Institute of Fluid Science, Tohoku University

Innovative Energy Research Center

What's Innovative Energy Research Center

The objective of this center is to realize a highly efficient, economical, and innovative energy utilization system through research and development related to conversion of unrealized energy, which has been only slightly possible using conventional technologies, through improved storage, transportation, and management of energy in both of conventional and new energy fields based on fluid science.

From the Director of the Center

Realization of a new energy technology nation based on SDGs

Tohoku University
Institute of Fluid Science
Professor
Jun Ishimoto

This research center was founded with the aim of realizing SDGs energy social infrastructure by concentrating combustion, geothermal heat, nuclear power, hydrogen energy, and green nanotechnology, which have been cultivated at the Institute of Fluid Science over many years. After the great earthquake occurred in 2011, development of a new energy system to replace nuclear power generation has been urgently sought. The future energy problems of Japan can only slightly be resolved using conventional energy alone or using renewable energy alone. It is now essential to realize environmentally coexistent types of energy supply systems, in which the use of fossil fuels is suppressed to the extreme, by achieving breakthroughs in unrealized energy through achievement of minimum exergy loss in conventional type energy and of ultra-high efficiency of next-generation renewable energy.

It is further requested that SDGs energy social infrastructure be realized by establishing a smart energy supply system by which these created energy resources can be implemented harmonically.

The Institute of Fluid Science has been establishing innovative energy generation and storage technology and management and conservation technology based on nano-interface material structure control technology, ultra-low damage process technology, micro-combustion technology, deep subterranean environment measurement technology, high-density hydrogen energy cycle, and nondestructive assessment technology. In addition to these research efforts, the institute intends to conduct studies aimed at realization of an innovative smart energy supply system through fusion of various types of power generation methods considering a good balance between costs and efficiency and by fusion of a power generation system and electricity accumulation system by introducing optimum design technology to contribute greatly to reconstruction of areas hit by the earthquake and regeneration of Japan. Furthermore, we intend to produce business models and make proposals actively for policies of energy and science technology toward the founding of a new Japanese nation based on energy and technology.

To attain this goal, we intend to promote coalition-building inside and outside the university and overseas. We are determined to create such an innovative energy research center that attracts excellent human resources from all over the world and which can transmit technologies and human resources to the world.

Prospectus

The objective of establishing this unattained energy research center is to develop and strengthen studies of fluid science related to the energy field, which this institute set as a goal and which has been deployed cross-organizationally, and which shall act as the center of strong promotion of studies for utilization of unattained energy, for which effective energy conversion has been only slightly possible using conventional technology, and which is the key to resolution of energy issues by conducting diverse energy studies based on fluid science and by mutually cooperating with different fields and academic areas.

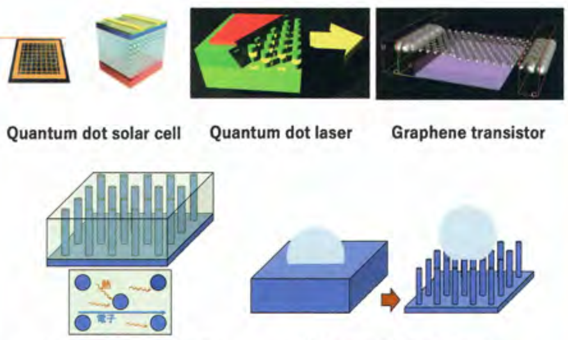
To realize an efficient, economical, and innovative energy utilization system in basic energy and new energy fields through collaboration of diversified energy studies in fluid science, this center promotes research efforts related to the conversion of unrealized energy resources for which effective energy conversion has been only slightly possible using conventional technology, storage, transportation and management of the energy. Particularly, we promote research of innovative green nano-devices using intelligent nano-processes, research into extensive utilization of the crust with the intention of resolving global environmental issues and energy problems, creation of high-exergy-efficiency combustion technology based on new concepts of combustion technology to be used in an era of diverse fuels, construction of highly efficient and innovative energy utilization systems to cope with social needs such as reduction of environmental loads and recycling society using micro-combustion, microgravity combustion and high-temperature oxy-fuel combustion as the mainstay, development of intelligent sensors and monitoring technology aiming at realization of improved conservation of energy plants and energy-saving of equipment, development of non-destructive evaluation technology, research into construction of energy-saving systems using low-friction system, development of innovative multiphase fluid analysis methods based on the fusion of supercomputing and advanced measurements and research of creation of environmentally conscious multiphase fluid energy.

Research contents

Green Nanotechnology Laboratory

Professor
Seiji Samukawa

Assistant Professor
Susumu Toko

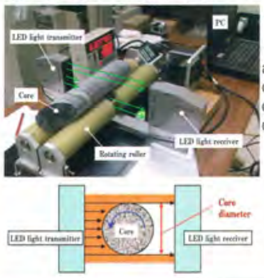


Quantum dot solar cell　Quantum dot laser　Graphene transistor
Thermoelectric device
High electron mobility transistor
Water repellent structure

Securing safe and less-expensive energy and efficient utilization of energy are important issues confronting modern civilization. To clarify these issues and aiming at founding a Japanese nation based on energy technology, we are promoting studies of innovative green nano-devices. Particularly, we have been developing power generation devices (such as quantum dot solar cells), electricity accumulation devices (such as high efficiency batteries using nanomaterials), low power consumption devices (such as quantum-dot lasers, Ge transistors, Graphene transistors) and nano-energy systems, which are a combination of these elements. For manufacturing of these nano-devices, nano-structures should be produced accurately and without defects. The original properties of materials and quantum nano-structure should be extracted. This sort of processing is made possible only after intelligent nano-process technologies such as beam process and bio-template and ultimate top-down etching technology, which are the background of this research laboratory, are fully used.

Energy Resources Geomechanics Laboratory

Specially-designed devise for dia. measurement



◀A newly developed apparatus for measuring circumferential distribution of core diameter.

▶Apparatus for shear slip experiment at fluid injection.

Professor
Takatoshi Ito

Assistant Professor
Yusuke Mukuhira

Development of Zero Emission Energy & Technology by "Geomechanics = Geo(地球) + Mechanics(力学)"

With the recent growth of the development for unconventional resources, we have realized that the knowledge of the geomechanics is quite crucial for the understanding of failure phenomena in subsurface and resource development. In our lab., we have been conducting the researches based on geomechanics for various applications such as CO2 geological storage, methane hydrate from deep seafloor, unconventional resources (shale gas & oil), easy and reliable in-situ stress measurement, and supercritical geothermal resource development. We develop the technology to highly utilize the subsurface environment (temperature, stress, closedness) to solve many challenges related to energy and to realize a sustainable society.

Measurement of in-situ rock stress is a critical parameter for the effective production of geothermal or unconventional hydrocarbon resources. We propose a new method of diametrical core deformation analysis (DCDA) for evaluating the in-situ stress of rocks from an elliptical deformation of boring cores. DCDA is game-changing method since we can directly estimate the magnitude of in-situ stress from simple core diameter measurement. At the various subsurface development associated with fluid injection, we experienced some felt size earthquake which possibly caused structural damage. To mitigate this seismic hazard risk of those anthropological earthquakes, we investigate the mechanism of those earthquakes and its causality to human activity.

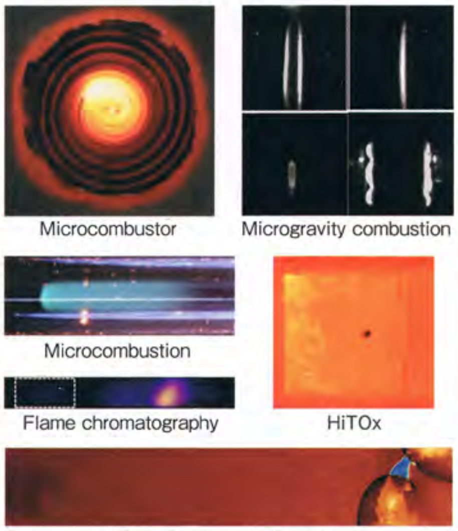
Energy Dynamics Laboratory

Professor
Kaoru Maruta

Associate Professor
Hisashi Nakamura

Assistant Professor
Youhi Morii

Assistant Professor (RACMaS)
Ajit Kumar Dubey



Microcombustor　Microgravity combustion
Microcombustion
Flame chromatography　HiTOx
2D engine knock simulation

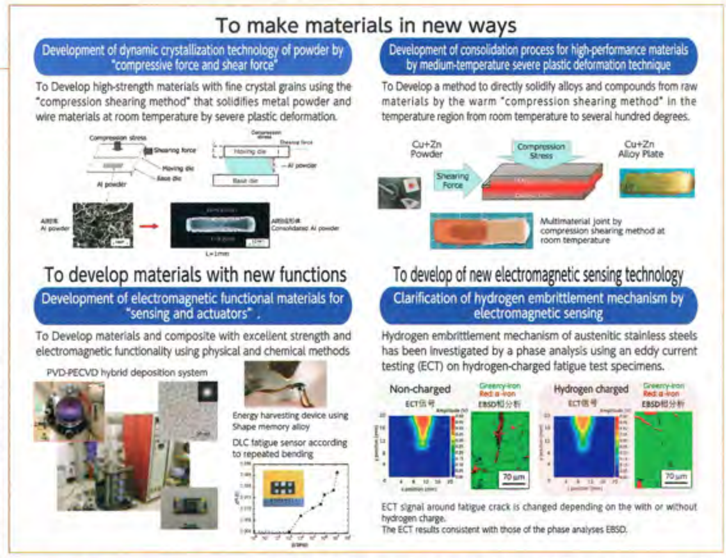
We pursue research and development on effective energy conversion and energy process in combustion and reactive thermal fluid systems with new technology concepts. By basing heat and/or mass regenerations for low-exergy-loss combustion as keywords, interdisciplinary researches are conducted with domestic and international collaboration partners in academic and industry.

- Micro-, Mild and Microgravity combustions
- Multi-stage oxidation by micro flow reactor with prescribed temperature profile
- Combustion with surrogate fuels, biomass, and synthetic fuels
- High-temperature oxygen combustion
- Large-scale combustion simulations and development of numerical methods

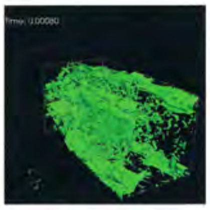
System Energy Maintenance Laboratory

Concurrent Professor
Tetsuya UCHIMOTO

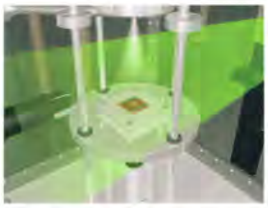
Associate Professor
Hiroyuki Miki



In this laboratory, we are conducting research to improve the reliability and stability of the system by improving the functionality of each machine component. Aiming to improve the potential of the system and to realize an energy-saving and highly efficient mechanical system, we are engaged in research for the design of high-performance machines. The main research topics are as follows; ① Development of dynamic crystallization process of powder metal by "compressive force and shear force", ② Development of consolidation process for high-performance materials by medium-temperature severe plastic deformation technique, ③Development of electromagnetic functional materials for "sensing and actuators", ④ Clarification of hydrogen embrittlement mechanism by electromagnetic sensing.



Coupled FSI computing of hydrogen leakage phenomenon accompany with crack propagation of pressure vessel



Nano device cleaning using cryogenic fine solid particulate spray

Multiphase Flow Energy Laboratory

Professor
Jun Ishimoto

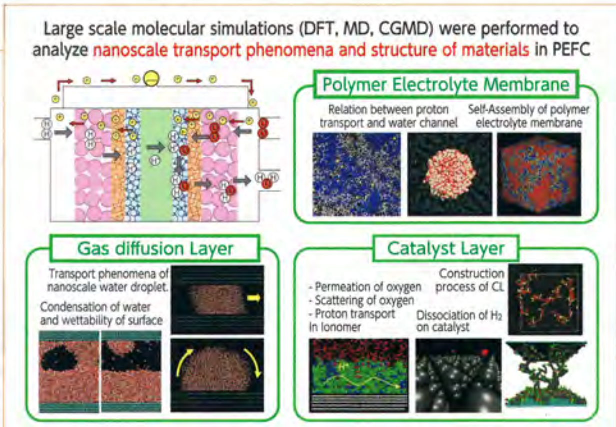
Assistant Professor
Naoya Ochiai

Development of Integrated Multiscale Multiphase Flow Energy System

Our laboratory is focusing in the development of innovative multiphase fluid dynamic methods based on the multiscale integration of massively parallel supercomputing and advanced measurements, and research related to creation of environmentally conscious energy systems. Furthermore, we promote basic research for the creation of risk management science and associated new multiphase flow system directly linked to sustainable energy represented by a high-density hydrogen storage technology. Particularly, we are focusing in different field integration research and development such as creation of environmentally conscious type nano-cleaning technology using reactive multiphase fluid that is a thoroughly chemical-free, pure water free, dry type semiconductor wafer cleaning system using cryogenic micro-nano-solid high-speed spray flow, and also focusing on removal-reusing technology for solar cells and ITO membranes for conducting organic polymer (including indium oxide tin). We also performed computational study of multiple bubbles behavior in megasonic field to clarify the mechanism of particle removal by megasonic cleaning. Furthermore, aiming to contribute disaster risk science field, fundamental mitigation effect of mega-floating structures on the water level and hydrodynamic force caused by the offshore tsunami has been computationally investigated using SPH method taking into account the fluid-structure interaction (FSI).

Novel Battery Nanoscale Flow Concurrent Laboratory

Professor
Takashi Tokumasu



Development of clean energy sources, such as solar cell, Lithium ion battery and fuel cell, is increasingly accelerated all over the world because of recent problems of global-warming and nuclear power plant. It is indispensable to comprehend and control the flow of reactants or products in these batteries to improve the efficiency and decrease the cost. However, it is impossible to comprehend the flow dynamics of these substances accurately by conventional experiments or simulations because the flow field in these batteries consists of aggregations of very fine structure which is of the order of nanometer. Our laboratory analyzes the "flow", or transport phenomenon of reactants or products in the batteries by large scale quantum calculation or classical molecular dynamics method using a supercomputer. Moreover, we aim to make a theoretical design of a next-generation battery which is high efficiency and low cost by comprehending the characteristics and governing factors of the transport phenomenon from the simulation results.

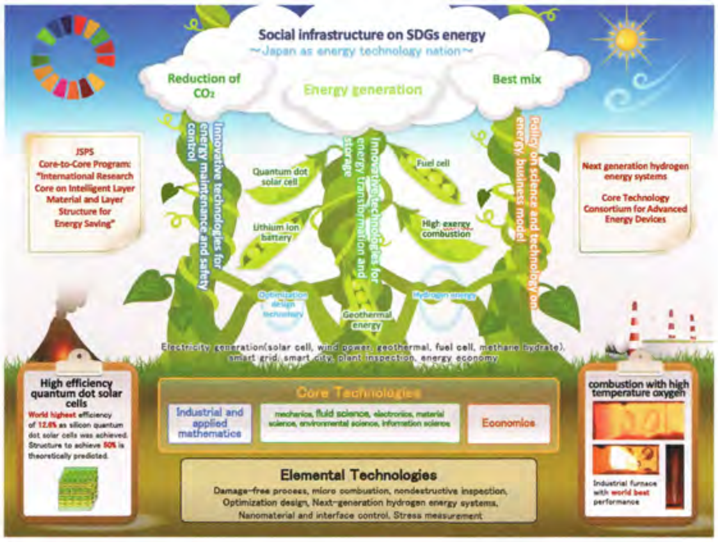
Research

Goal

Based on SDGs, realization of minimum energy loss when using conventional types of energy and of super-high efficiency of next generation renewable energy will enable suppression of the use of fossil fuels to the extreme or will usher in a highly efficient, environmentally compatible type of energy supply system. Furthermore, smart energy supply systems that incorporate these created energies harmonically can be established to realize a sustainable energy social infrastructure.

Research vectors

- Construction of a green smart city by using the next-generation hydrogen energy cycle
- Realization of an innovative smart energy supply system by fusion of various types of power generation methods, considering a good balance between costs and efficiency and by fusion of power generation system and electricity accumulation system by introducing optimum design technology.
- Building of business models and proposals for energy and science technology policies intended for the founding of a new Japanese nation based on energy and technology.



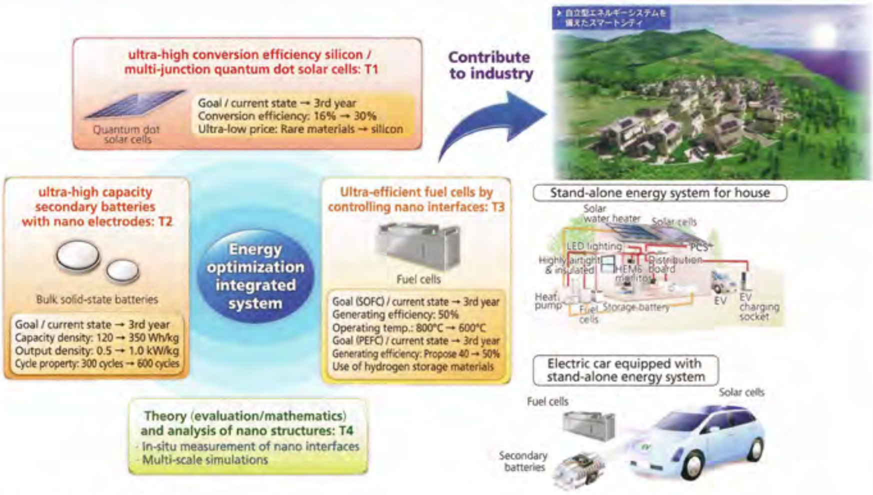
Benefits of the Innovative Energy Research Center

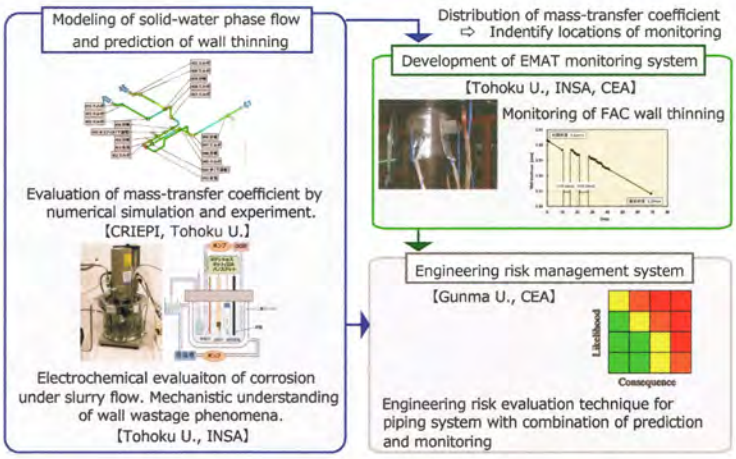
- Mutual compensation type use of high-density hydrogen as a renewable energy medium and realization of smart grid science city.
- We proposed high-exergy-efficiency combustion capable of greatly reducing irreversible loss (exergy loss) that was unavoidable in the combustion by improving exergy rate at combustion start, and specific challenges such as a high-temperature oxygen combustion is being promoted currently.
- World-leading lithium ion battery characteristics by high-volume and high-output type electrodes using techniques to synthesize a uniformly sized, highly crystalline active material (LiFePO4) at a 10-50 nm level.
- Realization of high-efficiency fuel cells using world-leading synthesis of diverse hydrides including complex hydrides and highly functional solid hydrogen carrier.
- Fusion of various types of power generation methods considering a good balance between costs and efficiency, and realization of a best mix of power generation systems and electricity accumulation systems using our own optimization design.

Related Projects

"Core technology consortium for advanced energy devices"

http://www.ifs.tohoku.ac.jp/consortium/eng/





ANR-MEXT Bilateral Program
Basic and Fundamental Technologies for Fukushima Decommissioning

PYRAMID (Piping sYstem,Risk management based on wAll thinning MonItoring and preDiction)

http://pyramid.cfrend.tohoku.ac.jp

Organization

Field distinction	Faculty affiliation
Green Nanotechnology Laboratory	Professor : Seiji Samukawa Visiting Professor : Kazuhiko Endo Assistant Professor : Susumu Toko
Energy Resources Geomechanics Laboratory	Professor : Takatoshi Ito Assistant Professor : Yusuke Mukuhira
Energy Dynamics Laboratory	Professor : Kaoru Maruta Associate Professor : Hisashi Nakamura Assistant Professor : Youhi Morii Assistant Professor (RACMaS) : Ajit Kumar Dubey
System Energy Maintenance Laboratory	Concurrent Professor : Tetsuya Uchimoto Associate Professor : Hiroyuki Miki
Multiphase Flow Energy Laboratory	Professor : Jun Ishimoto Assistant Professor : Naoya Ochiai
Energy Science and Technology Laboratory	Visiting Professor : Atsuhiko Fukuyama
Advanced Energy Engineering Laboratory	Visiting Professor : Yiming Li (2018.7.12-2018.8.21) Visiting Professor : Pierre CALMON (2018.8.10. -2018.9.10) Visiting Professor : Philippe GUY (2018.8.24-2018.10.5) Visiting Associate Professor : KHALID M. SAQR (2018.10.11-2019.1.31) Visiting Professor : Chenguang LAI (2019.1.23-2019.2.28)
Novel Battery Nanoscale Flow Concurrent Laboratory	Professor : Takashi Tokumasu

Access

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