Fuel Cell Nanomaterials Center
University of Yamanashi

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

UNIVERSITY
OF
YAMANASHI

Outline of the Center

Director, Fuel Cell Nanomaterials Center,University of Yamanashi

Akihiro Iiyama

Towards the full, large-scale market penetration of fuel cells

To establish a "Hydrogen Society," which has been proposed in the 4th Japanese National Energy Basic Strategic Plan*, it is necessary to reduce the cost of fuel cells, as well as to further improve both durability and performance. For this purpose, innovative fuel cell material concepts are being awaited by industry, and therefore, it is necessary to carry out research and development based on basic science.

This Center was established in April 2008, with the great support of Yamanashi Prefecture and related Ministries and agencies, for the purpose of contributing to the actual proliferation of fuel cells. Since then, the Center has been carrying out a NEDO project (the "HiPer-FC" project), in which the analysis of degradation mechanisms, together with research and development of high performance, low cost catalysts, electrolyte membranes and MEAs, have established the basic technology that simultaneously provides high performance, high reliability and low cost for fuel cells.

At present, we are conducting research aimed at creating innovative concepts for durable, high performance, low cost fuel cell materials, such as electrocatalysts, catalyst supports, and electrolyte materials (membrane and binder), with confirmation of their usefulness through catalyst layer evaluation and analysis, so that the targeted material properties will be brought to the utmost level. We would like to contribute to full, large-scale fuel cell market penetration by promoting the wide utilization of these research results by industry.

Thus, the Center is sincerely working to create innovative, fruitful research achievements, and at the same time, to develop human resources, both researchers and engineers, who can lead the way in this green energy area and cope with the forthcoming Hydrogen Society with full-fledged fuel cell technology, through active participation in graduate education and joint research activities among industry, government and academia, by full utilization of the Center's capable researchers and world-class facilities.

I do hope for your warm support and guidance.

*http://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/4th_strategic_energy_plan.pdf

History

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

Division Managers

Metals Research Division
Makoto Uchida

Ceramics Research Division
Kazutoshi Higashiyama

Polymer Research Division
Kenji Miyatake

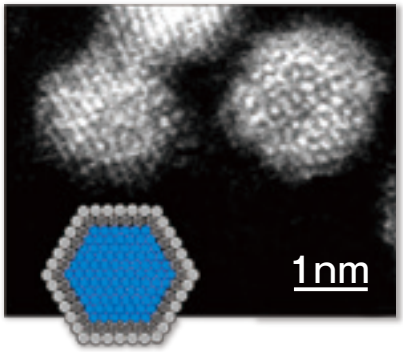
Research Planning Division
Tomio Omata

S-Per-FC Project

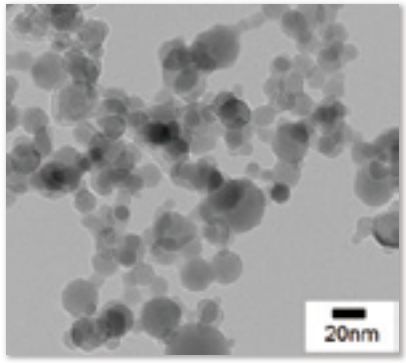
Superlative, Stable, and Scalable Performance Fuel Cell Project

Project Objectives

The Center has been investigating new catalysts and membranes for polymer electrolyte fuel cells with high performance, reliability and low cost under the “HiPer-FC (High Performance Fuel Cell)” project funded by NEDO, Japan (starting in April, 2008). The project was rewarded with the development of superior materials and a number of new scientific insights, as shown below: Stabilized Pt-skin alloy catalysts; conducting ceramic supports with fused-aggregated network structure, with excellent stability during potential variation; and hydrocarbon electrolyte membranes, with similar proton conductivity and higher durability compared with the fluorocarbon electrolyte membranes.



Pt-skin alloy catalyst



Conducting ceramic support with fused-aggregated network structure

Hydrocarbon electrolyte membrane

The present “S-Per-FC” (Superlative, Stable, and Scalable Performance Fuel Cell) project started in May, 2015 with funding from NEDO, Japan, in which our Center is the core of the project organization. The main purpose of the project is to contribute strongly to the large-scale proliferation of fuel cells vehicles based on these superior outcomes. Membrane-electrode assemblies, in which both catalysts and membranes have shown limited performance, will be developed on the basis of scientific insights, and the performance will be elucidated by the use of state-of-the-art analytical systems. The new concept of high power, high durability and high efficiency materials will be pursued. Using this new concept, we will contribute to the development of low cost fuel cell vehicles, including commercial vehicles, using low amounts of precious metals and with higher durability.

Research Items

1 Creation of a new concept for the cathode catalyst material

Create a new concept for the dramatic improvement of activity and durability of the cathode catalyst via analysis of Pt-skin alloy catalysts, carbon supports, conductive ceramics, as well as the detailed structure of their interfaces and surface electronic states. The effects of the new concepts will be verified via measurements on the carbon-support-based and ceramic-support-based cathode catalysts and MEAs using those catalysts.

2 Creation of a new concept for the electrolyte material

Create a new concept for a highly durable, highly conductive electrolyte material, even under the fuel cell operating conditions of a wide range of temperature and humidity, via the evaluation and analysis of the molecular structure, the higher order structure, and morphology of the hydrocarbon-based electrolyte membrane and binder, taking into account the behavior of water molecules.

3 Creation of a new concept for next-generation anode catalysts with higher resistance to impurities

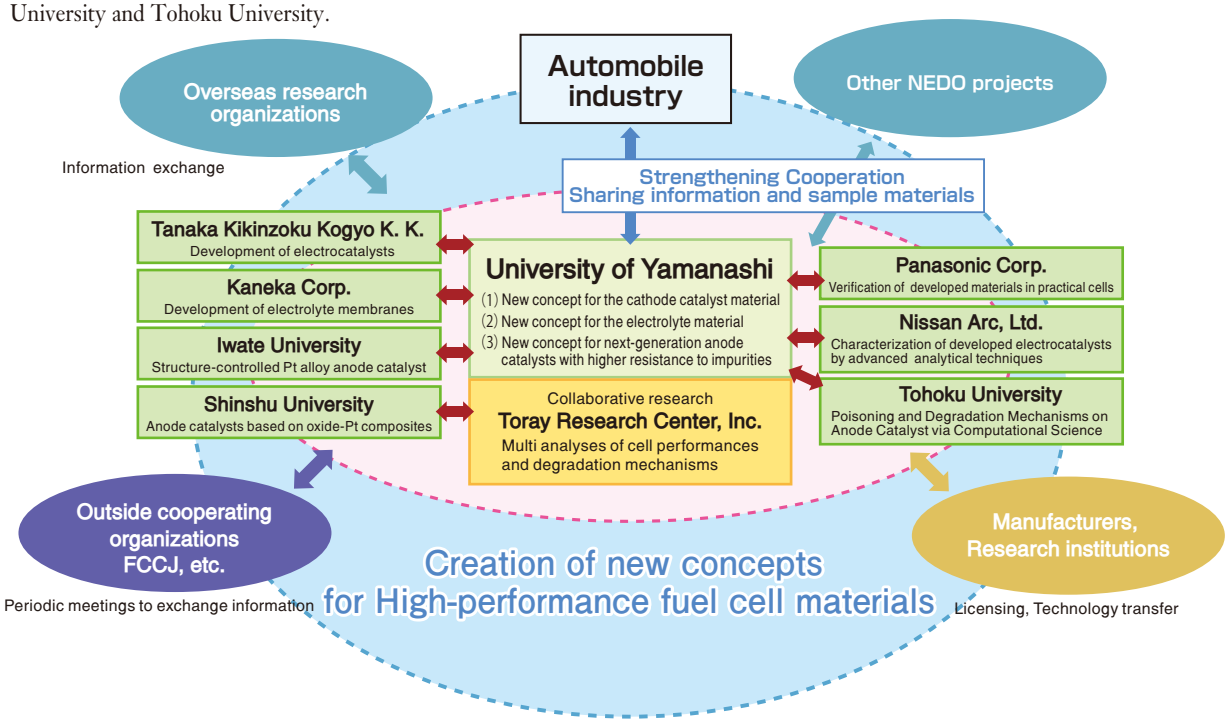
Establish design guidelines for anode catalysts that can enable low-platinum usage, high robustness and high durability, via evaluation of MEAs using these catalysts.

Target of the Project

In order to put the materials developed using these concepts into practical use by the next stage of proliferation of fuel cell vehicles starting in FY 2025, we will establish the fundamental technology by FY 2019, realizing a 10-fold increase in the cost performance based on the quantity (power density × lifetime) / (mass of precious metals) compared to that of the conventional fuel cell.

Organization of the Research and Development

As the Project Leader, the University of Yamanashi is carrying out the research and development in cooperation with Tanaka Kikinzoku Kogyo K. K., Kaneka Corp., Panasonic Corp., Nissan Arc, Ltd., Toray Research Center, Inc., Iwate University, Shinshu University and Tohoku University.



Members of the Center

Under the Center Director, there are four research divisions, the Metals Research Division, the Ceramics Research Division, Polymer Research Division and the Research Planning Division. The Administration Office is attached to the Research Planning Division. Including four additional faculty who are serving concurrently in the Clean Energy Research Center, which is a sister Center, the number of faculty members is 27. In addition, research is being carried out in close cooperation with domestic and foreign researchers.

Center Director, Professor
Akihiro Iiyama

Professor, Senior Adviser
Masahiro Watanabe

Metals Research Division
Manager, Professor / Makoto Uchida
Professor / Junji Inukai
Professor / Katsuyoshi Kakinuma
Professor / Takao Tsuneda
Associate Professor / Mitsuru Wakisaka
Associate Professor / Hiroshi Yano
Research Associate / Youngchul Park
Researcher / Ketpang Kriangsak
Researcher / Makoto Aoki
Researcher / Teppei Kawamoto

Ceramics Research Division
Manager, Professor / Kazutoshi Higashiyama
Professor / Toshihiro Miyao
Visiting Professor / Hisao Yamashita
Research Associate / Hanako Nishino

Polymer Research Division
Manager, Professor / Kenji Miyatake
Visiting Professor / Takeo Kamino
Researcher / Ryo Akiyama

Research Planning Division
Manager, Professor / Tomio Omata
Professor / Donald Alexander Tryk
Visiting Professor / Shigehito Deki
Visiting Professor / Shoji Tange
Visiting Professor / Osamu Tajima
Visiting Professor / Noboru Hashimoto
Visiting Professor / Hidemi Onaka
Visiting Professor / Yuji Nagata
Researcher / Mika Kodama

Administration Office
Manager / Mitsumoto Harashina
Subsection Chief / Mina Kimura

Clean Energy Research Center
Center Director, Professor / Hiroyuki Uchida
Professor / Kenji Miyatake
Associate Professor / Shinji Nohara
Research Associate / Junpei Miyake
Researcher / Takahiro Inoue

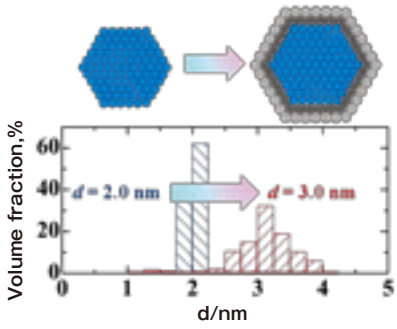
Researchers from various countries (visiting professors, etc.)

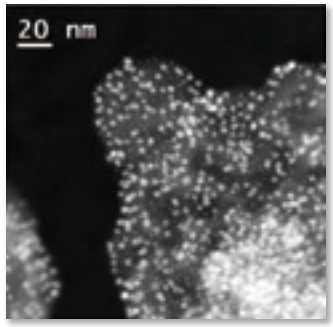
Chinese Academy of Science, Professor / Lijun Wan
Daegu Gyeongbuk Institute of Science and Technology, Professor / Hasuck Kim
Waseda University, Professor / Hiroyuki Nishide
Kogakuin University, Professor / Hiromitsu Takaba

Research Facilities and Activities

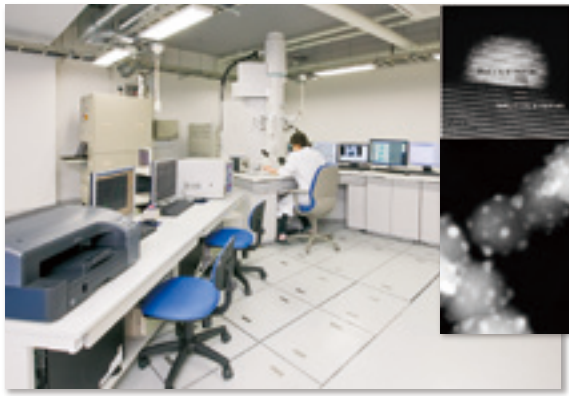
Highly Active, Highly Durable Alloy Catalysts

We have developed a new electrocatalyst with both high activity for the oxygen reduction reaction and high durability. We have succeeded in preparing a stabilized Pt-skin layer on Pt-alloy nanoparticles, which were of uniform size and composition. R&D efforts toward practical application are in progress.

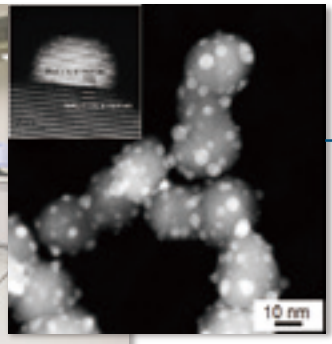




STEM image of stabilized Pt skin-PtCo alloy/C catalysts



Transmission electron microscope



Pt/Nb-SnO_2 catalyst

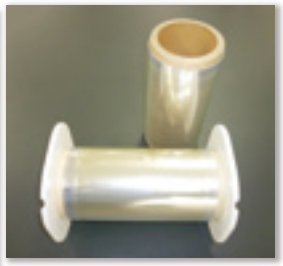
Highly Durable Supports and Supported Catalysts

We have developed highly durable supports (highly electronically conductive oxides, etc.) in the high potential region, which are capable of replacing commonly used carbon supports. The evaluation of catalytic activity and corrosion resistance for platinum alloy catalysts on these newly developed supports has been conducted.

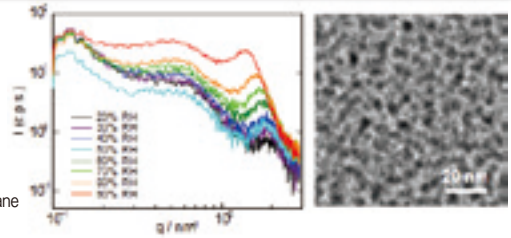
New Polymer Electrolyte Membranes

We develop polymer electrolyte membranes that demonstrate high proton conductivity that is stable even under a variety of environmental and vehicle driving conditions. We have successfully synthesized hydrocarbon membranes that are less expensive and have higher conductivity and better mechanical strength over long-term operation than conventional fluorinated electrolyte membranes. These are making a major contribution to achieving a PEFC that can handle the extreme high and low temperature and high humidity conditions to which fuel cell vehicles will be subjected.

Facility for synthesis of polymer electrolyte membranes



Small angle X-ray scattering (SAXS) system



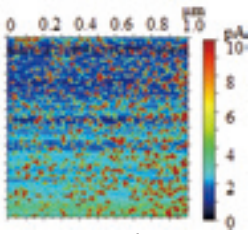
SAXS profile of polymer electrolyte membrane

Fundamental Studies for New Design of Catalysts and Membranes

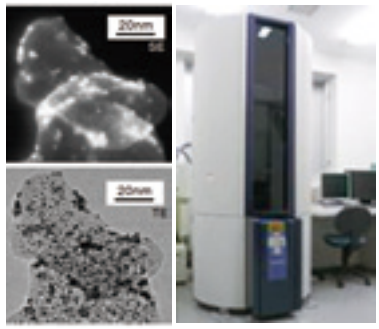
The multiscale structure of the catalysts and polymer electrolyte membranes are evaluated to invent new materials. Electrochemical analysis, atomic level surface analysis, infrared spectroscopy, photoelectron spectroscopy and computer simulation based on quantum chemistry are used in an integrated fashion to analyze catalytic reactions and to develop concepts for the design of new materials.

Catalyst Layers and MEAs

We are designing and conducting R&D on optimized catalyst structures that promote efficient reactions among gas (reactant molecules), ions, and electrons so that the electrocatalyst will function effectively. We combine these optimized electrocatalysts with new electrolyte membranes to produce original membrane electrode assemblies (MEAs).



AFM image of proton-conducting path on membrane surface



Visualization of Pt catalysts by 3D-STEM characterization

Evaluation system for single cell performance

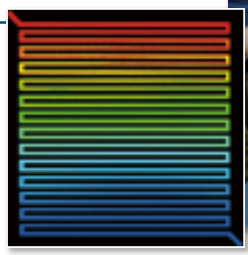
Evaluation of PEFCs

The MEAs described above are used to test the PEFC durability in fuel cells for automobiles and for stationary installation under the expected operating conditions. We are researching the factors that affect the performance characteristics and useful life and are using the results as feedback for electrocatalyst and electrolyte membrane design guidelines to further improve the fuel cell characteristics.

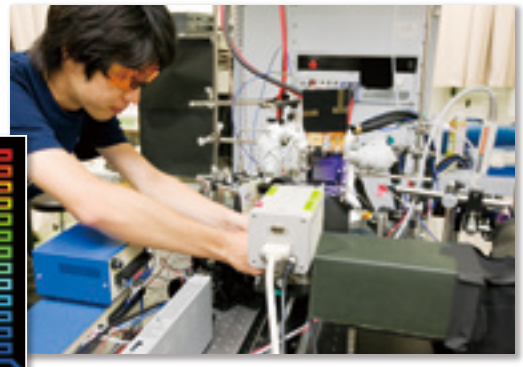
Single cell

Visualization of Reaction Distributions in Fuel Cells

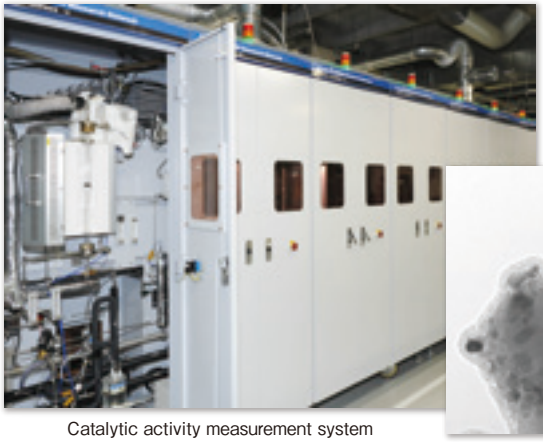
Understanding the reaction distribution within the fuel cell is very important for analyzing degradation mechanisms and cell design. We are using a newly developed visualization device to successfully visualize the distribution of gas pressure and temperature within the fuel cell during operation as well as the electrode corrosion behavior with high resolution, both temporally and spatially.



Visualized oxygen partial pressure in a cell



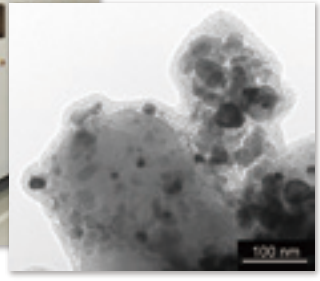
Visualization system



Catalytic activity measurement system

Catalysts for Hydrogen Production and Purification

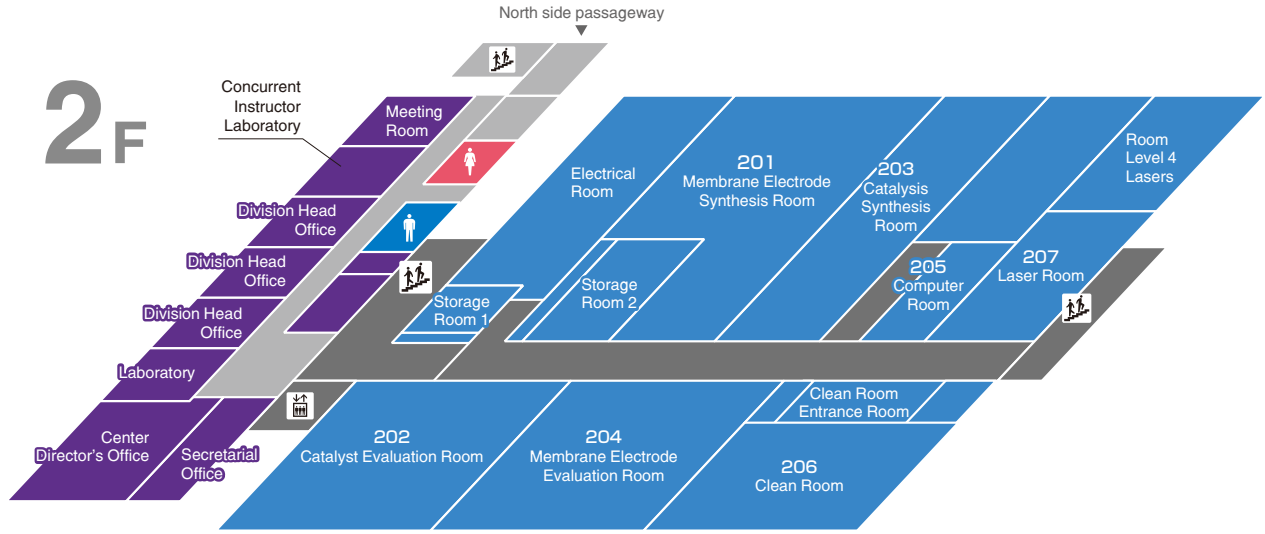
We are developing novel catalysts for hydrogen production and purification for residential PEFC systems and hydrogen stations. Selective CO methanation catalysts, which are promising candidates for cost-effective CO removal from hydrogen-rich gas, and catalysts for hydrogen production via the decomposition of ammonia, which is attracting great attention as an energy carrier, are the main targets of our study.



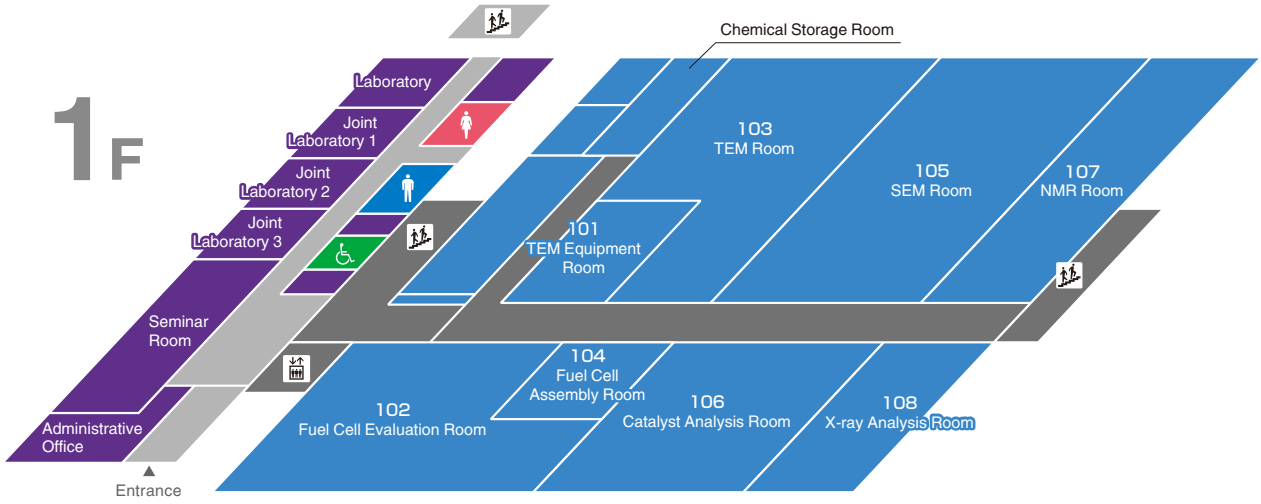
TEM image of hydrogen purification catalyst

Center Layout

Fuel Cell Nanomaterials Center

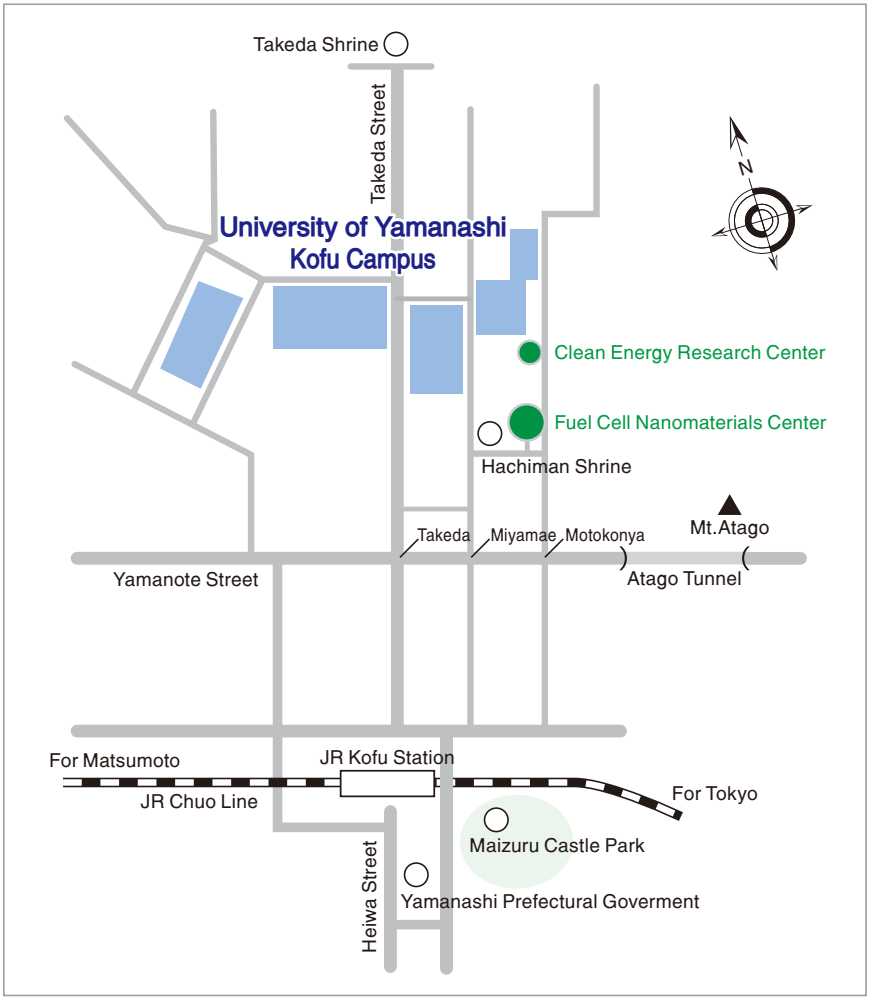


Office Wing (299 ㎡)　　Laboratory Wing (1262 ㎡)



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

Meeting rooms and researcher offices (683 ㎡)



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