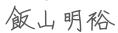




Outline of the Center



Director, Hydrogen and Fuel Cell Nanomaterials Center, University of Yamanashi



Akihiro Iivama

Strengthening research and development of water electrolysis and fuel cells to expand hydrogen utilization

In the Sixth Basic Energy Plan formulated in 2021, hydrogen was positioned as an essential secondary energy source for achieving carbon neutrality, and fuel cells were designated as key devices for decarbonization using hydrogen. In 2025, the New Energy and Industrial Technology Development Organization (NEDO) revised the "NEDO Fuel Cell and Hydrogen Technology Development Roadmap" ("NEDO Technology Roadmap"), outlining technical goals for 2035 and beyond in areas such as HDV (heavy-duty

This center was established in April 2008 with the aim of contributing to the widespread adoption of fuel cells, with the tremendous support of Yamanashi Prefecture and related government agencies.

From 2008 to 2014, we worked on projects commissioned by the Ministry of Economy, Trade and Industry and NEDO to gain insights into the mechanisms of reactions and degradation, and to integrate cutting-edge technologies such as nanotechnology.

From 2015 to 2019, the center achieved its goal of improving the overall performance of output, cost, and durability by approximately tenfold through projects commissioned by NEDO.

From 2020 to 2024, we worked on research and development of electrocatalysts by use

of ceramics supports and ordered mesoporous carbon supports, hydrocarbon electrolyte membranes that combine chemical stability and mechanical strength, and ionomers with excellent gas permeability in projects commissioned by NEDO. Concurrently, we worked on NEDO-commissioned projects including "reduction of precious metal content in anode catalysts for proton exchange membrane-type water electrolysis devices," "elemental research on anion exchange membrane-type water electrolysis cells," "GDL-integrated flat separators," and "electrostatic spray method."

Currently, we are working on the following seven NEDO-commissioned projects that contribute to the realization of NEDO's technology roadmap goals. ① Next-generation catalysts and catalyst layers for fuel cells using automated experiments, ② Ceramic supported catalysts (layers), 3 High proton conductivity electrolyte membranes and ionomers operable in a wide temperature and humidity range, (4) Elemental technologies related to electrostatic spray methods, (5) Elemental technologies related to porous rib GDL/MPL, ® Innovative low-precious metal-loaded anode catalysts and MEAs for proton exchange membrane-type water electrolysis devices, ② Catalysts, electrolytes, and MEAs for anion exchange membrane-type water electrolysis devices.

Our center will make full use of our talented researchers and world-class cutting-edge facilities to ensure that these research and development results are widely utilized by industry, thereby dramatically expanding the use of hydrogen and fuel cells. At the same time, we will actively engage in joint research between industry, academia, and government, as well as education from undergraduate to graduate school levels, to create cutting-edge research results and nurture researchers and engineers who will lead the field of green energy.

We look forward to your warm support and guidance.



Research Planning Division

Takayuki Urata

Center operations planning

We devise methods for the efficient utilization of external funding, primarily through NEDO projects, and promote various matters essential for center operations, thereby ensuring smooth and effective management.

Project promotion

We ensure the success of major projects led by our Center, such as NEDO initiatives, by proactively fostering close collaboration with all internal and external stakeholders and relevant organizations to successfully achieve our objectives.

Public engagement

Research Planning Division

We aim to broaden public understanding of our center's activities and achievements by sharing the latest information on hydrogen, fuel cells, and our initiatives. These efforts align with the principles of the "Dialogue on Science and Technology with the Public," promoted by the Council for Science, Technology and Innovation.





Metals Research Division

Metals Research Division Manager

Makoto Uchida

Equipments for evaluating various practical operating conditions

Utilizing a group of advanced analytical instruments and cell evaluation devices, we conduct various evaluations for polymer electrolyte fuel cells (PEFCs) and anion exchange membrane/proton exchange membrane water electrolysis (AEM/PEMWE) that are in line with actual operating conditions. We are promoting the understanding of catalyst layer/gas diffusion layer structures that maximize the characteristics of various developed catalysts and electrolyte materials, the interactions between various materials, the effects of interface conditions, and the elucidation of degradation mechanisms.

Single cell evaluation systems for PEFCs



Standard environment model (Room temperature to 100°C)



Temperature, humidity, and gas replacement model (Room temperature to 100°C)



High temperature, high pressure, and temperature, humidity, and gas replacement model (Room temperature to 140°C)

Water electrolysis cell evaluation (AEMWE/PEMWE)

We are developing evaluation equipment for material development and device demonstration for water electrolysis. We aim to achieve dramatically higher efficiency and power output for non-precious metal catalysts, low-Ir catalysts, and anion membranes and catalyst layers, as well as to elucidate degradation mechanisms.





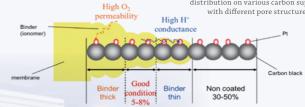
Anion exchange membrane water electrolysis evaluation device

Catalyst layer structure, catalyst, and ionomer distribution

establish the ideal three-phase interface structure of the catalyst layer (electrochemical reaction field), we are studying the effects of support structure, catalyst particle and polymer electrolyte (ionomer) distribution/coating generated water distribution, ionomer poisoning, and other factors on perforionomer expression and degradation mechanisms actual operating conditions.



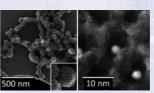
Conceptual diagram of Pt and ionomer distribution on various carbon support with different pore structures



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

We are developing a new type of carbon catalyst for the PEFC cathode, where ordered mesoporous carbon nanoparticles form a three-dimen-

sional network structure supporting platinum within the mesopores. This approach aims to realize next-generation cathode catalysts that maximize platinum utilization efficiency.



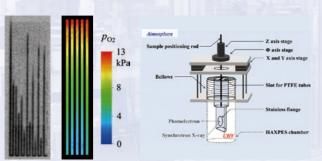
Newly developed Pt/C-based electrocatalyst



XPS system equipped with an ultrahigh-vacuum pretreatment chamber

Operando structural study

The internal reactions in real time and space during power generation using a fuel cell with developed membrane and electrode catalyst. The information obtained will be used to develop new materials and to optimize operating modes.



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

Oxygen partial pressure measured using optical probes with dye

Catalyst layer formation processes

We are developing a dry process using electrospraying, utilizing Rayleigh fragmentation of charged droplets, to achieve ideal Pt and ionomer coating conditions and a catalyst layer pore structure for oxygen transport. Using jet-cone mode ejection, which allows for sub-micron droplets to be ejected, the ionomer instantly dries and adheres to the catalyst surface, easily forming a three-phase interface. Furthermore, coating with dried catalyst particles forms a porous, high-order structure, increasing the reaction area and reducing the diffusion resistance of oxygen, protons, and other molecules. We are also developing a multi-nozzle system with the aim of adapting this to mass production processes.

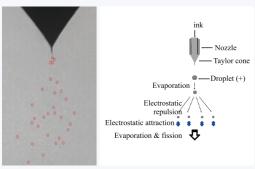
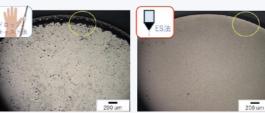


Image of Taylor cone

Steps of microparticle production by ES

Compared to the electrode surface created by drop casting, no coffee ring effect occurs, enabling uniform dispersion and coating of the catalyst.









RDE ES coating devic highly durable

FRAMI

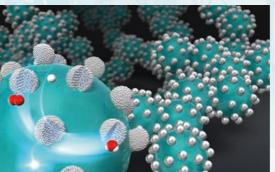


Ceramic Research Division

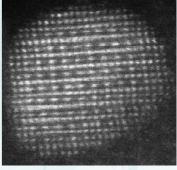
Ceramic Research Division Manager Katsuyoshi Kakinuma

Electrocatalysts and support for fuel cells

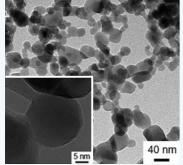
Highly original electrocatalysts for fuel cells are developed by use of highly original ceramic supports, of which the catalytic activity and durability are superior to conventional Pt/C catalysts. The developed electrocatalyst contributes toward the wide-spread use of fuel cells.



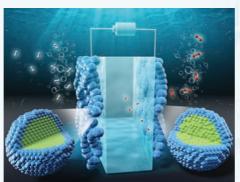
Highly durable and active Pt catalyst supported on ceramic nanoparticles with fused-aggregate network microstructure



High resolution transmission microscopy image of Pt alloy nanoparticles



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



Schematic diagram of efficient hydrogen generation reaction and oxygen generation reaction $% \label{eq:condition}$

Electrocatalysts and support for electrolysis

The oxygen evolution/hydrogen evolution reaction active electrocatalysts for electrolysis are developed by use of nano-sized ceramic supports. The original multiscale-design of the electrocatalysts can supply the non noble hydrogen generation electrocatalyst with high activity and durability.

Function analysis of polymer membrane and ionomer

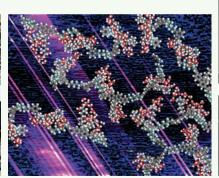
To understand the structures of proton- and anion-conducting polymer membranes and binders at the atomic to micrometer level, analytical methods, such as neutron reflectivity, grazing incidence small-angle X-ray scattering, X-ray absorption spectroscopy, are used. Furthermore, to analyze the functions, the movements of ions and water molecules using current-detecting atomic force microscopy, neutron quasi-elastic scattering, nonlinear laser spectroscopy are used. Aiming for further performance improvement, we are feeding back this information into the synthesis of new ionomer materials.



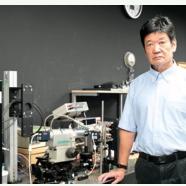
Operando monitoring of water molecules inside polymer membranes



Operando monitoring of oxygen inside $\ensuremath{\mathsf{GDL}}$



Water molecules within the anion-conductive polymer membrane



Operando monitoring of temperature inside cell

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

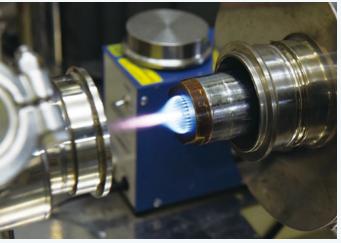
Our deliverables of ceramic nanoparticles/catalysts are generated actively by low-cost and suitable mass production techniques through collaboration with several materials companies.



Highly durable ceramic nanoparticles



Highly durable and conductive ceramic nanoparticles



Ceramic nanoparticle synthesis system



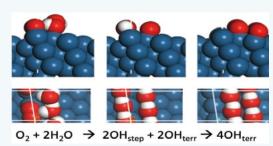




- 1.The latest transmission electron microscopy
- 2.In situ small angle X-ray scattering system
- 3.Rotating disk electrode method

Evaluation of conducting ceramic nanoparticles

The interface and surface structure of ceramic supports and electrocatalysts are evaluated by the latest analytical systems. The mechanism of high activity and durability of the electrocatalyst using the ceramic supports are clarified to develop the new electrocatalysts.



DFT calculation for oxygen reduction reaction mechanism on Pt surface

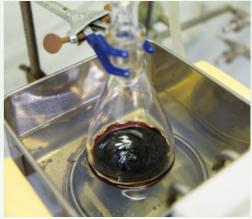


Polymer Research Division

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 fluorine-free 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



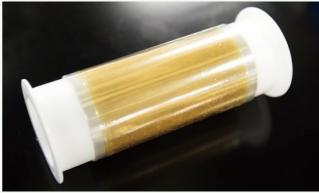
 $Nuclear\ magnetic\ resonance\ apparatus\ (NMR)$

Anion-conductive polymer membranes

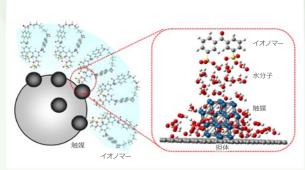
Highly anion-conductive and chemically robust ionomer membranes are being developed. The target anion-conductive membranes are fluorine-free, alkaline-resistive, and gas impermeable. Through the collaboration with industry, the emerging anion-conductive membranes are being investigated for alkaline eletrolyzers.

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, fluorine-free 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.

History of the Center

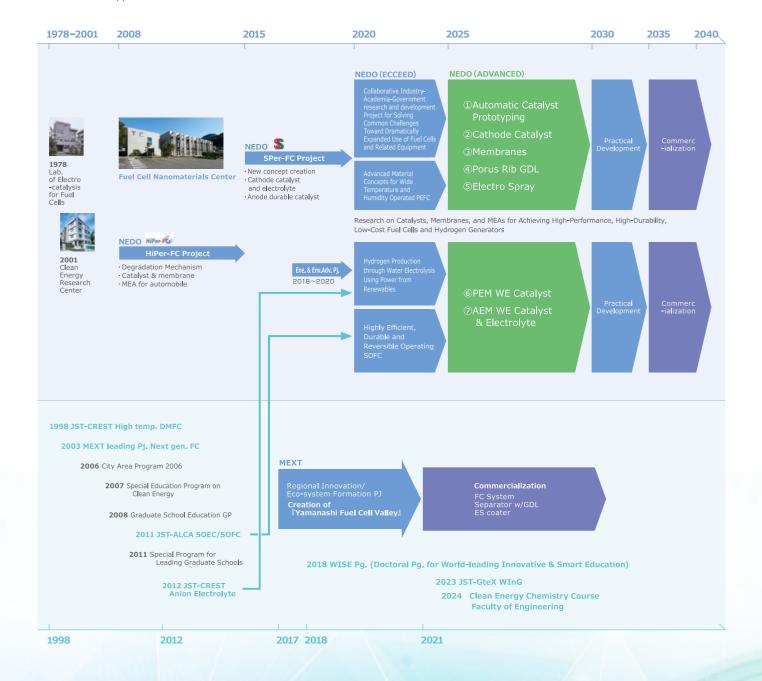
- ■1978.4~1988.3 Laboratory of Electrocatalysis for Fuel Cells
- ■1989.4~2001.3 Laboratory of Electrochemical Energy Conversion
- ■2001.4~ Clean Energy Research Center

- ■2008.4~ Fuel Cell Nanomaterials Center
- ■2022.6∼ Hydrogen and Fuel Cell Nanomaterials Center



History of the Research and Education Projects

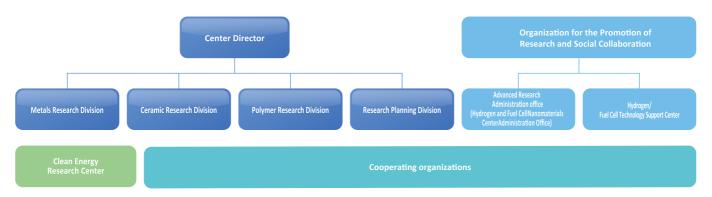
University of Yamanashi collaborates with other universities, research institutions, and industry to advance research and practical applications.



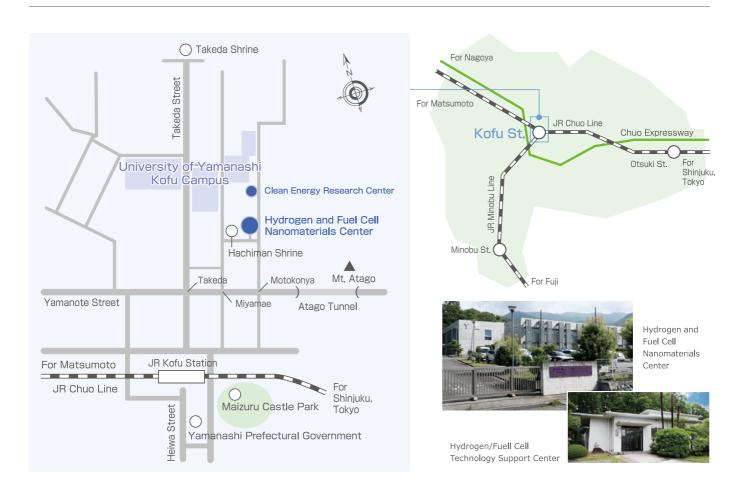
Organization of the Center

Under the direction of the Center Director, we are engaged in research in four departments: metals research, ceramics research, polymer

research, and research planning. In addition, we are supported by Advanced Research Administration office (Hydrogen and Fuel Cell Nanomaterials Center Administration 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. Furthermore, we are promoting research in close cooperation with researchers in Japan and overseas.



Access Guide





Hydrogen and Fuel Cell Nanomaterials Center, University of Yamanashi



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https://fc-nano.yamanashi.ac.jp/