Research Trands on Rare Earth and Critical Elements in Japan

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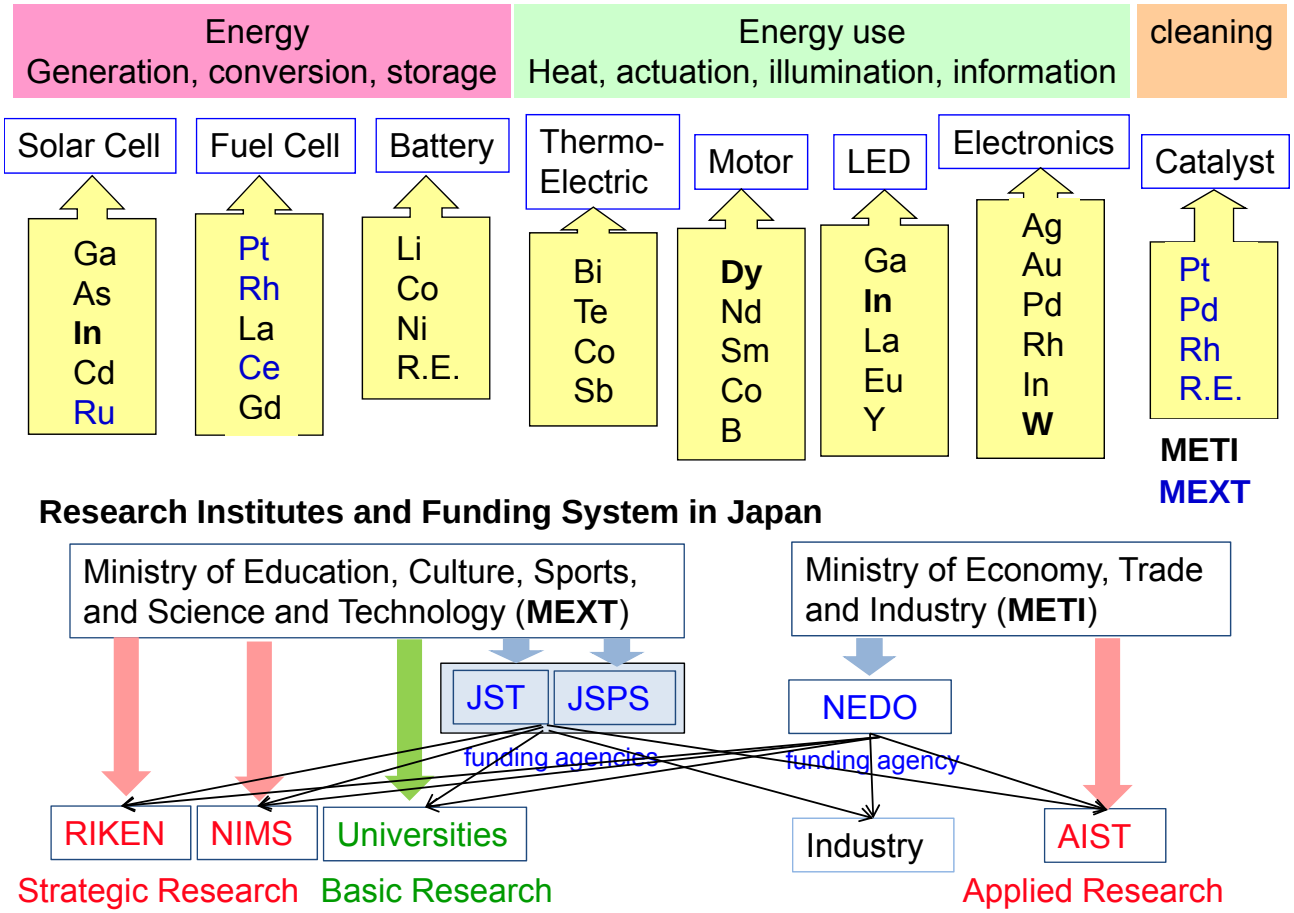
Critical Elements for Energy and Environment



Elements Science and Technology Project

- Designing Material Functions through Fundamental Research on Elements' Roles

started 2007

Background

Rare earths and other **rare metals** utilized for electronics, automotives, information technologies, and robotics are facing their price increase and tight supply due to the rapid increase of their consumptions and export policies of producing countries.

Project Outline

Establish sciences on the roles of critical elements in materials to use alternative elements

R&D Aspects on Research Subjects

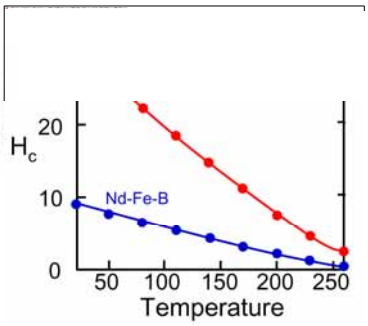
1. Alternative materials composed of ubiquitous and nonhazardous elements
2. Advanced utilization of functions stemming from strategic elements
3. Practical material design for the effective use of strategic elements

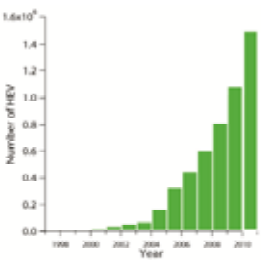
METI also started **Rare Metal Substitution Project** in 2007

Why Dy?

(Nd,Dy)-Fe-B sintered magnets for HV and EV

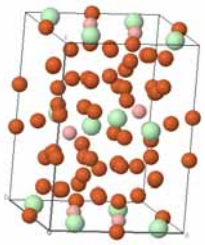
Operation temperature: 200°C





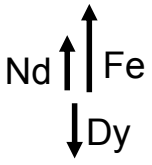
Sales of HV

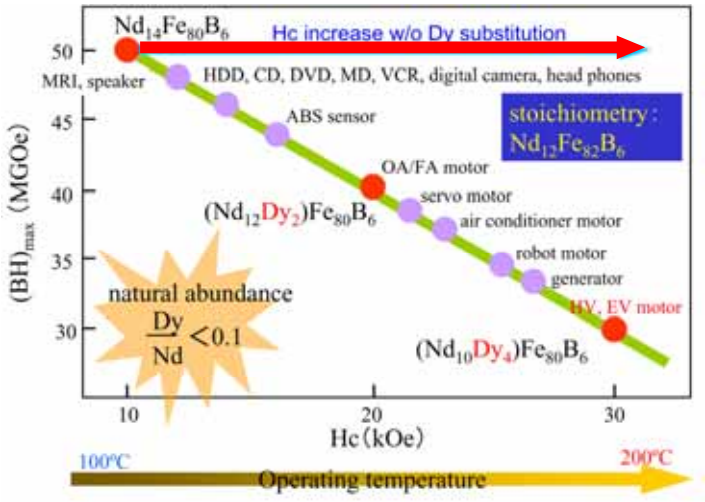
Nd,Dy Fe B



$Nd_2Fe_{14}B$

$K_1(Dy) >> K_1(Nd)$



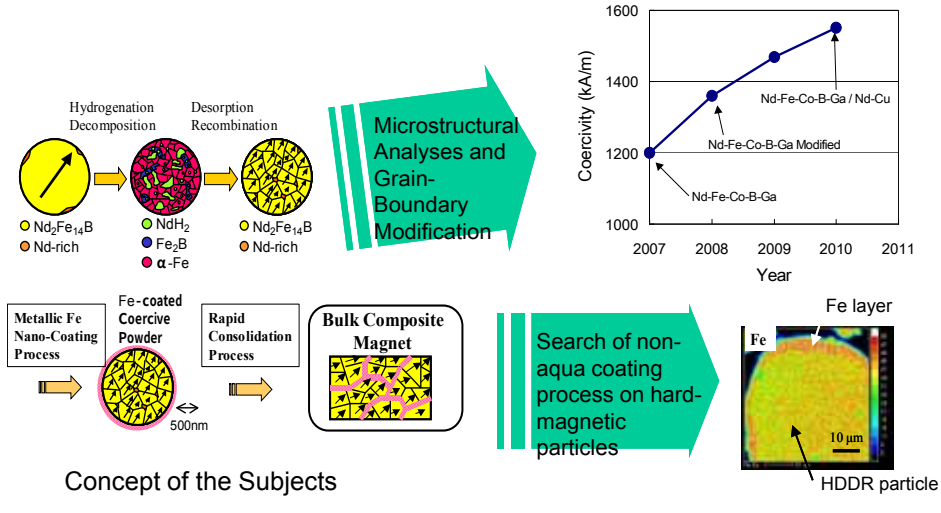


Elements Science and Technology

High Performance Anisotropic Nanocomposite Permanent Magnets with Low Rare Earth Content

S. Hirosawa, *Hitachi Metals., Ltd.,*
Hitachi Metals, NIMS, Ehime Univ., Kitakyushuu Univ.

A new category of permanent magnet materials with no Dy and less Nd with comparable magnetic properties with those of current (Nd,Dy)-Fe-B sintered magnets using HDDR (Hydrogenation-Decomposition-Desorption-Recombination) and Fe-nanocoating processes.

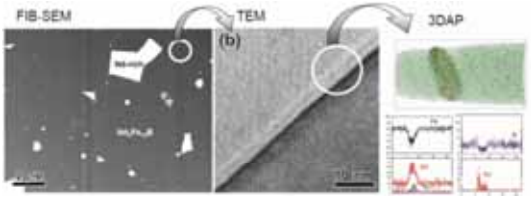


Materials Magic 日立金属 NIMS Kyutech 愛媛大学

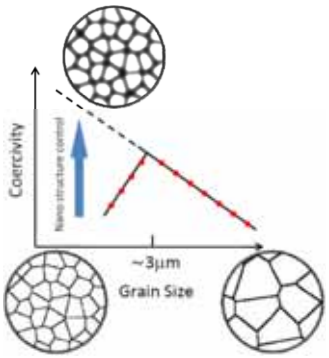
Rare Metal Substitute Materials Development Project

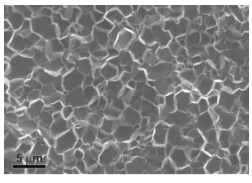
Development of technology for reducing Dy usage in Nd-Fe-B magnets

Operation temperature: 200°C



PL: S. Sugimoto, Tohoku U.





1. Grain Refinement

(1) Santoku
SC → Atomization (Hybrid)
~1 μm
Grain size (μm)
Alloy powder size (μm)

(3) Tohoku Univ.
Nd-rich Existence Probability In JM Powders
Ratio of Nd-rich, P(%)
Particle size, d_{50} /μm
Good
Bad

(1) Toyota

2. Interfacial Microstructure Control

(2) Intermetallics
He JM → Fine Powder
Dy Saving > 40 %
Nitrogen JM
Helium JM
50%
30%
20%
10% Dy
H_c (kOe)

(3) TDK
H-HAL Process
Dy Saving > 20 %
30%Dy Saving
20%Dy Saving
7%Dy
8%Dy
10%Dy
0%Dy Saving

(2) Yamagata Univ.
Increase in Hc

(1) Tohoku Univ.
Improvement of SR

(4) Tohoku Univ.
CF parameter: Negative
bulk
at surface
inside
(001) surface model

(3) SIST
Mag. reversal → Grp. of grains

(1) NIMS
High Hc → Thick G.B.

(2) JAEA

3. Guiding Principles

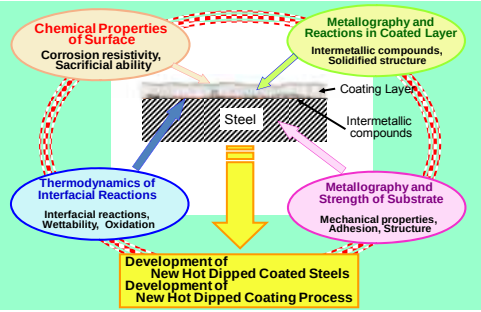
4. Application

MEXT Elements Science and Technology: Granted in FY2007

Development of Hot-dipped Aluminum Alloy Coated Steels

T. Tsuru, *Tokyo Institute of Technology*

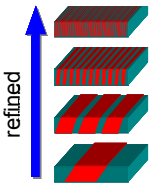
Substitution of **Zn** with Al on Zn coated steel



Development of Barium-based New Lead-free Piezoelectric Materials with Ultrahigh Piezoelectric Property for Piezoelectric Frontier

S. Wada, *Yamanashi University*

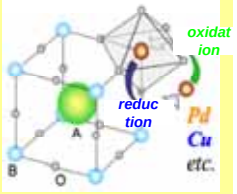
Ba-based new **Pb-free piezoelectric materials** with ultrahigh piezoelectric properties for future automobile MEMS applications.



Self-forming Nano-particle Catalyst without Precious Metals

Y. Nishihata, *Japan Atomic Energy Agency*

Substantial reduction and/or total substitution of the **precious metals** in the automotive catalyst for gasoline engine.

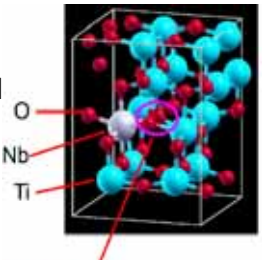


Solution / precipitation nano recycle

Development of TiO_2-based Transparent Electrode

T. Hasegawa, *Kanagawa Academy of Science and Technology*

As an **ITO** (Indium Tin Oxide) alternative, the sputtering- and CVD (Chemical Vapor Deposition) -based practical processes for fabrication of indium-free TNO (niobium-doped titanium dioxide) transparent conducting thin films will be developed.



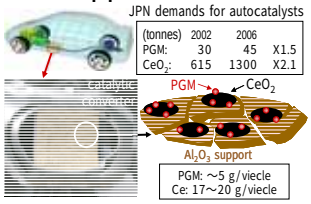
O (interstitial sites)

MEXT Elements Science and Technology: Granted in FY2008

Material Design and Processing of Highly-dispersed Catalysts with Minimum Precious Metal Loadings

M. Machida, *Kumamoto University*

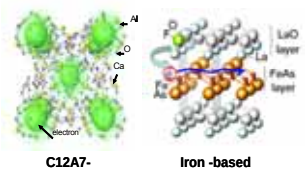
Minimizing the loading of precious metals (PGM=**Rh, Pt, Pd**) and rare earth elements (**Ce**) in automotive catalysts by realizing thermally stable and highly dispersed PGM nano-particles anchored onto support surface.



Ubiquitous Element Strategy for Function Emergence

H. Hosono, *Tokyo Institute of Technology*

Novel functionality based on abundant elements utilizing built-in nanostructures, interface/surface and/or defects.

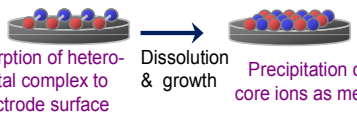


C12A7-Electride | Iron -based superconductor

Nano-hybridized Precious-metal-free Catalysts for Chemical Energy Conversion

K. Uosaki, *Hokkaido University*

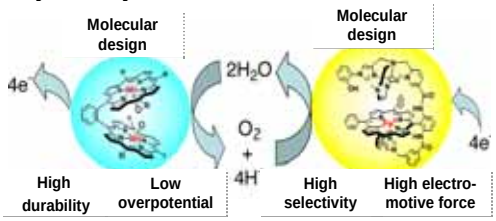
Nano-hybridized **precious-metal-free catalysts** for the innovation of fuel cell and photo-electrochemical cell.



Development of Innovative Energy Conversion Systems with Molecular Catalysts Replacing Precious Metals

Y. Naruta, *Kyushu University*

Development of **molecular catalysts w/o precious metal ions** for water decomposition to H_2/O_2 as well as O_2 reduction using organic-inorganic hybrid systems.

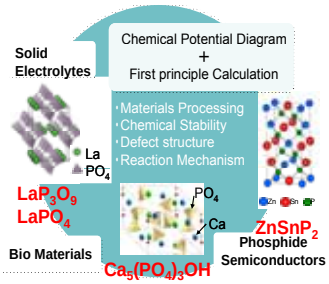


MEXT Elements Science and Technolgoy: Granted in FY2009

Design and Processing of Functional Materials with Multi-elements Based on Chemical Potential Diagrams

T. Uda, *Kyoto University*

The development of new **phosphate electrolytes** for fuel cells, **phosphide semiconductors** for photovoltaic cells, and **calcium hydroxyapatite** for bio-materials by computational thermodynamics and the first principle calculations.



Organic Molecular Approach to High-performance Rechargeable Batteries and Mechanistic Elucidation of Charge-discharge Processes

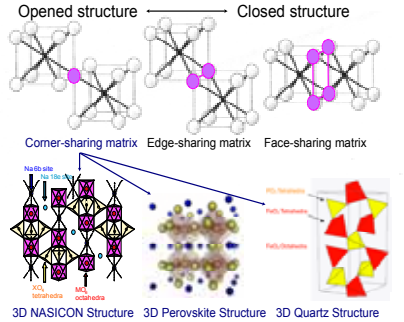
Y. Morita, *Osaka University*

Organic molecule high performance rechargeable batteries by using the with multi-stage redox ability.

Development of Eco-friendly Post Lithium-ion Batteries

S. Okada, *Kyushu University*

Replacement of the rare-metal elements massively used in anode and cathode active materials of **lithium-ion battery** with economically and ecologically friendly elements such as sodium and iron.



National Instiute for Materials Science (NIMS)

Science and Technology Agency

National Research Institute for Metals (NRIM) (since 1956)

National Institute for Research in Inorganic Materials (NIRIM) (since 1966)

April 2001 MEXT

Independent Administrative Institution

National Institute for Materials Science

– The only national lab dedicated to materials science in Japan –

1. **Fundamental and inovative research on materials science**
2. **Promotion of widespread use of research results and applications**
3. **Shared use of advanced research facilities**
4. **Cultivation of researchers in the materials science discipline**

Budget : $200 million (subsidy from MEXT$150M)
Personnel : 450 researchers, 100 staffs
500 visiting researchers

Where is NIMS ?

Sengen Site

Namiki Site

Sakura Site

Organization

President

Auditors

Advisory Board

Vice Presidents

Fellows

Coordinating Directors

Administration Offices
- Secretary's Office
- Audit Office
- General Affairs Division
- Planning Division
  - Integrated Strategy Office
  - Research Evaluation Office
  - International Affairs Office
  - Public Relations Office
  - Human Resources Development Office
- Collaboration-promotion Office
- Scientific Information Office
- Planning & Research Office
- Information Technology Office

Nanotechnologies
- Nano System Functionality Center
- Advanced Nano Characterization Center
- Computational Materials Science Center
- Quantum Dot Research Center
- Quantum Beam Center

Nanoscale Materials
- Nanoscale Materials Center
- Organic Nanomaterials Center
- Nano Ceramics Center

Materials for Information Technology
- Advanced Electronics Materials Center
- Optronics Materials Center
- **Magnetic Materials Center**

Materials for Biotechnology
- Biomaterials Center

Materials for Environment and Energy
- High Temperature Materials Center
- Fuel Cell Materials Center
- Superconducting Materials Center
- Photocatalytic Materials Center
- Structural Metals Center

Materials for Reliability and Safety
- Material Reliability Center
- Composites and Coating Center
- Sensor Materials Center

Department of Materials Infrastructure
- High Voltage Electron Microscopy Station
- High Magnetic Field Station
- Beam Line Station
- Materials Data Sheet Station
- Materials Database Station
- Materials Manufacturing and Engineering Static
- Materials Analysis Station

International Center for Materials NanoArchitectonics (MANA)

International Center for Young Scientists (ICYS)

Doctoral Program in Materials Science and Engineering

NIMS Nanotechnology Support Network

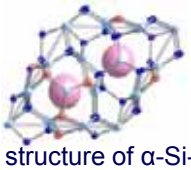
Interdisciplinary Clusters
- Strategic Use of Scarce Materials
- Social Acceptance of Nanotechnology
- Corrosion
- Non-Destructive Evaluation

Topics in energy materials at NIMS

Si-Al-O-N, High efficiency fluorescent material

Point of Research

Doping Eu^{2+} into Si-Al-O-N structure
High efficiency & durability due to its structure



Cristal structure of α-Si-Al-O-N

Developed Si-Al-O-N materials

Doping Eu2+ into Si-Al-O-N structure
↓
Heat resistant and long life

LED illumination lamp

Daylight color Daylight white | White color Warm white | Light bulb

Fluorescent in RED, GREEN colors + Blue LED
⇒ LED light source with excellent color reproducibility

Mass-produced for backlight Of Liquid crystal TV and cell-phone

Dy-free permanent magnets

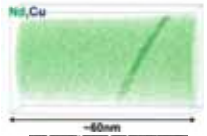
Point of Research

Analysis and control of nanostructure
Improving coercivity of NdFeB w/o Dy

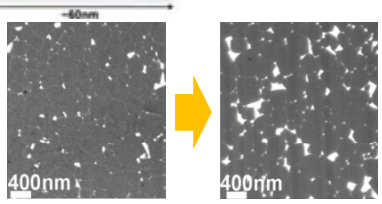
Nd-based magnet
$(Nd_{10}Dy_4)Fe_{80}B_6$

Dy is indispensable
in high performance permanent magnet
Quantitative Risk (Rare) +eccentrically-distributed in China, Country Risk↓
Challenge for Dy-free magnet

Analysis and control of nano-structure



Nd and Cu mapping by 3DAP



Coercive force=16kOe =20kOe

Diffusing Nd-Cu Alloy in grain boundary

A new center on Elements Science and Technology at NIMS from FY2011

Designing parmanent magnets with elements science

Micro-, Nano-, Atomic-scale characterization of materials - understand roles of alloying elements

Rare metal free structural materials

Steel, Mg-alloy, Ti-alloy, Stainless-steel,

Hierarchical control of metallic texture
Innovative process techniques to improve properties

Catalyst, reducing critical elements(Pt, Pd…)

Introducing active atoms into inter-metallic alloy
Morphology control in nano-scale

Separation and aggregation techniques of critical elements

From the Urban Mines

Mesoporous materials precisely modified pore accuracy

Summary

2005 A feasibility study on the development of Dy-free NdFeB magnets was approved by **NEDO** to a team lead by Sagawa.

TOYOTA started a consortium for Dy free NdFeB magnets in Japan. Later, it was expanded to four teams from EU.

2007 **METI** called proposal on **Rare Metal Substitute Materials Development Project**, which cover Dy, In, and W.

MEXT called proposals on basic research on Elements Science and Technology

2008 TOYOTA funded **NIMS-TOYOTA Research Center** for Dy-free permanent magnets and all solid Li-ion battery research.

2010 JST called proposals on **Elements Science and Technology** as its large grant scheme, **CREST** and **PREST** for FY2011.

2011 NIMS will start "**Elements Science and Technology Center**".

Elements Science and Technology is being recognized as important research discipline in Japan getting supports form both **MEXT** and **METI**.