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Towards the Carbon Circulation Society: Direct Air Capture by Kawasaki CO_2 Capture Technology and CO_2 utilization

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Abstract

Global warming is an important problem that requires humanity's urgent action. The Paris Agreement advocated setting a goal to limit the increase in global average temperature to 2°C and recommended that a maximum increase of 1.5°C should be pursued. As described in the 1.5°C Special Report by the Intergovernmental Panel on Climate Change, to achieve the 2°C goal, greenhouse gas emissions in 2050 should be reduced by 50%–80% compared to 2010, and even more rigorous emission reductions (65%–90%) are required to attain a goal of 1.5°C.

One of the ways to realize such significant reduction of CO_2 emissions is Carbon Capture and Storage (CCS) from large-scale emission sources. Many practical studies have been conducted on CCS, and commercial plants for Enhanced Oil Recovery (EOR) with CO_2 capture are already in operation. However, it is difficult for this technology alone to achieve such ambitious CO_2 reduction targets. This is because large amounts of CO_2 are emitted from small-scale distributed CO_2 emission sources such as automobiles, small power generation facilities, and boilers, and individual CO_2 capturing devices are not yet installed.

Direct air capture (DAC) is a technique that can be used to recover the uncaptured CO_2 mentioned above. DAC technology can capture ultra-low concentrations of CO_2 released into the atmosphere by various industrial exhaust gases and the breathing of humans and livestock. By removing CO_2 from the air, DAC can directly reduce the greenhouse effect. Furthermore, because DAC installation is not restricted to the vicinity of CO_2 emission sites, it can easily use waste heat and excess renewable energy. This technology has been developed by several companies in Europe and the United States since 2010.

For DAC systems, adsorption processes are mainly being developed and amine-impregnated porous materials, amino polymers, and potassium carbonate are being investigated as adsorbents. Fasihi et al.[1] noted that the current technology requires a heat source of 80–100°C to regenerate the adsorbent, but decreasing the regeneration temperatures is desirable as it would reduce heating costs and enable the use of use waste heat.

We have developed Kawasaki CO_2 capture (KCC) system, a solid-sorbent CO_2 capture technology with the goal of life-support gas control in a closed space and CCS for combustion exhaust gases[2-4]. The solid sorbent used in KCC can be regenerated using steam at approximately 60°C. Therefore, it is expected that KCC can realize cheaper DAC than in the past.

For treating the captured CO_2 in DAC, carbon capture and utilization (CCU), a process that converts CO_2 into valuable materials, is often investigated. Such valuable materials that have been previously produced using fossil fuels as raw materials are finally transformed to CO_2, thus promoting the greenhouse effect. In contrast, when CO_2 is recovered and used to produce those useful materials again, carbon is recycled and the increase in atmospheric CO_2 can be suppressed. However, to realize CCU, it is essential to know the site's location, how the required energy can be obtained without using fossil fuels, how to capture CO_2 at that site, and how to sell the useful materials that are produced at that site. Such investigations are not limited to technological development but can also lead to the construction of a social model that enables carbon circulation. Therefore, in 2019, with the support of the Ministry of Environment (MoE), Government of Japan, we started examining a social model consisting of DAC and the efficient use of recovered CO_2 to realize a carbon circulation society.

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This presentation describes the results and prospects of our carbon circulation social model building project. Figure 1 shows the project's organization diagram. With the support of the MoE, KHI will develop a CO_2 capture system and build a carbon circulation social model. To adapt KCC to DAC, methods for the effective use of CO_2 will be studied and a DAC system suitable to this use will be developed. To efficiently recover low-concentration CO_2, it is necessary to tune the reactivity of the amine on the solid sorbent, thus new amines will be developed in cooperation with Waseda University. The usefulness of our proposed social model will be verified through a life cycle assessment (LCA) of CO_2 conducted by the Mizuho Information & Research Institute. This LCA compares the amount of CO_2 emitted from the operation of the social model, which includes the production of equipment needed for the model, the electricity and heat usage during the operation and the CO_2 conversion to useful materials, along with the amount of CO_2 emitted from the production of the materials through the conventional system. The project period covers three years (2019–2022). During the first year, a reference device applying KCC technology developed for combustion exhaust gas to DAC will be manufactured and tested to obtain the current KCC system performance data. LCA will be conducted subsequently for evaluating CO_2emission reduction by applying the social model. The development of new amines will be also conducted. In the second year, we will further improve the amines and develop DAC demonstration equipment. In the third year, we will conduct commercial-scale demonstration tests that include all elements from CO_2 capture to transformation into useful materials and assuming an actual CO_2-utilizing site. Then, we will verify the effectiveness of our proposed social model through LCA evaluation.

Figure 2 shows a conceptual diagram of the DAC system, which consists of a tower filled with solid absorbent material, gas supply/discharge lines, and a steam generator. During CO_2 adsorption, $CO_2$is captured from the supplied air, and CO_2 is released by the generated steam at the desorption step. The steam absorbed during desorption naturally evaporates in the CO_2 adsorption process and is discharged together with the CO_2-free air. For this reason, the air is dehumidified before being supplied. For continuous operation, two or more towers are installed with switching absorption and desorption processes.

In this presentation, we will report on CO_2 capture performance of the reference system, LCA results, and amine development status, to discuss the feasibility of a carbon circulation social model consisting of a DAC.

Figure 1 Organization diagram

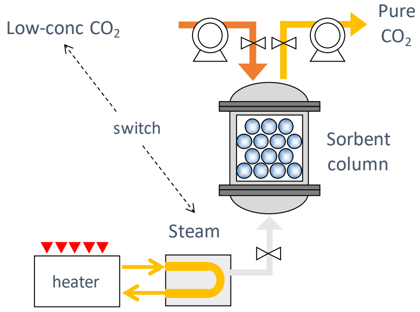

Figure 2 Conceptual diagram of DAC system

Reference

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