Section 3 ■ Returning the Results of Science and Technology to the Society - Utilization of Knowledge –

1 Results of science and technology that have changed the society

(1) Maintaining health and overcoming diseases

Advancement in science and technology has improved the standards of medical practice, nutrition, and hygiene conditions. On the other hand, however, health maintenance is now facing new challenges such as how to deal with various metabolism-related syndromes (obesity, diabetes, hyperlipidemia, high blood pressure, hyperuricemia, etc.) as well as cancer. Rapid internationalization is also making it necessary for us to prepare for unknown infectious diseases.

Here, we give examples of "utilization of knowledge" involved in the development of therapeutic technology and medicinal products.

("Heavy Ion Cancer Treatment" to overcome "Cancer"[18])

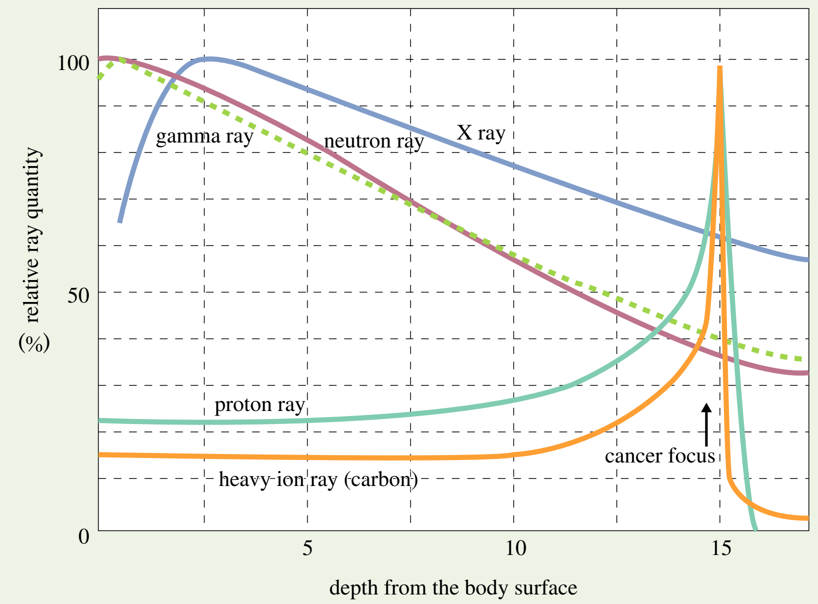
In 1993, the world's first heavy-ion cancer treatment equipment (HIMAC, or Heavy Ion Medical Accelerator in Chiba)[19] was built, and 3,178 patients received cancer treatment between the beginning of its clinical trial in 1994 and the end of 2006.

Treatment by radiation has advantages such as not burdening the patients because neither anesthesia nor surgery by incision is necessary. In heavy ion cancer treatment, in particular, the concentration of the beam is so high that interference to benign systems can be kept minimum by aligning the beam peak right to the cancer-damaged spot; in addition, because the heavy ion beam has a powerful ability to annihilate cancer cells, it is expected that even types of cancer that could not have been sufficiently eliminated by conventional radiation can be treated this way (Figure 7).

The National Institute for Radiological Sciences began doing research and development in technologies that would lead to size reduction, with the goal of having heavy ion cancer treatment equipment all over the country; their result has made it possible to obtain a beam with a performance equivalent to the current beam performance, with equipment about 1/3 of the size of the HIMAC. With this success, in 2006, Gunma University began building a small-size trial unit.

[18] Heavy ions refer to particles larger than protons; at the National Institute of Radiological Sciences, carbon rays are used.
[19] HIMAC (Heavy Ion Medical Accelerator in Chiba): heavy ion cancer treatment equipment

■ Figure 7 Comparison of various types of radiation and heavy ion radiation



Source: National Institute of Radiological Sciences

(Detecting infectious diseases)

In February 2003, in the province of Guangdong of China, 305 people were infected with an acute respiratory illness, and 5 of them died. The cause was the SARS (Severe Acute Respiratory Syndrome) corona virus.

Under these circumstances, a research group led by Hiroshi Yoshikura, the director-general of the National Institute of Infectious Diseases of the Ministry of Health, Labour and Welfare, carried out the project "Urgent Research Study on the Diagnostic and Testing Methods of SARS." They developed a method for detecting the SARS virus and a method for identifying a viral respiratory infectious disease.

The SARS test sample developed in this project is able to detect the virus within 20 minutes; it was jointly developed by Prof. Koichi Morita (Institute of Tropical Medicine, Nagasaki University), Dr. Masato Tashiro (National Institute of Infectious Diseases), and Eiken Chemical Co., Ltd.

(Overcoming lifestyle-related diseases - development of medicine to lower the cholesterol level)

Coronary artery diseases (cardiac arrest, cardiac infarction, etc.) due to a high blood-cholesterol level are becoming a very serious type of illness in Japan, second only to cancer. The development of "statin drugs[20]," later referred to as the "penicillin of arteriosclerosis and cholesterol," was aided by significant contribution of the research results of Dr. Akira Endo (currently the director of the Biopharm Research Laboratories, Inc. and professor emeritus of Tokyo University of Agriculture and Technology).

[20] "Statin" refers to any substance that lowers cholesterol in the blood (an anti- cholesterolemic agent). According to fundamental clinical research in recent years, statin is proved effective for Alzheimer's disease and osteoporosis as well.

Dr. Endo, after graduating from Tohoku University, began doing research at a pharmaceutical company in 1957. After his 2-year experience of studying in the United States (at the Albert Einstein College of Medicine in New York as a postdoctoral researcher), he moved on to the Tokyo University of Agriculture and Technology in 1979, and there discovered a substance called "Manacolin K" (a.k.a. mevinollin, lovastatin) from a mold (fungus) called "*Monascus purpureus*" (beni koji mold, red malt mold)[21]. About the same time, the same substance was discovered from a different fungus by the U.S. pharmaceutical company Merck. The discovery of this substance was a breakthrough, leading to speedy advancement in the development of statin drugs afterwards.

Sales of statin drugs began in 1987 in the United States and 1989 in Japan.

(Medicines made from "immunology," a strength of Japan)

Medicine that uses the operation of the defense system called "immunity," with which human bodies are equipped, is called antibody medicine.

Tocilizumab (humanized anti-human interleukin-6 (IL-6) receptor antibody)[22] is an antibody medicine originated in Japan, and it is the world's first IL-6 inhibitor. Results of basic research conducted at Osaka University led to the invention of a medicine against Castleman's disease[23] in 2005 through subsequent collaboration with Chugai Pharmaceutical Co., Ltd. At present, this medicine is going through a clinical study for its effectiveness in "joint rheumatism."

In 1986, Prof. Tadamitsu Kishimoto discovered the genes of IL-6 for the first time in the world. Chugai Pharmaceutical Co., Ltd., which was doing research on antibodies against lymphocytes, began its collaborative research with Osaka University, and joint work also began with the MRC National Institute for Medical Research in UK. Then Prof. Kazuyuki Yoshizaki, et. al. discovered that Castleman's disease is caused by IL-6, and clinical trials were carried out by Prof. Norihiro Nishimoto, et. al. All these events led to the development of the first antibody in Japan.

At Osaka University, there is a powerful school of immunology research; there is an accumulation and succession of knowledge, beginning with Prof. Yuichi Yamamura, a former president of the university, a pioneer in cancer immunity treatment, and the first president of the Japanese Society for Immunology, going down to Prof. Kishimoto, and, more recently, Prof. Akira. The knowledge and accumulation of the basic research on lymphocytes and immunity done by Prof. Kishimoto led to the prediction of the existence of IL-6, which was yet unknown. Then Dr. Toshio Hirano (currently a professor at Osaka University), without any of today's high-performance analyzing equipment, isolated the IL-6 genes after 8 years of hard work; this achievement provided the most crucial key to the success. Then, the production of a mass culture of antibodies, which is a technological strength of a corporation, enabled the clinical trial.

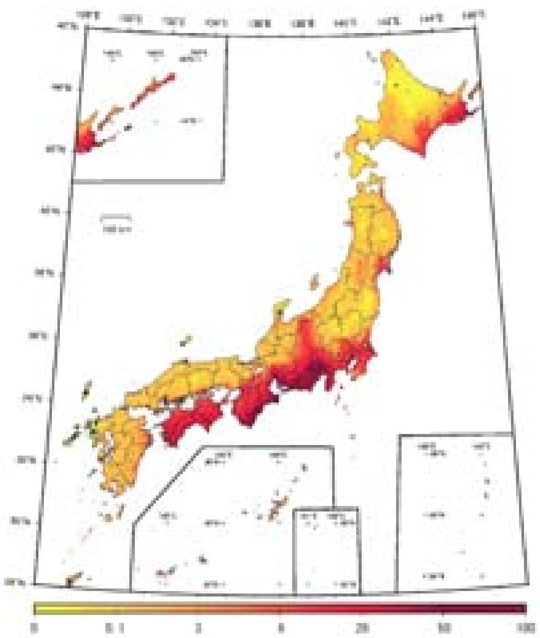
This is an example where the "knowledge" and "people" developed by basic research enabled the research results to make their way back to society through collaborative research with a company.

[21] Red malt has been used as health food since ancient times in China. It is used in red bean curds, Chinese white liquors (*shaoxingjiu*), vinegar, and food additives (red coloring), as well as Chinese medicine.
[22] Interleukin (IL) is a protein secreted by white blood cells and is a substance with an immunity function. To date, over 30 types are known. Among them, IL-2 is used for immunity treatment for cancer.
[23] Castleman's disease is a lymphoproliferative disorder with about 1500 patients in Japan. The medicine for its treatment is designated as an orphan drug under the Pharmaceutical Affairs Law.

Column 3: "Toward a Safe and Secure Society"

1. "Seismic Prediction Map" (introducing the Probabilistic Seismic Hazard Map of Japan, created by the Headquarters for Earthquake Research Promotion, in which all predicted earthquakes in the future are taken into account and the quakes in every square kilometer of every part of the Japanese islands are predicted)

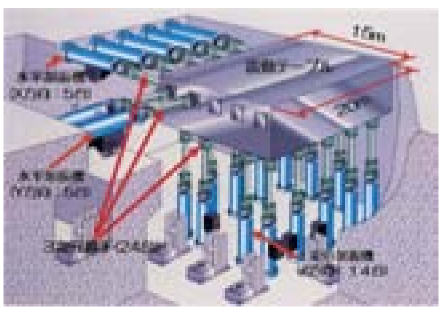
Probabilistic Seismic Hazard Map of Japan



Probability (%)

Source: Headquarters for Earthquake Research Promotion

2. "Earthquake resistance experimental research using E-defense" (introducing the 3-dimensional full scale earthquake testing facility ("E-Defense") of the National Research Institute for Earth Science and Disaster Prevention, which is capable of simulating damage and collapse of structures by applying powerful shaking to the actual structures)



E-Defense earthquake table

Wooden-house collapsing experiment

Source and photo provided by the National Research Institute for Earth Science and Disaster

3. "Daichi," Advanced Land Observing Satellite (ALOS) (Introducing "Daichi" (ALOS), an advanced land observing satellite developed by the Japan Aerospace Exploration Agency and launched on January 24, 2006, on H-IIA rocket 8 at the Tanegashima Space Center)

4. Japan's space technology found in everyday life - spin-off (examples of how technologies originally developed for space are used in our daily lives (spin-off; technology transfer))

■ Ignition technology for solid rockets
⇒ applied in airbags by Nissan Motors, Co., Ltd.
■ Structure design technology for weight reduction and enhanced strength for rockets, etc.
⇒ diamond-cut cans by Toyo Seikan Kaisha, Ltd. ("Hyoketsu," a canned liquor by Kirin Brewery Co., Ltd.)
■ Heat insulator technology for rocket tip
⇒ insulator coating for construction
■ Washing technology for space
⇒ washing machines
■ H-II rocket joint technology
⇒ Seismic-isolation multilayer rubber bearings
■ Sensor technology for each observation satellites
⇒ sugar content sensor for fruits
■ Explosion blast propagation simulation program in rocket launching
⇒ the engine (leading) vehicle design in linear-motor cars and bullet trains

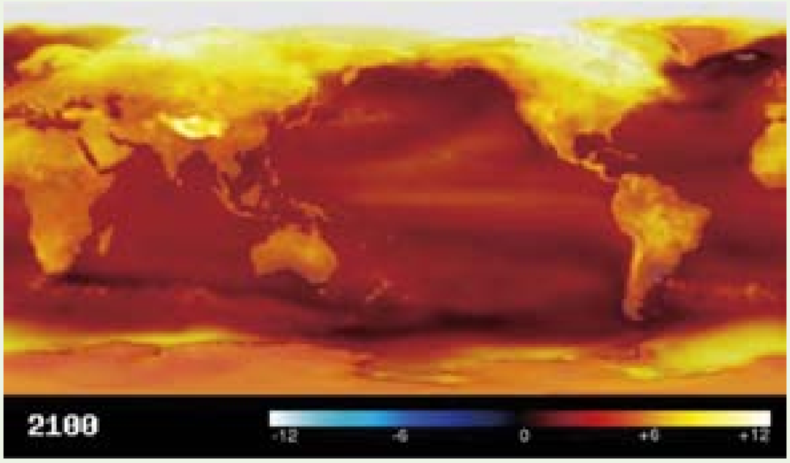
(2) Harmony between human activities and the earth's environment

(Future prediction of the earth's environment by the Earth Simulator, etc.)

The Earth Simulator is a supercomputer with the highest level of computation capabilities in the world as of the time of the commencement of its operation, which was 2002.

Various conditions of the earth can be simulated by the Earth Simulator. In particular, its simulation of global-level climate changes has contributed significantly to the research in the field of global environment. The Fourth Assessment Report (February 2, 2007) of the United Nations' "Intergovernmental Panel on Climate Change" (IPCC) quoted many of the results of Japanese researchers that have used the Earth Simulator, including "Calculations to Predict Global Warming to A.D. 2100," carried out by Profs. Akimasa Sumi and Masahide Kimoto of the Center for Climate System Research at the University of Tokyo, Dr. Toru Nozawa of the National Institute for Environmental Studies, and Seita Emori, the group leader of the Frontier Research Center for Global Change at JAMSTEC (Figure 8).

■ **Figure 8 Simulation results of global warming 100 years from now**



Sources: Center for Climate System Research at the University of Tokyo, National Institute for Environmental Studies, Frontier Research Center for Global Change

(Photovoltaic power generation)

To address global warming, it is urgent to further promote science and technology related to the environment, energy, and resources. To this end, the importance of R&D in photovoltaic power generation is ever increasing.

Practical implementation of solar cells did not begin until 1954, when silicon solar cells were developed in the U.S. They were first used in Japan in 1958, but it was not until the mid 1960s when their mass production was planned. Incidentally, the generating efficiency of the silicon solar cells developed in the U.S. was about 6% whereas the efficiency of solar cells now is about 12 to 15%. It is said that theoretically an efficiency of 30% could be attained.

In 1993, "the New Sunshine Plan" was begun, in which the New Energy and Industrial Technology Development Organization promoted R&D on common basic technology for photovoltaic power generation systems and cost reduction of photovoltaic power generation. As a result, they advanced the technology that allowed them to reach the target, "keeping the manufacturing costs at 140 yen or less per watt," which they had hoped to reach by year 2000. Through these technology-developing projects, Japan now has about half of the production share of the world's solar cells.

(3) Toward more convenient and pleasant daily life

(Realization of large-capacity memory units by perpendicular magnetic recording system)

With increased storage capacities of hard disk drives (HDDs), it is now possible to record a long TV program; with smaller, lighter video players, we can carry the images around and enjoy them anywhere. Notebook PCs are getting even smaller and lighter. Our lifestyles are thus changing drastically.

It was thought that the longitudinal magnetic recording method used in conventional HDD units would soon push the HDDs to their limits in terms of increasing their capacities and reducing their sizes and weights.

It is said that the perpendicular magnetic recording method can break these limits and increase the capacity beyond 8 times as much as the conventional longitudinal magnetic recording method can. This method is already in use by Japanese companies to make 2.5-inch HDD units in the class of 200 gigabits per square inch.

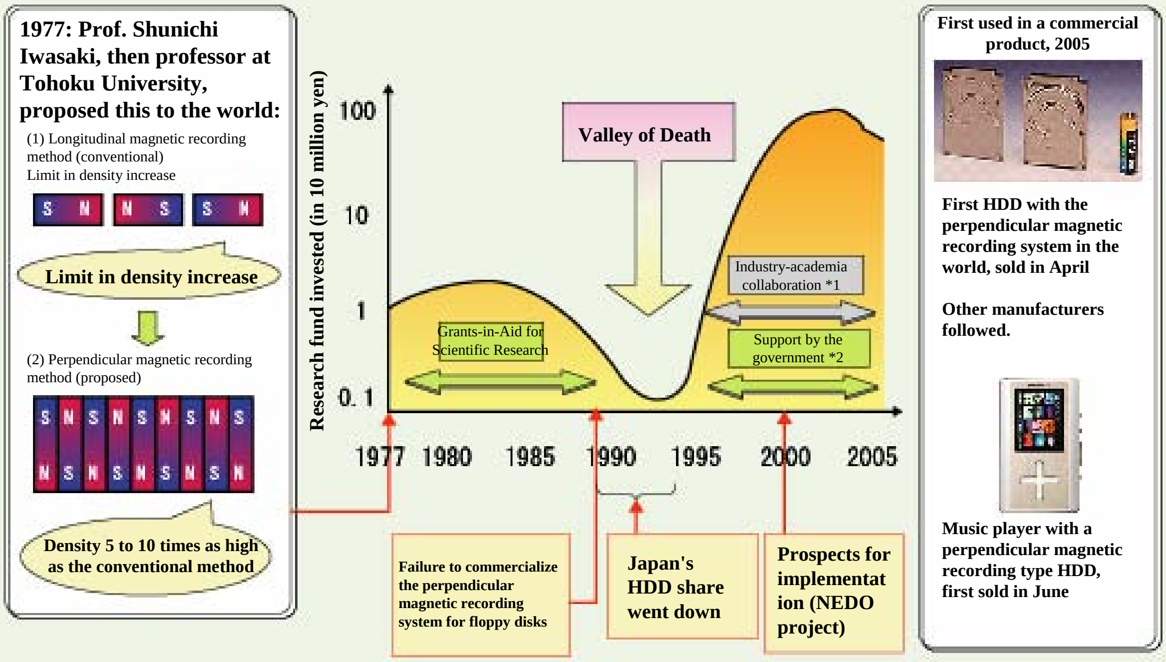
Prof. Shunichi Iwasaki, who at that time was professor at Tohoku University, began his research on magnetic storage back in 1951. In 1977 he announced the high density of the perpendicular magnetic recording system in an international conference; this attracted a lot of attention as a future technology. However, partly because its implementation was originally attempted for flexible disks[24], there was a period of uncertainty between the late 1980s and the early 1990s. In 1989, Prof. Iwasaki retired, at which time the research at Tohoku University was inherited by Prof. Yoshihisa Nakamura (currently of the Japan Science and Technology Agency), who had been supporting Prof. Iwasaki up to that time. He switched the research to a research project on HDD using the perpendicular magnetic recording system, but the technology of HDD using the longitudinal magnetic recording method continued to be improved, even leading some to conclude that the perpendicular magnetic recording method is unnecessary. The break came around 2000. When the conventional method actually approached its limitations, students taught by Profs. Iwasaki and Nakamura finally implemented the perpendicular magnetic recording method in the private sector. This triggered a rapid increase in the HDD market, which was about 2.5 trillion yen in 2004 but is expected to be as much as 6 trillion yen in a few years. All HDD units are very likely going to be replaced with those using the perpendicular magnetic recording method.

Throughout this period, public funding continued. During the 1970s and 80s, when Prof. Iwasaki proposed the new method, there was continual support for basic research by the university and public funding such as Grants-in-Aid for Scientific Research. At some points, the advancement in the longitudinal magnetic recording method questioned the need for implementing the new method, leading even to the opinion that it is unnecessary; however, the basic research funding by the university went on without ceasing, supporting the research. The innovative value of the perpendicular magnetic recording method was still highly recognized even after that time, and the research received support from various sources, including industry-academia-government collaboration, the Japan Society for the Promotion of Science, the New Energy and Industrial Technology Development Organization, and the “IT Program” by MEXT (Figure 9).

When the longitudinal method reached its limits, the need for HDD using the perpendicular magnetic recording method skyrocketed. Finally in 2005, a domestic HDD manufacturer began making products using this technology. One can thus say that this technology saw its fruition because of the significant contribution made by long-term public funding.

[24] Generally, these are referred to as floppy disks (FDD), but the JIS uses this term.

■ Figure 9 Public funding that supported the perpendicular magnetic recording method: "through the valley of death"



*1 SRC: Storage Research Consortium (interested parties in the industry and Tohoku University) (1995-)
*2 NEDO (New Energy and Industrial Technology Development Organization) of METI (1996-2002), Japan Society for the Promotion of Science (1999-2003), and MEXT (2002-2007)
Prepared by the Council for Science and Technology Policy of the Cabinet Office (Council for Science and Technology Policy 47th session, June, 2005) based on sources from Prof. Yoshihisa Nakamura of Tohoku University

(Practical use of blue light-emitting devices)

Modern traffic lights which use LEDs (Light Emitting Diodes) allow the lights to be distinguished clearly and significantly reduce the consumption of power.

LEDs are also introducing many other new products such as large outdoor color displays and cellular phones with color liquid crystal displays, continuing to cause big ripple effects in our society economically and socially.

Regarding the three primary colors[25], red and green LEDs were already in use in various aspects of our daily lives by inventions of people such as Jun-ichi Nishizawa, then professor at Tohoku University. However, the last of the three colors, blue LED, was extremely difficult to produce, and its implementation had long been anticipated. Eventually various researchers and research groups, independently, made progress toward this goal, including a group led by Prof. Isamu Akasaki and Prof. Hiroshi Amano (of Nagoya University at the time), Mr. Takashi Matsuoka, a researcher in the private sector (a researcher at the NTT Basic Research Center at the time; now at Tohoku University), and Dr. Shuji Nakamura (of Nichia Corporation, Ltd. at the time).

There were two candidates for blue LEDs: zinc selenide and gallium nitride. While most researchers chose the former, it was the researchers who gambled on the possibility of gallium

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[25] The three primary colors for light are red, green, and blue. All colors are combinations of these three. Mixing all of these colors, red, green, and blue results in white (color of solar light and a fluorescent light).

nitride, of which high-quality crystals were difficult to make, that eventually produced the revolutionary result.

For this accomplishment, Dr. Nakamura won the Millennium Technical Prize, awarded with support of the government of Finland in 2006.

The Japan Science and Technology Agency summarizes the economic ripple effect of the contracted development project “Manufacturing technology for gallium nitride (GaN) blue LEDs” as follows. During the 9-year period from 1997 to the end of 2005, the total sales of application products reached approximately 3.6 trillion yen. As direct results, this has created almost 350 billion yen of add-on value to the industry of Japan and about 32,000 new jobs. It also brought in royalty revenues of approximately 4.6 billion yen to the government.

Column 4: “Carbon nanotube: a new material that will change the society” (discovery of carbon nanotubes and carbon nanohorns by Dr. Sumio Iijima (Special Senior Researcher at NEC, Professor in the Faculty of Science and Technology, Meijo University), introduction of “Drug delivery system (DDS) directly attacking cancer cells using carbon nanohorns with anticancer drugs,” a joint project of NEC, Cancer Institute of the Japanese Foundation for Cancer Research, and the Japan Science and Technology Agency)

2 Industry-academia-government collaboration: a key to application of science and technology results

(1) Industry-academia-government collaboration steadfastly planted

By the promotion of policies regarding industry-academia-government collaboration based on the Second Science and Technology Basic Plan, accomplishments of joint research by universities and companies have drastically increased; the number of joint research projects at national universities, etc. in 2005 exceeded 13,000 if all national, public, and private universities are combined. The total amount of research funds given to universities, etc. by research institutions was 32.3 billion yen in 2005, the highest amount ever.

The number of contract research projects at national, public, and private universities, etc. was 16,960, with 126.5 billion yen in contract research projects fees, both numbers being highest in history. Meanwhile, during the 5-year period covered in the Second Basic Plan, the number of patent applications submitted by national universities, etc. grew to about 10 times the number at the beginning of the period, indicating a remarkable accomplishment.

(2) Examples of results of industry-academia-government collaborative research

(Metallic glass)

Metallic glass is a metallic material created in Japan. It is different from metal, which has a crystal structure, in that the atomic configuration is “random and dense”; it is a revolutionary metallic material which is strong, flexible, rust-resistant, smooth-faced, and easy to fabricate.

This field of research was initiated by a group led by Dr. Akihisa Inoue, then director of Tohoku University’s Institute for Materials Research and currently president of Tohoku University. Many metallic glass materials were discovered in the 1980s, and researchers found the conditions under which metals change to glass, the structure of metallic glass, and its properties in the 1990s.

Later this topic was selected to be a project by the New Energy and Industrial Technology Development Organization. The micro-geared motor was developed through a joint project of the Institute for Materials Research at Tohoku University, R&D Institute of Metals and Composites for Future Industries (RIMCOF), Namiki Precision Jewel Co., Ltd., and YKK Corporation. A type of pressure sensor was also developed through a joint project of the Institute for Materials Research at Tohoku University, RIMCOF, Nagano Keiki Co., Ltd., and YKK Corporation.

(Development of intelligent emission catalyst for automobiles)

The automotive emission standards have become more restrictive since the 1990s around the world, drastically raising the price of palladium, which is used as a catalyst. An “intelligent catalyst” self-regenerates palladium (the catalyst) as the vehicle is driven. The depletion of palladium is extremely small, and the performance in purifying the exhaust gas does not deteriorate, thus greatly reducing the amount of palladium used.

The self-regenerating function of an intelligent catalyst was discovered by Dr. Hirohisa Tanaka, et. al. of Daihatsu Motor Co., Ltd. in the 1990s. Together with Dr. Yasuo Nishihata of the National Institute of Japan Atomic Energy Development, they explained the principle of the self-regenerating mechanism using a large synchrotron radiation facility called SPring-8.

Trial calculations showed that over 100 tons of precious metals for automotive catalysts can be saved per year, so the prices of precious metals are expected to stabilize.

(3) Project to create knowledge clusters

A “knowledge cluster” refers to a technology-innovation system directed under a regional initiative, centered on a public research institution such as a university, with participants coming from in and out of the region, including companies. The seeds of the public research institution and the companies’ need for implementation are joined, enabling new industries to be created. A project to create these knowledge clusters was carried out in 18 regions across the nation as a five-year project of MEXT from 2002 to 2006 (12 regions in 2002 when it began).

(Involvement in regional science and technology promotion in the Hamamatsu area)

In the “knowledge clusters creation project” of the Hamamatsu area, active efforts are made to train coordinating human resources, led by the Organization for Hamamatsu Technopolis, the core institution. Science and technology coordinators, well familiar with the regional collaboration situations, use their information and human networks in “imaging technology project research consortium” that are held to provide an organic meeting place of the industry, academia, and government. This type of coordination of a structure necessary for the project’s collaboration and thorough progress management are bringing forth solid advancement in the collaboration. Through human-resource training that promotes the region, for instance, by involving the region’s technical high schools (not just universities), the project is having extensive influence on the greater

Hamamatsu area.

(Detailed inspection of metal materials by X-ray)

The first result of the industry-academia-government collaboration under the knowledge clusters creation project in the Hamamatsu area was the “X-ray imaging device equipped with the energy-identification function,” a result by an industry-academia collaborative project by Dr. Yoshinori Hatanaka of the Research Institute of Electronics, Shizuoka University (at the time), Dr. Toru Aoki, and Hamamatsu Photonics K.K.

By detecting the difference in the X-ray energy going through an object or a material, this allows one to identify very small bumps and dents on the metal surface and in the internal structure for each material, thus contributing to increased reliability and accuracy in non-destructive inspection. In addition, an imaging device that measures the wavelength difference of the penetrating X-ray and indicates it using colors was developed as a product.