A unique strategy developed by resource-poor Japan

“Element Strategy”

for tackling issues of element resources with science

Building a sustainable society
with innovative materials

MEXT

Element Strategy Initiative:
to Form Core Research Centers

New Japan-made materials that have changed the world

Smartphones, computers, and gasoline, electric, and hybrid vehicles are commonplace things we use every day. The fact that they have become so pervasive and convenient can be attributed to the emergence of unprecedented high-performance component materials that have improved convenience, safety, and reliability. Many of these materials were discovered and developed by researchers and companies in Japan.

The basic constituents of these materials are chemical elements. By combining the inherent properties of these elements, a wide variety of materials can be created. The types and quantities of elements being used have increased markedly in recent years. High-performance component materials in particular use large amounts of critical materials with low production or availability.

Researcher affiliations are those at the time of the announcement. Titles have been omitted. Precious metals and rare-earth elements in the compositions are indicated in the column-shaped icons.

Neodymium magnets

RE
rare-earth element
(neodymium and so on)

Masato Sagawa (Sumitomo Special Metals Co., Ltd., 1982)
Neodymium magnets possess ten times the magnetic energy of conventional ferrite magnets.

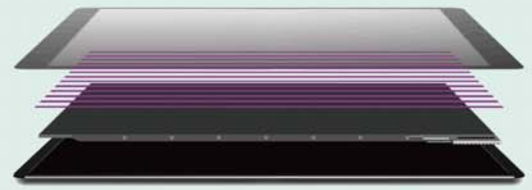
Vibrator for a smartphone

Drive motor for an automobile

IGZO amorphous oxide semiconductors

In indium | Ga gallium | Zn zinc

Hideo Hosono (Tokyo Institute of Technology, 2004)
IGZO has become widely used in high-resolution displays due to its low power consumption and an electron mobility several tens of times that of conventional amorphous silicon.



Smartphone display

Lithium-ion batteries

Li lithium | Co cobalt

Akira Yoshino (Asahi Kasei Corporation, 1985)
Li-ion batteries have about three times the energy density as nickel-metal hydride batteries.

Batteries for driving automobiles

Blue LEDs

Ga gallium

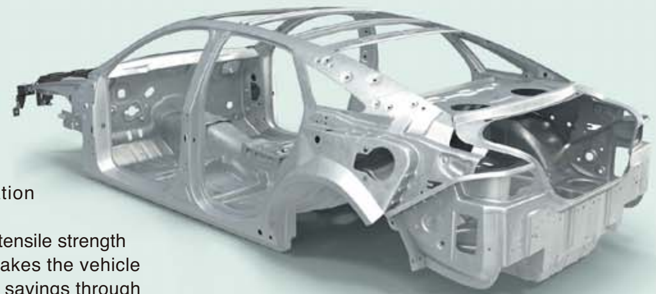
Isamu Akasaki and Hiroshi Amano (Nagoya University, 1989) and Shuji Nakamura (Nichia Corporation)
The development of blue LEDs, together with the existing red and green LEDs, completed the full set of primary colors, allowing for the expression of all colors and a wide variety of uses.

In car headlights, blue LED light incident on yellow or other phosphor generates a bright white light.

High tensile strength steel sheets

Mn manganese | Ni nickel | Nb niobium

Developed in the mid-1970s by Japanese steel makers in collaboration with the Japanese automotive industry.
The steel sheets have about twice the tensile strength of conventional steel sheets, which makes the vehicle parts lighter and contributes to energy savings through better mileage.



Vehicle frame

Three-way catalysts for vehicle emissions

Rh rhodium | Pd palladium | Pt platinum

Japan's automobile manufacturers developed a practical system in the mid-1970s for simultaneously removing the harmful components nitrogen oxides (NOx), hydrocarbons (HC), and carbon monoxide (CO) from exhaust gas.

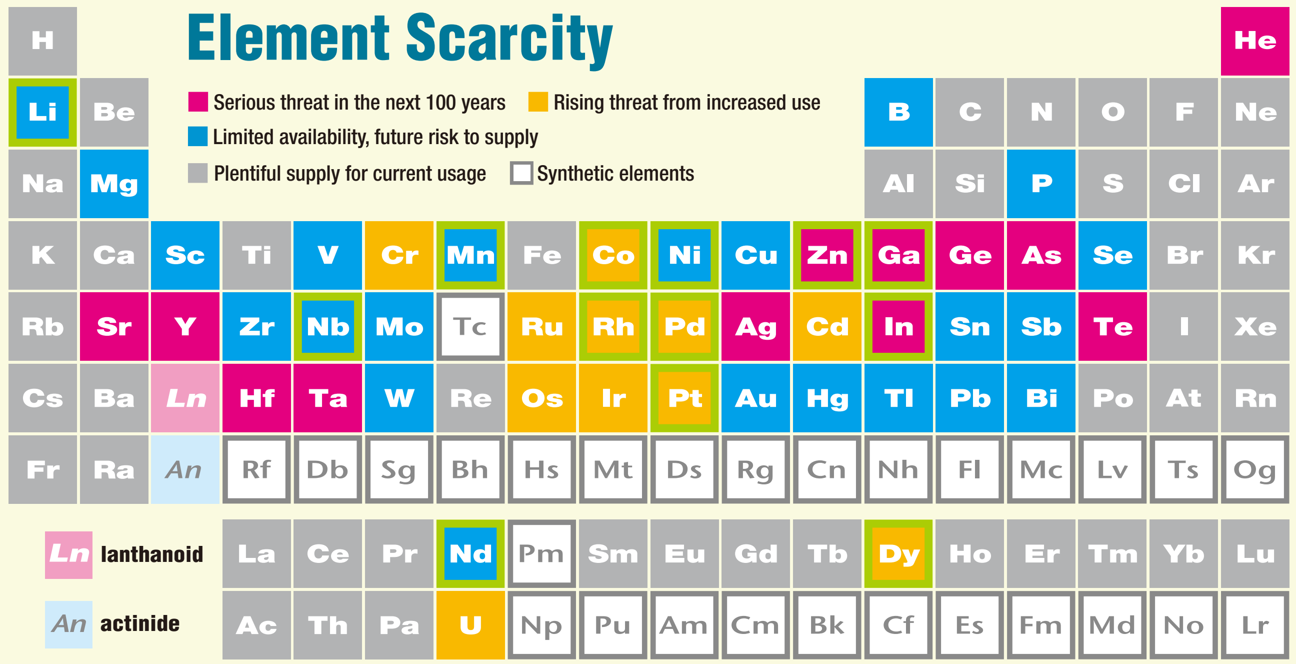
Catalytic Converter for a car

Manufacturing aligned with the Earth

The Earth has limited deposits of mineral resources. Yet the demand for critical materials will continue to increase, and there is concern that we will be faced with a shortage of many elements a few decades from now (refer to the chart on the right). Moreover, mineral resources cannot be produced anywhere on Earth as their reserves are severely unbalanced regionally (see the lower diagram).

Balancing the supply and demand of mineral resources is a challenge the entire world now faces. Solving this problem will require developing technologies for the global circulation of resources and innovative uses for elements that do not impact the environment.

Element Scarcity

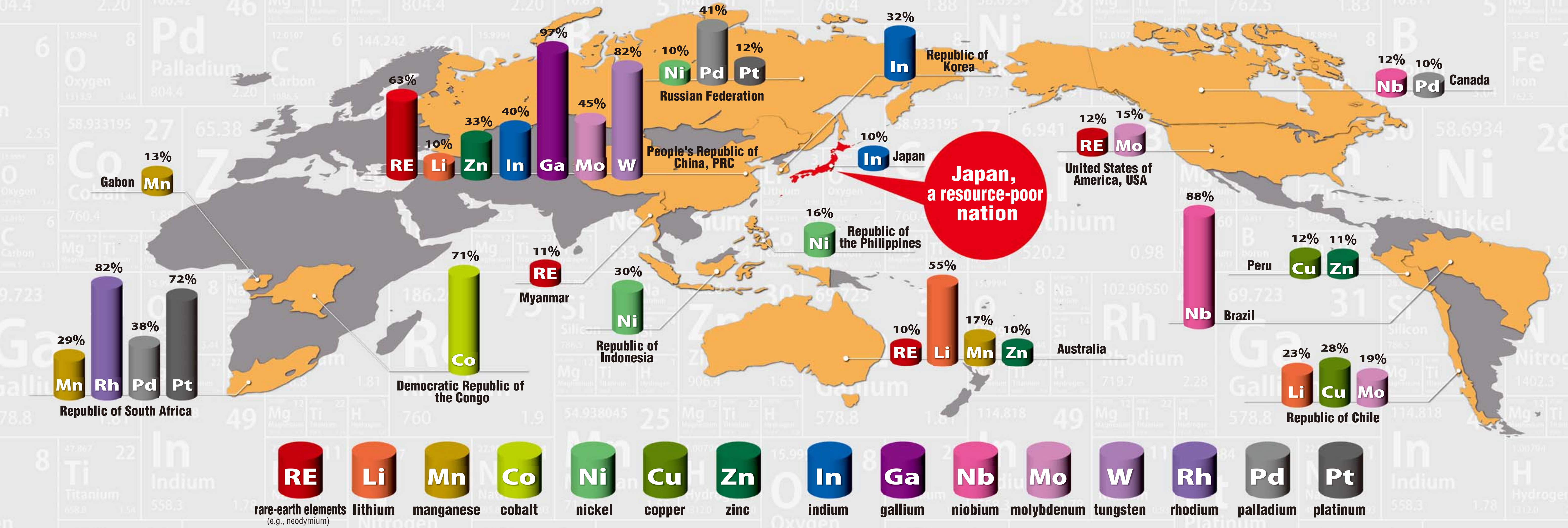


□ Denotes the precious metals and rare-earth elements that are constituents of the component materials introduced on pages 2 and 3. The production rates of these elements are represented by the height of their columns in the map of "Important element resource-producing countries and their market share."

Source : Based on the periodic table published by the European Chemical Society (EuChemS) for the International Year of the Periodic Table 2019 (https://www.euchems-periodic-table/).
Acknowledgments: Professor David J. Cole-Hamilton, University of St. Andrews, UK

Important mineral-producing countries and their market share

This diagram shows countries that account for at least 10% of global production.



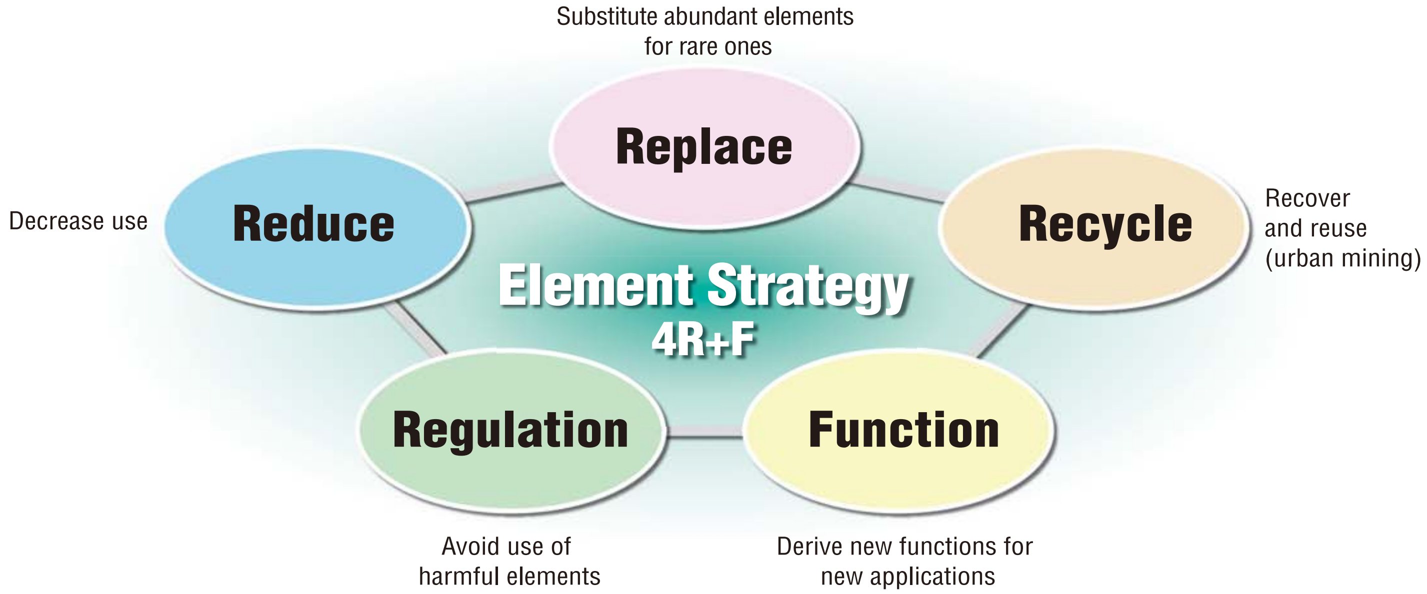
Sources : The United States Geological Survey (USGS) "Mineral Commodity Summaries 2020" and the Japan Oil, Gas and Metals National Corporation (JOGMEC) "Material Flow of Mineral Resources 2019"
Contributors : Tomohiro Nakayama and Satoshi Miyashita (Japan Science and Technology Agency (JST) Center for Research and Development Strategy)

A unique strategy developed by resource-poor Japan

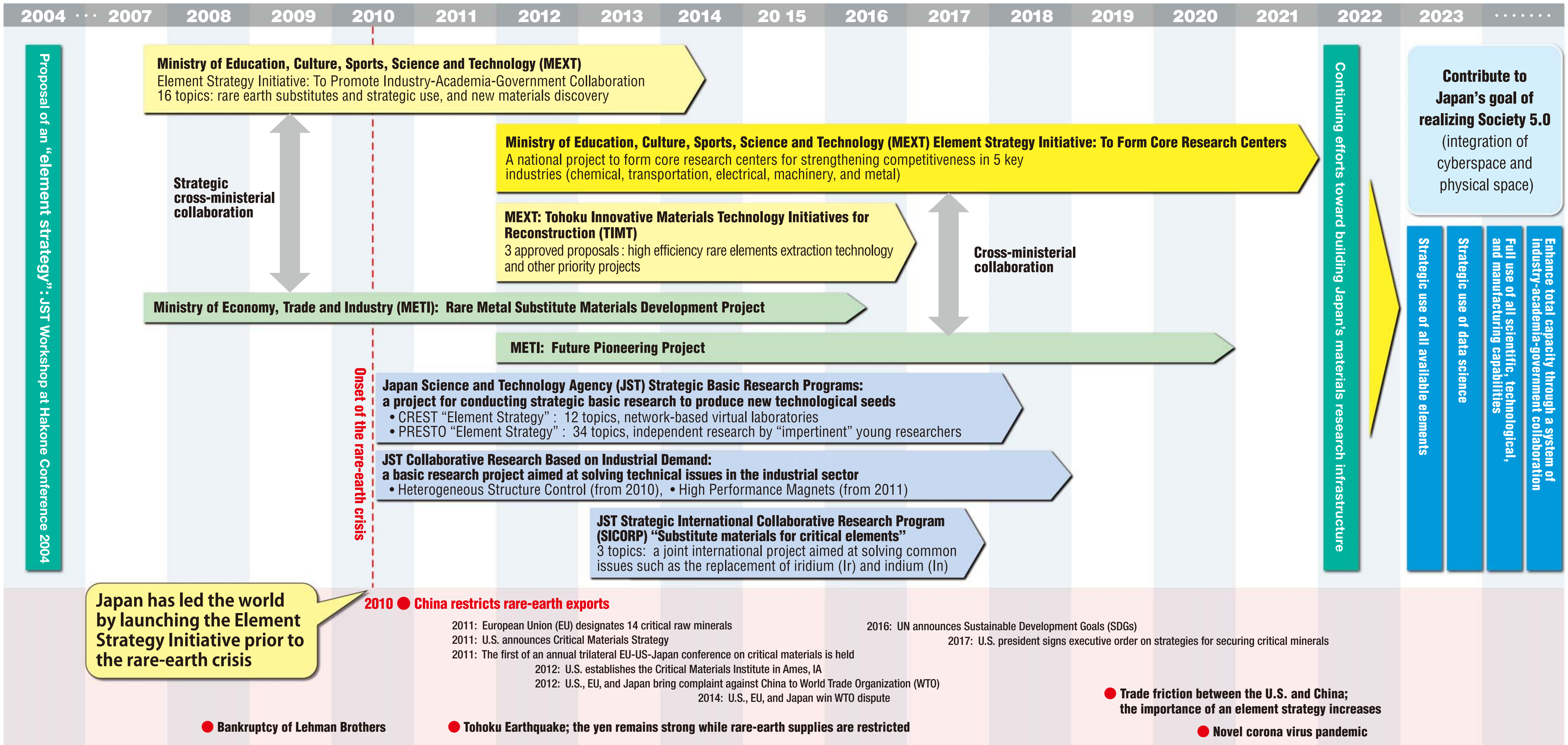
Element Strategy

A national project strategy for developing innovative solutions that use science to overcome mineral resource risk and create a safe, secure, and sustainable society.

- 2004: Propose concepts   2007: Begin national project
- Develop a strategy to benefit Japan and earn international respect
- Anticipate UN Sustainable Development Goals (SDGs) and contribute to achieving their targets



Timeline of the Element Strategy Initiative with Domestic and Foreign Trends



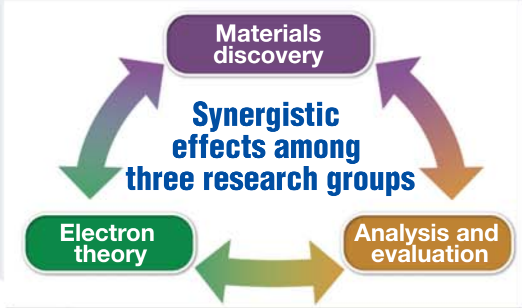
Achievements

of the MEXT Element Strategy Initiative : To Form Core Research Centers

Progressing steadily from the formulation of scientific principles to the trial manufacture of functional materials, we link scientific outcomes to industrial applications and social implementation

- A system of four research centers directly involved in strengthening Japan's competitiveness in 5 key industries (chemical, transportation, electrical, machinery, and metal)
- Engaging all efforts of industry, academia, and government: trust and expectations from the industrial sector
- Future generation human resource development and long-term strategies

Research system



Taking full advantage of large-scale, cutting-edge research facilities

SPring-8

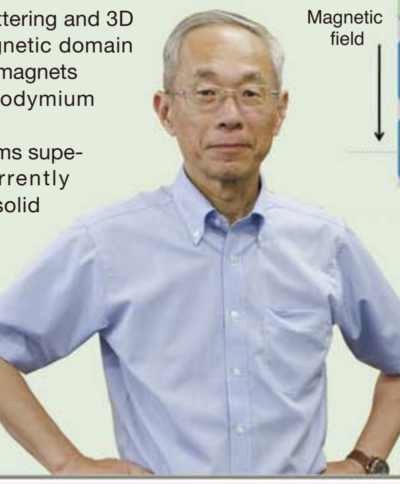
J-PARC

Fugaku (K-computer)

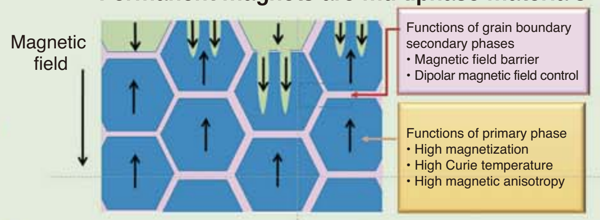
Elements Strategy Initiative Center for Magnetic Materials (ESICMM, NIMS)

Development of ultimate magnet materials without critical elements

- Developed technology using neutron scattering and 3D atom probe tomography to analyze magnetic domain structures near grain boundary phases in magnets
- Succeeded in developing a Dy-free neodymium permanent magnet
- Discovered 1-12 type Sm(Fe-Co)$_{12}$ thin films superior to neodymium magnets and currently engaged in process development for a solid form
- Organized the Materials Open Platform (MOP) on which a database of multi-component thermodynamic calculations has been created to enhance collaboration between industry and academia



Permanent magnets are multiphase materials



Structural refinement and magnetic control at the grain boundary phases is fundamental to magnet performance!

Director General
Satoshi Hirosawa

Tokodai Institute for Element Strategy (TIES)

Developing electronic materials from abundant elements that can withstand practical use

- Constructed the Materials Research Center for Element Strategy (2012)
- Iron-based superconductors: Identified the roles of hydride ions H- and applied them to superconductive magnets
- Semiconductors: Developed electron transport material of ZSO (ZnO-SiO$_2$) for a perovskite LED that achieves high-efficiency and luminance (500 times that of a smart-phone)
- Discovered the first p-type transparent amorphous semiconductor Cu-Sn-I with electron mobility comparable to n-type IGZO
- Electrides: Developed intermetallic electrides such as LaNiSi as catalysts for low-temperature ammonia synthesis and established a venture company

Materials Research Center for Element Strategy

Extracting functions for tracking electron movements!

Representative
Hideo Hosono

Elements Strategy Initiative for Catalysts and Batteries (ESICB, Kyoto University)

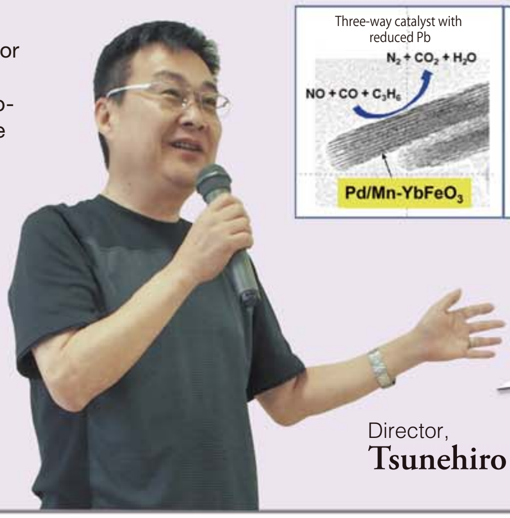
Developing a three-way catalyst for exhaust gas that is free of precious metals and inventing a high-performance Na battery system

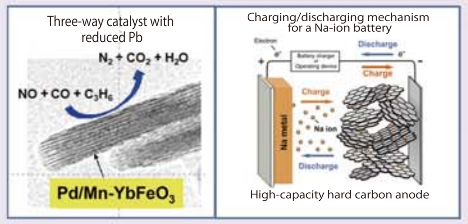
Catalysts

- Elucidated the metal-support interaction and anchor effect to design a high-performance catalyst
- Developed a tandem metal oxide three-way automotive catalyst (Zn, Cr, and Cu) free of noble metals (Rh, Pd, and Pt)
- Developed two-dimensional Rh thin film and single atom alloy (Cu$_9$Pd$_1$) automotive catalysts using less noble metals

Batteries

- Developed flame-retardant high-performance electrolytes for manufacturing a safe Li-ion battery prototype exhibiting long life
- Developed a new method of synthesizing high-capacity hard carbon (anode material) for manufacture of Na-ion batteries





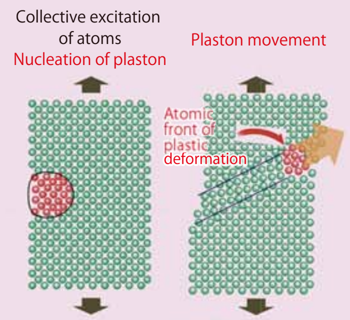
Interface control is the determining factor in both catalysts and batteries that enables us to achieve high performance without rare elements and noble metals!

Director,
Tsunehiro Tanaka

Elements Strategy Initiative for Structural Materials (ESISM, Kyoto University)

Formulating scientific principles and discovering innovative materials that achieve both strength and ductility in structural metals

- Proposed a new concept on the elementary process of plastic deformation in structural materials called "plaston," which is the collective excitation of atoms in a singular stress field
  Formulated scientific principles for achieving a balance of strength and ductility in metal materials while suppressing fatigue failure, paving the way to innovative materials
- Discovered bulk nanostructured materials having plaston-induced ductility: titanium and magnesium alloys, steel materials, etc.
- Elucidated the mechanism of plastic deformation in brittle materials and acquired guidelines for developing practical automotive materials such as galvannealed (GA) steel sheets
- Developed software and a database for calculating lattice vibrations, which are used throughout the world as the de facto standard



Pursuing tougher structural materials for a safe and secure society!

Director
Isao Tanaka

Young researchers fostered
by the Element Strategy Initiative

Researchers from different fields of specialization and overseas students mixed together and studied. The research centers of the Element Strategy Initiative provide an ideal opportunity for the fostering of human resources. We listened to the views of researchers in charge of research at the centers, people who have graduated from the initiative and conduct research in Japan, and those who are spreading their places of activity to the global platform.

My research

Park Myeong-heom
Elements Strategy Initiative for Structural Materials (ESISM)

In order to enhance the strength and ductility of steels and other structural materials, we are attempting to elucidate the deformation nature of such materials and to determine what happens to their microstructures during deformation and how that relates to strength and ductility.

Keitaro Sodeyama
Elements Strategy Initiative for Catalysts and Batteries (ESICB)
Currently at the National Institute for Materials Science.

First-principles simulations are used to investigate the mechanisms of material properties in order to discover new electrolyte materials for batteries. I propose promising new materials using data-driven science after searching a large number of candidates.

Masatoshi Hiraishi
Tokodi Institute for Element Strategy (TIES)
Currently at the High Energy Accelerator Research Organization

I investigate dilute hydrogen added as an impurity in such materials as semiconductors and solar cells using muons, one of the elementary particles, infer what occurs from the hydrogen behavior, and construct models for analysis.

This is the interesting part!

Synchrotron radiation x-ray diffraction uses x-rays with high brightness and directivity for measurements. Each measurement takes a short amount of time, enabling us to obtain detailed information on crystal structures. During the annealing process of sintered neodymium magnets, it is fascinating to track the moment-by-moment changes in the structure and quantity of crystals.

Wakana Ueno
Elements Strategy Initiative Center for Magnetic Materials (ESICMM)
Japan Synchrotron Radiation Research Institute (JASRI) / SPring-8

Lo Yu-Chieh
Elements Strategy Initiative for Structural Materials (ESISM)
Currently at the National Chiao Tung University

My focus is on investigating and developing leading structural materials and functional materials based on computational materials science. Knowing that I could provide new insight into existing assumptions is what makes my research fascinating.

While theoretical and computational chemistry is my area of expertise, most of my colleagues specialize in machine learning. I am conducting research with experimental researchers toward common objectives. Each researcher has their own strengths and expertise, and those moments that our talents mesh and complement each other are an indescribable joy.

Masaki Okoshi
Elements Strategy Initiative for Catalysts and Batteries(ESICB)
Currently at Panasonic Corporation

Research and dreams I want to pursue

Takao Shimizu
Tokodai Institute for Element Strategy (TIES)
Currently at the National Institute for Materials Science

Recent studies on ferroelectrics have produced crystal structures different from conventional perovskite structures, expanding the range of candidate substances. I hope to create ferroelectrics with well-known crystal structures.

Since I was a student, my dream has been to create the world's strongest magnet. Utilizing TDK' s strengths in materials technology and production and analytical techniques, I hope to realize that dream.

Liu Lihua
Elements Strategy Initiative Center for Magnetic Materials (ESICMM)
Currently at TDK Corporation

Shun Kondo
Elements Strategy Initiative for Structural Materials (ESISM)
Currently at Chalmers University of Technology (Sweden)
Overseas Research Fellow, Japan Society for the Promotion of Science (JSPS)

The mechanical properties of a material are largely influenced by their internal microstructures and textures, as well as their constituent elements. I would like to clarify these mechanisms to lay the foundation for developing new structural materials.

Message from a forerunner

Carry on believing that you can change the world with your own powers. — Masato Sagawa

Now is a splendid chance to be the one and only researcher in the world. — Akira Yoshino

In order to retain your convictions you need to thoroughly equip yourself with basic strengths. — Hiroshi Amano

Dig, and you will find water. And if you don't find water you're not digging deep enough. — Hideo Hosono

As the next leaders in materials research

Kim Junghwan
Tokodai Institute for Element Strategy (TIES)

Diverse researchers employ their individual methods and ways of thinking to achieve a single important objective. This is the power of the Element Strategy Initiative. Among these efforts, we expect to gain a concrete picture of research for "turning matter into usable materials."

We should strive to gain a better understanding of the physicochemical features in different environments such as adjacent atoms, co-present gas compositions, and thermal conditions. Strategies for controlling or enhancing features of elements may prove effective in future materials research.

Hiroshi Yoshida
Elements Strategy Initiative for Catalysts and Batteries(ESICB)
Currently at Kumamoto University

Yusukke Hirayama
Elements Strategy Initiative Center for Magnetic Materials (ESICMM)
Currently at the National Institute of Advanced Industrial Science and Technology (AIST)

In recent materials research, machine learning has made it possible to predict, without experimentation, the properties of materials to a degree. I hope to contribute to the creation of new materials by developing processes for synthesizing materials that have been thus far difficult to produce.

Ask the pioneers: What's next for materials science?

At the beginning, we introduced various materials produced in Japan that have changed the world. How was Japan able to achieve such groundbreaking accomplishments? And what is necessary for Japan to continue churning out such results? In the face of mounting global challenges, the various roles to be filled by new materials will continue to increase. I asked the founders of Japan's materials science to tell us based on their experience what Japan must do to retain its strength in materials science considering the limits on element resources.

Interviewer: Atsuko Tsuji

Completely new materials will be discovered by humans, not AI

Dr. Masato Sagawa, developer of the neodymium magnet

▶How were neodymium magnets created?

The strongest magnets at that time were samarium-cobalt magnets, but I felt that a strong inexpensive magnet could be produced by replacing cobalt with iron. This thought stayed with me until one day at a lecture I had the idea of incorporating boron. The experiments with boron proved promising, and I also found that neodymium worked well. We completed the actual neodymium magnet two months after I joined a magnet manufacturer called Sumitomo Special Metals. Two weeks after we applied for a patent, a similar application was filed in the U.S.

▶That was very close timing.

I think the manufacturing company played a major role by making the snap decision to invest in me as a venture and facilitate my research.

▶Thanks to your early action, magnet research was expanded as a major area in the Element Strategy Initiative.

We applied a deductive approach to advance from basic research to applications, expanding research into both industrial and academic areas, and I believe we produced some world-leading results. Surprisingly some of these results contradicted conventional theories on the role of boron in neodymium magnets, which has heightened the mystery.

▶It gives one a sense of profundity, does it not?

Magnets using iron cannot exist without boron, yet we still don't know the role of boron. Perhaps my initial idea was correct, but I don't know. One cannot produce something entirely new through deductive thinking alone. Trial and error is also indispensable. Even with our element strategy, we have great hopes of discovering through trial and error new magnets with the potential to be the strongest ever. I hope we continue to value such an approach.

A 1-g neodymium magnet can lift 3 kg of iron

Masato Sagawa

An advisor for Daido Steel Co., Ltd. who developed new materials for permanent magnets from a unique perspective, discovering a Ne-Fe-B (neodymium, iron, and boron)-based composition in 1982. Over the course of developing processing techniques, he perfected a composition for industrial use. Neodymium magnets are far superior to other types and have maintained their place as the strongest in the world.

▶Does it appear that AI will be of use?

AI is certainly powerful, but it is powerless to discover entirely new things. Only humans can do that. They may even discover a new magnet that does not use iron.

▶What does Japan need in order to grow its materials research?

A research system and training capable of challenging research on the creation of a new "core" is essential above all else.

Synergy among different fields will awaken Japan's potential

Dr. Akira Yoshino, developer of the lithium-ion battery

▶What were the main factors that led to the successful development of the lithium-ion battery?

Firstly, Japan's strength in materials science has supported its success in compact batteries. In other words, cathodes, anodes, electrolytes, and separators—the four main components of such batteries—were the culmination of new materials, which is Japan's specialty. My research was triggered by the conductive polymer polyacetylene, which had recently been developed by Mr. Hideki Shirakawa. While exploring applications for this polymer, I discovered it could be useful as an anode material, which had been an impediment to the development of new 2D batteries. This revelation led to my development of a carbon anode.

Discovering springboard materials and ascertaining their natures may ultimately lead to usable materials, even if the original materials do not prove useful. I think this process is important in materials research.

▶Advances were also made on battery research in the Element Strategy Initiative.

The introduction of computational science, which provided the second wheel of the cart to go along with empirical science, I think was a brilliant move for advancing battery research. Moreover, I believe that material informatics has been a great force recently in materials science. The next important step will be the synergy among dissimilar fields. For example, by combining computations with experiments and multiplying their results, you may come up with something even more extraordinary.

Lithium-ion batteries comprise four main elements.
© Asahi Shimbun and Pacific Press Service

Akira Yoshino

Honorary Fellow, Asahi Kasei Corp. Professor, Meijo University. In 2019, was awarded the Nobel Prize in Chemistry for developing the lithium-ion battery. Owing to their light weight, high-output, and ability to be recharged repeatedly, Li-ion batteries sparked the mobile age with their use in smartphones and other devices. More recently, they have been used in electric vehicles and have contributed to the realization of a society not reliant on fossil fuels.

▶The participation of companies is also important, is it not?

Absolutely. We used special carbon fibers developed by Asahi Kasei Corporation for our anodes as they have exceptional properties. One could not obtain these at a university. By cultivating an honest relationship between companies, their multiplication could awaken Japan's potential.

▶How should we handle the issue of rare elements like lithium?

There are three important approaches: production without use of rare metals, recycling, and sharing, such as repurposing solar cells at night.

▶Do you think AI will be helpful?

Japan is dominant in materials science and has amassed a lot of data, but the key will be how much failure data is incorporated into big data in the AI age. Without such data, AI will never become intelligent in the true sense but will provide incorrect answers. So perhaps we should collect failure data.

It is essential to create an environment for tackling difficult challenges

Dr. Hiroshi Amano,
developer of the blue LED

▶What were the main factors that led to the successful development of the blue LED?

The most important factor was the presence of Professor Isamu Akasaki, who led the way. We elected to use gallium nitride for the solidity of its crystal as Professor Akasaki, who had a strong spirit of commercial practicality, felt there was no point in research into something people cannot use, and was persistent in this tough stance. Materials that are easy to make have a short lifetime. When I was assigned to the Akasaki Laboratory, Prof. Akasaki showed me a crystal he had created during his research stint at Matsushita Electric Industrial, and I thought "this is it!" I became obsessed with it, not knowing how difficult it would be.

▶And now you are working on the development of high-frequency, high-voltage devices using the same gallium nitride?

The blue LED was born from a preference for gallium nitride.
© Asahi Shimbun and Pacific Press Service

Hiroshi Amano
Professor, Nagoya University. Director of the Center for Integrated Research of Future Electronics at the Institute of Materials and Systems for Sustainability. Awarded the 2014 Nobel Prize for Physics together with Isamu Akasaki and Shuji Nakamura for the development of a blue LED from high-quality gallium nitride. Currently working on developing next-generation power devices using gallium nitride.

Such power devices also require the use of tough materials. I believe that research must be thought through all the way to an innovative achievement. To earn the trust of a company, it's important to take the first steps at a university and demonstrate actual viability.

▶In the Element Strategy Initiative, you have also been applying a coherent approach from theory to materials discovery.

Elucidating the mechanisms of functional expression and achieving that expression with a different element is a magnificent scientific and design technique. On the other hand, substitution techniques have the potential for increasing costs. So I think it is crucial to set comprehensive R&D objectives in coordination with the research system.

As for eventual applications, there are limitations for what a single material can do. I would rather use materials in combination to expand the number of applications. For example, developing a system using deep UV LEDs to inactivate coronavirus would require various new materials that do not degrade under UV light. I would like to see more efforts toward encouraging new collaborations through information sharing.

▶Gallium is also a rare element.

The gallium reserves are mostly confined to China, but aluminum, which belongs to the same group, can be refined from bauxite. Thus, bauxite-producing countries such as Guinea and Australia have the potential to become gallium-producing countries. There are likely other elements that have been needlessly discarded due to the nation not understanding their commercial value or not having the necessary refining technology. Thus, cooperation with resource-rich countries from a technological and business standpoint, as well as building good relationships with those countries on an administrative level, will likely be essential.

▶What will be needed for future research growth?

Above all else, it will be important to create an environment for taking on difficult challenges and particularly a system in which young researchers can feel secure in tackling such challenges. I'm convinced that there are no challenges that cannot be overcome by combining the best fields and personnel for the various projects and I expect we will develop a strategy and organization that will enable us to compete with the rest of the world.

A 65-inch OLED display using IGZO, gifted by LG.

Hideo Hosono
Institute Professor and Honorary Professor at the Tokyo Institute of Technology. Director of the Materials Research Center for Element Strategy. Produced such outstanding research achievements as the creation of iGZO semiconductors used in LCD and OLED TVs, the development of a method to synthesize ammonia at low temperature and pressure using electrides expected to have a ripple effect throughout the energy industry, and the discovery of an iron-based superconductor that defies conventional wisdom.

Creating a system that allows free rein to impertinent youth

Dr. Hideo Hosono,
developer of the IGZO semiconductor

▶What's your secret to continually producing such diverse achievements like IGZO, iron-based superconductors, and synthetic ammonia catalysts?

The properties of a material are not determined by their elements alone. Structure is also important because structure affects states of electrons and states of electrons determine the function of the material. The key is connecting structure to function. I felt that there was no reason iron could not be used to make a superconductor, so I actually made one. I was told that glass would not make a good semiconductor, so I designed and created IGZO. Throughout, I have worked only with electrons.

▶Your work seems closer to physics than chemistry.

More like physics + chemistry. The key is "tunneling," whereby electrons pass smoothly through a barrier. To me, that is what's interesting in materials science. However, unlike those who study condensed matter, I am always considering the "use" of matter as a material. Above all else, I am searching for chemical stability, not simply good performance at instantaneous wind speed. If it can be used, it is a material.

▶I suppose companies play a major role in what is used.

Manufacturing materials on actual machinery at a production site produces better performance. A company also helped resolved issues I had with IGZO. The role of the researcher is to develop materials that make the company want to use them even if it takes time and effort.

▶Which is the aim of the Element Strategy Initiative, isn't it?

Yes. It is important to develop new scientific concepts. In the Element Strategy, foundations were consistently established on new science, and we were free to conduct research to produce desired outcomes. This pursuit is expected to realize materials that can be produced worldwide without reliance on rare elements, which is the objective of the Element Strategy Initiative.

▶What is essential to continue producing new concepts?

You can't conduct materials research among only materials researchers. It is necessary to cross boundaries and break molds, and we need a system and funding to do that. I am particularly hopeful for such impertinent youths who make declarations like, "It's not as simple a problem as the professor thinks." I want to create a system with no social order in which these people can work freely. Naturally, it's also important to challenge the senior researchers to compete. I'd like to create an environment in which young people can thrive without being coddled.

Final Thoughts

These interviews made me realize once again the important role that companies play. Drs. Sagawa and Yoshino talked about the indispensable assistance they received from companies, and Dr. Akasaki's corporate experience also proved to be key. Thus, the importance of industry-academia collaboration in the true sense of company involvement is an opinion shared by all. They also talked about the need for university researchers to take a step forward and the company-side to have an eye toward technology. I look forward to the Element Strategy Project creating more opportunities for collaboration in order to produce more world-changing achievements.

Atsuko Tsuji
Professor, University Research Administrator Organization, Chubu University. Was engaged in science-based reporting at Asahi Shimbun and, from 2004 through 2013, was an editorial writer in charge of editorial articles on science and technology and medicine. Became a designated professor for Nagoya University International Organization in October 2016. For three and a half years, published *Nagoya University Watch* on the university's website showing the university from a journalist's perspective. Nagoya University also published a paperback edition with the same themes. Was appointed to her present position in June 2020.

Leading the world with “Element Strategy”

— Striving for further development —

Japan developed the concept of an element strategy sixteen years ago to use science for solving problems related to element resources. These efforts have created numerous materials with innovative functions and have contributed to the creation of an enriched, sustainable society. Though originating in Japan, this concept is shared in all countries of the world and similar efforts have been advanced on a global scale. In fact, these efforts may be entering a phase of global competition with science-based initiatives being implemented in a competitive atmosphere. Resource-poor Japan should play a key role in guiding the world by contributing its scientific and technological might, which are grounds for the continued and even enhanced implementation of these efforts as a national project.

We are prepared for this possibility. Through our efforts thus far, we have constructed an infrastructure for Japan’s materials science research and have developed many young researchers to lead the next generation. Further development of the Element Strategy Initiative as a national strategy is needed for developing innovative solutions.

Program Director, Element Strategy Initiative:
To Form Core Research Centers

Kohei Tamao
President, Toyota Physical and Chemical Research Institute

“Element Strategy”
for tackling issues of element resources with science and for building a sustainable society with innovative materials

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