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Functions and Activities of Catalysis Research Center, Hokkaido University, for Catalysis Research Communities

Wataru Ueda

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Abstract Materialization of sustainable society that balances the economy and the natural environment has been high priority. For this issue, catalysis has been regarded as a key technology and there is no doubt that catalysis researches have to be greatly promoted everywhere in the world in order to sustain and to secure the nature, the life, and the society. Recent activities of Catalysis Research Center in Hokkaido University for contributing to the above issues are introduced.

Keywords Catalysis · Center · Community

1 Introduction

Catalysis Research Center (CRC) in Hokkaido University originated in the Institute of Catalysis which had been founded for the first time in the world in 1943 in order to promote fundamental studies on catalysis. According to the research trends and interests from fundamental to application, the institute had been completely modified and reorganized and then in 1988 CRC has started as a national collaborating institution, followed by scale-up reorganization in 1998. In 2007, CRC again made an organization renewal in order to play a leading role in catalysis communities and a bridging role among interdisciplinary scientific fields and their researches. It is not too much to say that the research framework of CRC has been reorganized vividly according to catalysis community with industrial and social demands.

W. Ueda (✉)
Catalysis Research Center, Hokkaido University,
N21-W10, Kita-ku, Sapporo 001-0021, Japan
e-mail: ueda@cat.hokudai.ac.jp

Nowadays, catalysis targets spread widely into other industrial and social areas. Since global warming and other environmental issues have become a matter of serious concern, the materialization of sustainable society that balances the economy and the natural environment has been high priority. In this situation, catalysis has been regarded as a key technology for this issue, namely *sustainable catalysis technology*. No doubt that it is time to promote catalyst developments greatly in order to sustain and to secure the nature, the life, and the society.

Here in this report, the renewal CRC research framework organized for enhancing interactive collaborative researches, the international activity of CRC for worldwide collaborations, and Global COE program for promoting high-level education on the basis of catalysis will be introduced.

2 CRC Research Framework and Functions

CRC has devoted so far its main efforts into constructing systems capable to analyze the reaction steps dynamically and to create new catalysts and catalytic reactions with chemistry of nano- or micro-level assembly of catalytic elements and molecules and has developed many catalysts and catalytic processes for new resources utilization, environmental catalysts, catalysts for bio-resources utilization, catalysts relating to fuel cell, photocatalysts, organic synthesis catalysts and so on, all of which have been developed either along with age-demand or in advance. It is, however, turned out that interactive collaborative researches become more necessary for creating outstanding new type catalysts with super functions and for their wide application in many scientific areas than ever before.

CRC, therefore, undertook dynamic and flexible transformations in its research directions beginning from 2007 by introducing novel research domains in addition to giving continuity to fundamental research. Now, CRC has a double-layered research system consisting of the Fundamental Research Division with seven research sections, and the Target Oriented Research Assembly with nine research clusters. Each research activity is summarized in Table 1.

The individual research sections in the Fundamental Research Division are unique in Japan, a country as the forefront of world-wide catalysis research, as sites dedicated to intensive research on basic catalytic chemistry and available for nation-wide research collaborations. The research clusters of the Target Oriented Research Assembly are led by young Associate Professor-level researchers, where vivid research aimed at innovative and high-level output in newly created catalytic research domains often goes beyond the existing boundaries of catalysis science. Current CRC set target is "*Innovation driven by catalysis*".

Because of the complexity of the sustainable catalysis technology, various types of research collaboration are indispensable. CRC research collaboration systems in the Target Oriented Research Assembly for promoting catalysis-bridged science and technology with researchers in various fields will function very effectively for realizing the sustainable catalysis technology in sooner future.

Table 1 Structure of the research cluster and the fundamental research division

Research cluster of	Major objective and activities
Asymmetric induction of Non-Centrochirality as novel media	The asymmetric reaction field characteristic of catalysts obtained from non-centrochiral compounds.
Well-defined surface structure for precise reaction control	The objective is to create and observe a well-defined surface structure for precise reaction control by modification of a single crystal surface of metal oxide using a wet chemical process.
Functionalized crystals	Design of new visible light-driven photocatalysts by band engineering of mixed oxides and development of highly efficient photocatalytic reactions over well-defined structure.
Energy conversion field	Innovation of solid electrolytic materials based on metal oxides, and development of novel power-generation system without novel metal catalysts.
Bio-interface	Development of novel method for the observation of dynamic changes in bio-molecules and biomaterials with newly discovered functions in aggregated states.
Biomass conversion	The aim is to synthesize sugar compounds by catalytic cracking of renewable biomass, that then will be converted into fuels and chemicals. The first catalytic cracking of cellulose into sorbitol was achieved over supported metal catalysts.
Reaction field based on molecular assembly	The aim is to construct precisely designed molecular assembly on solid surface in order to obtain novel catalytic functions. The approach will explore an interdisciplinary research field originated from catalysis study, organic chemistry and surface science.
Rationally-designed nanocatalyst	The aims are to synthesize alloy nano particles with well-defined structure and to apply to catalysts for hydrogen energy utilization. The targets cover the alloy system where component elements are distributed randomly, arranged regularly, or segregated into a core-shell structure.
Networking of researchers in catalytic science	Cooperation and fusion of activities in catalysis research, and execution of international programs to cultivate novel fields in catalysis chemistry.
Section of	**Major objective and activities**
Surface structure chemistry	Development of techniques, completely new at the global level, that is suitable for the analysis of surface in space and time.
Interfacial spectrochemistry	Developments of innovative and original techniques for real-time monitoring of reaction dynamics at interfaces between different material states (solid, liquid, and gas).
Catalytic reaction chemistry	Developments in the synthetic chemistry of photocatalytic nanostructural particles.
Catalytic materials chemistry	Developments of new nano-scale inorganic synthetic methods. Establishment of synthetic chemistry that deals with oxidation catalysts with highly-ordered, micro- to nano-revel structures.
Molecular catalysis chemistry	Identification of complex reactions in classic organic chemistry that involve transformations of carbon bonds, and investigations into various organic synthesis reactions. Synthesis of organic electronic materials.
Catalytic transformation	Investigations into the catalytic response of mesopourous solid materials, and realization of super-selective catalytic reactions.
Catalytic assemblies	General contributions to the chemistry of cluster assemblies, elucidation of the chemistry of metal assemblies, and use of the results for catalytic reactions.

3 International Activity of CRC

CRC does think that not only domestic research collaboration activity but also international one is very important. It should be time to promote catalyst developments greatly with world-wide collaboration in order to sustain and to secure the nature, the life, and the society. In this context, CRC had organized "Catalysis Summit" last year 2008 in Sapporo, which was constructed by eight major catalysis institutions including CRC in the world and released the statement that chemical processes and energy production systems have to be practiced with the concept of harmonic collaboration between natural activities and artificial catalytic process. The brief report of the summit and duplicated statement are in the following.

The G8 summit was held in Toyako in Hokkaido from the 7–9 of July 2008. One of the main topics of the summit was the global environment and the impact caused by CO_2 emissions through human activities. The leaders discussed how mankind has to take action to address this issue and concluded that we need a combination of solutions.

Undoubtedly, all areas of science and technology have to work harmonically and concertedly to address these issues. Particularly, chemistry will play a pivotal role as well as contribute as a central player because chemistry is one of the scientific fields that have a high responsibility for the global warming issue and that at the same time can commit fundamentally and directly to the issue. Since many of chemical transformation are central subjects of *Catalysis Chemistry*, *Catalysis Chemistry* is of great importance and will be a key enabling technology for a sustainable society.

Seizing the opportunity of the G8 summit, the CRC, Hokkaido University organized a "Catalysis Summit" in order to discuss what Catalysis Chemistry can do and what Catalysis research Chemistry has to do in the future. The catalysis summit was held at Hokkaido University on 7 July, 2008. Panel members from eight countries participated: UK (Cardiff University), USA (University of Delaware), Germany (Fritz- Haber-Institut der Max-Planck-Gesellschaft), France (CNRS/Ecole Centrale de Lyon), Russia (Boreskov Institute of Catalysis), India (Innovation Center, Tata Chemicals Ltd.), China (State Key Laboratory of Catalysis, DICP), and Japan (CRC). After a stimulating discussion covering many aspects related to the presentations, the participants announced the following statement at the end of the catalysis summit.

3.1 Statement of Catalysis Summit 2008

It is now clear that global warming is a result of human activities and the phenomenon is no longer in doubt. Many remedial actions have been proposed, including the development of better methods of chemicals and energy production. Such developments will be enabled by the application of the scientific skills of scientists and engineers to the reduction of CO_2 emissions, and perhaps, in the longer term, to the reduction of absolute CO_2 levels in the atmosphere. A diversity of scientific disciplines need to be engaged together for this purpose, but Chemistry is essential to new developments in these fields, since the production of CO_2 often involves rather primitive chemical transformations which need to be evolved to clean technologies for a developing world.

Chemistry has been at the centre of the developments of our modern society, particularly over the last century. In the past, much of this technology produced large amounts of pollution, often resulting in far more undesired by-products than desired ones. This has changed in recent years and we have entered the era of "Green Chemistry". For the sake of our children's children's children this development has to be accelerated at the global level and applied to the energy production sector with the utmost urgency.

Hence, this summit will concentrate it's focus on international efforts in this direction. An essential aspect of chemistry to achieve these objectives is the application of *CATALYSIS* to this problem. The whole petrochemical industry is based on the application of catalysis to chemical transformations of low grade materials into useful products (automotive fuels, plastics, pharmaceuticals), which we all need and use everyday. During this summit, we discussed what catalysis can contribute to a new, greener world and especially to the evolution of a sustainable fuels economy and then summarized necessary research areas as listed in Table 2. In order to be successful in such research areas a much better fundamental understanding of catalytic processes on the molecular level is necessary. Such understanding can only be obtained through the concerted development of novel experimental and theoretical technologies and approaches. Efforts in those areas are under way, but need to be enhanced and accelerated in order to move towards a sustainable future society on our planet.

Have no doubt about it, catalysis will play a pivotal role in the new global economy which MUST arise in the next 20 years or so. It is essential that you know about this technology.

4 Global COE Program "Catalysis as the Basis for Innovation in Materials Science"

The transformation and syntheses of materials using catalysts are key technologies that traverse and encompass the main fields of Japanese government's scientific and technological policy. In accordance with this policy, catalysis

Table 2 Necessary catalysis research areas

Catalysis for the hydrogen economy	Hydrogen production using the combination of solar energy and photocatalysts
	Electrocatalysis and fuel cells
	Hydrogen storage facilitated by catalytic materials
Catalysis for environmental protection	Catalytic gas emission control
	Catalytic water purification
Catalysis for chemicals production	Catalysts with ultimate product selectivity
	Catalysts with ultimate energy efficiency
	New C1-chemistry-CO_2 utilization
	Alkane chemistry
	Catalysts for new chemicals
Catalysis for the conversion of biomass	Biomass conversion to fuels and chemicals

chemistry has been vigorously pursued at Hokkaido University since the early twentieth century, and many pioneering achievements were resulted in such areas as fundamental theory, surface analysis and modification, and the development of practical catalysts and catalytic reactions, These researches on catalysis are currently being conducted at eight schools including the Graduate School of Engineering and the Graduate School of Science and institutes including CRC. Recognition of these achievements in the university led to the establishment of Global COE program entitled "Catalysis as the Basis for Innovation in Materials Science" starting from 2007. The goal of this program is to establish a base for fundamental research on the transformation and syntheses of materials using catalysts. For this aim, two fundamental school systems are introduced: first, chemistry related organizations are reorganized into the "Graduate School of Pure and Applied Chemistry" and second, the "Asian Graduate School (AGS) of Chemistry and Materials Science" is established to form a trans-Asian network and to educate top-class researchers.

For educating talented top-class young students in chemistry, the international educational program of AGS in GCOE has started in 2008 (http://www.eng.hokudai.ac.jp/ags/index.html) with strong ties of leading universities in Asian countries, Hokkaido University, Peking University, Seoul National University and National Taiwan University. These universities will enroll a limited number of elite students for this program. All qualified students will be fully supported by a scholarship. Each university will participate in the educational program of "Graduate Schools of Chemistry and Materials Science (Doctoral Course)", which includes all major fields in chemistry and materials science, including recent advances in organic chemistry, inorganic chemistry, organometallic chemistry, polymer chemistry, catalysis, materials chemistry, biochemistry and chemical engineering. This integrated program is expected to provide students who will lead the next generation in scientific and technological innovations addressing both academic and social issues in chemistry and materials science.