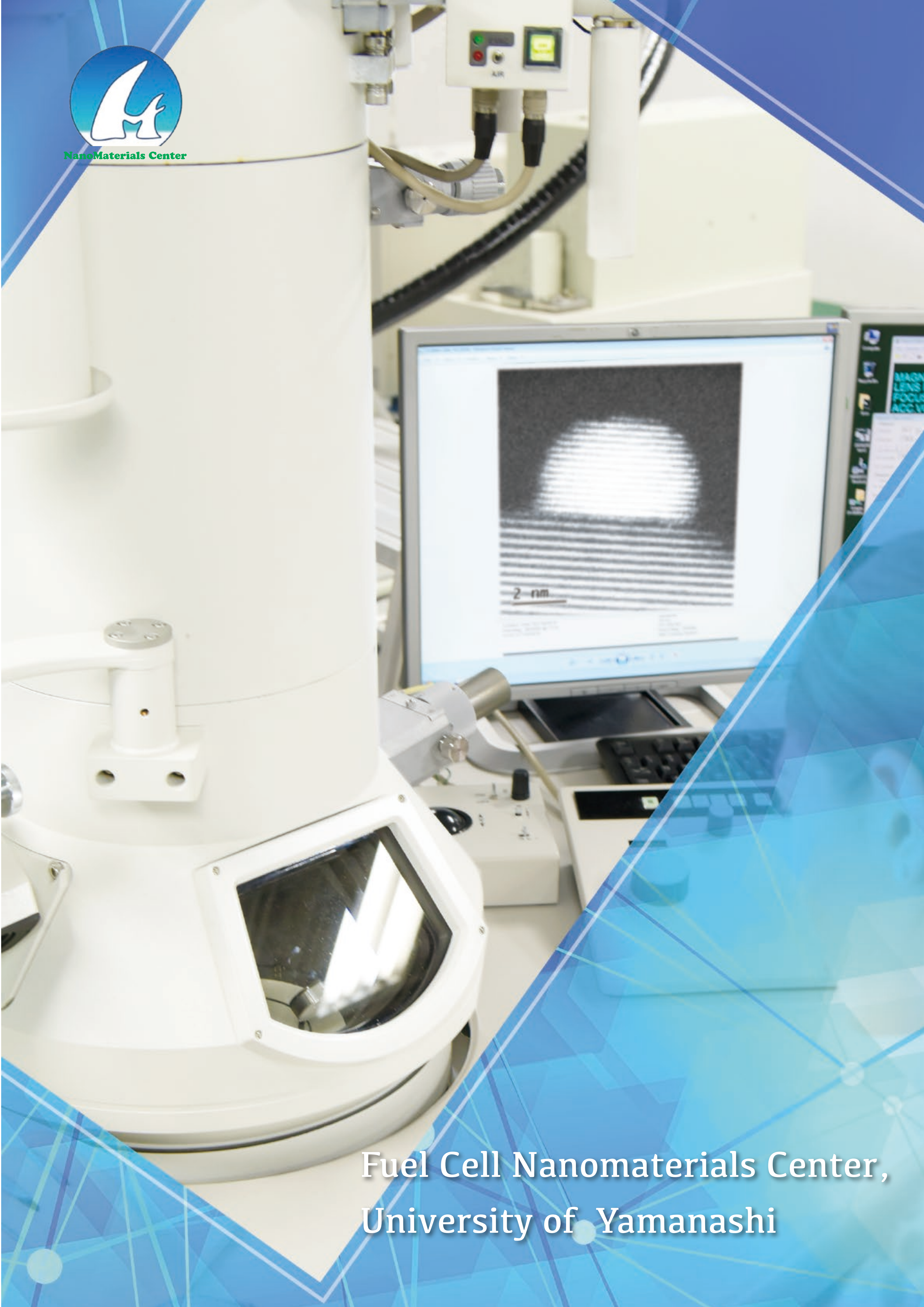


Fuel Cell Nanomaterials Center, University of Yamanashi

OUTLINE

Outline of the Center

Director,
Fuel Cell Nanomaterials Center,
University of Yamanashi

Akihiro Iiyama

Towards the dramatic expansion of fuel cell utilization

Fuel cells are expected to play a central role in the use of hydrogen energy, whose position was emphasized in Japan's “Basic Energy Plan (Fifth).” In 2018, the New Energy and Industrial Technology Development Organization (NEDO) released the “NEDO Fuel Cell / Hydrogen Technology Development Roadmap” (hereinafter referred to as the “NEDO Technology Map”), which organizes technical issues in chronological order, and the importance of working on technological development by industry, academia and government collaboration was shown there. In order to achieve this, there is a strong demand from industry for the practical application of low-cost, high-efficiency, high-output, and high-durability fuel cells through innovative research and development of fuel cell materials. It is necessary to carry out the research and development by the best use of high-level collaboration between industry, academia and government.

This center was established in April 2008 with the tremendous support of Yamanashi Prefecture and related ministries and agencies with the aim of contributing to the full-scale deployment of fuel cells. The Ministry of Economy, Trade and Industry, NEDO commissioned a project “Development of basic materials for high-performance cells that integrate deterioration mechanisms and nanotechnology” (abbreviation: HiPer-FC project, 2008-2014), and a project “Creation of materials concepts related to cell stacks / Concept creation of high output, high durability, high performance fuel cell materials” (abbreviation: SPer-FC project, 2015-2019). In these projects, through the fusion of knowledge related to the mechanism of reactions and deterioration and advanced technologies such as nanotechnology (HiPer-FC project), the creation of new catalysts, support materials and electrolyte materials, and the evaluation and analysis of catalyst layers that maximize their functions, we have worked to improve output performance, reduce the amount of precious metals used, and improve durability and have achieved the goal of improving performance by about a factor of ten based on the overall effects (SPer-FC project).

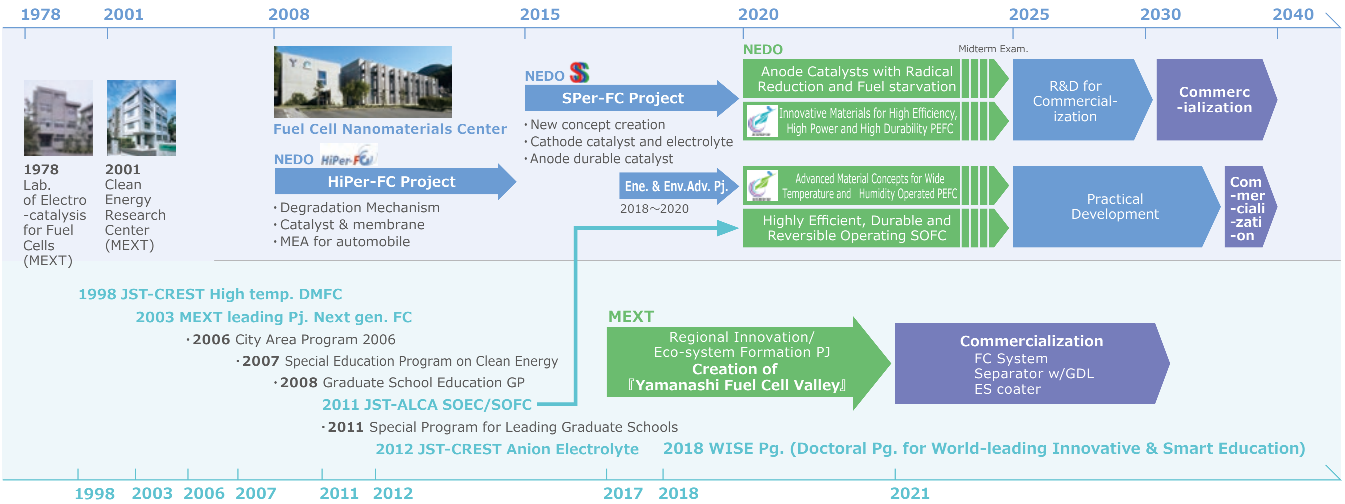
Currently, in order to enable the dramatic expansion of the use of fuel cells, we are developing innovative materials technology that realizes technologies such as high-efficiency power generation, high-load operation, high-durability start-stop operation, and prevention of deterioration in extreme environments, (NEDO consignment project, named the ECCEED’30-FC project). Also, we are working on the creation of a new polymer electrolyte membrane concept and catalysts with ceramic support technology concept that can operate even in high temperature and low humidity environments (NEDO consignment project, named the ECCEED’40-FC project). Furthermore, with the support of various national projects, we are working on the research and development of non-precious metal catalysts and anion exchange-type electrolyte materials to realize low-cost, highly efficient and highly durable anion exchange-type fuel cells and water electrolyzers. We would like to contribute to the dramatic expansion of hydrogen and fuel cell use by making the results of these research and development efforts widely available to everyone in the industrialized world.
In this way, this Center makes full use of the world’s top-level advanced equipment and a team of versatile researchers, so that it can respond to a full-scale hydrogen-based society that makes dramatic use of fuel cells and, at the same time, joint research between industry, academia and government. We are also actively involved in graduate school education, creating cutting-edge research results and developing researchers and engineers who will lead the green energy field.

We look forward to your continuous warm support and guidance.

HISTORY

History of the Center

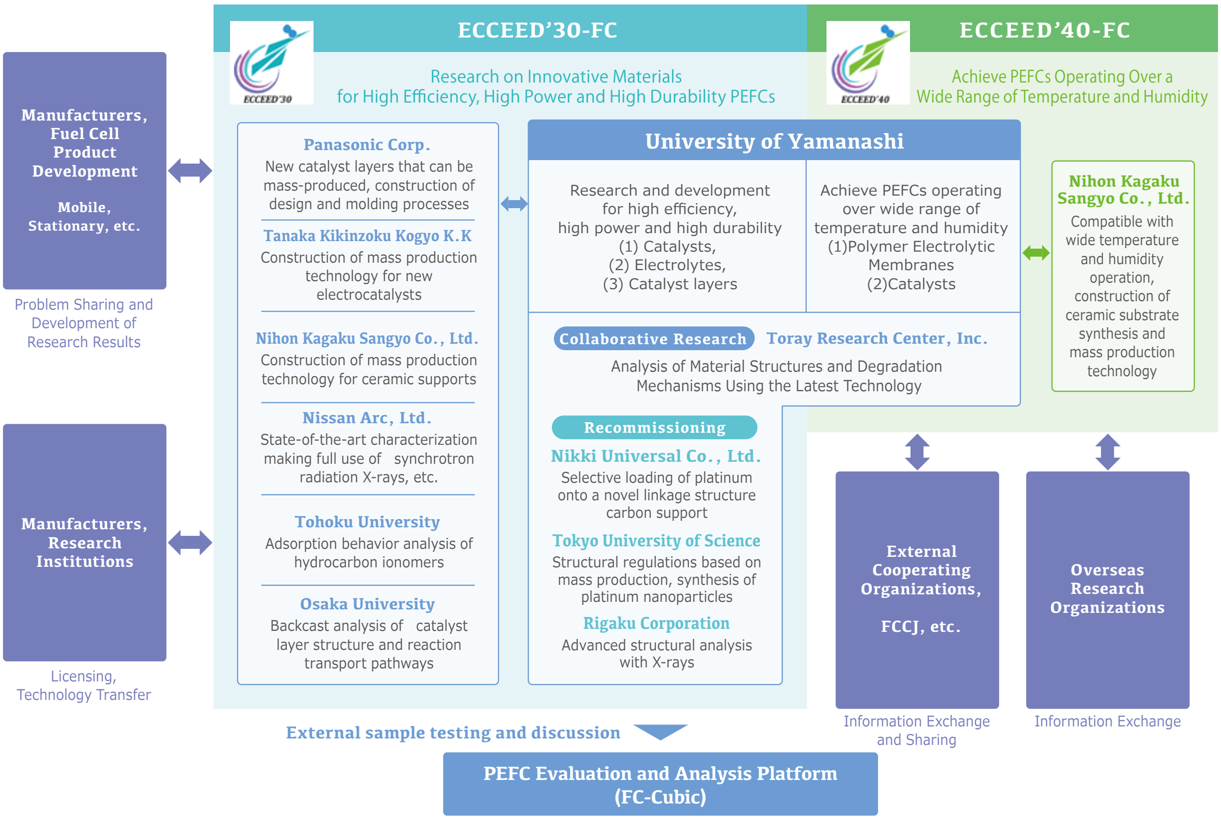
- ■1978.4～1988.3 Laboratory of Electrocatalysis for Fuel Cells
- ■1989.4～2001.3 Laboratory of Electrochemical Energy Conversion
- ■2001.4～ Clean Energy Research Center
- ■2008.4～ Fuel Cell Nanomaterials Center



ORGANIZATION

Organization of the R&D

The University of Yamanashi has become a representative for collaborative research being carried out by Panasonic Co., Ltd., Tanaka Kikinzoku Kogyo K.K, Nihon Kagaku Sangyo Co., Ltd., Nissan Arc, Tohoku University, Osaka University, Toray Research Center, Nikki Universal Co., Ltd., Rigaku, and the Tokyo University.



MEMBERS

Members of the Center

Under the direction of the Center, we are engaged in research in four departments: metals research, ceramics research, polymer research, and research planning. In addition, we are supported by the Fuel Cell Research Center Support Office and the Hydrogen / Fuel Cell Technical Support Office, which have been set up in the Research Promotion and Social Cooperation Organization of the University of Yamanashi. The number of faculty members is 14, including 5 faculty members who also serve in the Clean Energy Research Center. Furthermore, we are promoting research in close cooperation with researchers in Japan and overseas.

Center Director, Professor

Akihiro Iiyama

Metals Research Division

Manager, Professor/ Makoto Uchida
Professor/ Donald A Tryk
Professor/ Toshihiro Miyao
Research Associate/ Hanako Nishino
Researcher/ Toshio Iwataki
Researcher/ Kayoko Tamoto
Researcher/ Hiroko Yamazaki

Polymer Research Division

Manager, Professor/ Kenji Miyatake
Professor/ Junji Inukai
Research Associate/ Teppei Kawamoto
Researcher/ Ryugai Sato
Researcher/ Hiromichi Nishiyama
Researcher/ Akinobu Matsumoto

Ceramic Research Division

Manager, Professor/ Katsuyoshi Kakinuma
Research Associate/ Guoyu Shi
Researcher/ Takayuki Asakawa
Researcher/ Takashi Kuriyama
Researcher/ Hitoshi Taniguchi
Researcher/ Tetsurou Tanou
Researcher/ Miho Yamaguchi

Research Planning Division

Professor/ Kiyoshi Yoshizumi
Visiting Professor/ Shigehito Deki
Visiting Professor/ Takeo Kamino
Visiting Professor/ Tomio Omata
Visiting Professor/ Kazutoshi Higashiyama
Visiting Professor/ Shoji Tange
Visiting Professor/ Osamu Tajima
Visiting Professor/ Yuji Nagata
Visiting Professor/ Noboru Hashimoto
Visiting Professor/ Hidemi Onaka
Visiting Professor/ Mitsuru Wakisaka
Visiting Professor/ Hiroshi Yano

Organization for the Promotion of Research and Social Collaboration

Administration Office

Manager/ Toshitaka Horiuchi
Assistant Manager/ Mitsumoto Harashina

Hydrogen/ Fuel Cell Technology Support Center

Manager/ Akihiro Iiyama
Deputy Manager/ Takashi Kanda
Professor,Senior Advisers/ Masahiro Watanabe
Associate Professor, Coordinator/ Yoshihiro Oka
Researcher/ Tomio Sugiyama

Clean Energy Research Center

Professor/ Kenji Miyatake
Professor/ Junji Inukai
Associate Professor/ Shinji Nohara
Associate Professor/ Junpei Miyake
Associate Professor/ Akiyoshi Kuzume

Cooperating organizations

Ochanomizu University
Kobe University
Tokyo Institute of Technology
Toyama Prefectural University
Nagoya University
Fukuoka University

High Energy Accelerator Research Organization
Japan Synchrotron Radiation Research Institute
Comprehensive Research Organization for Science and Society
Japan Atomic Energy Agency

Boston University
Changchun Institute of Applied Chemistry
National Sun Yat-sen University
National University of Malaysia
Paul Scherrer Institut
Technische Universität Braunschweig

Metals Research Division

Metals Research Division Manager
Makoto Uchida

Evaluation equipment groups for single cell performance and durability under various actual operating conditions.

We are carrying out various evaluations for PEFCs according to the actual operating conditions by making the best use of advanced analysis equipment and cell evaluation equipment. We are constructing catalyst layer technology by clarifying the catalyst layer structure that maximizes the characteristics of various developed materials, the interaction between various materials, the influence of the interface state and the deterioration mechanism, and these are fed back to the material technology development.

Single cell evaluation systems for PEFCs

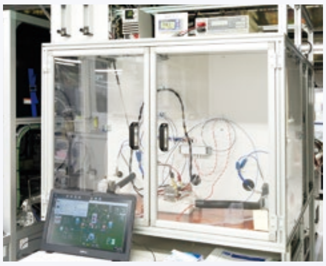
Fuel cell evaluation system
(standard and gas exchange)

Fuel cell evaluation system
(sub-zero temperature environment)

Fuel cell evaluation system
(High temperature & pressure and gas exchange)

Alkaline fuel cell / water electrolysis evaluation

Established evaluation equipment for material development and membrane-electrode assembly of alkaline fuel cells and water electrolyzers. We are aiming to achieve dramatically higher efficiency and higher output of non-precious metal catalysts, anion membranes, and catalyst layers.

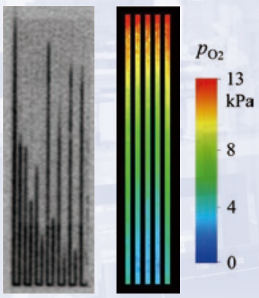


Single cell evaluation systems for AEMWE

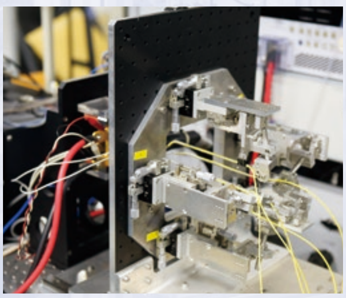
Single cell evaluation systems
for AEMFC-WE

Operando Structural Study

During power generation of fuel cells with the developed catalyst layers, the physical/chemical parameters inside the cells in real time and space are visualized. The information obtained will be used for the improvement of materials and catalyst layers and for the optimization of operation modes.



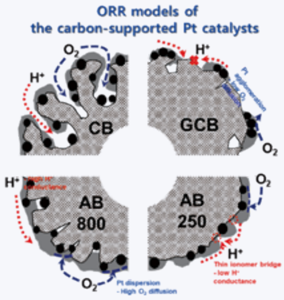
(L) Visualization of liquid water
(R) Visualization of oxygen
partial pressure



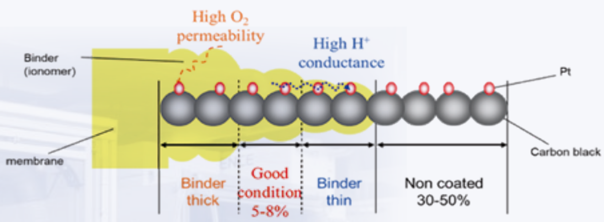
Oxygen partial pressure measured
using optical probes with dye

Research of catalyst layer structure, catalyst, ionomer distribution

Aiming to construct a catalyst layer that maximizes the performance of catalyst materials and polymer electrolyte materials, we elucidated the coating state and interface structure of catalyst electrolyte materials and the ideal form of oxygen and proton diffusion pathways. We are investigating in detail the effects of the pore structure and the distributions of both the Pt catalyst and the coated ionomer on the performance and durability.

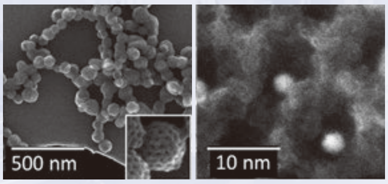


Schematic ORR models of a carbon
-supported Pt catalys

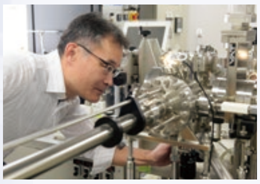


Schematic depiction of the variation of ionomer film thickness
and diffusions of oxygen & proton within the catalyst layer

We are focusing on the development of new platinum-carbon-based electrocatalysts with hierarchical nanostructure consisting of ordered mesoporous carbon nanoparticles forming a three-dimensional network structure. This unique catalyst can achieve higher efficiency and higher power generation in the PEFC system.



Newly developed Pt/C-based electrocatalyst



XPS with a UHV oven chamber

Research of catalyst layer formation process (electrostatic spray method)

We are working on the electrostatic spray (ES) method as one of the methods to realize a catalyst layer structure that maximizes the characteristics of the materials. By controlling the ionization mode, a uniform coating of the polymer electrolyte binder and the porous catalyst layer are realized without individual drying processes, demonstrating a dramatic improvement in fuel cell performance and durability.

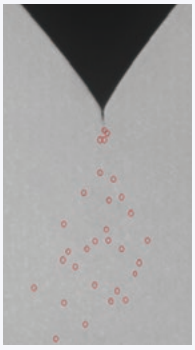
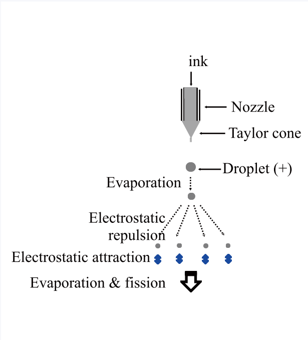
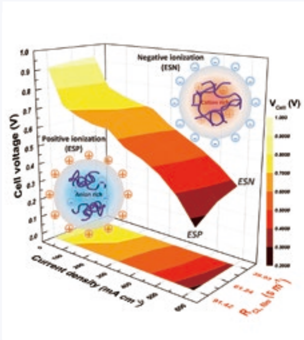


Image of Taylor cone



Steps of microparticle production by ES



Dependence of cell performance on ionization mode

Multi-nozzle ES coating system (prototype)

CERAMICS

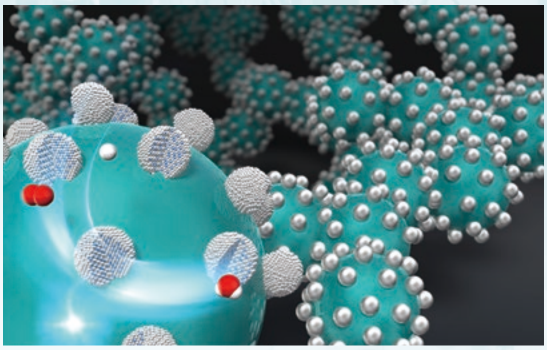
Ceramic Research Division

Ceramic Research Division Manager

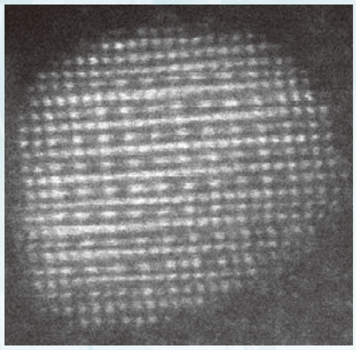
Katsuyoshi Kakinuma

Pt catalysts supported on conducting ceramic nanoparticles for widespread use of polymer electrolyte fuel cells

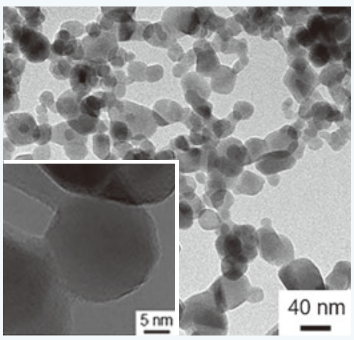
Highly durable and active Pt catalysts supported on highly conductive ceramic nanoparticles with unique fused aggregate network microstructure are being invented in our Center. The original catalysts have several advantages to overcome some of the issues of conventional Pt catalysts supported on carbon.



Artistic concept of Pt/Pt alloy catalyst nanoparticles supported on ceramic particles with a fused aggregate network microstructure



High-resolution transmission microscopic image of a PtCo alloy nanoparticle



Transmission electron microscopic images of ceramic support with fused aggregate network microstructure

Specific surface area measurement system for nanoparticle catalyst

Ceramic nanoparticle catalysts for hydrogen generation toward the construction of a sustainable hydrogen-based society

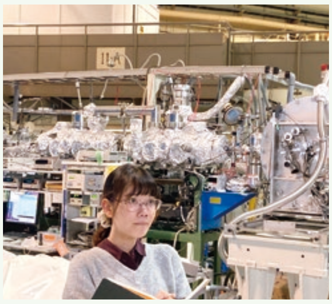
Ceramic/metal composite catalysts for highly efficient hydrogen production without using precious metals (Pt and Ir) are being invented by multi-scale design techniques.

Structural and Functional Analysis of Polymer Membranes and Binders

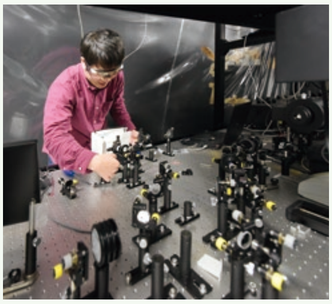
Neutron reflectometry, grazing incidence small angle X-ray scattering, and grazing incidence X-ray absorption spectroscopy are used to understand the structures of proton-exchange and anion-exchange polymers and binders from the atomic level to micrometer level.

For functional analyses, current-sensing atomic force microscopy, neutron quasi-elastic scattering, and nonlinear laser spectroscopy are used to elucidate the motions of ions and water molecules.

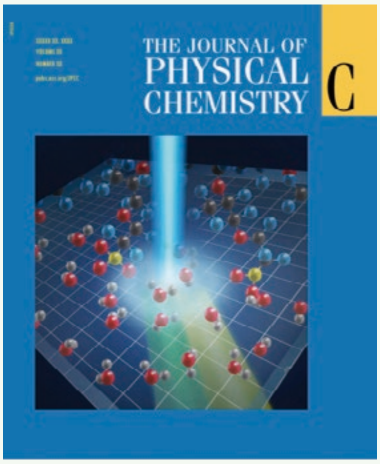
We feed this information back to the synthesis of new ionomeric materials to further improve their performances.



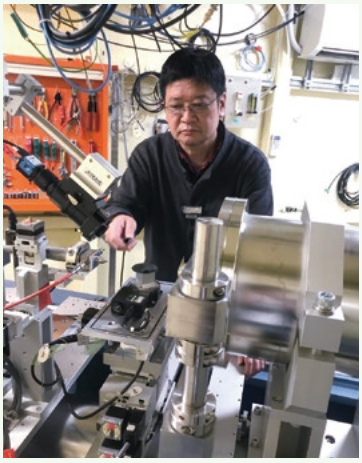
Photon Factory, KEK



Measurement of oxygen partial pressure by optical probes



CARS spectroscopy inside electrolyte membrane



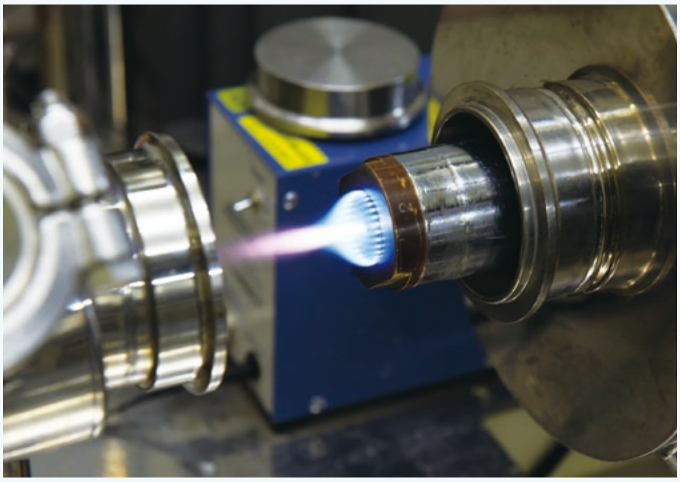
Grazing incidence small angle synchrotron X-ray scattering

Mass production of ceramic nanoparticles toward their application in a sustainable society

Our deliverables of ceramic nanoparticles/catalysts are generated actively by low-cost and suitable mass production techniques through collaboration with several materials companies.

Highly durable ceramic nanoparticle support

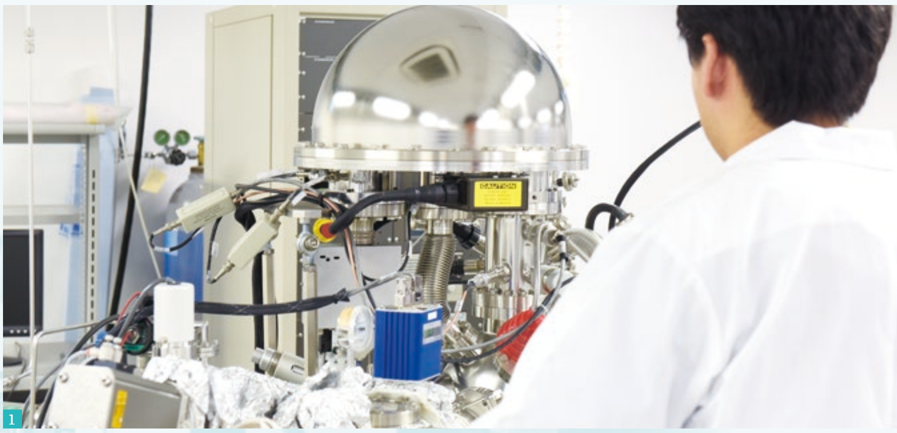
Highly durable and conductive ceramic nanoparticle support

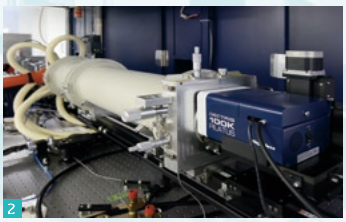


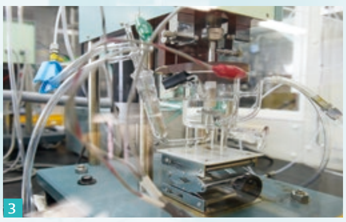
Ceramic nanoparticle synthesis system

Elucidation of functions of ceramic nanoparticles for contributing to deepening academic insights

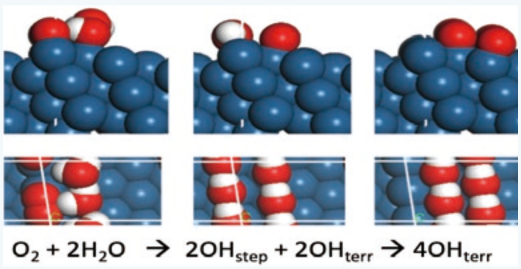
The functional mechanims of ceramic/metal catalysts are being eludated by use of the latest analytical equipment at the world's highest level. The insights of atomic-level surface/interface chatacterizations are being summarized, which introduce new discoveries for functions and chemical properties of new catalysts.







1. Electrochemical X-ray photoelectron spectroscopic system
2. Environmental small angle X-ray scattering mesurement system
3. Rotating disk electrode system



DFT calculation for oxygen reduction reaction mechanism on Pt surface

POLYMER

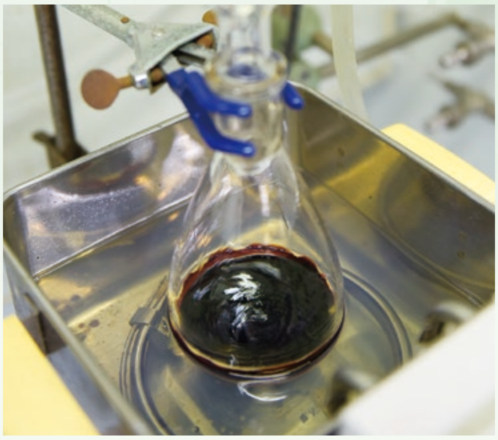
Polymer Research Division

Polymer Research Division Manager

Kenji Miyatake

Proton-conductive polymer membranes

High performance proton conductive membranes are being developed to achieve highly efficient, powerful, and durable fuel cells. The main subject includes hydrocarbon ionomer membranes with thin film-forming capability, gas impermeability, and stability under harsh conditions. Furthermore, the proton conductivity at low humidity, mechanical strength, and interfacial compatibility are also being improved.



Synthesis of proton conductive polymers

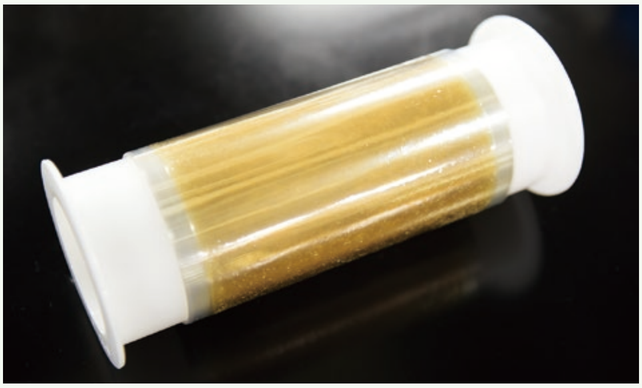
Nuclear magnetic resonance apparatus (NMR)

Anion-conductive polymer membranes

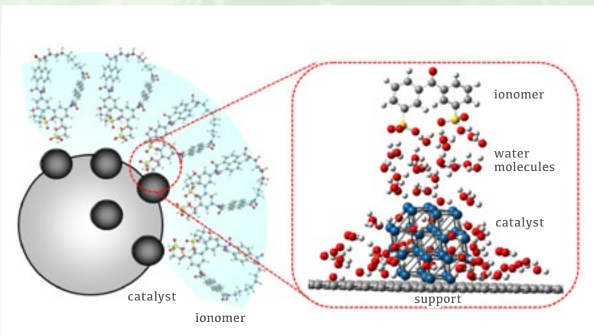
Highly anion-conductive and chemically robust ionomer membranes are being developed. The molecular design of the proton-conductive membranes is applied to the anion-conductive membranes. Through the collaboration with industry, the emerging anion-conductive membranes are being investigated for alkaline fuel cells and water eletrolyzers.

Scale-up synthesis and reinforcement of the ionomer membranes

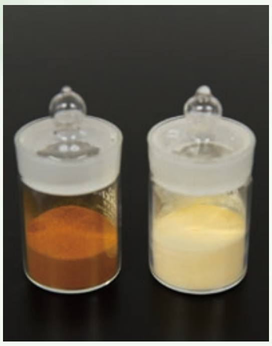
Polymerization reactions and membrane processing are being investigated on a larger scale. The fabrication of ionomer membranes is scaled-up from solution casting to bar-coating and roll-to-roll processing to obtain optimum ionomer membranes on the meter scale. Furthermore, hydrocarbon ionomers are being reinforced with porous substrates to achieve ultrathin, robust membranes.



Rolled sample of hydrocarbon ionomer membrane



Ionomer-coated catalysts

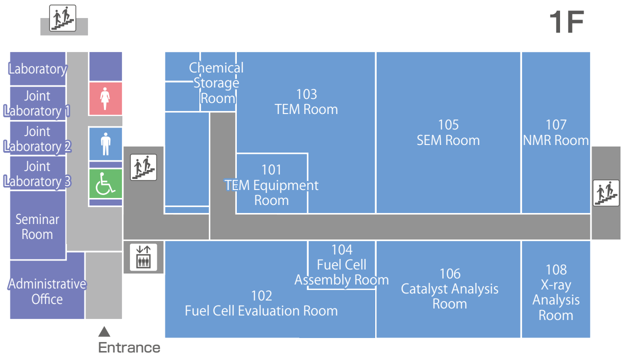


Ionomer powder samples

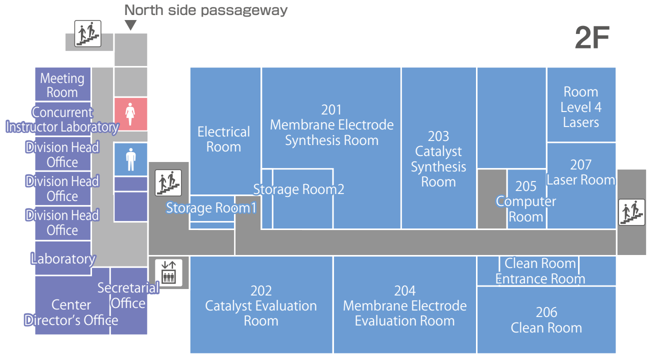
Ionomers for catalyst layers

High performance ionomer materials are being developed as electrode binders. For the proton or anion-conductive ionomers, mass transport capability (hydrogen, oxygen, and water) and compatibility with catalyst nanoparticles are created. The properties of the ionomer materials are being optimized according to each application.

Center Layout
Fuel Cell Nanomaterials Center

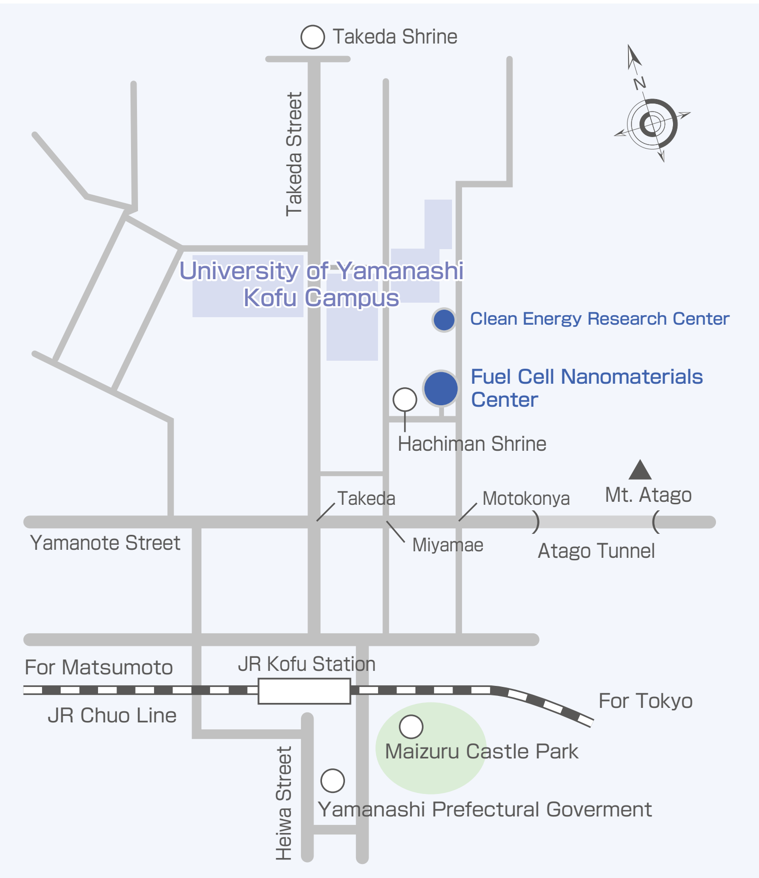


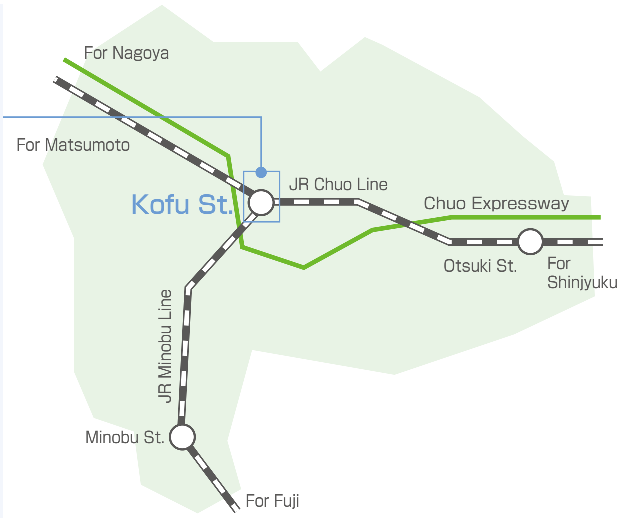
Office Wing (299 m²) Laboratory Wing (1291 m²)



Office Wing (299 m²) Laboratory Wing (1262 m²)

Access Guide
University of Yamanashi Kofu Campus





Fuel Cell Nanomaterials Center

Hydrogen/Fuell Cell Technology Support Center

UNIVERSITY OF YAMANASHI
Regional Core & Global Professionals

Fuel Cell Nanomaterials Center University of Yamanashi

6-43 Miyamae-cho,Kofu 400-0021
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