Pioneering on a new frontier: Non-conventional catalytic chemistry

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[Short bio]

Ph.D. (Engineering) in Applied Chemistry from the University of Tokyo, Graduate School, Faculty of Engineering.
After holding positions as a research associate in the Department of Applied Chemistry at the University of Tokyo, and lecturer and associate professor in the Waseda's School of Science and Engineering, Prof. Sekine was promoted his current position in 2012. Prof. Sekine is also a JST fellow; an editor for Elsevier's *Fuel* journal; a member of the Green Innovation Project Committee of the Industrial Structure Council, METI; a member of the Government Green Innovation Strategy Promotion Council; chairperson of a green innovation working group; and research supervisor of a JST PRESTO. He received the 2020 Commendation for Science and Technology awarded by MEXT, and is a Fellow of the Royal Society of Chemistry (UK).

- How will your research contribute to carbon neutrality?

My field of expertise is chemistry, especially catalytic chemical processes. Catalysts are a group of materials that act as command centers for chemical reactions. Conventional catalytic reactions are conducted at high temperatures and on a large scale, and are very efficient. However, those features are becoming less useful in the era of renewable energy, which exists in a dispersed manner and reconfigures substantially day by day. Catalytic reactions for the creation of next generation materials and energy will require technology for efficient control of chemical reactions at low temperatures, with flexible timing and volume, driven by renewable energy. To contribute to carbon neutrality, we are developing a catalytic reaction method that can operate at low temperature and can set in motion a locally produced and locally consumed chemical process using dispersed energy.

- What is the motivation behind this research?

Japan has begun to take major steps toward becoming carbon neutral by 2050 in line with the Paris Agreement. Looking at the Earth from space, we can see it is a closed system in terms of elements. From the perspective of the earth's sustainability, our continuing reliance on fossil resources such as coal, oil, and gas, which are a legacy of the earth's 300 million years of life, is considered to be an issue. Thinking toward the future, we can see that it will be important to create an energy and material society that can keep human beings thriving for a long time, using only the blessings of the sun and the resources of the earth, notably biomass (plant resources), municipal waste, carbon dioxide, and water.

It is said that about 90% of the industrial chemical processes that humans have utilized until now, in fields such as plastics manufacturing, pharmaceutical manufacturing, and petroleum refining, are catalytic processes. On the other hand, catalysts also play an important role in the chemical reactions necessary to produce next-generation materials and energy that can replace fossil resources.

- What kind of research are you currently engaged in?

Within the above scenario, we have been conducting catalytic reaction research in a manner reminiscent of the old saying, “If the cuckoo doesn’t sing, make it sing.” We are working with low-temperature catalytic reactions using surface protonics, in which hydrogen ions (protons) move actively on the surface of a catalyst when a DC electric field is applied externally. Using those protons, we have pioneered catalytic reactions that can be induced even at low temperatures. We also use computational chemistry to analyze the phenomena that occur on the surface of catalysts. The understanding that we acquire will help us to predict better catalysts.

Renewable energy, which will become an ever more important source of energy in our future, is generated at a time and place different from the time and place where we want to use it. For example, in the evening and at night, when most people are active at home, and thus consuming more energy, the amount of electricity generated by the solar panels on our roofs will be zero. In order to overcome this mismatch, it is important to both improve the performance of rechargeable batteries and convert the energy into synthetic fuels and hydrogen. Among the means toward such improvements, we are studying catalytic reactions to support the use and storage of hydrogen and synthetic fuels. We are also developing technologies to protect the global environment, such as a catalyst that can efficiently recycle carbon dioxide at much lower temperatures than previously possible; a catalyst that can efficiently convert methane to chemicals; and a catalyst that can activate nitrogen at much lower temperatures than before.

We are currently working on these kinds of research in large joint projects with the national government and in collaboration with a number of companies, with the aim of implementing the findings in society.

- Do you have a message for our readers?

We will continue pioneering in the world of new non-conventional catalytic chemistry, creating technologies that can contribute to carbon neutrality; developing human resources who can effectively lead a sustainable society; and disseminating the latest research results from Waseda University to the world.