6. INTEGRATED RESEARCH CENTER FOR CARBON NEGATIVE SCIENCE

2024 Activities

Introduction

The Integrated Research Center for Carbon Negative Science (ICaNS) was established in August 2022 to promote carbon negative science research toward the realization of a carbon neutral society in 2050. Currently, the balance between carbon dioxide emissions and absorption has been disrupted, resulting in an excess of carbon dioxide emissions and a serious impact on the earth in the form of climate change. Restoring the balance is difficult with "zero emission" technologies alone and requires the development and implementation of more active carbon dioxide fixation processes, so-called "carbon negative" technologies. The Center will work to develop such new carbon dioxide fixation technologies in collaboration with the Graduate School of Engineering and Graduate School of Energy Science at Kyoto University. It will also work to develop human resources for "carbon negative science," which has not been done before.

In the fiscal year (FY2022), three major research projects were launched: 1) Solar Energy Utilization for CO_2 Capture and Conversion, 2) Conversion of CO_2 into Useful Substances, 3) Biological Utilization of CO_2. This fiscal year (FY2024), continuing from the previous year, we promoted these priority research projects and established an educational system for "carbon negative science". In addition, an international seminar on carbon negative energy science was held, and the center's laboratories were upgraded and experimental equipment was installed.

1. Solar Energy Utilization for CO_2 Capture and Conversion

The objective of this group is to establish novel science and technology for efficient solar energy utilization required for capturing CO_2 and/or converting CO_2 into valuable materials. In FY2024, the following studies were primarily conducted in this group: Studies on developments of carbon nanotube-based high-performance selective solar absorber for so-lar energy harvesting and wavelength-selective thermal emitter for high efficiency thermophotovoltaic energy conversion; novel energy con-version and generation technologies based on quantum optical science; on-surface electro-chemical synthesis of a strong electron-donating graphene nanoribbon catalyst; electrochemical performance of laser-textured electrodes for efficient hydrogen evolution; light-induced nitrogen fixation; and conversion of pollutants and biomass to value-added chemicals.

2. Conversion of CO_2 into Useful Substances

This project group aims to convert CO_2 into useful substances. We are particularly interested in electrochemical methods of conversion. By using high-temperature molten salts as electrolytes, for example, CO_2 could be converted into a wide variety of valuable carbon materials, such as diamonds, carbon nanotubes, and graphite. If aqueous solutions, organic solvents, or ionic liquids are used as electrolytes at relatively low temperatures, CO_2 can be converted into methane, ethylene, and other materials. In FY2024, various types of carbon were electro-deposited using CO2 as the raw material in molten chloride salts at temperatures of 500 to 900 °C. It was found that amorphous carbon was likely to be obtained at low temperatures, and that graphite could be obtained under certain conditions at high temperatures. In addition, although only in small quantities, diamond was also obtained as another carbon allotrope.

3. Biological Utilization of CO_2

Research in this project focuses on bio-related methods, materials and enzymes with the goal to contribute to Carbon Negative Science. In FY2024, studies that were carried out include the following: the development of tools to better understand the biological cell and its energy conservation, and technology to enhance and/or prolong the activity of enzymes, particularly those related to CO_2-fixation. Engineering of the CO_2-fixation enzyme and enhancement of substrate specificity have been carried out to enable the production of valuable molecules from CO_2, thereby improving CO_2 fixation through a novel reaction. Development of membranes, reactors and processes to enhance biomass utilization and establish efficient biorefineries have been performed. New microbial enzymes or metabolic pathways that can utilize CO_2 or prevent its release have been identified. Our collaborative research has been continued in pursuit of our shared goals and to contribute to the development of a bio-based society.

4. Education Activity

The content of "Carbon Negative Energy" was incorporated into the existing undergraduate course "Advanced Energy Science". As for graduate-level lectures, "Carbon Negative Energy" was incorporated into "Socio-Environmental Energy Science I and II" in the Graduate School of Energy Sciences, as in the previous fiscal year. The concept of "Carbon Negative Energy" was also promoted to visitors to the institute.

5. Other Activities

Fig. 1-1 A dehumidifier.

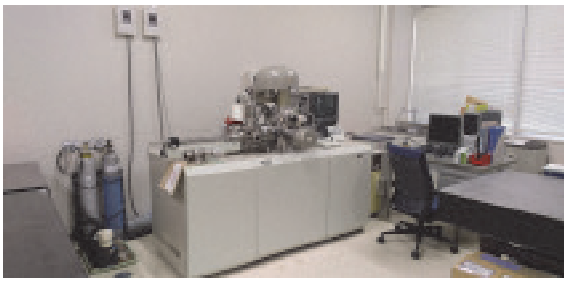

Fig. 1-2 An X-ray photoelectron spectroscopy.

Fig. 1-3 An experimental bench.

We further upgraded Laboratory 1-5, Waiting Room 1-2, Program-Specific Associate Professor's Room and Program Specific Assistant Professor's Room in the main building of the Uji Campus. As for experimental equipment, a dehumidifier, an X-ray photoelectron spectroscopy (XPS), and an experimental bench were installed, as shown in Figs 1-1, 1-2, and 1-3.

ICaNS Events

June 25: The 1st Steering Committee meeting was held.
December 13: Symposium Session of Exploring Carbon Negative Energy Science was held in 15th International Symposium of Advanced Energy.
December 12: Symposium on Exploring Carbon Negative Energy Science 2024 was also held as a parallel seminar of the 15th International Symposium of Advanced Energy.
December 21: The 2nd Steering Committee meeting was held.
February 22: The 3rd Steering Committee meeting was held.