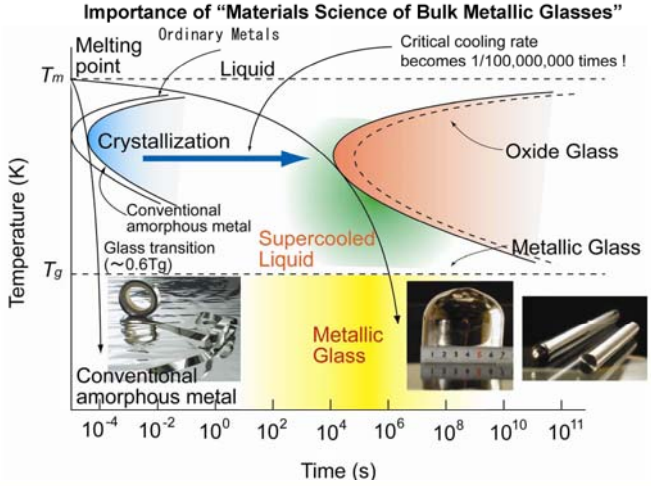
Materials Science of Bulk Metallic Glasses

Akihisa Inoue, Institute for Materials Research, Tohoku University, Japan

Importance of "Materials Science of Bulk Metallic Glasses"



Research Organization

An ultimate goal of this project will be establishment of a new disciplinary of 'Materials Science of Bulk Metallic Glasses' which will bring us new future metallic materials.

A01 Development of Optimized Fabrication Processes for Bulk Metallic Glasses
Principal Researchers -14 (3 groups), Supporting Researchers-26 (8 groups)
A02 Structures and Physical Properties of Metallic Glasses
Principal Researchers -15 (4 groups), Supporting Researchers-12 (6 groups)
A03 Computational Modeling and Prediction of Material Properties of Metallic Glasses
Principal Researchers -16 (5 groups), Supporting Researcher-1 (1 group)
A04 Deformation and Fracture Mechanics in metallic Glasses
Principal Researchers -18 (4 groups), Supporting Researchers-7 (3 groups)
A05 Nanocrystallization and Nanocomposite Microstructure Control of Metallic Glasses
Principal Researchers -10 (4 groups), Supporting Researcher-8 (4 groups)

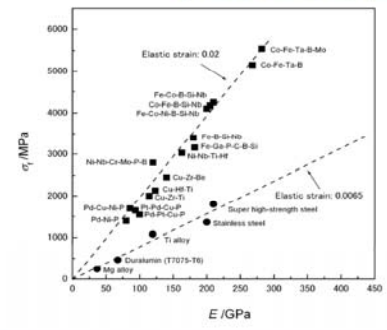
Total Principal Researchers 73 Supporting Researchers 54

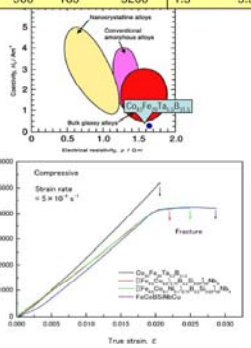
Joints Programs

1. Mechanism for ultimate phase stability
2. Deformation and fracture mechanics of bulk metallic glasses
3. Finding of extreme high functional capabilities establishment of nanofabrication techniques

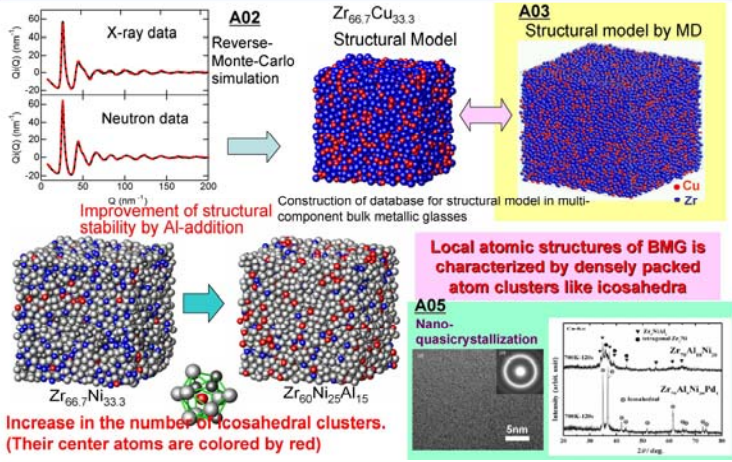
The Development of New Fe-based Bulk Glassy Alloys with Superhigh Strength and Excellent Soft Magnetic Properties (A01+A02)

Alloys	Diameter(mm)	Mechanical properties			Magnetic properties	
		H_v	E (GPa)	σ_f (MPa)	I_s (T)	H_c(A/m)
$[(Fe_{0.6}Co_{0.4})_{0.75}B_{0.2}Si_{0.05}]_{96}Nb_4$	4	1250	210	4250	0.93	1.7
$[(Fe_{0.5}Co_{0.5})_{0.75}B_{0.2}Si_{0.05}]_{96}Nb_4$	5	1220	210	4210	0.84	1.5
$(Fe_{0.8}Co_{0.2})_{73}Ga_4P_{11}C_5B_4Si_3$	5	900	185	3260	1.3	3.5



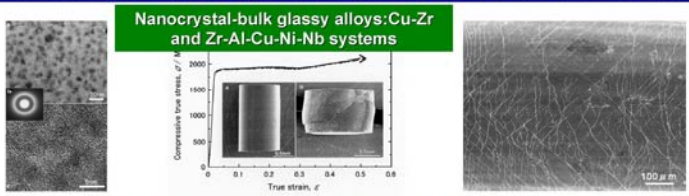


Structural Model of Bulk Metallic Glasses determined by synchrotron X-ray, neutron and electron diffractions (A01+A02+A03+A05)



Development of new bulk metallic glasses with good mechanical properties Part 1 (A01)

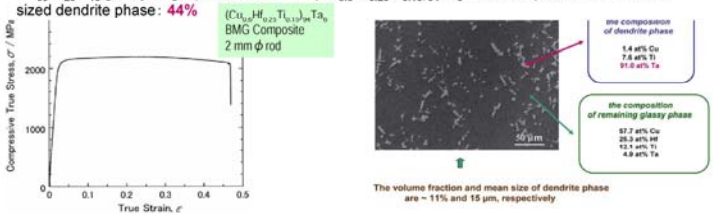
Nanocrystal-bulk glassy alloys:Cu-Zr and Zr-Al-Cu-Ni-Nb systems



Micron-sized crystal-bulk glassy alloy : Cu-Hf-Ti-Ta system (dendrite)

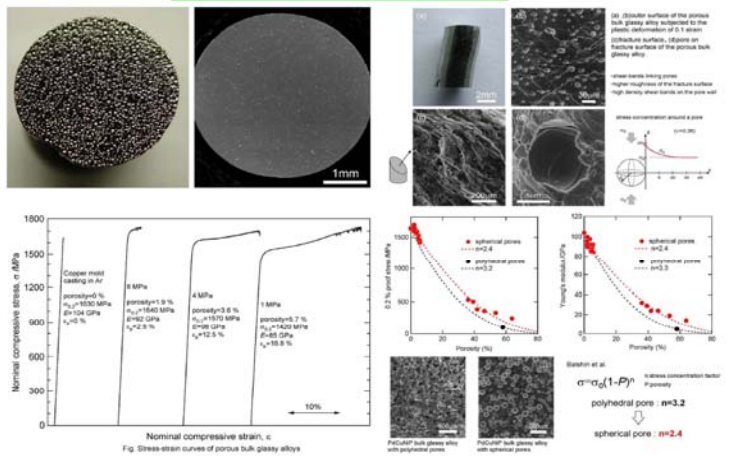
A BMG composite containing micron-sizeddendrite phase with a largest plastic strain

$Cu_{60}Hf_{25}Ti_{15}$ glassy single phase: 1.6% → $(Cu_{0.6}Hf_{0.25}Ti_{0.15})_{94}Ta_6$ BMG composite with a micron-sized dendrite phase: 44%



Development of new bulk metallic glasses with good mechanical properties Part 2 (A01)

Stress dispersion : porous bulk metallic glasses

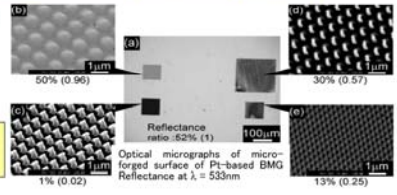


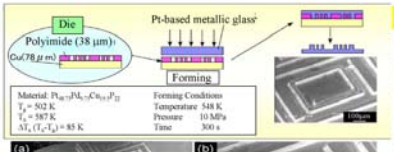
Superplastic nano-forming of metallic glasses (A01+A04)

FIB is used for the fabrication of glassy metal nano-molds

Creation → mass production of surface structures (2D/3D)

SEM microphotographs of die forged periodically nano-structured surface of Pt-based BMG
Periodic intervals of : (b,c,d); 800 nm, (e):400 nm





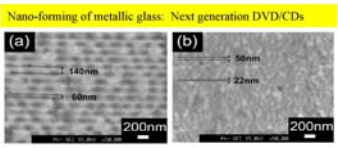


Fig. SEM photograph of super-plastically formed patterns on Pt-based metallic glass using a nano-die made by FIB deposition, and RIE of SiO_2 .
(a) Track distance 140 nm, data bit pattern width 60 nm
(b) Track distance 50 nm, data bit pattern width 22 nm

Future Studies in Materials Science of Bulk Metallic Glasses

(1) Based upon systematic understanding of structural stability mechanism of thousands BMGs by the group in IMR of Tohoku University, we will develop a new guiding principle for preparation of new BMGs in corporation of A01, A02, A03 and A05.

(2) By accumulating high reliable experimental data for deformation and fracture mechanics and atomic structures, we will level up the technique of deformation and fracture simulation in BMGs and establish a method to predict their mechanical propertiesin corporation of A01, A02, A03 and A05.

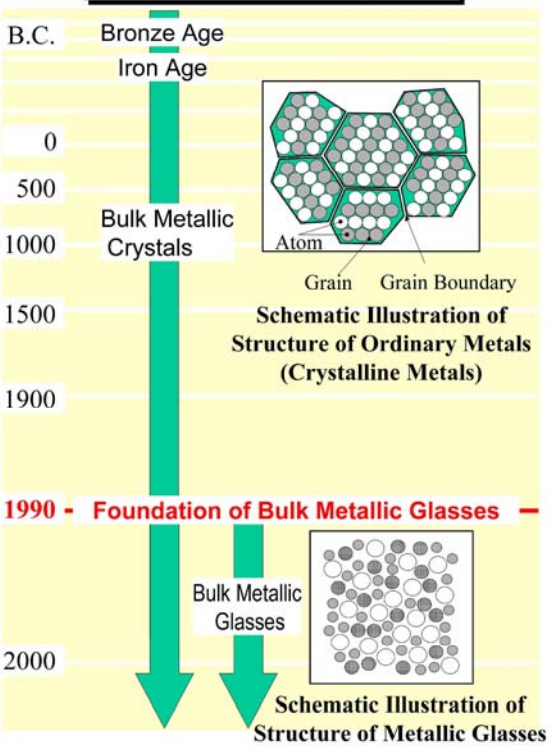
(3) We will search for new preparation and fabrication processes of BMGs to precisely control their composition, structure, texture and surface morphology in atomic and nano-scale levels and search their superb mechanical and functional properties in corporation of all groups.

Establishment of a new disciplinary of 'Materials Science of Bulk Metallic Glasses' for applications as new future metallic materials

Stabilization of Supercooled Liquid and Development of Bulk Metallic Glasses

Akihisa Inoue, Institute for Materials Research, Tohoku University, Japan

Transition of Bulk Metallic Materials After Recorded History



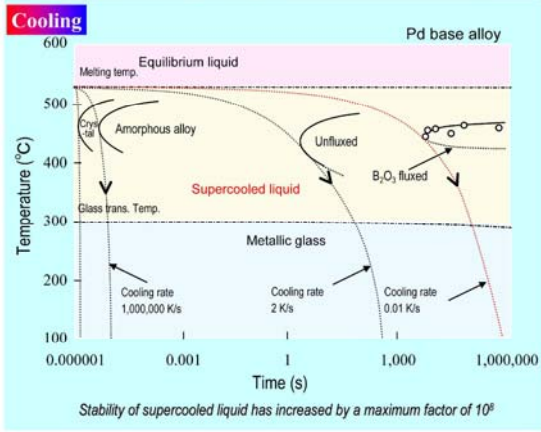
Typical bulk glassy alloy systems reported up to date together with the calendar years when the first paper or patent of each alloy system was published.

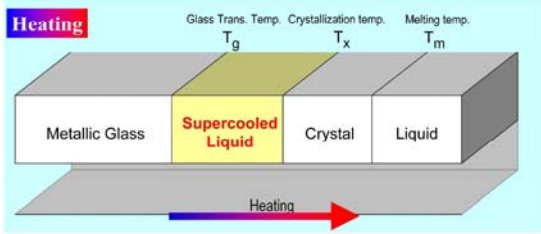
1. Nonferrous alloy systems	Year
Mg-Ln-M (Ln=Lanthanide Metal, M=Ni,Cu,Zn)	1988
Ln-Al-TM (TM=Fe,Co,Ni,Cu)	1989
Ln-Ga-TM	1989
Zr-Al-TM	1990
Ti-Zr-TM	1993
Zr-Ti-TM-Be	1993
Zr-(Ti,Nb,Pd)-Al-TM	1995
Pd-Cu-Ni-P	1996
Pd-Ni-Fe-P	1996
Pd-Cu-B-Si	1997
Ti-Ni-Cu-Sn	1998
Cu-(Zr,Hf)-Ti	2001
Cu-(Zr,Hf)-Ti-(Y,Be)	2001
Cu-(Zr,Hf)-Ti-(Fe,Co,Ni)	2002
2. Ferrous alloy systems	**Year**
Fe-(Al,Ga)-(P,C,B,Si,Ge)	1995
Fe-(Nb,Mo)-(Al,Ga)-(P,B,Si)	1995
Co-(Al,Ga)-(P,B,Si)	1996
Fe-(Zr,Hf,Nb)-B	1996
Co-(Zr,Hf,Nb)-B	1996
Ni-(Zr,Hf,Nb)-B	1996
Fe-Co-Ln-B	1998
Fe-Ga-(Cr,Mo)-(P,C,B)	1999
Fe-(Nb,Cr,Mo)-(C,B)	1999
Ni-(Nb,Cr,Mo)-(P,B)	1999
Co-Ta-B	1999
Fe-Ga-(P,B)	2000
Ni-Zr-Ti-Sn-Si	2001
Ni-(Nb,Ta)-Zr-Ti	2002
Fe-Si-B-Nb	2002
Co-Fe-Si-B-Nb	2002

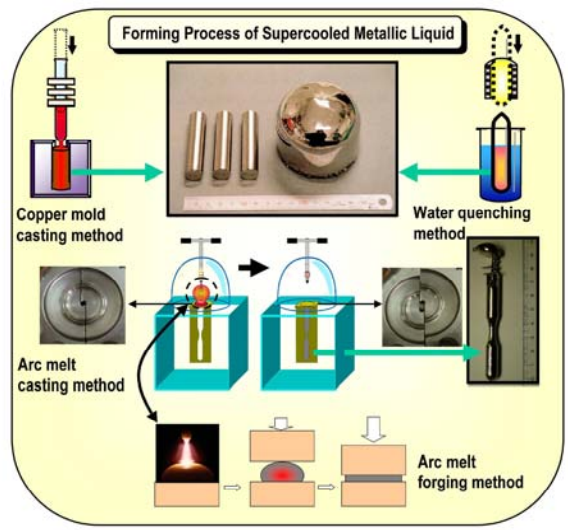
Alloy systems in red were found by Sendai Group

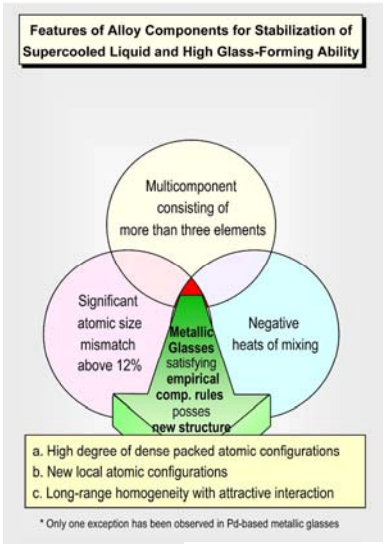
Stabilization of Supercooled Liquid

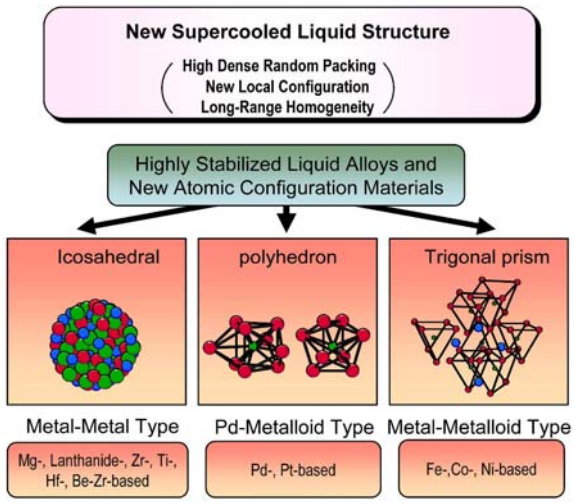
Supercooled liquid state can be stable in a wide ranges of temperature and time in the course of heating and cooling as well. This stabilization phenomenon enable us to utilize for fundamental researches and engineering developments. The resultant outcomes lead to the establishment of the supercooled liquid stabilizing techniques.

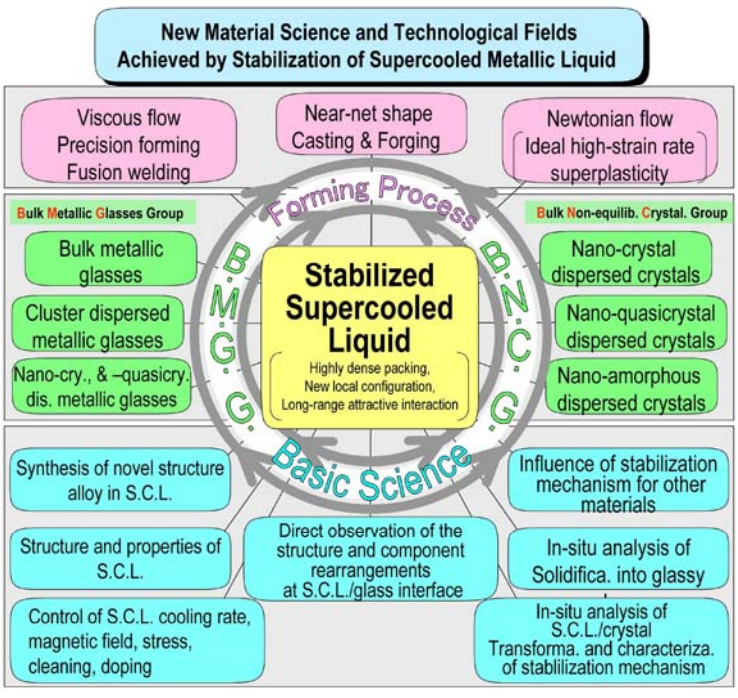












The Characteristics and Their Application of Nonequilibrium Metallic Materials Group Containing Bulk Metallic Glasses Developed by the Use of the Stabilization Phenomena of Supercooled Liquid

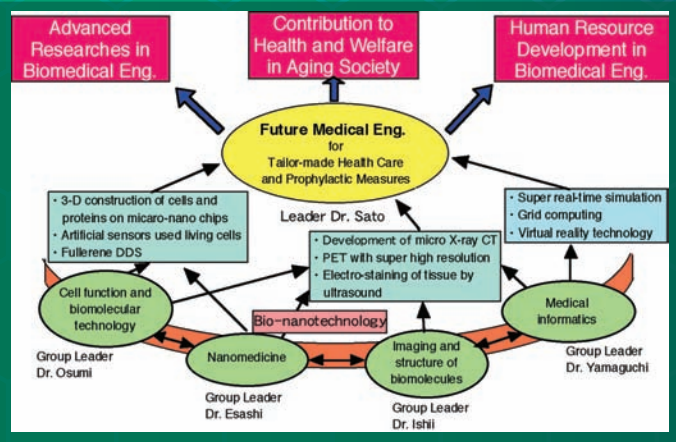
	Characteristic	Final Production	Developing
Zr-, Ti-, Ni-, Cu-base	high strength high ductility high impact fracture energy high elastic elongation high repulsion power high distortion energy loss high fatigue strength high corrosion resistance	optical materials precise abrasive materials joining materials frame materials sporting materials precise joining terminal for optical fiber secondary forming processing technique of simultaneous S.C.L. molding/forging technology	bio/medical materials spring materials antivibration materials high-speed carrier materials shock absorption materials hydrogen transmission thin films coriolis meter microactuator laser Disk producing mold materials
Fe-, Co-base	soft magnetism extremely low coercivity super high permeability high magnetic flux density high strength high corrosion resistance	choke coil electric power trans sensor magnetism shield precise abrasive materials supercooled powdersl producing technology	electric & magnetic materials power transformer motor elements nano-scale-positioning controll elements voice coil motor separator
Nd-Fe, Fe-base	hard magnetism high coercivity high energy product		electric and magnetic materials (permanent magnets)
Pd,- Pt-base	high efficiency electrode (chlorine generator) high strength high ductility high corrosion resistance	electrode materials precision die decoration materials precise S.C.L. processing / joining technology	bio/medical materials precision antivibration materials hydrogen transmission thin films laser Disk producing mold materials
Mg-, V-base	battery characteristic low specific gravity high electric discharge capacity		battery materials hydrogen transmission thin films
Al-, Mg-base	high specific strength high elongation high heat resistant strength high corrosion resistance high abrasion	high-speed operation machinery materials robot materials die materials, wheelchair, Motor bike, fishing rods, Tools, sporting materials (baseball bat, golf club, tennis racket etc.)	high-speed carrier materials potable electronic gadgets materials

Future Medical Engineering based on Bio-nanotechnology I

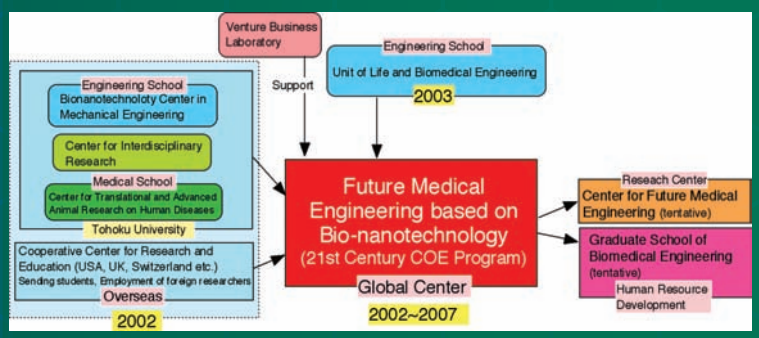
Future Medical Engineering based on Bio-nanotechnology 21st Century COE Program

Introduction

Advanced research at Tohoku University has led the way in the fields of cell function and biomolecular technology, nanomedicine, imaging and structure of biomolecules, and medical informatics. This program aims to unite various technologies in order to develop the ultimate in prophylactic measures for age-dependent diseases, using tailor-made diagnostic and therapeutic procedures. The overall objective of this program is to form a global center of excellence in biomedical engineering.



Education System



a. Faculty meetings: Educational policy, self-assessment, and an advisory system for students.
b. New curriculum: A new curriculum for students enables students to acquire the necessary experience and knowledge.
c. Education center: An administration office where faculty and students can conduct research and further their education.
d. Nomadic education system: students will be selected to participate in cooperative research at universities abroad.
e. Itinerant education system: self-reliant students will be selected and trained individually under a special apprenticeship program.

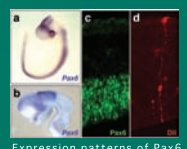
Research in Cell Group

N.Osumi
Department of Developmental Neurobiology, Graduate School of Medicine

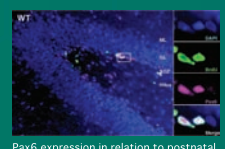
M.Sato
Department of Bioengineering and Robotics, Graduate School of Engineering

H.Wada
Department of Bioengineering and Robotics, Graduate School of Engineering

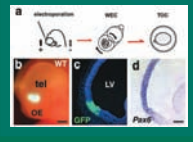
N.Osumi



Expression patterns of Pax6 transcriptional factor during brain development.
(a) At embryonic day (E) 11,
(b) At E13,
(c) Section of E16 neocortex.
(d) A neuroepithelial cell visualized with fluorescent dye, DiI.

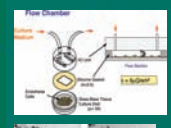


Pax6 expression in relation to postnatal neurogenesis typically observed in the hippocampal dentate gyrus.

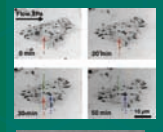


Direct method transferring exogenous genes into the brain of mammalian embryos by electroporation.
(a) Strategy.
(b) Expression of the gene(s) starts after a few hours.
(c) A section of the sample shown in (b).
(d) A neighboring sectionof (c), showing a focal introduction of the gene.

M.Sato

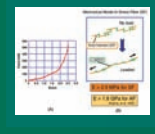


A flow chamber was designed to expose fluid shear stress to cultured endothelial cells to simulate human body conditions.



When an endothelial cell is laid in shear flow condition (shear stress = 2 Pa) changes in actin filaments and focal adhesional proteins are seen.

Micro-tensile testing process for the stress fiber isolated from cultured smooth muscle cells is shown. Stress fibers have very important roles to keep cell shape from the view points of biomechanics.



Results of tensile testing for stress fibers
(A) A typical example of force - strain curve of an isolated stress fiber from smooth muscle cells
(B) Mechanical model of stress fiber and the Young's modulus
Stress fibers had characteristic properties such as high extensibility, nonlinear elasticity, residual strains and hysteresis.

H.Wada

The outer hair cell (OHC) in the organ of Corti produces force by its motility in response to its membrane potential change for the fine tuning and the wide dynamic range of hearing.

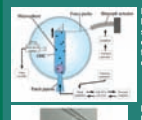


Fig. 1.
Block diagram of the measurement system for the OHC response to electrical stimulation. The active force was obtained from this deflection.

Fig. 2.
Photograph of the OHC attached to the force probe and patch pipette at the apical and basal ends, respectively.

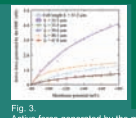


Fig. 3.
Active force generated by the motility of OHCs versus their membrane potentials.

The structure of the cortical lattice plays an important role in the motility of the OHC.

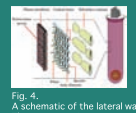


Fig. 4.
A schematic of the lateral wall.
There are protein motors termed prestin.

Fig. 5.
An AFM image of the cytoskeleton in the OHC lateral wall.
(a) The position of the scanning area.
(b) The AFM image acquired in the rectangular region in panel (a).
(c) A schematic of the domains and filaments in panel (b).

Fig. 6.
A scheme of the cortical lattice.

Future Medical Engineering
based on Bio-nanotechnology Program

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Future Medical Engineering based on Bio-nanotechnology II

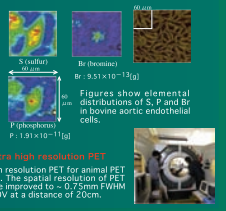
Future Medical Engineering based on Bio-nanotechnology 21st Century COE Program

Development of Micro-PIXE Camera, Micron CT and Ultra high resolution PET

Keizo Ishii Ph.D.
Department of Quantum Science and Energy Engineering,Accelerator Science and Engineering

1. Micro PIXE Camera
The distribution of elements in the cell can be observed by the Micro-PIXE Camera.

2. Micron CT
X-ray CT in which the interior structure of living cells can be imaged by using characteristic X-ray.



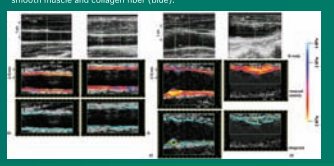
Figures show elemental distributions of S, P and Br in bovine aortic endothelial cells.

3. Ultra high resolution PET
A high resolution PET for animal PET study. The spatial resolution of PET can be improved to ~ 0.75mm FWHM for FOV at a distance of 20cm.

Electronic-Based staining using Ultrasound

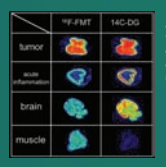
Hiroshi Kanai Ph.D.
Dept. of Electronic Engineering, Electronic Control System

Common carotid arteries of two healthy male subjects ((a) and (b)) and two male patients with hyperlipidemia ((c) and (d)). (Top) Conventional echo system, (middle) the *in vivo* measured spatial distribution of elasticity, and (bottom) the categorized results, of lipid (yellow) and of the mixture of smooth muscle and collagen fiber (blue).



A New Tumor Marker for PET

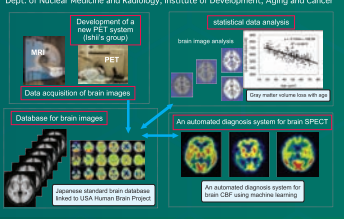
Masatoshi Itoh M.D., Ph.D.
Division of Nuclear Medicine, Cyclotron Radioisotope Center



A newly made ^{18}F-fluoro-methyl-tyrosin (left column) unlike deoxy-glucose (right column) is expected to differentiate tumor and inflammation using positron tomography.

Structural and Functional Imaging of the Brain

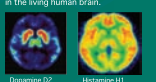
Hiroshi Fukuda M.D., Ph.D.
Dept. of Nuclear Medicine and Radiology, Institute of Development, Aging and Cancer



Development of Molecular Imaging and its Application to Medical Science

Kazuhiko Yanai M.D., Ph.D.,
Department of Pharmacology, School of Medicine

1. PET Imaging of Specific Neurotransmission in the human brain
Figures illustrate the PET visualization of specific dopamine and histamine H1 receptors in the living human brain.



Development of specific C-11 and F-18 receptor ligands

2. PET Imaging of "Subjective Feelings" by 3D-PET and O-15 Water

Using 3D-PET and O-15 water, a subjective feeling of sleepiness can be imaged.

Imaging Group

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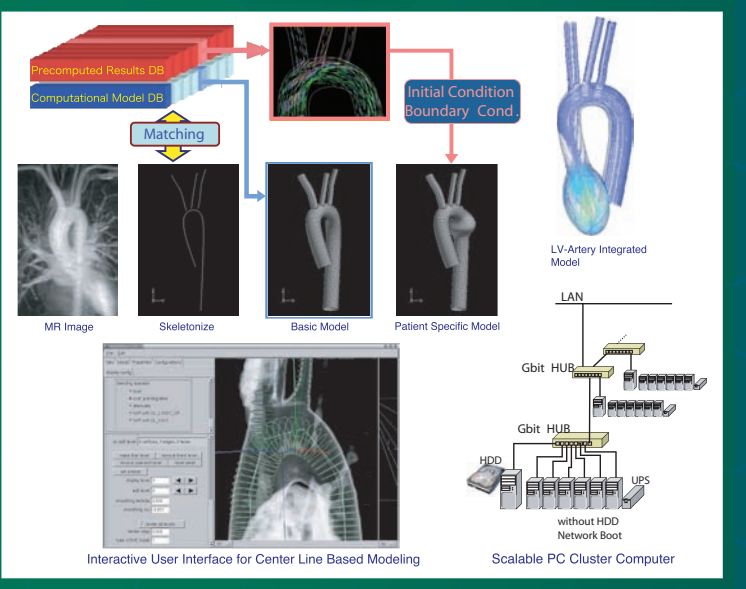
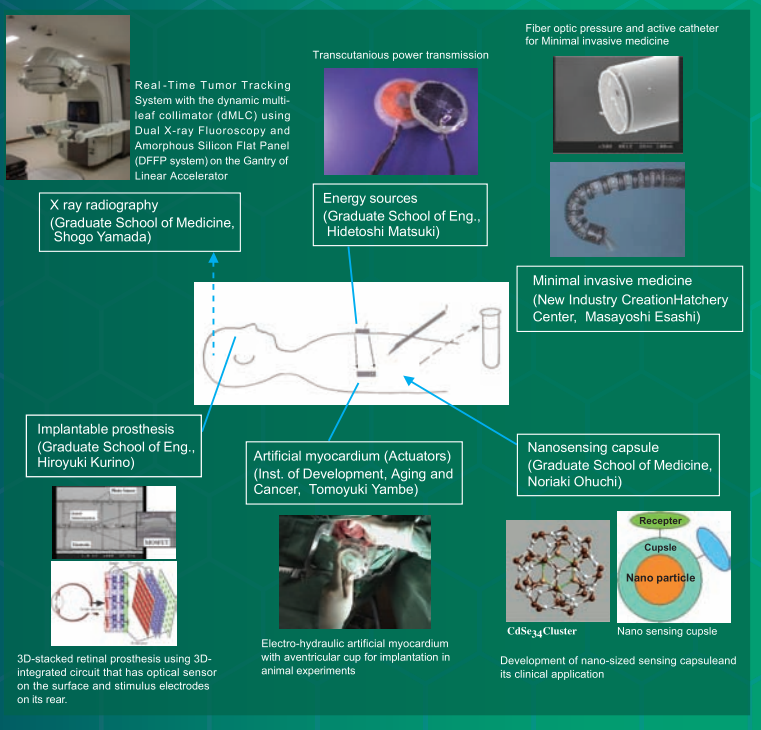
H.Kanai Department of Electronic Engineering, Graduate School of Engineering
H.Fukuda Department of Nuclear Medicine and Radiology, Institute of Development, Aging and Cancer
K.Yanai Department of Pharmacology, Graduate School of Medicine

Medical Informatics

T.Yamaguchi Department of Bioengineering and Robotics, Graduate School of Engineering
A.Takahashi Department of Neuroendovascular Therapy, Graduate School of Medicine
T.Hayase Super Real-Time Medical Engineering Laboratory, Targeted Research Division, Transdisciplinary Fluid Integration Research Center, Institute of Fluid Science
M.Yoshizawa Advanced Information Technology Research Division, Information Synergy Center, Tohoku University



Vascular trees are represented using their centerlines and their normal planes defined by a combination of normal and binormal vectors. Each branch is modeled separately and connected using an overset (or a chimera) mesh technique when fluid mechanical computations are made. To model each vessel geometrically, we devised an interactive clinical interface for MR images using a graphical user interface window. Finally the image data, its structure, computational model based on the structure, and the precomputed results are stored in a comprehensive database.



3D-stacked retinal prosthesis using 3D-integrated circuit that has optical sensor on the surface and stimulus electrodes on its rear.

Electro-hydraulic artificial myocardium with aventricular cup for implantation in animal experiments

Development of nano-sized sensing capsuleand its clinical application

Nanomedicine Group

M.Esashi New Industry Creation Hatchery Center
N.Ohuchi Division of Surgical Oncology, Graduate School of Medicine
H.Matsuki Department of Electrical and Communication Engineering, Graduate School of Engineering
S.Yamada Division of Therapeutic Radiology, Graduate School of Medicine
H.Kurino Department of Bioengineering and Robotics, Graduate School of Engineering
T.Yambe Department of Medical Engineering and Cardiology, Institute of Development, Aging and Cancer

Future Medical Engineering based on Bio-nanotechnology Program

URL http://www.fmbe.coe.tohoku.ac.jp E-Mail: secretary@fmbe.coe.tohoku.ac.jp
Department of Bioengineering and Robotics, Tohoku University
01 Aoba, Aoba-ku, Sendai 980-8579, Japan Tel/Fax +81-22-217-7005

Tohoku University Electro-Related Departments
21st Century COE Program

"System Construction of Global-Network-Oriented Information Electronics"

Awarded by Ministry of Education, Culture, Sports, Science and Technology, Japan

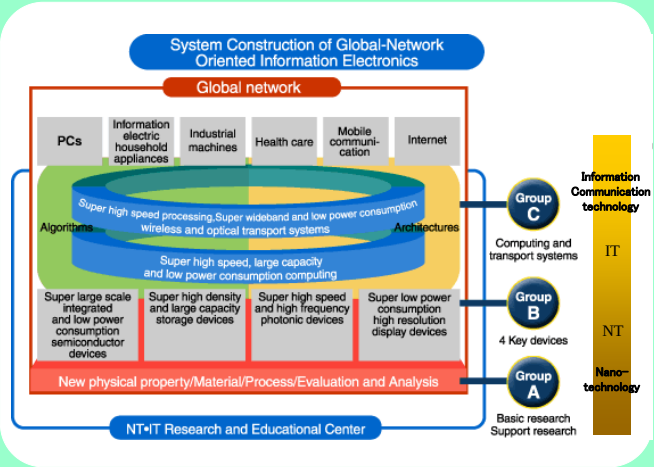
Objective

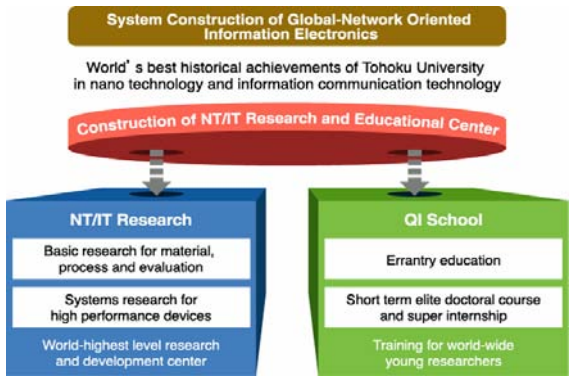
The industries of semiconductor, magnetic recording and liquid crystal are strategically very important in Japan for constructing an advanced information communications society of our country. They are keenly competing with both sides of the Europe/America and Asia. It is highly desirable to use the wisdom of universities for keeping a long-term competitive edge in these fields. The Tohoku University has long been conducting the world-class original researches in the fields of the information communication technology (IT) and the nano-technology (NT) for material and device developments. The Department of Electronic Engineering was selected by Ministry of Education, Culture, Sports, Science and Technology, Japan as a educational and research COE due to its great research achievements. With the Department of Electronic Engineering as a core, an NT-IT research and educational center has been founded to form the world-strongest interdisciplinary COE in the fields of electrical communication and electronic engineering. Department of Electrical and Communication Engineering, Research Institute of Electrical Communication (RIEC) and New Industry Creation Hatchery Center (NICHe) join this program to expect a strong synergistic effect. Basic research achievements of material process evaluation etc. will be widely utilized for applied research of the advanced devices and systems. The original technologies created by this program will strengthen the international competitive power of the country.

NT-IT Research and Educational Center

For managing the NT-IT research and educational center, a steering committee has been established. The steering committee consists of a COE leader, 3 research leaders, a QI school leader and a few external intellectuals. The committee determines all the important matters for managing the COE program. The NT-IT research is promoted in a top-down manner under the strong leadership of the COE leader. Following three research groups have been set up and are closely cooperating one another for acquiring the international leadership in the fields of next generation electronics devices, communications networks, etc.

A: Fundamental Research and Analysis/Evaluation Technology
B: Semiconductor, Magnetic, Optical and Display Devices
C: Computing and Transport Technology

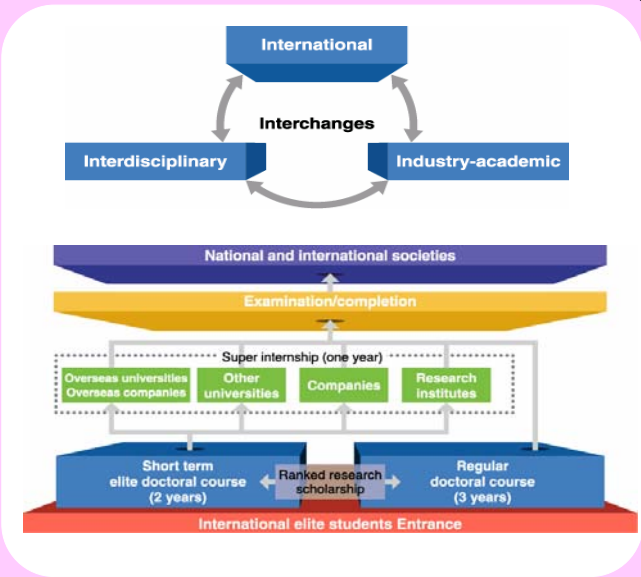




Education Plan

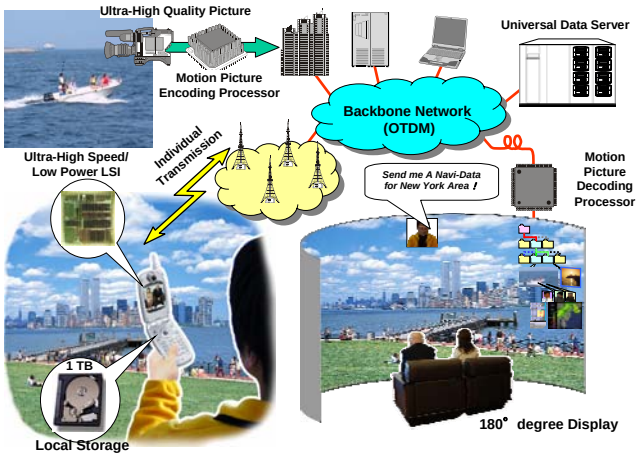
In the COE program, the QI school has been established. Practical lecture and seminars by the first-class foreign researchers are introduced into the curriculum for the second half of the doctoral course. Worldwide excellent students will be solicited as elite doctoral candidate students in the short term course of the QI school. Also the best students will be selected from the regular courses. They are given 3-ranked research grant.

The QI school will hold annually a international mini-conference organized by students. The first-class researchers will be invited to this conference to give interdisciplinary tutorial lectures. The students will be trained to improve their ability to present and debate in English. Elite doctor students in the short term course will be dispatched for an errantry education to the industries overseas research institutes etc. under the young researcher training and super internship program of the QI school. The QI school is employing postdoctoral researchers to conduct international joint researches in cooperation with the first-class researchers. This program is considered as the gateway to become worldwide-class researchers with cutting-edge technologies.



Research Activities

Universal Visual Communication

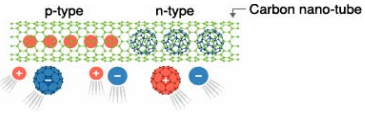


Group A Basic research/support research

Material/Process

Development of control scheme for nano-scopic self-assembled surface material process

Nano-size electric devices

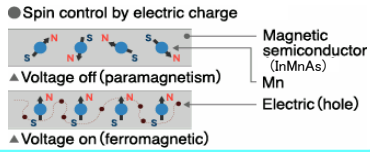


The nanometer-scale technology will become important as a technical infra-structure for the realization of the next generation of information/communication society. To develop this technology, it is inevitable, at first, to establish the method of material structure-control in the nanometer scale. In this research, we develop a method for the realization of very small-sized and high-speed electronic circuits by using plasma-nano technology. To be more concrete, a novel different-polarity-ion plasma, which consists of an alkaline metal positive-ion (A^+) as an electronic donor, and the halogen (Ha^-) or fullerene molecule (C_{60}^-) negative-ion as an electronic acceptor, is generated and utilized to create the brand-new structure inside carbon nanotubes which include the hollow inner space with a diameter of several nanometers. Finally, our ultimate goal of this research is the development of the nano-scaled nonlinear electronic devices using our novel-structured carbon nanotubes, which enable ultra high-speed computing.

New physical properties

Development of semiconductor electronics utilizing electric change and spin

Magnetic semiconductors
Spin devices with 3 terminals

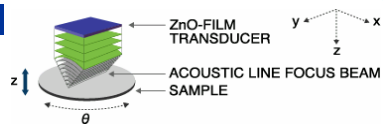


Semiconductor devices have so far advanced using the electron charge. We expect new functionalities and new paradigms can be realized by using not only charge but also spin of electrons. The semiconductor electronics realized by using both charge and spin of an electron is called semiconductor spintronics. Our goal is to establish the foundation of semiconductor spintronics and to realize novel schemes such as integrated nonvolatile memory - logic, spin switches, high sensitivity magnetic sensors, ultra high-speed photonic switches, and devices for quantum computing and quantum communications.

Evaluation/Analysis

Development of next generation process evaluation method using supersonic micro spectroscopy

Super high accuracy physical and chemical analysis : 6th order high accuracy evaluation



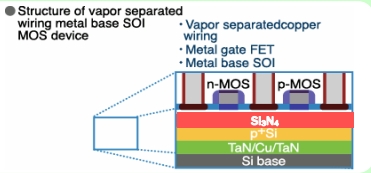
Ultrasonic micro-spectroscopy (UMS) has been developed as a new technology for characterizing and evaluating isotropic/anisotropic solid materials. This is an original technology developed at Tohoku University. The characterization/evaluation can be conducted by measuring with superior accuracy the propagation characteristics (phase velocity and attenuation) of the leaky surface acoustic waves (LSAWs), propagating on the water-loaded specimen surface, and the bulk longitudinal and shear waves. This technology is applied for the development of the higher quality single crystals ($LiNbO_3$, $MgO:LiNbO_3$, $LiTaO_3$, etc.) and the device fabrication processes for future highly functional SAW devices and optical devices. This technology is expected to become a next generation basic technology to develop new materials and to resolve various materials problems in science and industry.

Group B 4 Key devices

Super large scale integrated and low power consumption semiconductor devices

Development of super large scale integrated, low power consumption and high performance system LSI

Up to 20 GHz
100~1000 TOPS/W

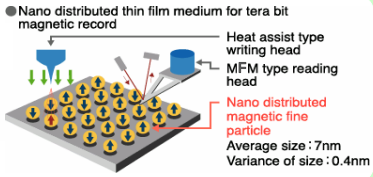


For leading the 21st century network information society, the materials, processes, devices, circuits, and system technologies are necessary to develop for reducing power consumption as well as improving the integration density and speed performance of system LSI's. To be concrete, we develop the high precision device technology which improves the current drivability by 10 times or more, the high-density interconnect technology which enables high-speed signal propagation of above 10GHz, the high precision process technology for realizing fluctuation-free highly-reliable/low-power devices. Furthermore, we integrate these technologies to realize highly integrated system LSI's.

Super high density and large capacity storage devices

Development of nano size distributed particle type thin film medium for tera bit magnetic record

Super high surface recording density
1 Tbit/inch2

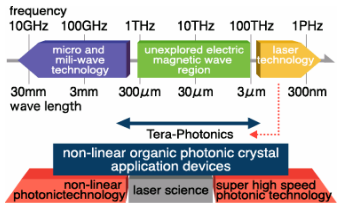


To realize ubiquitous networks, where all information is transferred instantaneously to all directions on a global scale, mass storage devices are necessary. For recording density of more than 300 Gbit/inch^2, establishment of new media fabrication technology, which realizes average ferromagnetic crystal particle diameter 7 nm and its distribution width of 0.4 nm, is indispensable. In this research, to break the limit of the conventional nano structure control technique of thin films based on the conventional sputtering method, we develop the new type of chemical synthesis method for the nano particle fabrication and also self-organization technology to attain an ultra uniform nano-scaled magnetic particle arrays, aiming the ultra high recording thin film medium higher than 1 Tbit/inch^2, consisting the nano-scale distributed ferromagnetic particle array.

Super high speed and high frequency photonic devices

Development of super high speed photonic devices by exploring super small size and wideband light source

THz light source
Large capacity and high speed optical devices



For exploitation of the frequency resources for the advancement of information communications, it is necessary to develop devices using tera-hertz (THz) bands between optical wave and microwave. Our research aims at ultra high-speed optical-communications technology of the next generation, making full use of the super-wideband characteristic of optical-wave. In this research, we develop a highly efficient and compact optical source based on high efficient wideband non-linear wavelength conversion, and ultra high-speed light control techniques. Inter-conversion technique between optical wave and millimeter/THz wave as well as an optical fiber network diagnosis technique are also studied.

Super low power consumption and high resolution display devices

Establishment of basic technology of liquid crystal and realization of super low power consumption and high performance display

High speed response : less than 1 msec
Super low power consumption : 1/10~1/100
Large area/wide-angle : diagonal length
6~10 m, 180° Paper like display

Demand for a high performance electronic display is increasing as a man machine interface of an information system. It is strongly required to reduce the power consumption and to improve the quality. We have analyzed and developed control technology of liquid crystal surface alignment, theory and technology of polarization control, etc. Based on these achievements, we develop a super-low power consumption/large size display based on a new principle.

Group C Computing and transport systems

Computing

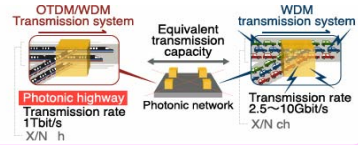
Construction of super high speed and large capacity computing algorithms and architectures

For a new generation telecommunication systems, it is necessary to develop advanced digital signal processing algorithms and VLSI's. Especially, adaptive digital signal processing is widely used in processing the voice, data, pictures, images, etc. In this research, we develop intelligent signal processing algorithms based on genetic and evolutionary algorithm, unlike the conventional signal processing based on the classic linear system theory, aiming at the realizations of high-speed high parallel VLSI's and their applications to information communications.

Photonic transport systems

Development of super high speed photonic transport and network systems

Tera bit/s
Time division duplex photonic transmission

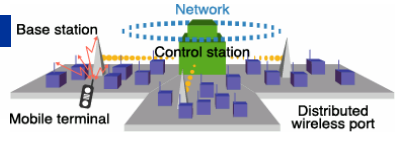


A lot of experiments on optical transmission using wavelength division multiplexing (WDM) which exceeds several hundreds of channels have been successfully reported. These experiments demonstrate that the performance of WDM systems is almost approaching its ultimate capacity. However, increasing the number of WDM channels makes the wavelength control more enormous and complicated. In the networks of the 21st century, it is important to exchange an increasing amount of information at a very high speed and with a large capacity. In addition, ultrahigh-speed optical signal processing will also be strongly required. This research aims at establishing fundamental technologies that enable us to handle ultrashort optical pulses in the femtosecond regime as an information bit in optical transmission. Indeed, such an ultrahigh-speed performance and flexibilities are crucial in the next generation optical networks. These technologies will have a great industrial and academic impact and contribute as a driving force of the next generation optical communication research.

Wireless systems

Realization of super high speed wireless communication network systems

Over 100Mb/s transmission
Virtual cellular concept



Ultimate goal of our desire is to communicate with anyone, anytime, from anywhere to exchange any type of information. To realize this, wireless technology plays an important role. Since information transferred over the Internet is becoming increasingly rich, there will be a strong demand for broadband data transmissions of over 100Mbps and close to 1Gbps even in mobile communications systems. To realize such a high-speed mobile communications network, we develop a giga-bit wireless technology (broadband adaptive wireless signal transmission technique and multiple access technique). As the transmission rate becomes higher, the cell size should be smaller due to limitation in transmit powers. Virtual cellular system (VCN), in which self-organized distributed small wireless ports are deployed, is under the study to realize pico-cell wireless networks.

21st Century Center Of Excellence Program (Oct. 2003-Mar. 2008)

The Exploration of the Frontiers of Mechanical Science Based on Nanotechnology

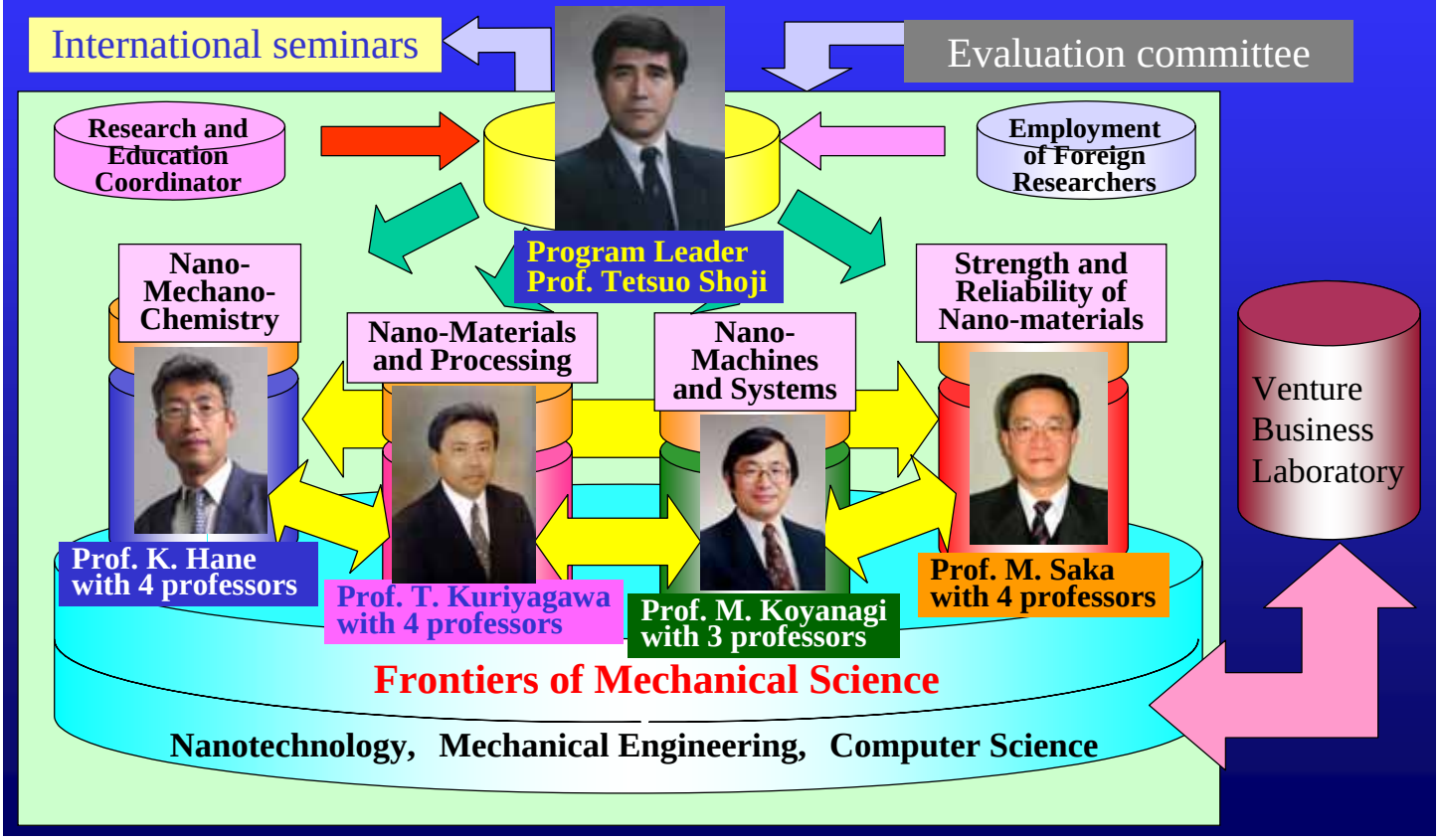
Program Summary

Advanced research in the field of new Mechanical Sciences will be undertaken in the following four areas: Nano-mechanochemistry, Nano-materials and processing, strength and reliability of Nano-materials, and Nano-machines and systems. Through a double-spiral research and education program that is a blend of interdisciplinary and international research and education, we intend to establish a world-class research & education center of mechanical science based on nanotechnology.

Objective

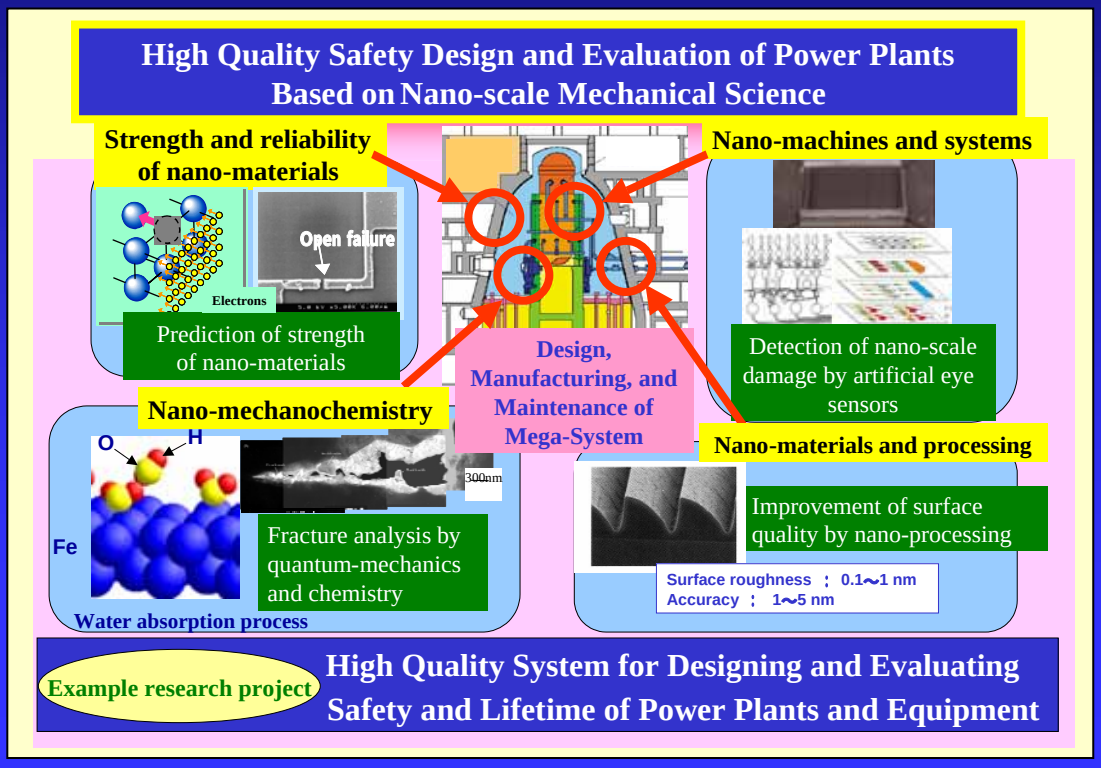
The objectives are to foster training of talented persons to participate internationally by including advanced levels of research in their education; to establish a new field of mechanical science to meet the needs of functional and structural designs for next-century machines through the scientific rationale of nano-scale from the broad point of mechanical engineering or continuum body; to establish an advanced center that blends mechanical, electrical, materials and chemistry fields based on the phenomenological approach and on the findings of essential principles in the nano-field. In order to satisfy the above objectives, international research and education satellite centers that will enable doctoral students to undertake international research internships through the double-spiral research and education programs will be established in America, Europe and Asia.

World-class Research & Education Center of Mechanical Science Based on Nanotechnology



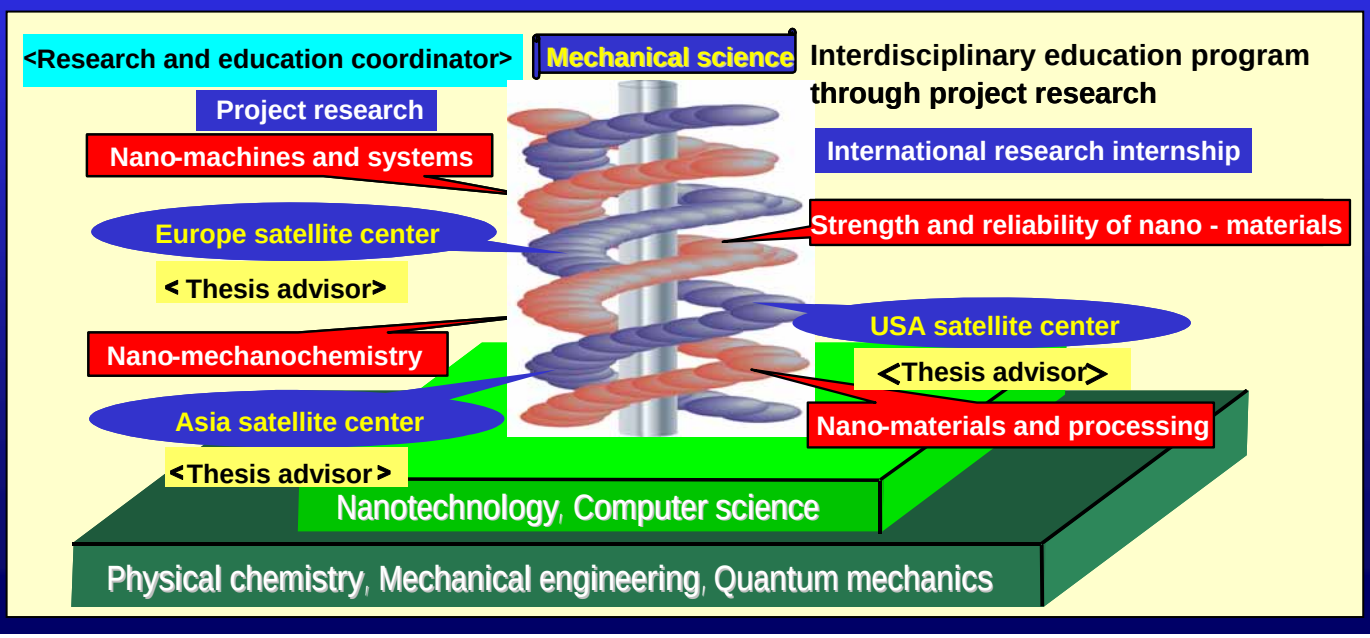
Research Project

Due to the rapid development of nanotechnology, there is a strong need to approach mechanical engineering at the nano- and atomic-scale level. This program will satisfy the above requirements by constructing a new and advanced academic foundation, which is named "The Exploration of the Frontiers of Mechanical Science Based on Nanotechnology", by including physical chemistry, quantum mechanics and computer science in traditional mechanical engineering.



Double-spiral Research & Education Program

A special and international research & education program will be well blended. The special research & education program will enhance special ability of talented persons by carrying out interdisciplinary research and education in a spiral state. The international research & education program, i.e., the double-spiral research and education program, will increase the special ability and the international view in a spiral state by exchanging visitors at the international research satellite centers. Active researchers will be invited to undertake cooperative research at Tohoku University, as well as to discuss subjects of mutual interest and to lecture students through conference presentations and discussions.



21st Century COE Program
International COE of FLOW DYNAMICS

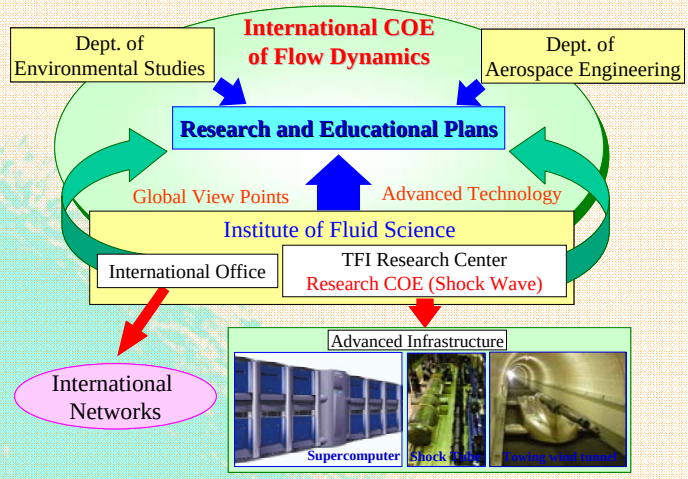
Program Leader, Professor,
Institute of Fluid Science,
Tohoku University
Shigenao Maruyama

About the COE

- The COE conducts the research of scientific principle of nano-mega spatiotemporal flow dynamics and creation of flow function, then expands beyond practical application. In the process of the research, we are establishing the COE of Flow Dynamics through the use of international research network.
- For the purpose of cultivating highly practical and talented researchers who have a good sense of internationality, Graduate School of Environmental Study and Department of Aerospace Engineering cooperate with Institute of Fluid Science that are currently expanding internationally in flow dynamic research field, and form an international research educational group.
- The COE will perform personnel training to the talents who may serve as a leader of international leading project research in the future through the various educational programs such as "International Internship" by the active use of Academic Liaison Offices, "Double Degree System", "Leading Researcher Hatchery Program", and through international summer school inviting a number of top researchers as invited lecturers.

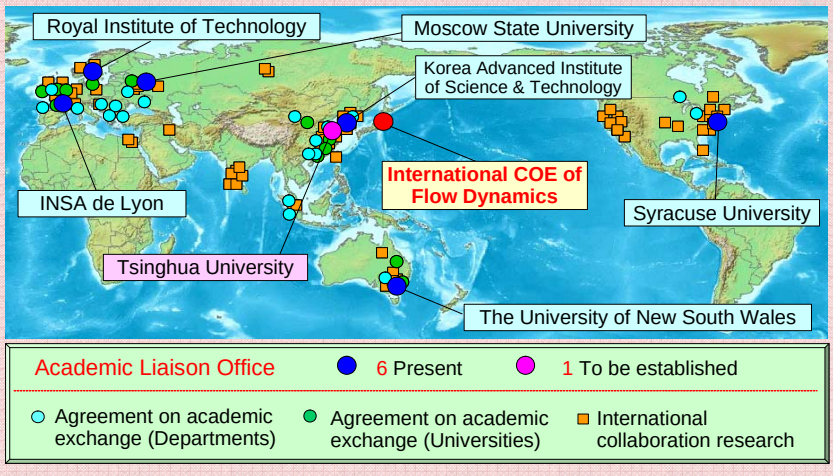
Objective

- The COE aims to cultivate human resources who have the high practical application capability and international outlook to contribute to the continuous development of human society and flow dynamics study.
- We plan to raise world-class leaders for the next generation by way of concentrated investment to graduate students and young researchers by COE programs through the active use of the research facilities such as Transdisciplinary Fluid Integration Research Center and Fluid COE of Institute of Fluid Science, that we have established by practicing the policy of Tohoku University "Research has the priority".
- We aim at cultivating the leading human resources with a global view and advanced expertise who can achieve world's most advanced research results by systematically developing and utilizing the overseas bases such as Academic Liaison Offices, sister universities, and joint-research universities which we constructed in order to fulfill one of the principle of Tohoku University, "Open University to the World and Community".



International Liaison Office & Project Base Foundation Plan

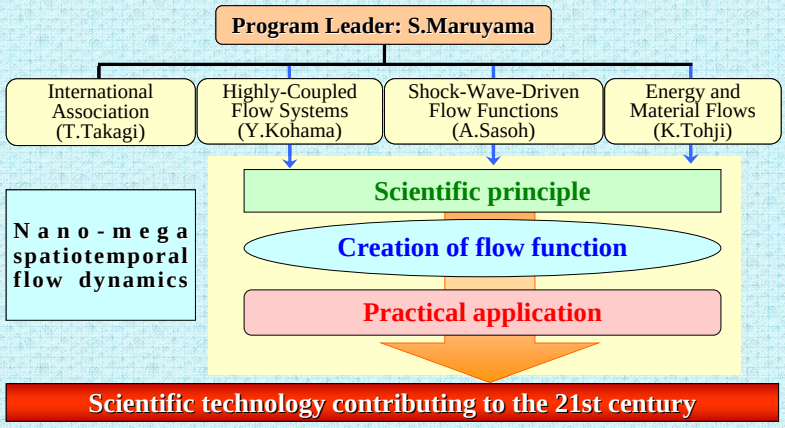
In addition to 6 existing Liaison Offices (Moscow State University, The University of New South Wales, Royal Academy of Science, INSA-Lyon, Korea Advanced Institute of Science and Technology, and Syracuse University), we are establishing Liaison Offices at Tsinghua University within the current fiscal year.



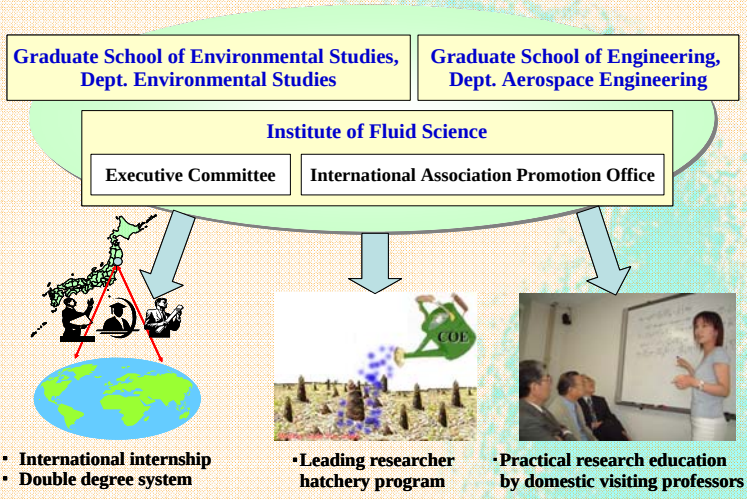
In collaboration with Graduate School of Environmental Studies and Department of Aerospace Engineering, a "Flow Dynamics International Research Educational Project Base" is established in fiscal 2003 with the following institutions as a core: Transdisciplinary Fluid Integration Research Center newly established in Institute of Fluid Science, the Ministry of Education, Culture, Sports, Science and Technology, and Miyazaki brunch of Institute of Fluid Science. (The COE secretarial building is scheduled to be completed in an Institute of Fluid Science site.)

Project Organization

COE conducts three major programs: Highly-Coupled Flow Systems, Shock-wave-Driven Flow Functions, and Energy and Material Flows. To complete these programs, three (3) steps are taken in the research of flow dynamics: (1) the understanding of flow dynamics on the nano-mega spatiotemporal scales, (2) creation of flow functions such as momentum, heat and mass transportation/ circulation of materials, and (3) practical application is produced through three steps, namely, (a) scientific principle, (b) creation of flow functions, and (c) practical application.



Educational Programs



- International internship
- Double degree system

・Leading researcher hatchery program

・Practical research education by domestic visiting professors

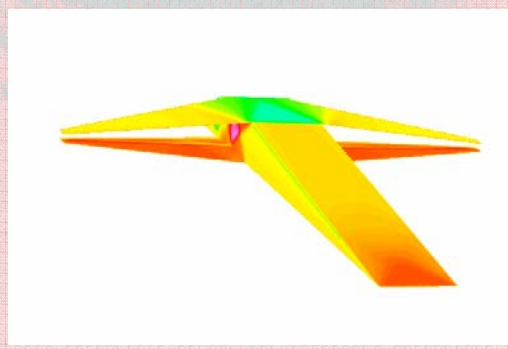
➢ The international human resource development program aims at training of the researchers who can plan and promote an international joint project:
- Implementation of International Mutual Internship Program (compulsory)
- Intensive course by top educators from the United States and Europe (compulsory)
- Double Degree System
- Assistance for international symposium organized by students and commending system

➢ Leading Research and Practical Education Program Based on Practicalism. Fostering a Self-Determining and Persistent Researcher:
- DERUKUINOBASU (Leading Researcher Hatchery) program Encouraging Self-Motivated Research by Students
- Doctors in Business Field Who Support Research Infrastructure - Toward The Innovation of New Industry

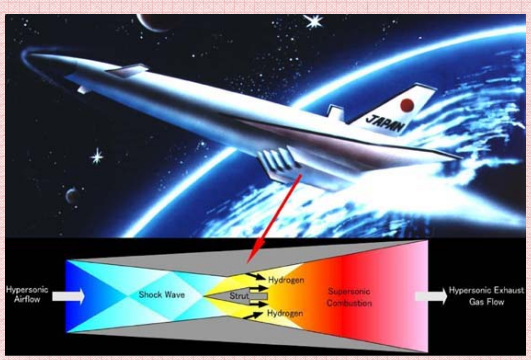
Research Activities

A new theory to reduce shock waves significantly for supersonic transport aircraft was established by Prof. Kusunose of COE program and his group

Invited visiting professor of COE program, Prof. Kusunose, and his group has successfully established a new biplane configuration which can eliminate shock waves of supersonic transport significantly. The theory introduce a second wing nearly parallel to the conventional wing and proved that the interaction between the two wings will cancel the shock wave effects felt at the ground by 85%, using the super computer at the Institute of Fluid Dynamics to calculate. Because one of the fundamental problems preventing commercial transport aircraft from supersonic flight is the generation of the strong sonic booms, new theory is a highly promising candidate in the achievement of nearly boomless supersonic flight in the near future.



Supersonic transport for sonic-boom-less flight



Scramjet engine

Aero-train