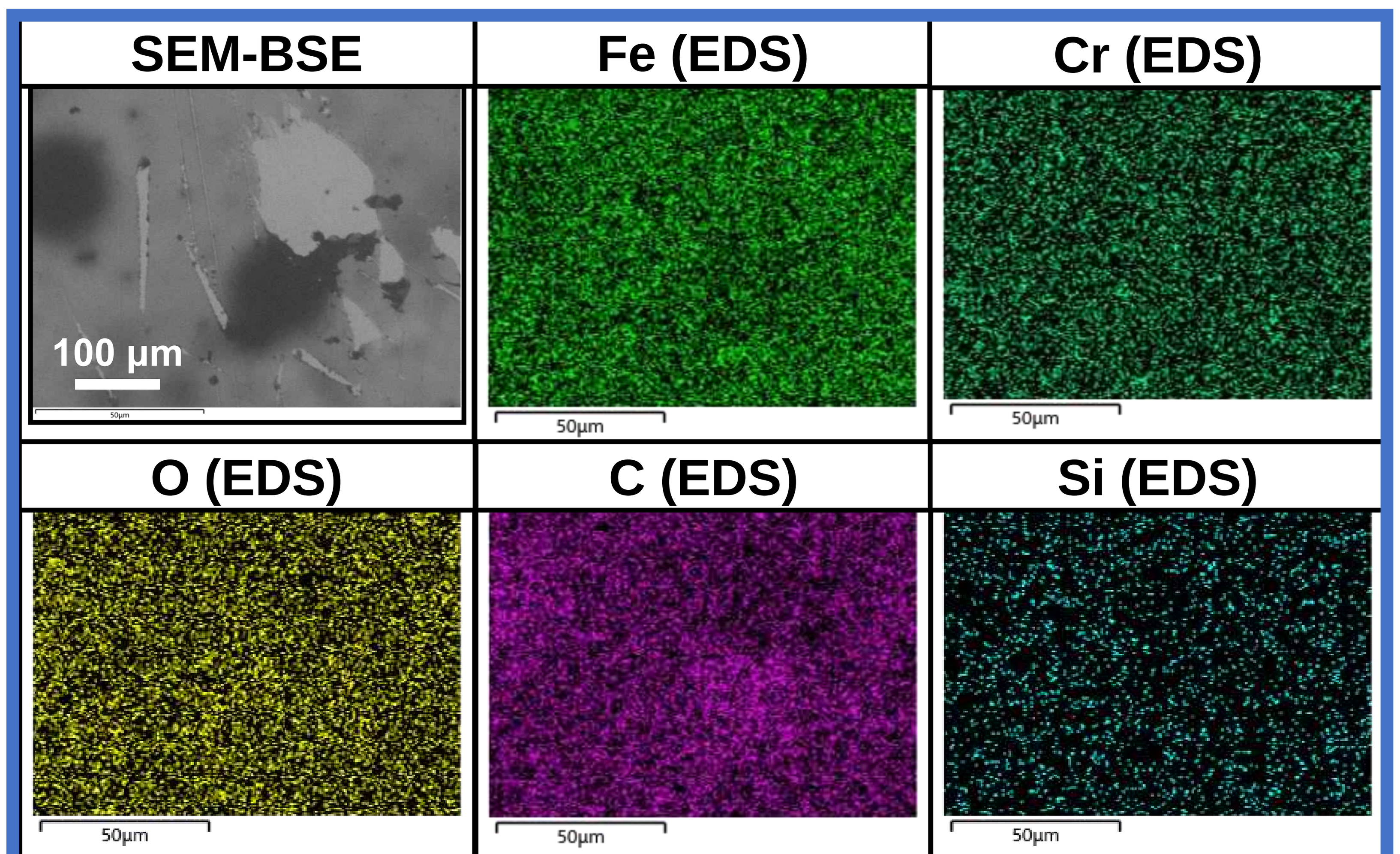
Up to 50 times of thermal shock tests were conducted on four austenitic stainless steels fixed on a low expansion alloy plate

Plate material: Super-Invar32-5 (CTE: 8.50×10^{-7}/K), Austenitic SUS (CTE: 1.69×10^{-5}/K)









There was no significant difference in composition before and after 50 cyclical thermal shock tests

Growth of voids and cracks depending on the cycle number of thermal shocks

⇒ There is a possibility of increased risk of fracture due to repeated thermal shocks near the joint interface where thermal expansion matching is poor

No. A-3-4E

PJ : Research and Development Toward Saving Energy for Direct Air Capture With Available Cold Energy

Theme: Designing the concept of Cryo-DAC® process/system

Organization: Toho Gas Co., Ltd.
Contact: Technical Research Institute, Toho Gas Co., Ltd., Yuki NAKAYAMA (nakayama-y@tohogas.co.jp)

Modeling of Cryo-DAC® process

- The calculation of absorption tower in the Cryo-DAC® process simulation model (Figure 1) has been improved from equilibrium-based to rate-based.
- Process performance improvement can be expected by identifying the rate-determining factor among the factors shown in Figure 2.

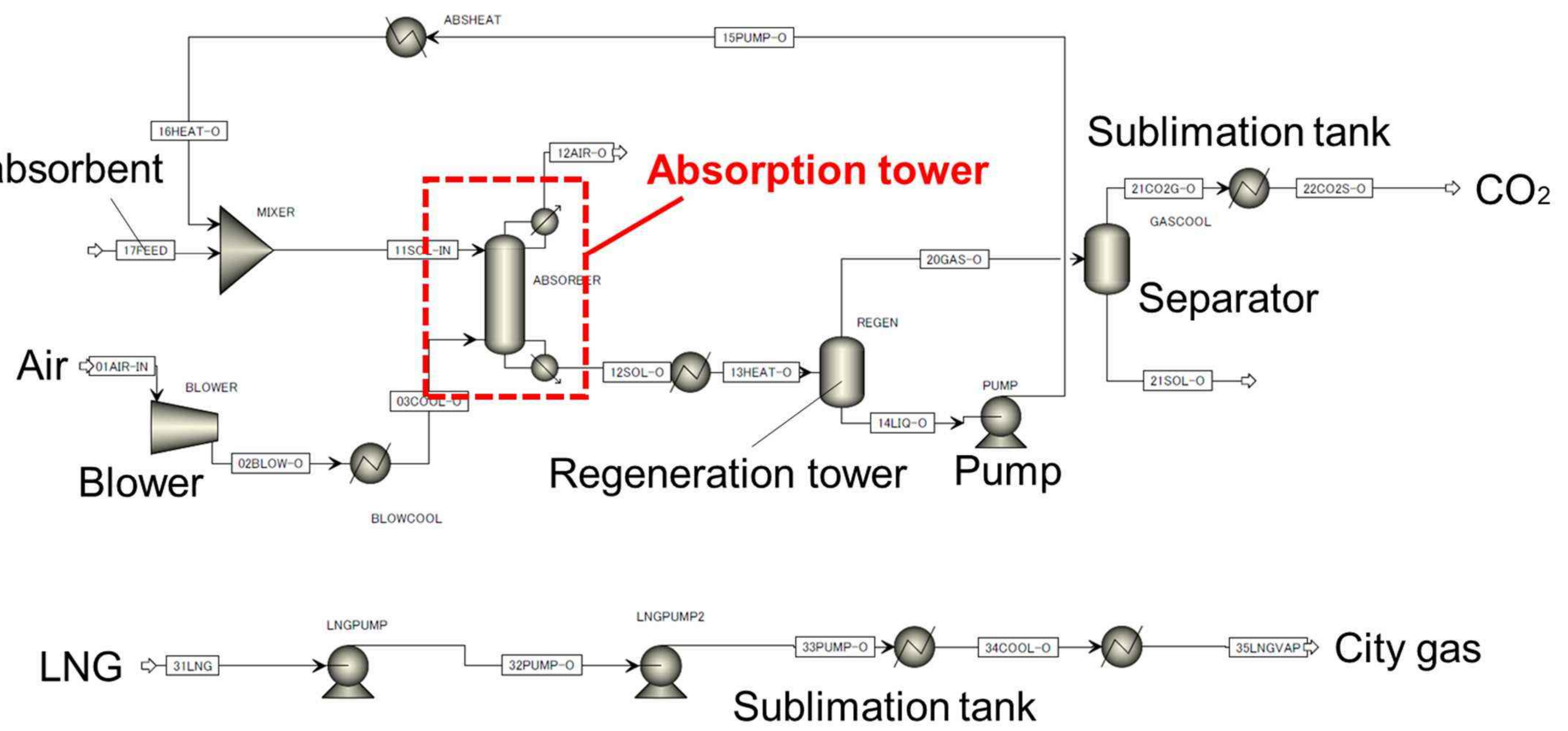


Figure 1. Process flow diagram of Cryo-DAC®.

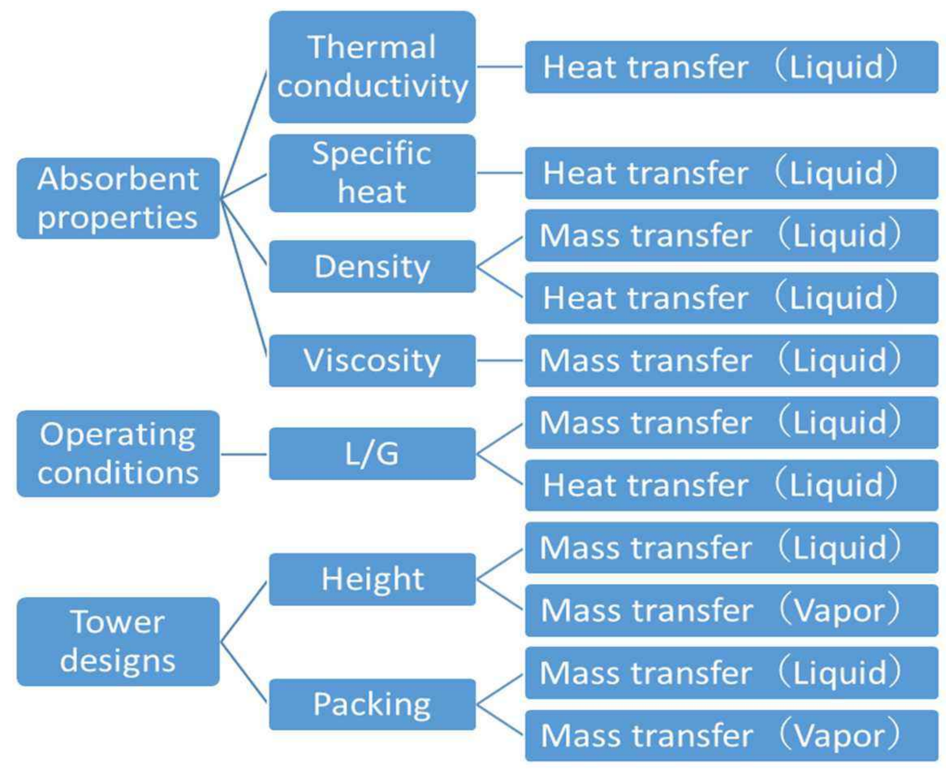


Figure 2. Factors affecting mass and heat transfer rates.

Exergy evaluation (by the University of Tokyo)

- Exergy evaluation has been conducting to optimize the energy utilization of the Cryo-DAC® process (Figure 3).
- It has been confirmed that the largest exergy loss is in the LNG vaporization process.

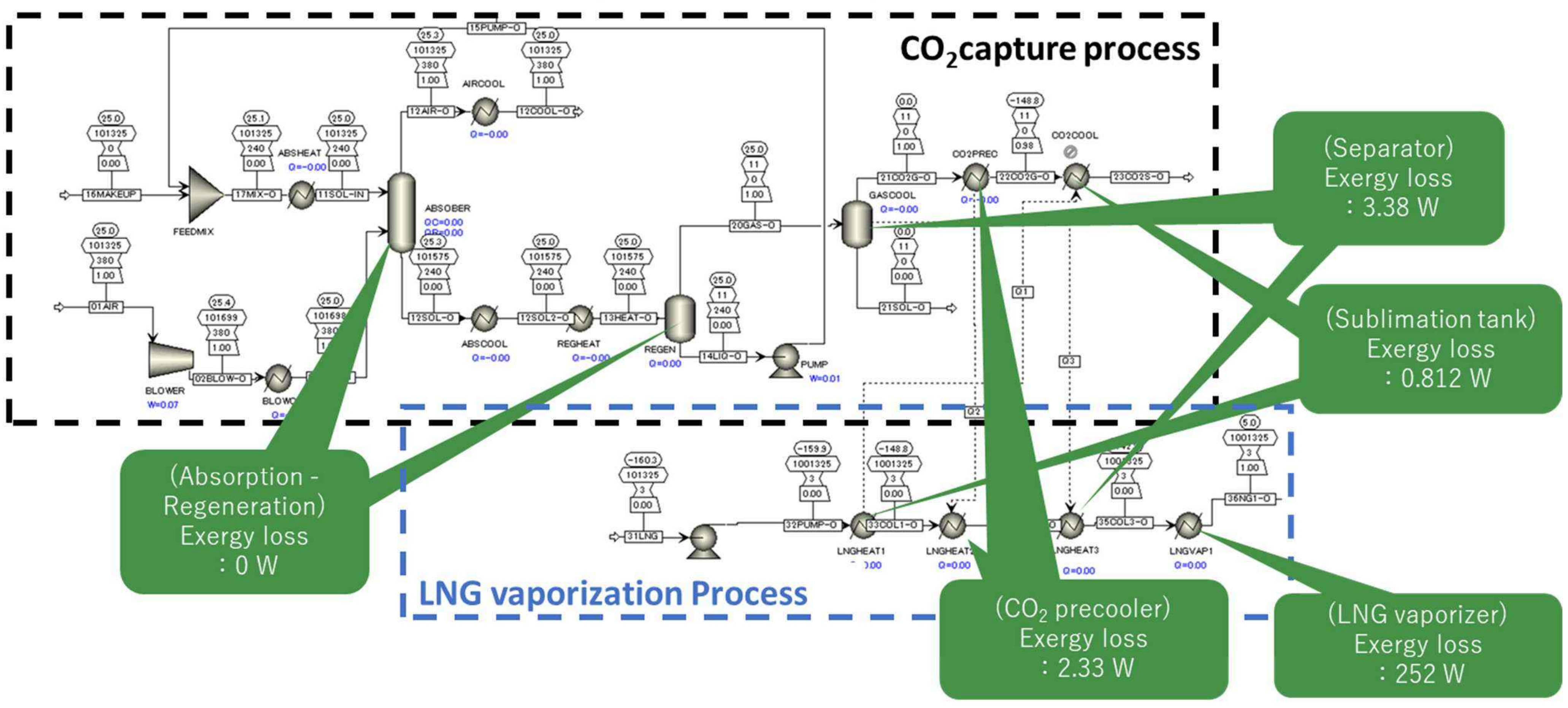


Figure 3. Results of exergy evaluation.

Life cycle assessment (by Chukyo University)

- Life cycle assessment (LCA) has been conducting to maximize net CO_2 removal.
- LCA boundary has been extended from Cryo-DAC® process only (Figure 4, Boundary I).
- For example, Cryo-DAC® can reduce CO_2 emissions by 19.7% to 28.3% (Figure 5) in the whole system (Figure 4, System Boundary).

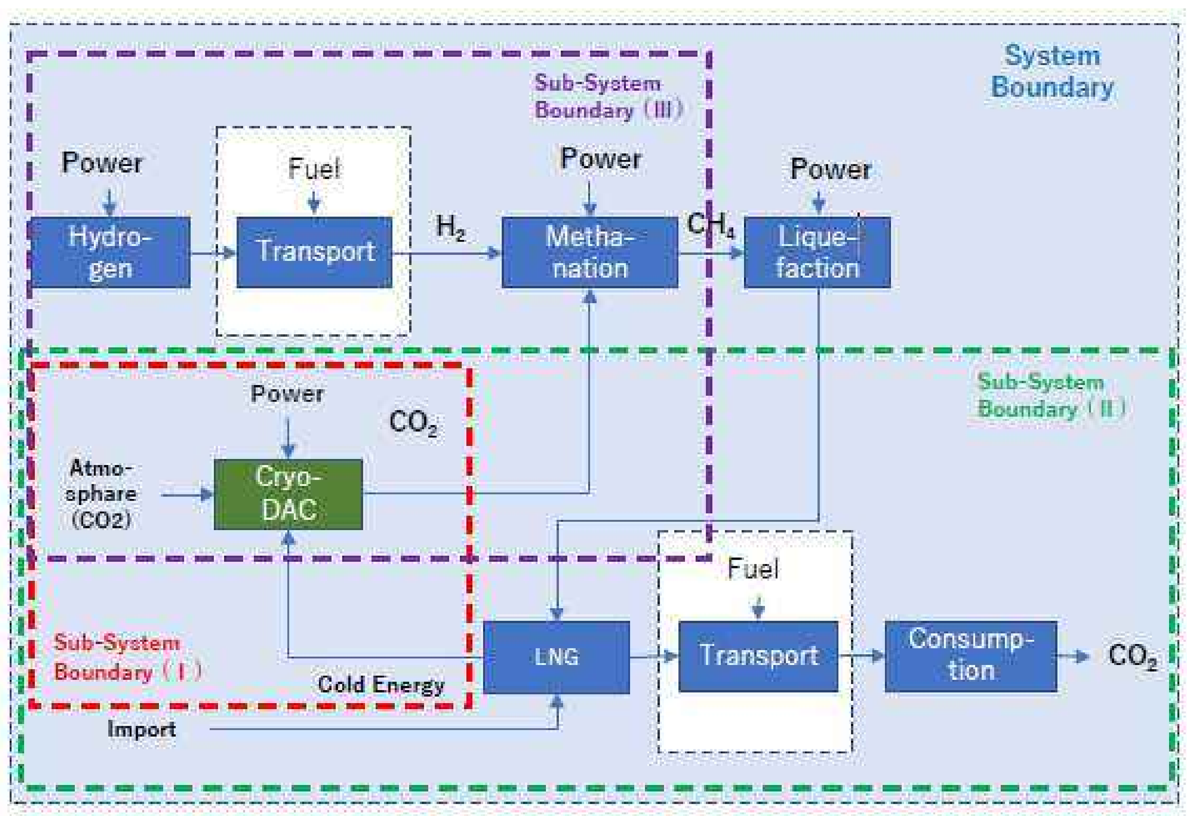
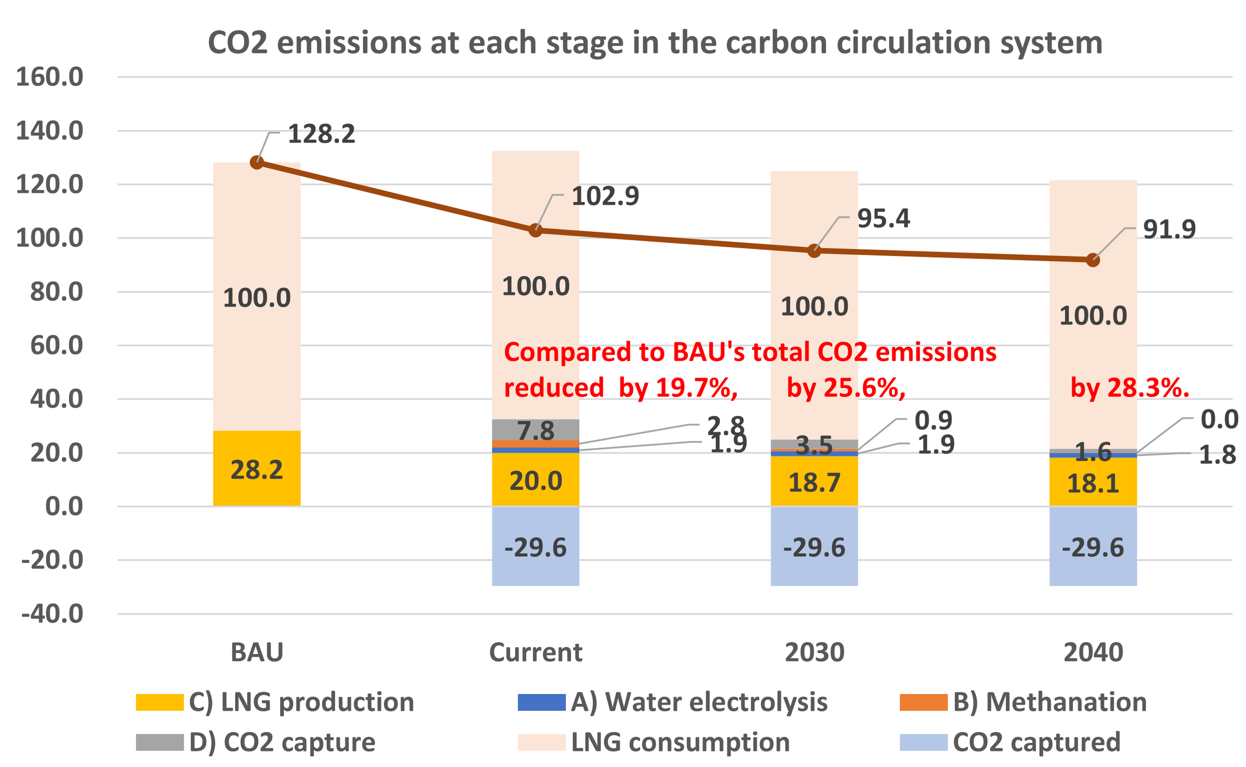


Figure 4. System boundaries for LCA.



※CO_2 emission factor: 0.506kg/kWh (Current, 2020), 0.158kg/kWh (2030), 0.00665kg/kWh (2040) from NEDO's guideline

Figure 5. Results of LCA (System Boundary).