The 3rd International Evaluation of Strategic Basic Research Program

Document for Evaluation

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Japan Science and Technology Agency

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Chapter 1 .   Overview of International Evaluation

Section 1 . Purpose of International Evaluation

The Strategic Basic Research Programs [hereafter refers to “Strategic Basic Research Programs (for creating the Seeds” for New Technologies)*” unless otherwise noted], run by the Japan Science and Technology Agency (JST), have undergone two international evaluations[1] from an international perspective (The first evaluation was in 2006 and the second in 2011).

The upcoming third international evaluation will focus mainly on the five year period (FY2011-2015) since the previous international evaluation and evaluate the overall Strategic Basic Research Programs based on the initiatives for promoting target-oriented basic research, their results and ripple effects as well as seek advice and proposals for initiatives that serve the creation of science, technology and innovation (STI) and thus JST must take on going forward.

*The specific programs for evaluation are CREST, PRESTO, ERATO, ACCEL, and ACT-C.

Section 2 . Placement of the International Evaluation of the Strategic Basic Research Programs

The evaluations related to the Strategic Basic Research Programs include a corporate evaluation; an international evaluation, an evaluation of research areas, and an evaluation of research projects (refer to Fig. 2-17). This round of the international evaluation will be performed one year prior to the conclusion of the 3rd term of the period of the mid-term plan (FY 2012-1016).

Section 3 . Evaluation Procedure

The evaluation committee comprises experts selected by JST from Japan and abroad who will evaluate the overall Strategic Basic Research Programs. The evaluation results are reported to the President, the Program Director Committee, and the JST Operations Committee. The results are also published on the website.

Section 4 . Evaluation Perspective and Criteria

In light of the purpose outlined in Section 1, the new schemes and operation methods implemented from 2011 that are based on past Strategic Basic Research Programs schemes and operation methods and the challenges presented to JST from the second international evaluation will be evaluated to assess whether the programs have been operated appropriately for creating STI.

Furthermore, from the viewpoint of the representative research output from the programs,
the evaluation will assess the outcome from the ripple effect that is conducive to the creation of STI and the nurturing of next generation research leaders.Given the perspective above, the criteria below will apply for the international evaluation.

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[1]Based on regulations for conducting Strategic Basic Research Programs (Excludes RISTEX and ALCA).

1. Evaluation on system and management
2. Evaluation on research output and outcome

Section 5 . The 3rd International Advisory Committee for the Evaluation of JST Strategic Basic Research Program List of Members

The International Advisory Committee is composed of experts from both Japan and abroad.

Chair

Shinichi Hirano*	Zhiyuan Chair Professor and Director of Hirano Institute for Materials Innovation, Shanghai Jiao Tong University (Past President of Nagoya University and former President of National Institution for Academic Degrees and University Evaluation of Japan)

Members

Tsuneya Ando*	Professor, Tokyo Institute of Technology
Hajime Hikino	Member of Editorial Board, Tokyo Chunichi Shimbun Co., Ltd.
Kazue Kurihara	Professor, Advanced Institute for Materials Research, Tohoku University Professor, Institute of Multidisciplinary Research for Advanced Materials, Tohoku University
Toshiyuki Nakata	Professor, University of Tokyo
Masahiro Nishijima	President, Showa Pharmaceutical University
Nobuyuki Osakabe	CTO, Healthcare Company, Hitachi, Ltd.
Per Eriksson*	Special Adviser, Lund University (Former President of Vinnova)

Anne Glover	Vice Principal for External Affairs and Dean for Europe, University of Aberdeen (Former Chief Scientific Advisor to the President of the European Commission)
Andy Hor Tzi Sum	Vice-President and Pro-Vice-Chancellor, the University of Hong Kong (Professor, National University of Singapore and Director of IMRE, A*STAR)
Matthias Kleiner	President, the Leibniz Association (JST Operation Committee member, Former president of DFG)
Edison T. Liu*	President and CEO, The Jackson Laboratory (Former President of Human Genome Organization (HUGO))

*Previous member of International Advisory Committee.

Chapter 2 . Structure and Operations of Strategic Basic Research Programs

Section 1 . S&T Policies of Different Nations

1. Overview of Japan's S&T Policy

(1) Science and Technology Basic Plan

The Science and Technology Basic Law was established in 1995 on the ideal of "achieving a higher standard of science and technology (hereinafter referred to as "S&T"), to contribute to the development of the economy and society in Japan and to the improvement of the welfare of the nation as well as to contribute to the progress of S&T in the world and the sustainable development of human society."[2]

This law was established against the backdrop of economic stagnation in Japan and exports that had been hurt by the steady increase in the value of the yen as well as predictions of the aging of society and increasingly fierce international competition in the future. Amidst these trends, there was active debate about the need for "the founding of a nation based on the creation of S&T" that could use Japan's intellectual resources to create new industries and ensure the long-term growth of the nation as well as helping to resolve the many problems facing humanity.[3]

Based on the Science and Technology Basic Law, a three-phase, 15-year plan called the Science and Technology Basic Plan ("Basic Plan") was formulated. Through the execution of this plan, Japan's investment in research and development has been expanded despite the difficult financial situation. Japan has also scored numerous achievements and produced some of the world's leading research findings.

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[2] The 4th Science and Technology Basic Plan
[3] JST "Panoramic View Report of Research and Development"(CRDS-FY2013-FR-07)

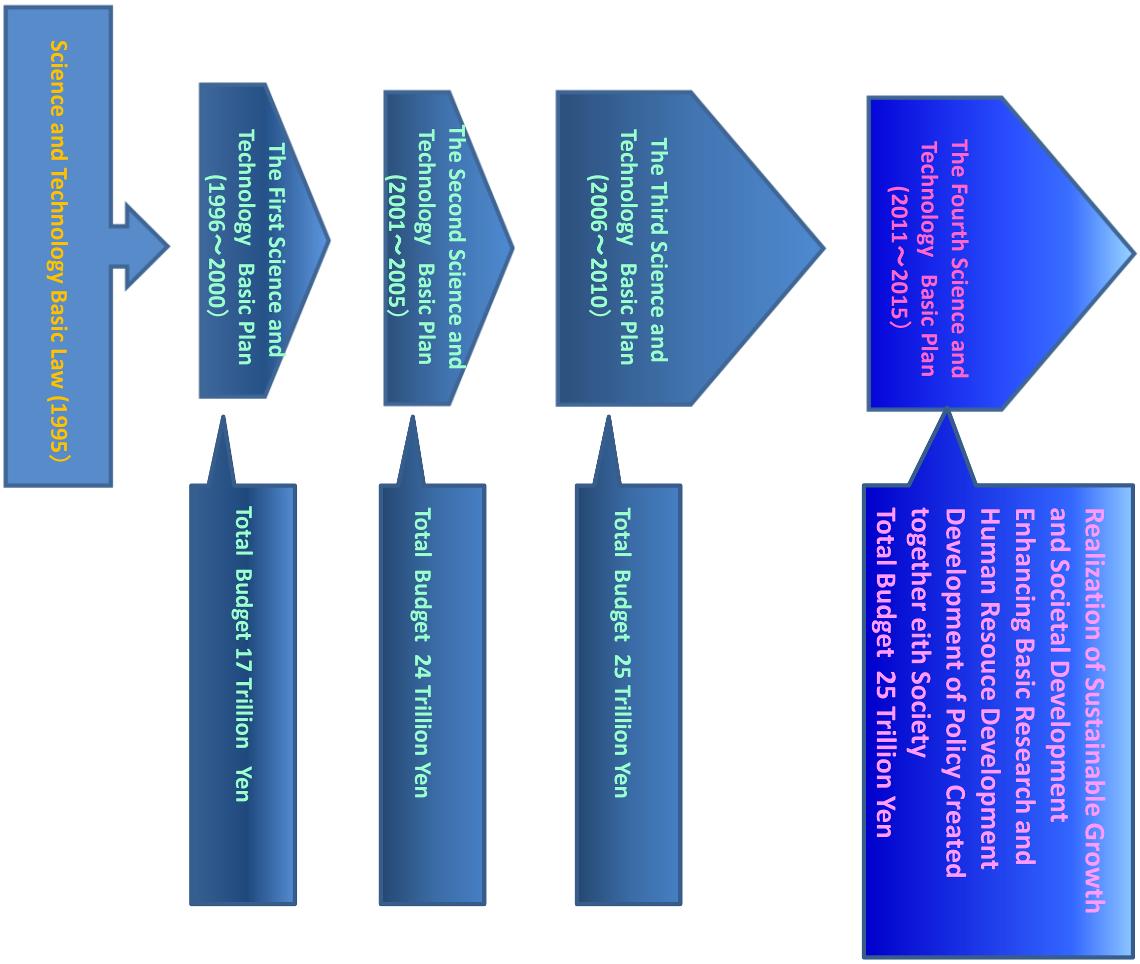

Fig. 2-1 The Science and Technology Basic Plan[4]

The 1st Science and Technology Basic Plan was limited largely to research and development systems. The 2nd Basic Plan incorporated a clear awareness of the relationship of S&T to society and indicated three goals that Japan should achieve (creation of wisdom, vitality from wisdom, and sophisticated society by wisdom) in addition to the reform of S&T systems that included returning the achievements of research to society. The relationship of S&T to society and the people was further emphasized in the 3rd Basic Plan, and the basic principle of "S&T to be supported by the public and to benefit society" was clearly identified. The innovations that would become important for this purpose were clearly identified as well.[5]

In 2011, the 4th Science and Technology Basic Plan was formulated. It was characterized primary by the fact that the role of S&T policy was taken to be not only the future advancement of S&T but also finding solutions to the various issues facing human society. To this end, relevant

[4] "Policy regarding science, technology and academia" MEXT http://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu0/shiryo/__icsFiles/afieldfile/2013/04/15/1333290_6.pdf

[5] The 4th Science and Technology Basic Plan

innovation policy was included within its targets in addition to S&T policy and activities were to be conducted through the comprehensive promotion of "science, technology and innovation (STI) policy." Another characteristic was that S&T policy was considered to be the bedrock of national strategy and one of the most important types of public policy and that policy should be developed based on organic coordination with other policies.[6]

(2) National Budget for S&T

To ensure that the overall government budget relating to S&T is concentrated on promising areas and policies and is used effectively, the Council for Science, Technology and Innovation (CSTI) takes a broad view of STI policy and formulates "Principles for the Allocation of Budget and Other Resources Relating to S&T ("Resource Allocation Policy") and plays a leading role in the efforts by relevant ministries and agencies. For example, to ensure that the Comprehensive Strategy on Science, Technology and Innovation was carried out with regard to the FY 2015 budget relating to S&T, initiatives were prioritized through action plan formulation as well as through the Cross-ministerial Strategic Innovation Promotion Program (SIP) and the Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT).[7] A Council for STI Budget Strategies was also established.

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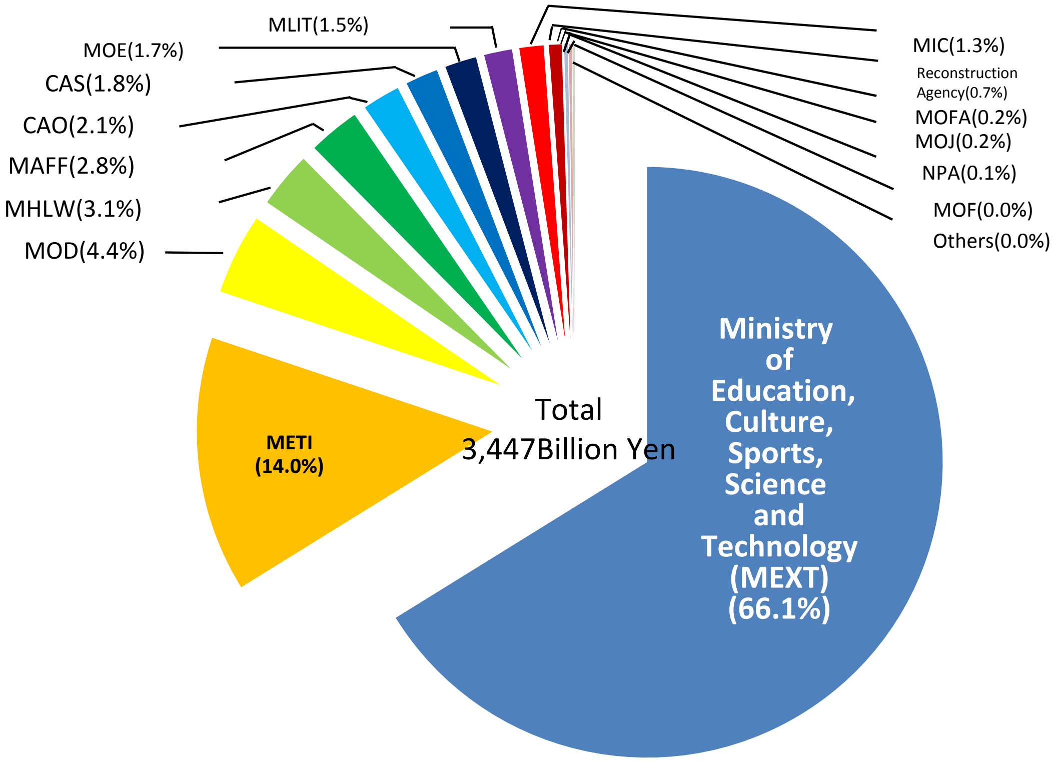
[6] JST "Panoramic View Report of Research and Development" (CRDS-FY2013-FR-07)
[7] White Paper on Science and Technology revised by JST



CAO	Cabinet Office
CAS	Cabinet Secretariat
MAFF	Ministry of Agriculture, Forestry and Fisheries
METI	Ministry of Economy, Trade and Industry
MHLW	Ministry of Health, Labour and Welfare
MIC	Ministry of Internal Affairs and Communications
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MOD	Ministry od Defense
MOF	Ministry of Finance
MOFA	Ministry of Foreign Affairs
MOJ	Ministry of Justice
NPA	National Police Agency

Fig. 2-2 Budget relating to S&T (FY 2015)[7]

As Fig. 2-2 shows, the budget relating to S&T in the initial budget for FY 2015 in Japan is 3,447 billion yen. Of this amount, the expenses for the advancement of S&T, the core expenses of the Special Coordination Funds for the promotion of S&T, amount to 1,285.7 billion yen.[8]

(3) Competitive Funds

Competitive funds are defined in the Phase 3 S&T Basic Plan as "R&D funds distributed to researchers; the entities of resource allocation are diverse and an expert team selects appropriate

[8] http://www8.cao.go.jp/cstp/budget/h27/h27gaiyou_1.pdf

projects to be funded from research projects gathered and proposed, mainly based on scientific or technological evaluation." The Plan also calls for the government to work to expand Competitive Research Funds, stating that "the government will continue to strive to increase competitive funds such as Grants-in-Aid for Scientific Research, which contribute to creating a competitive R&D environment by expanding the breadth and freedom of the selection of researchers' research grants."

Meanwhile, based on the "Expansion of Strategic Funding and Promotion of Institutional Innovation" (June 14, 2007, Expert Panel on Basic Policy, Council for S&T Policy), etc., the government is working to promote institutional reforms that include ensuring the diversity and continuity of basic research, building seamless mechanisms, creating an attractive research environment for young researchers and female researchers, intensifying high-risk, high-impact research and creative research and establishing systems for fair, transparent allocation and use.[9]

As shown in Fig. 2-3, the FY 2015 competitive funds total approximately 421.3 billion yen and the budget for Strategic Basic Research Programs accounts for approximately 14% of competitive funds. As will be shown later, the Strategic Basic Research Programs that are the target of the third International Evaluation include ERATO, PRESTO, CREST, ACCEL and ACT-C.

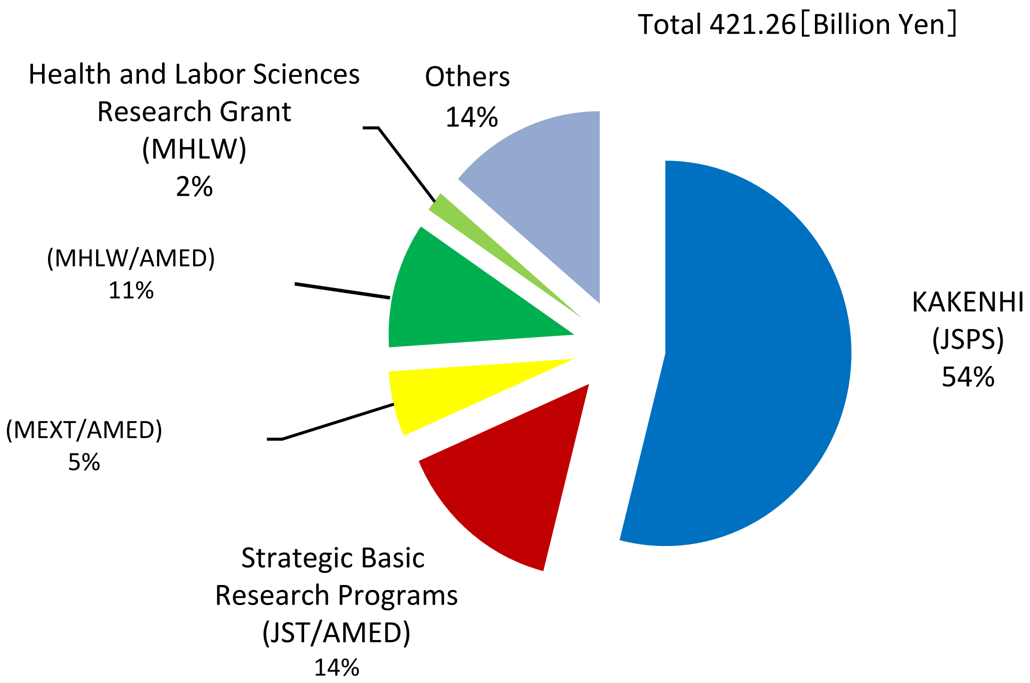


Fig. 2-3 Competitive funds in FY 2015[10]

[9] http://www8.cao.go.jp/cstp/compefund/
[10] http://www8.cao.go.jp/cstp/compefund/kyoukin27.pdf

2. Overview of Other Institutions, etc. in Japan

(1) Japan Society for the Promotion of Science (JSPS): Grants-in-aid for Scientific Research (KAKENHI)

JSPS Grants-in-aid for Scientific Research (KAKENHI) are grants provided for research proposals that are based on the free thinking of individual researchers to encourage creative, pioneering, academically outstanding research in order to promote diverse learning through research activities.

Strategic Basic Research Programs differ from Grants-in-aid for Scientific Research in that they are top-down projects. The JST receives the policy objectives of the national government (strategic objectives), establishes research areas and appoints Program Officers and pursues research aimed at achieving the strategic objectives with the goal of creating the technological seeds that will help to create innovation.

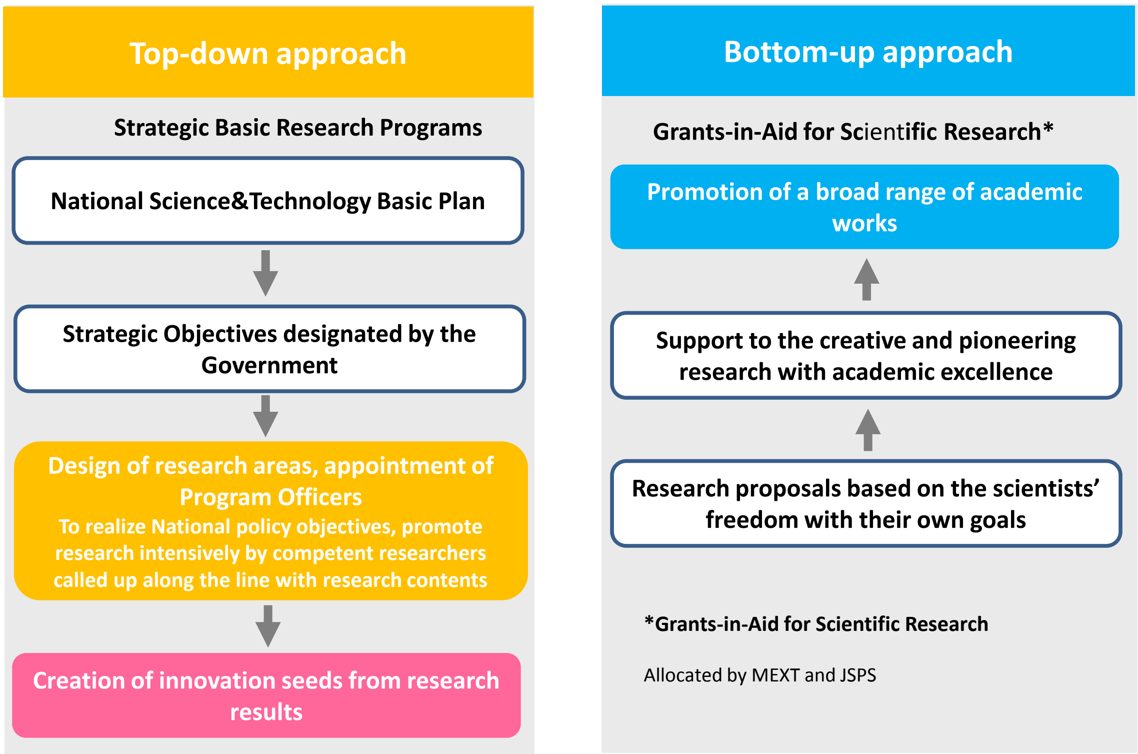


Fig. 2-4 Differences between Strategic Basic Research Programs and Grants-in-aid for Scientific Research (KAKENHI)[11]

(2) New Energy and Industrial Technology Development Organization (NEDO)[12]: National Projects

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[11] http://www.jst.go.jp/kisoken/en/about/index.html

The New Energy and Industrial Technology Development Organization (NEDO) is one of the largest public research and development management agencies in Japan. As one part of the government's economic and industrial administration, its two missions are to address energy and global environmental problems and enhance industrial technology.

(i) Addressing energy and global environmental problems

NEDO aims for the development of new energy (e.g., photovoltaic, wind power, biomass and waste, geothermal power, thermal utilization, and fuel cells) and energy conservation technologies. It also conducts research to verify technical results. Through these efforts, NEDO promotes greater utilization of new energy and improved energy conservation. NEDO also aims for a stable energy supply and the resolution of global environmental problems by promoting the demonstration of new energy, energy conservation and environmental technologies abroad based on knowledge obtained from domestic projects.

(ii) Enhancing industrial technology

With the aim of raising the level of industrial technology, NEDO pursues research and development of advanced new technology. Drawing on its considerable management know-how, NEDO carries out projects to explore future technology seeds as well as mid- to long-term projects that form the basis of industrial development. It also supports research related to practical application (FY 2015 budget: 131.9 billion yen, of which 121.5 billion yen is for national projects). NEDO projects are aimed primarily at strengthening Japanese technological capabilities and resolving energy issues. NEDO develops development-oriented projects with the aim of providing support up through the development of practical applications. In this respect, it is different from Strategic Basic Research Programs which emphasize basic research. These programs are coordinated with NEDO projects in that NEDO develops practical applications for the research achievements of Strategic Basic Research Programs.

(3) Japan Agency for Medical Research and Development (AMED) [13]

The Japan Agency for Medical Research and Development (AMED) was established in April 2015 as a new agency to play a central role in research and development and environmental improvement in the medical field. AMED conducts integrated management of medical research and development from the stage of basic research to application. Previously, this was handled by three different ministries (Ministry of Education, Culture, Sports, Science and Technology, Ministry of Health, Labour and Welfare and Ministry of Economy, Trade and Industry). (FY 2015 budget: 124.8 billion yen)

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[12] http://www.nedo.go.jp/english/index.html

[13] http://www.amed.go.jp/en/aboutus/

Of the projects implemented by the JST, some medical-related research projects have been transferred to AMED. In the future, the JST will pursue research into areas such as plants and agriculture for which AMED does not provide support as well as basic and foundational research in the life science field that is expected to contribute to a wide range of fields. In this way, a collaborative relationship will be established to enable JST research achievements to be turned over to AMED.

(4) Council for Science, Technology and Innovation (CSTI) : ImPACT, SIP

In 2014, CSTI established new programs such as the Impulsing PAradigm Change through disruptive Technologies Program (ImPACT) and the Cross-ministerial Strategic Innovation Promotion Program (SIP) to fund "problem-driven research" (as opposed to the Strategic Basic Research Programs to fund measures for "value-exploring research").

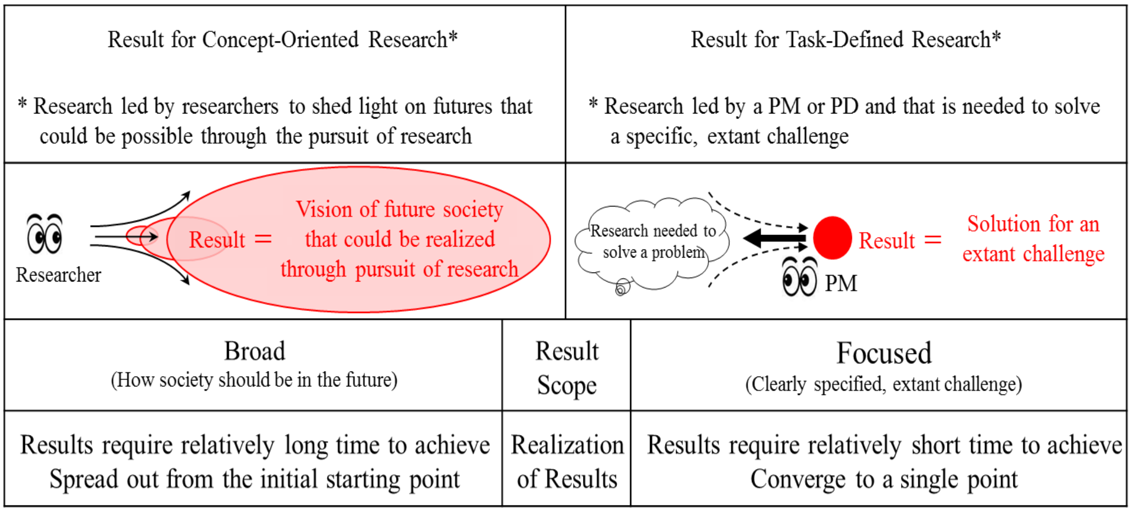

Fig. 2-5 "Value-exploring research" and "problem-driven research"[14]

1) Impulsing Paradigm Change through Disruptive Technologies (ImPACT)

The ImPACT program is based on a recognition of the need for a new science and technology system in which universities and corporations can boldly tackle challenging research issues and open new areas of growth (innovation). The program was established to promote high-risk, high-impact research and development and achieve a sustainable system for innovation that can continue to grow. The program is characterized by the fact that Program Managers (PM) with outstanding ideas are given bold authority to pursue high-risk, high-impact strategic research and development aimed at creating groundbreaking scientific and technological innovation whose achievement will bring about profound changes in industry and society (Budget: 55 billion yen (5-year fund beginning FY 2014).

14 http://www.mext.go.jp/component/english/__icsFiles/afieldfile/2014/10/09/1352423_01.pdf

2) Cross-ministerial Strategic Innovation Promotion Program (SIP)

The Cross-ministerial Strategic Innovation Promotion Program (SIP) was founded in order to achieve scientific and technological innovation. Helmed by the Council for Science, Technology and Innovation (CSTI), it plays a leading role in providing management that goes beyond the boundaries between ministries and agencies and the boundaries between traditional fields. CSTI identifies important research projects and appoints a Program Director (PD) for each project and pursues research with a view to everything from basic research to "exit" (practical and commercial application) as well as the use of regulatory reform, the special zone system and so on. At present, 11 projects have been established, of which the JST is in charge of five (innovative combustion technology, innovative structural materials, energy carriers, technologies for maintenance/upgrading/ management of infrastructures, and reinforcement of resilient function for preventing and mitigating disasters). (FY 2015 budget: 50 billion yen (total))

The above includes the recommendation of the previous International Evaluation: "The JST should continue its activities as a separate organization with a mission that is clearly distinct from that of the JSPS that administers KAKENHI. The same should be true of the relationship between JST and NEDO and so on.

3. Funding Agencies in Major Nations

Table 2-1 shows the major programs of the funding agencies in major nations.[15,16,17]

(1) Funding Agencies in the US

The United States uses a multi-funding system in which there are numerous research funds, each with a different purpose. Individual government agencies support basic, applied and developmental research within their respective areas. The major financial resource allocation institutions are the National Science Foundation (NSF) in the areas of science and engineering, the National Institute of Health (NIH) in the area of medicine and the Department of Energy (DOE) in the area of energy. NIH provides support for medical research. While 80% of its research funding goes to extramural research, the NIH allocates the remaining 20% to intramural research for research and development at 27 affiliated research institutes and research centers.

(2) Funding Agencies in the EU

The European Union (EU) has a principle that the EU does not execute projects that can be implemented by the member countries themselves but the EU conducts various projects to assist

[15] CRDS-FY2012-CR-01
[16] CRDS-FY2012-OR-02
[17] CRDS-FY2014-FR-01

policies implemented by member countries. This principle is applied in the fields of scientific and technological innovation as well. Following the creation of the European Research Area (ERA) and the Framework Program 7 (FP7), a new scientific and technological innovation policy called Horizon 2020 was initiated in January 2014 to invest in high-risk, high-reward research and development projects.

The Research Council (RC) in the UK that allocates strategic financial resources is made up of missions in seven different sectors: three Research Councils (EPSRC, AHRC and ESRC) that provide only research funding assistance, three Research Councils (BBSRC, MRC and NERC) that provide research funding assistance and also have affiliated research organizations and conduct basic and applied research themselves and the Science and Technology Facilities Council (STFC) for broad-based science and technology fields.

In Germany, the German Research Foundation (DFG) supports basic research using a bottom-up approach, and also gives various science-related awards and conducts researcher invitation programs and so on. It is also commissioned by the federal government to conduct an Excellence Incentive that provides grants focusing on a select number of universities.

In France, the French National Research Agency (ANR), which has jurisdiction over national education and higher education as well as researchers, allocates competitive research funds in all sectors, from natural science and engineering to the humanities and social sciences.

In Sweden VINNOVA provides funding for needs-driven research and encourages collaboration on the part of companies, universities, research institutions and public sector organizations. Its role also includes serving as the government's negotiating agency for the EU framework program.

(3) Funding Agencies in Asia

In Singapore, the Agency for Science, Technology and Research (A*STAR) is an institution that allocates financial resources for the government ministries and agencies under its jurisdiction. It has eight engineering laboratories and 12 biomedical research centers and leads research and development with a strong emphasis on off-ramps for research through industry-academic collaboration.[18]

In China, competitive financing from the central government is allocated primarily by the Ministry of Science and Technology and the National Natural Science Foundation of China (NSFC). The NSFC was set up in 1986 as the Chinese version of the NSF in the U. S., and it provides grants for basic research and some applied research projects.

[18] Respective agencies web site

Table 2-1 Funding Agencies in major countries and nature of activities

Country	Funding Agency	Budget*	Nature of activities
US	NSF	USD 7.3 billion (FY 2015)	Provides bottom-up research funding assistance to university science and engineering sectors
	NIH	USD 30.3 billion (FY 2015)	Provides bottom-up research funding assistance to university medical sectors
	DOE	USD 10.7 billion (FY 2015)	Provides bottom-up research funding assistance to energy, physics, mathematics, and computer science sectors of government-funded research and development centers
	DARPA	USD 2.9 billion (FY 2015)	Provide innovative research assistance: (top-down approach to issue identifications and bottom-up approach to idea search)
UK	BBSRC	USD 530 million (FY 2015)	Provides research funding assistance to the biology sector and also has affiliated research organizations that conduct basic and applied research themselves
	EPSRC	USD 1.19 billion (FY 2015)	Provides research funding assistance for the engineering, mathematics, physics, chemistry, material science and information and communications technology sectors
Germany	DFG	USD 3.2 billion (2014)	Operates research grant programs and joint research center programs in the medical, mechanical engineering, biology, physics and humanities sectors for the advancement of basic science
France	ANR	USD 590 million (2015)	Provides bottom-up and top-down research funding assistance to universities and public research institutions in the areas of biology, medicine, the environment and biological resources, sustainable energy, ICT, engineering, the humanities and social sciences
Sweden	VINNOVA	USD 330 million (2014)	Provides needs-based research funding to promote collaboration on the part of companies, universities, research institutions and the public sector

EU	ERC	USD 14.6 billion (2014-2020)	Supports high-risk, high-reward research by outstanding individuals and teams within the Horizon 2020 “Priority (1): Outstanding Science”
Singapore	A*STAR	USD 1.05 billion (2014)	Leads research and development based on industry-academic collaboration, primarily in the areas of engineering and biomedicine
China	NSFC	USD 2.67 billion (2012)	Provides bottom-up research funding assistance to universities and research organizations in the areas of mathematics, physics, chemistry, life sciences, earth science, engineering, material science, information science, management science and medicine
Japan	JST	USD 1.01 billion (FY 2015)	Provides top-down research funding assistance for universities and public research institutions in the areas of engineering, mathematics, physics, chemistry, material science, information and communications technologies and biological science (Strategic Basic Research Programs)
	JSPS	USD 2.54 billion (FY 2015)	Provides bottom-up research funding assistance for across-the-board basic research at universities and public research institutions

* USD conversion rate as of October 6, 2015

Section 2 . Overview of JST

1. History of JST

The Japan Science and Technology Agency (JST) was established in October 1996 through the integration of the Japan Information Center of Science and Technology (JICST) and the Research Development Corporation of Japan (JRDC). The name of the agency at that time was Japan Science and Technology Corporation. Its mission was to conduct comprehensive and efficient construction of infrastructure to promote science and technology and to vigorously promote the policies established in the Science and Technology Basic Law. In October 2003, the entity became an Independent Administrative Agency and its name was changed to the current name (Japan Science and Technology Agency or JST). In April 2015, the agency was changed to a National Research and Development Corporation but the English name remained the same.[19]

The Japan Information Center of Science and Technology (JICST) was set up in August 1957 to be the central institution for science and technology information in Japan and to quickly and accurately provide information relating to science and technology from Japan and other countries. The Research Development Corporation of Japan (JRDC) was established in July 1961 to reduce Japan's dependence on overseas technology by disseminating the outstanding research achievements from Japanese universities, national laboratories etc. and developing commercial applications for these achievements. The latter organization was subsequently tasked with additional responsibilities and in 1989 the Japanese name was changed but the English name remained the Research Development Corporation of Japan.

2. General Overview of JST's Activities

The JST is the core agency of the Science and Technology Basic Plan. Its mission is "Contributing to the Creation of S&T Innovation," and it has the following three goals:

I. Achieving innovations in science and technology through creative research and development.

II. Maximizing research outcomes by managing research resources under the "Virtual-network based Research Institutes" scheme

III. Developing Japan's infrastructure for science and technology so as to accelerate innovation in science and technology.

The JST promotes the following activities under the twin rubrics of "Promoting innovation in science and technology" and "Building Infrastructure for innovation in science and technology."

1) Strengthen JST's capabilities in R&D strategy formulation

(i) Planning of research and development strategy for the creation of S&T innovation

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19 http://www.jst.go.jp/EN/about/history.html

(ii) Proposal for research and analysis and social scenario and strategy for realizing low-carbon society

2) Creation of innovation in science and technology

(i) Strategic promotion of R&D

(ii) Application of research and development outcomes in cooperation with the industry and academia

(iii) Support for reconstruction and revitalization after the Great East Japan Earthquake

(iv) Promotion of international joint research in science and technology

(v) Creation of an innovation hub centering on National Research and Development Agencies

(vi) Promotion of the utilization of IP

(vii) Promotion of "ImPACT" program

3) Building infrastructure for the creation of S&T Innovation

(i) Construction of knowledge infrastructure

(ii) Construction of human resources infrastructure to support S&T innovation

(iii) Construction of communication infrastructures

4) Other operations

(i) Promotion of contract businesses from the relevant administrative organizations

(ii) Implementation of Cross-ministerial Strategic Innovation Promotion Program (SIP)

Note: Establishment and Management of Virtual-network based Research Institutes (see Fig. 2-6, Fig. 2-7)

The JST builds Virtual-network based Research Institutes (time-limited research organizations that go beyond organizational boundaries) made up of researchers from universities, companies, public research institutions and so on. The Program Director (PD) supervises the overall program and studies operational policy and the like. The Program Officer (PO*) serves as the director who runs the virtual research institute. Under their leadership, researchers pursue research while forming networks with other researchers and other entities in industry, etc.

* Program Officer in CREST and PRESTO and Project Leader in ERATO correspond to PO

3. 3rd Mid-Term Plan (FY2012 - FY2016)

In establishing the 3rd Mid-Term Plan, the JST conducted a thorough review of the project configuration up to that time. In order to create a system capable of quickly achieving scientific and technological innovation that would have a major impact on society and the economy, the previous activities were reorganized into two activities based on the JST goals: "Promoting innovation in science and technology" and "Building Infrastructure for innovation in science and technology."

Section 3 . Strategic Basic Research Programs

1. Overview of Strategic Basic Research Programs

(1) Overview and Objectives

Strategic Basic Research Programs are intended to advance basic research aimed at achieving the strategic objectives established by the national government and to produce the seeds of creative, innovative technologies from new scientific knowledge that gives rise to innovation in science and technology leading to social and economic change. As such, Strategic Basic Research Programs seek to build virtual research institutes (time limited research organizations spanning organizational boundaries) consisting of networks of researchers at universities, companies and public research institutions. Researchers pursue their work, while building networks of other researchers, industrial concerns that will benefit from the fruits of research work and interested parties in society at large under the leadership of a Program Officer etc. performing the role of the institute director.[20]

[20] http://www.jst.go.jp/kisoken/en/brochure/pamph_en_2015-2016.pdf

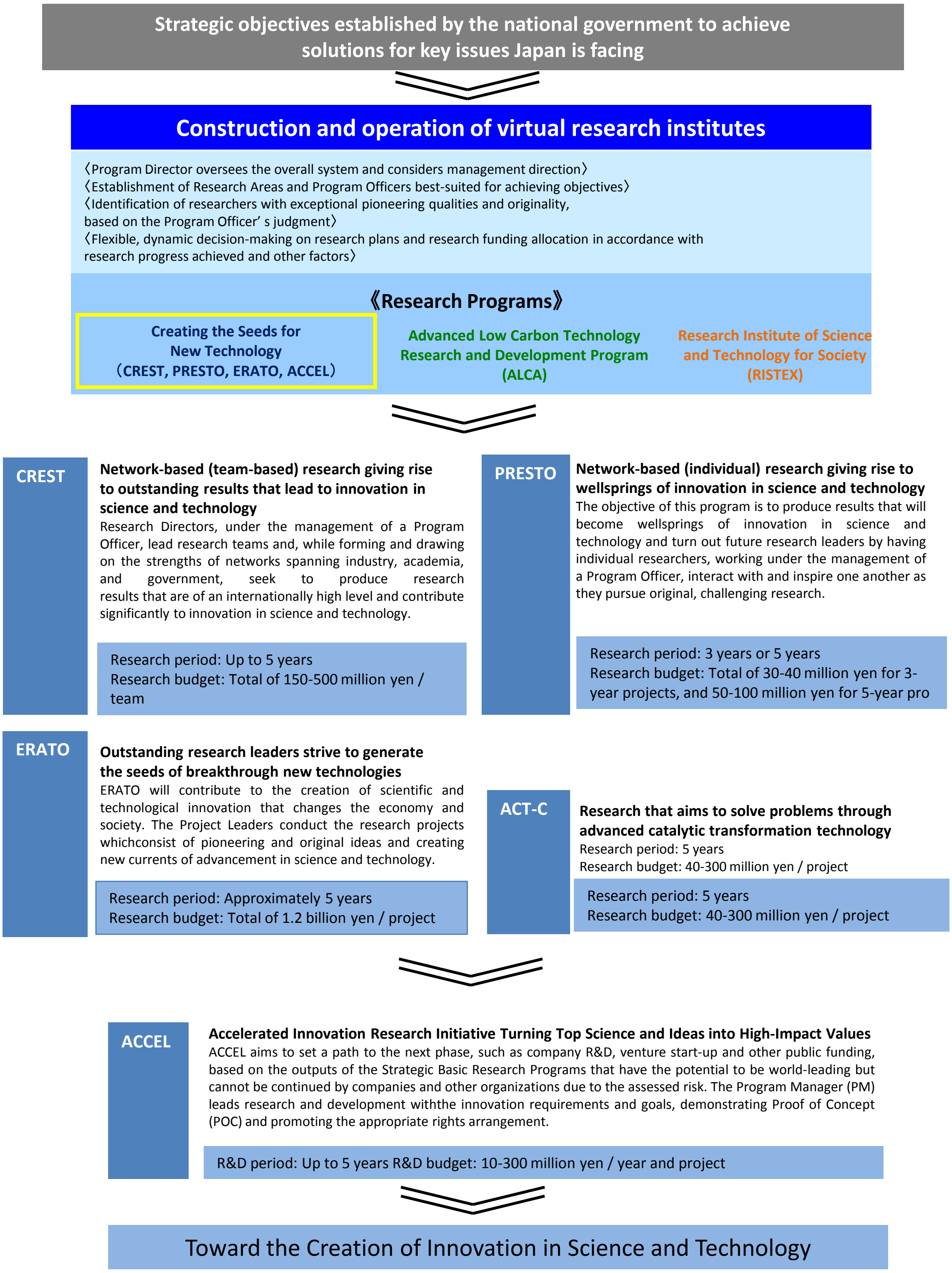

Fig. 2-6 Overview of Strategic Basic Research Programs[20]

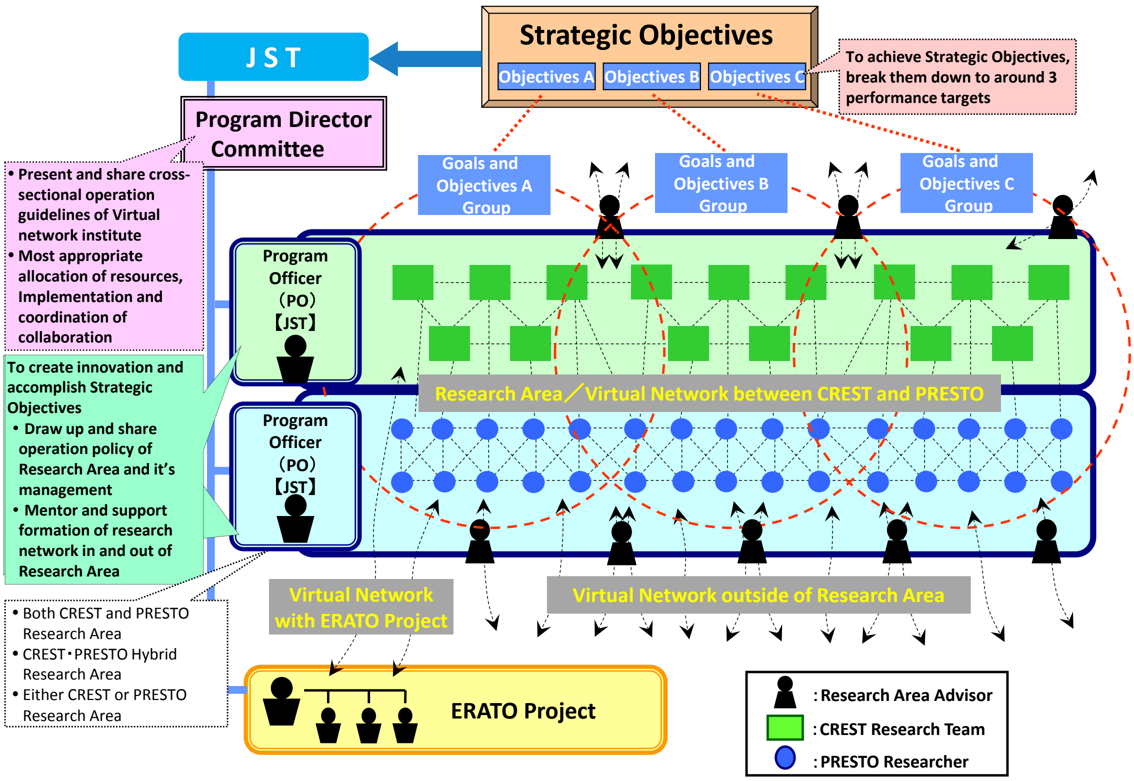

Fig. 2-7 CREST and PRESTO "Virtual-network based Research Institute" models[21]

(2) History of Strategic Basic Research Programs

Fig. 2-8 shows the starting years for the programs that are subject to International Evaluations.

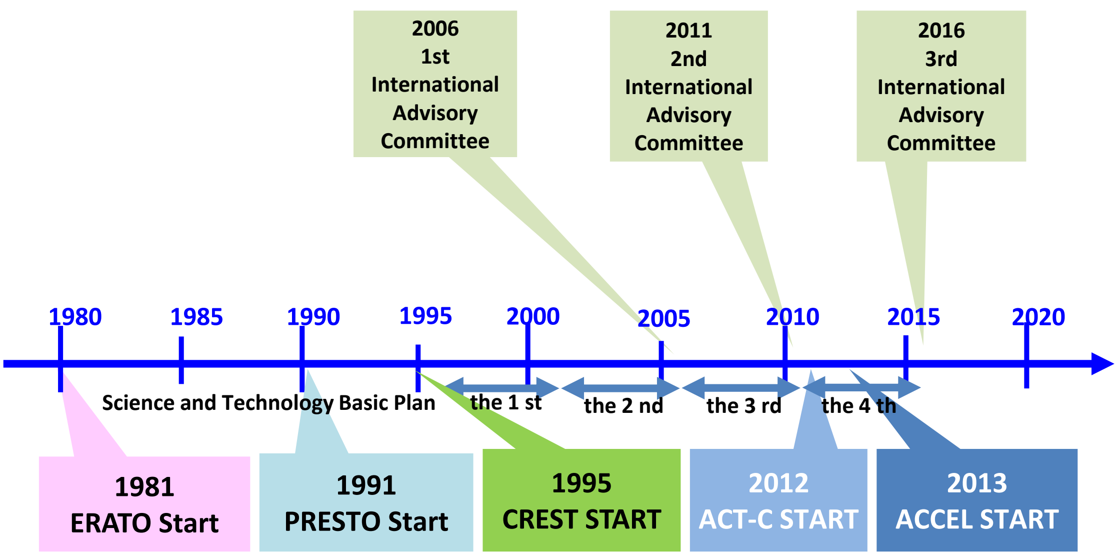

Fig. 2-8 History of Strategic Basic Research Programs[21]

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[21] Prepared by the JST

(3) Budget

Fig. 2-9 shows the budget for Strategic Basic Research Programs (creation of new technological seeds). As the figure shows, the annual budget has been maintained at approximately 50 billion yen in recent years.

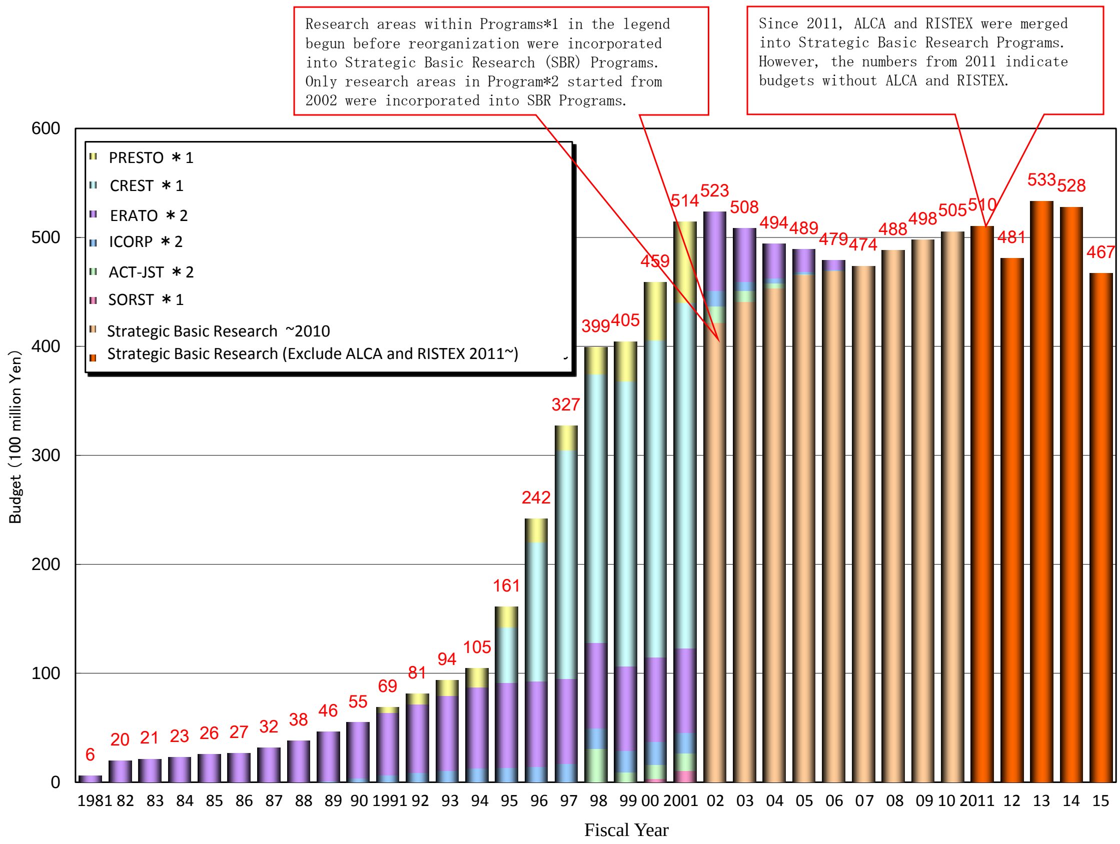


Fig. 2-9 Budget for Strategic Basic Research Programs (creation of new technological seeds) [20]

(4) Establishment of Strategic Objectives

Strategic Basic Research Programs are promoted based on strategic objectives established by the national government. These strategic objectives are studied and formulated by the Ministry of Education, Culture, Sports, Science and Technology. From 2014 fiscal year, it is established as follows:

Step 1 : Broad overview of the trends in basic and other types of research

Scientometric techniques are used to conduct an analysis of the trends in basic research and other types of research in Japan or other countries throughout the world to determine research trends

Step 2 : Identification of notable research trends through knowledge gathering

These analysis results etc. are used to conduct questionnaire surveys of organizations and researchers with knowledge of the latest research trends and the like, in order to identify notable research trends based on the results of the surveys.

Step 3 : Establishment of strategic objectives capable of balancing scientific value with the creation of social and economic value

After workshops that studies the prospects for society and the economy as a result of the progress of these research trends, MEXT finalizes strategic objectives capable of balancing scientific value with the creation of social and economic value.

2. Structure for Strategic Basic Research Programs

(1) PD/PO structure

CREST, PRESTO and ERATO programs are managed by a Program Director (PD) Council that oversees the overall program and drafts institutional reforms, operational policy and so on. The PD Council checks policies, operation and research evaluations, studies the drafting of reforms, establishes Research Areas, conducts Ex-ante evaluations and the like for the appointment of Program Officers (PO) and determines the allocation of resources to research areas.

The Program Officer for CREST and PRESTO serves as the head of the Virtual-network based Research Institute made up of researchers from universities, companies, public research institutions and so on. In this capacity, he or she selects research projects, conducts Midterm and Ex-post Evaluations and determines the progress of research and allocates resources such as the budgets for research projects. At ERATO, the Project Leader directs research in order to achieve his or her own research vision (Fig. 2-10).

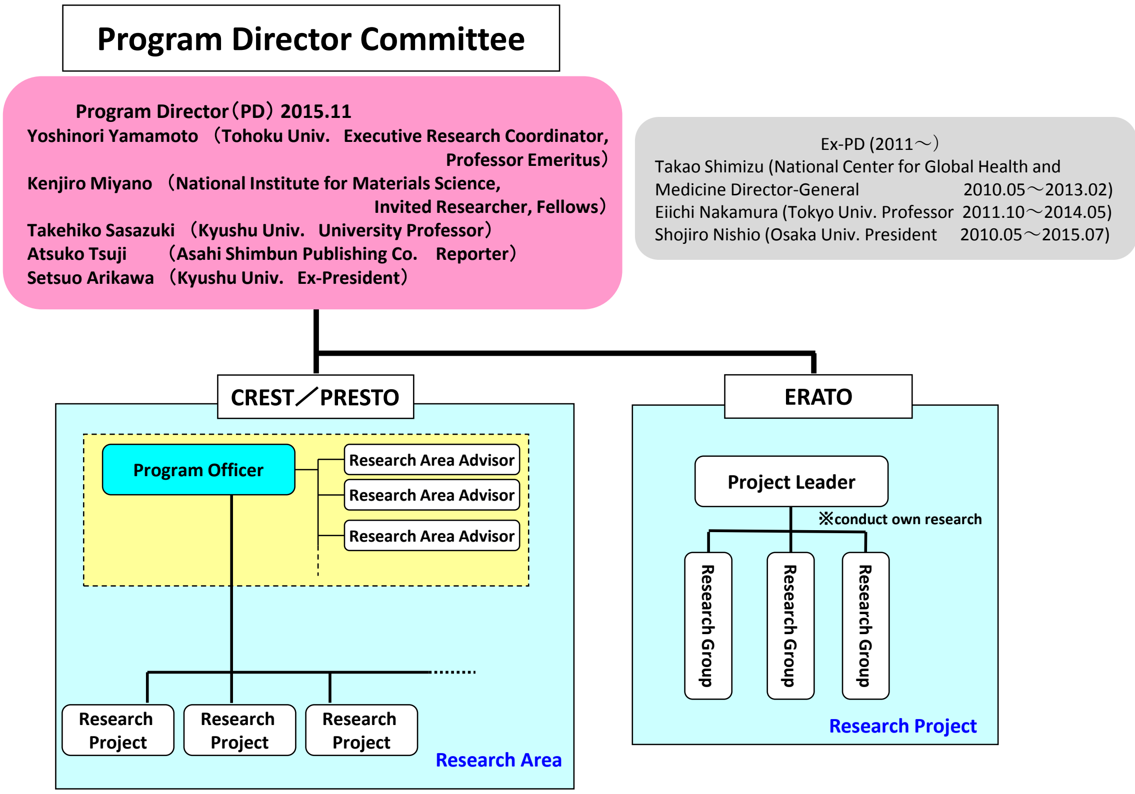


Fig. 2-10 PD/PO structure for Strategic Basic Research Programs (CREST, PRESTO and ERATO)[21]

(2) Overview of Each Program

1) CREST

<u>Concept</u>

To achieve Strategic objectives established by the Japanese government, the CREST program promotes unique and world-leading directed basic research. The CREST program seeks to produce outstanding results that contribute significantly to scientific and technological innovation.

<u>Outline</u>

(i) Management of Research areas by Program Officers

Program Officers oversee the activities of Research Directors affiliated with industrial, academic and governmental institutions and manage Research Areas as virtual research institutes. To maximize the research results in each Research Area, Program Officers manage the Research Areas by setting directions of Research Areas, selecting Research Projects, coordinating and approving research plans, sharing views with and advising Research Directors, evaluating Research Projects, etc.

(ii) Strong leadership of Research Directors

In pursuit of the research concept he or she has proposed, a Research Director will assemble a single optimal research team consisting of multiple researchers. The Research Director bears responsibility for the entire research team and advances research in a way that contributes to achievement of the Research Area's overall objectives.

(iii) Formation of Networks for Scientific and Technological Innovation

Each Research Director, with the support of the Program Officer and Research Area Advisors, will form a network of researchers inside and outside the Research Area and actors from industry and others. Research Directors utilize this network for the effective production of results and development of innovation by sharing information and collaborating with these people.

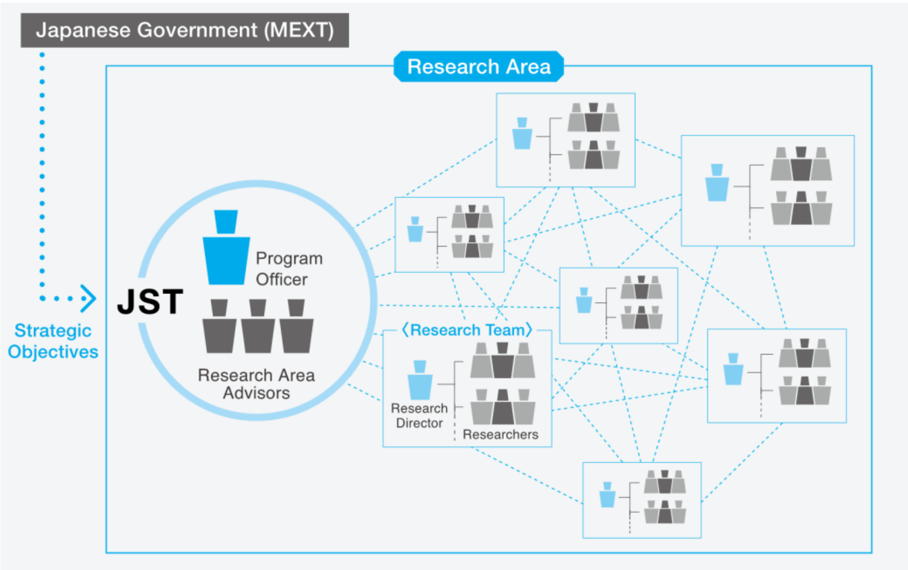


Fig. 2-11 Research framework of CREST[19]

2) PRESTO

Concept

To achieve Strategic Objectives established by the Japanese government, the PRESTO program promotes pioneering directed basic research that is original and challenging and expected to lead to the development of high international standards. The PRESTO program aims to lead the world in the production of results that serve as a wellspring of innovation.

Outline

(i) Strong Support Structure for Advancing Research

A PRESTO researcher takes responsibility for advancing a Research Project he or she has proposed within a Research Area led by a Program Officer. In advancing the Research Project, the researcher can gain various types of advice and guidance from the Program Officer and Research Area Advisors. JST will assist researchers with patent applications, public relations activities and other needs, as well.

(ii) Research Area Meetings as an Opportunity for Interacting and Networking with People in Other Fields

At the meeting held closed (essentially twice yearly), all researchers are lodging together and the progress of research is checked. Researchers can interact with their Program Officer, advisors and researchers working in other fields of the same Research Area and form networks that will continue beyond the end of their participation in the PRESTO program.

(iii) Generous Accommodation of Life Events (Nadeshiko Campaign)

Research activities can be temporarily suspended for child care, nursing care or other life events. Research periods can be extended by up to one year.

(iv) Research Institution Affiliation Not Required for Application to the PRESTO Program

When it is acknowledged that an individual would be able to properly pursue PRESTO research even without a research institution affiliation at the time of his or her selection to the program, arrangements can be made to allow that individual to pursue research as an Exclusive Appointment Researcher employed by JST.

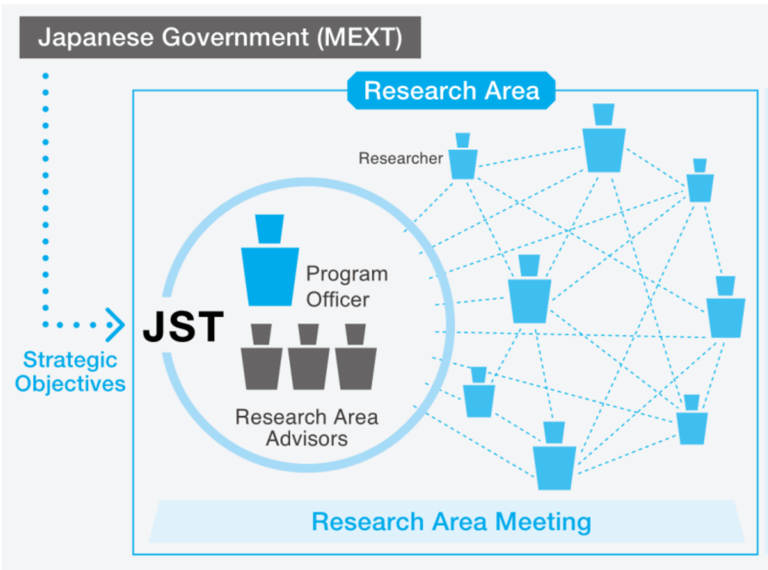


Fig. 2-12 Research framework of PRESTO[19]

3) ERATO

Concept

Form a headstream of science and technology and ultimately contribute to innovation in science and technology that will change society and the economy in the future.

Outline

(i) Flexible and Functional Organization

In the ERATO program, in order to promote a creative and challenging research project, “a Virtual Research Institute” is organized under the leadership of a Project Leader, and cooperatively managed by JST and a research institute. This “JST-Institute Collaboration Framework” has been newly established for the ERATO program and is different from typical contract based research.

(ii) Research Group without Boundaries

In order to drive the research project efficiently, researchers and research administrators work at a research base together with the Project Leader. The project team consists of several research groups and the Project Headquarter office for the research administration work.

(iii) Research Bases Independent from the Existing Facilities

ERATO builds new research bases for research projects, meaning that each Project Leader establishes and operates a new research facility independent from the existing one.

(iv) Making the Best Possible Use of the Research Period

In order to best utilize the unique features of the ERATO program and maximize the breakthrough discoveries and innovations from each project, as a trial, the program is currently allowing up to one year for a project setup before the official start of the project.

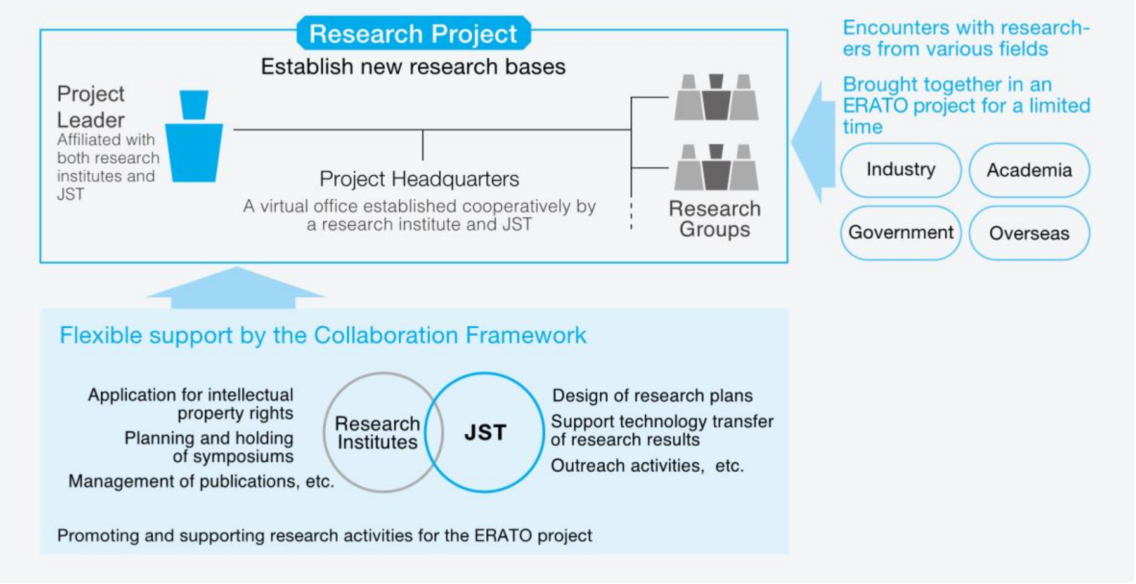


Fig. 2-13 Research framework of ERATO[19]

4) ACCEL

<u>Concept</u>

ACCEL aims to set a path to the next phase, such as company R&D, venture start-up and other public funding, based on the outputs of the Strategic Basic Research Programs that have the potential to be world-leading but cannot be continued by companies and other organizations due to the assessed risk. The Program Manager (PM) leads research and development with the innovation requirements and goals, demonstrating Proof of Concept (POC) and promoting the appropriate rights arrangement.

<u>Outline</u>

The PM appointed for each R & D project is involved from the stage of establishment of the vision for value creation and specific applications. He or she works with the Research Director and handles everything from proposal through management of the R&D project that he or she is overseeing.

(i) Management structure led by the PM and Research Director

• A Program Manager (PM) is appointed for each R&D project. The PM works with the Research Director to manage the R & D project.

• Research and development is conducted by the Research Director.

• The Research Area Advisors who have been appointed as needed provide appropriate advice.

• The R&D Management Committee made up of outside specialists provides evaluations and advice to the Research Director.

(ii) Development and provision of Proof of Concept (POC)

(iii) Appropriate rights arrangement

The study and formation of patent licensing strategies, intellectual property strategies and the acquisition of rights are operated in each R & D project.

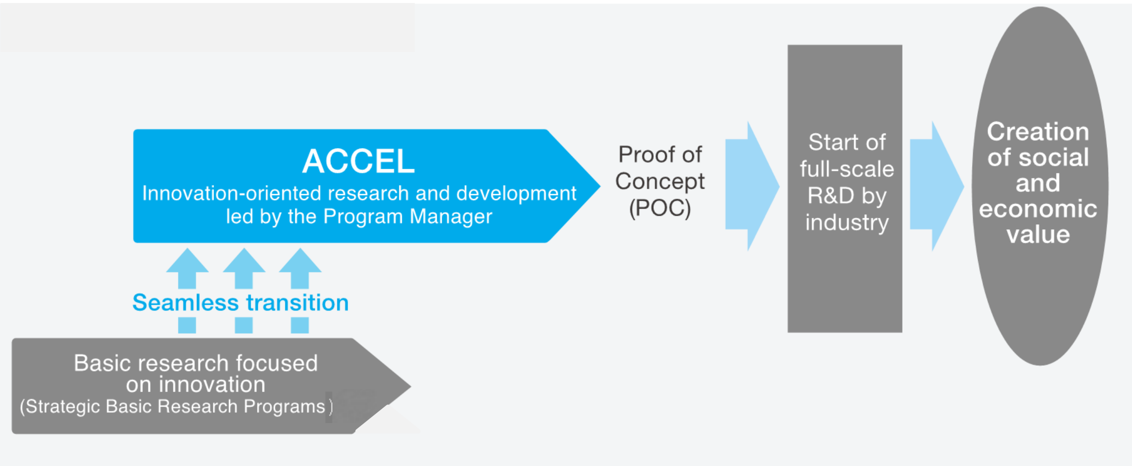


Fig. 2-14 Structure of ACCEL[19]

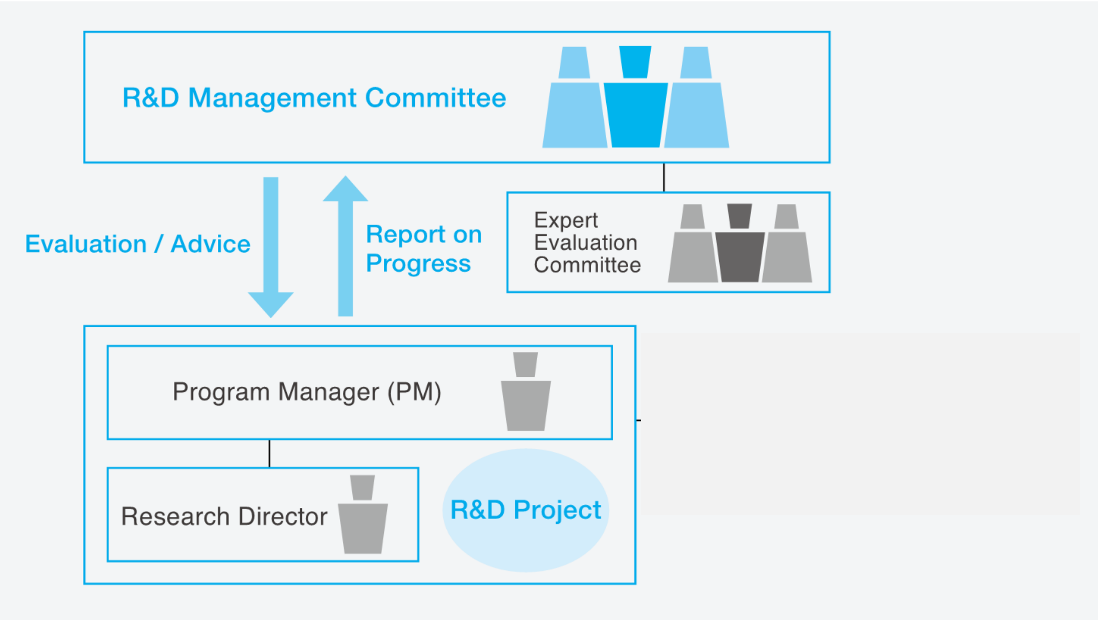


Fig. 2-15 Research framework of ACCEL[19]

5) Advanced Catalytic Transformation program for Carbon Utilization (ACT-C)

Concept

The ACT-C program aims to produce advanced substance transformation technologies that are based on catalysts and can help to solve various problems - in areas like realization of a low-carbon society, and the sustainable, evolutionary production of pharmaceuticals and functional materials - that are confronting not only Japan but the world as a whole.

Outline

(i) Detailed Research Progress Monitoring

The Program Officer and Area Advisors divide the research projects among themselves and provide various types of advice on the advancement of research. In addition, the research framework and resources are re-examined and flexibly revised depending on research progress.

(ii) Research Result Presentations and Networking at Research Area Meetings

Research results and other information are presented (at least once a year) through venues like twice-yearly research report meetings (research area meetings). Furthermore, researchers, including the Program Officer, Principal Program Director, and Area Advisors, build inter-disciplinary research networks by interacting with researchers in other fields.

(iii) Creation of Intra-Area Synergistic Effects

Through measures like sharing information on the background of research projects among researchers within a research area, the ACT-C program aims to promote joint research, and create synergistic effects.

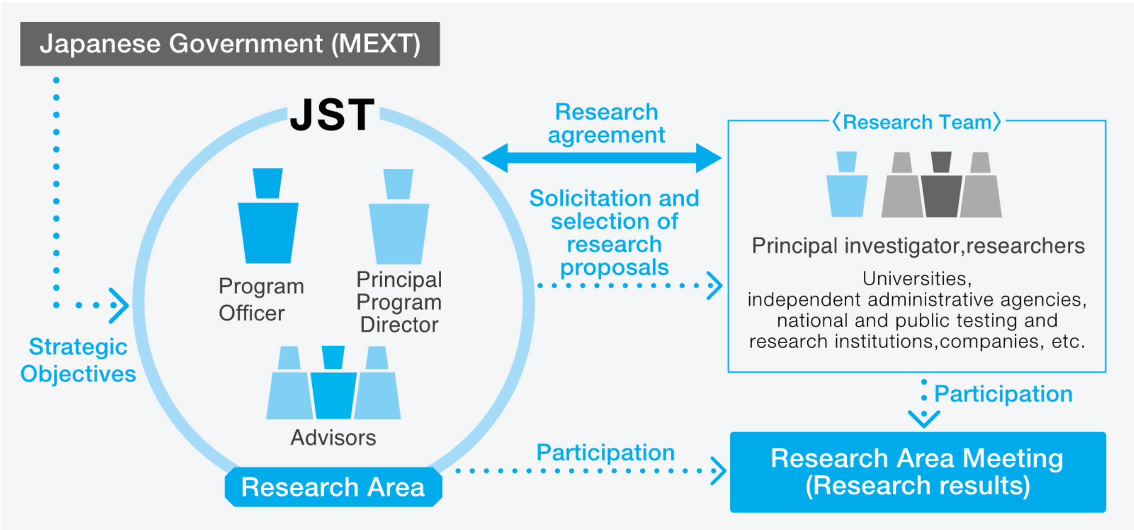


Fig. 2-16 Research framework of ACT-C[19]

(3) Evaluation System

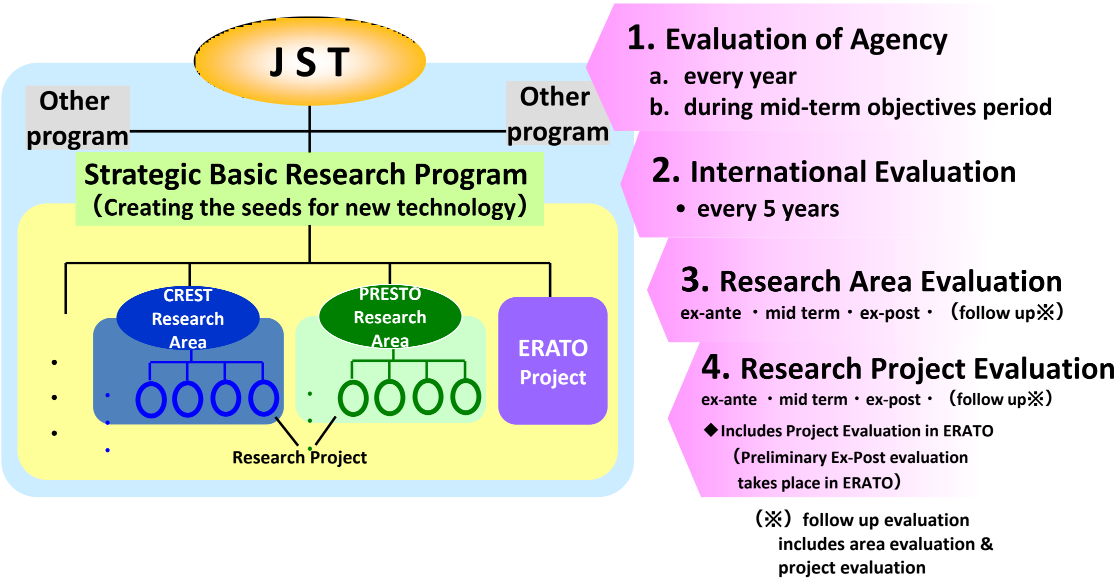


Fig. 2-17 Evaluation system[20]

In accordance with the "Guidelines for Evaluation of Research and Development by the MEXT (Minister of MEXT, April 2014), the JST conducts evaluations.

Evaluations of Strategic Basic Research Programs comprise Evaluations of Agency, International Evaluations, Research Area Evaluations and Research Project Evaluations (Fig. 2-17). International Evaluations are conducted one year before the end of the interim objective period. The current

International Evaluation corresponds to one year before the end of the Phase 3 interim objective period (2012 - 2016). Research Area Evaluations and Research Project Evaluations are made up of Ex-ante evaluations, Midterm evaluations, Ex-post Evaluations and follow-up evaluations (the latter conducted approximately five years after completion)(Fig.2-18).

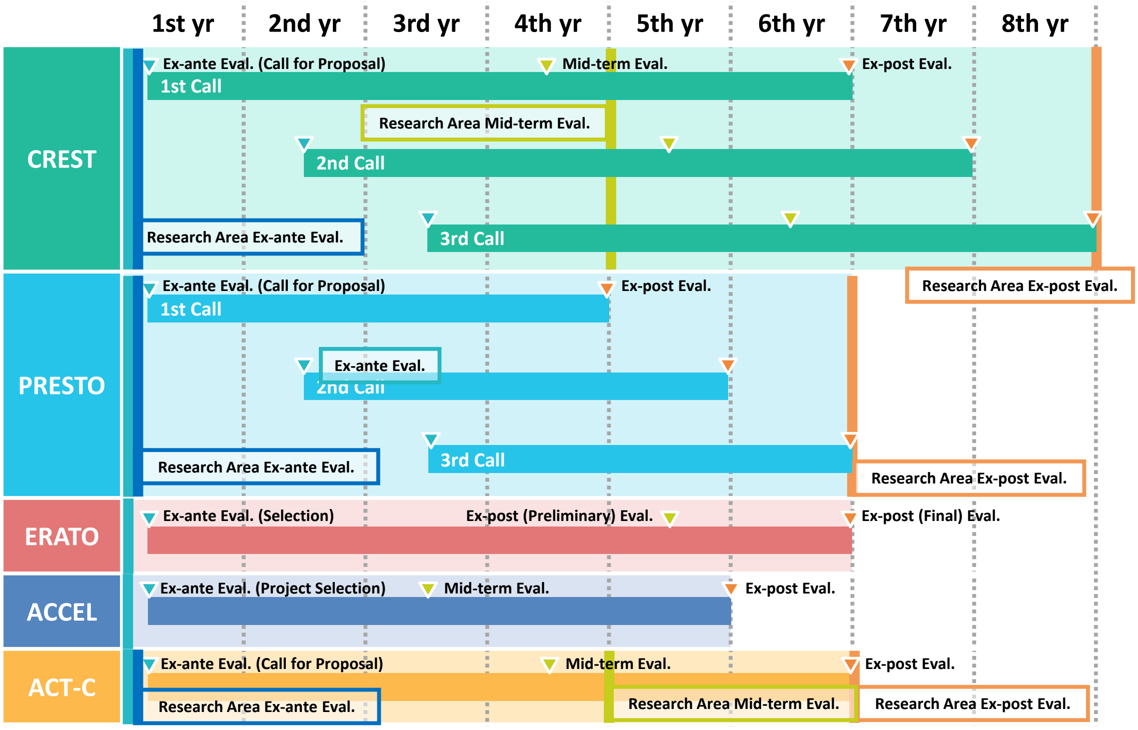


Fig.2-18 Evaluation outline of each program[20]

3. Program Operation

(1) CREST• PRESTO

1) Determination of Research Area and Program Officer (Ex-ante evaluation of Research Area)

The Program Director Council conducts an Ex-ante evaluation based on JST implementation regulations, and the decision is finalized at a meeting of the JST Board of Directors.

【Evaluation Standards】

(i) Research Area

- A Research Area that is appropriate for achieving the strategic objectives
- A Research Area that is appropriate based on the current state of research in Japan, one in which many outstanding research proposals are anticipated

(ii) Program Officer

- A person who has vision and discernment with regard to the Research Area

• A person who has the experience and capacity to manage research in an appropriate manner to make effective and efficient progress in the research project

• A person who has a record of outstanding research achievements and who has the confidence of researchers in related areas

• A person who conducts fair and impartial evaluations

【Process used to determine Research Area and Program Officer】

(i) Ex-ante Survey by JST Based on Status of Study of the Strategic Objective

• The JST conducts an Ex-ante survey in order to determine the Research Area and Program Officer, based on information provided by the Ministry of Education, Culture, Sports, Science and Technology starting from the stage of study of the strategic objectives.

• The JST Ex-ante survey is conducted using the following methods. The JST references reports, etc. from various review boards (which are also referenced during studies conducted by the Ministry of Education, Culture, Sports, Science and Technology), as well as strategic proposals and other reports from the JST Center for Research and Development Strategy (CRDS). The JST also collects and analyzes information on research trends and technological trends in relevant fields, the situation at related academic societies and so on.

Interviews are conducted with leading figures in related fields.

• The progress of the aforementioned Ex-ante survey is reported to the relevant Program Director appointed for each strategic objective and in-depth discussions are held.

• After formal notification of the strategic objectives is received from the Ministry of Education, Culture, Sports, Science and Technology, the JST conducts a further survey (area survey).

(ii) Ex-ante Evaluation and Finalization of Research Area and Program Officer

• The Program Director Council conducts a Ex-ante evaluation of the Research Area and Program Officer.

• Upon receipt of the results of the Ex-ante evaluation, the Research Area and Program Officer are finalized at a meeting of the JST Board of Directors.

2) Research Project Selection (Ex-ante Evaluation of Research Project)

The Program Officer selects the research project with the assistance of the area advisors, etc., based on the implementation regulations and the decision is finalized at a meeting of the JST Board of Directors.

【Evaluation Standards (CREST)】

• A project that contributes to the achievement of strategic objective.

• A project that is consistent with the Research Area intent

• Basic research that is unique highly appreciated internationally and expected to produce outstanding results that contribute greatly to science and technology innovation. Projects must meet all of the following conditions.

• The research project applicant has produced research results for accomplishing research objectives.

• Promising preliminary results have been obtained for pursuing the research initiative.

•The research proposals must separately and clearly specify: (i) the background to the research initiative (its necessity and importance); (ii) the actual research record of the research project applicants; and (iii) the research initiative and plan.

• An optimal research organization is in place.

• The research project applicant will exercise strong leadership and bear responsibility for the entire research team, and, if there will be Lead Joint Researchers, they are essential for pursuing the research project applicant's research initiatives, and a collaboration framework sufficient for enabling significant contributions toward the achievement of research objectives will be constructed.

• Research budget planning necessary and sufficient for pursuing the research project applicant's research initiatives has been performed.

• The research institutions with which the research project applicant and Lead Joint Researchers are affiliated have R&D capabilities and other technical foundations in the subject research field.

【Evaluation Standards (PRESTO)】

• A project that contributes to the achievement of Strategic Objectives.

• A project that is consistent with the Research Area intent.

• Basic research that is unique, challenging, internationally expected to develop at an advanced level, and can be expected to produce groundbreaking results that lead to science and technology innovation.

• The research project applicant can be expected to contribute to the development of the subject overall PRESTO Research Area and to the ongoing development of related research fields through the content of the proposed research the applicant's research approach and the applicant's efforts to engage with other researchers in discussions and activities that mutually inspire.

Project must meet all of the following conditions.

• The uniqueness of the research project application is based on the original ideas of the research project applicant.

• Promising preliminary results have been obtained for pursuing the research initiative.

• The proposed research project is of a scale appropriate for pursuit by an individual researcher.

【Evaluation Process】

• The basic approach to selection is studied by the Program Officer with the assistance of the area advisors, etc. in order to achieve consensus between the Program Officer and area advisors, etc. (Selection policy meeting)

• The area advisors review the research proposals.

• Based on the results of the document review, the Program Officer conducts document selection with the assistance of the area advisors, etc. to determine the interview candidates. (Document screening)

• The Program Officer conducts the interview screening for the interview candidates with the assistance of the area advisors, etc., and the Program Officer selects the final candidates and additional final candidates. (Interview screening)

• From among the additional final candidates, the additional final candidate projects are determined at a Joint Study Meeting, based on a consideration of JST priority areas, diversity and other considerations.

• The final candidate projects are reported to the Program Director Council.

• The final projects are finalized at a meeting of the JST Board of Directors.

3) Project Evaluations: Midterm and Ex-post Evaluations

(i) Midterm Evaluation

The Midterm Evaluation is conducted by the Program Officer with the assistance of Area Advisors, etc. The progress and research outcome are determined and based on the results, appropriate resources are allocated, research plans are reviewed and so on with the aim of helping to promote research more effectively in order to achieve the objectives of the research project, etc. Midterm evaluations are performed approximately three years after the start of research projects that are, as a general rule, scheduled to continue for five years or more.

【Evaluation Standards】

• Research progress and future prospects

• Structure for research execution and status of research fund disbursement

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by the Program Officer with the assistance of area advisors, etc. The status of achievement of the research project, etc. and other research objectives, status of research implementation, ripple effect and so on are determined, in order to develop research achievements in the future and help to improve project administration. Ex-post Evaluations are conducted as soon as possible after the conclusion of research or at an appropriate time prior to the conclusion of research, in accordance with the characteristics and stage of development of the research.

【Evaluation Standards】

• Status of achievement of research objectives

• Structure for research execution and status of research fund disbursement

• Ripple effect of research achievements on science and technology as well as society and the economy

4) Research Area Evaluations: Midterm and Ex-post Evaluations

(i) Midterm Evaluation

The Midterm evaluation is conducted by an outside specialist selected by the JST. The status with a view to achievement of strategic objectives and the status of research management are determined and, based on the results, appropriate resources are allocated and so on with the aim of helping to improve research administration and the JST support organization. The Midterm evaluation is conducted approximately three to four years after the start of research in a Research Area in which research projects are expected to continue for five years or more.

【Evaluation Standards】

• Status with a view to achievement of strategic objectives

• Status of research management

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by an outside specialist selected by the JST. The status of achievement of the strategic objectives and the status of research management are determined with the aim of helping to improve future project administration. Ex-post Evaluations are conducted as quickly as possible after the conclusion of research in the Research Area or at an appropriate time prior to the conclusion of research.

【Evaluation Standards】

• Status of achievement of strategic objectives

• Status of research management

5) Follow-up Evaluations

The follow-up evaluation is conducted by an outside specialist selected by the JST. The status of development (including secondary effects) and status of use of research achievements, ripple effect of the research and so on are determined, with the aim of helping to improve the project and project administration and so on. Follow-up evaluations are conducted after a certain period of time has elapsed following the end of research.

【Evaluation Standards】

• Status of development and status of use of research achievements

• Ripple effect of research achievements on science and technology as well as society and the economy

(2) ERATO

1) Determination of Research Project and Project Leader (Ex-ante Evaluation)

The selection of the Research Area and Project Leader is evaluated by the Panel Officer with the assistance of the panel members.

【Evaluation Standards】

- Novel, unique and transformative research which could change the direction of thought in a discipline or make a substantial discovery to break new ground in science and technology
- Appropriate from the standpoint of the strategic objectives
- In the case of research that will be conducted jointly with a foreign research institution or the like, a project in which the combination of research capabilities with those of the joint research partner institution can be expected to create the seeds of innovative science and technology and contribute to international research exchanges

Projects must meet all of the following conditions.

- An outstanding and competent scientist who is qualified to lead an ERATO Project.
- Capable of leadership and be a person who can inspire young scientists.
- In the case of research that will be conducted jointly with a foreign research institution or the like, someone who can promote joint research smoothly with the partner institution
- Appropriate research execution organization and scale of execution

2) Ex-post Evaluation (preliminary evaluation) and Ex-post Evaluation (final evaluation)

(i) Ex-post Evaluation (preliminary evaluation)

The Ex-post Evaluation (preliminary evaluation) is conducted by an outside specialist selected by the JST, taking into account the views of the Panel Officer as needed. The progress and status of execution of research in each Research Area are determined and, based on the results, appropriate resources are allocated, research plans are reviewed and so on, in order to help promote research in a more effective manner in order to achieve the objectives of the Research Area and so on. The evaluation is generally conducted three years after the start of research.

【Evaluation Standards】

- Research progress and future prospects
- Structure for research execution and status of research fund disbursement

(ii) Ex-post Evaluation (final evaluation)

The Ex-post Evaluation (final evaluation) is conducted for each Research Area by an outside specialist selected by the JST. The status of achievement of the research objectives, status of research execution, ripple effect and so on is determined, in order to develop research achievements in the future and help improve project administration. The evaluation is conducted as soon as possible after the conclusion of research in the Research Area or at an appropriate time prior to the conclusion of research.

【Evaluation Standards】

• Status of achievement of strategic objectives

• Status of research management

3) Follow-up Evaluations

The follow-up evaluation is conducted by an outside specialist selected by the JST. The status of development (including secondary effects) and status of use of research achievements, ripple effect of the research and so on are determined, with the aim of helping to improve the project and project administration and so on. Follow-up evaluations are conducted after a certain period of time has elapsed following the end of research.

【Evaluation Standards】

• Status of development and status of use of research achievements

• Ripple effect of research achievements on science and technology as well as society and the economy

(3) ACCEL

1) Selection (Ex-ante Evaluation)

The selection of R&D Projects, Program Managers and Research Directors is conducted by the R&D Management Committee with the assistance of the Expert Evaluation Committee.

【Evaluation Standards】

(i) R&D Project

• Significant, world-leading research achievements must be produced as a result of the promotion of research in Strategic Basic Research Programs.

• It must be possible to create scenarios in which the achievements of research derived through Strategic Basic Research Programs, etc. are developed to strength industrial competitiveness and leads to a transformation of society, in a way that meets the expectations of society.

• Research and development by companies, etc. must be expected to continue even after the research period has ended.

• The research plan must be appropriate in terms of specific Proof of Concept for companies, etc.

• Efforts must be planned to train personnel who will enable ongoing research and development, as well as corporate collaboration, venture company startups and other practical applications and the incorporation of personnel with a global outlook, even after the conclusion of the ACCEL program.

(ii) PM

• A person who possesses experience and specialist knowledge relating to research and development, product development, the acquisition of rights and so on

• A person with experience and a proven track record in technology transfer, company startup, product development etc.

• A person with project management experience in business administration or a thorough education in that area

• A person with the practical experience, specialist knowledge etc. deemed to be necessary for each Research Area

(iii) Research Director

• A researcher with outstanding research achievements who is capable of directing overall research in the Research Area as the leader of the research team

2) Midterm/Ex-post Evaluation/Follow-up Evaluations

(i) Midterm Evaluation

The Midterm Evaluation is conducted for each research and development project by the R&D Management Committee with the assistance of the Expert Evaluation Committee. The progress and achievements of research are determined and, based on the results, allocation of an appropriate budget, review of research plans, suspension of research and so on are conducted, in order to help improve research administration and so on. As a rule, the evaluation is conducted approximately three years after the start of research.

【Evaluation Standards】

• Current progress of research and prospects when research period ends

• Current status of research achievements and prospects when research period ends

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by R&D Management Committee with the cooperation of the Specialist Council. The status of research execution and research achievements, etc. are determined in order to ensure the development of achievements in the future and help improve project administration. The evaluation is conducted as quickly as possible after the conclusion of research or at an appropriate time prior to the conclusion of research.

【Evaluation Standards】

• Status of execution of Proof of Concept and related corporate collaboration

• Status of acquisition of industrial property rights and other rights

(iii) Follow-up Evaluations

The follow-up evaluation is conducted by an outside specialist selected by the JST. The status of development (including secondary effects) and status of use of research achievements, ripple effect of the research and so on are determined with the aim of helping to improve the project and project administration and so on. Follow-up evaluations are conducted after a certain period of time has elapsed following the end of research.

【Evaluation Standards】

- Status of development and status of use of research achievements
- Ripple effect of research achievements on science and technology as well as society and the economy

(4) ACT-C

1) Determination of Research Area and Program Officer (Ex-ante evaluation of Research Area)

According to JST implementation, PD committee conducts Ex-ante evaluation and the decision is finalized at the meeting of the JST Board Directors.

【Evaluation Standards】

(i) Research Area

・ A Research Area that is appropriate for achieving the strategic objectives

・ A Research Area that is appropriate based on the current state of research in Japan, one in which many outstanding research proposals are anticipated

(ii) Program Officer

・ A person who has vision and discernment with regard to the Research Area

・ A person who has the experience and capacity to manage research in an appropriate manner to make effective and efficient progress in the research project

・ A person who has a record of outstanding research achievements and who has the confidence of researchers in related areas

・ A person who conducts fair and impartial evaluations

【Process used to determine Research Area and Program Officer】

(i) Ex-ante Survey by JST Based on Status of Study of the Strategic Objective

・ The JST conducts an Ex-ante survey in order to determine the Research Area and Program Officer, based on information provided by the Ministry of Education, Culture, Sports, Science and Technology starting from the stage of study of the strategic objectives.

・ The JST Ex-ante survey is conducted using the following methods.

The JST references reports, etc. from various review boards (which are also referenced during studies conducted by the Ministry of Education, Culture, Sports, Science and Technology) as well as strategic proposals and other reports from the JST Center for Research and Development Strategy (CRDS). The JST also collects and analyzes information on research trends and technological trends in relevant fields, the situation at related academic societies and so on.

Interviews are conducted with leading figures in related fields.

・ The progress of the aforementioned Ex-ante survey is reported to the relevant Program Director appointed for each strategic objective and in-depth discussions are held.

・ After formal notification of the strategic objectives is received from the Ministry of Education, Culture, Sports, Science and Technology, the JST conducts a further survey (area survey).

(ii) Ex-ante Evaluation and Finalization of Research Area and Program Officer

・ The Program Director Council conducts an Ex-ante evaluation of the Research Area and Program Officer.

・ Upon receipt of the results of the Ex-ante evaluation, the Research Area and Program Officer are finalized at a meeting of the JST Board of Directors.

2) Research Project Selection (Ex-ante Evaluation of Research Project)

The Program Officer selects the research project with the assistance of the area advisors, etc., based on the implementation regulations, and the decision is finalized at a meeting of the JST Board of Directors.

【Evaluation Standards】

・ A project that contributes to the achievement of strategic objective.

・ A project that is consistent with the Research Area intent.

・ Basic research that is pioneering, unique and highly appreciated internationally and expected to have an impact on science and technology innovation.

・ A project that can be expected to create the seeds of innovative science and technology and to contribute to get a hint of scientific and technological innovation creation.

・ The research project applicant has produced research results for accomplishing research objectives and bears responsibility for the entire research team.

・ The proposed research project is of a scale appropriate for pursuit.

・ The proposed research project is of a period appropriate for pursuit.

・ An optimal research organization is in place. Lead Joint Researchers outside of the research applicant are essential for pursuing the research project applicant's research initiatives.

・ The research institutions with which the research project applicant and Lead Joint Researchers are affiliated have R&D capabilities and other technical foundations in the subject research field.

・ Research budget planning necessary and appropriate for pursuing the research project applicant's research initiatives has been performed and the cost-effectiveness of the research should be considered.

3) Project Evaluation: Midterm/Ex-post Evaluation

(i) Midterm Evaluation

The Midterm Evaluation is conducted by the Program Officer with the assistance of Area Advisors, etc. The progress and research outcome are determined and based on the results, appropriate resources are allocated, research plans are reviewed and so on with the aim of helping to promote research more effectively in order to achieve the objectives of the research project, etc. Essentially evaluations are conducted approximately three years after the start of research in all research projects.

【Evaluation Standards】

・ Research progress and future prospects
・ Structure for research execution and status of research fund disbursement

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by the Program Officer with the assistance of Area Advisors, etc. The status of achievement of the research objectives, status of research execution, ripple effect and so on of the research project, etc., are determined in order to develop the research achievements in the future and help improve project administration. The evaluation is conducted as quickly as possible after the conclusion of research or at an appropriate time prior to the conclusion of research.

【Evaluation Standards】

・ Status of achievements of research objectives for research project, etc
・ Structure for research execution and status of research fund disbursement
・ Ripple effect of research achievements on science and technology as well as society and the economy

4) Research Area Evaluations: Midterm and Ex-post Evaluations

(i) Midterm evaluation

The Midterm evaluation is conducted by an outside specialist selected by the JST. The status with a view to achievement of strategic objectives and the status of research management are determined and, based on the results, appropriate resources are allocated and so on with the aim of helping to improve research administration and the JST support organization. The Midterm evaluation is conducted approximately three to four years after the start of research in a Research Area.

【Evaluation Standards】

・ Status with a view to achievement of strategic objectives

・ Status of research management

(ii) Ex-post Evaluation

The Ex-post Evaluation is conducted by an outside specialist selected by the JST. The status of achievement of the strategic objectives and the status of research management are determined with the aim of helping to improve future project administration. Ex-post Evaluations are conducted as quickly as possible after the conclusion of research in the Research Area or at an appropriate time prior to the conclusion of research.

【Evaluation Standards】

・ Status of achievement of strategic objectives

・ Status of research management

5) Follow-up Evaluations (Research Area)

The follow-up evaluation is conducted by an outside specialist selected by the JST. The status of development (including secondary effects) and status of use of research achievements, ripple effect of the research and so on are determined, with the aim of helping to improve the project and project administration and so on. Follow-up evaluations are conducted after a certain period of time has elapsed following the end of research.

【Evaluation Standards】

・ Status of development and status of use of research achievements

・ Ripple effect of research achievements on science and technology as well as society and the economy

4. Improvement of Program and Operations and New Activities

(1) Restructuring and Improvement of Business Management by Program Director Council

A Program Director Council made up of the JST President, Program Director (PD), Program Officer (PO) and Principal Investigator (PI) has been established to ensure a shared common recognition and realization that the main purpose of Strategic Basic Research Programs is to advance basic research aimed at achieving the strategic objectives established by the national government, and to produce the seeds of creative, innovative technologies from new scientific knowledge that gives rise to innovation in science and technology leading to social and economic change. Up to now, the following activities aimed at restructuring and improvement has been conducted.

1) Review of Evaluation Standards (selection) of Research Project and Principal Investigator (PI)

The selection criteria for CREST and PRESTO are based on "unique, highly appreciated basic research," and the fact that the research is "expected to produce outstanding results that contribute greatly to science and technology innovation" was clearly stated.

The selection criteria for ERATO are based on "basic research that is unique, challenging and internationally expected to develop at an advanced level," and the fact that the research "can be expected to produce groundbreaking results that lead to science and technology innovation" was clearly stated.

2) Review of Role of Program Officer and Guidelines, etc. for Research Area Administration (CREST and PRESTO)

The following points were revised and clarified in order to encourage the initiative of the Program Officer.

- The Program Officer alone has the authority for project selection, evaluation and budget allocation (in other words, a council system is not used).
- The scale of the budget and so on are established flexibly in accordance with the characteristics of the Research Area. For example, the scale of the budget is established in accordance with the anticipated number of applications.
- The Research Area is administered flexibly in accordance with the characteristics of the Research Area

Examples:

- ➢ Reorganization of the most capable team for CREST "Creation of Fundamental Theory and Technology to Establish a Cooperative Distributed Energy Management System and Integration of Technologies Across Broad Disciplines Toward Social Application" Research Area
- ➢ Integration acceleration method for the CREST "Scientific Innovation for Energy Harvesting Technology" Research Area

- Flexible review of research plans, budgets etc. for each project based on project evaluations, etc. (including quick termination)
- Required makeup of Research Area advisors: approximately 30% from industry, 20% or more female, and one who can offer an assessment opinion from the point of view of society in general

3) Exchange of Views by Program Director and Program Officers

This meeting is held primarily for new PO (including ERATO Panel Officers). The Program Director explains the purpose of the project and the role of the PO to the PO to achieve a shared perspective. Examples of techniques for administering the Research Area, issues encountered and so on are also given as noted below, in order to share information and hold discussions.

- Techniques for applicant selection

Example: How to appeal to applicants (PI candidates) in order to achieve strategic objectives

- Techniques for Research Area administration
- Collaboration within Research Area following selection
- Collaboration between related Research Areas and between CREST and PRESTO
- Communication of information internationally

4) Clarification and Documentation of Evaluation Criteria for Early Termination of Project

The Midterm evaluation of research projects was improved to enable early termination in the event that there is a significant inadequacy in the management capabilities of the Research Director, or if there is a major change in the state of research worldwide and the initially envisioned achievements that would have a major impact cannot be anticipated or if the progress of research is significantly delayed and there are no prospects for the achievement of the objectives of the research project and so on.

5) Newly established PRESTO Research Areas with Increased Cross-Sectoral and Confluent Nature

In PRESTO, new Research Areas that integrate the goals of multiple strategic objectives and have an increased cross-sectoral, confluent nature were established.

Two Research Areas inaugurated in FY 2014 (2014 - 2019)

- “Collaborative Mathematics for Real World Issues”
- “Design of Information Infrastructure Technologies Harmonized with Societies”

Two Research Areas inaugurated in FY 2015 (2015 – 2020)

- “Advanced Materials Informatics through Comprehensive Integration among Theoretical, Experimental, Computational and Data-Centric Sciences”
- “Innovational technical basis for cultivation in cooperation with information science”

(2) Permanent Stationing of ERATO Panel Officers

Previously, Panel Officers were selected based on the area and the expected Project Leader candidates, but now multiple (approximately 10) Panel Officers are appointed in advance without identifying specific areas to enable them to cover the scope of JST study. The Panel Officers collaborate with the JST at each stage of the study and selection process. In addition to study and selection by the Panel Officers from a scientific perspective with this organization the JST is able to reflect administrative policy (the standpoint of innovation creation) in the study and selection process.

(3) Establishment of New Program to Maximize Achievements

ACCEL was initiated in FY 2013 to conduct research management to promote activities ranging from Proof of Concept to appropriate rights acquisition, in order to turn the significant, world-leading research achievements created by Strategic Basic Research Programs into top innovations.

In addition, the ACT-C program was initiated in FY 2012 to produce advanced substance transformation technologies that are based on catalysts and can help to solve various problems - in areas like realization of a low-carbon society and the sustainable, evolutionary production of pharmaceuticals and functional materials - that are confronting not only Japan but the world as a whole.

The program includes responses to the recommendation in the previous International Evaluation: "Clear, rational standards should be established to turn the existing system into a mechanism that provides ongoing support to research projects that have produced outstanding achievements.

(4) Program Improvements to Maximize Achievements

1) Integrated Acceleration and "Small Start"

(i) Formation of the "Most Capable" Team in the EMS Area

The goal of the CREST "Creation of Fundamental Theory and Technology to Establish a Cooperative Distributed Energy Management System (EMS) and Integration of Technologies Across Broad Disciplines Toward Social Application" Research Area (FY 2012 - FY 2019) is to integrate researchers from a broad range of fields and strengthen collaboration to develop an ideal energy management system in response to future societal circumstances. To this end, a variety of small-scale teams were selected in the call for applications in FY 2012 and FY 2013 to conduct research and development of elemental technologies in various fields, with a research period of 2.5 years and 1.5 years, respectively. During these research periods, open discussions that included research communities from outside the Research Area were held regarding the type of energy system that Japan should aim for, and a venue to deepen mutual understanding between different fields was provided. Thorough discussions that extended beyond the boundaries of individual fields were held, and as a result the teams were reorganized into five "most capable teams" that integrated different fields. The size of the budget for these five teams was increased, and research for a period of up to five years began in 2015.

In reorganizing these teams, discussions were also held regarding research progress reports and research content, and a total of seven area meetings including training camp style meetings were held. In addition, both the Program Officer and the Area Advisors made site visits (two visits and 35 visits, respectively) to seek the potential for collaboration among teams based on these "most capable" teams.

(ii) Introduction of Integrated Acceleration System for Microenergy Research Area

In the CREST and PRESTO "Scientific Innovation for Energy Harvesting Technology" Research Area (FY 2015 - FY 2022), it was decided that, for the research projects selected for FY 2015, the research period for CREST would be 3.5 years, the same as that for PRESTO. Moreover, by means of the project progress study to be conducted in FY 2018 when the research project concludes, the research projects will be reorganized as needed and then developed and enhanced in order to maximize the achievements in the second half phase of the Research Area. This Research Area, therefore, will be an integrated CREST/PRESTO where work will be pursued under the strong leadership of the Program Officer and Deputy Program Officer and efforts will be made to reorganize research teams, coordinate research programs and promote strong communication among researchers pursuing different themes, all for the maximization of research achievements.

2) Measures to Enhance Collaboration in PRESTO from the Project Proposal Stage Onward

In the PRESTO "Creation of next-generation fundamental technologies for the control of biological phenomena in field-grown plants" Research Area (FY 2015 - FY 2020), due to the need for collaborative activity at a high level based on a combination of plant science and information science and so on, it is now possible for PRESTO researchers to work on not only ordinary proposals but also collaborative proposals with other PRESTO researchers. In cases in which it is difficult for the applicant alone to accomplish a portion of the proposed research project, it is now possible for the information science researcher and the plant science, etc. researcher to hold discussions in advance regarding the possibility of collaboration, or otherwise for each to submit separate proposals to the Research Area noting their respective roles and the anticipated synergistic effect.

3) Strengthening International Collaboration

The CREST and PRESTO programs have promoted intellectual collaboration as a means of accelerating and augmenting research while at the same time keeping in mind the need to secure the national interest which includes appropriate protection and use of intellectual property. Specific activities have included (1) priority funds allocation for research areas and research area groups for which internationalization is strategically important, (2) strengthening of international response capabilities for research area management and (3) active collaboration with JST international divisions.

(i) Intensive Resource Allocation to Research Area or Research Area Cluster from a Strategical Standpoint of Internationalization

An example of priority funds allocation required from CREST Research Directors or PRESTO Researchers and approved by Program Officer is the invitation (issued in September 2014) for joint public participation in the Priority Program "Software for Exascale Computing" (SPPEXA) being implemented collaboratively by the German Research Foundation (DFG), the French National Research Agency (ANR) and JST-CREST. Additional research funds have been allocated for the CREST research team (the "Development of System Software Technologies for post-Peta Scale High Performance Computing" CREST Research Area and the "Advanced Application Technologies to Boost Big Data Utilization for Multiple-Field Scientific Discovery and Social Problem Solving" CREST Research Area), which is participating in international joint research projects that have been selected in an international review process. The goal is to maximize the achievements of CREST research through international collaboration.

JST joined the Partnerships for International Research and Education (PIRE) conducted by NSF (U.S.A.) as a partnering agency and constructed a framework for additional funding to the joint research work of Japanese researchers conducive to CREST or PRESTO research thorough this partnership.

(ii) Strengthen International Rresponse Capabilities for Research Area Management

The JST has participated in the International Human Epigenome Consortium (IHEC) since 2011 in the "Development of Fundamental Technologies for Diagnosis and Therapy Based upon Epigenome Analysis" CREST Research Area. Epigenome analysis is the cornerstone of various types of research and the aim is to support increased competitiveness for Japan's life science and disease science research in the face of international cooperation.

(iii) Cooperation with JST Department of International Affairs

Furthermore, The CREST and PRESTO programs are collaborating with the JST Strategic International Collaborative Research Program (SICORP) in an effort to accelerate the achievement of strategic objectives. Specifically, the Program Officers of the CREST "Establishment of Molecular Technology towards the Creation of New Functions" Research Area and the PRESTO "Molecular Technology and Creation of New Functions" Research Area also serve as the Program Director and the Deputy Program Director for the SICORP "France-Japan Molecular Technology" Program (France-Japan joint research). Effective collaboration between CREST and PRESTO research and development and Japanese-French joint research will further accelerate and augment Japanese research into molecular technology to enable it to lead the world. Similarly, the Program Officer and Deputy Program Officer of the CREST and PRESTO "Advanced Core Technologies for Big Data Integration" Research Area also serve as the Program

Director and the Deputy Program Director for the call for proposals for the SICORP “Big Data and Disaster Research” Program (US-Japan joint research).

The above includes responses to the recommendation in the previous International Evaluation: “A relationship with the international scientific community should be enhanced.”

4) SciFoS Activities

The goal of these activities is for young CREST and PRESTO researchers to develop the capacity to reflect on their own research from the perspective of Science for Society (SciFoS). Researchers use the newly developed Value Proposition Validation Method to summarize what value their research creates for society and what societal needs it fulfills. Then they conduct interviews outside the laboratory to reflect on their research from the standpoint of science within society. The aim is to enable researchers to reorganize their efforts and take their research a step further in the future. SciFoS activities are conducted for a period of six months under the supervision of the Program Officer and a person with a deep knowledge of industry affairs and a wide network of contacts serves as an advisor. These activities have been conducted since FY 2013, and in those three years 24 researchers in five research areas have participated in the program. Contact with the expectations of society enables the researchers to cultivate the perspective not only of “problem-driven basic research” but of “value-exploring basic research.” Learning about various needs on the periphery of their research also enables them to become aware of new research topics. This experience is the first step toward being able to conduct research while constantly being in touch with society’s needs, and subsequently the researchers develop their own interview subjects and conduct their own interviews. Other goals are that researchers improve their own communication skills, and that the program will serve as an opportunity for researchers to develop relationships with people in the corporate world, with whom they can have a long and rewarding relationship.

5) Efforts to Promote Diversity

As efforts to promote diversity such as gender equality, beginning in FY 2010 assistance to support a balance between research and childrearing and so on has been provided to ensure that researchers are able to continue their research without having to put their careers on hold at the time of major life events (birth, childrearing and nursing care) and, even when a temporary suspension is inevitable, to enable them to resume their research when it is possible for them to return, and to provide support for the subsequent continuation of their careers. Research periods are extended in accordance with the period of research interruption, and research funds can be used as originally planned. In the current evaluation period, 25 PRESTO researchers have received assistance.

Beginning in FY 2013, application briefings have been held in English for foreign researchers. Each year applications from approximately 50 researchers are received by PRESTO, and 12 to 13 are received by CREST.

The above includes responses to the recommendation in the previous International Evaluation: "There is a need for more effective efforts to increase interest in this project on the part of female researchers, and to support and train them."

6) Efforts to Prevent Research Misconduct

Efforts are made to prevent research misconduct and measures to deal with unreasonable duplication and undue concentration, including mandatory e-learning programs relating to research integrity for ERATO, CREST, PRESTO, ACCEL and ACT-C Project Leaders, Research Directors and researchers, as well as lectures in research integrity relating to research fraud and the fraudulent use of public research funds as part of explanatory briefings for newly hired CREST and PRESTO researchers.

7) Efforts Relating to Open Access

The "JST Policy Regarding Open Access" was established in 2013, and efforts are underway to ensure open access.

To respect the researcher's freedom with regard to his or her academic papers and at the same time use the Institutional Repository Program to ensure that academic papers, etc. produced with JST research funds are accessible in their entirety on the Internet at no charge as quickly as possible, specific use as an infrastructure is made of the Institutional Repository that has been promoted as a national government policy, and it is clearly stated in the application procedures that it is recommended to researchers that they obtain the consent of the journal that published the researcher's paper and then make it publicly available in the Institutional Repository for "a set period of time." Researchers are also able to publish papers in magazines on the presumption that open access will be provided.

5. Future Approach to Reform and Improvement

Study of the following points is currently underway with regard to project restructuring.

1) Enhancement of the Distinctiveness and Competitiveness of Strategic Basic Research Programs

2) Enhancement of the Formulation of Strategic Objectives and Research Areas, including the Perspective of Building a Common Future

3) Enhancement of Seamless Collaboration Leading from Academic Research to Commercialization KAKENHI, JST industry-academic collaboration projects and collaboration with NEDO

4) Enhancement of International Joint Research

Further enhancement of collaboration with overseas funding institutions

5) Increased Opportunities for Young Researchers and Female Researchers to Conduct Challenging Research, and Opportunities for Research that Extends beyond the Boundaries between Different Fields and Organizations

6) Training of JST Personnel Capable of Creating and Managing the Above

Chapter 3 . Strategic Basic Research Programs Research Results and Ripple Effects

Section 1 . Strategic Basic Research Programs Research Results

The Strategic Basic Research Programs are intended to bring about scientific innovation by promoting research in four main priority fields. These are (1) Nanotechnology and Materials, (2) Green Innovation, (3) Life Innovation, and (4) Information and Communications Technology (ICT). Research areas and research projects are being set up, administered, and operated according to strategic objectives defined by the national government. This section will first describe the research flow of four fields and their research projects that have been set up so far. It will also present a field by field listing of researchers involved in Strategic Basic Research Programs who have contributed to the advance of science and technology and who were selected by Thomson Reuters in June 2014 to be among "The World's Most Influential Scientific Minds: 2014." Details of the THOMSON REUTERS's selection method will be described at greater length in Section 2. 2. (Scientists who are influential worldwide), section (1) (Numbers of researchers in the world in each research field).

1. Nanotechnology and Materials Field

(1) Research Flow

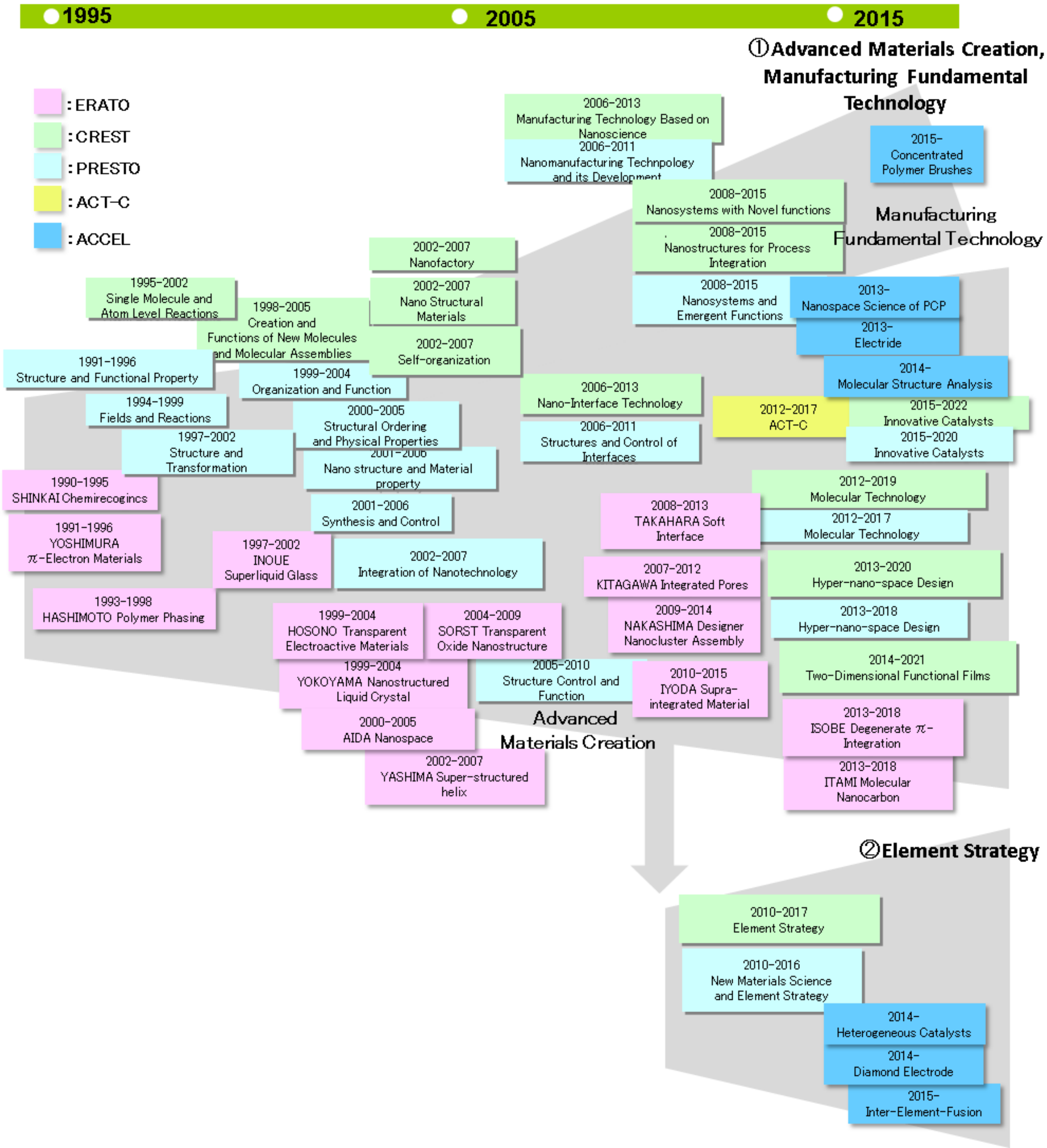
For the Nanotechnology and Materials field, research areas and research projects are being pursued with priority assigned to four areas. Their purpose is to realize more advanced performance with existing materials, devices, and systems, and to promote research and development that also takes cognizance of new services and applications in building the foundation for a new industrial structure. Specifically, the four areas are ① Advanced Materials Creation, Manufacturing Fundamental Technology, ② Element Strategy, ③ Low-power-consumption and Multifunctional Nanoelectronics and ④ Optical/Quantum Analysis and Measurement Fundamental Technology (Fig. 3-1).

① Advanced Materials Creation, Manufacturing Fundamental Technology started with fundamental research in nanomaterial creation conducted under ERATO and PRESTO. This has expanded into the creation of nanomanufacturing technology and devices as well as of materials with new functions. From around 2002, the CREST-PRESTO Research Area related to nanotechnology was started and work in the nano-manufacturing technology and nanosystems research areas was accelerated.

② Element Strategy expanded the results obtained in creation of materials, and the CREST-PRESTO element strategy research area was started in 2010. The results achieved in this element strategy area have been applied in ACCEL.

③ Low-power-Consumption and Multifunctional Nanoelectronics work started with the device-related CREST research area in 2001 and expanded to the CREST-PRESTO next-generation nanoelectronics research area. The results from spin-related research projects were also taken up by ERATO from 2001, and the spintronics field has been developing out of that.

④ Optical/Quantum Analysis and Measurement Fundamental Technology, the beginning was in ERATO fundamental research in such areas as optical crystals and materials, quantum effects, near-field optics and so on. A number of CREST research areas were inaugurated in 2004 and these have been developing applications in measurement and analysis technology, photonic crystals and other new photonic devices and applications in advanced light sources and imaging including the X-ray area. Work on photonic crystals has advanced into high-power laser applications in ACCEL.



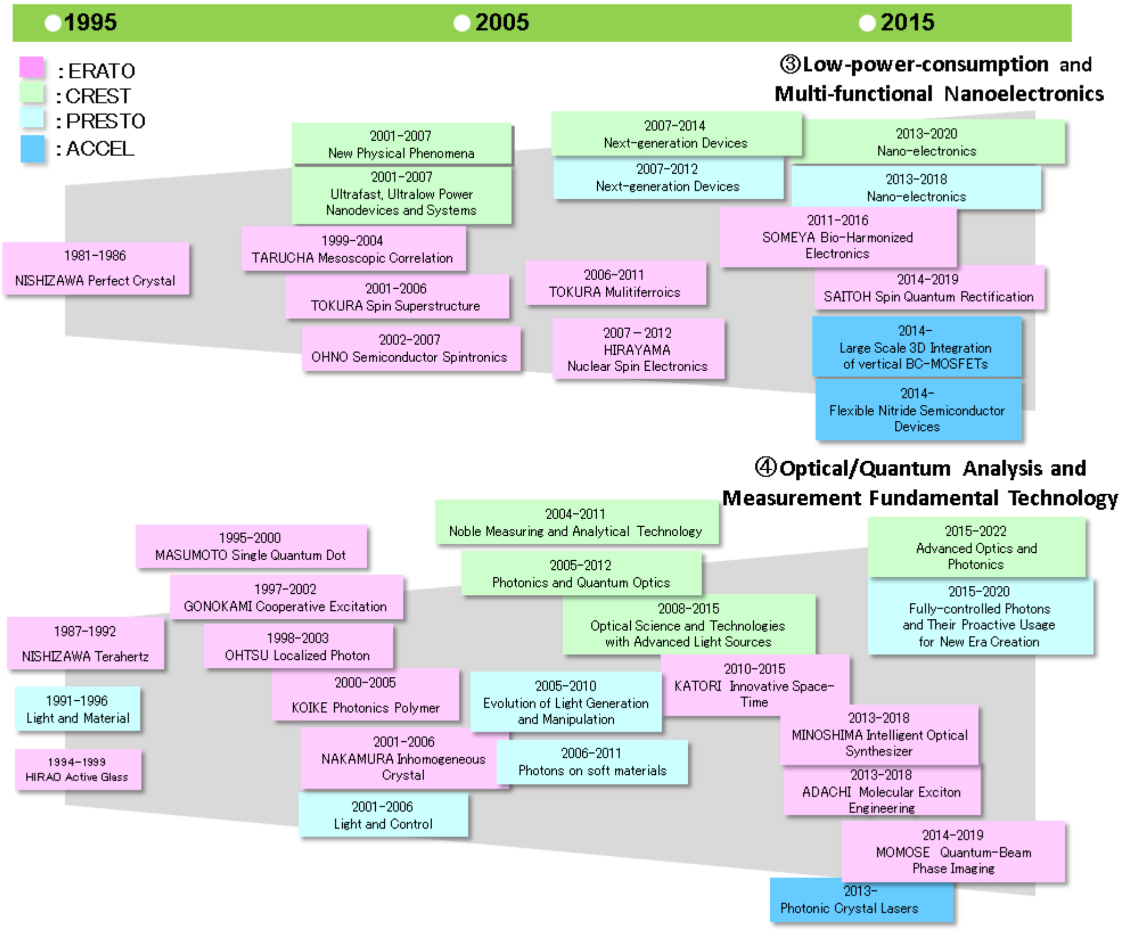


Fig. 3-1 Research flow in the Nanotechnology and Materials field

(2) Contributions to the Advance in Science and Technology

Table 3-1 The world’s most influential Researchers in the Nanotechnology and Materials Field

Research Area/Project	Researcher	Position , Affiliation
CREST “Nano Structural Materials”	Naoto Nagaosa	Group Director, Strong Correlation Theory Research Group, The Center for Emergent Matter Science, RIKEN
	Hidenori Takagi	Professor, Graduate School of Science, Tohoku University
CREST “Manufacturing Technology Based on Nanoscience”	Kazunori Kataoka	Professor, Graduate Schools of Medicine / Engineering, The University of Tokyo
ERATO “TOKURA Multiferroics”	Yoshinori Tokura	Professor, Graduate School of Engineering, The University of Tokyo

ERATO “HOSONO Transparent ElectroActive Materials” SORST “Transparent Oxide Nanostructure” ACCEL “Electrides”	Hideo Hosono	Professor, Materials and Structures Laboratory / Frontier Research Center, Tokyo Institute of Technology Director, Materials Research Center for Element Strategy, Tokyo Institute of Technology
CREST “Nano-Interface Technology”	Xu Qiang	Chief Senior Researcher, Research Institute for Ubiquitous Energy Devices, National Institute of Advanced Industrial Science and Technology
ERATO “KITAGAWA Integrated Pores” ACT-C ACCEL “Nanospace Science of PCP”	Susumu Kitagawa	Professor, Graduate School of Engineering, Kyoto University
ACT-C	Tetsuya Sato	Professor, Graduate School of Science, Osaka City University
CREST “Nanostructures for Process Integration”	Katsuhiko Ariga	Principal Investigator, International Center for Materials Nanoarchitectonics (MANA), National Institute for Materials Science (NIMS)
CREST “Nanosystems with Novel functions” ERATO “SOMEYA Bio-Harmonized Electronics”	Takao Someya	Professor, Graduate School of Engineering, The University of Tokyo
	Tsuyoshi Sekitani	Professor, Institute of Scientific and Industrial Research, Osaka University

2. Green Innovation Field

(1) Research Flow

The main continua in the Green Innovation field are in energy-related research areas and research projects. Specifically, these are made up from the separate areas of ① Energy Management Systems (overall energy supply and demand optimization systems), ② Energy Saving for Use (ultra-high efficiency utilization of fossil fuel resources, industry and consumer energy saving), and ③ Energy Creation, Transport Storage (photovoltaic batteries, artificial photo synthesis, biomass, hydrogen and energy carriers, fuel cells, electric power storage devices). Other than these, there are also continua relating to ④ resource recycling with a focus on water (Fig. 3-2).

The CREST "Social Systems for Better Environment Performance" Research Area, inaugurated in 1995, was made up of research topics in a variety of different specialized fields relating to energy and resource recycling. However, these were later split up into specialized areas to address environmental problems and other such matters, and the research results and human resources produced in the initial research area were inherited and advanced by the following Research Areas.

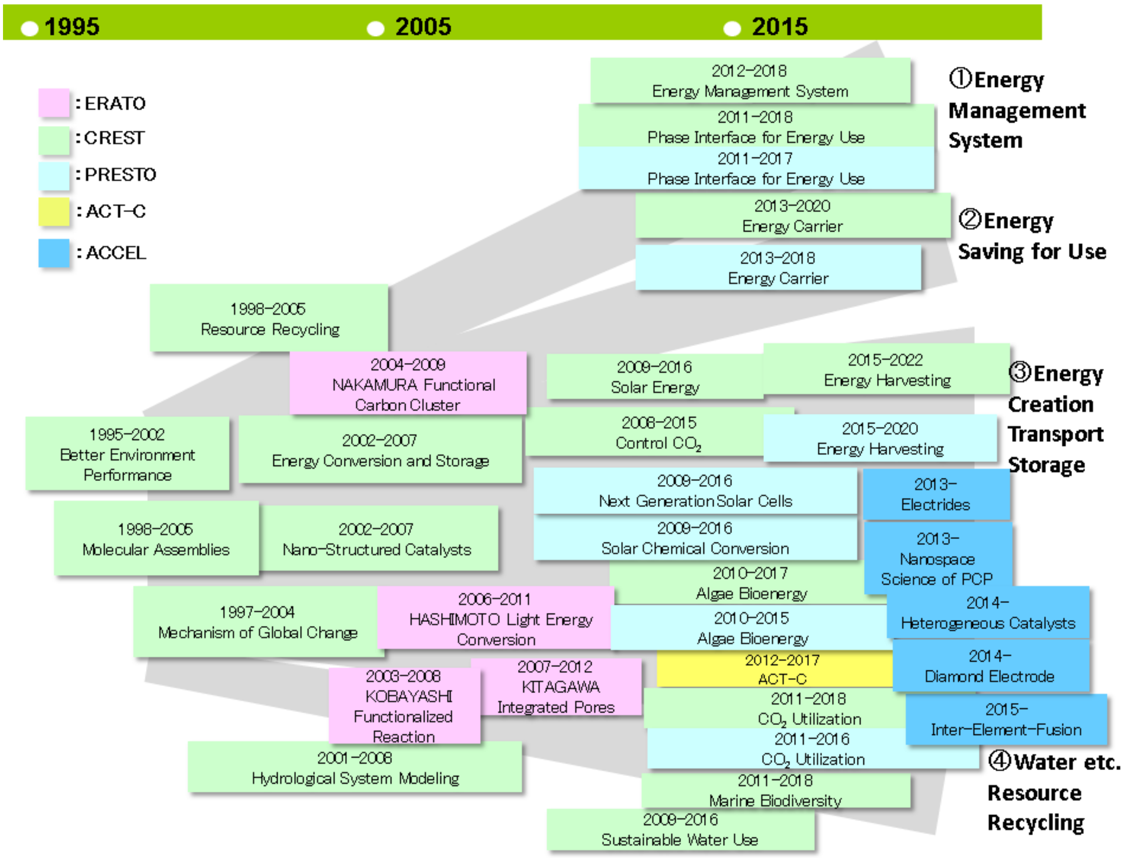


Fig. 3-2 Research flow in the Green Innovation field

(2) Contributions to the Advance in Science and Technology

Table 3-2 The world's most influential Researchers in the Green Innovation field

Research Area/Project	Researcher	Position , Affiliation
ERATO "KITAGAWA Integrated Pores" ACT-C ACCEL "Nanospace Science of PCP "	Susumu Kitagawa	Professor, Graduate School of Engineering, Kyoto University
CREST "Control CO_2"	Motoaki Seki	Team Leader, RIKEN Center for Sustainable Resource Science
CREST "Phase Interface for Energy Use"	Mingwei Chen	Professor, Advanced Institute for Materials Research, Tohoku University
CREST "CO_2 Utilization"	Toshiharu Shikanai	Professor, Graduate School of Science, Kyoto University
	Tadao Asami	Professor, Graduate School of Agricultural and Life Sciences, The University of Tokyo
	Hitoshi Sakakibara	Group Director, RIKEN Plant Science Center

3. Life Innovation Field

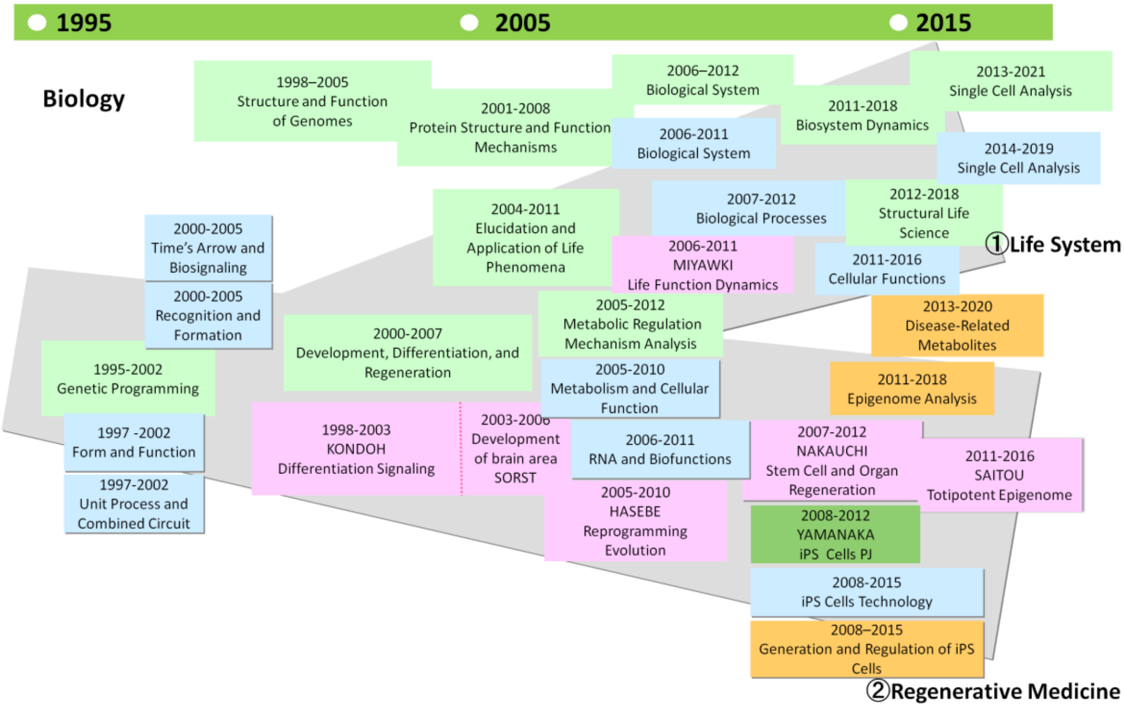
(1) Research Flow

The Life Innovation field has promoted the development of new technologies founded in life functions in order to satisfy diverse societal needs, including needs for food, environment, and health. It has developed from classic molecular biology research of elements in reduced form to the field of Systems biology to integrate the elements. The field of development and differentiation research and the research for the mechanisms of regeneration such as regenerative medicine has been invested strategically in terms of policy responses and studies in the field of biology, immunology and brain sciences have been conducted. (see Fig. 3-3).

The CREST "Genetic Programming" Research Area, started in 1995, underwent a dual expansion, that is the research in CREST "Structure and Function of genomes" and CREST "Protein Structure and Function Mechanisms" Research Area led to research in CREST "Biological System" Research Area (①life System). The other stream is the research in CREST "Development, Differentiation and Regeneration" Research Area advanced into ERATO "NAKAUCHI Stem Cell and Organ regeneration" Project, CREST "Generation and Regulation of iPS Cells" Research Area and PRESTO "iPS Cells Technology" Research Area (②Regenerative Medicine), while The CREST "Host defense Mechanism" Research Area has expanded into research on immunity and on allergies, chronic inflammation, and other such disorders(Fig. 3-3).

In the field of Brain Sciences, the CREST "Understanding the Brain" Research Area and the CREST "Protecting the Brain" Research Area gave rise, for example, to brain research that has worked on basic research as well as to the PRESTO "Brain Information" Research Area that focuses on brain science and its applications. The research areas marked by an orange color in the figure have been transferred to the Japan Agency for Medical Research and Development (AMED), which was established in April 2015, and research is continuing in those areas.

There is also the CREST "Plants Function and Their Control" Research Area, which aimed to elucidate the diverse functions of plants as well as to control and utilize those functions. This has also given rise to the stream of green biotechnology, which aims to develop new food production, functional food products, and other such new technologies.



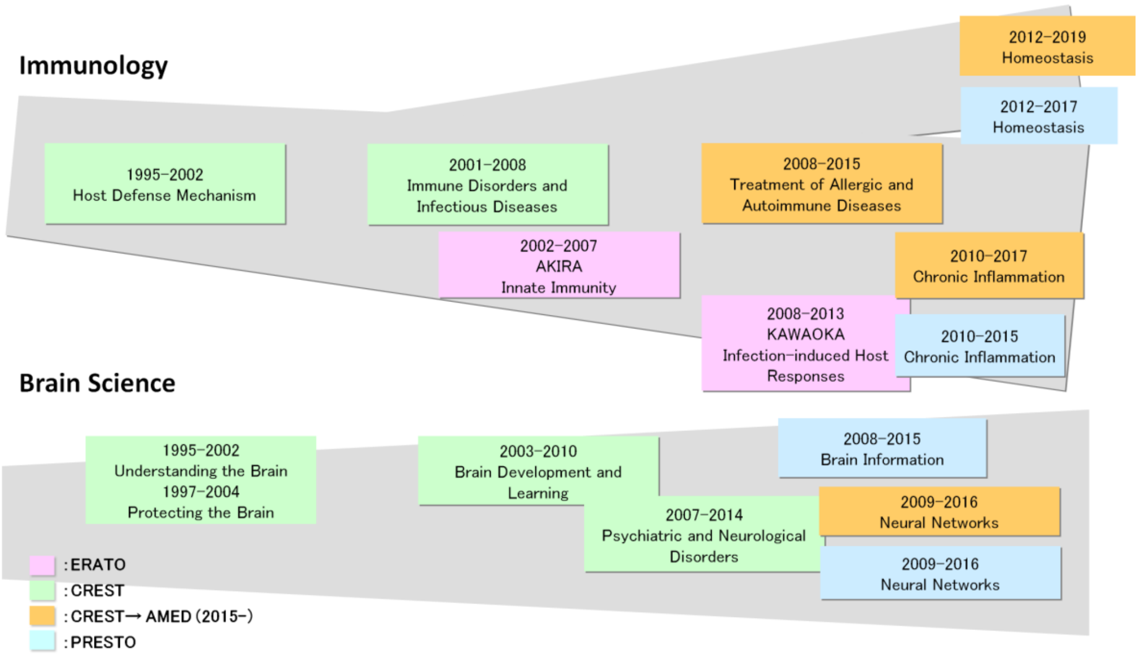


Fig. 3-3 Research flow in the Life Innovation field

(2) Contributions to Advances in Science and Technology

Table 3-3 The world's most influential Researchers in the Life Innovation field

Research Area/Project	Researcher	Position , Affiliation
CREST "Host Defense Mechanism" ERATO "AKIRA Innate Immunity"	Shizuo Akira	Professor, Immunology Frontier Research Center, Osaka University
CREST "Host Defense Mechanism"	Yuichi Sugiyama	Laboratory Head, RIKEN Innovation Center (RInC)
PRESTO "Unit Process and Combined Circuit" PRESTO "Time's Arrow and Biosignaling"	Noboru Mizushima	Professor, Graduate School of Medicine, The University of Tokyo
CREST "Protein Structure and Functional Mechanisms" CREST "Homeostasis"	Tamotsu Yoshimori	Professor, Graduate School of Medicine, Osaka University
CREST "Immune Disorders and Infectious Diseases" ERATO "KAWAOKA Infection-induced Host Responses"	Yoshihiro Kawaoka	Professor, Institute of Medical Science, The University of Tokyo

CREST "Immune Disorders and Infectious Diseases" CREST "Chronic inflammation"	Shimon Sakaguchi	Distinguished Professor, Osaka University/ Professor, Immunology Frontier Research Center, Osaka University
CREST "Plants Function"	Kazuki Saito	Professor, Graduate School of Pharmaceutical Sciences, Chiba University
PRESTO "Recognition and Formation"	Tatsuo Kakimoto	Professor, Graduate School of Science, Osaka University
CREST "Plants Function"	Masaru Takagi	Invited Senior Researcher, National Institute of Advanced Industrial Science and Technology (AIST)
	Kazuo Shinozaki	Group Director, RIKEN Center for Sustainable Resource Science
ERATO "AKIRA Innate Immunity" CREST "Development of the Foundation for Nano-Interface Technology"	Ken Ishii	Project Leader, National Institute for Biomedical Innovation (NIBIO)
ERATO "AKIRA Innate Immunity"	Taro Kawai	Associate Professor, Graduate School of Sciences, Nara Institute of Science and Technology
CREST "Metabolism and Cellular Function"	Masami Hirai	Team Leader, RIKEN Center for Sustainable Resource Science
PRESTO "RNA and Biofunctions"	Mitsutoshi Yoneyama	Professor, Medical Mycology Research Center, Chiba University
PRESTO "Biological System" CREST "Homeostasis"	Kenya Honda	Team Leader, RIKEN Center for Integrative Medical Sciences
PRESTO "Metabolism and Cellular Function"	Masaaki Komatsu	Project Leader, Tokyo Metropolitan Institute of Medical Science
CREST "Treatment of Allergic and Autoimmune Diseases"	Yoichiro Iwakura	Professor/Director,, Research Institute for Biomedical Sciences, Tokyo University of Science
	Tadatsugu Taniguchi	Professor, Department of Molecular Immunology, Institute of Industrial Science, The University of Tokyo
	Kiyoshi Takeda	Professor, Graduate School of Medicine, Osaka University
CREST "Chronic inflammation"	Osamu Takeuchi	Professor, Institute for Virus Research, Kyoto University

PRESTO “Chronic inflammation”	Susumu Nakae	Associate Professor, Center for Experimental Medicine and Systems Biology Institute of Medical Science, The University of Tokyo

4. Information and Communications Technology Field

(1) Research Flow

In the Information and Communications Technology (ICT) field, the development of new technology is promoted. The purpose is for people to coexist and interact with ICT while building a prosperous, safe and secure society through the creation of innovative ICT technology. The main areas of activity are in ① Symbiosis of Human and Information Systms, ② Information Systems and ③ Computational Science and Applied Mathematics. (Fig. 3-4.)

① There was the “Kawato Dynamic Brain Project started in 1996 under ERATO. This project developed a humanoid robot based on measurement and modeling of human brain functions and opened up a new area of research. This subsequently expanded into research areas relating to media and society the information environment, and intelligent information processing and has developed into research on the coexistence of human beings and information systems.

② Information Systems, areas of research on devices with novel functions, quantum code communication and basic quantum computer technology were started up from 1998 to 2003. These led to research areas on ultra-low power consumption information systems, dependable integrated circuits, and embedded operating systems, then developed into basic and applied research in the area of big data.

③ Computational Science and Applied Mathematics, research areas that gave rise to movements in computational science were started up from 2002 to 2005. Research on applications in other areas of mathematics was then pursued from 2008 and that has connected with research in super computer hardware, software, and applied technology.

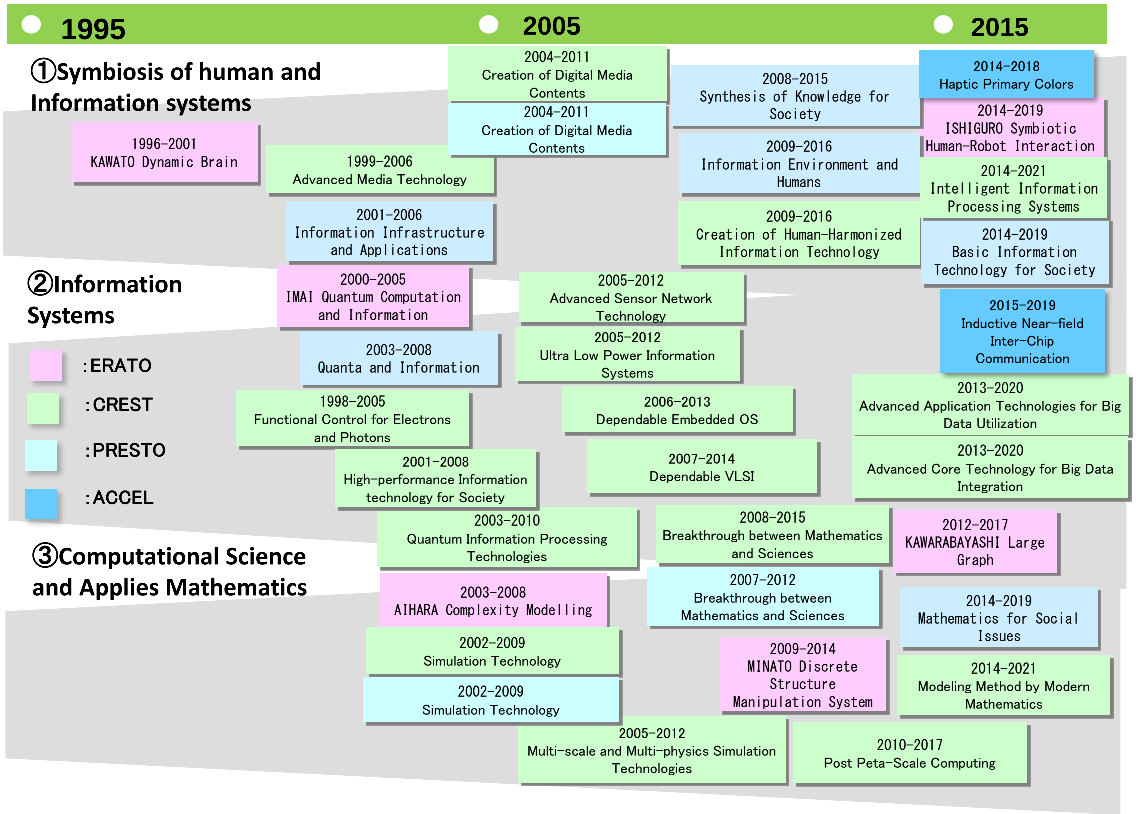


Fig. 3-4 Research flow in the Information and Communications Technology field

(2) Contributions to Advances in Science and Technology

Table 3-4 The world's most influential Researchers in the Information and Communications Technology field

Research Area/Project	Researcher	Position, Affiliation
CREST "Quantum Information Processing Systems"	Yasunobu Nakamura	Group Director, RIKEN Center for Emergent Matter Science

Section 2 . Research Results Published

1. Worldwide Research Trends

(1) Methods for Analyzing Research Results

The number of papers is the most basic bibliometric indicator for measuring research productivity and ranking of country, research institutions and so on, and it enables comparison of activity research output of country or institution. The citation data can be used in measuring the impact and influence of a paper. Citation analysis is taken over a certain period of time as the total number of citations and the total number of citations received by institutions or researchers over a certain period of time can be compared as a way of ranking the impact of their research. Highly cited papers are defined as the top 1% of papers in number of citations from the 22 research field categories (which include natural science fields and social science fields) of the Essential Science Indicators (ESI) database for paper trend analysis. This is a powerful indicator of how much influence has on worldwide academics and research and other such matters that can suggest a global ranking.

Here the Web of Science (WOS) database provided by THOMSON REUTERS, the data analysis tool InCites and ESI are used to determine the number of papers, the highly cited papers, and other such quantities and to show their trends over time. Further comparisons were made of trends in the numbers of highly cited papers, trends in percentage of highly cited papers to the total number of papers, and distinctive characteristics by research field, in order to compare the impact of the papers.

In order to obtain the research results of the Strategic Basic Research Programs a search formula was developed for each program of the Strategic Basic Research Programs (CREST, PRESTO, ERATO, ACT-C, ACCEL, TRiP[22], SORST[23], ICORP[24], Yamanaka iPS, Strategic Basic Research Programs, and Research Acceleration Program) based on the affiliation or funding organization of each program. The total numbers of each group were obtained from WOS without overlapping and then put into InCites and analyzed to get the highly cited papers and numbers of paper per field.

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22 This research area was set up urgently in 2008 in order to provide accelerated development of the highly promising technological potential in the high-temperature superconductor with magnetic elements that had been newly discovered in Japan. The aim was to leverage that effort into a sustainable development of Japan's science and technology, particularly in materials science, that would overcome global competition. http://www.jst.go.jp/kisoken/htsc/ryouiki/index.html

23 The aim of SORST was to provide support for research continuing seamlessly beyond the initial research period for research topics and projects among those like those of the Strategic Basic Research Program (CREST, PRESTO sakigake, and ERATO) that present superior prospects for results and expansion. In this way, SORST was intended to contribute to the production of major research results that would become keys to future science and technology or that were anticipated to yield future practical applications. http://www.jst.go.jp/kisoken/sorst/

24 ICORP was a new research program format that was started in 2002 for international joint research under the Strategic Basic Research Program. http://www.jst.go.jp/icorp/jpn/concept/index.html

(2) Trends in Research Results by Country

1) World Economic Conditions and Research Results

A comparison was made of trends in the numbers of papers, the number of researchers and total R&D investments in the United States, the United Kingdom, France, Germany, China, South Korea, Singapore, and Japan.

(i) Trends in the Numbers of Papers

A comparison was made of trends in the number of papers from 2005 to 2014. the United States published three to five times more papers than other countries, although China has been rising rapidly, as though to overtake the United States, since 2007（See Fig. 3-5).

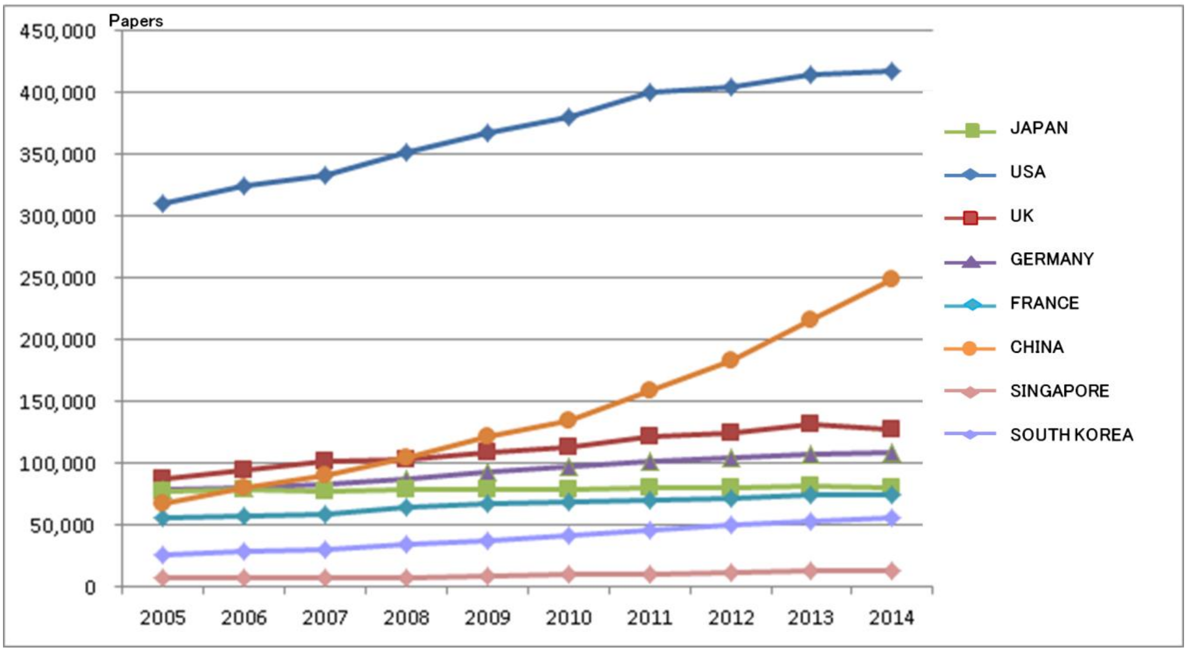


Fig. 3-5 Trends in numbers of annual total papers by country

(ii) Trends in Numbers of Researchers and Total R&D Investments

To provide a better understanding of the background to trends in the numbers of papers in those countries, the trends in numbers of researchers and the total R&D investments are shown in Fig. 3-6 and Fig. 3-7. It is clear that the numbers of researchers are greater in the United States and China than in other countries. The total R&D investment in the United States is nearly three times that of other countries, and it can be seen that China has been investing two to three times as much as other countries since 2009. The rankings indicate generally the same trends as seen in numbers of papers.

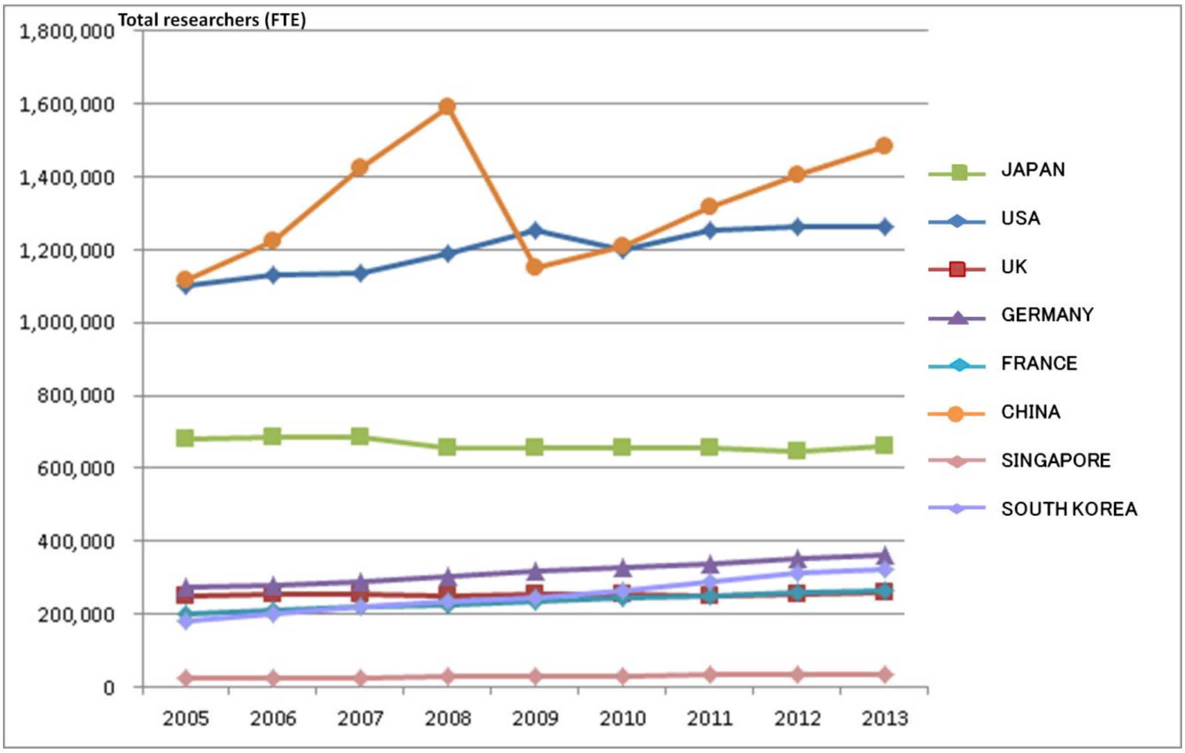


Fig. 3-6 Trends in numbers of researchers by country

Source: OECD Main Science and Technology Indicators (MSTI 2015 July)

(Note: Figures for China in 2005-2008 do not meet OECD criteria.)

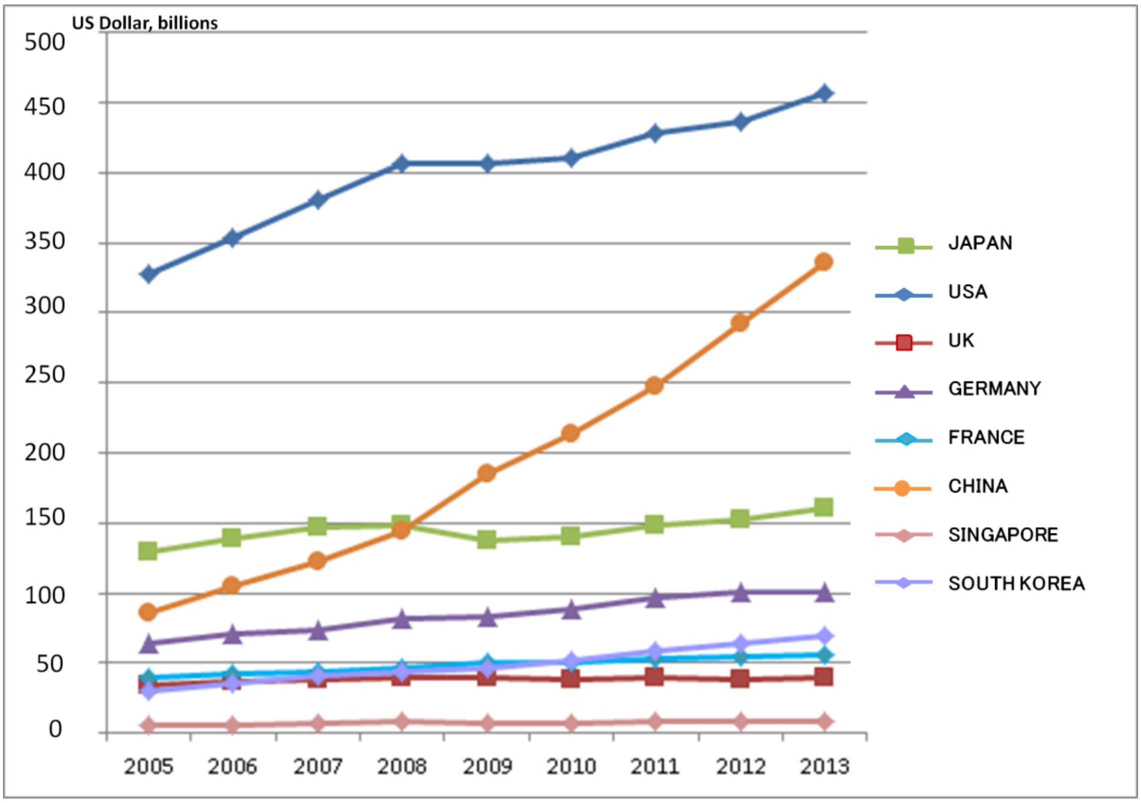


Fig. 3-7 Trends in total R&D investments by country

Source: OECD Main Science and Technology Indicators (MSTI 2015 July)

(iii) Trends in Numbers of Highly Cited Papers and Percentage of the Highly Cited Papers to the total papers

As shown in Fig. 3-8, trends in the numbers of highly cited papers place the United States, United Kingdom, Germany, France, Japan, South Korea, and Singapore in the same order as in total numbers of papers. However, China rose to fourth place after Germany in 2008, then to third place with Germany in 2011, and in 2014 was pressing against the United Kingdom for second place.

On the other hand, as shown in the Fig. 3-9, the percentage of highly cited papers to the total number of papers in the United States remained flat at 1.7% from 2005 to 2014, while the figure in the United Kingdom started rising in 2008 going from 1.7% to 2%. From 2009 on, Singapore went from 1.7% to 2.7%, rising to the top from 2011 on, China has held above 1% and though Japan and South Korea fall short of the 1% level, a trend to move upward in that direction is apparent.

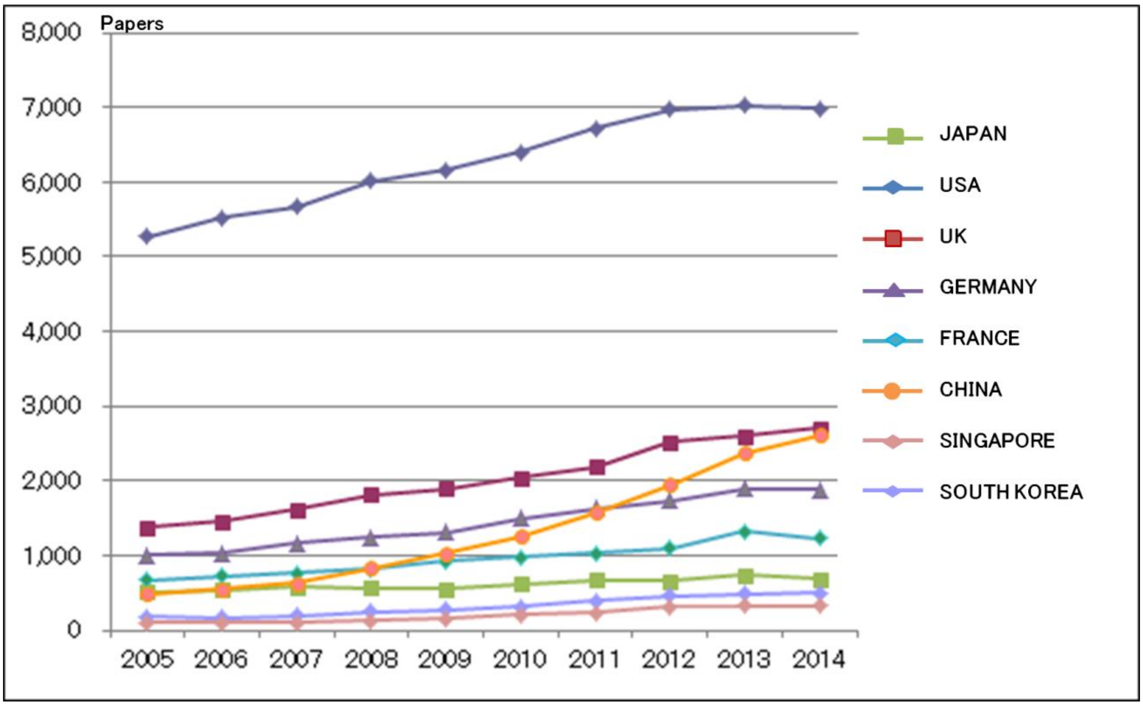


Fig.3-8 Trends in numbers of Highly Cited Papers by country

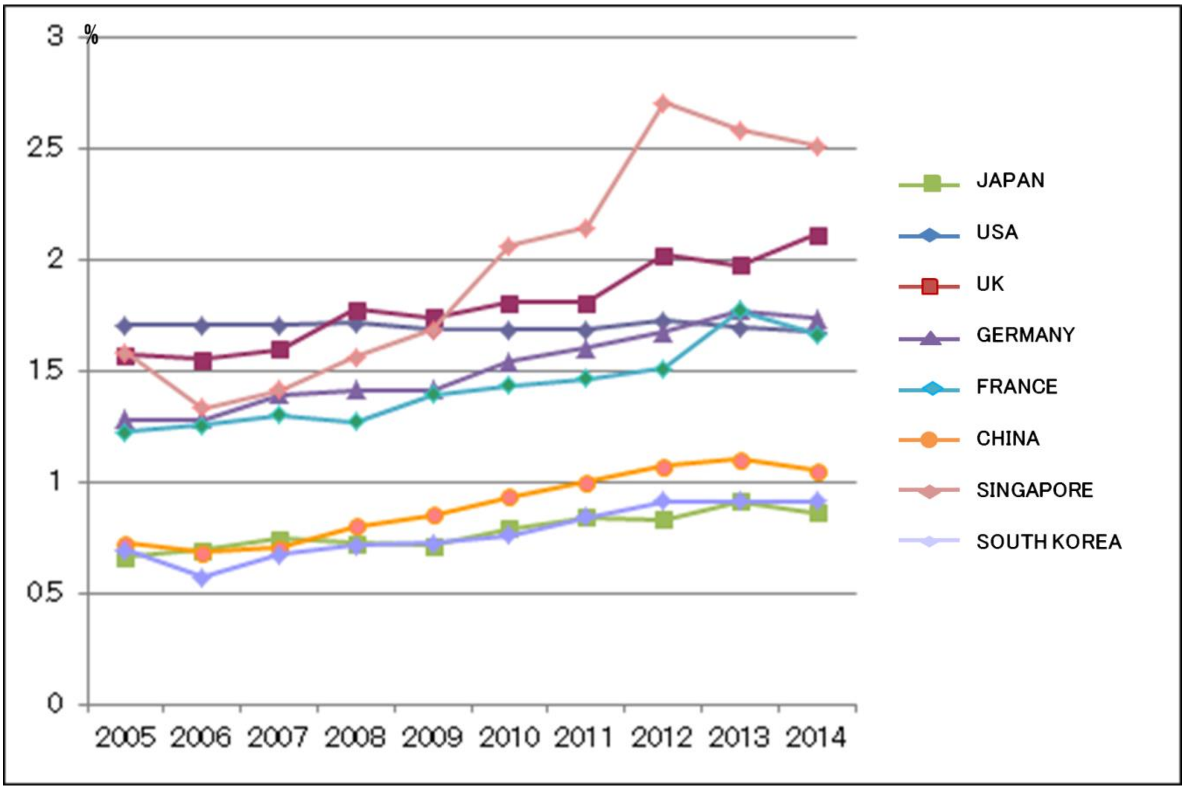


Fig. 3-9 Trends in percentage of the highly cited papers to the total papers by country

2. Scientists who are Influential Worldwide

(1) Numbers of Researchers in the World in Each Research Field

In "The World's Most Influential Scientific Minds: 2014," described in Section 1. was published by THOMSON REUTERS in June 2014 based on two independent axes of evaluation: (i) "Highly Cited Researchers" (authors of highly cited papers) and (ii) "Hottest Researchers" (the researchers who attracted the greatest attention in 2013). The present publication drew its authors of highly cited papers from those who had a certain number of highly cited publications over and above the highly cited publications in the top 1% in 22 research field (including natural science fields and social science fields). This shows which fields Japanese researchers are influential in worldwide, the numbers of researchers in each field worldwide, the number of Japanese researchers and the number of researchers involved in the Strategic Basic Research Programs (JST). (See Table 3-5) Out of those fields from which Japanese researchers were selected, the fields in which Japan ranks in the top 10 internationally are shown in Table 3-6.

Table 3-5 Number of the world's most influential researchers and these numbers of researchers in Japan and in the Strategic Basic Research Programs in each research field

Research Field		No. of researchers (Worldwide) (A)	No. of researchers (Japan) (B)	(B)/(A)	No. of researchers (JST) (C)	(C)/(B)
1	AGRICULTURAL SCIENCES	112	0	0.0%	0	
2	BIOLOGY & BIOCHEMISTRY	195	6	3.1%	4	66.7%
3	CHEMISTRY	198	4	2.0%	3	75.0%
4	CLINICAL MEDICINE	422	4	0.9%	1	25.0%
5	COMPUTER SCIENCE	117	0	0.0%	0	
6	ENGINEERING	187	3	1.6%	0	0.0%
7	ENVIRONMENT/ECOLOGY	98	0	0.0%	0	
8	GEOSCIENCES	160	2	1.3%	0	0.0%
9	IMMUNOLOGY	87	19	21.8%	11	57.9%
10	MATERIALS SCIENCE	147	8	5.4%	5	62.5%
11	MATHEMATICS	99	1	1.0%	0	0.0%
12	MICROBIOLOGY	114	1	0.9%	1	100.0%
13	MOLECULAR BIOLOGY & GENETICS	201	1	0.5%	1	100.0%
14	NEUROSCIENCE & BEHAVIOR	120	0	0.0%	0	
15	PHARMACOLOGY & TOXICOLOGY	133	5	3.8%	2	40.0%
16	PHYSICS	144	14	9.7%	9	64.3%
17	PLANT & ANIMAL SCIENCE	176	25	14.2%	10	40.0%
18	SPACE SCIENCE	106	5	4.7%	0	
	Total	2816	98	3.5%	47	48.0%

* Those of the 22 ESI fields (excluding the social science fields) in which Japan shows strengths are marked by pink shading for life science-related fields and green shading for physics and chemistry-related fields.

Table 3-6 Number of the world's most influential researchers in countries

Fields related to the life sciences

Biology & Biochemistry

Country	No. of researchers	%
USA	115	59.0%
UK	39	20.0%
Switzerland	10	5.1%
Germany	7	3.6%
Japan	6	3.1%
Canada	3	1.5%
Denmark	3	1.5%
Others	12	6.2%

Pharmacology & Toxicology

Country	No. of researchers	%
USA	63	47.4%
UK	11	8.3%
Netherlands	9	6.8%
France	6	4.5%
Italy	6	4.5%
Germany	5	3.8%
Japan	5	3.8%
South Korea	4	3.0%
Sweden	4	3.0%
Australia	3	2.3%
China	3	2.3%
Switzerland	3	2.3%
Others	11	8.3%

Immunology

Country	No. of researchers	%
USA	56	64.4%
Japan	19	21.8%
UK	3	3.4%
Germany	3	3.4%
Switzerland	3	3.4%
Others	3	3.4%

Plant & Animal Science

Country	No. of researchers	%
USA	65	36.9%
Japan	25	14.2%
Germany	18	10.2%
UK	16	9.1%
Belgium	8	4.5%
France	7	4.0%
Saudi Arabia	7	4.0%
Switzerland	7	4.0%
Netherlands	5	2.8%
Australia	4	2.3%
Canada	4	2.3%
Others	10	5.7%

Fields related to physics and chemistry

Chemistry

Country	No. of researchers	%
USA	105	53.0%
China	28	14.1%
Germany	16	8.1%
Saudi Arabia	7	3.5%
South Korea	6	3.0%
Switzerland	5	2.5%
UK	4	2.0%
Japan	4	2.0%
Canada	4	2.0%
Spain	4	2.0%
Others	15	7.6%

Materials Science

Country	No. of researchers	%
USA	49	33.3%
China	30	20.4%
Germany	14	9.5%
UK	10	6.8%
Japan	8	5.4%
Singapore	6	4.1%
Netherlands	4	2.7%
France	3	2.0%
South Korea	3	2.0%
Switzerland	3	2.0%
Australia	3	2.0%
Others	14	9.5%

Physics

Country	No. of researchers	%
USA	71	49.3%
Japan	14	9.7%
China	14	9.7%
Germany	10	6.9%
UK	7	4.9%
Austria	6	4.2%
Spain	5	3.5%
Switzerland	4	2.8%
Canada	3	2.1%
Others	10	6.9%

(2) Research Fields where Japan Has Strengths

Based on 22 research field categories of ESI, world's most influential researchers in Japan are listed in biology and biochemistry, immunology, pharmacology and toxicology, and plant and animal science in fields related to the life sciences and in chemistry, engineering, materials science and physics in fields related to physics and chemistry. Table 3-5 shows that among Japanese researchers studying in these fields, those in the JST Strategic Basic Research Programs make up 40-75% of the total. This indicates that the Strategic Basic Research Programs are driving world-level research in Japan.

3. Research Trends Published in Japan

(1) Research Results in Trends in the Number of Papers

The top four universities in Japan in terms of the number of papers (University of Tokyo, Kyoto University, Osaka University, and Tohoku University), RIKEN and the Strategic Basic Research Programs (JST) were compared in terms of trends in the numbers of papers. As shown in Fig. 3-10 and Fig. 3-11, the Strategic Basic Research Programs are fifth in the number of papers in Japan following the University of Tokyo, Kyoto University, Osaka University, and Tohoku University. In terms of the number of highly cited papers, however, it comes in second after the University of Tokyo.

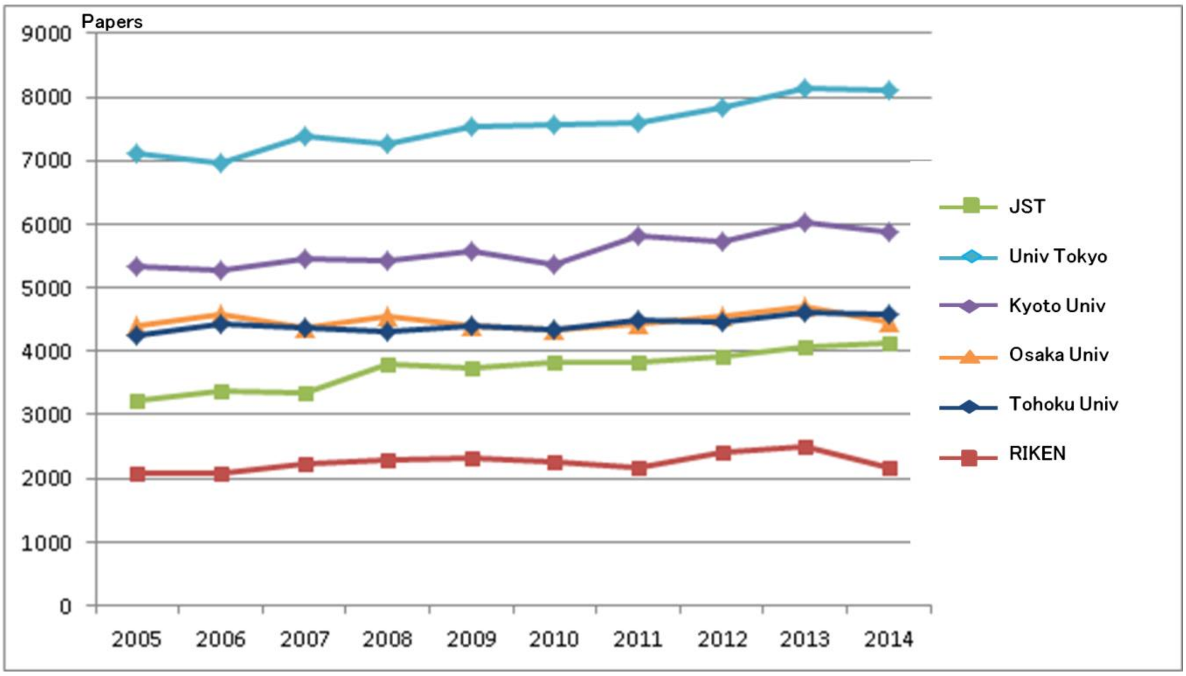


Fig. 3-10 Trends in the number of annual total papers by institute

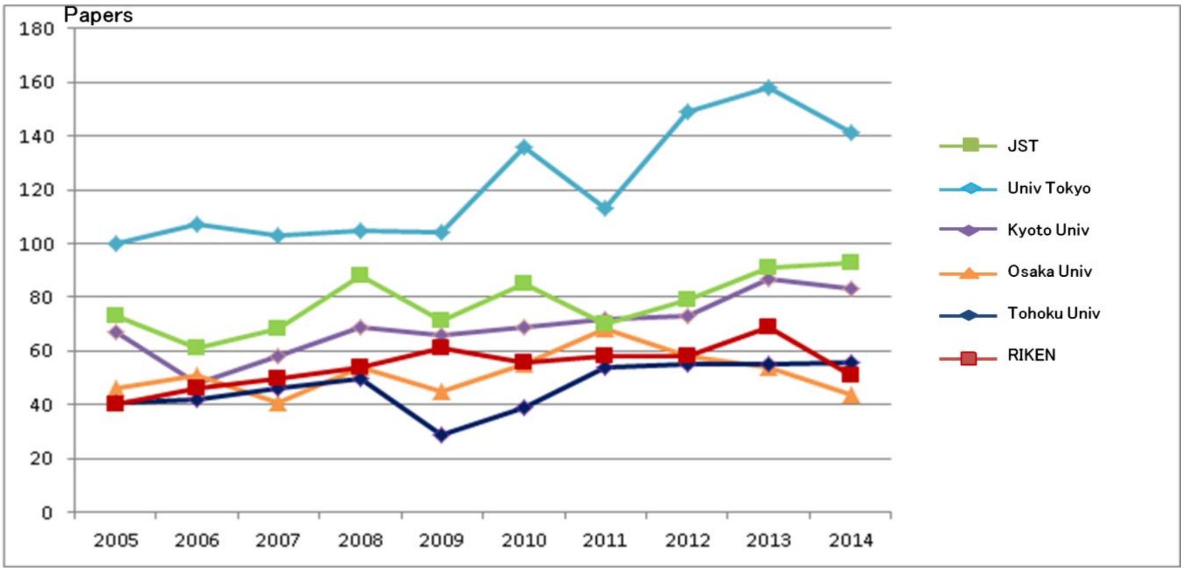


Fig. 3-11 Trends in number of highly cited papers

A comparison was also made of the percentage of highly cited papers to the total number of papers and as shown in Fig. 3-12, RIKEN is at the top in recent years followed by the Strategic Basic Research Programs, the University of Tokyo, Kyoto University, Tohoku University, and Osaka University.

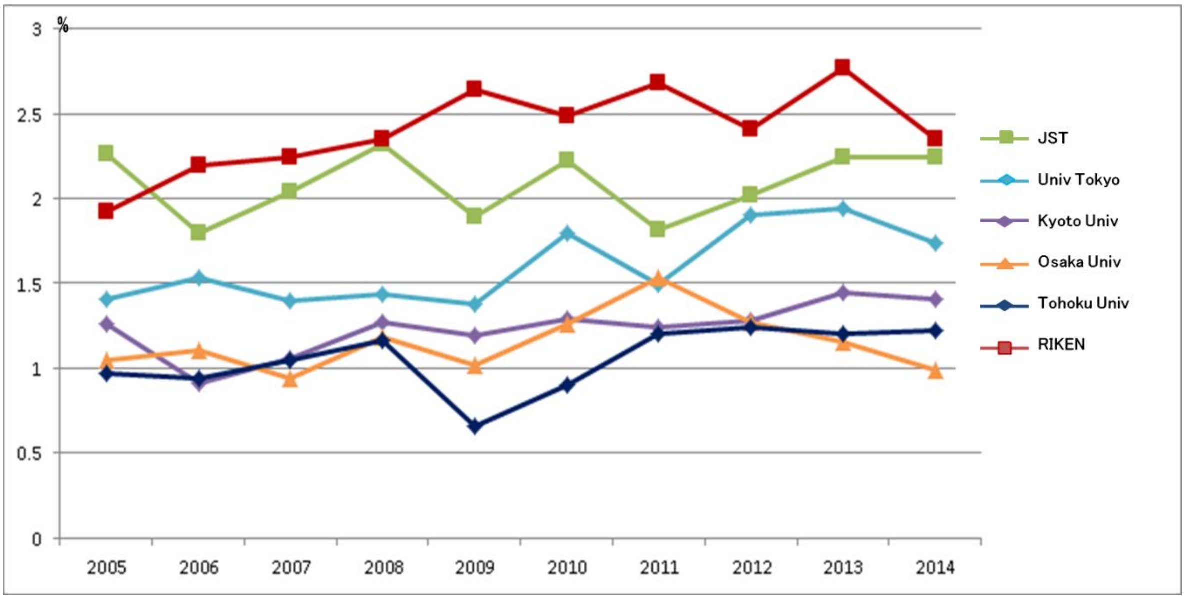


Fig. 3-12 Trends of percentage of the highly cited papers to the total papers (2005-2014)

(2) Characteristics of the Research Fields

To compare the advantage of the fields in each institution, the THOMSON REUTERS database and InCites research field analysis were used. As shown in Fig. 3-13, the University of Tokyo had a larger number of highly cited papers in physics, chemistry, clinical medicine and geosciences, while Kyoto University had more in physics and chemistry, Osaka University in immunology and Tohoku University in physics and clinical medicine. Meanwhile, RIKEN had a larger number of highly cited papers in physics and in plant and animal science and the Strategic Basic Research Programs had more in chemistry, materials science, molecular biology and physics.

Next the characteristics of research fields in the universities, RIKEN and the Strategic Basic Research Programs were examined in detail. This was done by comparing the average figures for the four universities (the University of Tokyo, Kyoto University, Osaka University, and Tohoku University) and the number of highly cited papers together with the number of highly cited papers as a percentage of the number of papers at RIKEN and the Strategic Basic Research Programs. The comparison was narrowed down to fields related to physics, chemistry, and the life sciences which are Japan's areas of strength.

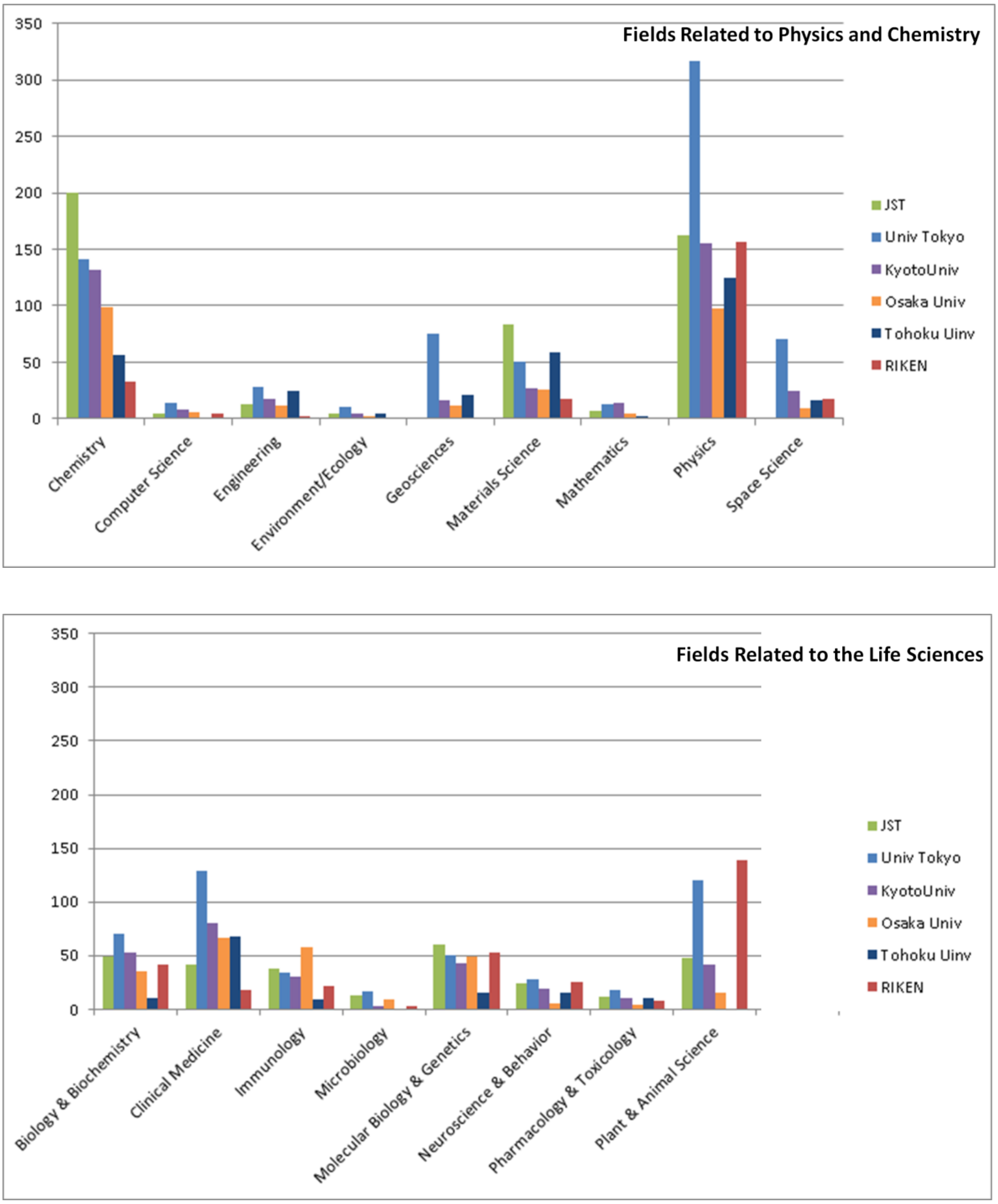


Fig. 3-13 Numbers of highly cited papers in ESI research field (2005-2014)

(3) Characteristics in Fields Related to Physics and Chemistry

As shown in Fig. 3-14, the number of highly cited papers is conspicuously larger in physics than in other fields and this is the case at every institution. The Strategic Basic Research Programs and the universities also show very high figures in chemistry. Furthermore, the Strategic Basic

Research Programs show results in the materials science field that put it ahead of any other institution.

A comparison of the percentage of highly cited papers to the number of papers places the Strategic Basic Research Programs in a high position in materials science, chemistry, and physics. RIKEN shows superior results in space science, materials science, and physics. The universities show smaller differences between fields than are seen in the Strategic Basic Research Programs and RIKEN, and the universities cover the entirety of the fields and the distinct characteristics of the individual institutions can be seen (Fig. 3-15).

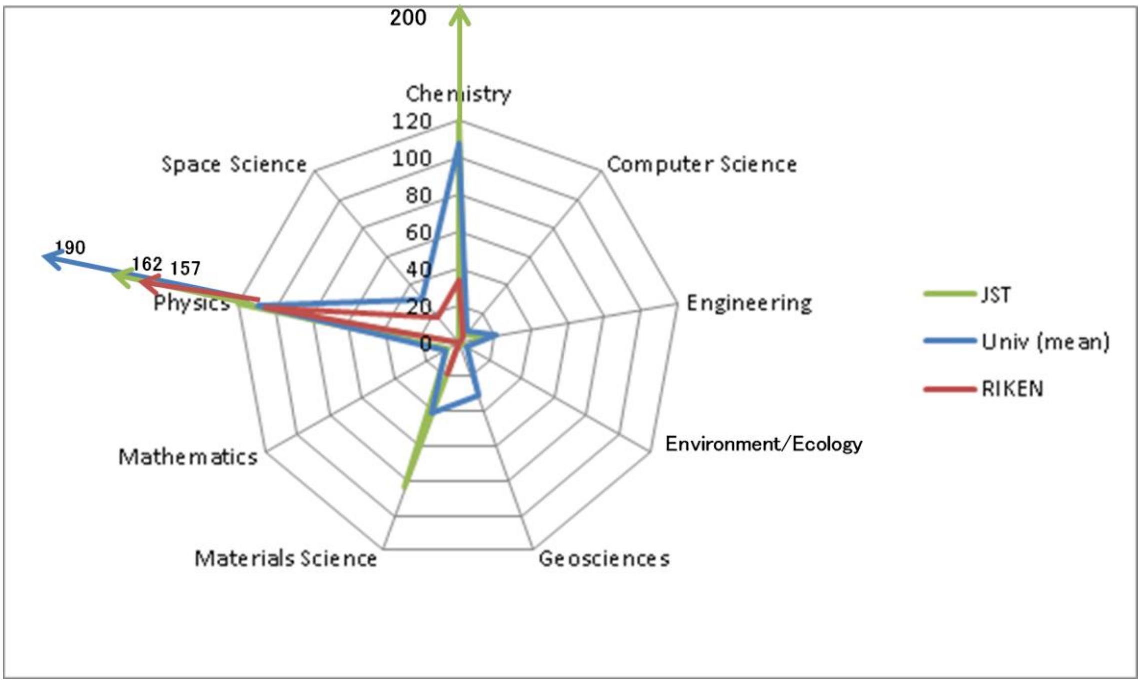


Fig. 3-14 Number of highly cited papers in fields related to physics and chemistry (2005-2014)

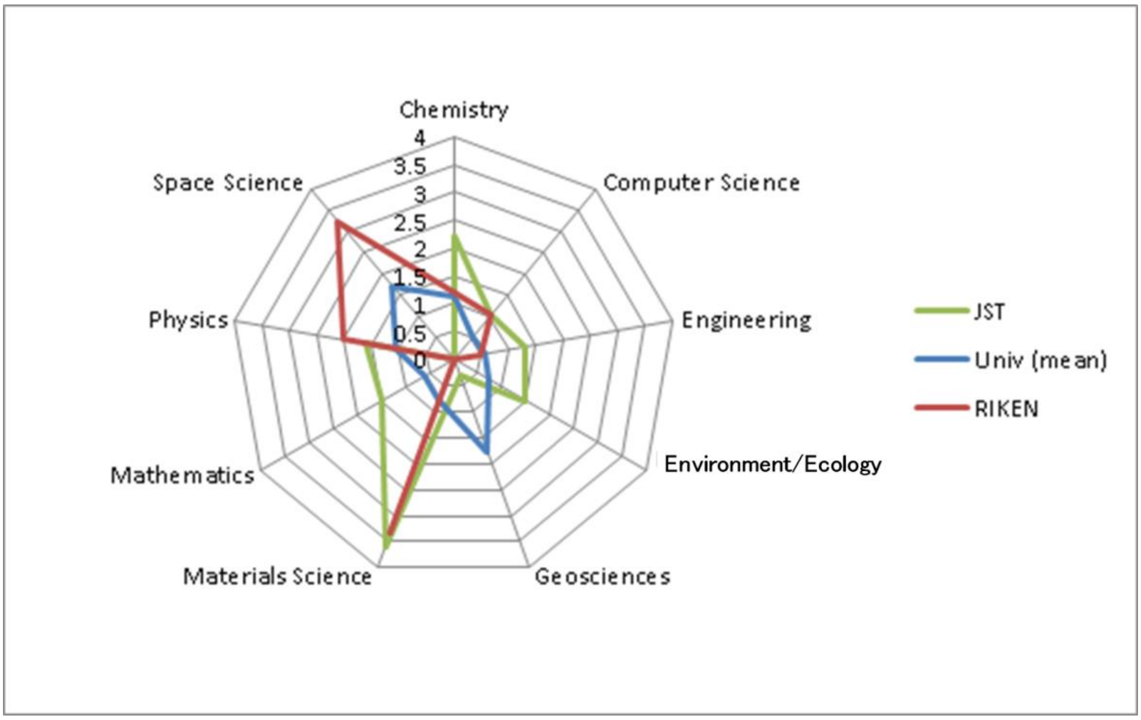


Fig. 3-15 Percentage of highly cited papers to the total number of papers in fields related to physics and chemistry (2005-2014)

(4) 9Characteristics in Fields Related to the Life Sciences

In fields related to the life sciences, as shown in Fig. 3-16 and Fig. 3-17, the mean values of universities show a larger number of highly cited papers in clinical medicine. RIKEN shows a greatly larger number of highly cited papers as well as a larger percentage of highly cited papers in plant and animal science. The Strategic Basic Research Programs show a larger number of papers in molecular biology and genetics as well as in biology and biochemistry while the percentage of highly cited papers is larger in immunology and plant and animal science.

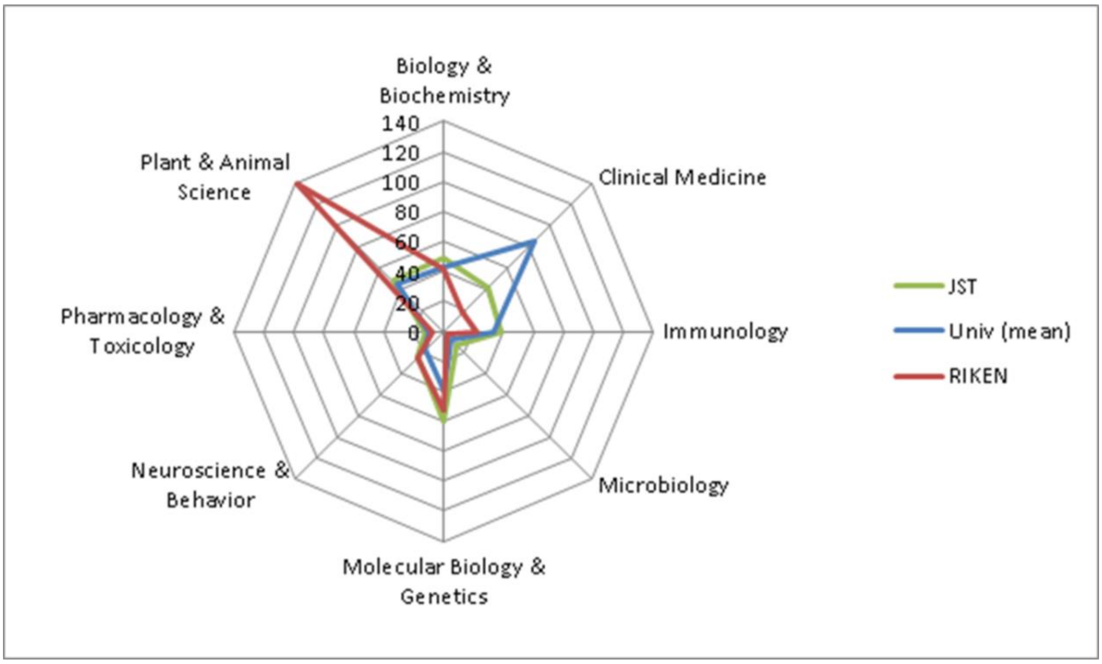


Fig.3-16 Number of highly cited papers in fields related to the life sciences (2005-2014)

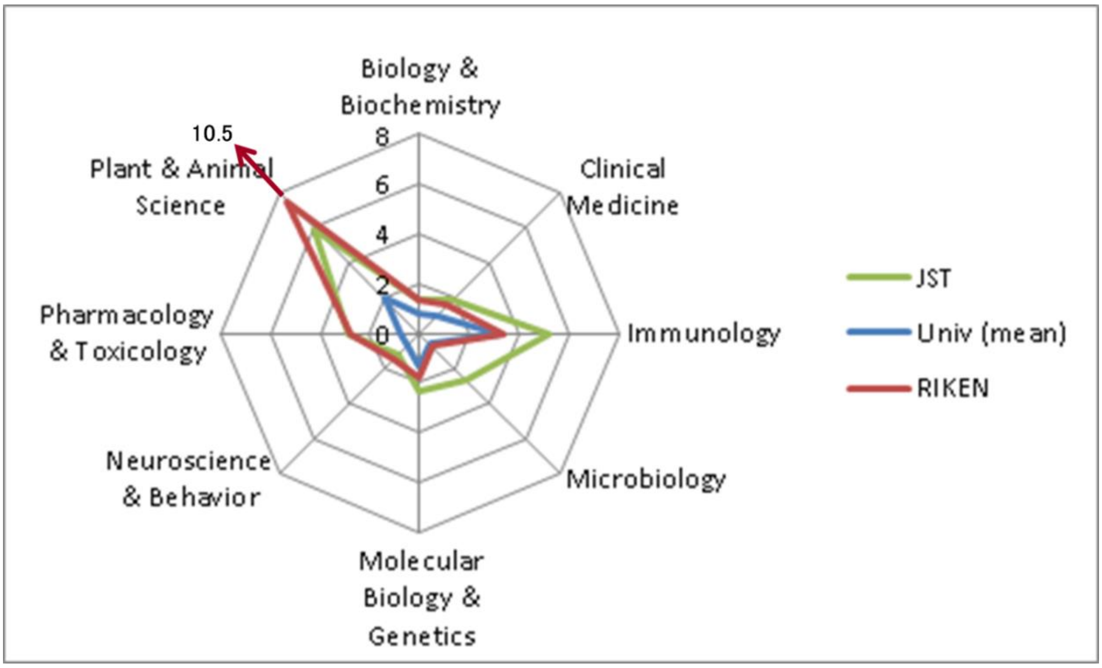


Fig. 3-17 Percentage of highly cited papers to the total number of papers in fields related to the life sciences (2005-2014)

Section 3 . Ripple Effects of Strategic Basic Research Programs

1. Results Leading Toward the Creation of Innovation in Science and Technology

(1) Expansion into Joint Research with Corporations

In order to ascertain the status of joint research with corporations in the Strategic Basic Research Programs, a study was made of CREST, PRESTO, and ERATO in section 3. 1. regarding joint research with corporations This study covered CREST, PRESTO and ERATO finished in fiscal years 2010 to 2013 and the results were summarized for the four fields of Nanotechnology and Materials, Green Innovation, Life Innovation, and Information and Communications Technology (Table 3-7).

The total number of joint research activities with corporations tended to be higher in the field of Nanotechnology and Materials. They were particularly numerous in the CREST "Development of the Foundation for Nano-Interface Technology" Research Area and the CREST "Establishment of Innovative Manufacturing Technology Based on Nanoscience" Research Area. In the Green Innovation field, the ERATO projects involved joint research with numerous corporations. In the Life Innovation field, the CREST "Basic Technologies for Controlling Cell Functions Based on Metabolic Regulation Mechanism Analysis" Research Area involved much joint research of that kind. In the Information and Communications Technology field, the ERATO projects involved joint research with many corporations.

Table 3-7 Number of joint research with corporations in CREST, PRESTO and ERATO

Field	CREST/PRESTO/ERATO	No. of projects	No. of joint research with corporations
Nanotechnology & Materials Nanotechnology & Materials	CREST “Novel Measuring and Analytical Technology Contributions to the Elucidation and Application of Material”	16	30
	CREST “Development of the Foundation for Nano-Interface Technology”	15	77
	CREST “Establishment of Innovative Manufacturing Technology Based on Nanoscience”	16	107
	CREST “Photonics and Quantum Optics for the Creation of Innovative Functions”	16	24
	PRESTO “Evolution of Light Generation and Manipulation”	24	14
	PRESTO “Structure Control and Function”	37	20
	PRESTO “Photons on Soft Materials”	28	33

Nanotechnology & Materials Nanotechnology & Materials	PRESTO “Structures and Control of Interfaces”	34	96
	PRESTO “Search for Nanomanufacturing Technology and its Development”	29	41
	PRESTO “Materials and Processes for Innovative Next-generation Devices”	33	69
	ERATO	1	1
	Total	249	512
Green Innovation	ERATO	2	24
	Total	2	24
Life Innovation	CREST “Elucidation of Mechanisms Underlying Brain Development and Learning”	15	21
	CREST “Novel Measuring and Analytical Technology Contributions to the Elucidation and Application of Life Phenomena”	14	28
	CREST “Basic Technologies for Controlling Cell Functions Based on Metabolic Regulation Mechanism Analysis”	15	74
	CREST “The Dynamic Mechanism of and Fundamental Technology for Biological System”	9	21
	PRESTO “Metabolism and Cellular Function”	33	27
	PRESTO “Life Phenomena and Measurement Analysis”	32	25
	PRESTO “RNA and Biofunctions”	29	18
	PRESTO “The Dynamic Mechanism of and Fundamental Technology for Biological System”	38	42
	PRESTO “Innovative Model of Biological Processes and its Development”	35	63
	ERATO	4	10
	Total	224	329
Information and Communications Technology	CREST “Creation of New Technology Aiming for the Realization of Quantum Information Processing Systems”	12	6
	CREST “Foundation of Technology Supporting the Creation of Digital Media Contents”	12	21

Information and Communications Technology	CREST "Advanced Integrated Sensing Technologies"	15	26
	CREST "Technology Innovation and Integration for Information Systems with Ultra Low Power"	12	23
	CREST "High Performance Computing for Multi-Scale and Multi-Physics Phenomena"	21	34
	CREST "Dependable Operating Systems for Embedded Systems Aiming at Practical Applications"	9	14
	PRESTO "Foundation of Technology Supporting the Creation of Digital Media Contents"	16	16
	ERATO	3	38
	Total	100	178

(The study was made one year after the finish of the project)

(2) Expansion into Practical Application Projects

The status of expansion from CREST, PRESTO and ERATO finished between 2010 and 2013 into practical application projects was studied next. Practical application projects include NEDO projects etc. as well as the JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) and other such programs and the status of these activities by field is shown in Table 3-8.

The expansion into practical application projects, like joint research with corporations tends to show the largest number of cases in the Nanotechnology and Materials field, followed by the number of cases in Information and Communications Technology and Life Innovation field. The number of cases in Green Innovation is small, since there are no CREST and PRESTO research areas in the period.

Table 3-8 Number of expansion into practical application projects

Field	CREST/PRESTO/ERATO	No. of projects	No. of application projects
Nanotechnology and Materials	CREST "Novel Measuring and Analytical Technology Contributions to the Elucidation and Application of Material"	16	12
	CREST "Photonics and Quantum Optics for the Creation of Innovative Functions"	16	7
	CREST "Development of the Foundation for Nano-Interface Technology"	15	13
	CREST "Establishment of Innovative Manufacturing Technology Based on Nanoscience"	16	19
	PRESTO "Evolution of Light Generation and Manipulation"	24	6
	PRESTO "Structure Control and Function"	37	7
	PRESTO "Photons on Soft Materials"	28	17
	PRESTO "Structures and Control of Interfaces"	34	19
	PRESTO "Search for Nanomanufacturing Technology and its Development"	29	20
	PRESTO "Materials and Processes for Innovative Next-generation Devices"	33	15
	ERATO	1	1
	Total	249	136
Green Innovation	ERATO	2	7
	Total	2	7
Life Innovation	CREST "Novel Measuring and Analytical Technology Contributions to the Elucidation and Application of Life Phenomena"	14	14
	CREST "Basic Technologies for Controlling Cell Functions Based on Metabolic Regulation Mechanism Analysis"	15	8
	CREST "The Dynamic Mechanism of and Fundamental Technology for Biological System"	9	3
	PRESTO "Metabolism and Cellular Function"	33	5
	PRESTO "Life Phenomena and Measurement Analysis"	32	11

Life Innovation	PRESTO “RNA and Biofunctions”	29	6
	PRESTO “The Dynamic Mechanism of and Fundamental Technology for Biological System”	38	8
	PRESTO “Innovative Model of Biological Processes and its Development”	35	12
	ERATO	2	2
	Total	207	69
Information and Communications Technology	CREST “Creation of New Technology Aiming for the Realization of Quantum Information Processing Systems”	12	5
	CREST “Foundation of Technology Supporting the Creation of Digital Media Contents”	12	11
	CREST “Advanced Integrated Sensing Technologies”	15	14
	CREST “Technology Innovation and Integration for Information Systems with Ultra Low Power”	12	12
	CREST “High Performance Computing for Multi-Scale and Multi-Physics Phenomena”	21	12
	CREST “Dependable Operating Systems for Embedded Systems Aiming at Practical Applications”	9	2
	PRESTO “Foundation of Technology Supporting the Creation of Digital Media Contents”	16	12
	ERATO	1	3
	Total	98	71

(The study was made one year after the finish of the project)

Table 3-9 presents a summation of the main cases of expansion into practical application with public funding. This is based on information of NEDO projects etc. and JST industry-academia collaborative programs such as A-STEP. The number of cases that advanced to NEDO projects excluding JST programs was 12 in CREST, 2 in PRESTO and 1 in ERATO.

.

Table 3-9 Main cases of expansion into practical application

Field	CREST/PRESTO /ERATO	Researcher	Position, Affiliation	① Public fund ② Joint research body (corporate name)
Nanotechnology and Materials	CREST "Creation and Application of "Soft Nano-machine", the Hyperfunctional Molecular Machine"	Yoshinori Fujiyoshi	Specially Appointed Professor, Graduate School of Pharmaceutical Science, Nagoya University	①JST Newly Extended Technology Transfer Program (NexTEP) ②JEOL Ltd.
	CREST "Research of Innovative Material and Process for Creation of Next-generation Electronics Devices"	Seiichi Tagawa	Specially Appointed Professor, Graduate School of Engineering, Osaka University	①JST Newly Extended Technology Transfer Program (NexTEP) ②Tokyo Electron Kyushu Ltd.
		Shinji Yuasa	Director, Spintronics Research Center, National Institute of Advanced Industrial Science and Technology (AIST)	①Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT) ②Toshiba Corporation
	CREST "Development of the Foundation for Nano-Interface Technology"	Hiroshi Kitagawa	Professor, Graduate School of Science, Kyoto University	①NEDO Development of Fundamental Technologies for Green-Sustainable Chemical Process ②Kuraray Co., Ltd., Showa Denko K.K., Toyobo Co., Ltd., Shoei Chemical Inc.

Nanotechnology and Materials	CREST "Development of the Foundation for Nano-Interface Technology"	Kazue Kurihara	Professor, Advanced Institute for Materials Research, Tohoku University Division of Hybrid Nano-Materials Research Center, Tohoku University	①Ultra-low Friction Technology Area, Tohoku Innovation Materials Technology Initiatives for Reconstruction, MEXT ②Akros Co., Ltd., Asahi Kasei Corp., Kao Corporation, Kyodo Yushi Co., Ltd., Denso Corporation, Toyota Motor Corporation, Toyota Motor East Japan, Inc., Toyota Motor East Japan, Inc.
		Masaharu Oshima	Professor Emeritus, The University of Tokyo, Project Researcher, Synchrotron Radiation Research Organization, The University of Tokyo	①NEDO "Development of Innovative Carbon Nanotube Composite Materials for a Low Carbon Emission Society" ②Sumitomo Electric Industries, Ltd.
		Kazuo Sakurai	Professor, Graduate School of Environmental Engineering, The University of Kitakyusyu	①JST Newly Extended Technology Transfer Program (NexTEP) ②DAIICHI SANKYO COMPANY, LIMITED.
	CREST "Establishment of Innovative Manufacturing Technology Based on Nanoscience"	Jiro Matsuo	Professor, Graduate School of Engineering, Kyoto University	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②Iwatani Corporation

Nanotechnology and Materials	CREST “Establishment of Innovative Manufacturing Technology Based on Nanoscience”	Mitsuru Akashi	Specially Appointed Professor, Graduate school of Frontier Biosciences, Osaka University	①JST Development of Systems and Technology for Advanced Measurement and Analysis ②Ricoh Company, Ltd. (The research project has been transferred to the Japan Agency for Medical Research and Development (AMED) since FY2015)
				①NEDO Development of Functional Biotissue Manufacturing Technology by 3D Modeling ②Toray Industries, Inc., Ricoh Company, Ltd., Kyowa Hakko Bio Co. Ltd. (The research project has been transferred to the Japan Agency for Medical Research and Development (AMED) since FY2015)
	CREST “Photonics and Quantum Optics for the Creation of Innovative Functions”	Hideki Hashimoto	Professor, Graduate School of Science Osaka City University	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②South Product Ltd.
		Katsumi Kishino	Professor, Faculty of Science and Technology, Sophia University	①NEDO “Development of New-generation Projection Display Devices by InGaN-based Nanocolumn Crystals” ②Seiko Epson Corporation

Nanotechnology and Materials	CREST "Photonics and Quantum Optics for the Creation of Innovative Functions"	Hideki Hirayama	Chief Scientist, Quantum Optodevice Laboratory, RIKEN	①NEDO "Robot and New Machinery Innovation Program" ② Panasonic Corporation
	CREST "Novel Measuring and Analytical Technology Contributions to the Elucidation and Application of Material"	Kiyonori Takegoshi	Professor, Graduate School of Science, Kyoto University	①JST Development of Systems and Technology for Advanced Measurement and Analysis ② JEOL RESONANCE Inc
		Satoshi Kawata	Distinguished Professor Osaka University , Professor, Graduate school of Engineering, Osaka University	①JST Development of Systems and Technology for Advanced Measurement and Analysis ②Nanophoton Corporation
		Kazuhiro Hono	NIMS Fellow, Magnetic Materials Unit, National Institute for Materials Science (NIMS)	①Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT) ②Toshiba Corporation
	CREST "Creation of nanosystems with novel functions through process integration"	Takao Someya	Professor, Graduate School of Engineering, The University of Tokyo	①NEDO "Development of Materials and Process Technology for Advanced Printed Electronics" ②Ricoh Company, Ltd., Toppan Printing Co., Ltd., Dai Nippon Printing Co., Ltd.

Nanotechnology and Materials	CREST "Creation of Innovative Functions of Intelligent Materials on the Basis of Element Strategy"	Hiroshi Kitagawa	Professor, Graduate School of Science, Kyoto University	①NEDO cutting-edge research ②Furuya Metal Co., Ltd.
	PRESTO "Structures and Control of Interfaces"	Makoto Koda	Associate Professor, Graduate School of Engineering, Tohoku University	①NEDO "Construction of Spin MOSFET with Electromagnetic Field Control of Gate Using Vertical Magnetization Material" ②NTT Basic Research Laboratories
	PRESTO "Structures and Control of Interfaces"	Junichi Takeya	Professor, Graduate School of Frontier Sciences, The University of Tokyo	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②Crystage Incorporation
	ERATO "TAKAHARA Soft Interface"	Atsushi Takahara	Director / Professor, Institute for Materials Chemistry and Engineering, Kyushu University	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②Tokai Rubber Industries Ltd.
	PRESTO "Search for Nano-manufacturing Technology and its Development"	Hidekazu Mimura	Associate Professor, Graduate School of Engineering, The University of Tokyo	①JST Development of Systems and Technology for Advanced Measurement and Analysis ②Natsume Optical Corp.

Nanotechnology and Materials	PRESTO "Search for Nano-manufacturing Technology and its Development"	Takeshi Saito	Team Leader, Nanotechnology, Materials & Manufacturing /National Institute of Advanced Industrial Science and Technology (AIST) /	①NEDO "nanotech/materials and components innovation program" ②Toray Industries, Inc., Teijin Ltd., Sumitomo Precision Products Co., Ltd., NEC, Zeon Corporation
		Takayuki Nozaki	Researcher, Spintronics Research Center, National Institute of Advanced Industrial Science and Technology (AIST)	①Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT) ②Toshiba Corporation、Fujitsu Limited
Green Innovation	ERATO "HASHIMOTO Light Energy Conversion"	Kazuhito Hashimoto	Professor, Graduate School of Engineering, The University of Tokyo	①NEDO"Development of Waste-water Treatment System Generating Electricity by Microbial Catalysts" ②SEKISUI CHEMICAL CO., LTD, Panasonic Corporation
Life Innovation	CREST "Creation of Innovative Technology for Medical Applications Based on the Global Analyses and Regulation of Disease-Related Metabolites"	Masaru Yoshida	Associate Professor, Graduate School of Medicine, Kobe University	①JST Development of Systems and Technology for Advanced Measurement and Analysis ②Shimadzu Corporation

Life Innovation	CREST “Elucidation and control of the mechanisms underlying chronic inflammation”	Hiroshi Kiyono	Professor, Institute of Medical Science, The University of Tokyo	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②Nisseiken Co., Ltd.
		Kazuhide Inoue	Professor, Graduate School of Pharmaceutical Sciences, Kyushu University	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②Nippon Chemiphar Co., Ltd.
		Toshinori Nakayama	Professor, Graduate School of Medicine, Chiba University	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②A-CLIP Institute, Limited liability company
	CREST “Fundamental technologies for medicine concerning the generation and regulation of induced pluripotent stem (iPS) cells”	Mitsuo Oshimura	Professor Emeritus, Tottori University, Specially Appointed Professor, Chromosome Engineering Research Center, Tottori University	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②Sekisui Medical Co., Ltd.

Life Innovation	CREST “Etiological basics of and techniques for treatment of allergic and autoimmune diseases”	Yoichiro Iwakura	Director /Professor, Research Institute for Biomedical Sciences, Tokyo University of Science	①National Agriculture and Food Research Organization (NARO), Bio-oriented Technology Research Advancement Institution (BRAIN) “Program Promoting Basic Research for Creation of Innovation” ②Nissei Bio Co., Ltd.
			Professor/Director, Research Institute for Biomedical Sciences, Tokyo University of Science	①Expansion and amalgamation stage of Japan Association for Techno-innovation in Agriculture, Forestry and Fisheries (JATAFF) projects promoting research on agriculture, forestry and fisheries and food science and technology ②Oriental Yeast Co., Ltd.
	ERATO “AKIRA Innate Immunity”	Ken Ishii	Senior Researcher & Project Leader Laboratory of Adjuvant Innovation, National Institutes of Biomedical Innovation Health and Nutrition/ Specially Appointed Professor Immunology Frontier Research Center, Osaka University	①JST Newly Extended Technology Transfer Program (NexTEP) ②DAIICHI SANKYO COMPANY, LIMITED

Information and Communications Technology	CREST “Fundamental technologies for dependable VLSI system”	Masahiko Yoshimoto	Professor, Graduate School of System Informatics, Kobe University	①NEDO “Development of Infrastructure for Normally-off Computing Technology” ②Recommissioned by ROHM Co., Ltd.
	CREST “Advanced Integrated Sensing Technologies”	Tomomasa Sato	Project Researcher, Future Center Initiative, The University of Tokyo	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②Tateyama System Laboratory Co., Ltd.
		Toshihiro Ito	Deputy Director, Research Center for Ubiquitous MEMS and Micro Engineering, National Institute of Advanced Industrial Science and Technology (AIST)	①NEDO “Sensor System Development Project to Solve Social Problems” ②Yokokawa Electric Corporation, Seiko Instruments Inc., OMRON Corporation, Olympus Corporation, ROHM Co., Ltd., Hitachi, Ltd., Dai Nippon Printing Co., Ltd.
		Koichi Kurumatani	Deputy Director, Human Informatics Research Institute, National Institute of Advanced Industrial Science and Technology (AIST)	①NEDO IT Fusion (Urban Transportation Field) ②KDDI R&D Laboratories

Information and Communications Technology	CREST “Technology Innovation and Integration for Information Systems with Ultra Low Power”	Kenichi Sato	Professor, Graduate School of Engineering, Nagoya University	①NICT commissioned research ②Nippon Telegraph and Telephone Corporation, NEC Corporation
				①Ministry of Internal Affairs and Communications, Strategic Information and Communications R&D Promotion Programme (SCOPE) & Promotion program for Reducing global Environmental load through ICT innovation (PREDICT) Santec Corporation
	CREST “Foundation of Technology Supporting the Creation of Digital Media Contents”	Hideyuki Tamura	Professor, Research Organization of Science and Technology, Ritsumeikan University	①JST Adaptable & Seamless Technology Transfer Program through Target-driven R&D (A-STEP) ②Crescent,inc.
				①NEDO “Development of Fundamental Technologies for Green-Sustainable Chemical Process” ②Kuraray Co., Ltd., Showa Denko K.K. Toyobo Co., Ltd.,、 Shoei Chemical Inc.
		Hitoshi Matsubara	Professor, School of Systems Information Science, Future University Hakodate	①NEDO “Development of Infrastructure for Normally-off Computing Technology” ②Re-entrusted by Renesas Electronics Corporation

(The study was made on Nov. 2015)

(3) Patent Licensing

Table 3-10 summarizes the numbers of cases of licensing in CREST and ERATO finished between 2010 and 2013 and ongoing programs are listed. The patents offered to use by corporations are included.

There were particularly large numbers of cases of licensing in the CREST "Advanced Integrated Sensing Technologies" Research Area and the ERATO, each of which had five cases.

There are many cases of licensing in Information and Communications Technology field among ongoing programs. CREST "Creation of Human-Harmonized Information Technology for Convivial Society" has 17 cases and CREST "Advanced Core Technologies for Big Data Integration" has 8cases.

Table 3-10 Numbers of licensing cases in CREST and ERATO

Field	CREST/ERATO	No. of projects	No. of licenses
Nanotechnology and Materials	CREST "Development of the Foundation for Nano-Interface Technology"	15	1
	CREST "Establishment of Innovative Manufacturing Technology Based on Nanoscience"	16	2
	CREST "Enhancing Applications of Innovative Optical Science and Technologies by making Ultimate Use of Advanced Light Sources" *	16*	1*
	CREST "Creation of Nanosystems with Novel Functions through Process Integration" *	16*	1*
	CREST Establishment of molecular technology towards the Creation of New Function" *	15*	2*
	ERATO *	4*	5*
	Total	82	12
Green Innovation	ERATO	1	1
	CREST "Creation of Innovative Technologies to Control Carbon Dioxide Emissions" *	15*	1*
	CREST "Creation of Basic Technology for Improved Bioenergy Production through Functional Analysis and Regulation of Algae and Other Aquatic Microorganisms" *	13*	1*
	CREST "Creation of essential technologies to utilize carbon dioxide as a resource through the enhancement of plant productivity and the exploitation of plant products" *	13*	1*
	Total	42	4

Life Innovation	CREST “Elucidation of Mechanisms Underlying Brain Development and Learning”	15	1
	CREST “Basic Technologies for Controlling Cell Functions Based on Metabolic Regulation Mechanism Analysis”	15	1
	CREST “iPS Cells Fundamental Technologies for Medicine Concerning the Generation and Regulation of Induced Pluripotent Stem (iPS) Cells（to AMED）	23	3
	CREST “Elucidation of the Principles of Formation and Function of the Brain Neural Network and Creation of Control Technologies（to AMED）	19	1
	CREST “Structural Life Science and Advanced Core Technologies for Innovative Life Science Research *	18*	2*
	ERATO**	5**	10**
	Total	95	18
Information and Communications Technology	CREST “Creation of New Technology Aiming for the Realization of Quantum Information Processing Systems”	12	1
	CREST “Foundation of Technology Supporting the Creation of Digital Media Contents”	12	1
	CREST “Advanced Integrated Sensing Technologies”	15	5
	CREST “Creation of Human-Harmonized Information Technology for Convivial Society” *	17 *	17 *
	CREST “Development of System Software Technologies for post-Peta Scale High Performance Computing” *	14 *	2 *
	CREST “Advanced Core Technologies for Big Data Integration” *	8 *	8 *
	Total	78	37

(The study was made one year after the finish of the project) *ongoing programs,
**ongoing programs included

<Example Case>

Representative examples of a major expansion of licensing from 2011 include the thin-film transistor, suited to application in high-resolution displays that came out of Hideo Hosono's work under ERATO-SORST(1999-2009)(Fig. 3-18). The results were licensed to private-sector corporations in Japan and other

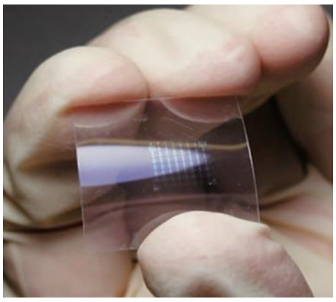


Fig. 3-18 Case of licensing implementation

countries and mass production of IGZO LCD panels started in fiscal year 2012.

(4) Venture Establishment

Table 3-11 shows the number of venture corporations established out of CREST and ERATO finished between 2010 and 2013 and ongoing are listed.

Research areas that produced the largest numbers of cases were the CREST "Novel Measuring and Analytical Technology Contributions to the Elucidation and Application of Life Phenomena" and the CREST "Foundation of Technology Supporting the Creation of Digital Media Contents" Research Areas, with nine and seven cases, respectively.

Table 3-11 Status of venture establishment in CREST and ERATO

Field	Research Area/Project	No. of projects	No. of ventures established
Nanotechnology and Materials	CREST “Development of the Foundation for Nano-Interface Technology”	15	2
	CREST “Establishment of Innovative Manufacturing Technology Based on Nanoscience”	16	5
	CREST “Establishment of molecular technology towards the Creation of New Function” *	15*	1*
	ERATO*	1*	1*
	Total	47	9
Green Innovation	CREST “Creation of Innovative Technologies to Control Carbon Dioxide Emission” *	15*	1*
	Total	15	1
Life Innovation	CREST “Novel Measuring and Analytical Technology Contributions to the Elucidation and Application of Life Phenomena”	14	9
	CREST “Basic Technologies for Controlling Cell Functions Based on Metabolic Regulation Mechanism Analysis”	15	2
	CREST “The Dynamic Mechanism of and Fundamental Technology for Biological System”	9	1
	ERATO**	2**	2**
	Total	40	14
Information and Communications Technology	CREST “Foundation of Technology Supporting the Creation of Digital Media Contents”	12	7
	CREST “Advanced Integrated Sensing Technologies”	15	5

Information and Communications Technology	CREST "Technology Innovation and Integration for Information Systems with Ultra Low Power"	11	3
	CREST "High Performance Computing for Multi-Scale and Multi-Physics Phenomena"	21	5
	ERATO	2	2
	Total	61	22

(The study was made on Nov. 2015) *ongoing programs, **ongoing programs included

Table 3-12 shows cases of venture corporations that were established. Only cases of ventures that have been published on corporate or university websites were selected for this table.

Table 3-12 Cases of venture corporations established

Field	CREST/PRESTO/ ERATO	Researcher	Position, Affiliation	① Name of venture corporation ② Year established ③ Description of business
Nanotechnology and Materials	PRESTO "Structures and Control of Interfaces"	Junichi Takeya	Professor, Graduate School of Frontier Sciences, The University of Tokyo	①Pi-Crystal Inc. ② 2013 ③ ・Manufacture and marketing of high-mobility organic semiconductor material for solution process, etc. ・Technical consulting ・Device prototyping service ・Printed organic device prototype facility (under development)

Nanotechnology and Materials	CREST “Development of the Foundation for Nano-Interface Technology”	Masatake Haruta	Professor, Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University	①Haruta Gold Inc. ②2013 ③ ・Gold nanoparticle catalyst: Manufacture and marketing of general purpose products ・Gold nanoparticle catalyst: Contract, manufacture, and marketing of special order products ・Gold nanoparticle catalyst: Development and marketing of study kits
	CREST “Establishment of molecular technology towards the Creation of New Function”	Takanori Yokota	Professor, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University	①Rena Therapeutics Inc. ②2015 ③ ・Promotion to practical use of nucleic acid pharmaceutical products by developing the heteroduplex oligonucleotide technology mainly.
	ERATO “SOMEYA Bio-Harmonized Electronics”	Takao Someya	Professor, Graduate School of Engineering, The University of Tokyo	①Xenoma Inc ②2015 ③Research, design, development, trial manufacture, sale and consulting related to a textile-type wearable sensors c

Green Innovation	CREST “Creation of Innovative Technologies to Control Carbon Dioxide Emissions”	Makoto Watanabe	Professor, Graduate school of Life and Environmental Sciences, Tsukuba University	①Sobio Technologies Inc. ②2015 shift to new company from New Industry Innovation Research Institute (2009) ③・Algae production and processing ・Marketing and import/export of processed algae products ・Development of algae cultivation and processing methods and areas for utilization ・Other related business
Life Innovation	PRESTO “The Dynamic Mechanism of and Fundamental Technology for Biological System”	Reiko Kobayakawa	Adjunct Professor, National Institute for Physiological Sciences	①Scent Science International Inc. ②2009 ③ Having discovered, through molecular screening, a functional odorant that artificially causes an animal to sense the presence of a natural enemy, effectively inducing innate fear, the company is presently developing applications in animal repellent that animals do not tend to become acclimated to
	ERATO “NAKAUCHI Stem Cell and Organ Regeneration”	Hiromitsu Nakauchi	Professor, The Institute of Medical Science, The University of Tokyo	①Megakaryon Corporation ②2011 ③Production of the blood platelet and the red blood cells of the high quality from the iPS cells strain without depending on the blood donation, and (1) stably and premeditated supply of it, (2) high safety, (3) development of the blood products with low medical cost.

Life Innovation	CREST "Fundamental technologies for medicine concerning the generation and regulation of induced pluripotent stem (iPS) cells)"	Mitsuo Oshimura	Professor Emeritus, Tottori University Specially Appointed Professor, Chromosome Engineering Research Center, Tottori University	①GPC Laboratory Co. Ltd. ②2012 ③・Provide functional evaluation systems for druggable target molecules ・Provide evaluation systems with inserted transcriptional regulatory region of genome size ・Provision of evaluation systems supporting new concepts of multiple-target evaluation screening founded in polypharmacological and phenomenal approaches, and contracting of screening
	ERATO "SATO Live Bio-Forecasting"	Thomas N. Sato	Director, Advanced Telecommunications Research Institute International The Thomas N. Sato BioMEC-X Laboratories	①Karyudo TherapeutiX, Inc. ②2015 ③ ・to create and present advanced technologies to "detect" illness early (discovery by diagnostics), "defend, exterminate, coexist" (prevention, predictive medical care, control).and to present the technological innovation which is effectively usable in anyone anywhere anytime.

Information and Communications Technology	ERATO “IGARASHI Design Interface“	Takeo Igarashi	Professor, Graduate School of Information Science and Technology, The University of Tokyo	①diatom studio (UK) ②2010 ③ ・Providing of various digital fabrication tools which enable end user to engage in a design process. ・Painter tools used the iPhone. ・Design and fabrication tool of the original chair. ・Low-cost small devices to enable CNC processing
	CREST “Foundation of Technology Supporting the Creation of Digital Media Contents”	Michitaka Hirose	Professor, Graduate School of Information Science and Technology, The University of Tokyo	①Xcoo, Inc. ②2011 ③ Engaged in development of interactive experiential systems for the visualization of large amounts of information that connects the realm of computers with the real world by means of the concept of Technology Bridge for Communication.
	CREST “Advanced Integrated Sensing Technologies”	Koichi Kurumatani	Deputy Director, Human Informatics Research Institute, National Institute of Advanced Industrial Science and Technology (AIST)	①Asure Co., Ltd. ②2012 ③ Developing business relating to information distribution systems that work by seamless indoor/outdoor positioning and urban space information support systems typified by an elder monitoring service.

Information and Communications Technology	ERATO "MAENAKA Human-Sensing Fusion"	Kazusuke Maenaka	Professor, Graduate School of Engineering, University of Hyogo	①AffordSENS Corporation ②2013 ③ Research, design, development, prototyping, marketing , and consulting in the below fields: ・Health monitoring devices ・Health management systems ・Sensor networks and systems ・Intellectual property management and licensing in the above fields of technology
	CREST "High Performance Computing for Multi-Scale and Multi-Physics Phenomena"	Hiroaki Takada	Professor, Graduate School of Information Science, Nagoya University	①APTJ Co., Ltd. ②2015 ③ Engaged in working jointly with automotive parts manufacturers and other such enterprises on software platform development based on the international standard of AUTOSAR specifications. Distinctive characteristics are that the developed software platforms are based on the most recent AUTOSAR specifications while efficiently supporting functional safety standards, cyber-security measures, and multicore processors by means of leading-edge functionality and implementation technology that utilize Nagoya University research and development results and knowledge.

Information and Communications Technology	PRESTO "Design of Information Infrastructure Technologies Harmonized with Societies"	Yoshihiro Kawahara	Associate Professor, Graduate School of Information Science and Technology, The University of Tokyo	①SenSprout Inc. ②2015 ③ ・Development and marketing of agricultural sensors ・Development and operation of internet services related to agriculture

(The study was made on Nov. 2015)

Fig. 3-19 shows a case of the further development of research results produced under CREST (2009-2015 research period) utilizing a venture corporation established in 2009.

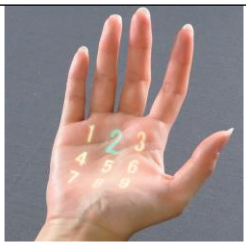
1999-2004
CREST： Creating the Brain
<Research Project>
"Artificial Hand-brain System Based on Sensory-Motor Fusion Theory"
<Research Director>
Masatoshi Ishikawa（Professor, The University of Tokyo）

2006 started
JST University Venture Program

" Research and development of high-speed vision module towards practical use"

※ " Exvision Inc." was founded in January 2009 based on the outcome of the research project by Prof. Ishikawa , and obtained investment from Innovation Network Corporation of Japan (INCJ) in 2013.

Exvision Inc. was founded in January 2009 based on the outcome of the research project in CREST (creating the brain) by Prof. Ishikawa. Before the foundation, they obtained funding from "JST University Venture program" and developed a new technology for voice search engine which functions on internet movie site. Moreover, this company is now developing high-speed tracking and video-monitoring systems by utilizing the outcome of the research project "Dynamic Information Space based on High-speed Sensor Technology"(2009-2015)in CREST (Creation of Human-Harmonized Information Technology for Convivial Society) as shown below.



Left: Image information is displayed on the paper by tracking its movement.
Right: Image and tactile information are transferred to the palm by tracking its movement.

Fig. 3-19 Case of a venture established on the basis of CREST research results

2. Researchers Nurtured by the Strategic Basic Research Programs

This section presents cases of researchers who received distinguished awards during this international evaluation period together with younger researchers who show promise for the future and representative researchers who developed into leaders in research for the next generation through the Strategic Basic Research Programs.

(1) Researchers Who Received International and/or Domestic Awards

In 2012, Shinya Yamanaka selected as the second Japanese winner of the Nobel Prize in Physiology or Medicine. He was awarded The Millennium Technology Prize. Six researchers from 2010 to 2014 were named as The Thomson Reuters Citation Laureates who are recognized as candidates likely to receive a Nobel Prize. Also in 2014, three people received the Humboldt Prize recognizing them as researchers who are expected to continue working at the leading edge of scholarship into the future. In 2015, Shimon Sakaguchi received the Gairdner Foundation International Award which recognizes world-level discoveries or contributions to medical science (Table 3-13). 11 researchers received The Keio Medical Science Prize, Gold Medal Prize and The Asahi Prize which are domestic prizes.

Table 3-13 International and domestic awards received
(International)

Prize	Researcher	Position, Affiliation	Research Area/Project	Awarded year
Nobel Prize	Shinya Yamanaka	Director, Center for iPS Cell Research and Application (CiRA), Kyoto University	CREST “Translational Research for Intractable Immune Disorders and Infectious Diseases”	2012
Thomson Reuters Citation Laureates	Hideo Ohno	Professor, Research Institute of Electrical Communication, Tohoku University	ERATO “OHNO Semiconductor Spintronics”	2011
	Masatake Haruta	Professor, Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University	CREST “Development of the Foundation for Nano-Interface Technology”	2012

Thomson Reuters Citation Laureates	Hideo Hoshono	Professor, Materials & Structures Laboratory / Frontier Research Center Director, Materials Research Center for Element Strategy, Tokyo Institute of Technology	ERATO "HOSONO Transparent ElectroActive Materials " SORST ACCEL "Materials Science and Application of Electrides" SORST "Exploring and developing applications for active functions utilizing nanostructure embedded in transparent oxides"	2013
	Noboru Mizushima	Professor, Graduate School of Medicine, The University of Tokyo	PRESTO "Unit Process and Combined Circuit" PRESTO "Time's Arrow and Biosignaling" SORST "Intracellular clearance mechanism by autophagy"	2013
	Yoshinori Tokura	Professor, Graduate School of Engineering, University of Tokyo Director, RIKEN Center for Emergent Matter Science	ERATO "TOKURA Spin Superstructure " ERATO "TOKURA Maltiferroics"	2014
	Shimon Sakaguchi	Distinguished Professor, Osaka University/Professor, Immunology Frontier Research Center, Osaka University	CREST "Creation of basic medical technologies to clarify and control the mechanisms underlying chronic inflammation"	2015
Humboldt Prize	Shinya Koshihara	Professor, Graduate School of Engineering, Tokyo Institute of Technology	CREST "Enhancing Applications of Innovative Optical Science and Technologies by Making Ultimate Use of Advanced Light Sources"	2014
	Masahiro Murakami	Professor, Graduate School of Engineering, Kyoto University	ACT-C	2014

Humboldt Prize	Shu Kobayashi	Professor, Graduate School of Science, The University of Tokyo	ERATO “KOBAYASHI Highly Functionalized Reaction Environments” ACT-C	2014
Canada Gairdner International Award	Shimon Sakaguchi	Professor, Immunology Frontier Research Center, Osaka University	CREST「Translational Research for Intractable Immune Disorders and Infectious Diseases -Aiming at Creation of Novel Strategies Through Elucidation of Molecular Mechanisms of Pathogenesis-」Research area CREST “Creation of basic medical technologies to clarify and control the mechanisms underlying chronic inflammation”	2015
The Millennium Technology Prize	Shinya Yamanaka	Director, Center for iPS Cell Research and Application (CiRA), Kyoto University	CREST “Translational Research for Intractable Immune Disorders and Infectious Diseases”	2012

(Domestic)

Prize	Researcher	Position, Affiliation	Research Area/Project	Awarded year
The Keio Medical Science Prize	Hiroyuki Mano	Professor, Graduate School of Medical Sciences,, The University of Tokyo	CREST「Basic Technology to Establishing Tailor-Made Medicine by Utilizing Genome Information」Research area	2012

The Keio Medical Science Prize	Shigekazu Nagata	Professor, Graduate School of Medicine, Kyoto University	CREST「Structure and Function of Genomes」 CREST「Etiological Basics of and Techniques for Treatment of Allergic and Autoimmune Diseases」 CREST「Structural Life Science and Advanced Core Technologies for Innovative Life Science Research」	2013
	Hiroshi Hamada	Professor, Osaka University	CREST “Genetic Programming” Research area CREST “Development, Differentiation, and Regeneration in Biological Systems”Research area CREST ”The Dynamic Mechanism of and Fundamental Technology for Biological System” Research area CREST ”Creation of Fundamental Technologies for Understanding and Control of Biosystem Dynamics”Research area	2014
Gold Medal Award	Shoji Takeuchi	Professor, Institute of Industrial Science, the University of Tokyo	ERATO “TAKEUCHI Biohybrid Innovation” Project	2012
	Yasuteru Urano	Professor, Graduate School of Medical Sciences,/Graduate School of Pharmaceutical Sciences, The University of Tokyo	CREST “Creation of Innovative Technology for Medical Applications Based on the Global Analyses and Regulation of Disease-Related Metabolites” Research area	

Gold Medal Award	Mitinori Saitou	Professor, Graduate School of Medicine, Kyoto University	ERATO “SAITOU Totipotent Epigenome” Project	2013
	Tetsuya Higashiyama	Professor of Graduate School of Science, Nagoya University	ERATO “HIGASHIYAMA Live-Holonics” Project	2014
	Noboru Mizushima	Professor, Graduate School of Medicine, The University of Tokyo	PRESTO ”Unit Process and Combined Circuit」Research area PRESTO「Time’s Arrow and Biosignaling” Research area SORST “Intracellular clearance mechanism by autophagy”	2014
	Eiji Saitoh	Professor, WPI-AIMR / Institute for Materials Research, Tohoku University	ERATO ”SAITOH Spin Quantum Rectification” Project	
The Asahi Prize	Hidetoshi Katori	Professor, Graduate School of Engineering, the University of Tokyo Chief Scientist, RIKEN	ERATO ”KATORI Innovative Space-Time” Project	2011
	Shimon Sakaguchi	Distinguished Professor, Osaka University/Professor, Immunology Frontier Research Center, Osaka University	CREST “Translational Research for Intractable Immune Disorders and Infectious Diseases -Aiming at Creation of Novel Strategies Through Elucidation of Molecular Mechanisms of Pathogenesis-“Research area CREST ”Creation of basic medical technologies to clarify and control the mechanisms underlying chronic inflammation” Research area	

The Asahi Prize	Kenjin Shin	Professor, ,Graduate School of Natural Science and Technology, Okayama University	PRESTO “Structure and Function of Biomolecules” Research area	2012

(The study was made on Nov. 2015)

(2) Women Researchers

Strategic Basic Research Program researchers received the Saruhashi Award which is given annually to one Japanese woman researcher for distinguished research achievement in the natural sciences are shown in Table 3-14. The Saruhashi Award was established in 1981 and as of 2015 there have been 35 recipients. Eight people are CREST Research Directors or PRESTO researchers (Table 3-14).

Table 3-14 Saruhashi Award recipients in CREST and PRESTO

Field	Research Area	Researcher	Position, Affiliation	Awarded year
Nanotechnology and Materials	CREST “Alliance for breakthrough between mathematics and sciences”	Motoko Kotani	Principal Investigator, Advanced Institute for Materials Research, Tohoku University Professor, Department of Mathematics, Graduate School of Science, Tohoku University	2005
	CREST “ional Materials with Advanced Properties by Hyper-nano-space Design”	Kyoko Nozaki	Professor, Graduate School of Engineering, The University of Tokyo	2008
	PRESTO “Structure Function and Measurement Analysis”	Emi Hifumi	Professor, Research Promotion Institute, Oita University	2014
Life Innovation	CREST “The Dynamic Mechanism of and Fundamental Technology for Biological System”	Ikue Mori	Professor, Graduate School of Science, Nagoya University	2006
		Mikiko Shiomi	Professor, Graduate School of Science, The University of Tokyo	2009

Life Innovation	CREST "Fundamental technologies for medicine concerning the generation and regulation of induced pluripotent stem (iPS) cells" CREST "Innovation for Ideal Medical Treatment Based on the Understanding of Maintenance, Change and Breakdown Mechanisms of Homeostasis among Interacting Organ Systems"	Yoshiko Takahashi	Professor, Graduate School of Science, Kyoto University	2010
	PRESTO "The Dynamic Mechanism of and Fundamental Technology for Biological System"	Keiko Torii	Visiting Professor, Institute of Transformative Bio-Molecules (WPI-ITbM), Nagoya University	2015
Information and Comunication's Technology	Alliance for Breakthrough between Mathematics and Sciences	Noriko Mizoguchi	Associate professor, Faculty of education, Tokyo Gakugei University	2011

(The study was made on Nov. 2015)

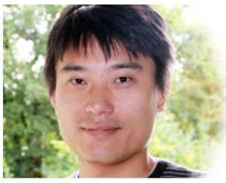
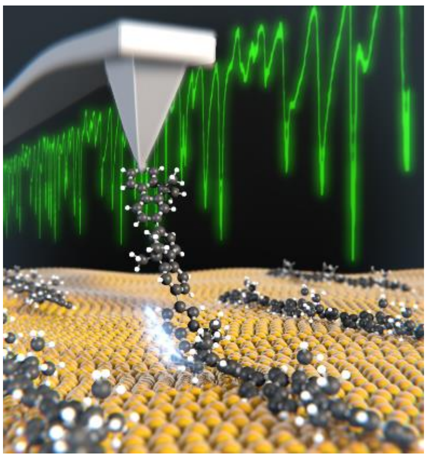
(3) Young Researchers

Table 3-15 shows representative younger researchers with PRESTO who have produced conspicuous research results in the relevant fields who have earned recognition in Japan and other countries and who are expected to make major contributions to future innovation in science and technology. An overview of the research achievements of younger researchers is also presented.

Table 3-15 Noteworthy young researchers

Field	PRESTO Research Area	Researcher	Position, Affiliation
Nanotechnology and Materials	"Molecular technology and creation of new functions"	Shigeki Kawai	Senior Researcher Department of Physics, University of Basel
Nanotechnology and Materials	"Molecular Technology and Creation of New Functions"	Rie Makiura	Associate Professor, Graduate School of Engineering,, Osaka Prefecture University
Green Innovation	"Phase Interface Science for Highly Efficient Energy Utilization"	Kenichi Uchida	Associate Professor, Institute for Materials Research (IMR), Tohoku University
Life Innovation	"Design and Control of Cellular Functions"	Miki Ebisuya	Unit Leader, RIKEN Quantitative Biology Center
	"Understanding Life by iPS Cells Technology"	Arata Honda	Tenure Track Associate Professor, Organization for Promotion of Tenure Track (OPTT), Miyazaki University
	"Elucidation and control of the mechanisms underlying chronic inflammation"	Kazuyo Moro	Team leader, RIKEN Center for Integrative Medical Sciences
Life Innovation	"Creation of Basic Technology for Improved Bioenergy Production through Functional Analysis and Regulation of Algae and Other Aquatic Microorganisms"	Takashi Osanai	Full-time lecturer, Meiji University

Information and Communications Technology	"Information Environment and Humans"	Hiroyuki Kajimoto	Associate Professor, Faculty of Informatics and Engineering, University of Electro-Communications
	"Synthesis of Knowledge for Information Oriented Society"	Kazunori Ohno	Visiting Associate Professor, New Industry Creation Hatchery Center, Tohoku University
	"Information Environment and Humans"	Tomohiro Tachi	Assistant Professor, Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo

Name (Position, Affiliation)	Research Area/Research Project/Objectives/ Research Results
 **Shigeki Kawai** **(Senior Researcher,** **Department of Physics,** **University of Basel)**	**Research Area:** Molecular technology and creation of new functions **Research Project:** Revealing mechanical, electronic, and chemical properties of molecules at atomic-scale (2012-2015) **Objectives:** The objective of the research is in-situ observation and measurement of the mechanical and electrical characteristics in single molecules and among single molecules at the atomic-level resolution. Detecting chemical reactivity in molecules using a novel atomic probe that is chemically modified is also studied. **Research Results:** Although the atomic force microcope (AFM) is a powerful tool to investigate the mechanical characteristics of biopolymers such as DNA and proteins, the mechanical behavior of a single molecular chain has yet to be realized In this research, the mechanical behavior of in-situ ploymerized fluorene chains could be successfully studied by pulling up individual polyfluorene molecular chains up to 80nm with the aid of a novel AFM technique at 4.8K in an ultra high vacuum environment. Details on the detachment mechanism of polymer chains from the substrate could be obtained for the first time by measuring the force gradient during the pulling up process. The.obtained information can contiribute to the understading of complex processes in living syytems and the realization of various bio-devices.  Fig. AFM probe for pulling up a polyfluorene chain from Au surface

Rie Makiura
(Associate Professor, Graduate School of Engineering, Osaka Prefecture Univ.)

Research Area: Molecular technology and creation of new functions

Research Project : Creation of highly oriented functional molecular films utilizing liquid phase interfaces(2012-2015)

Objectives:

Creating large area interfaces for efficient charge separation and molecular path for fast electron/hole transfer is one of most important issues for the realization of organic solar cells. In addition, facile and low energy processes are required for cell fabrication. The aim of the present research is to establish a molecular engineering approach to create nano-heterojunctions where molecular columns of electron acceptors and donors are alternately aligned at the nanoscale. Self-assembling features of molecules in an oriented manner at the air/liquid interface are utilized for the creation of the nano-heterojunctions.

Research Results:

Based on the first success in obtaining a highly-crystalline metal-organic framework (MOF) nanosheet by utilizing air/liquid interfacial reaction, the original methodology was further developed, leading to creation of three dimensional nano-assemblies on both flat substrates and particle surfaces. Novel MOF nanosheets in which the pore size/shape and the molecular arrangements are well controlled have been extensively developed for potential applications to energy devices. For instance, an ideal structure for organic solar cells (Fig.) can be strategically created by applying the molecular-based crystalline nanosheet.

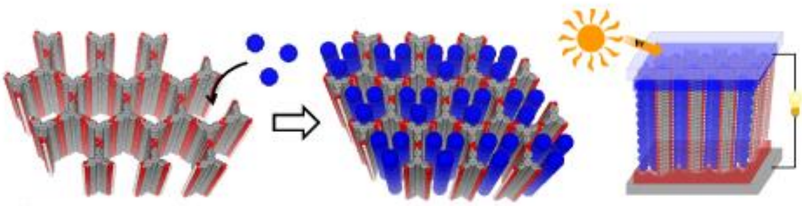


Fig. Strategy for creating a nanoheterojunction which is ideal as an active layer of organic solar-cells

Ken-ichi Uchida

(Associate Professor, Institute for Materials Research, Tohoku University・)

Research Area：Phase Interfaces for Highly Efficient Energy Utilization

Research Project：Creation of Innovative Energy Device Technology Based on Spin Currents (2012-2017)

Objectives：

Innovation for power-generation and energy-saving devices to harvest and utilize ubiquitous energy in our life through the flow of spin angular momentum, called “spin current”, is attempted.

Research Results:

“Spin-Seebeck effect” is the generation of a spin current from a thermal gradient, discovered by Uchida. Furthermore, his group also found that a spin current can also be generated by acoustic waves, and enabled thermoelectric conversion using various materials including insulators. In this project, Uchida succeeded in creating a spin current by light irradiation as well, and is creating as novel energy conversion systems driven by spin currents generated from thermal gradients, acoustic waves, and light. By exciting “surface plasmon – collective oscillation of electrons –” in a magnet, which is induced in certain metal particles by light irradiation, Uchida succeeded in convertinging photon energy into a spin current for the first time in the world and established a new energy-conversion principle through these results. In addition to light, Uchida could clearly prove the conversion to spin currents or charge currents in the same device structures as those using conventionally established heat, acoustic, or electromagnetic waves. These discoveries are expected to greatly contribute to the development of electronic and magnetic devices without an outside power supply.

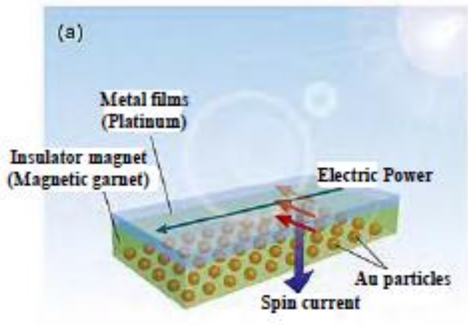


Fig. Schematic of light-spin convolution

Miki Ebisuya
(Unit Leader, RIKEN Quantitative Biology Center)

Research Area: Design and control of cellular function

Research Project: Reconstitution of cell-cell feedback circuits that regulate cell fate determination (2013-2015)

Objectives:

In the developmental processes of multicellular organisms, initially identical cells must adopt different cell fates. One mechanism to generate asymmetry between homogeneous cells is a positive feedback loop between adjacent cells. This cell-cell positive feedback loop amplifies slight differences between adjacent cells and generates a stable difference between the cells. In this study, Ebisuya reconstructs the cell-cell positive feedback loop in mammalian cultured cells and seeks to identify quantitative conditions and minimal requirements for the genesis of asymmetry. In addition, controlling the ratio of different cell types using the cell-cell positive feedback loop is attempted.

Research Results:

Cell-type diversity in multicellular organisms is created through a series of binary cell fate decisions. Lateral inhibition controlled by Delta–Notch signaling is the core mechanism in the adoption of alternative cell types by homogeneous neighboring cells. Here, cells engineered with a Delta–Notch-dependent lateral inhibition circuit spontaneously bifurcate into Delta-positive and Notch-active cell populations. The synthetic lateral inhibition circuit promotes transcriptional repression of Delta and intracellular feedback of the Lunatic fringe (L fng). Simple artificial gene networks are constructed only by 4 genes (Delta, Notch, tTS, Lfng) and are transfected to mammalian cultured cells. The cell-type ratio can be adjusted by the architecture of the lateral inhibition circuit as well as the degree of cell–cell attachment. Thus, the minimum lateral inhibition mechanism between adjacent cells not only serves as a binary cell-type switch of individual cells but also governs the cell-type ratio at the cell-population level. Ebisuya was awarded the young scientist's prize by the Minister of Education, Culture, Sports, Science and Technology in 2013.

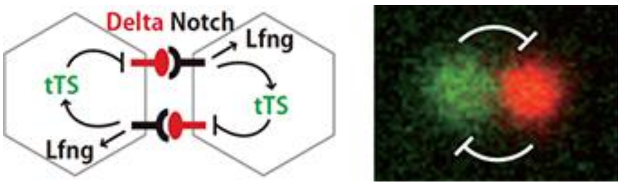
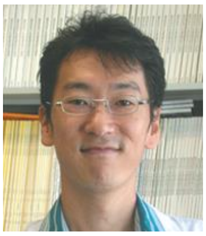


Fig. Diagram of an artificial gene network (left) and the resulting asymmetry between neighboring cells (right)



Arata Honda (Associate Professor, Organization for Promotion of Tenure Track, University of Miyazaki)

Research Area：Understanding Life by iPS Cells Technology

Research Project：Establishment of comprehensive assessment system for iPS cells using rabbit models (2009-2012)

Objectives:

The aim of this study is to establish experimental models using laboratory rabbits for the safety assessment of iPS cells in human regenerative medicine. We seek to derive rabbit iPS cells from somatic cells and induce them to differentiate in vitro, according to methods established in other species with necessary modifications. The cells are

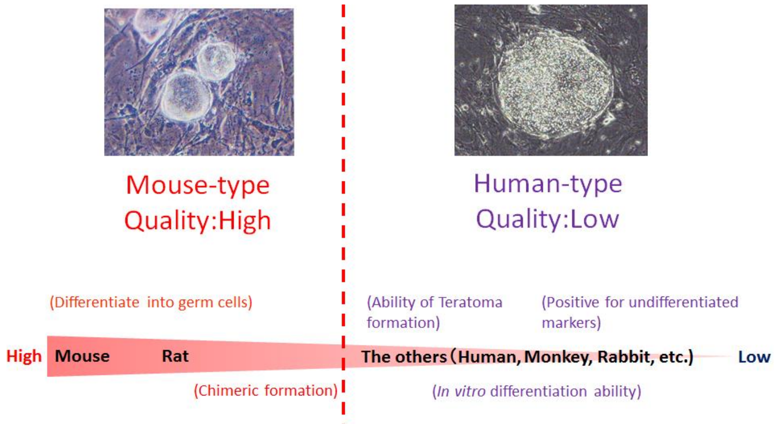


Fig. ES/iPS cells can be categorized into Mouse-type and Human type

transplanted to host rabbits including human disease models for assessment of the effectiveness and safety of iPS cell-based medicine. Using rabbit, nuclear transfer ES cells can be generated as alternative cell-therapy resources. Honda hopes that the comprehensive assessment system using rabbit iPS cells will accelerate the transition from basic iPS research to clinical applications in humans.

Research Results:

iPS cells can be categorized into Human-type and Mouse-type. Mouse-type ES/iPS cells generated from rodents exhibit much higher capacity of differentiation into several cells than that of Human-type ES/iPS cells which are generated from almost all mammalian species. Honda succeeded in modifying Human-type rabbit iPS cells to Mouse-type by changing the culture conditions and overexpression of OCT3/4.The converted Mouse-type iPS cells can be differentiated effectively into neural cells in vitro than those of Human-type ES cells. Improving the quality of iPS cells read to the development not only industrial usage but also medical applications in future.

Kazuyo Moro

(Team leader, RIKEN Center for Integrative Medical Sciences)

Research Area: Elucidation and Control of the Mechanisms Underlying Chronic Inflammation

Research Project: Action mechanism of natural helper cells regulating the Th1/Th2 balance in IL-33-dependent chronic inflammatory diseases (2010-2015)

Objectives:

IL-33 is produced by epithelial cells and endothelial cells during helminth infection and allergic inflammation, and acts as an alarmin. Natural helper (NH) cells, which have been recently identified by Moro and her colleagues, respond to IL-33 and produce large amounts of Th2 cytokines involved in various inflammatory processes. This project has been focused on the dynamics of NH cells in IL-33-related chronic inflammation, and aim to identify a new strategy to control chronic inflammatory diseases.

Research Results:

This project demonstrates a new concept in allergic inflammations. Type 2 immune responses were previously thought to be evoked by antigen-specific Th2 cells. However, not only Th2 cells, but NH cells also induce strong antigen-independent type 2 immune responses during asthma. It has been shown that NH cell development, proliferation and cytokine production depend on GATA3 signaling, similar to Th2 cells. The steroid resistant asthma model induced by IL-33 plus antigen injection indicates that NH cells become steroid resistant by co-stimulation with IL-33 and TSLP, which is reported to be activated in severe asthmatic patients. TSLP is one of the major Stat5 activators, and anti-TSLP antibody treatment or Stat5 inhibitor treatment resulted in the recovery of steroid resistance in this model. Moreover, IFNγ and IL-27 were elucidated as strong suppressors of NH cells in this project. The suppressive effects of both cytokines were dependent on STAT1 signaling, and seemed to be important for the switching of type 2 immune response from NH cells to Th2 cells.

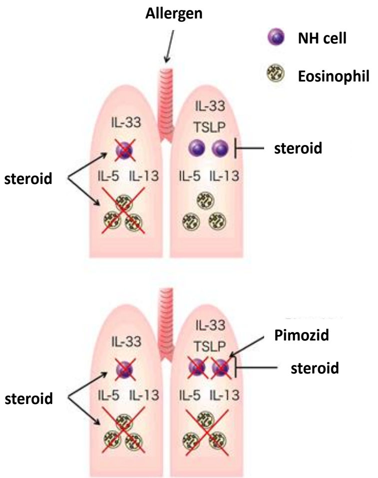
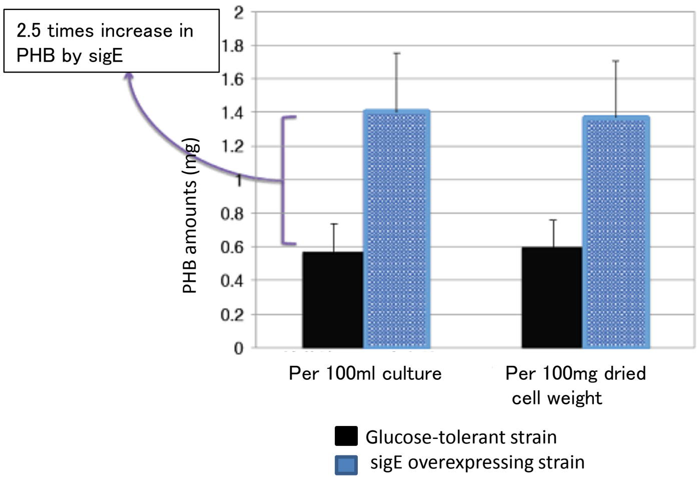


Fig. Pimozid recovered the effect of steroids on steroid resistance asthma

 **Takashi Osanai (Senior Assistant Professor, School of Agriculture, Meiji University)**	**Research Area:** Creation of basic technology for improved bioenergy production, through functional analysis and regulation of algae and other aquatic microorganisms. **Research Project:** Increased production of cyanobacterial polyhydroxybutyrate (PHB) via modification of sugar metabolism (2010-2013) **Objectives:** Production of bioplastics from biomass is a key technology to overcome global environmental problems. The objective of this research is to increase the productivity of bioplastics PHB via direct conversion of CO_2 using unicellular cyanobacteria. To change metabolic flow, cyanobacterial strains overexpressing transcriptional regulators were generated and their PHB productivity was tested. **Research Results:** To increase bioplastic production via increasing the metabolic flux, the strain overexpressing *sigE*, encoding an RNA polymerase sigma factor, was generated. As shown in the figure, PHB levels in the *sigE*-overexpressing strain increased 2.5 times of the parental wild-type strain after nitrogen depletion. This is the first example that genetic engineering of a sigma factor resulted in a large change in both sugar metabolism and PHB productivity, indicating that sigma factor is key target for metabolic engineering of cyanobacteria. Knowledge obtained in this research will contribute to efficient bioplastic production from CO_2 using cyanobacteria for future sustainable development of the world..  Fig. Effect of sigE on PHB production

Hiroyuki Kajimoto
(Associate Professor, The University of Electro-Communications Department of Human Communication)

Research Area: Information Environment and Humans

Research Project: Optimal Design of Real World Tactile Interface Based on Spatio-Temporal Cognitive Model of Tactile Modality

Objectives:

Due to its real-time response and intuitiveness, tactile modality is suitable for real world interface. This research aims to design an optimal real world tactile interface based on the knowledge of spatio-temporal tactile perception model. The interface will be used for both information display and navigation.

Research Results:

Kajimoto focuses on the phenomenon called "Hanger Reflex" (Fig.), where the head automatically rotates when a wire hanger is worn on the head. This phenomenon can be regarded as a simple and efficient way for navigation. He found that it is based on the shear deformation of the skin. Based on this knowledge, it was applied as a new rehabilitation device and the treatment device for cervical dystonia (head-posture related sickness). This therapeutic method greatly reduces surgical burden on patients compared to conventional methods such as the stimulation of the deep part of the brain. Clinical trials using this method are now underway by several medical organizations. As stated above, Kajimoto established a concept of presenting motion perception by using haptics illusion phenomena.

Fig. Hanger Reflex

Kazunori Ohno
(Associate Professor,
New Industry Creation
Hatchery Center,
Tohoku University)

Research Area: Synthesis of Knowledge for Society

Research Project: Environment Recognition based on Visual and Tactile Information for a Mobile Robot.

Objectives:

Our final goal is to develop search robots that can autonomously gather environment information in the real world. We are developing an environment recognition method based on visual and tactile information. In our approach, visual information includes color, shape and motion data. Tactile information includes contact point and contact force data. Unknown objects can be recognized using both kinds of information.

Research Results:

In order to realize so called "partner robots" which can cooperate with humans, the robots must recognize various information about objects in daily life environment. We propose a new two-step method for that goal. The first step is to find and gather information that is new to the robot. The second step is to acquire knowledge by applying division modeling based on touch and movement of the unknown objects. In our experiments, we used range sensors and video cameras to find an unknown object. Then, the robot moves to get divided information and rotates simultaneously to perform all perimeter modeling. Achievements from this experiment will contribute to a future society where humans and mobile robots can work together in daily life.

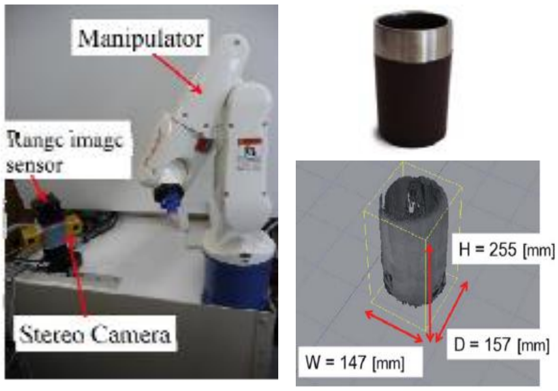


Fig. Experimental system and the obtained 3D modeling picture

Tomohiro Tachi
(Assistant Professor, Graduate School of Arts and Sciences, The University of Tokyo)

Research Area: Information Environment and Humans

Research Project: Interactive Environment for Physics-based Design

Objectives:

In this research, an interactive environment for physics-based design, i.e., design that maximally utilizes physical properties of elements such as origami and tension structures, for personal manufacturing, is developed. We aim to construct a system that can be used by persons without technical knowledge through interaction in a design space where physics- and design-based conditions can be satisfied. In addition, knowledge and knowhow of specialists and researchers in fabrication technologies are made to be intuitively usable.

Research Results:

Using origami structures, while satisfying both physical properties and design conditions of the member, a system which can design an intuitive structure even without expertise was developed. In cooperation with architects and structural design house, et al., the practical use of the structure transmutative along the lines of the weather or environmental conditions is also expected.

One outstanding achievement in our research of geometry and algorithm of origami is the development of the interactive software "Freeform Origami" which enables us to make 3D figure freely using just two papers and to architect a pattern to make 3D structure flat for the first time in the world.

Data of a 3D structure is inputted into the computer, and the software automatically generates a developmental view to make the structure not only out of paper but also out of any sheet material. An example of a 3D free form surface made by metal sheet is shown in Figure. Additionally, by applying the "Origami" theory to architecture and structural objects, it is possible to form a strong wall face for folding architecture or thin structures.

Fig. 3D shape by calculation origami

Moreover, Dr. Tachi has developed the new structure, which was both the deformation potential of the structural strength and folding by expanding the "Rigid Body Origami" theory that allows handling without material distortion.

Research results such as these are leading innovations in the fields of art, architecture design, and material development for space applications, etc.

(4) Next-Generation Leaders

In the research community, PRESTO is known as the gateway to success for young researchers and the expectation is that PRESTO will produce leaders in future research. Next-generation leaders have already been emerging from PRESTO and some representative examples are shown in Table 3-16.

Out of the researchers in PRESTO, the number who became CREST Research Directors from 2011 to 2014 was 117 researchers. These made up 17% of the total number of researchers.

Table 3-16 Next-generation leaders developed from PRESTO

Field	PRESTO Research Area	Researcher	Position, Affiliation	Program Officer/Project Leader
Nanotechnology and Materials	"Structure Control and Function"	Kenichiro Itami	Director, Institute of Transformative Bio-Molecules (WPI-ITbM), Nagoya University / Professor, Graduate School of Science, Nagoya University	ERATO "ITAMI Molecular Nanocarbon" Project Leader
	"Structural Ordering and Physical Properties"	Hiroshi Kitagawa	Professor, Graduate School of Science, Kyoto University	PRESTO "Science and Creation of Innovative Catalysts" Program Officer ACCEL "Development of Materials and Applications Founded on Inter-Element Fusion" Research Director CREST "Creation of Innovative Functions of Intelligent Materials on the Basis of Element Strategy" Research Director CREST "Development of the Foundation for Nano-Interface Technology" Research Director

Nanotechnology and Materials	“Evolution of Light Generation and Manipulation”	Takashige Omatsu	Director of Molecular Chirality Research Center, Professor, Graduate School of Advanced Integration Science, Chiba University	CREST “Enhancing Applications of Innovative Optical Science and Technologies by making Ultimate Use of Advanced Light Sources” Research Director
	“Materials and Processes for Innovative Next-generation Devices”	Eiji Saitoh	Professor, Advanced Institute for Materials Research / Institute for Materials Research, Tohoku University	ERATO “SAITOH Spin Quantum Rectification” Project Leader CREST “Creation of nanosystems with novel functions through process integration” Research Director
	“Nanostructure and Material Property”	Shinji Yuasa	Director of Nanospintronics Center, National Institute of Advanced Industrial Science and Technology	CREST “Research of Innovative Material and Process for Creation of Next-generation Electronics Devices “ Research Director

Green Innovation	"Creation of Basic Technology for Improved Bioenergy Production through Functional Analysis and Regulation of Algae and Other Aquatic Microorganisms "	Yutaka Amao	Professor, The OCU Advanced Research Institute for Nature Science and Technology Head of Artificial Photosynthesis Research Center, Osaka City University	PRESTO "Creation of Basic Technology for Improved Bioenergy Production through Functional Analysis and Regulation of Algae and Other Aquatic Microorganisms " Researcher
Life Innovation	"Form and Function" "Synthesis and Control"	Mikiko Sodeoka	Chief Scientist, Synthetic Organic Chemistry Laboratory, RIKEN	ERATO "SODEOKA Live Cell Technology" Project Leader CREST "Creation of Innovative Technology for Medical Applications Based on the Global Analyses and Regulation of Disease-Related Metabolites" Research Director
	"Organization and Function" "Synthesis and Control"	Itaru Hamachi	Professor, Graduate School of Engineering, Kyoto University	PRESTO "Innovative Technology Platforms for Integrated Single Cell Analysis" Program Officer CREST "Creation of Fundamental Technologies for Understanding and

Life Innovation	"Organization and Function" "Synthesis and Control"	Itaru Hamachi	Professor, Graduate School of Engineering, Kyoto University	Control of Biosystem Dynamics" Research Director CREST "Development of High-Performance Nanostructures for Process Integration" Research Director
	"The Dynamic Mechanism of and Fundamental Technology for Biological System"	Tetsuya Higashiyama	Professor of Graduate School of Science, Nagoya University	ERATO "HIGASHIYAMA Live-Holonics" Project Leader
	"Information and Cell Function"	Mitinori Saitou	Professor, Graduate School of Medicine, Kyoto University	CREST "Fundamental technologies for medicine concerning the generation and regulation of induced pluripotent stem (iPS) cells" ERATO "SAITOU Totipotent Epigenome" Project Leader
	"Design and Control of Cellular Functions"	Shoji Takeuchi	Professor, Institute of Industrial Science, The University of Tokyo	ERATO "TAKEUCHI Biohybrid Innovation" Project Leader

Information and Communications Technology	"Information and Human Activity"	Hiroshi Ishiguro	Professor, Graduate School of Engineering Science, Osaka University Visiting Director (ATR Fellow), Hiroshi Ishiguro Laboratories, Advanced Telecommunications Research Institute International (ATR)	ERATO "ISHIGURO Symbiotic Human-Robot Interaction" Project Leader CREST "Creation of Human-Harmonized Information Technology for Convivial Society" Research Director
	"Light and Control"	Hidetoshi Katori	Professor, Graduate School of Engineering, The University of Tokyo Chief Scientist, Quantum Metrology Laboratory, RIKEN	ERATO "KATORI Innovative Space-Time" Project Leader CREST "Creation of New Technology Aiming for the Realization of Quantum Information Processing Systems" Research Director

(5) Representative Researchers

As described above, the Strategic Basic Research Programs has contributed to producing talented personnel in the various different fields of research. Some researchers (Table 3-17) who are representative of the Strategic Basic Research Programs because of the noteworthy results they have produced and have the high expectations for their creative innovations in science and technology are presented in overview with some of their research results.

Table 3-17 Representative researchers

Prize	Researcher	Position, Affiliation	Research Area/Project
Nanotechnology and Materials	Tetsuro Endoh	Director, Center for Innovative Integrated Electronic Systems Professor, Graduate School of Engineering, Tohoku University	CREST “ Research of Innovative Material and Process for Creation of Next-generation Electronics Devices“ ACCEL “Three-Dimensional Integrated Circuits Technology Based on Vertical BC-MOSFETs and Its Advanced Application Exploration“
	Hiroshi Fujioka	Professor, Institute of Industrial Science, The University of Tokyo	CREST “Creation of nanosystems with novel functions through process integration” ACCEL “Development of flexible nitride semiconductor devices with PSD “
	Makoto Fujita	Professor, Graduate School of Engineering, The University of Tokyo	CREST “Single Molecule and Atom Level Reactions” CREST“ Creation of Novel Nano-material/System Synthesized by Self-organization for Medical Use” CREST “Development of the Foundation for Nano-Interface Technology” ACCEL“ Innovative Molecular Structure Analysis based on Self-Assembly Technology”
	Hideo Hoshono	Professor, Materials & Structures Laboratory, Frontier Research Center/ Director, Materials Research Center for Element Strategy, Tokyo Institute of Technology	ERATO “HOSONO Transparent ElectroActive Materials “ SORST” Transparent Oxide Nanostructure” ACCEL “Materials Science and Application of Electrides”

Nanotechnology and Materials	Hidetoshi Katori	Professor, Graduate School of Engineering, The University of Tokyo Chief Scientist, Quantum Metrology Laboratory, RIKEN	PRESTO “Light and Control” CREST “Creation of New Technology Aiming for the Realization of Quantum Information Processing Systems” ERATO “KATORI Innovative Space-Time” Project Leader
	Hiroshi Kitagawa	Professor, Graduate School of Science, Kyoto University	PRESTO “Science and Creation of Innovative Catalysts” Program Officer CREST “Development of the Foundation for Nano-Interface Technology” CREST “Creation of Innovative Functions of Intelligent Materials on the Basis of Element Strategy” ACCEL "Development of Materials and Applications Founded on Inter-Element Fusion" Research Director
	Susumu Noda	Professor, Graduate School of Engineering, Kyoto University	CREST “Function Evolution of Materials and Devices based on Electron/Photon Related Phenomena” CREST “Photonics and Quantum Optics for the Creation of Innovative Functions” CREST “Creative research for clean energy generation using solar energy” ACCEL “Photonic Crystal Surface-Emitting Semiconductor Laser” -Towards Realization of High Power and High Brightness Operation
	Kyoko Nozaki	Professor, Graduate School of Engineering, The University of Tokyo	PRESTO “Conversion and Control by Advanced Chemistry” CREST “Creation of Innovative Functional Materials with Advanced Properties by Hyper-nano-space Design”

Nanotechnology and Materials	Eiji Saitoh	Professor, Advanced Institute for Materials Research / Institute for Materials Research, Tohoku University	PRESTO “Materials and processes for innovative next-generation devices” CREST “Creation of nanosystems with novel functions through process integration” ERATO “SAITOH Spin Quantum Rectification” Project Leader
	Takao Someya	Professor, Graduate School of Engineering, The University of Tokyo	CREST “Creation of nanosystems with novel functions through process integration” ERATO “SOMEYA Bio-Harmonized Electronics”
	Yoshinori Tokura	Professor, Graduate School of Engineering, The University of Tokyo Director, RIKEN Center for Emergent Matter Science	ERATO “TOKURA Spin Superstructure “ ERATO “TOKURA Maltiferroics”
	Yoshinobu Tsujii	Professor, Institute for Chemical Research, Kyoto University	CREST “Creation of nanosystems with novel functions through process integration” ACCEL “Reinforcement of Resiliency of Concentrated Polymer Brushes and Its Tribological Applications － Development of Novel “Soft and Resilient Tribology (SRT)” System “
Green Innovation	Yasuaki Einaga	Professor, Faculty of Science and Technology, Keio University	CREST “Creation of Innovative Functions of Intelligent Materials on the Basis of Element Strategy” ACCEL “Development of innovative technologies using diamond electrodes for improving environment “
	Susumu Kitagawa	Director of Institute for Integrated Cell-Material Sciences Professor, Graduate School of Engineering, Kyoto University	ERATO “KITAGAWA Integrated Pores” ACT-C ACCEL “The Nanospace Science of PCP for Molecular Control”

Green Innovation	Eiichi Nakamura	Professor, Graduate School of Science, The University of Tokyo	ERATO “NAKAMURA Functional Carbon Cluster” CREST “Establishment of Molecular Technology towards the Creation of New Functions”
	Yasuhiro Uozumi	Professor, Institute for Molecular Science, National Institute of Natural Sciences	CREST “Creation of Nano-Structured Catalysts and Materials for Environmental Conservation” CREST “Creation of Innovative Functions of Intelligent Materials on the Basis of Element Strategy” ACCEL “Development of Key Chemical Processes of Extremely High Efficiency with Super-Performance Heterogeneous Catalysts “
Life Innovation	Masayoshi Kawaguchi	Professor, National Institute for Basic Biology, National Institute of Natural Sciences	PRESTO “Unit Process and Combined Circuit” CREST “Plants Function and Their Control” ACCEL “Molecular Basis of Symbiotic Networks and its Application “
	Shimon Sakaguchi	Distinguished Professor, Osaka University/Professor, Immunology Frontier Research Center, Osaka University	CREST “Translational Research for Intractable Immune Disorders and Infectious Diseases” CREST “Creation of basic medical technologies to clarify and control the mechanisms underlying chronic inflammation”
	Mikiko Sodeoka	Chief Scientist, Synthetic Organic Chemistry Laboratory, RIKEN	PRESTO “Form and Function” PRESTO “Synthesis and Control” ERATO “SODEOKA Live Cell Technology” Project Leader CREST “Creation of Innovative Technology for Medical Applications Based on the Global Analyses and Regulation of Disease-Related Metabolites” Research Director”

Information and Communications Technology	Hiroshi Ishiguro	Professor, Graduate School of Engineering Science, Osaka University Visiting Director (ATR Fellow), Hiroshi Ishiguro Laboratories, Advanced Telecommunications Research Institute International (ATR)	PRESTO “Information and Human Activity” CREST “Creation of Human-Harmonized Information Technology for Convivial Society” ERATO “ISHIGURO Symbiotic Human-Robot Interaction”
	Masatoshi Ishikawa	Professor, Graduate School of Information Science and Technology, The University of Tokyo	CREST “Creating the Brain” CREST “ Creation of Human-Harmonized Information Technology for Convivial Society”
	Motoko Kotani	Director, Advanced Institute for Materials Research, Tohoku University Professor, Department of Mathematics, Graduate School of Science, Tohoku University	CREST ”Alliance for breakthrough between mathematics and sciences”
	Tadahiro Kuroda	Professor, Faculty of Science and Technology, Keio University	CREST “Technology Innovation and Integration for Information Systems with Ultra Low Power” CREST “Fundamental Technologies for Dependable VLSI System” ACCEL “Realization and development of innovative information processing system and application using near–field coupling integration technology”
	Susumu Tachi	Professor Emeritus, The University of Tokyo	CREST “Advanced Media Technology for Everyday Living” CREST “ Creation of Human-Harmonized Information Technology for Convivial Society” ACCEL “Toward the realization of future abundant society achieved by advanced Telexistence technology”

Tetsuro Endoh (Director, Center for Innovative Integrated Electronic Systems, Professor, Graduate School of Engineering, Tohoku University)

CREST（2008-2013）
ACCEL（2014-）

“Quest to Develop an Innovative Transistor – from Planar to Vertical”

1. Research Objectives

Endo is developing a device technology for a new transistor with a vertical structure. Unlike a conventional planar-type transistor, the vertical structure transistor accommodates a flow of drive current through its entire body region. He has also been consistently developing circuit designs, materials, and process technologies for what will be a new universal technical platform for semiconductor LSIs with greatly improved driving current characteristics, leakage current characteristics, and integration density compared with the planar-type MOSFET (Metal Oxide Semiconductor Field Effect Transistor). His team is using these features to advance research and development for the application of working memory to various integrated circuits in ACCEL.

2. Results

The three-dimensional device structure of the vertical body channel (BC) MOSFET realizes a high on/off ratio and low power consumption through reduced leakage current. The team has developed a layout design tool for vertical BC-MOSFET devices and established a new universal technology platform for semiconductor LSIs toward higher integration (see Fig. 1).

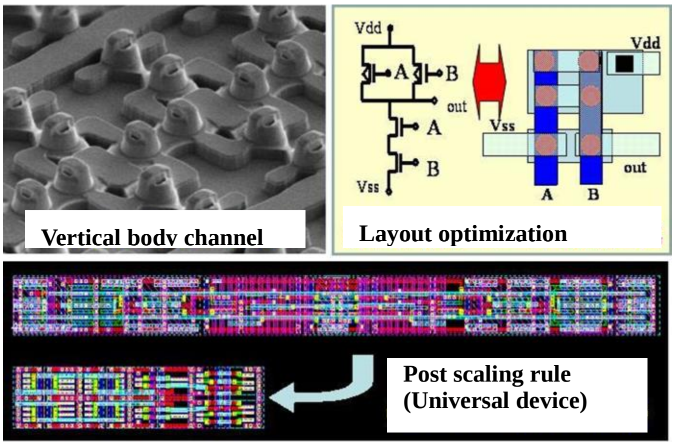


Fig. 1 BC-MOSFET improves LSI density

3. Contribution to Science, Technology and Innovation

The advantages of a three-dimensional structure demonstrate how mesoscopic physics can be applied to nanoscale silicon device applications. In addition to

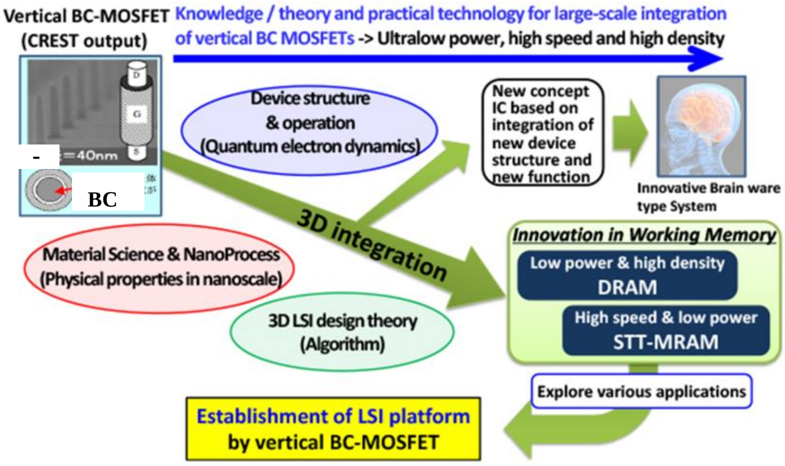


Fig. 2 Establishment of the LSI Platform

the device technology, the consistent development of circuit designs, materials, and process technologies for vertical BC-MOSFET has substantially improved the drive current characteristic, leakage current characteristics, and integration density without depending solely on device miniaturization. These characteristics provide a new integrated circuit platform for semiconductor LSIs. When applied in combination, the advantages of the vertical BC-MOSFET will enable various working memory applications using large-capacity, high-speed, and low-power-consumption integrated circuits (see Fig. 2). The global market for 3D-LSI will reach 64 billion USD in 2018. This will represent a 1.8% share of the global market for all LSIs (350 billion USD) in the same year.

Hiroshi Fujioka (Professor, Institute of Industrial Science, The University of Tokyo)

CREST(2008-2013)
ACCEL(2014-)

"Development of flexible nitride semiconductor devices with PSD "

1. Research Objectives

Although GaN-related semiconductors have excellent characteristics such as high mobility, high breakdown voltage and high luminous efficiency, their applications in various industries are not fully widespread. The main reasons are as follows: high cost single crystal wafer and epitaxial crystalline growth method, and immature growth technique for high quality crystals on low cost and large substrates.

In our ACCEL project, we will firstly realize deposition of high quality GaN-related crystal layers on flexible low-cost substrates by utilizing PSD（Pulsed Sputtering Deposition）methods which are low cost sputtering processes under low growth temperature. Then we will establish the basic technology for electro-optical integrated devices by developing and experimenting display systems composed of GaN-related LED's and driving transistors. These research outcomes will bring about unprecedented electronic platforms of high functional devices and systems for future society.

2. Results

Under the previous CREST project, the new pulsed sputtering deposition method (PSD) which made low-temperature (under 500 degree C) and high-quality growth possible by supplying material sources periodically, was originally developed. By applying this crystal growth method to nitride semiconductors (compound semiconductors composed of group 13 elements and nitride), we have successfully grown high- quality InGaN multi layers for the fabrication of prototype RGB full color LEDs on amorphous substrate.

3. Contribution to science, technology and innovation

As for the contribution to science in crystalline growth field, this ACCEL will open outstanding methods for low-temperature growth of high-quality crystal films on various substrates such as metal foils, graphite sheets and glass sheets.

On the other hand, innovative and promising applications will be the integration of electronic and optical circuits using nitride semiconductor devices, medical and environment monitoring sensors and wearable

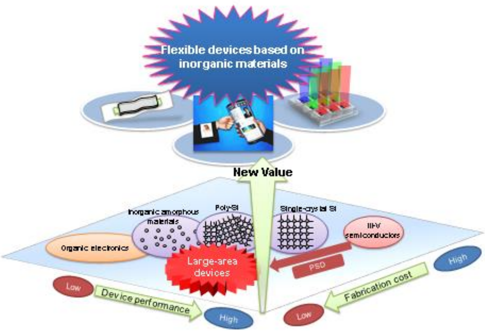


Fig.1 Promising market zone opened by this ACCEL project

mobile terminals utilizing the characteristics of GaN-related semiconductors such as bio-compatibility, environment-resistance and chemical-resistance. Additionally, introduction of sequential rolling mass production system will bring about further cost-down of the devices on flexible substrates.

Makoto Fujita (Professor, Graduate School of Engineering, The University of Tokyo)

CREST(1997-2002)
CREST(2002-2007)
CREST(2007-2012)
ACCEL(2014-)

"X-ray crystallographic structural analysis methods using the crystalline sponges for micro amount of compounds"

1. Research Objectives

In this study, M.Fujita thinks of the surface and the inside of a self-assembled nano-space as "an unambiguous structure of a finite nano-interface" and study a finite pro-surface chemistry and inside chemistry on a macromolecule with clear structure.. M.Fujita aims to clarify the groundwork for the interface phenomenon and create useful material, in particular (1) precise construction of a molecule based on a molecularly-designed finite interface, (2) development of a new interfacial function and a new reaction in solution state based on interface characteristics, (3) analysis of phenomena on a finite interface by solution-crystal chemistry technique.

2. Results

The metal-directed self-assembly of nano-meter sized frameworks gives us an opportunity to develop the chemistry of "isolated nano-space". For example, stabilization of labile molecules, specific chemical transformations, and the synthesis of labile molecules have been achieved within the cavities of the self-assembled cages and capsules.

The 3D networked porous complexes (the crystalline sponges) can absorb target sample molecules from their solution into the pores, rendering the incoming molecules regularly ordered in the crystal. Accordingly, the molecular structure of the absorbed guest will be displayed, along with the host framework by the crystallographic analysis of the networked porous complexes. This method attracts attention as an epoch-making method that an X-ray crystallographic analysis was enabled to determine structure of a tiny amount with less than μg of compound and sample having difficulty in crystallization.

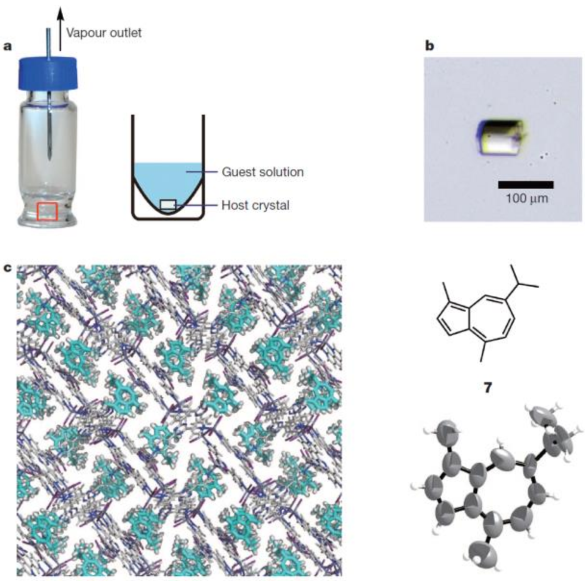


Fig. Nanogram-scale guest with a crystal of crystalline sponges :micro amount of sample (80 ng~5μg) can be absorbed into the crystalline sponges (0.1 mm pore)

3. Contribution to science, technology and innovation

X-ray structural analysis methods using the crystalline sponges that is “a crystalline sponges method” has been developed to build-out a practical analytical method in an ACCEL program.

① Aim to satisfy the optimized analytical system toward the practical use of “a crystalline sponges method”

② Aim to contribute to expanding self-assembled techniques for the structure analysis of protein molecule and development for manufacturing food, chemical industrial products and advanced medicinal products introducing “a crystalline sponges method” as a revolutionary analytical technique for organic compounds

“A crystalline sponges method ” would be expected to apply in many fields such as development of medicinal products, safety inspection of foods, forensic sciences, fragrance studies, only in basic research.

Hideo Hosono (Professor, Materials & Structures Laboratory, Director Materials Research Center for Element Strategy, Tokyo Institute of Technology)

ERATO （1999-2004）
SORST （2004-2009）
ACCEL （2013-）

"Great Discoveries and Trends in Material Science:
-New Electrides from Transparent Semiconducting Oxides and Iron-based Superconductors-**"**

1. Research Objectives

Transparent semiconducting oxides are large compounds composed of elements which are rich in natural resources, stable in air, and environmentally friendly. Utilizing characteristics of transparent oxides, such as a wide band-gap, electron properties which have been overlooked are now gaining interest. In particular, compounds which are composed of layer structures and cage-structures on the nanoscale have been selected as research targets. Furthermore, features of all electrides, namely stability in thermal processes and ease in electron emission, gained from results of ERATO, electrides are been developing as highly effective catalysts and new electronic materials, and are discovery of new material families in addition to new electrides have been strongly promoted in ACCEL.

2. Results

In ERATO, various functional materials such as "amorphous oxide semiconductor, In-Ga-Zn-O (IGZO) system with wide range of carrier concentration", "wide-gap p-type semiconductor (LaCuOSe)", "ultraviolet-transparent conducting materials (Ga_2O_3)", "Vacuum-ultraviolet transparent glass (F-doped silica glass)", and "electrides ($C12A7:e^-$) with high stability in ambient temperature and air" were successfully developed. The above mentioned features have been applied in the next SORST and ACCEL programs.

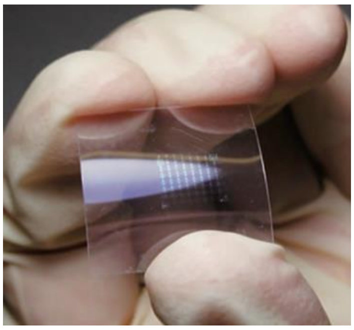


Fig. 1 IGZO flexible transparent transistor fabricated on a plastic substrate.

3. Contribution to Science, Technology and Innovation

By controlling the nanostructure of transparent oxides, Hosono and his group could activate electrons of these materials, as shown in the following examples.

The thin film transistor (TFT) using amorphous oxide semiconductor In-Ga-Zn-O (IGZO), which is an improvement over $InGaO_3(ZnO)_m$ single crystal, not only can be fabricated at room temperature, but also shows higher electron mobility by one digit than amorphous silicon TFT. As this result, a flexible transparent transistor could be successfully established as shown in Fig. 1. Contracts with various international and domestic manufacturers and JST to license this IGZO-based TFT technology have been concluded in order to spread this technology. Currently, IGZO-TFTs have been put into practical use and incorporated into many liquid crystal displays.

Research on wide-bandgap p-type semiconductors (LaCuOSe) has led to the discovery that oxy-pnictide LaOFeP with the same layered structure has magnetic properties which differ from those of common BCS theory-based superconductors. This discovery of iron-based superconductors, has led to great progress and impact on research around the world. Two important facts about electrides (Fig.2) could also be clarified. First, Ru-supported catalyst (Ru/C12A7:e^-) has only half the activation energy of the conventional ammonia-synthesis, and exhibits a reaction speed approx. 10 times faster than before. Second, dissociation of a N≡N triple bond, which was conventionally thought to be rate-determining, was found to not be rate-determining. As a result, Hosono's group could demonstrate the possibility of lower temperature synthesis of ammonia. Ammonia is commonly mass-produced for fertilizer material but is currently receiving much attention as an effective hydrogen-energy carrier. In near future, development of a highly efficient catalyst for ammonia synthesis, for on-site low-temperature synthesis at small scale plants is expected. Innovation of "IGZO" is being widely applied today in the TFT of organic light emitting diodes (OLED), and the invention of C12A7-electrides applied to industrial ammonia synthesis as nitrogen fertilizer, a catalyst for chemical products, and a hydrogen carrier. The market size for a flexible OLED display is expected to reach 4 trillion yen in 2020, and global production related to ammonia is expected to exceed 160 million tons.

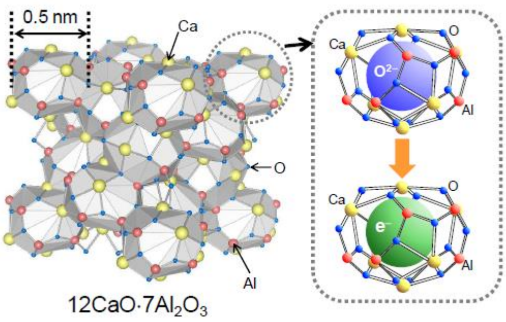


Fig. 2 Crystal structure of C12A7.

Electrides is composed of electron (e^-) instead of oxygen anion (O^{2-}) in the cages.

Hidetoshi Katori (Professor, Graduate School of Engineering, University of Tokyo / Chief Scientist, RIKEN)

PREST (2002-2005)
CREST (2005-2010)
ERATO (2010-2015)

"Creating New Scientific and Technological Paradigms with an Optical Lattice Clock"

1. Research Objectives

Innovative optical lattice clocks far more accurate than conventional atom clocks have now been developed. This research will contribute to the redefinition of "a second" by exploring underground resources and disaster alarm systems (monitoring movements of magma, plates, and active faults) using ultra-accurate methods for measuring time. Another aim of this research is to contribute to basic physics by verifying phenomena such as the universality of physical constants by comparing optical lattice clocks with different kinds of atoms.

2. Results

First, millions of strontium atoms in a vacuum chamber are cooled down to one micro kelvin by exposure to a decelerating (cooling) laser. Next, an optical lattice is created with the interference fringes of a laser with the "Magic" wavelength (in this situation, the electro-magnetic field constructing the optical lattice has a negligible effect on the resonant frequency of the strontium atoms) to settle down the positions of the atoms, as shown in Fig. 1. Finally, the resonance frequency of the strontium atoms is measured by a "clock" laser. Due to the reduction of the Doppler effect and quantum fluctuating noise, an ultra-accurate 18-digit atom clock (1 second error per 16 billion years) was successfully achieved. This clock has an accuracy about 1000 times higher than the conventional cesium atom clock.

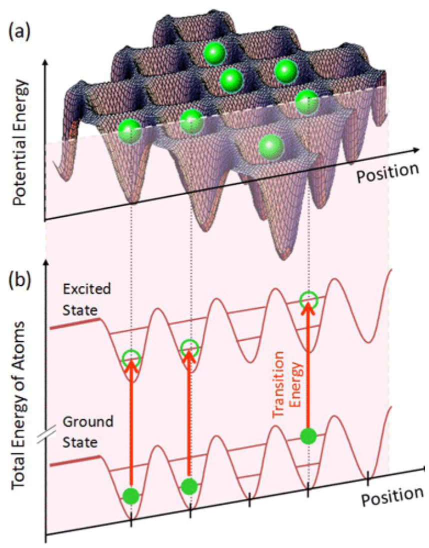


Fig. 1 Schematic representation of the basic principle of an optical lattice clock

3. Contribution to Science, Technology and Innovation

The ultra-accurate optical lattice clock will give us clues in cosmic research by detecting gravitational waves and dark matter. In basic physics, it will shed light on the universality problem of basic physical constants (whether or not the Boltzmann constant "k," Plank constant "h," elementary electronic charge "e," etc. depend on time and space).

On a more practical level, it will lead innovative and promising applications for society such as the following:

<1> Re-definition of “a second” for a new time standard and commercialization of a super-accurate standard clock.

<2> Accurate clocks for high-speed, highly secured telecommunication systems.

<3> Accurate GPS infrastructure systems for self-driving cars.

<4> Advanced system for exploring natural resources by measuring changes of gravity force.

<5> Alarm systems for earthquakes and volcanic eruptions using fiber networks for relativistic surveys that link and compare optical lattice clocks to detect the movements of active faults, plates, and magma.

Thanks to this ERATO project, centers for the “Optical Lattice Clock” have been established and are now operating effectively. Fruitful and innovative outcomes are expected in the future.

Hiroshi Kitagawa (Professor, Graduate School of Science, Kyoto University)

PRESTO (2000-2003)
CREST (2006-2011)
CREST (2011-2015)
ACCEL (2015-)

"Development of Novel Functional Materials through the Fusion of Elements"

1. Research Objectives

Metal catalysts, such as palladium (Pd) and rutheniums (Ru) were not considered to be miscible at the atomic level even in liquid phases more than 2,000 degrees Celsius.

In this research, the fusion of elements by creating a solid-solution that combines various metal elements at the atomic level was investigated in order to create many new compounds for use in the development of innovative materials.

2. Results

Pd and Ru were mixed at the atomic level using poly (N-vinyl-2-pyrrolidone) as an agent to control particle diameter and their particle size was decreased to the order of nanometers. Kitagawa has succeeded in creating a new Pd-Ru solid-solution nano-alloy for the first time (Fig.).

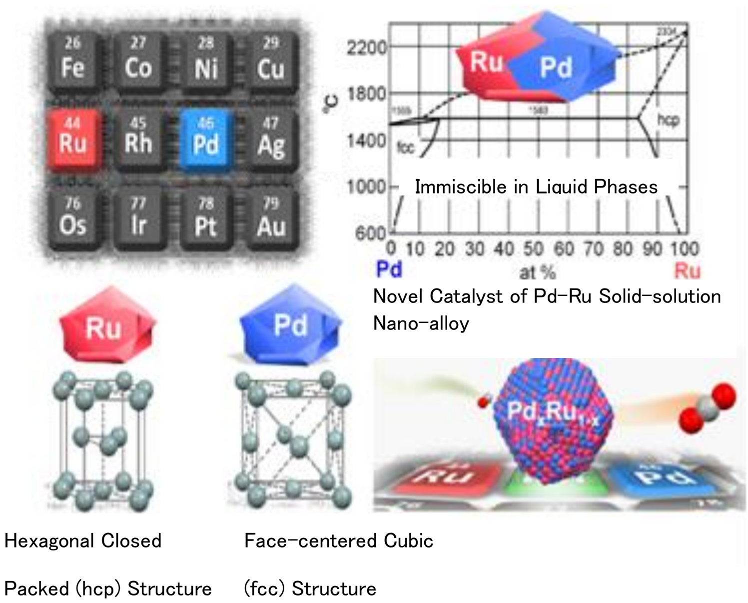


Fig. Pd-Ru Solid-solution Nano-alloy Catalyst Mixed at the Atomic Level

Evaluation of the catalytic oxidation reaction of carbon monoxide ($CO \rightarrow CO_2$) showed that the Pd-Ru nano-alloy had low T50, which is the temperature where the oxidation conversion rate of carbon monoxide reaches 50%.

Pd-Ru nano-alloy shows high activity even in mild conditions compared to nanoparticles of Ru or rhodium (Rh) as a conventional catalyst (Pd-Ru: T50 = approx. 130°C, Ru or Rh: T50 = approx. 165°C).

3. Contribution to Science, Technology and Innovation

Ru is a catalyst which shows optimal performance in the oxidization and removal of carbon monoxide (CO) and is currently used for ENE-FARM as the world's first fuel cell for practical home use.

CO concentration in the feed gas (hydrogen) must be maintained at 10ppm or less since the platinum catalyst is deactivated by CO in fuel cells. The Pd-Ru nano-alloy is expected to be an innovative new catalyst to replace Ru due to highly effective removal of CO.

In addition, the Pd-Ru nano-alloy is expected to become widely used since the raw material used in Pd-Ru nano alloy costs less than one-third of that of Rh and a performance higher than Rh (which is conventionally used as the catalyst in the purification of exhaust gas from motor vehicles). The fuel cell catalyst market is estimated to be 400 billion yen in 2025.

Susumu Noda (Professor, Graduate School of Engineering, Kyoto University)

"Innovative Fusion of Photonic Crystals and Semiconductor Lasers and Development of Applications"

CREST (2000-2005)
CREST (2005-2010)
CREST (2011-2016)
ACCEL (2013-)

1. Research objective

The new road toward high power (watt-class) semiconductor lasers with not only the most homogeneous wavelength but also single mode byincorporating the original design on photonic crystals with a semiconductorlaser technology was planned. In addition to the point and line defects of two-dimensional photonic crystals, a concept of novel photonic heterostructures was proposed. As a result, various control of photon-mode, including beam-profiling, was clearly demonstrated, by adjoining the original band- engineered structure to semiconductor lasers. The ACCEL is aiming at drastic technology changing and wide applications in information communication, production, medical technology and bio-industries.

2. Results

A novel device design and fabrication method which based on fundamental equations of electromagnetism on two and three dimensional photonic crystals, were established through basic research. Several evidences making the best use of characteristics of photonic crystals: control of spontaneous emission, photon-trap and emission by incorporation of artificial defects, wavelength demultiplexer using heterostructures and nanocavity with ultrahigh Q-value (>1 million) resulted as the world's leading research. Through realization of surface-emitting lasers using GaN photonic crystals, 10 watt-class semiconductor lasers is energetically developed using the model structure as shown in Fig..

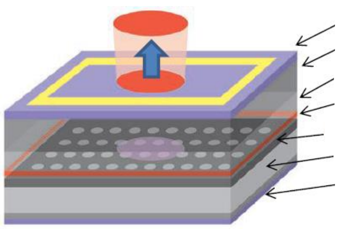


Fig. The structure of a photonic crystal laser

3. Contribution to science, technologies and innovation

Original combination of photonic crystals and semiconductor lasers brings about the great progress for photo-quantum physics with related to trap, emission and transmission, by means of its stable controlling of photon. Furthermore, high-power photonic crystal laser with preciously controlled wavelength and optical phase will be brought about innovation in various technical field of information communication, production, medical technology and characteristic measurement. This technology has a potential for drastically-changing the world semiconductor- laser markets beyond conventional semiconductor laser. On the other hand, as a new application, highly-effective photovoltaic devices with photonic-nanostructures will be proposed in near future, utilizing optical confinement effect under the desired wavelength region. The world-wide market size of lasers will be about 1.5 trillion yen in 2020.

PRESTO (2000-2003)
CREST (2013-2018)

Kyoko Nozaki (Professor, Graduate School of Engineering, The University of Tokyo,)

"Synthesis of Organic Compounds Using a Molecular Catalyst"

1. Research Objectives

Seeking to discover an original reaction based on the concept called Molecular Catalyst and to develop a chemical process with high conversion efficiency in terms of all atoms involved, Nozaki has developed effective methods to synthesize various organic compounds such as organic materials, polymers, medicine and pesticides, in order to build a sustainable society.

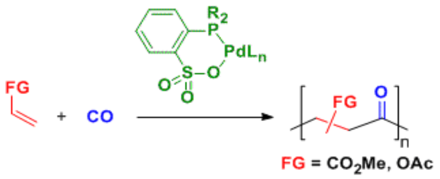


Fig. 1 Copolymerization Reaction of Propylene and Carbon Monoxide

2. Results

Nozaki applied a catalyst originally prepared from palladium with chiral phosphine phosphite ligands to a copolymerization reaction of propylene and carbon monoxide to achieve asymmetric synthesis of a complete alternating copolymer (Fig. 1).

Another newly developed polymerization catalyst promotes the reduction of cyclic carbonate as a by-product and selective synthesis of polycarbonates could be achieved by alternating copolymerization of the end of epoxides and carbon dioxide (Fig. 2.).

A new catalyst has recently been studied to provide "a novel polypropylene" in which a polar functional group is directly introduced into the polypropylene main chain by the copolymerization of propylene and a polar monomer such as acrylic ester, vinyl acetate and acrylonitrile.

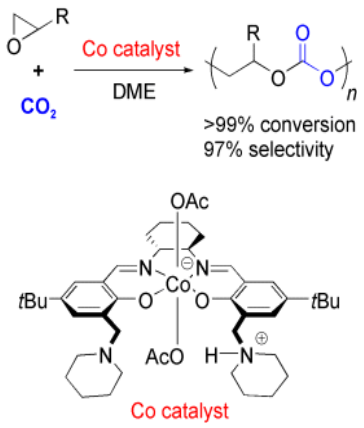


Fig. 2 Alternating Copolymerization of End Epoxide and Carbon Dioxide

3. Contribution to Science, Technology and Innovation

Conventionally difficult reactions have been carried out in high yields by designing and preparing a molecular catalyst. Nozaki succeeded in creating novel polymers for the first time. In particular, optically active high polymers with extremely high three-dimensional control were synthesized by complete alternating copolymerization of a vinyl monomer and carbon monoxide. With this invention, asymmetric polymer chemistry has begun.

Polyketones are expected to be used in engineering plastics due to their excellent mechanical strength and thermal stability. Similarly, the previously mentioned polycarbonate is expected to be used in the production of eco-friendly plastic.

On the other hand, polypropylene is used in general-purpose resins has a large market due to its low cost and excellent strength, and heat and chemical resistance. However, several drawbacks remain, such as insufficient adhesion, poor compatibility and coloring properties. By copolymerization of propylene and a polar monomer, these drawbacks can be overcome and application in a wide field is expected.

Eiji Saitoh (Professor, Advanced Institute for Materials Research / Institute for Materials Research, Tohoku University)

"Pioneering a new paradigm of spin currents in the fields of ICT and energy conversion"

PRESTO (2007-2010)
CREST (2010-2014)
ERATO (2014-2019)

1. Research Objectives

Almost all conventional information processing systems and devices, such as computers and electronic memory utilize the characteristics of electrons for charge transport and storage. Regarding spin states of electrons related to magnetic phenomena, there are some cases of application in memory and logic devices. However, research on controlling "spin currents" (continuous transport phenomena of spin states in material space) has only recently begun. In this research area, Saitoh focuses on developing new functionalities of "spin currents" in order to establish a new paradigm in the fields of computers, electronic memory, information-processing and energy conversion.

2. Results

Saitoh discovered that the "spin currents" can be transported in insulating material, which is outstanding feature compared to conventional electrical currents. First, "spin currents" are injected into YIG ($Y_3Fe_5O_{12}$) and are successfullytransported in the insulating material as shown in Fig. 1. Then Pt electrodes are connected to YIG and a temperature gradient is formed. By this, Saitoh achieved the "spin Seebeck effect" (Fig.2), which is an exchange interaction between heat currents and spin currents at the interface of ferromagnetism and paramagnetism materials. As this effect appears not only in metalsand semiconductors but also in magnetic insulators, the combination of the spin Seebeck effect andreverse spin-hall effect (transforming spincurrents to electrical currents) can result inthermoelectric conversion using insulators, which is not possible by conventional technologies.

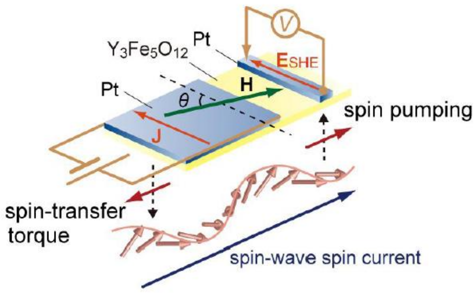


Fig.1. Spin Currents in Insulator

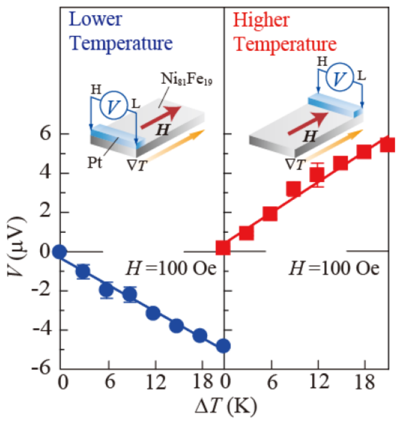


Fig. 2 Spin-Seebeck Effect

3. Contribution to Science, Technology and Innovation

Research on "spin currents" (flow of spin angular momentums) will lead to the discovery of new phenomena, such as the spin Seebeck effect, which are new technological seeds for various industries. For example, insulating thermoelectric conversion devices using spin Seebeck effect, and developing memory devices for large-scale storage systems which use the reverse magnetizing phenomena by spin-hall effect are expected, as well as their commercialization in the future. Furthermore, application of ultra-low power information-processors and digital transmission technologies using insulators, new spin power generators, quantum motors and spin integrated circuits also looks promising.

Takao Someya (Professor, Graduate School of Engineering, The University of Tokyo)

CREST(2009-2011)
ERATO(2011-2016)

"Fabrication of the World's Lightest, Thinnest, Flexible Electronic Circuits"

1. Research Objectives

In order to create a large nano-system that can integrate various functions onto a sheet of plastic or rubber, a fabrication process for nano-functional devices in a system on the meter size scale is being developed. Advancing this technology, Someya develops bio-organic devices which can harmonize humans and electronics, and aims to develop new implantable flexible devices which can receive electrical or chemical signals from human cells and then visualize the signal.

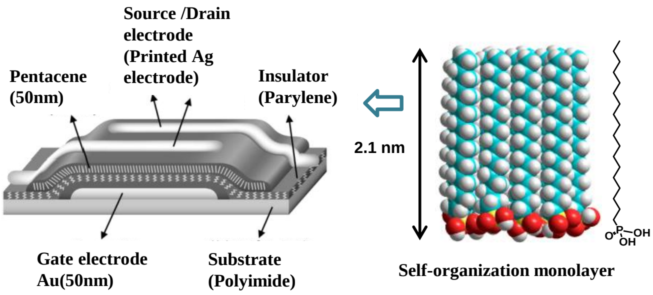
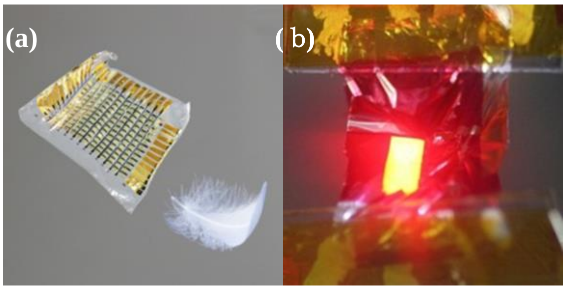


Fig.1 Device fabrication on sheet

2. Results

By ultimately controlling of the self-organization of molecules and the printing process as shown in Fig. 1, Someya establishes a nano-printing technique which can apply nano-functional integrated devices to a system over a large area on a sheet of plastic or rubber. Using this technique, Someya has successfully developed flexible electronic circuits. For example, Figure 2 (a) shows the world's lightest (3g / m^2) and thinnest (2μm) electronic circuit, and Figure 2 (b) shows the world lightest (3 g / m^2) and thinnest (2μm) flexible organic LED.



(a) Electronic circuits as light as a feather

(b) Flexible organic LED

Fig. 2 The world lightest devices

3. Contribution to Science, Technology and Innovation:

The low temperature and low damage process for uniform and dense self-organized monolayer on a plastic film over a large area can provide a gate insulator with high insulation properties and high mechanical flexibility to FET (Field Effect Transistor) devices. This contributes to high performance, low voltage organic transistors in a

Fig. 3 Flexible device

large system. By integrating a bottom up process with self-organization and a top down process, flexible, high-performance organic integrated circuits can be achieved, and the concept of nano-systems in the organic electronics field can be introduced. In addition, development of the lightest, thinnest, flexible electronic circuit can be applied in various applications such as health care sensors which can be worn without drawing the attention of the wearer, providing stress-free input devices for welfare, sensors for medical electronic equipment, sensors with strong shock resistance for use in sports, unique organic LED lighting on free-form surfaces, digital signboards, flexible solar cells, etc. Figure 3 shows an example of a flexible device. A nano-system that can cover a wide area can be applied to many fields, such as safety and security, environment and energy, and medical health care, and a large impact on various fields such as electronics, automotive, housing, or health care industry is expected. The global market for biological information devices in 2025 is expected to be 15 billion USD.

Yoshinori Tokura (Professor, Graduate School of Engineering, The University of Tokyo, Director, RIKEN Center for Emergent Matter Science)

ERATO (2001-2006)
ERATO (2006-2011)

"Innovation for New Solid State Physics Characterized by Various Electrons"

1. Research Objectives

Tokura started this research project to create novel materials with electron spin superstructures and to understand the electronic, magnetic, and optical properties in strongly correlated electron systems such as high-temperature superconducting materials. "Multiferroic materials," a class of materials with coexisting ferroelectricity and ferromagnetism, were discovered in an examination of materials whose dielectric constants increased hundreds of times when exposed to magnetic fields. The basic aims for this project were to create new multiferroic materials with original designs and understand the mechanism of this system. A further aim was to establish a methodology manifesting unique physical properties and to evolve a new form of solid state physics by controlling electrons. Lastly the project sought to establish a new discipline of "magnetoelectric optics" evolved from the study of various optical phenomena induced by strong magneto-electronic correlations.

2. Results

In addition to discovering various multiferroic material systems such as perovskite-type manganites ($AMnO_3$), Tokura's group developed a new theoretical model for understanding this system and successfully discovered interesting phenomena such as electromagnetic responses. A large number of important materials that remain stable at room temperature and have strong potential to become the "next electronics" were exhibited around the world in this project. A "skyrmion crystals" forming spiral spin textures was also observed (Fig. 1).

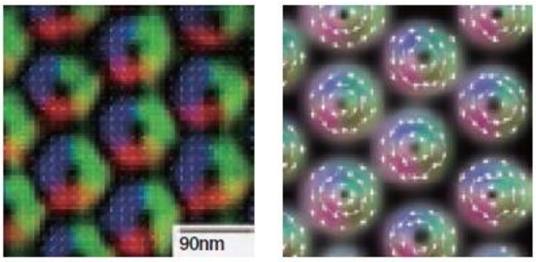


Fig. 1 Two-dimensional skyrmion crystal image observed by Lorentz TEM (left) and a skyrmion crystal lattice image simulated by the Monte Carlo method (right).

3. Contribution to Science, Technology and Innovation

Tokura received the Thomson Reuter Citation Laureates Award in 2014 in recognition of these outstanding achievements. This highly lauded project suggests that innovation with multiferroic materials will become a common approach for discovering novel materials and will open the door to a new discipline of correlated quantum science. When stable multiferroic properties are realized at room temperature, great advances for future electronics and medical technologies such as high-sensitivity magnetic sensors and large capacity, multi-value solid-state-memories will inevitably follow (Fig. 2). The innovation of multiferroic materials will be widely applicable to high-performance nonvolatile solid-state memories with high access speeds (such as SRAM), high densities (such as DRAM), and nonvolatile properties (such as a flash memory). Scale-wise, the market for future solid-state memory (e.g., nonvolatile memory such as ReRAM and MRAM) is expected reaches about 7,000 million yen by 2020.

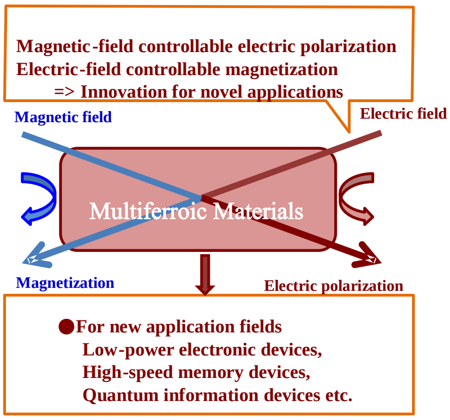


Fig. 2. Characteristics and application of multiferroic materials.

Yoshinobu Tsujii (Professor, Institute for Chemical Research, Kyoto University)

"Reinforcement of Resiliency of Concentrated Polymer Brushes and Its Tribological Applications — Development of Novel "Soft and Resilient Tribology (SRT)" System"

CREST (2009-2014)
ACCEL (2015-)

1. Research Objectives

Y. Tsujii et al. newly succeeded in the synthesis of concentrated polymer brush (CPB) by living radical polymerizations to discover attractive properties, derived from CPB effect, such as high resilience, high elasticity, ultra-low friction and size-exclusion. They aim to apply CPB to high-performance mechanical slide system, an allsolid lithium-ion battery and a supersensitive biosensor through the systematic research of organic synthesis and solid-state science.

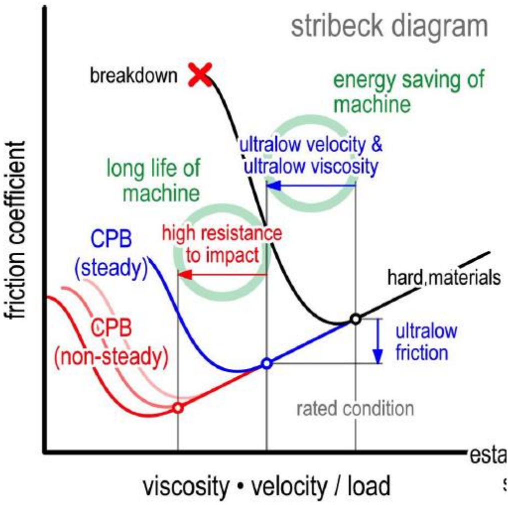


Fig. 1. Sribeck diagram (Relationship between friction coefficient and viscosity velocity/load)

2. Results

They succeeded in fabricating novel nanosystems through hierarchically assembling of CPB structure and the advancement of its properties. And they have developed functional material and functionalization method for the application to solid state ionics and a biocompatible coating by a novel concept method, the regular arrangement of CPB-fixed nanoparticles. The CPB film having significantly enough thickness was very recently formed on the large surface of material by the innovative surface modification technology. The material shows high tribology properties and high potential for practical use at mechanical system (Fig.1).

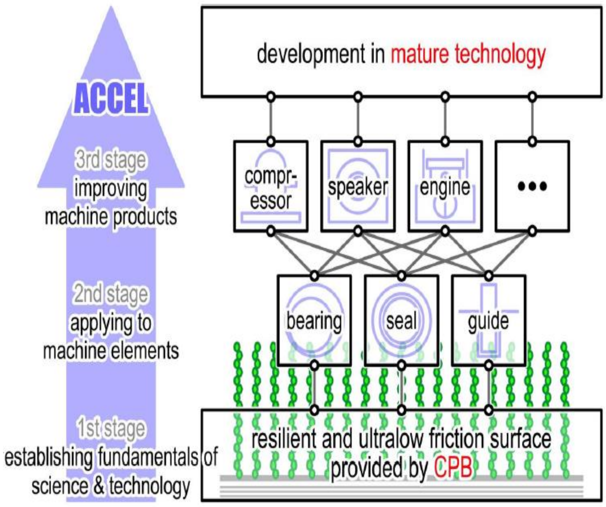


Fig. 2. ACCEL project and unique properties of CPBs

3. Contribution to science, technology and innovation

On the basis of such breakthroughs not only in precision polymer synthesis but also in polymer physics, he aims to reinforce both soft and resilient properties derived from the CPBs and hence to apply them on various slide members of mechanical elements, e.g., sliding bearings and seals, for their prolonged life and energy saving (Fig. 2). The final goal is to commercialize a novel “Soft and Resilient Tribology (SRT)” system, which achieves both soft and resilient properties, through industry -academia collaboration.

Yasuaki Einaga (Professor, Faculty of Science and Technology, Keio University)

"Development of innovative technologies using diamond electrodes for improving environment"

CREST (2011-2014)
ACCEL (2014-)

1. Research Objectives

This project aims to develop innovative technologies using conductive diamond electrodes as rare-meta-free next generation functional materials for improving global environment. Our research continuously proceeds from studies on the fundamentals of the functional interfaces to the development of the devices such as electrochemical sensors, wastewater treatment systems, and carbon dioxide reduction systems.

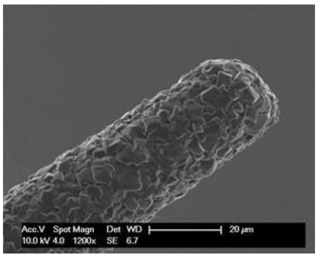


Fig.1 Needle electrode covered diamond thin films on tungsten probe.

2. Results

The diamond electrode intrinsically has high stability and excellent electrochemical properties such as a very wide potential window and a sufficiently small residual current. The research in CREST shows high potential for a functional electrochemical sensor. For example, the realization of sensing several ions is listed in the environmental field. In the medical one, by fabricating needle-type electrode (Fig.1), success of sensing of a brain chemistry, dopamine and a cancer-marker, glutathione (Fig.2).is also listed.

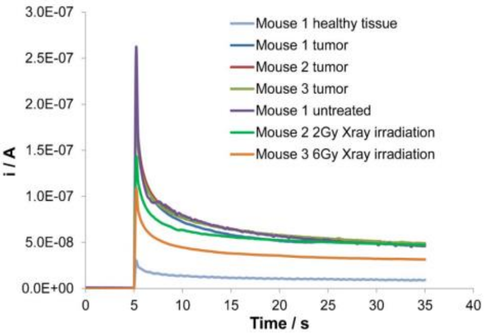


Fig.2 In-vivo measurement of biomarker of cancer using the needle-type diamond electrode.

On the other hand, synthesis of an osteoblast differentiation inducer by organic electrolysis, integrating a diamond electrode with micro-flow cell system is presented. Furthermore, from the reason that generation of formaldehyde by reduction of CO_2 is announced, big innovation is coming to be born in environmental and energy fields.

3. Contribution to science, technology and innovation

This ACCEL project aims to establish designing guidelines of optimized diamond electrodes for electrochemical applications and to develop appropriate electrochemical

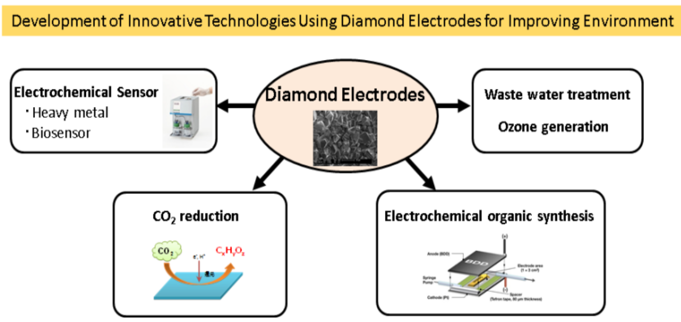


Fig.3 Development of Diamond Electrodes

application systems. We will continuously proceed from studies on the fundamentals of the functional interfaces to the development of the systems（Fig.3）.

Susumu Kitagawa (Director, Institute for Integrated Cell-Material Sciences, Professor, Graduate School of Engineering, Kyoto University)

ERATO (2007-2012)
ACT-C (2012-2017)
ACCEL (2013-)

"Chemistry and Application of Porous Coordination Polymer (PCP) Containing a Nano Pore"

1. Research Objectives

Conventional porous materials have been used to separate impure substances in the petroleum industry and in environmental purification. However it is difficult to precisely control the size of nano pores and there are limitations in separation and purification for high resolution.

PCP was invented for the first time as new material and research accelerated in the ERATO project. PCP has an infinite frame structure made by the connection of organic ligands and metal ions.

In this research, Kitagawa aims to first build PCP with a single function, such as separation, adsorption or synthesis, by controlling the size and the surface properties of the nano pore in PCP. Next, he aims to combine these functions and to create a new function which can respond to the surrounding environment.

2. Results

Separation of oxygen and nitrogen , the sensing of volatile organic compounds such as benzene, toluene and xylene and the removal of carbon monoxide, nitrogen oxide and sulfur oxide became possible by introducing tetracyanoquinodimethane (TCNQ), naphthalene diimide and azide iso-naphthalene (as a precursor of nitrene), etc. as functional substituents into PCP.

Another newly synthesized PCP could effectively separate carbon dioxide at about room temperature from mixed gas including nitrogen and oxygen and showed high stability even in an acid or alkaline aqueous solution.

Creation of new catalytic chemistry using PCP as a nanospace reaction field is currently being considered in order to isolate carbon dioxide from the air and to directly convert this carbon dioxide into methanol.

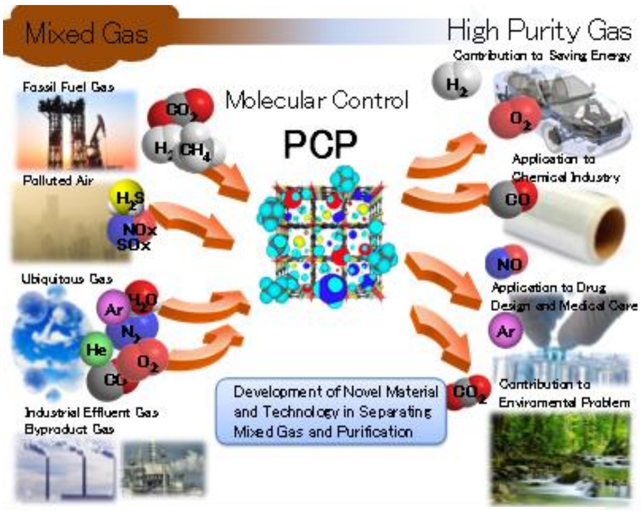


Fig. 1 Development of Gas Separation by the Nanostructure Control of PCP

3. Contribution to Science, Technology and Innovation

PCP research has increased exponentially worldwide since the discovery PCP. As a result, various PCPs have been synthesized and their functions have been studied. Kitagawa has established the foundation of PCP technology.

Technology which can selectively separate and effectively store oxygen, nitrogen, carbon monoxide, carbon dioxide, hydrogen and methane using PCP is expected to significantly contribute to solving energy and environmental problems (Fig. 1).

Eiichi Nakamura (Professor, Graduate School of Science, The University of Tokyo)

ERATO (2004-2009)
CREST (2014-2019)

"Utilization of Nanocarbon Materials with the Knowledge of Synthetic Chemistry"

1. Research Objectives

The chemistry of aromatics was ignited by the discovery of benzene in the in the early 19th Century, greatly contributing to the development of science and technology in the 20th Century. Nanocarbon materials such as fullerenes form unique molecular framework and new functions of those materials are being designed, and are similarly causing a revolution in the 21th Century. Nakamura seeks to understand the potential of nanocarbon materials and aims to develop new electronic, energy and medical applications, based on the knowledge of synthetic chemistry.

2. Results

Nakamura has led a business-academia collaboration team of this project, and has successfully synthesized over 700 kinds of fullerene derivatives (including the endohedral metallofullerenes) in order to establish an effective organic semiconductor library. Mass production technology to synthesize very high-purity fullerene derivatives could be achieved. Furthermore, improvement in interface adhesion of PN-junction in organic photovoltaic cells could be attained by the synthesis of benzoporphyrin (BP) and the amorphous phase in fullerene derivative [$C_{60}(CH_2SiMe_2Ph)_2$:SIMEF]. Achieving this molecular contact in the PN-junction, a new type organic photovoltaic cell with an interpenetrating junction was developed for the first time, reaching an extremely high energy conversion efficiency of 12%. (Fig.1) Visualization of the chemical movement of a single molecule and crystallization of fullerene derivatives was carried out using a high-resolution transmission electron microscope, and the foundation for "molecular crystal engineering" could be established.

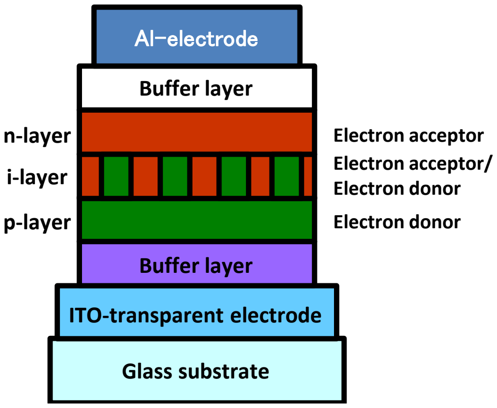


Fig. 1 Structure of originally-designed organic thin film solar cell.

3. Contribution to Science, Technology and Innovation

Creation of various fullerene derivatives (Fig. 2) using molecular control techniques developed in collaboration with the industry is a crucial element in the success of a flexible organic thin film solar cell with a roll-to-roll process. In fact, commercial products such as see-through solar cells for laminated windows are now appearing on today's market. This synthetic technology has been applied to the manufacturing process of medical products such as dry powder absorption agents. Introduction of time-resolved observation techniques of single molecules in nanocarbons is expected to be a key technology on the path to next generation molecular chemistry through a deeper understanding of mechanisms involved in molecular crystal growth, chemical reaction, etc. Nanocarbon materials composed of fullerene derivatives are expected to be widely applied in chemical products, medicine, and electronics. In particular, control of crystallization and phase separation, and reasonable determination of protein structures in designed catalytic reactions are particularly considered.

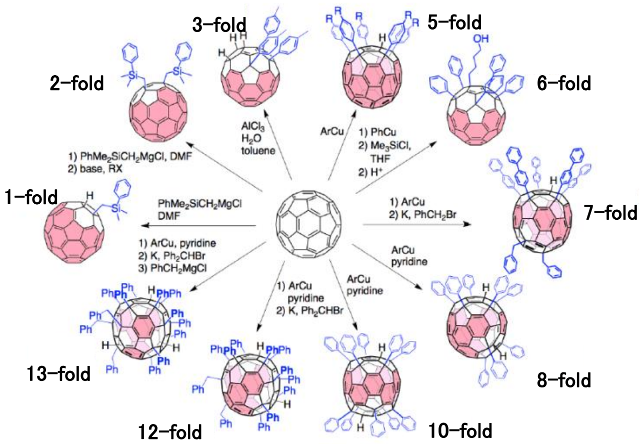


Fig. 2 Organic fullerene library created by synthetic methods originally developed in this project.

Yasuhiro Uozumi (Professor, Institute for Molecular Science, National Institute of Natural Sciences)

CREST (2002-2007)
CREST (2011-2016)
ACCEL (2014-)

"Development of Key Chemical Processes of Extremely High Efficiency with Super-Performance Heterogeneous Catalysts"

1. Research Objectives

Y. Uozumi has been engaged in the development of transition metal-catalyzed reaction systems toward ideal (highly efficient, selective, green, safe, simple, etc.) organic transformation processes. For example, "water" is safe and nontoxic solvent and the fixed catalyst enables general transformation process to proceed efficiently even in water. The hydrophobic interaction of organic molecules is a key factor to drive the reaction. Replacement of organic solvent by water in chemical industry contributes to the improvement of global environments. However, the reactions of organic compounds, which are "oil", in water are theoretically difficult and extremely limited. This research will accomplish the paradigm shift of the organic transformation processes.

2. Results

Various types of catalytic organic molecular transformations such as carbon-carbon and carbon-heteroatom bond forming reaction, aerobic alcohol oxidation, etc., efficiently proceeded in water under heterogeneous conditions by using the catalyst of amphiphilic polymer-supported transition metal complexes and nanoparticles (Fig. 1).

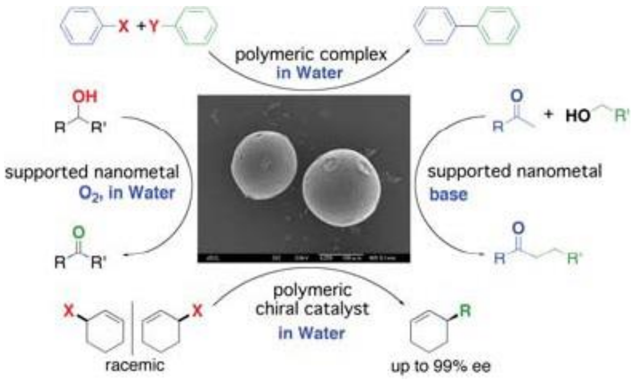


Fig. 1. Heterogeneous Aqua-catalyses using Amphiphilic Polymer-Supported Metal Complexes

3. Contribution to science, technology and innovation

He aims at the practical use of the catalysts for the production of high added value and functional material such as pharmaceutical products, hole-transporting agent, novel detergent etc. through the achievement as follows (Fig. 2.). And he advances the development of various fine chemicals such as electronic and medical materials.

・To study and develop super-performance heterogeneous transition metal catalysts which achieve key chemical transformations at a ppm-ppb loading level with high chemical greenness.

・To technologically build particular prototypes of continuous flow chemical processes using easy-handling and storable cartridges of heterogeneous catalysts.

・To study and develop novel catalytic processes with ubiquitous metal and/or non-metal elements.

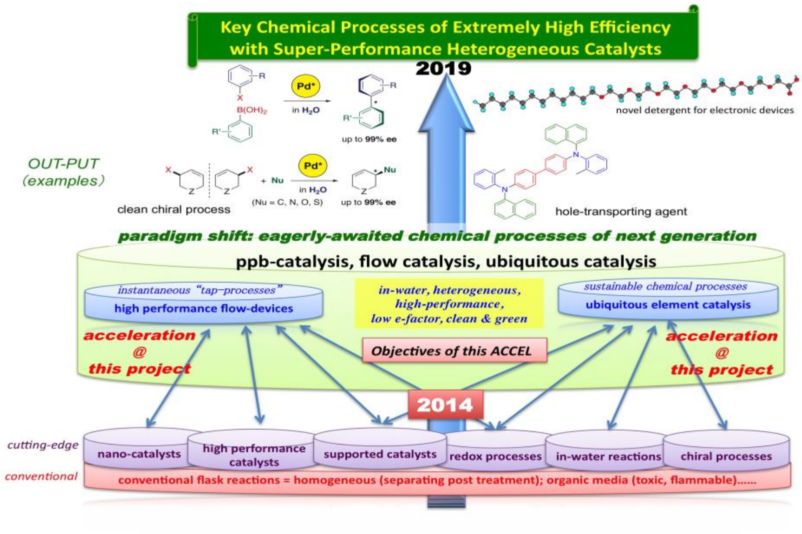


Fig. 2. Key Chemical Processes of Next

Masayoshi Kawaguchi (Professor, National Institute for Basic Biology, National Institute of Natural Sciences)

PRESTO(1998-2001)
CREST(2002-2007)
ACCEL(2014-)

"Molecular Basis of Symbiotic Networks and its Application"

1. Research Objectives

Arbuscular mycorrhizal (AM) fungi establishes symbiotic relationship with plants on the roots and receives photosynthetic products (e.g., sugar) from plants in exchange for nutrients (e.g., phosphate) and water, which the fungi extract from the soil. In their research, they will perform field inoculation experiments on multiple locations in Japan to evaluate the efficacy of AM fungi in terms of reduction of phosphorous fertilizer use. Simultaneously, they will sequence the genome of mycorrhizal fungi to obtain insights into the molecular basis of obligate symbiosis. Their goal is to develop a diagnostic technology to reduce use of phosphorus fertilizer and to enhance the applicable use of AM fungi.

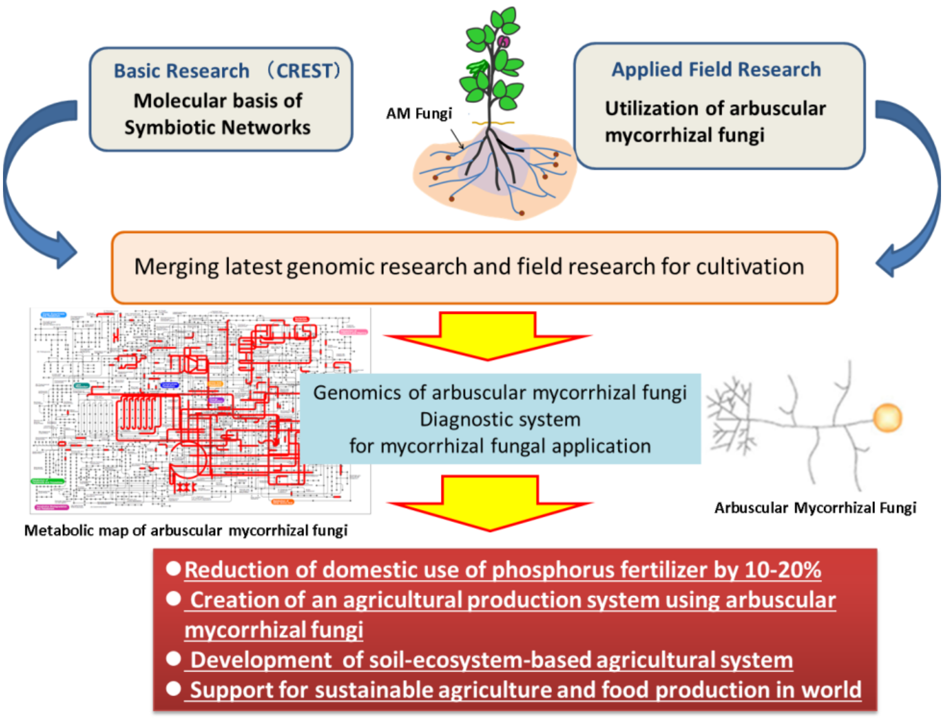


Fig.1 Vision of the research

2. Results

They have tried to identify a host factor playing a role in the signal transduction pathways shared by arbuscular mycorrhiza symbiosis and root nodule symbiosis and to analyze the related genes. They have obtained the following results in CREST project.

(i) They identified a symbiotic signaling factor, strigolactone, from the root exudates of *Lotus japonicus*.

(ii) They identified four factors relating to common signaling pathway required for AM symbiosis and root-nodule symbiosis.

(iii) They identified NUP85 gene of *Lotus japonicas* and showed that it is required for calcium spiking and seed production.

Furthermore, they continued the research after end of CREST project and obtained the following results.

(i) They identified CYCLOPS protein from *Lotus japonicus cyclops* mutants on which microbial infection was severely inhibited. They observed physical interaction between CYCLOPS and calmodulin-dependent kinase in the absence of symbiotic stimulation.

(ii) Host legumes control root nodule numbers by sensing external and internal cues. They found two peptides genes responding to the cues.

(iii) They showed that the FEN1 gene of *Lotus japonicus* overcomes the lack of NifV encoding homocitrate synthase in rhizobia in symbiotic nitrogen fixation.

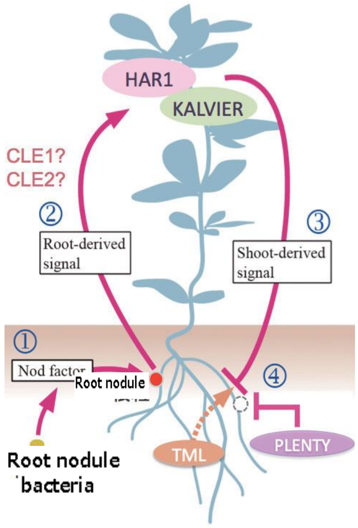


Fig.2 Model chart for overall mechanism of feedback regulation in root nodule formation

(iv) They identified KLAVIER gene which mediates the systemic negative regulation of nodulation in *Lotus japonicus*. They showed that KLAVIER also plays multiple roles in shoot development.

3. Contribution to science, technologies and innovation

In the ACCEL project, they will develop a technology for effective use of arbuscular mycorrhizal fungi to reduce use of phosphorus fertilizer. They will sequence the genome of mycorrhizal fungi to gain insights into the molecular basis related to AM fungi symbiosis with plants. Then, it is expected that efficiency of nitrogen fixation and improvement of biomass in leguminous plants will contribute to solve the food and environmental problem. Because Japan is 100% of phosphorous resource dependent on import, reducing phosphorus fertilizer use is particularly crucial problem and expected to make a great contribution for society.

Shimon Sakaguchi (Distinguished Professor, Osaka University/ Professor, Immunology Frontier Research Center, Osaka University)

CREST (2003-2008)
CREST (2012-2017)

"Development of Immunological and Chronic Inflammation Control Technology Using Regulatory T cells"

1. Research Objectives

By understanding the development and maintenance of immune tolerance in normal individuals can provide basic information not only regarding mechanisms of the onset of autoimmune diseases, and their treatment and prevention, but also the immune response for cancer cells and the protection of transplanted organs, and the development of treatments for various diseases such as allergies.

By clarification of the molecular mechanisms involved in the function of regulatory T cells, which play an important role and are responsible for immune tolerance, this research aims to comprehensively understand hyper-responsiveness of the auto-immune system.

2. Results

Sakaguchi has discovered the importance of the Foxp3 gene in the development and differentiation of regulatory T cells and could identify related molecules. He also discovered that cancer immunity could be enhanced by removing T regulatory cells. (Fig. 1) Development of fatal autoimmune disease were seen in mice which CTLA-4 (Cytotoxic T Lymphocyte Antigen 4) in T regulatory cells is knocked out On the other hand, these mice showed to a stronger anti-tumor immune activity.

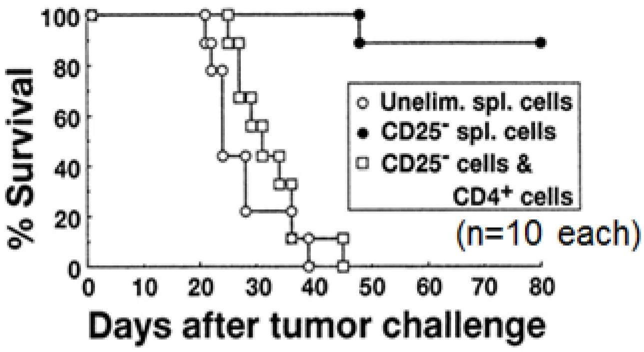


Fig. 1 Enhancement of cancer immunity by the removal of T regulatory cells

Sakaguchi also reported that change in Foxp3 gene expression is independent of changes in the epigenome in T regulatory cells and both changes are involved in T regulatory cell development.

Fig. 2 Cancer immunotherapy has been elected to be the most important research results in 2013

3. Contribution to Science, Technology and Innovation

CTLA-4 proteins and PD1 (programmed death 1) have received much attention as immune checkpoint proteins.

Immune checkpoint proteins were described in *Science* as a cancer immunotherapy in 2013 (Fig.2).

Regarding cancer immunotherapy, the effectiveness of anti-CTLA-4 antibodies (ipilimumab) in patients with malignant melanoma was evaluated and the antibodies were shown to enhance the effect of certain anti-tumor immune responses. As a result, ipilimumab has been approved by FDA (Food and Drug Administration, U.S.A.) as the first immune activation antibody drug in the world. Currently, clinical trials using ipilimumab in combination with standard chemotherapy to other malignant tumors are underway.

Sakaguchi is now working on the application of these antibodies and the development of products containing these antibodies as autoimmune disease therapeutic agents and anti-cancer agents. The global market for anti-cancer agents in 2018 is estimated to be $122.3 billion and will continue to even beyond 2024.

Mikiko Sodeoka (Chief Scientist, Synthetic Organic Chemistry Lab, RIKEN)

PRESTO(1998-2001)
PRESTO(2001-2004)
ERATO(2008-2013)
CREST(2013-2018)

"Elucidation of the Necrosis Mechanism and Development of Imaging Technology for Small Molecules Using Raman Microscopy"

1. Research Objectives

Necrosis has been considered as passive, non-physiological cell death, but recent studies have indicated the existence of signaling pathways involved in necrosis. Although details of the mechanism are still unclear, understanding the compounds which can inhibit necrosis are considered to be key to the elucidation of the mechanism. With Raman microscopy direct visualization of intracellular molecules is possible by observing the Raman scattering, Sodeoka seeks to elucidate the molecular mechanism of necrosis.

2. Results

Sodeoka has successfully developed IM-54 and NT-1, compounds that selectively inhibit and induce necrosis, respectively. Using these compounds, IM-54 was found to suppress necrosis induced by cellular oxidative stress, and the target molecule of the compound was a channel protein in mitochondrial membrane. Similarly, the target molecule of NT-1 was also a channel protein in mitochondrial membrane. Although details are still unclear, understanding the compounds that inhibit or induce necrosis are considered to be key to the elucidation of the necrosis mechanism (Fig. 1).

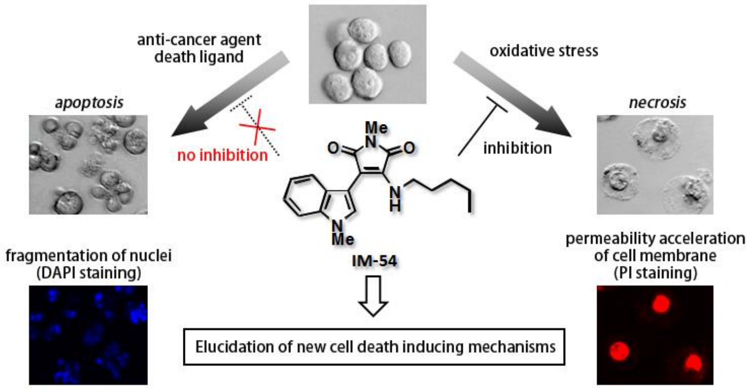


Fig. 1 Elucidation of the molecular mechanism of necrosis

In order to analyze localization of the necrosis inhibitor in living cells, Sodeoka developed a new method of real-time visualization of small molecules in living cells using Raman microscopy. Raman microscopy can directly analyze molecules by observing their Raman scattering, reflecting the vibration frequency of specific functionalities. Small alkyne tags exhibit characteristic and strong Raman scattering which are not originally present in

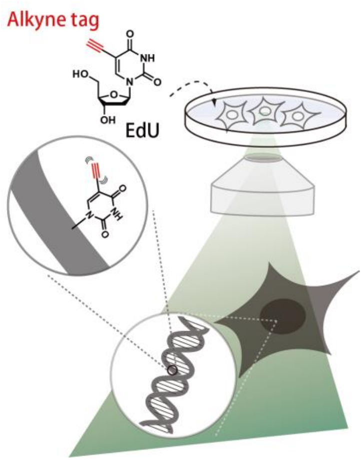


Fig. 2 Observation of a viable cell using EdU with an alkyne

cellular molecules. EdU (5-ethynyl-2’-deoxyuridine) was examined aAs a model molecule possessing alkyne moiety, and the progressive incorporation of EdU into the nucleus of the cell could be successfully monitor by Raman microscopy (Fig. 2).

3. Contribution to Science, Technology and Innovation

Development of real-time imaging and an identification method of target proteins in a biologically active molecule using the Raman spectroscopy and alkyne tags are expected to greatly impact various fields. Understanding the behavior of a target molecule in living cells is expected to contribute to drug development and the elucidation of mechanisms in various biological phenomena. For example, studies on necrosis are expected to shed light on mechanisms involved in neurodegenerative diseases (e.g. Alzheimer’s disease) and ischemic diseases (e.g. myocardial and cerebral infraction) and promote the development of therapeutic reagents for these diseases.

Hiroshi Ishiguro (Professor, Graduate School of Engineering Science, Osaka University, Visiting Director (ATR Fellow), Hiroshi Ishiguro Laboratories, Advanced Telecommunications Research Institute International (ATR))

PRESTO (1997-2002)
CREST (2010-2014)
ERATO (2014-2019)

"Toward the Realization of an Autonomous and Symbiotic Android"

1. Research Objectives

Humanoid robots are expected to one day play an active role in human life. The realization of truly socialized autonomous robots will require technologies to mimic various human communication modalities such as gestures, expressions of the face and eyes, contact by touch, etc. Ishiguro's group has been researching and developing technologies for advanced interactions between robots and humans using both software and hardware.

2. Results

Ishiguro proposed a concept of "perceptual informative infrastructure" in the research program he founded in the PRESTO project under JST. After the PRESTO project, he extended the concept to intelligent robotics and developed an intelligent robotics platform. Figure 1 shows a pair of tabletop "dialogue robots" developed by his group (left side, CommU, 304 mm in height; right side, Sota, 282 mm in height). The two robots can hold dialogues with each other and with humans, communicating both with words and various expressive movements of their eyes.

Fig. 1 Tabletop "dialogue robots"

Ishiguro also developed ERICA, a 166 cm tall android equipped with advanced elemental technologies for voice recognition, motion, facial expression, etc. to allow for "natural" communication with humans (see Fig. 2). The technologies are further evolving and adopting more sophisticated approaches for voice synthesis and eye-movement to move closer to more human-like androids.

3. Contribution to Science, Technology and Innovation

Autonomous communication technologies will be realized by robust and flexible voice recognition, proper gestures, facial expressions, eye-movements, etc. Actuators and other "soft" hardware mechanisms developed for human-symbiotic robotics may also become important forefront technologies. Symbiotic robotics

Fig. 2 An android named ERICA

will be applied in fields such as therapy and education and is expected to play roles in information conveyance and help society surmount potential challenges with human communication as the population ages. The domestic market for “watch robots” and “communication robots” is expected to grow to 1.1 billion yen by 2020 and 3.6 billion yen by 2025. The domestic market for nursing care robots is expected to grow to 54.3 billion yen by 2020 and 123.9 billion yen by 2025. There are no clear estimates on the size of the market for humanoid robots.

Masatoshi Ishikawa (Professor, Graduate School of Information Science and Technology, The University of Tokyo)

CREST (1999-2004)
CREST (2009-2015)

"Realizing a Highly Future-oriented Information Environment"
—Transforming Surrounding Environments into Ubiquitous Computers—

1. Research Objectives

Miniaturization and performance upgrades of computers and smart-phones have recently been advancing at a very fast pace. Yet for some people, the methods for inputting and outputting information with computing devices can be unwieldy or unfriendly. This field of research seeks to integrate and establish an innovative and ubiquitous information environment that everyone will find convenient and friendly to use by introducing new concepts for improved input and output methods and enhanced freedom within systems.

2. Results

Various new information environments have been developed based on high-speed sensing and display technologies. A common functional target is to track moving objects (a palm of the hand, moving papers, or ball) quickly and send visual and actuating information freely without delay (in the case of human communication, palms are used for receiving projected visual images and tactile stimulations, as shown in Fig. 1 and Fig. 2, respectively).

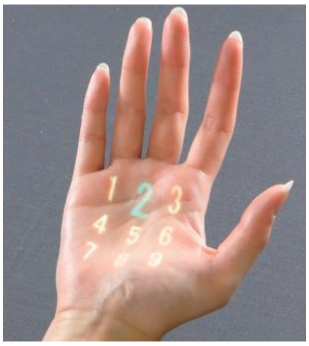


Fig. 1 Image displayed on the palm of a hand in motion

3. Contribution to Science, Technology and Innovation

Advanced systems will enable all people to freely access methods for inputting and outputting information anywhere at any time, realizing an environment of ubiquitous computers. Unlike conventional research on human interfaces, which usually aims at reaching levels comparable to human abilities, this innovative research will realize new forms of visual and tactile information that go beyond current human abilities in daily life.

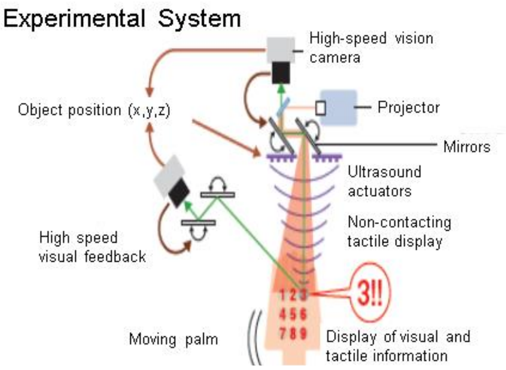


Fig. 2 Method for displaying video and tactile information

Expected products and applications include high-speed scanners, high-speed projectors, car-mounted cameras, tactile displays, high-speed three-dimensional displays, ubiquitous displays, and high-speed non-contact diploma distribution sensors, mainly in industries that use high-speed sensor technologies and high-speed information-presentation technologies for applications such as robotics.

Motoko Kotani (Director, Advanced Institute for Materials Research, Professor, Graduate School of Science, Tohoku University)

CREST (2008-2013)

"Working to Discover Innovative Materials Based on Discrete Geometric Analysis"

1. Research Objectives

Developing innovative materials with outstanding features that address environmental and resource related issues is essential for a safe and prosperous society. This research aims to design innovative materials without relying on conventional and empirical approaches. In particular, Kotani seeks to establish guiding principles based on the discrete geometric approach which is useful in predicting the characteristics of the designed materials to discover new materials.

2. Results

By applying Euclidean design theory (extended theory of spherical design method), Kotani developed a method to systematically study C_{60} fullerene with a core shell. Also, regarding the theoretically discovered K4 lattice structure which has maximum symmetry and isotropy like a diamond, Kotani discovered that a crystal with 50:50 ratio of carbon and nitride is promising as high enthalpy material with high energy density. Moreover, by utilizing phase separation of different kinds of polymerizing structures, simultaneous realization of high thermal conductivity, high electrical resistivity and process flexibility could be successfully achieved.

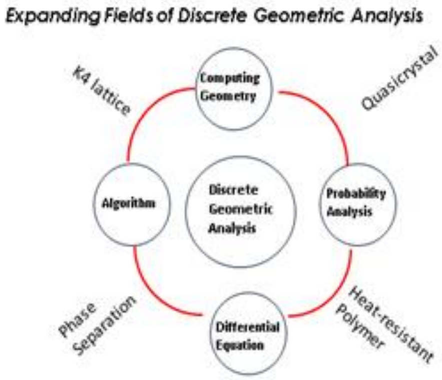


Fig. Spread of discrete geometry

3. Contribution to Science, Technology and Innovation

Through practical discrete geometric analysis, this research has contributed to a new crystal model and theories for innovative material design. This research area promotes the fusion and development of mathematics and material science by strengthening the application bridge between them. Following the good example in material design for polymers which have both high thermal resistance and high electrical conductivity, carrying out strategic material design which can meet various specifications simultaneously is possible. Outcomes in this research area will contribute to science and technology innovation by pioneering new industrial fields.

Tadahiro Kuroda (Professor, Faculty of Science and Technology, Keio University)

CREST (2005-2010)
CREST (2009-2014)
ACCEL (2015-)

"New Development for an Innovative 3D-IC Using Electro-magnetic Coupling between IC Chips"

1. Research Objectives

While the miniaturization of IC chips continues to progress smoothly according to the Moore's law, approaching limitations are expected due to various issues in fabrication systems, processing techniques, and production costs. Professor Kuroda is conducting advanced research on 3D-IC technologies with the potential to meet requirements for further miniaturization, higher speeds, up-graded functionality, lower energy consumption, and lower cost. In the CREST project, his group established the TCI (Thru-Chip Interface), an advanced 3D-IC technology using electro-magnetic coupling as chip communication. Starting from where CREST left off, the ACCEL project aims to make further headway toward the realization of advanced devices such as TCI-assembled DRAM and 3D processors.

2. Results

High-speed, low-power-consumption signal transmission (100 mW/10 Tbps, one thousand times smaller than the conventional methods) was achieved by establishing a non-contact electro-magnetic coupling between IC chips (Fig. 1).

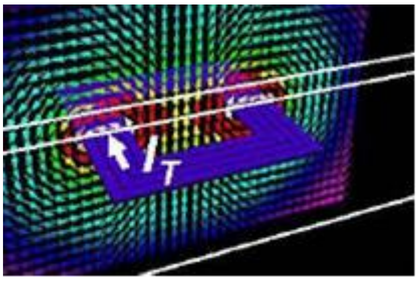


Fig. 1 Magnetic field distribution of an inter-chip

This TCI method enables the use of the standard CMOS fabrication process via the non-contact magnetic coupling between the interconnecting layers of the IC chips and the appropriate communication circuits (Fig. 2). This will bring about outstanding features such as low production cost and simple fabrication processes.

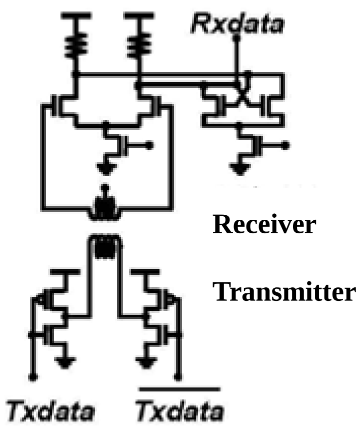


Fig. 2 Transceiver of the equivalent circuit

3. Contribution to Science, Technology and Innovation

The outcomes of this research have shown the potential for a new 3D-IC technology that will surpass the current trends of conventional methods in functionality and low power consumption. It may also be straightforward to combine this 3D-IC technology with various IC elements such as non-volatile memories, analogue circuits, CPUs, and FPGAs (field-programmable gate arrays). This will bring about essential core technologies for robotics, “deep learning,” and so on.

Susumu Tachi (Professor Emeritus, The University of Tokyo)

CREST(2000-2005)
CREST(2009-2014)
ACCEL(2014-)

"Toward the realization of future abundant society achieved by advanced Telexistence technology "

1. Research Objectives

Telexistence technology can be achieved by the integration of virtual reality, robotics and communication technologies. Prof. Tachi focuses his attention to develop advanced telexistence technology with haptic sensation transmission technique for the contribution in wide application fields, such as medical support, education, rescue, entertainment, etc.

2. Results

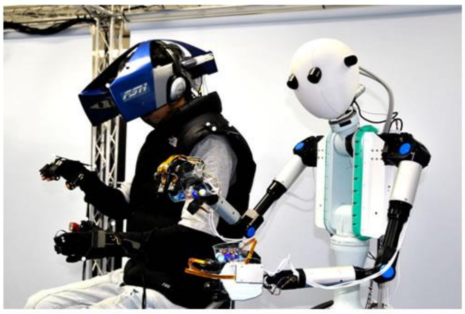


Fig. 1 TELESAR V
Left: Operator
Right: Avatar robot

The research in the field of haptic sensation is lagging as compared to that of visual and auditory sensations. Hence, Prof. Tachi proposed a haptic representation technique which uses sensory elements to sense pressure, vibration, temperature etc. and named them as haptic primary colors, emulating the name of the three primary colors. A tactile sensor based on these haptic primary colors is mounted onto an avatar robot that moves in accordance with the body movement of the person operating it and presents the haptic primary colors to the operator. He pioneered the development of world's first haptic telexistence system, TELESAR V (Fig. 1), capable of performing fine and detailed haptic transmission of the sensation of holding an object, temperature sensation, the texture feel of a cloth etc. He and his team verified its efficacy through demonstrations.

3. Contribution to Science, Technology and Innovation

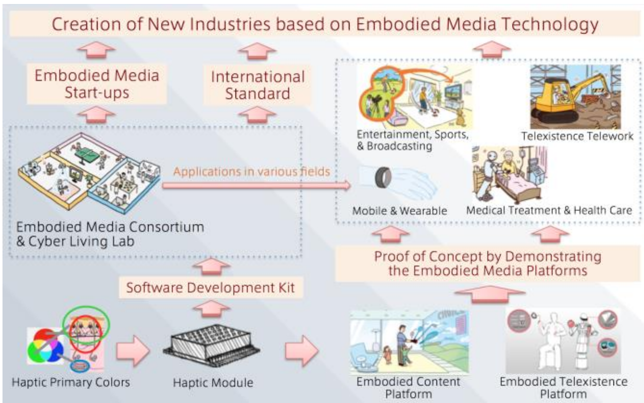


Fig. 2 Perspective for future applications

Based on the concept of "haptic primary colors", compact and integrated tactile sensation transmission modules will be developed. The wide applications of such modules to a variety of industrial users will allow for the emergence of new industries of products and services by recording, transmission, and reproduction of physical experiences with haptic sensations (Fig. 2).

(6) Researchers from JST News

Researchers and research results from JST News are shown in Table 3-18.

Program : CREST Research Area “Development of the Foundation for Nano-Interface Technology”
Research Project : “Energy conversion via the interface with hydrogen activation aqua catalysts”
Research Director : Seiji Ogo (Professor, Graduate School of Engineering, Kyushu University)
Research Period : 2008-2014

•Objectives

The effective utilization of hydrogen is an important issue from a point of view such as the construction of sustainable energy supply systems. Hydrogen activation enzyme “[NiFe] hydrogenase” in nature extracts an electron from hydrogen under mild conditions such as ordinary temperature and ordinary pressure. But an artificial catalyst , which was inexpensive, was not capable of proceeding a similar reaction under the same conditions.

•Results

Ogo succeeded in synthesis of [NiFe] catalyst as a artificial model of [NiFe] hydrogenase. And he showed that this catalyst was capable of activating hydrogen and reducing substrates by electron transfer under ambient conditions.

•Points of the Research

The [NiFe] hydrogenase declines catalytic activity as time passes because of its instability. On the other hand, the developed [NiFe] catalyst has good stability and durability.
The conventionally best artificial model was a [NiRu] catalyst synthesized by Ogo. It was necessary to develop an inexpensive catalyst for the practical use because ruthenium was a expensive noble metal.
Fe price (0.06 yen/g) is 1/4,000 of Ru price (240 yen/g). The success of hydrogen activation using the [NiFe] catalyst advances drastically research of hydrogen activation, and that will contribute to the innovative progress of application such as catalysts for fuel cells.

•Future Perspectives

The research results are expected to lead to the development of the hydrogen energy technology, e.g., the development of the platinum-free fuel cell using the [NiFe] catalyst for the creation of sustainable society.

Summary Chart

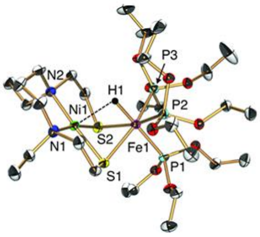


Fig. 1 Crystal structure of Ni-Fe catalyst

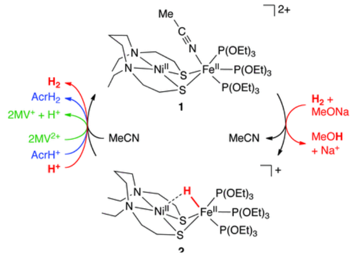


Fig. 2 Electron transfer from hydrogen using Ni-Fe catalyst

Program : CREST Research Area “Development of the Foundation for Nano-Interface Technology”
Research Project : “Manipulation of nano interface of drug-delivery system and its application to vaccine for bird flu”
Research Director : Kazuo Sakurai (Professor, Graduate School of Environmental Engineering, The University of Kitakyusyu)
Research Period : 2008-2013

- **Objectives**
  The function of nanoparticles employed to drug delivery system (DDS) is mainly governed by interactions through hydrophobic/hydrophilic interface. A lot of new information to control DDS, which is a main research objective, will be obtained by exploring nanostructure of the particles and how to trap the drugs in the interface in the particles by use of synchrotron X-ray scattering. One of the major applications is to provide novel methodology for molecular design of vaccine based on the information about DDS.
- **Results**
  Anomalous small-angle x-ray scattering (ASAXS) at SPring-8 revealed that the hydrophobic drugs were infiltrating into the water-soluble domain of the micelles. This finding provides useful insight to understand the drug delivery mechanism, that shows the importance of the infiltration, and to design more efficient DDS carriers.Sakurai developed a novel adjuvant*1 (K3-SPG) as a DDS nanoparticle of the complex made from therapeutic oligonucleotide CpG oligodeoxynucleotide (ODN) and natural beta-glucan as a carrier. (*1 : Adjuvant is added to vaccine to stimulate the immune system’s response to the target antigen (vaccine).)
- **Points of the Research**
  It was conventionally very difficult to solve the problem instability (aggregation) of CpG ODN. He firstly succeeded in the improvement of the stability by covering CpG OD with the carrier.
  When he administered this complex with influenza vaccine, immune stimulation due to the vaccine dramatically increased for monkey as well as mice. This result shows the possibility of the application to human.
- **Future Perspectives**
  This technology can be used for wide applications such as novel influenza drug, anti-cancer drug and anti-allergy drug.

Summary Chart

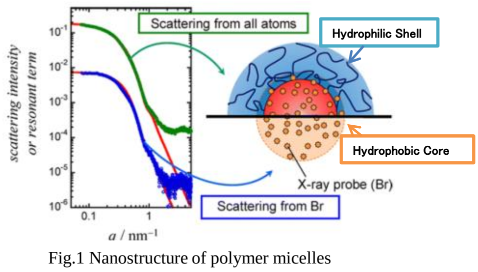


Fig.1 Nanostructure of polymer micelles

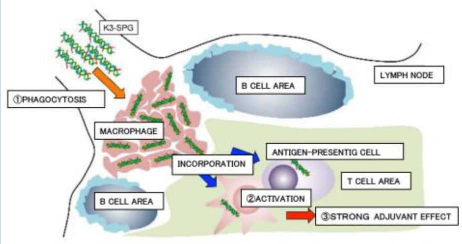


Fig.2 Working mechanism of a novel adjuvant K3-SPG

Program : CREST Research Area “Creation of Nanosystems with Novel Functions through Process Integration ”
Research Project : “Digital counting systems for biological assay ”
Research Director : Hiroyuki Noji (Professor, Graduate School of Engineering, The University of Tokyo)
Research Period : 2010-2015

Research Objectives

Detection in extremely early stage of each disease, such as cancer, or in the border prevention of a pandemic, has a difficulty in detecting a small amount of virus using a conventional ELISA(Enzyme-Linked Immunosorbent Assay oxygen-linked immunosorbent assay). Because, this requires large antigen-antibody reaction volume, which results in a large measurement error due to low sensitive analog measurement. To solve the problem, a single biomolecules digital counting is established, and low-cost handy type detection system is developed .

Results

The confined molecule made by the antigen-antibody reaction, in the ultra-fine space fabricated by micro-manufacturing technology with one million micro holes in a glass plate of 1 cm^2, is captured one by one with florescence microscopy (Fig.1).. A single molecule digital ELISA for quantitatively measuring in one molecular unit has been established, and succeeds in detecting the marker for prostate cancer (PAS) with million times higher sensitivity (60ag/mL) than that of conventional ELISA (Fig.2).

Points in the Research

In detection of a protein involved in lung cancer patients cancer cells and viruses, a method for the detection with high sensitivity even conventional one million times from the sweat and blood has been realized This will realize the diagnose from the saliva or urine, and will expand to early detection of various diseases.

Future Perspectives

A compact and portable one-molecule measurement system integrating a CMOS imaging sensor will be developed for the clinic in the town as well as a large general hospital and inspection agency.

Summary Chart

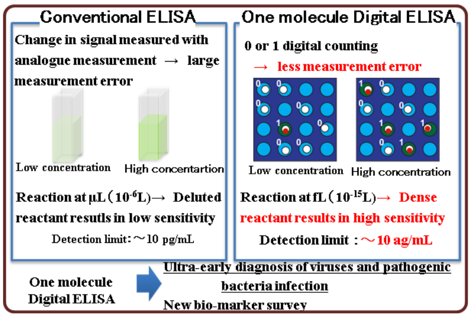
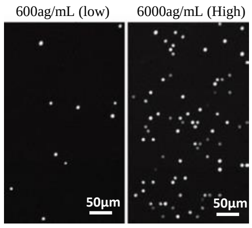


Fig.1 One molecule digital ELISA



Left:
10-molecules are detected at a concentration of 600ag/mL

Detection limit: 60 ag/mL
⇓
10^6 times higher than conventional method

Fig.2 Example of PSA marker detection

Program: CREST Research Area ”Creation of Innovative Functions of Intelligent Materials on the Basis of Element Strategy”
Research Project: Coercivity Mechanism of Nd-Fe-B Permanent Magnets
Research Director: Kazuhiro Hono (Fellow, Magnetic Materials Unit, National Institute for Materials Science (NIMS))
Research Period: 2011-2016

Objective

The development of high performance permanent magnets is one of key technologies for the next-generation electric vehicles for the low-carbon society. Japan has a long tradition in the development of high performance permanent magnets starting from the invention of the KS steel by Prof. K. Honda in 1917 to the invention (1982) of neodymium (Nd) magnets by Dr. M. Sagawa in 1982, which gave tremendous impacts to the society. The neodymium magnet is still the world strongest permanent magnets; however, the need of 5-10% of dysprosium (Dy) that is scarce in natural resources has becomes a big issue recently. This work aims at developing high coercivity neodymium permanent magnets without using dysprosium based on fundamental studies on the coercivity mechanism.

Results

The coercivity of the hot-deformed neodymium magnets that are composed of submicron sized crystal grains have been substantially improved by isolating the grains by infiltrating low-melting temperature Nd-Cu alloy [$Nd_{70}Cu_{30}$] along grain boundaries. By confining the volume expansion during the process, the volume fraction of the non-ferromagnetic phase has been successfully controlled as shown in Fig. 1. As a result, Dy-free high performance magnet with the coercivity of 1.92T and the remanent magnetization of 1.36T was developed (Fig.2).

Points of the Research

The microstructure optimization to maximize the coercivity and the remanence, i.e., magnetic isolation of fine crystal grains by Nd-Cu allloy infiltration while constraining the volume expansion during the process. This idea originates from the detailed microstructure investigations of conventional neodymium magnets.

Future Perspectives

The temperature dependence of the coercivity of the developed Dy-free neodymium magnets is lower than that of 4%Dy-containing conventional magnets (Fig.3). Furthermore, at 200℃, which is the operation temperature of traction motors, this magnet exhibited higher performance than the 4%-Dy containing conventional magnets. This material design is based on the fundamental research on the structure of existing neodymium magnets. This development is a big step toward the coercivity of 0.8T at 200℃, which is the requirement for practical use.

Summary Chart

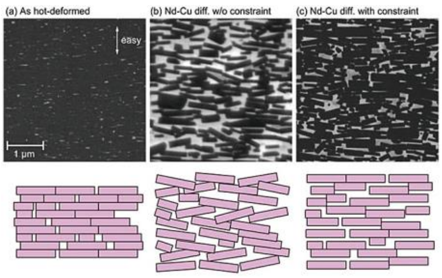


Fig.1 Microstructures of the hot-deformed Nd-Fe-B magnet and the samples that were $Nd_{70}Cu_{30}$ diffusion-processed with and without an expansion constraint. The dark area represents $Nd_2Fe_{14}B$ crystal, the bright one Nd element.

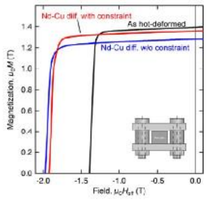


Fig.2 Demagnetization curves of the original hot-deformed sample and the samples that were diffusion-processed with and without an expansion constraint.

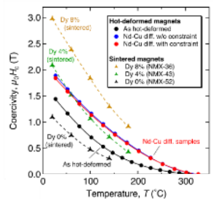


Fig.3 Temperature dependence of the coercivity of the hot-deformed magnet and the samples that were $Nd_{70}Cu_{30}$ diffusion-processed with and without an expansion constraint.

Program: CREST Research Area "Innovative Nano-electronics through Interdisciplinary Collaboration among Material, Device and System Layers "
Research Project : "Development of Tunneling MOSFET Technologies for Integrated Circuits with Ultra-Low Power Consumption"
Research Director : Shinichi Takagi (Professor, Graduate School of Engineering, The University of Tokyo)
Research period : 2013-2018

Research Objectives

The power consumption of IT equipment is rapidly increasing in recent years and, thus, becomes a serious issue. To solve this problem, transistors utilizing tunneling current through a potential barrier has stirred a strong interest. However, a large current on/off ratio under a small voltage change has not been obtained yet, and it is also difficult to realize them by using the current semiconductor technology for practical use. Here, we are aiming at developing practically viable technologies of high performance tunneling FET devices as well as the design and circuit technologies of the tunneling FETs for realizing extremely-low power consumption systems.

Results

Combination of a Ge source with a tensile strain Si channel realized new ultra-low power band-to-band tunneling FETs by controlling the energy bands to lower the potential barrier between the source and the channel. The FET achieved both a minimum S factor of 28 mV/decade and an on/off current ratio of 10^{-7}, allowing us to operate under much lower supply voltage than that of conventional devices.

Points in the Research

While using Si-process-compatible materials, the device structure with ultra-thin tunneling distance is developed As a result, both rapid current change under a slight input voltage change and large on/off ratio are successfully realized for low power integrated circuits.

Future Perspectives

The present transistor compatible to the conventional Si infrastructure is suitable for mass production of LSI using TFETs. By the large scale integration of the tunnel FETs, significant power saving of IT equipment can be realized. In addition, integrated circuits using the TFETs can open up new applications such as systems with no battery, because of the low standby power.

Summary Chart

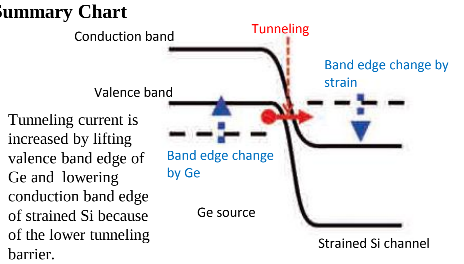
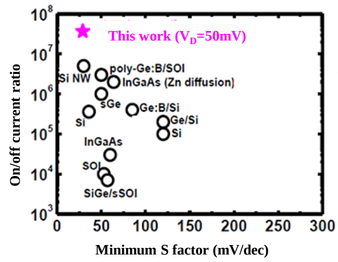


Fig.1. Mechanism of Increased Tunneling Current in Tunneling FETs



S factor : Gate voltage change for 1 decade change in current

Fig.2 Benchmark of tunneling FETs
Smaller S factor and larger on/off ratio show better device performance.
○: Conventional, ★: this work

Program: PRESTO Research Area "New Materials Science and Element Strategy"
Research Project : "Investigation of Material Process using Supercooled Liquids"
Researcher: Junpei T. Okada (Associate Professor, Institute for Materials Research, Tohoku University)
Research Period : 2012-2015

Objectives

In order to understand and utilize properties of materials, knowledge about not only the solid state, but also the liquid state is very important. However, it is difficult to hold a liquid state of material with high-melting point because of its high reactivity. Therefore, electrostatic levitation devices were developed to keep liquid materials with Coulomb's force, and researches have been conducted to understand the properties of liquid materials using those devices. Electrostatic levitation devices do not require containers to keep materials, but are able to levitate liquid materials stably. This PRESTO research aims to investigate the liquid state of Silicon (Si) and Boron (B) which are very important from element strategy stand point, and to create new materials.

Results

X-ray Compton scattering measurement on liquid B was carried out, with the electrostatic levitation device which was installed in the large synchrotron radiation facility (SPring-8), in order to analyze the properties valence electrons of liquid B. By analyzing the behavior of the valence electrons, using the measurement result combined with the first principle calculation, it was concluded that the semiconducting properties dominates the physical properties of liquid B.

Points of the Research

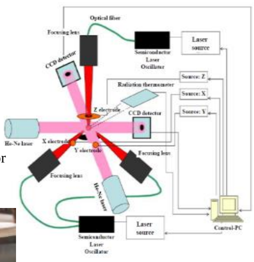
Electrostatic levitation method which has been jointly developed by JAXA and NASA has been applied to the analysis of high-melting point liquid material, and succeeded to identify the electronic properties of liquid Si and liquid B electrons.

Future Perspectives

The electrostatic levitation device which was used in this research has been developed mainly for the high-melting point materials experiments in space station. The device requires up to 100,000 V/cm high voltages to levitate liquid materials on the earth. Therefore, experiments of evaporative materials are difficult to conduct. The electrostatic levitation device which has been installed in the space station enables to conduct melting experiments under gas atmosphere. It is important to carry out experiments in space and on the earth complementally, to understand the properties of high temperature liquid and to leads to the development of new materials.

Summary Chart

Fig.1 Electrostatic Levitator



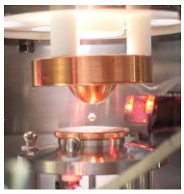


Fig.2 Levitated .metal melt in chamber.

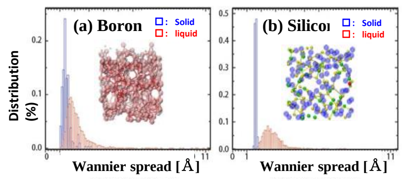


Fig.3 Wannier spread distributions for various phase of Boron (a) and Silicon (b).

Program : PRESTO Research Area "Hyper-nano-space design toward Innovative Functionality"
Research Project : "Quasi High Pressure Assisted Photoreactions for Creations of Unexplored Conducting Materials inside Hierarchical Nanospaces"
Researcher : Toshihiko Fujimori (Associate Professor, Center for Energy and Environmental Science, Shinshu University)
Research Period: 2013-2016

- **Objectives**
  Despite extensive research for more than 200 years, the experimental isolation of monatomic sulphur chains, which are believed to exhibit a conducting character, has eluded scientists. Fujimori aimed to synthesize unexplored conducting materials by consisting of monatomic chains of non-metals among the ubiquitous elements in the extremely small space less than a one-10,000th of the hair, called "hyper-nano-space", in which various mysterious phenomena may be caused.
- **Results**
  He succeeded in the synthesis of a previously unobserved composite material of elemental sulphur, consisting of monatomic chains stabilized in the constraining volume of a carbon nanotube. His observations indicate the conducting character of the one-dimensional sulphur chains under ambient pressure.
- **Points of the Research**
  His observations firstly indicated the conducting character of the one-dimensional sulphur chains under ambient pressure. This is in stark contrast to bulk sulphur that needs ultrahigh pressures exceeding ~90 GPa to become metallic. And he elucidated the mechanism of conduction along the monatomic sulphur chains by calculations of corresponding electronic structure and quantum transport.
- **Future Perspectives**
  He aims at the transformation to metallic conductor from various non-metallic substance consisting monatomic chains in the hyper-nano-space.

Summary Chart

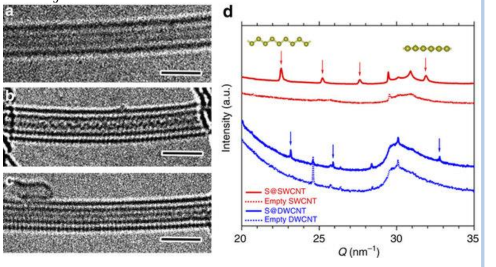


Fig.1 Structural identification of 1D sulphur chains inside CNTs

High-resolution transmission electron microscopy (HRTEM) images of sulphur encapsulated inside a single-walled carbon nanotube (SWCNT) and a double-walled carbon nanotube (DWCNT).
X-ray diffraction (XRD) analysis reveals the presence of highly ordered zigzag or linear atomic sulphur chains.
(**a**) The two lines correspond to 1D sulphur chains encapsulated inside a SWCNT.
(**b**) A DWCNT with the 1D sulphur chain in zigzag conformation.
(**c**) A 1D linear chain inside a DWCNT. Scale bar, 2 nm.
(**d**) XRD profiles of sulphur-filled SWCNTs, empty SWCNTs, sulphur-filled DWCNTs and empty DWCNTs. Arrows indicate the Bragg peaks of 1D sulphur chains.

Program: ERATO "Nakajima Designer Nanocluster Assembly"
Project Leader: Atsushi Nakajima (Professor, Faculty of Science and Technology, Keio University)
Research Period: 2009-2014

Objectives

Carbon nanoclusters were extensively studied, and their various industrial applications have been realized. Although Si nanoclusters have also drawn a considerable attention for their potential, the deposition of stable thin film of Si nanoclusters has never been realized.
The objective of the study is to establish new nanomaterial science consisting of nanoclusters through fine controlled synthesis, designer assembly, characterization of advanced functional nanoclusters.

Results

Si cage nanoclusters with encapsulated metallic atom (Fig.1) were synthesized in gas phase, and first successfully deposited on conductive surface terminated with C_{60} (Fig. 2).
The deposition mechanism of Si cage nanoclusters was revealed, and high thermal and chemical stabilities of the clusters up to 700 K and oxygen exposure were confirmed.

Points of the Research

A novel technique to deposit the thin films of Si caged nanoclusters onto various substrates was developed.
The chemical robustness of the nanoclusters shows a promising possibility of the applications to novel nanodevices, catalysts, and so on.

Future Perspectives

The development of the innovative techniques for the nanoclusters assembly (Fig. 3) will realize novel electronic- and optomagneto-nanodevices, catalysts, and so on.

Summary Chart

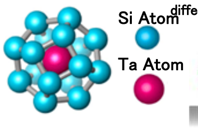


Fig. 1 Metallic (Ta) atom encapsulated in Si cage nanocluster

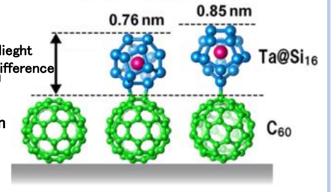


Fig. 2 Examples of theoretical motifs of neutral $Ta@Si_{16}$-C_{60} complexes.

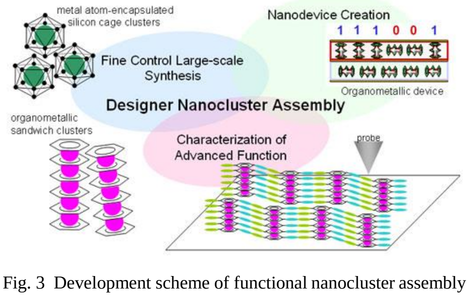


Fig. 3 Development scheme of functional nanocluster assembly

Program: CREST Research Area "Innovative Technology and Systems for Sustainable Water Use"
Research Project: "Development of innovative technologies to exploit groundwater resources in mountainous regions in order to achieve a sustainable supply of un-polluted high-quality water"
Research Director: Ken'ichirou Kosugi (Professor, Graduate School of Agriculture, Kyoto University)
Research Period: 2011-2016

Objectives
Water management in mountainous regions is a very important issue from the respect of water resource potential and disaster mitigation. Currently, the existence of aquifer under the bedrock layer in mountainous regions has been pointed out, but the details of the groundwater has not been extensively studied.
The objective of this research is to exploit and utilize the groundwater in mountainous headwater regions (Fig. 1) as a potential natural water resource.

Results
Fundamental accumulation mechanisms of the groundwater in mountainous regions were first revealed by detailed hydrological, geographical and geological studies.
Effective and precise monitoring systems by the combination of the hydrological methods and remote sensing techniques were developed.

Points of the Research
New knowledge of the veiled characteristics of groundwater in mountainous regions for sustainable water supply and disaster mitigation was obtained.

Future Perspectives
Both sustainable supply of high quality of water and disaster mitigation in mountainous regions will be achieved (Fig.2).

Summary Chart

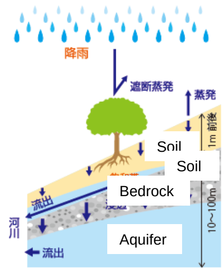


Fig. 1 Groundwater in mountainous regions

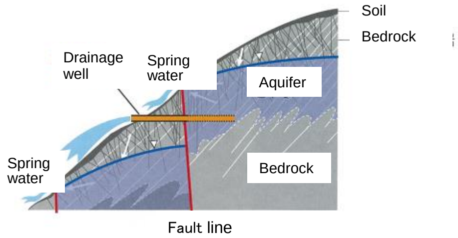


Fig. 2 Utilization of groundwater in mountainous regions

Program: CREST Research Area "Phase Interface Science for Highly Efficient Energy Utilization"
Research Project: "Interface science inspired nanoporous composites for next-generation energy devices"
Research Director: Migwei Chen (Professor, Advanced Institute for Materials Research, Tohoku University)
Research Period: 2011-2016

Objectives
Li-air batteries are expected as the next generation secondary batteries for the applications in electric vehicles, renewable energy utilization, so on. One of the key issues for practical implementations of Li-air batteries is to develop high-performance electrode materials which can provide a high durability in charge/discharge cycle at lower overpotentials and high electric conductivity.
The objective of the research is the development of 3D highly conductive nanoporous materials for advanced energy devices, including Li-air batteries.

Results
3-D nanoporous graphene (Fig. 1) was successfully realized by using 3-D nanoporous metal as a template for CVD growth. The light weight, highly conductive, large surface area and large porosity materials show outstanding performances as a new electrode materials for Li-air batteries (Fig. 2). By chemical doping, the inert nanoporous graphene can be rewarded new catalytic properties, which not only benefit the Li-air battery properties with reduced charge/discharge overpotentials and improved cycling stability, but also present new functions in hydrogen production, solar thermal conversion, et al..

Highlighted Points of the Research
3D bicontinuous nanoporous structure was first realized in graphene. 3D nanoporous graphene has been applied in energy devices with demonstrated advantages as a novel electrode material.

Future Perspectives
Promotions of hydrogen utilization as an energy media, renewable energy, and the realization of advanced EV (electric vehicles) are expected.

Summary Chart

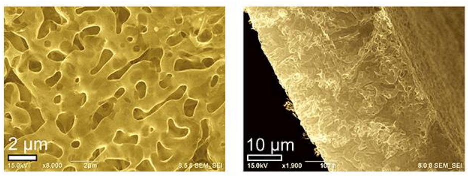


Fig. 1 3-D nanoporous graphene
Left:: Surface Right:: Cross section

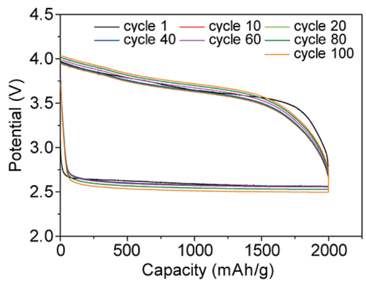


Fig.2 Cyclic charge/discharge characteristics of Li-air battery with 3-D nanoporous graphene-based cathode (very stable in the course of 100 charge/discharge cycle)

Program : CREST Research Area: "Basic Technology to Establishing Tailor-Made Medicine by Utilizing Genome Information"
Research Project: "Characterization Human Disorders with a High-throughput Analysis of the Regulatory Mechanism for Gene Expression"
Research Director:Hiroyuki Mano (Professor, Graduate School of Medicine, The University of Tokyo)
Research Period: CREST(2002-2007)
Research Acceleration: Novel cancer gene identification project (2009-2014)

- **Research Objectives**
  Since lung cancer has the largest number of deaths (1.6million people/year) in industrialized countries, it is expected to develop an effective treatment. To create drugs for molecular targets which regulate key molecules for cancer cell growth, aim to develop new drug screening methods to search for new oncogenes.
- **Results**
  The original method to screen new oncogenes in cancer cells from lung cancer patient was developed and new lung cancer gene, EML4-ALK was found(Fig 1).
- **Key Points in the Research**
  Based on this result, crizotinib which has ALK inhibiting activity and was used in the clinical trial in the US was administered to lung cancer patients who were positive for EML4-ALK gene and it was found that about 60% of the patients showed regression of cancer. In response to this, the drug was approved as an anti-cancer drug merely 4 years after the start of the clinical trial in the US (Fig.2). Next in Research Acceleration Project, "The elucidation of mechanisms of drug resistance in lung cancer" and "Discovery of new lung cancer genes and ongogenes" were successfully achieved. Based on these results, "Alectinib" which showed that 93.5% of cancer patients had regression of cancer was developed and approved in Japan in July 2014.
- **Future Perspectives**
  The project which aims at the discovery of therapeutic targets in clinical trials started in AMED and successful outcomes are continuously obtained.

Summary Chart

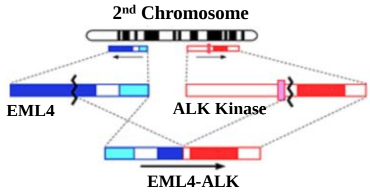


Fig. 1 New Lung Cancer Gene EML4－ALK

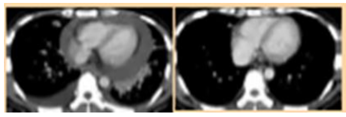
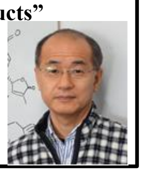


Fig. 2. The regression of Lung cancer by ALK inhibitor crizotinib (Right)

Program : CREST Research Area "Creation of Essential Technologies to Utilize Carbon Dioxide as a Resource Through the Enhancement of Plant Productivity and the Exploitation of Plant Products"
Research Project : "Development of plants with high biomass productivity by chemical and biological regulations of plant hormone cross talk"
Research Director : Tadao Asami (Professor, Graduate School of Agricultural and Life Sciences, The University of Tokyo)
Research Period : 2012-2017



- **Objectives**
  The population on the earth is increasing and it is estimated to reach 10 billion in the middle of this century. The increase in production of the food is an very important issue. Plant hormone is confirmed to regulate several biological events that are involved in plant life cycle. And control of plant growth by the plant hormone is more likely to become the key technology. The aim of this project is to find biomass high producing methods by combining the chemicals that can control the molecular events in cross talk (which refers to instances in which one or more components of one signal transduction pathway affects another) and the manipulation of the factors that mediate plant hormone cross talk.
- **Results**
  Plant growth inhibitor "Brassinazole (Brz)" is recognized to freely control biosynthesis of the plant hormone "Brassinosteroid"(BR). Asami performed a plant growth experiment by adding Brz in experimental model plant, Arabidopsis, with the tools of chemical biology. He discovered BSS1 protein which controlled BR signaling and the signaling mechanism at plant hormone cross talk.
- **Points of the Research**
  BR was known to play important roles in plant development. But he firstly elucidated the model of elongation on plant height by the signaling mechanism.
- **Future Perspectives**
  The R&D controlling the growth of plants advances to contribute to the production of plant biomass and the promotion of the technology for fixing carbon dioxide.

Summary Chart

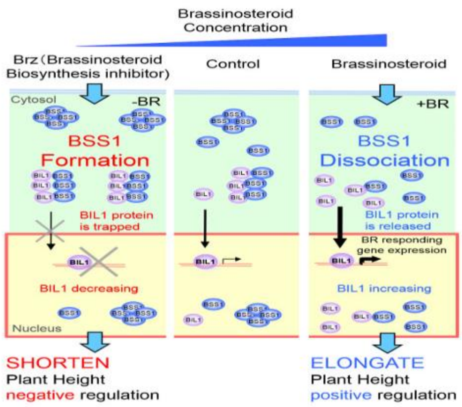


Fig. 1. Model of BSS1 Function in Brassinosteroid (BR) Signaling
LEFT : When brassinosteroids are not activated by Brz, the BSS1 protein complex binds to BIL1, preventing it from moving to the nucleus, causing shortened plant height.
RIGHT : When brassinosteroids are activated, the BSS1 protein comes apart and BIL1 is released, leading plant cells to elongate and the plant to grow.
15

Program: CREST Research Area "Establishment of Core Technology for the Preservation and Regeneration of Marine Biodiversity and Ecosystems"
Research Project: "Application of environmental DNA for qualitative monitoring of fish community and ecosystem assessment"
Research Director: Michio Kondo (Professor, Faculty of Science and Technology, Ryukoku University)
Research Period: 2013-2018

Objectives

Bio-monitoring of fishes is one of the key issues in the preservation and regeneration of marine biodiversity and ecosystems.
The objective of this research is to develop novel high-throughput multispecies identification systems using environmental DNA originated from fishes for bio-monitoring the fishes in oceans.

Results

The effectiveness of the multispecies identification systems developed, the so-called "meta-barcoding", was demonstrated, and qualitative agreement with observation was confirmed (Fig. 1).
168 species from 180 species in aquarium pools were successfully identified by sampling seawater from the pools (Fig. 2).

Points of the Research

The novel bio-monitoring systems for fishes in oceans will drastically simplify the present field monitoring systems, and a high precision and rapidity can be achieved.

Future Perspectives

The technology to be developed will greatly contribute the preservation and regeneration of marine biology systems.

Summary Chart

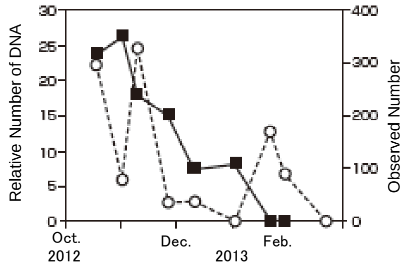


Fig. 1 Comparison of relative number of DNA of Jack mackerel (dotted line) with observed number (solid line)

Fig. 2 168 species of 180 species in aquarium were determined by seawater sampling.

Program: CREST Research Area "Creation of Innovative Technology for Medical Applications Based on the Global Analyses and Regulation of Disease-Related Metabolites"
Research Project: "Creation of search techniques for disease-related metabolic activities based on live imaging of clinical specimen and its application to drug developments"
Research Director: Yasuteru Urano (Professor, Graduate School of Medical Sciences, Graduate School of Pharmaceutical Sciences, The University of Tokyo)
Research Period: 2014-2019

Objectives

For the purpose of diagnoses of cancer and effective surgical removal of tumor tissue, it is important to distinguish small metastatic sites from normal tissues clearly. Therefor, development of a novel fluorescence probe to react with tumor tissues rapidly and sustainably with minimalizing non-specific reaction is useful for shortening surgical time, reducing patient's burden and accelerating recovery from surgery. Urano would develop a novel fluorescence probe to meet the above expectations.

Results

Urano focused on β-galactosidase overexpressing in tumor cells, and optimized the structure of probe molecule reacted with the glycosidase, then developed high fluorescent probes on the reaction. The probes fluoresced brightly over 1000 times more than existing probes. After administration of the probe to several ovarian cancer mouse metastasis models, metastases could be detected specifically as small as <1 mm in diameter.

Points of the Research

Urano achieved visualization of tumor tissues that was difficult to be detected with the naked eyes and not visualized with existing probes.

Future Perspectives

It is expected that applicability of the probe will be expanded to removal method of tumor tissues by spraying the probe not only pre-operatively but also intra-operatively when suspicious lesions are encountered during diagnosis and/or surgery. In addition, Urano aims to develop proper fluorescence probes to other glycosidases that are enhanced in various diseases.

Summary Chart

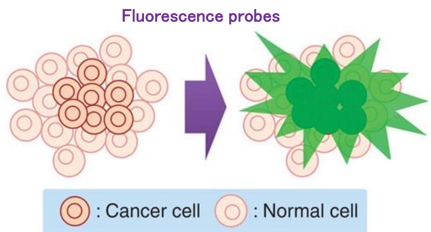


Fig. 1 Fluorescence detection of cancer cells

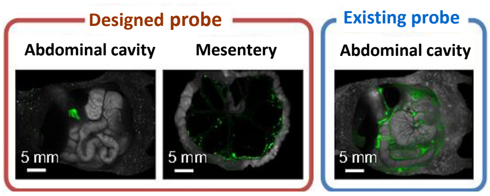


Fig. 2 Visualization of metastases by fluorescence probe
Metastases as small as <1 mm in diameter inside the peritoneal cavity were clearly and specifically visualized by the novel designed probe, but not by existing probe.

Program: PRESTO Research Area "Creation of Basic Technology for Improved Bioenergy Production through Functional Analysis and Regulation of Algae and Other Aquatic Microorganisms"
Research Project: "Development of plant growth promoting system using the fastest motor Chara myosin"
Researcher: Motoki Tominaga (Assistant Professor, Faculty of Education and Integrated Arts and Sciences, Waseda University)
Research Period: 2011-2014

Objectives

Algae are promising biomass resources for environment friendly production of energy and various materials. The key issue for the realization is the increase in the productivity and the reduction of the production cost.
The objective of this research is the control of growth rate and size of plants by the control of cytoplasmic streaming velocity for the increase in the production of bioenergy, foods, et al.

Resutls

Moving mechanism of myosin on actin filaments in cytoplasmic streaming was revealed (Fig. 1).
In a model plant, *Arabidopsis*, the growth control by means of the control of myosin was successfully demonstrated (Fig. 2).

Points of the Research

The veiled role of cytoplasmic streaming was first revealed, and it was pointed out that cytoplasmic streaming was a key determinative factor for the growth speed and size of plants.

Future Perspectives

The research conducted in PRESTO program was accepted and is continued in ALCA (Advanced Low Carbon Technology Research and Development Program) (2014-2019).

Summary Chart

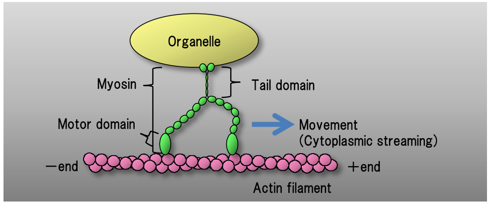


Fig. 1 Moving mechanism of myosin on actin filaments

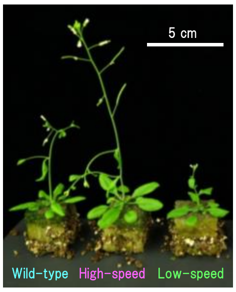


Fig. 2 Effect of myosin on plant growth

Program: PRESTO Research Area "Creation of Basic Technology for Improved Bioenergy Production through Functional Analysis and Regulation of Algae and Other Aquatic Microorganisms"
Research Project: "Study on the development of a precious metal recycling system coupled with algae biofuel production by using thermophilic red algae"
Researcher: Ayumi Minoda (Assistant Professor, Graduate school of Life and Environmental Sciences, University of Tsukuba)
Research Period: 2011-2014

Objectives

Although rare metals are one of strategic materials in the present high-tech industries, no resources are available in Japan. Recycling of rare metals is, therefore, indispensable. Effective recycling systems, however, have not been realized due to high cost, limited recovery conditions, et al.
The objective of this research is the development of effective and environment-friendly recycling systems for rare metals coupled with algae biofuel production.

Results

High efficient selective recovery of dilute (0.5-25 ppm) rare earth metals in red algae was successfully confirmed (Fig. 1).
Fundamental knowledge for the mechanism of metal accumulation in the cell was obtained. It was found that metals were accumulated inside the cell instead of the surface of the cell previously considered (Fig. 2).

Points of the Research

.The potential of red alga for the recovery of rare earth metals from dilute acidic waste water was confirmed.

Future Perspectives

Through a detailed understanding of the accumulation mechanism in the cell, the realization of effective and environment-friendly novel recycling systems for rare earth metals with red alga is expected.

Summary Chart

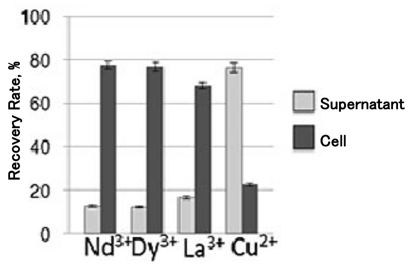


Fig. 1 Metals recovered in red alga

Fig. 2 Metals in cell (stained with alizarin red)
Left: Without alizarin red Right: with alizarin red

Program: PRESTO Research Area "Elucidation and control of the mechanisms underlying chronic inflammation"
Research Project: "Elucidation of the role of chronic inflammation underlying pathogenesis of Alzheimer's disease"
Researcher: Takashi Saito (Deputy Team Leader, Laboratory for Proteolytic Neuroscience, Brain Science Institute, Riken)
Research Period: 2012-2015

Objectives

Experimental studies of Alzheimer's disease (AD) have largely depended on transgenic mice overexpressing amyloid precursor protein (APP). These mice, however, are not affirmed proper model of human AD because of strong nonphysiological effects such as memory impairment by overexpressing APP and poor similarity to deposition of amyloid β peptide (Aβ) of AD patients. Saito would create a new model, that is more similar to AD patients.

Results

Saito's group generated APP knock-in mouse models (Fig. 1). The mice were detected initial deposition of Aβ at 6 months (at 12 months in APP-Tg mice) in spite of equal amount of APP to wild-type mice. And the mice showed neuroinflammation, synaptic alterations and memory impairment in an age-dependent manner at 18 months. Furthermore, the mice showed Aβ typical pathology more similarly to human AD patients (Fig. 2).

Points of the Research and Future Perspectives

There is a high possibility that the novel generated models would be used worldwide as standard models instead of existing mouse models. And they are expected to become important research tools used for identifying unclarified mechanisms of AD pathology and development of drugs and diagnostic methods for prevention and therapy of AD.

Summary Chart

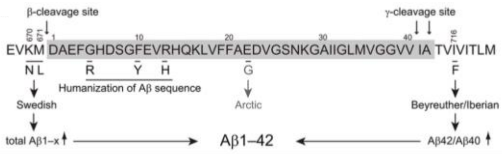


Fig1. Concept for generating new AD mouse models
We humanized the mouse Aβ sequence and introduced Swedish and Beyreuther/Iberian mutations by knockin technology. We also generated mutant mice that in addition carried the Arctic mutation.

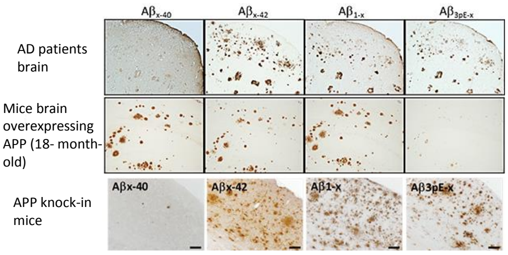


Fig.2. Deposition of Aβ in brains
APP knock-in mice showed Aβ typical pathology similarly to AD patients.

Program : PRESTO Research Area "Creation of essential technologies to utilize carbon dioxide as a resource through the enhancement of plant productivity and the exploitation of plant products"
Research Project : "Construction of monomer library for commodity plastics derived from furfural"
Researcher : Yuya Tachibana (Assistant Professor, Faculty of Science and Technology, Gunma University)
Research Period : 2013-2016

- **Objectives**
  The effective utilization of biomass is indispensable for reduction of carbon dioxide (CO2) - discharge and fossil fuel - dependence.
  A large amount of poly(ethylene terephthalate (PET), used as PET bottle container and fiber materials, is produced from oil and natural gas as fossil fuel. Replacement of fossil fuel by inedible biomass which does not compete with food is particularly expected to construct a sustainable society.
  Furfural is an ideal biomass resource, as it is traditionally produced from cellulosic and waste biomass such as corncob, corn stock, and rice hull. The research aims to realize the creation of a sustainable society by synthesizing terephthalic acid (TPA) as a raw material of PET from furfural.
- **Results**
  He firstly developed a very simple synthetic process for the production of TPA from furfural.
- **Points in the Research**
  The production of commodity plastics from biomass is vitally important from the point of view of CO_2 recycling.
  Replacement of fossil fuel by furfural on the production of PET can realize CO2 immobilization of approximately 970,000 tons a year only in Japan and it will contribute to the construction of a sustainable society.
- **Future Perspectives**
  We will replace the general production process of PET in the world with the novel process through the improvement of the process efficiency and the cost reduction of the terephthalic acid prepared from inedible biomass.

Summary Chart

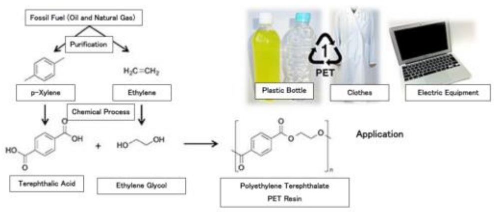


Fig 1. Synthesis of PET form fossil fuel

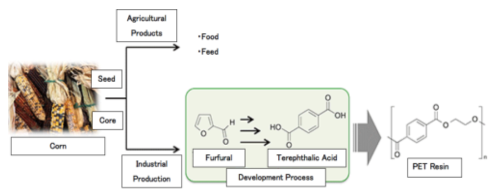


Fig 2. Synthetic route of PET form biomass

Program: ERATO “NAKAUCHI Stem Cell and Organ Regeneration”
Project Leader: Hiromitsu Nakauchi (Professor, Institute of Medical Science, The University of Tokyo)
Research Period: 2007-2012

- **Objectives**

  It is one of the ultimate goals to make organs from pluripotent stem cells in regenerative medicine. However, it is quite difficult to have three‐dimensional structural organ in vitro. For that reason, aiming at making transplantable three‐dimensional organs from patients own cells in vivo.
- **Results**

  By using Blastocyst complementation method (Fig.1)*, inject normal rat iPS cells into blastocyst from genetically pancreas deficient Pdx1 KO mouse and the construction of organ from normal iPS cells was elucidated. As shown in Fig. 2, it was successful to make rat derived pancreas in the offspring mouse body.

  *: Normal pluripotent cells are injected into some gene deficient mouse and are transplanted into the uterus of the expedient parent.
- **Key Points of the Research**

  Although it was pretty difficult to make three dimensional structures like an organ in vitro, rat pancreas was successfully made in the mouse body by using Blastocyst complementation method. These results are expected to make patient organs in the animal body in the future.
- **Future Perspectives**

  The mechanisms of formation of human organs in vivo will be studied in different species and the results will contribute to make human organs in other species. The research for a new paradigm of regenerative medicine technology is progressing.

Summary Chart

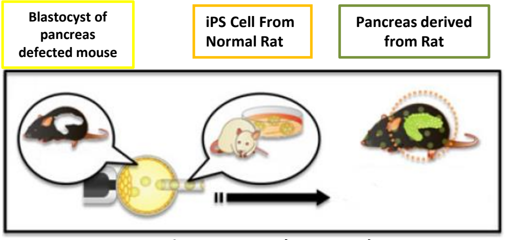


Fig.1 Balstcyte Complementation

Pancreas Derived from Rat

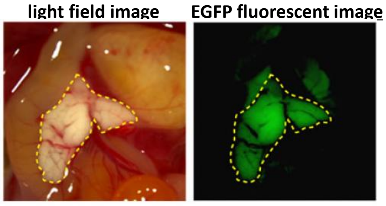


Fig. 2. Rat iPS derived pancreatic cells (Surrounded by dot) in Mouse

Program: ERATO “TAKEUCHI Biohybrid Innovation”
Project Leader: Shoji Takeuchi (Professor, Institute of Industrial Science, The University of Tokyo)
Research Period: 2010-2015

Objectives

Development of sensor technique for detecting odorants in the environment is behind other sensors. Therefore, it is expected to develop a high sensitive sensor to evaluate odorants as well as noses of dogs. Takeuchi’s research group has developed a cell sensor technique for detecting odorants in the environment by using three-dimensional spheroids expressing olfactory receptors, that mimics olfactory sensors of animals.

Results

Takeuchi’s research group expressed insect olfactory receptor complexes in cell spheroids and arranged them in a hydrogel microchamber array. The spheroids showed olfactory responses to their ligand, which diffused from chemical vapors through the thin surface aqueous layer.

Points of the Research

Takeuchi succeeded in developing cell spheroids reacting to volatile organic compounds in the air like an animal nose. That is the first case in the world. Takeuchi also showed that nasal mucus and lymph contain certain compounds required to bring about the olfactory response.

Future Perspectives

It is expected that sensor technique for distinguishing various odorants simultaneously and evaluating them in high sensitivity as noses of dogs will be achieved. The research is expected to clarify the importance of the role of nasal mucus, which has received little attention, and provide important knowledge in public health and sensory physiology research.

Summary Chart

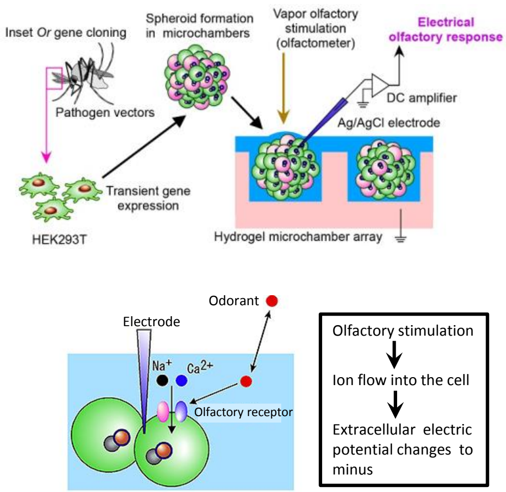


Fig. Scheme of the research

Program: PRESTO Research Area "Information Environment and Humans"
Research Project: "Real-World Intelligence Based on Large-Scale Web Information and Life Log"
Researcher: Tatsuya Harada (Professor, Graduate School of Information Science and Technology, The University of Tokyo)
Research Period: 2009-2012

Objective

Our goal is the development of the cognitive intelligence for the multimodal data which can be utilized in the real world. In order to realize the cognitive intelligence, it is a crucial issue to obtain the useful knowledge of the real world. For that purpose, we make full use of both the large amount of web data and the life-logs. By extracting the concept and context from the huge amount of such data, we develop the real world recognition algorithm that overcomes the semantic gap.

Achievements

Firstly, we designed the image features which are efficient and contain rich information for the visual recognition. By using the findings in designing those features, we developed the large scale visual recognition systems (Figure 1), and got the first place in the fine-grained object recognition task and the second place in the classification task in the ILSVRC2012 which is the most famous competition in the CV and AI communities. We also developed the automatic caption generation system to describe the details of the contents in an image (Figure 2).

Points in Research

We have developed the large scale image recognition system in 2012 which is the best visual recognition system in the shallow networks. The image captioning system is the pioneer work, because this system can learn from only the pairs of image and captions without any special annotations about a subject, a predicate and an object.

Future Perspectives

By realizing the real world recognition system, we can make a contribute not only to the information science, but to shedding light on a human's recognition process and the application of the robot intelligence in an aged society.

Summary Chart

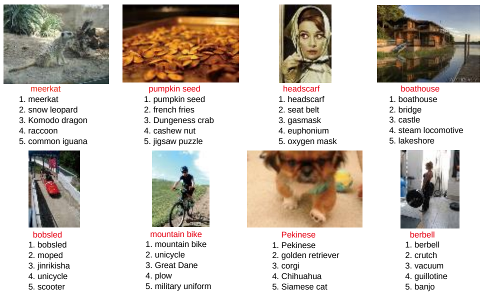


Fig. 1 Recognition examples of the visual recognition system

Fig. 2 Recognition examples of the image captioning system

Program: CREST Research Area "Development of system software technologies for post-Peta scale high performance computing"
Research Project: "Advanced computing and optimization infrastructure for extremely large-scale Graphs on post Peta-scale supercomputers"
Research Director: Katsuki Fujisawa (Professor, Institute of Mathematics for Industry, Kyushu University)
Research Period : 2011-2016

Objective

As for the attractive application fields of super-computers, large-scale graphical analysis and data processing are being highlighted recently. Graphical analysis is very useful in our society such as planning for the evacuation in large-scale disasters, introduction of effective social networks in public policy by governments and business management in companies. However due to the vast scale of the calculation and data, these applications are not necessarily easy based on the conventional approaches. So that the researcher is pioneering effective and ultra-large scale graphical processing based on the new technologies in high-performance computing.

Achievements

In 2014 and 2015, the Japanese supercomputer "K" (Fig.1) installed our graph algorithm took the first place in the benchmark contest "Graph500" which is most famous internationally in the field of graphical algorithm as shown in Fig.2. Our graph algorithm is based on newly developed highly scalable 2D division method.

Points in Research

The graphical analysis is very important as the various complicated phenomena in society and science can be mathematically expressed by graphs. Examples are transportation networks, financial transactions and neural networks in brain. This research made breakthrough for solving such huge problems which were very difficult to solve by conventional methods.

Future Perspective

The researches on solving large-scale problems by advanced graphical analysis will contribute to strengthening the basis for safe and secured society, and advancing science and technology through developing effective graph algorithms.

Summary Chart

Fig. 1 Japanese supercomputer "K" located in RIKEN.

Ranking	Super-Computer	Institute (Country)	G- TEPS
1	K computer	RIKEN (Japan)	17,977
2	Sequoia	LLNL (USA)	16,599
3	Mira	ANL (USA)	14,328
4	JUQUEEN	FZJ (Germany)	5,848
5	Fermi	CINECA (Italy)	2,567
6	Tianhe-2	NUDT (China)	2,061

Fig. 2 Top six institutes for "Graph 500" contest in 2014
(K computer took first place in 2014 and 2015 consecutively.)

Program: CREST Research Area "Advanced Application Technologies to Boost Big Data Utilization for Multiple-Field Scientific Discovery and Social Problem Solving"
Research Theme: "Innovating "Big Data Assimilation" technology for revolutionizing very-short-range severe weather prediction"
Research Director: Takemasa Miyoshi (Team Leader, RIKEN)
Research Period: 2013-2018

Objective

For daily weather forecast, the meteorological agency is utilizing super computers and large scale data obtained from networks of radars (on satellites and ground) and various observation systems. However, there are many phenomena which are difficult to predict. Especially at present, the phenomena of sudden local torrential rains are unpredictable as to the accurate regions and times of the outbreak. Sudden local torrential rains often cause disasters, because heavy and sudden rains caused by rapidly-grown cumulonimbus will sometimes submerge riverbeds locally in ten minutes at worst. The researchers aim to reduce the disaster of sudden local torrential rains by developing innovative 30-minute severe weather forecasting.

Achievements

The virtual simulations for predicting sudden local heavy rains by using archive data and supercomputer K (Fig.1) are under way by developing "big data assimilation" method which bridges between high-level simulations and dense/frequent observed data. Additionally, the "ensemble prediction" method based on 100 kinds of simultaneous simulations is successfully developed in order to enhance the accuracy of the simulation (Fig.2)

Points of the Research

The key factors for predicting sudden local heavy rains are based on the Japanese next-generation technologies including the phased array weather radar, new-generation geostationary weather satellite and Japanese fastest supercomputer "K".

Future Perspective

Based on the ongoing researches, this project aims to perform high-level and high-accuracy experiments for 30-minutes and real-time weather forecast in five years.

Summary Chart

Fig. 1 Supercomputer "K" for predicting guerrilla heavy rains

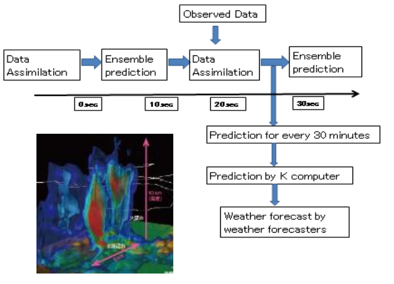


Fig. 2 30-minute severe weather forecasting system
(The inserted graphic is obtained from a weather radar)