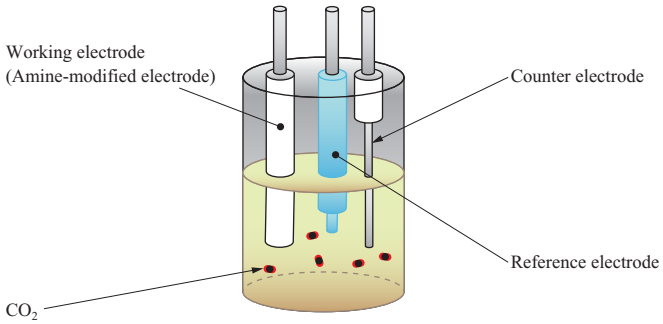
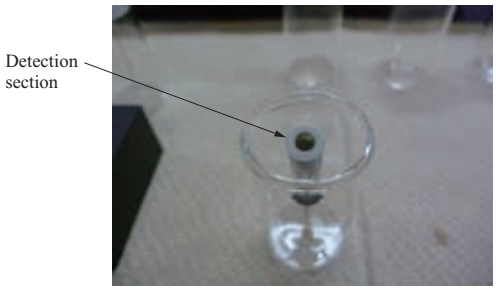
Directly Detecting Aqueous CO_2

Chemical CO_2 detection sensor for meeting the needs of monitoring leakage of stored CO_2

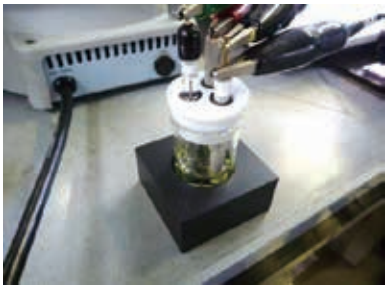
Global warming has reached the point where there's no time to waste in taking preventive measures. Ocean storage of CO_2 is one of several atmospheric greenhouse gas reduction measures. In this paper, we describe the useful results of our study on leakage monitoring, which is essential for practical use of this measure.



Measurement system for using the amine-modified electrode



Prepared amine-modified electrode



Experiment using amine-modified electrode

Underwater leakage monitoring is essential for the practical use of CO_2 ocean storage

The news about the historic agreement to "bring greenhouse gas emissions to zero by the second half of the century," reached in the COP21 (The 21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change) meeting held in Paris from the end of November to December 2015, is still fresh in our memory. In the industrial world, the challenge of "how to reduce carbon dioxide (CO_2) emissions from industrial activities" has reached the point where there's no time to waste in taking preventive measures, and various technology development projects are already underway.

Among the various approaches taken to suppress the increase of the concentration of CO_2 in the atmosphere, Carbon dioxide Capture and Storage (CCS) technologies have received considerable attention. These technologies separate and collect the CO_2 contained in exhaust gas from factories and store it so that it will not escape into the atmosphere. Possible storage locations are the immense untouched space underground or in the ocean where the impact on human activities is minimum.

In Alberta, Canada, an international underground storage project is underway. Offshore Tomakomai (Hokkaido), Japan, a demonstration experiment on ocean storage aimed at practical use around 2020 led by the Ministry of Economy, Trade and Industry will begin in FY2016.

As a CCS related technology, IHI has a CO_2 capturing technology using the chemical absorption technique (IHI ENGINEERING REVIEW, Vol. 45 No. 1, pp. 2-5). In the present article, we describe our study for meeting the needs of monitoring leakage of CO_2 collected by CCS stored in the ocean.

Assuming the storage of CO_2 in the ocean floor, a system for long-term monitoring of any CO_2 leakage into the ocean is necessary. However, until recently there were only indirect approaches that use pH fluctuations as an index, for example, to detect aqueous CO_2. The approach IHI verified detects leakage directly into the water. It is expected to achieve detection with higher sensitivity than conventional approaches, and therefore improved accuracy of leakage monitoring can be expected. The following describes the outline of this study. For details on the study, please refer to the article on this journal (pp. 25-29).

Chemical sensor that reacts to aqueous CO_2

A chemical sensor is used to determine if a certain chemical substance is present by using the properties of chemicals that cause changes, such as an electrical current or change in color triggered by a chemical bonding of the substances.

As a system for capturing CO_2, a chemical absorption technique using amine has already been put into a practical use. The properties of amine make it a substance that readily bonds with CO_2. In this approach, CO_2 contained in exhaust gas from factories is captured with an amine absorption liquid, and then the CO_2 is extracted by heating that liquid.

By using amine for the detection section of the sensor, IHI used a change in the electrochemical properties of the detection section caused when CO_2 bonds with amine.

In order to verify the principle of direct detection, we conducted an experiment by creating an electrode with its surface modified with amine and ferrocene at the same time. Ferrocene is a substance that causes an electrical current when a voltage is applied to the electrode. When we inserted an electrode in a solution simulating seawater and measured the voltage-current properties, we were able to confirm the phenomenon that current is less likely to flow as the aqueous CO_2 concentration increases.

It is thought that the following phenomenon occurs in this experiment. In the absence of aqueous CO_2, the amine at the electrode surface is electrically neutral or positive. At this time, electrons can freely move from ferrocene molecules to the electrode. However, when aqueous CO_2 is present, CO_2 bonds with amine to generate electrically negative ions on the electrode surface. At this time, however, the movement of electrons from ferrocene molecules to the electrode is prevented due to the repulsive force of static electricity.

As a result of this experiment, we confirmed that aqueous CO_2 can be detected directly using a chemical sensor with its surface modified with amine and ferrocene at the same time.

This chemical sensor is still in the basic research stage, and we must overcome many challenges before we can put it into practical use for monitoring CO_2 stored in the ocean. For example, the size of this sensor is suitable at the experimental level, but we must increase it to the extent that it can actually be used in the ocean. There is also a challenge regarding durability (withstanding the temperature, water pressure, ocean current, and attachment of marine life such as corals). On the other hand, this is potentially applicable to other areas, such as food and natural environment monitoring.

Incidentally, this sensor was well received when we presented it at an academic conference on CCS in 2014 and another conference on chemical sensors in 2015. Particularly in the latter academic conference (the 11th Asian Conference on Chemical Sensors), it was awarded the 10 Best Paper Award and 10 Best Presenter Award, and researchers attending the conference commented that the idea of a private company conducting such basic research and utilizing the results in the industrial field is very interesting. IHI is advancing the research day by day with the aim of applying this chemical invention focused on a micro phenomenon to a macro industrial field.

Ceremony at the 11th Asian Conference on Chemical Sensors (ACCS2015)

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