GREATER GREEN
CENTER FOR GREEN RESEARCH ON ENERGY AND ENVIRONMENTAL MATERIALS
Aiming for the world’s highest research center on energy and environmental materials

Our mission is developing energy and environment-related materials for realizing energy network systems that enable us to utilize a wide variety of energy with high efficiencies. In particular, we are developing materials for solar cells, rechargeable batteries, hydrogen production systems, thermoelectric devices, etc.; and electrode catalysts as a common material among these devices. Computational science and materials informatics for material design and mechanism elucidation are also our research subjects to accelerate the materials development. This center includes Cryogenic Center for Liquid Hydrogen and Materials Science (CLEan) and NIMS Battery Research Platform; the former is developing materials and systems for magnetic refrigeration, which is crucial for efficient liquid hydrogen production in the coming hydrogen society, and the latter is an infrastructure facility for developing next-generation batteries. We are aiming for the world’s leading research center on energy and environmental materials with the aids of these infrastructures.

Director of Greater GREEN  Kazunori Takada

Research themes in Energy flow
Research for Li-air battery

Li-air battery module of 10-cell stacking (a) and discharge curves (b). It exhibits much larger capacity than commercial Li-ion batteries, and research for increasing energy density and cycle life is under progress.

All Solid-State Battery Group

High-performance rechargeable batteries have been supporting an advanced information society as power sources in portable electronics, and they are expected to contribute to realizing an environment-friendly society. We aim for the realization of solid-state batteries with high reliability.

Preparation of high-performance anode from Si nanoparticles for all solid-state cells

Cross-sectional SEM images of Si particulate anode on stainless steel plates prepared from Si nanoparticles by spray deposition: (a) the as-prepared and (b) the 11th fully charged state. The anode exhibits excellent performance, comparable to those of continuous films prepared by evaporation process, with the aid of problematic Si volume expansion.

Photovoltaic Materials Group

Focusing on next-generation solar cells with high energy conversion efficiency and low manufacturing cost, we are working on elucidating the photoelectric conversion mechanism, developing solar cell materials and devices.

Development of high-efficient and low-cost next generation solar cell devices

Next-generation solar cells devices: (a) Quantum dot solar cells, utilizing quantum dots as light absorption layers, (b) Lead-free perovskite solar cells. Low-cost solution process, the world’s highest level, (c) Thin silicon heterojunction solar cells.

Thermoelectric Materials Group

Our target is development of ubiquitous-element thermoelectric materials superior to Bi-Te at 300-600 K and their power generation modules to meet an urgent social need of energy recovery from low-grade exhausted heat distributed widely in our societies.

Development of ubiquitous-element thermoelectric materials and modules

Thermoelectric modules under development of (a) Fe-Al-Si, (b) Fe-Si and (c) PEDOT/PSS. Application temperatures are in the range of 300~400K. Power generating performance of thermoelectric materials and manufacturing efficiency of modules are being improved.
Hydrogen Production Materials Group
Group Leader  Chikashi Nishimura

There are many issues that remain to be solved to establish “Hydrogen Society”. Hydrogen Production Materials Group focuses particularly upon the key materials of hydrogen producing devices, in order to realize the price reduction and to offer technical advantages.

Theme: Novel catalysts to produce hydrogen from methane, Ni#Y2O3
We have successfully developed nano-composite catalyst Ni#Y2O3, where Ni metal and Y2O3 oxide are well entangled each other. The composite catalyst enables low temperature (<500 °C) and long term (>1000 hr.) operation of dry reforming methane to hydrogen.

Interfacial Energy Conversion Group
Group Leader  Hidenori Noguchi

We are carrying out fundamental studies on the methods to construct functional phases by the assembly of atoms, molecules, nanoclusters and cells mainly at solid/liquid interfaces for interfacial energy conversion processes such as electrocatalysis and photoelectrochemistry.

Interface Computational Science Group
Group Leader  Yoshitaka Tateyama

We investigate essential processes in batteries and catalysts in energy & environmental issues via novel computational and data-science techniques associated with first-principles calculations.
Group URL: https://www.nims.go.jp/group/nscs/

Advanced Low-Dimensional Nanomaterials Group
Group Leader  Jie Tang

Aiming for the most sophisticated industrial use in energy storage and electron imaging, our research thrust is focused in two types of nanomaterials: (i) Fundamental research on two-dimensional graphene and graphene composites for energy storage applications in supercapacitors and (ii) Development of one-dimensional metallic compound nanowires for applications in electron emission.
Japan has two important issues—reducing carbon dioxide emissions and reducing nuclear power plants—securing new, inexpensive and safe core energy is an extremely important theme. Hydrogen is attracting attention as one of the leading candidates for new energy carriers. In particular, possibilities are expected for thermal power generation, P2G (Power to Gas), large mobility such as ships and trucks, and reducing agents in metal refining. The purpose of this center is to research and develop basic technologies for materials required to supply and use liquid hydrogen cheaply and safely among the technologies that support the realization of a society that consumes large amounts of hydrogen. Specifically, by using a magnetic refrigeration system, we are developing hydrogen liquefaction technology and zero boil-off technology that are more efficient than conventional technologies.

**Development of liquefaction and refrigeration technology using magnetic refrigeration**

![Basic Image of Magnetic Refrigeration](image1)

**Development of Magnetic Refrigerator for Hydrogen Liquefaction**

(1) Principal of AMR: Figure(1) shows the AMR case filled with a large number of magnetic particles which exhibit magneto-caloric effect. By retaining cold heat by regenerative effect of magnetic materials, a sizable temperature profile along the AMR case from the hot end to the cold end emerges.

(2) A picture of the magnetic refrigerator being developed and the inner structure of the magnetic refrigerator. A superconducting magnet and the AMR case are integrated into the same system to reduce the heat leak and increase the cooling power.

**Development of novel electrocatalysts and elucidation of reaction mechanism in Li-air battery**

To develop electrocatalysts for O₂ reduction and H₂ evolution reactions by combining theoretical and experimental studies.

To clarify the mechanisms of reactions of Li-air battery, which has high theoretical energy density but has many problems, by utilizing various analytical tools.

Novel electrocatalysts for oxygen reduction and hydrogen reactions were developed based on insulting BN and inner Au substrate. For practical applications, carbon substrate and alloy with non-precious metals are under investigation.

Effects of impurities such as H₂O and HF on the product distribution at Li-O₂ battery cathode by various analytical methods.

**Design of ‘state-of-the-art fuel cells’ by fusion of microanalysis, modeling and fabrication**

Our research aim is fabrication of the state-of-the-art fuel cells with the quality of exceeding the limit of conventional fuel cells guided by modeling on the basis of microanalysis results. Also, we try the social implementation of our fuel cell devices and systems by multidisciplinary research team work.

We perform the modeling based on the microanalysis results. Then, we have good opportunity to see better performance of our cells if our model was reasonable. To see breakthrough, we polish up our model on the basis of second careful microanalysis. Finally, we believe that we have great chance to fabricate the ‘state-of-the-art’ fuel cell devices and systems with multidisciplinary research team members.
High Magnetic Field Measurement Group

Group Leader  Yasutaka Imanaka

In order to study material properties and new functions in various energy functional materials, we have developed special measurement techniques under extreme conditions with using high magnetic fields exceeding 20 Tesla.

Development of High Magnetic Field and its application for Material Science

Right figure shows the Bitter pulsed magnet system (a), (b) and the cryogenic measurement system (c) with a He cryostat. We have studied various functional materials under high magnetic fields with using these developed systems.

Magnetocaloric Materials Group

Group Leader  Hiroya Sakurai

Our group aims to discover magnetocaloric materials for the hydrogen-liquefaction active magnetic regenerator developed in NIMS. Among material requirements, the most important one is a large entropy change, |ΔS|, induced by application of magnetic field.

Search for magnetocaloric materials

Isothermal magnetization and adiabatic demagnetization of a magnetocaloric material cools the material and gas around it. Its efficiency depends on the entropy change induced by the magnetization and demagnetization. Materials with heavy lanthanoid elements tend to have large |ΔS| because of their large magnetic moments, and so they are promising candidates of the materials for our cooling system.

Hydrogen Materials Engineering Group

Group Leader  Yoshihiko Takeda

Hydrogen Materials Engineering Group studies functional material development and advanced characterization for the realization of a hydrogen energy based society and applies the accumulated beam technology, operand and multiscale measurements to GREEN materials.

Characterization with ultrafast spectroscopy and ion beam analysis

(a) Time-of-Flight Secondary Ion Mass Spectrometer
   Spatial resolution < 100 nm
   Au, Ge emitters with 30 kV
(b) Femto-sec Pump-probe Spectroscopic System
   Laser pulse width: < 130 fs (1 kHz, 300 nm-10 μm)
   Spectral range: 300 - 1700 nm

Battery Research Platform

Platform Director  Shoji Yamaguchi

The NIMS Battery Research Platform is a world-class facility for next-generation battery R&D covering everything from battery cell assembly to materials analysis. All the equipment is installed under one roof in the NanoGREEN Building at the Namiki site. To provide the ultra-low humidity environment necessary for battery research, a super-dry room with a dew point of < -90°C (Water Content < 0.1 ppm) was constructed.

R&D Support to solve common issues for next-generation batteries

- Super-dry room 80m², Supplied dry air (DP < -90°C)
- Glove box and battery assemble equipments
- FIB-SEM
- TEM/STEM
- HAXPES
- TOF-SIMS(GCIB)
### History of Greater GREEN

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<tr>
<th>Year (H)</th>
<th>Event</th>
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<tr>
<td>2009 (H21)</td>
<td>Foundation of GREEN (October)</td>
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<td>2011 (H23)</td>
<td>GREEN became a core project of TIA Nano-Green.</td>
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<tr>
<td>2012 (H24)</td>
<td>Relocation to a new research building (May)</td>
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<td>2013 (H25)</td>
<td>Inauguration of two Specially Promoted Research Teams (All Solid Battery, Lithium Air Battery) in GREEN (April)</td>
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<td>2014 (H26)</td>
<td>Inauguration of ad hoc team of Perovskite PV Cells in GREEN (October)</td>
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<td>Foundation of Battery Research Platform (October)</td>
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<td>2016 (H28)</td>
<td>Foundation of Greater GREEN including GREEN and Battery Research Platform (April)</td>
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<td>The 13th GREEN Symposium (June)</td>
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<td>2017 (H29)</td>
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<td>International Workshop on Electrified Interfaces for Energy Conversions (May)</td>
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<td>The 15th GREEN Symposium (June)</td>
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<td></td>
<td>The 3rd Tohoku Univ. &amp; GREEN Joint Symposium (December) (The 16th GREEN Symposium)</td>
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<td>2018 (H30)</td>
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<td>The 18th GREEN Symposium (June)</td>
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<td>2019 (H31)</td>
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<td>The 20th GREEN Symposium (February)</td>
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<td>2020 (R2)</td>
<td>The 21st GREEN Symposium (March)</td>
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