Nanotechnology in JST Basic Research

Virtual Laboratory in Nanotechnology Areas

CREST/PRESTO 2005

http://www.jst.go.jp/kisoken/nanoe.html

Japan Science and Technology Agency
http://www.jst.go.jp

Outline of JST (Japan Science and Technology Agency)

JST (Japan Science and Technology Agency) made a new start as an independent administrative institution on October 1, 2003. JST aims to function as a core promotion entity for fundamental projects of science and technology in Japan.
The predecessor Japan Science and Technology Corporation was founded on October 1, 1996 through the integration of two organizations, the Japan Information Center of Science and Technology (JICST) and the Research Development Corporation of Japan (JRDC). JICST (founded in August, 1957) was mainly engaged in dissemination of the information related to science and technology, while JRDC (founded in July, 1961) was mainly engaged in promotion of basic research, new technology development and transfer, and promotion of research exchange. In addition to succeeding and further developing the activities of these two organizations, JST is pursuing objectives to provide adequate foundation for enhancing Japan's science and technology, to promote innovative cutting-edge research and development, and to promote public understanding of science and technology in line with the Science and Technology Basic Law enacted and promulgated on November 15, 1995.

Launch of "Nano Virtual Lab (Virtual Laboratory in Nanotechnology Areas)" — Intensive Promotion of Nanotechnology Programs in FY2002 —

JST set up 10 Research Areas for the intensive and comprehensive promotion of nanotechnology under three Strategic Sectors which were proposed by MEXT (the Ministry of Education, Culture, Sports, Science and Technology) in FY2002. JST widely called for proposals from researchers in universities and public and private research institutes. Research Supervisors, in collaboration with their Research Area Advisers, reviewed and selected successful proposals. Research Supervisors manage the research activities in their own research area, and JST supports the researchers, who perform the research at their own locations. The "Nano Virtual Lab" aims to create results with greater impact by having interactive discussion, collaboration, research area meetings, joint symposia, and exchanging information across the boundaries of these areas, in addition to area-specific research promotion.

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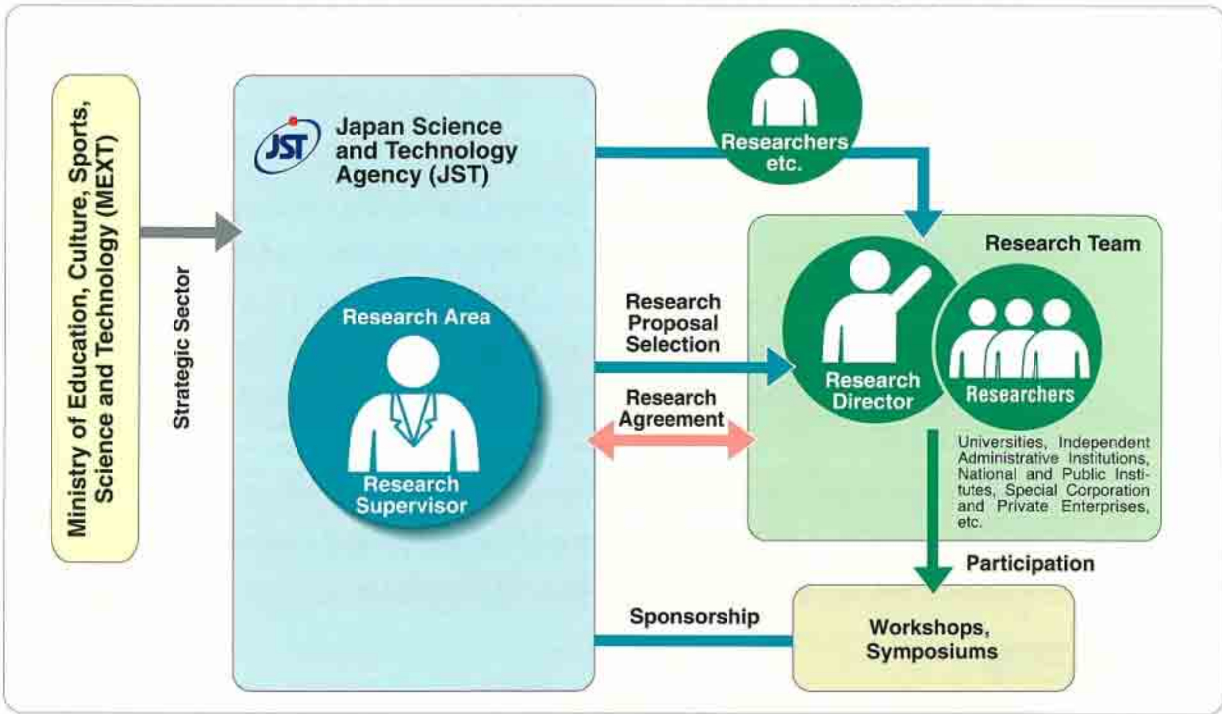
Program Flow

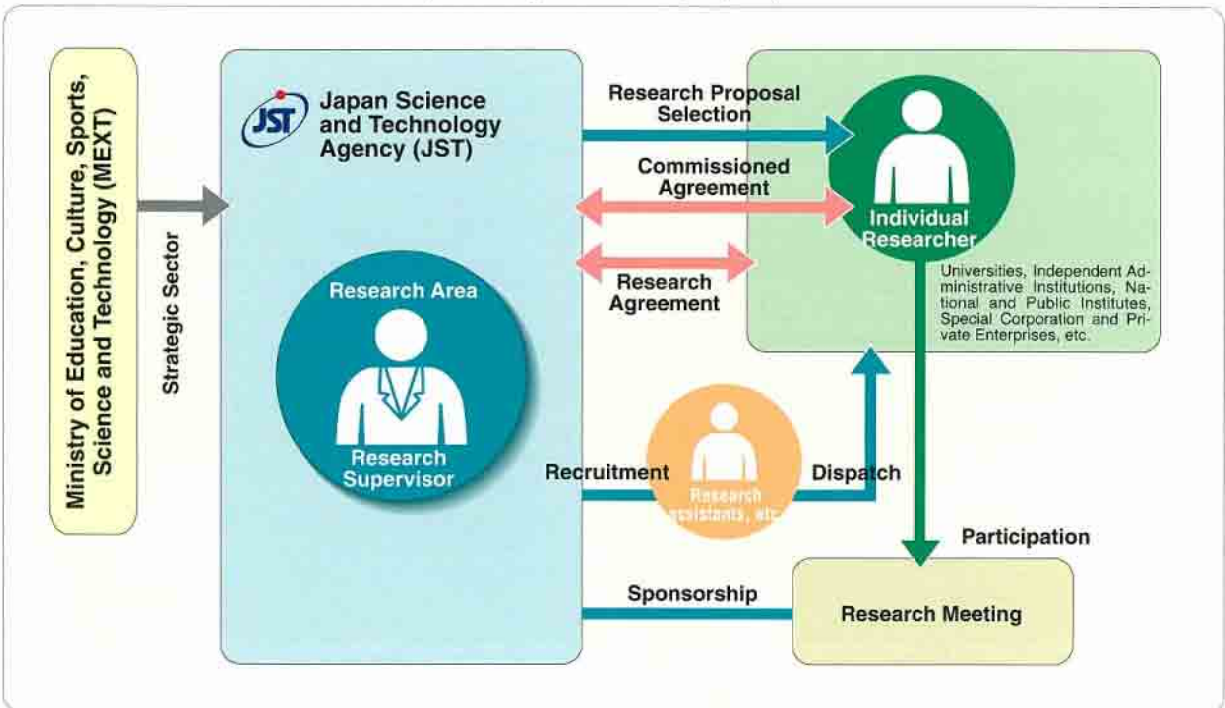
CREST

JST selects research directors and research proposals through public invitation, concludes research agreements with research organizations to which researchers belong, and promotes basic research for producing intellectual property.



PRESTO

JST calls for and selects the research themes and individual researchers. Concluding research agreements with research site for individual researchers, JST promotes basic research aimed at producing intellectual property.



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Strategic Sector

*1	Creation of Nanodevice / Material / System for Overcoming Integration / Function Limits in Data Processing and Communications
*2	Creation of Functional Materials / System that Utilize Nano Biotechnology for Realizing a Noninvasive Medical Treatment System
*3	Creation of Nano Materials / System for Realizing Environmental Conservation and Advanced Energy Recycling to Minimize Stress on the Environment

Research Area

Creation of Ultrafast, Ultralow Power, Super-performance Nanodevices and Systems

Abstract of Research Area

The research area covers exploratory studies for the creation of advanced nanodevices and systems that substantially upgrade or supersede the current information processing and communication systems. Focus is placed on those devices to be created by the use of new nanostructures, nanoprocesses, and/or nano-integration technology.
More specifically, this area includes such research subjects as (a) new device structures and materials which will lead to ultrafast, ultrawide-band, and/or ultralow power information and communication systems, (b) innovative nanomaterials and nanoprocessings which could remove fundamental limits of nano-scale devices, (c) elucidation and control of electron physics in nanodevices, (d) creation of unprecedented photonic devices based on advanced nanostructures, and (e) other related research subjects.

Research Supervisor:
Dr. Hiroyuki Sakaki
Professor,
The University of Tokyo

FY2002

Quantum Wire Lasers with Novel Device Performances

Hidefumi Akiyama
Associate Professor, The University of Tokyo

We fabricate quantum wire lasers using quantum wires with very high structural uniformity, and characterize their high device performances such as low threshold current and high differential gain, which enable high-speed and low-power operation of lasers. Furthermore, we measure such quantum wire lasers in detail to extract physical and device characteristics inherent to 1D systems. We perform both experimental and theoretical study to clarify lasing mechanisms and many-body electron interaction effects in high-density electron-hole systems.

Realization of Organic Laser Diodes and the Device Physics

Chihaya Adachi
Professor, Chitose Institute of Science and Technology

After achievement of high efficiency organic light emitting diodes, realization of organic laser diodes has been anticipated. First, we focus on development of new laser materials, styrylbenzene derivatives and phosphorescent materials for aiming low lasing threshold. Second, we introduce optical resonators using organic nano-technologies. We also clarify exciton-exciton and exciton-charge carrier interactions under extremely high current density (~KA/cm^2). With understanding of carrier injection, transport and recombination processes in organic thin films, we will realize organic laser diodes.

Realization of Functional Photonic Devices Based on Low-Dimensional Quantum Structures

Shigehisa Arai
Professor, Tokyo Institute of Technology

Due to an enhancement of the quantum-size effect in the active region of ultra-fine structures, semiconductor lasers are expected to operate at lower consumption power than ever reported one. The purpose of this research project is to realize the high quality low-dimensional quantum structures by using an electron-beam lithography, a low-damage etching and an embedding growth process as well as to realize high performance semiconductor lasers based on them. Furthermore, realizations of low-dimensional structures with artificial anisotropic shapes and possibilities of novel functional photonic devices based on them will be explored.

Nano-processes by Slow Highly Charged Ion-impact

Shunsuke Ohtani
Professor, University of Electro-Communications

A highly charged ion (HCI) can carry a large amount of potential energy even at low kinetic energy. When it interacts with a surface, this massive energy is released into a nanoscale area in a femtosecond scale, which results in modification of the target material on the surface layer. In the present research programme, we are going to explore some potential applications to produce novel nano-devices based on the interaction of slow HCIs with solid surfaces.

Creation of Ultrafast Optical Memory with Shift Register Function

Hitoshi Kawaguchi
Professor, Yamagata University

The aim of this project is creation of an ultrafast optical memory with optical shift register function using a two-dimensional array of the polarization bistable vertical-cavity surface-emitting lasers. This novel optical memory will be used as an optical buffer memory for all-optical packet switched networks, in which routing and switching are performed in the optical domain.

Novel Nonvolatile Memory with Resonant Magnetic Tunneling Nanodots

Mitsumasa Koyanagi
Professor, Tohoku University

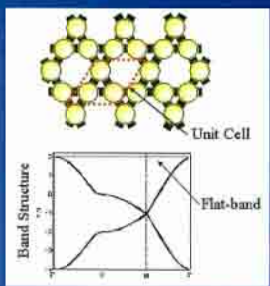
A new nonvolatile memory with resonant magnetic tunneling nanodots is proposed. Magnetic tunneling nanodots are incorporated in the gate insulator and a pinned ferromagnetic layer is formed underneath the gate electrode of MOS transistor in this memory. This memory performs writing operation and data retention by utilizing an asymmetrical tunneling effect among magnetic nanodots and pinned ferromagnetic layer. Therefore, energy band structure, spin states of tunneling electrons and charging states of magnetic nanodots are very important in this memory. In the research project, memory devices are fabricated and their fundamental characteristics are evaluated. In addition, new high speed and low power circuits and new system architecture with this memories are proposed and evaluated. A possibility of a high speed and low power terabit memory is demonstrated by successful operation of this new nonvolatile memory.

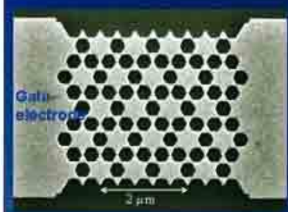
Semiconductor Spin Engineering

Junsaku Nitta
Professor, Tohoku University

Functional devices utilizing the spin degree of freedom in non-magnetic semiconductors are explored in this project. The development of techniques to control electron spins in semiconductor quantum dot arrays and tailor-made heterostructures using metallic gate electrodes is the first requirement to be accomplished. These structures could provide basic building blocks to form spin-based quantum computers which have a much higher speed, less power consumption, and novel functionality compared to today's conventional computer technology.

Ferromagnetism in semiconductor quantum dot arrays





Scanning electron micrograph of a semiconductor quantum dot array

Calculations showed that a flat-band can form in an array of coupled semiconductor quantum dots forming a Kagome lattice. For certain electron fillings, which are experimentally controlled by the gate voltage, the system possesses a ferromagnetic ground state.

Creation of Ultrafast, Ultralow Power, Super-performance Nanodevices and Systems

Single-Flux-Quantum Terahertz Electronics

Akira Fujimaki
Professor, Nagoya University

Future network core devices are required to have the reduced power consumption together with improved performances. Our project aims at creating 'Terahertz Electronics' based on the single-flux-quantum (SFQ) circuits using high-temperature superconductors, which have the nature of low power consumption and of high-speed. Optical Interfaces with the SFQ circuits will be also developed in our project, because these are essential for the Terahertz Electronics. The SFQ Terahertz Electronics is expected to cover the applications of imaging systems, A/D converters, digital signal processors, etc.

Ballistic Electron Devices of Super-Hetero Nano-Structures

Kazuhito Furuya
Professor, Tokyo Institute of Technology

Using three-dimensional super-hetero nano-structures consisting of semiconductor, metal and insulator, novel ballistic electron devices will be created to show ultra-fast operation. Using quantum effects in the structures, novel electron-wave device and THz devices will be explored for information processing and electromagnetic wave amplification, respectively.

New Evolution in Nano-processes /Nano-devices Focused on MBE-grown InN-based III-Nitrides

Akihiko Yoshikawa
Professor, Chiba University

Recently the bandgap of InN was found to be around 0.7 eV. This fact highlights the plausibility of nitride semiconductor devices to cover the wavelength range for optical communications. In this project, we will develop the MBE-nano-process technology to produce the "ultra-thin layer and super-abruptness of heterointerfaces" for InN-based III-nitrides. As a result, we will obtain the crystals showing the intrinsic physical properties of InN, and investigate the possibility of lasers for optical communications, ultra-high speed optical devices, and ultra high speed • ultra energy-saving electronic devices, which are the key devices for large scale and ultra-high speed image-information processing in the near future.

Research Area

Creation of Nanodevices and System Based on New Physical Phenomena and Functional Principles

Abstract of Research Area

The research area covers studies for new phenomena and functional principles in quantum physics, and for the realization of new nanodevices and systems based on such phenomena and principles.
More specifically, this area includes research for (a) the realization of new data processing devices for computation and memory based on electron and spin physical properties that first appear on the nano scale, and (b) the creation of devices and new data processing system for sensing, operating and controlling nano-scopic characteristics using physical techniques and functional principles of electronics, mechanics, optics. It also includes nanostructure research on new physical phenomena which will lead to new technology that break through the boundary of existing technology, and studies that lead the phenomena, whose properties are still a research target, to devices.

Research Supervisor:
Dr. Koji Kajimura
Vice President, Japan Society for the Promotion of Machine Industry, Director of Technical Research Institute

FY2001

Development of Fundamental Technology for Spin Quantum Dot Memories

Koichiro Inomata
Professor, Tohoku University

This research aims at the creation of spin quantum dot memories based on a novel concept. The essential part of the research is to demonstrate the spin-dependent Coulomb blockade effect due to single electron tunneling at room temperature in ordered magnetic nano dots, in which the tunneling magnetoresistance can be controlled by applying a voltage. We will develop novel materials or structures to achieve enhanced tunneling magnetoresistance and thus large signal voltage. In addition, the fabrication technology to create two-dimensional array of dots and new memory devices will also be developed. We anticipate, at the end of this research, the creation of terabits non-volatile memories and new spread of spintronic devices.

Nanoclusters: Control of Configuration, Rotation, and Electronic States in Device Structures

Yoshihiro Iwasa
Professor, Tohoku University

The aim of this project is to explore a new area of materials science by introducing device techniques. In particular, we focus on nanoscale cluster materials with 1-10 nm in size, which exhibit unique properties both in isolated and solid forms. The properties of these nanoclusters, which have been modified by chemical means so far, are controlled by electric field in a device structure, fabricated on high quality thin film. With this technique, we will search for new superconducting materials and other quantum states, and demonstrate field-controlled cluster orientations and its application to molecular devices.

Development of Diamond Ultraviolet Nanodevices Taking Advantage of Highly Condensed Excitonic States

Hideyo Okushi
Scientific adviser, Diamond Research Center, National Institute of Advanced Industrial Science and Technology

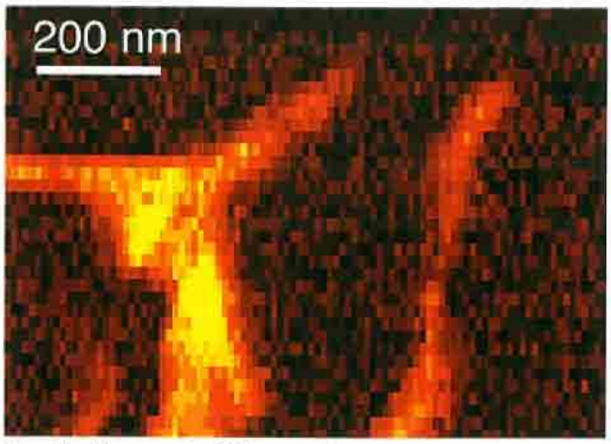
Our group has successfully synthesized high quality homoepitaxial diamond by the microwave plasma chemical vapor deposition (CVD) and discovered a nonlinear effect of excitonic emission of 5.27 eV (235 nm) from them. It is strongly suggested that this effect is related with the phenomena of highly condensed excitonic states such as Bose-Einstein condensation (BEC). In this project, we will try to realize the nonlinear effect of excitonic emission in the nano-scale region (nano-space) and to clarify the mechanism of the phenomena of highly condensed excitonic states in the diamond. We will also attempt to make nano-devices of an ultraviolet-light emission diode (U-LED), an ultraviolet laser diode (U-LD) and an ultraviolet-light censer (U-LC) based on the phenomena of highly condensed excitons. It is expected developments of U-LED, U-LD and U-LC and their applications for new-information systems and characterization technology in ecology and epidemiology.

Creation of Nanodevices and System Based on New Physical Phenomena and Functional Principles

Nonlinear Nano-Photonics

Satoshi Kawata
Professor, Osaka University

Marvelous novel functions that are not accessible by conventional nanotechnologies are expected if photons are utilized for sensing, manipulating, and processing features at nanoscale. In this research, we will combine the concepts of near-filed optics and non-linear optics, conducting fundamental research on nonlinear nano-photonics and pushing it for practical applications. Of particular interest is applying femtosecond lasers to plasmon field-enhanced technologies for nano-spectroscopy and nano-devices.

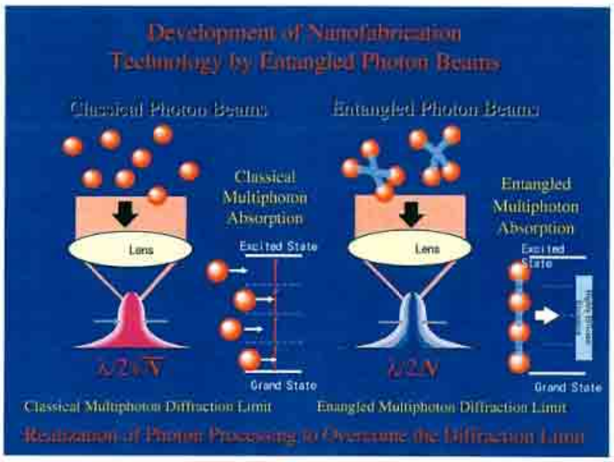


An optical image of a DNA network nano-structure obtained by the combination of near-field optics and nonlinear spectroscopy. The distribution of adenine base molecules, one of the DNA bases, is visualized.

Development of Nanofabrication Technology by Entangled Photon Beams

Hiroaki Misawa
Professor, Hokkaido University

We will develop laser nanofabrication technology based on unique photophysical behavior of "entangled photons", which enables one to enhance optical resolution of the fabrication beyond the diffractive limit. This technology will use high throughput beams of multi-entangled-photons, and will allow fabrication of, e.g., 3D photonic crystal structures for the visible and/or ultraviolet wavelengths, as well as development of quantum communication and information processing devices, such as single photon-photon switches.



Coherent Quantum-Control and Information-Processing Technology

Kazuhiro Komori
Group Leader,
National Institute of Advanced Industrial Science and Technology

The purpose of this research is to realize the novel nanodevices using coherent quantum control technology, where the coherent electronic states in the nano-structure are all-optically controlled by the phase-locked ultrashort pulses. This research can be applied to the development of ultrafast all-optical devices operating in the femtosecond time domain and also of the solid-states quantum information-processing devices.

FY2002

Creation of Novel Functional Devices Using Nanoscale Spatial Structures of the Radiation Field

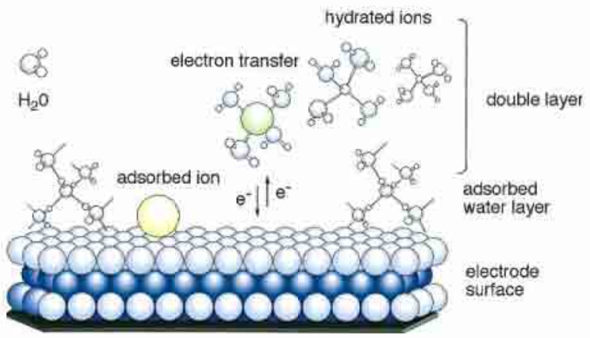
Hajime Ishihara
Professor, Osaka Prefecture University

The recent studies of nano-systems have revealed the peculiar optical processes arising from the nanoscale spatial structure of the internal radiation field that is generally neglected in conventional analyses of optical properties of solids. In this research, we pursue the possibility of unconventional optical devices being based on such a new type of mechanism, aiming to demonstrate the ultrafast optical switch and the quantum phase gate with extraordinary high nonlinearity. It is expected that the results will open the way to novel photo-engineering that explicitly utilizes the degree of freedom of microscopic spatial structures of the radiation field.

Atom Processes in Solid/Liquid Interfacial Reactions: Elucidation and Application

Kingo Itaya
Professor, Tohoku University

In this study, knowledge of chemistry is employed to invent the nano-device system based on new physical phenomena and operation principles. This field aims to establish methods for creating new devices through electrochemical fundamentals, inducing formations of self-organization of atoms and molecules into nanostructures at solid/liquid interfaces. On the basis of these results, it is expected that highly-functional nano LSI processes and organic electronic devices can be manufactured, and the field of molecular electronics can be advanced.

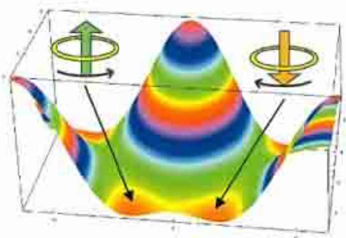


Schematic model of atomic/molecular interactions at solid/liquid interfaces.

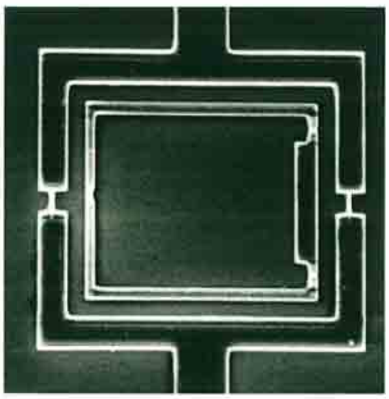
Implementation of the Entangled States Using Superconducting Flux Qubits

Hideaki Takayanagi
NTT R&D Fellow, NTT Basic Research Laboratories

In this project, we will investigate superconducting flux quantum bits (qubits). These qubits have a micron-size SQUID geometry, a long coherence time, are capable of being integrated in solid state chips. First, we try to realize single qubits experimentally. We will then test their high-speed operation, classical-mechanically correlated behaviors in double qubit (SQUID) systems, and clarify the physical origin of the decoherence by a detailed comparison of our experimental results and our theoretical analyses. After that, we will realize quantum-mechanically entangled double qubit systems will enable us to construct fundamental logic gates, which perform simple quantum logical operations. The realization and the detailed analysis of the quantum-mechanical entanglements in coupled qubits is an important first step on the road to quantum computers, and we are convinced that our study will open the way to the construction of some prototypes.



Bird's-eye view of the Josephson energy of the qubit in phase space.



Scanning electron microscope image of a superconducting qubit(inside loop) and a dc-SQUID(outside loop) as a detector.

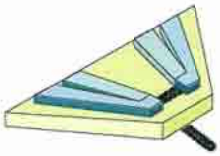
Creation of Nanodevices and System Based on New Physical Phenomena and Functional Principles

Carbon Nanotube Single Electron/Spin Measuring System

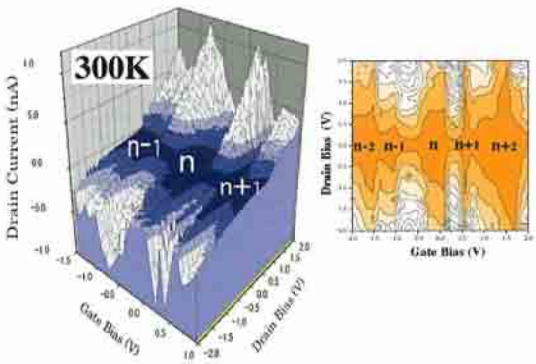
Kazuhiko Matsumoto
Professor, Osaka University

The effective size of 1~2nm is realized by introducing the defects into carbon nanotube by the controlled manner and its electrical property is modulated. The room temperature single electron transistor is realized using the defective carbon nanotube as a channel, which is used as an ultra-high sensitive sensor. The sensor will detect the distribution of single electron/spin on the surface of the semiconductor and/or the nano-bio materials for the deeper understanding of the device and/or the material physics.

Carbon Nanotube Single Electron/Spin Measurement System



Carbon Nanotube Single Electron/Spin Scanning Probe



Room temperature Coulomb diamond characteristics and its contour plot of single electron transistor with defective carbon nanotube used as a channel. Coulomb energy is as high as 400meV and its equivalent Coulomb temperature is 5000K. Effective size of quantum dot is 1nm.

FY2003

Gigantic Spin Tunnel Functionality Atomically-controlled by Perovskite Interface Engineering

Hiroshi Akoh
Deputy Director, Correlated Electron Research Center, National Institute of Advanced Industrial Science and Technology

On the correlated electron system, many electrons are strongly interacting with each other, thus forming the quantum electronic phases. These electronic phases can be switched by external stimuli, resulting in new device functionalities with the drastic gigantic response. In this research, with focusing on the perfect spin polarization of perovskite magnetic oxides, we will establish a new research approach of "perovskite interface engineering", which includes the direct observation of interface magnetization, and the design and atomically control of the interface. Based on this concept, we aim to realize the gigantic spin tunnel functionality of perovskite oxides, and furthermore to explore a device functionality of spin tunnel injection.

Research Area

Nano Factory and Process Monitoring for Advanced Information Processing and Communication

Abstract of Research Area

The research area covers studies of new processing technology for realizing nanostructures and nanodevices that contribute to advanced data processing and communication, and studies of new technology for monitoring, measuring and evaluating nanostructures and their functions.
More specifically, this area includes reserach on new applications of photon, X-ray, electron and ion beams for establishing new nanofabrication technologies, research on nanostructure growth and related technology by controlling materials in atomic and molecular scale, and research on measurement and characterization technology of nanostructures and their functions.
This research area is also expected to contribute to other strategic sectors, "Creation of Functional Materials/ System that Utilize Nano Biotechnology for Realizing a Noninvasive Medical Treatment System" and "Creation of Nano Materials/ System for Realizing Environmental Conservation and Advanced Energy Recycling to Minimize Stress on the Environment."

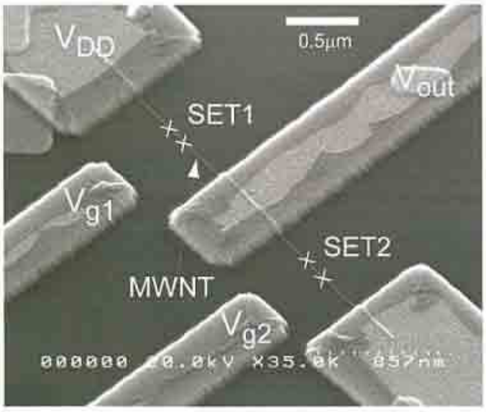
Research Supervisor:
Dr. Kenji Gamo
Professor Emeritus, Osaka University / Fellow, National Institute of Information and Communications Technology

FY2002

Development of Fabrication Processes for Quantum Nanodevices in Carbon Nanomaterials

Koji Ishibashi
Chief Scientist, RIKEN

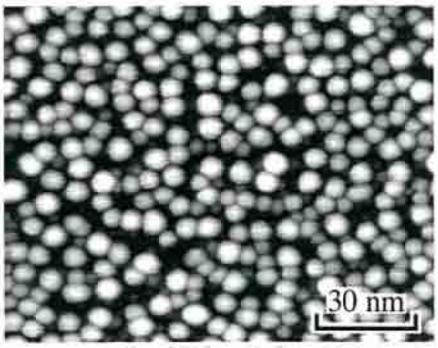
Carbon nanotubes are attractive for the building blocks of nanodevices for single electronics, quantum computing and other nanoelectronics because of their extremely small diameter. In this project, we develop device processes to realize these nanodevices and their network with carbon nanotubes and fullerene, and demonstrate their performance. It may serve for exploring an experimental realization of new functional nanoelectronics.



Formation and Characterization of ultra-small Nanodots with Ultra-high Density

Masakazu Ichikawa
Professor, The University of Tokyo

Synthetic technologies are developed to form nanodot superlattices and artificial nanodot structures composed of Si, SiGe, Ge and Fe-silicide by using our original technique of ultrathin Si oxide films to make ultra-small nanodots with ultra-high density. Some technologies are also developed to characterize optical and electric properties of the individual nanodots and the superlattices. If some devices with very high optical efficiency can be produced by using these technologies, Si optical devices can be unified with Si electric devices.



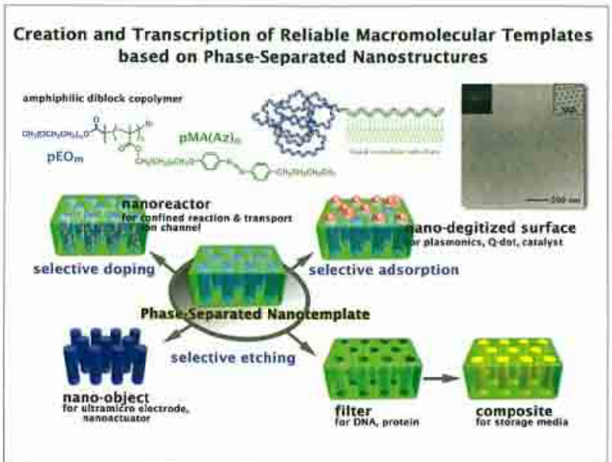
Ultra-small Ge nandots with ultra-high density on ultra-thin SiO_2 films

Nano Factory and Process Monitoring for Advanced Information Processing and Communication

Creation and Transcription of Reliable Macromolecular Templates based on Phase-separated Nano-structures

Tomokazu Iyoda
Professor, Tokyo Institute of Technology

New hierarchical processing technologies for deca-to-hecto nanometer-sized molecular functional materials are developed by self-assembly and transcription processes of macromolecular building blocks based on advanced polymer architectures. Nanophase-separations based on precisely designed multifunctional macromolecules are focused as reliable and productive nano-structured templates for transcription processes such as regioselective etching, plating, doping, and so on, leading to the promising nanodevices that contribute to high-speed data processing and communication.

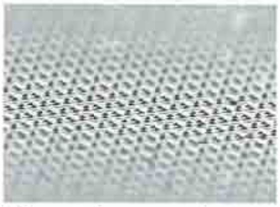


Ultrafast Ultraparallel Nanomechanics

Hideki Kawakatsu
Professor, The University of Tokyo

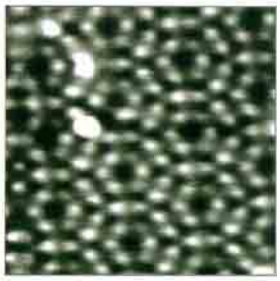
Submicron-sized scanning probes will be fabricated using silicon and carbon nanotube techniques. The probes will be used for scanning probe microscopy operating up to the GHz range, enabling atomic level mass resolution and detection of fast phenomena. Detection schemes for parallel operation of millions of probes will also be studied for detection of molecules, proteins, and motion of living cells.

High compliance cantilevers made of silicon nanowires



A forest of nanomushrooms.

An Atomic Force Microscope operating up to 200 MHz incorporating a heterodyne laser doppler interferometer



Atomic Force Microscopy with subAngstrom Amplitudes. Amplitude 0.8 Å.

Surface Observation and Metrology of High-Performance Material by Extreme Ultraviolet Microscope with Phase-Shifting Interferometer (EUVM/PSI)

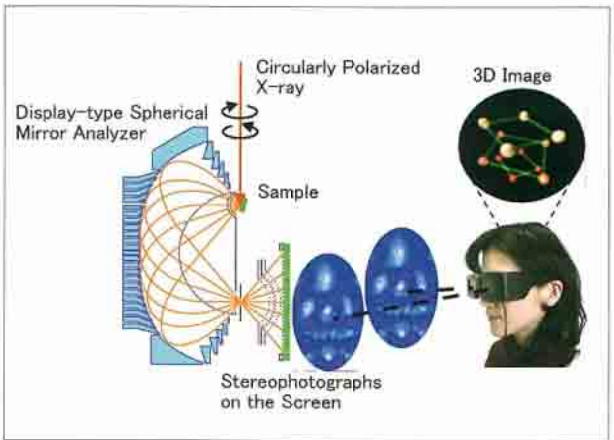
Hiroo Kinoshita
Professor, University of Hyogo

The Observation and measurement technology for the sub nano-meter and pico-meter structure level is the most important subject for growing up the nano-industry in Japan. In our research, we will build up extreme ultraviolet microscope with phase-shifting interferometer (EUVM/PSI). The key technology for EUVM/PSI is the fabrication of the beam splitter which has both the high reflectivity and high transmittance at the extreme ultraviolet wavelength. Only EUVM/PSI can be detect the phase defects and the particle defects in the multilayer. From 2007, EUVL/PSI contributes the semiconductor devices which includes the ultra fine circuit pattern width of 50 nm- 30 nm. Furthermore, EUVM/PSI technology will be lead the pico-meter structure measurement technology for the global use.

Development of Atomic Stereomicroscope for the Analysis of Nanostructure

Hiroshi Daimon
Professor, Nara Institute of Science and Technology

This research aims to develop an atomic stereomicroscope which can take stereo photographs of atomic arrangement of nano materials. The angular distributions of photoelectrons excited by right- and left-hand circularly polarized X-ray create stereo photographs when they are measured by "Display-type spherical mirror analyzer" developed by ourselves. This research involves (1) Establishment of the technology of stereo microscope, (2) Development of a new analyzer which can be used easily, and (3) Development of imaging function to select viewing area. These developments will enable the atomic level analysis of nano materials, which can promote nano technology significantly.

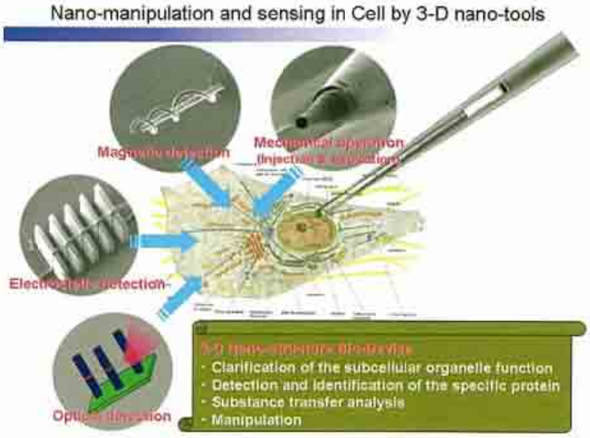


Concept of Atomic Stereomicroscope

High-functional Nano-three-dimensional Device and Process

Shinji Matsui
Professor, University of Hyogo

A nano-three-dimensional fabrication process with a local hetero-junction that uses different materials and local doping can add the sensing and driving functions of nano-machines, and signal conversion and amplification to nano-structures. The aim of this project is to develop the high-functional nano-three-dimensional device process such as nano-three-dimensional electro-, optical and bio-devices for the actual proof, based on the original three-dimensional structure fabrication technology developed by us. These devices have different architecture from that of conventional two-dimensional layered devices.



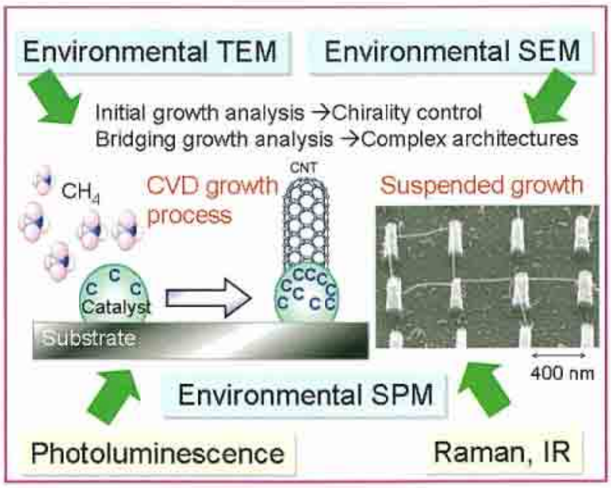
Nano Factory and Process Monitoring for Advanced Information Processing and Communication

FY2003

In Situ Characterization of Carbon Nanotube Growth Process for the Physical Property Control

Yoshikazu Homma
Professor, Tokyo University of Science

Carbon nanotubes (CNTs) are the most promising nanomaterial. Their application to electronic devices, however, cannot be realized without establishing highly controlled growth of CNTs on the substrate. Our research team aims at the development of in situ characterization methods of CNT growth processes in chemical vapor deposition using electron microscopy and optical spectroscopy. By revealing the growth mechanism, we will gain precise controls of nanotube growth and their properties. This enables realization of integrated quantum devices and integrated optoelectronic devices based on CNTs.



Research Area

Creation and Application of Nano Structural Materials for Advanced Data Processing and Communication

Abstract of Research Area

This research area covers studies to create new materials having distinctive properties and advanced or new functions that are quite different from those of bulk materials, by controlling nano-scale structure and constitution, and also to develop new application of such materials, which will contribute to advanced data processing and communication.
More specifically, this area includes (a) research to create evolutionary new materials of innovative functions and properties by controlling structures of nanoparticles, cluster atoms/ molecules, molecular materials, inorganic-, organic- and their hybrid materials, in addition to ultra-thin films and ultra-fine particles, namely to create nano-structural materials by making bulk materials more hyperfine, (b) research for creating advanced functional materials such as fullerens and carbon nanotubes, and (c) research to explore application to nanodevices/systems.
This research area is also expected to contribute to other strategic sectors, "Creation of Functional Materials/ System that Utilize Nano Biotechnology for Realizing a Noninvasive Medical Treatment System" and "Creation of Nano Materials/ System for Realizing Environmental Conservation and Advanced Energy Recycling to Minimize Stress on the Environment".

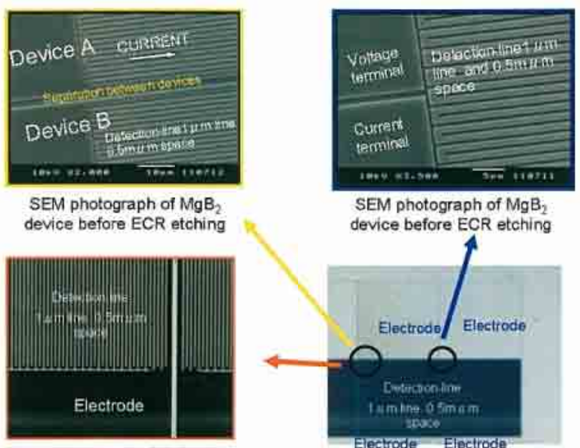
Research Supervisor:
Dr. Hidetoshi Fukuyama
Professor,
Tohoku University

FY2002

Basic and Applied Researches of Nanofabricated Superconductors

Takekazu Ishida
Professor, Osaka Prefecture University

The project [NANOFABSUPER] devotes every effect to extract the various aspects of nanofabricated superconductors. First, we develop a novel neutron detector based on nanosized MgB_2. This might be one of the promising candidates for neutron detectors in High Intensity Proton Accelerator Project (JAERI and KEK Joint Project). Second, we propose nanofabricated exotic superconducting composite structures to search for a novel ordered state in internal degrees of the freedom. Our dream is to develop a new area called "d-tronics" by using high-T_c cuprates. Both experimental and theoretical scientists intensively join this project to bring to completion of fruitful joint researches.



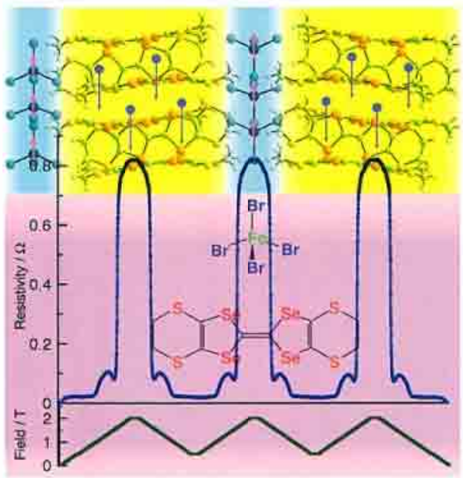
Nanofabrication of MgB_2

Construction of Nanostructured Molecular Assemblies with Novel Electronic Functions

Hayao Kobayashi
Professor, National Institutes of Natural Sciences

Development of molecular systems with novel electronic functions is essential to the future molecular devices and electronics. This research is aimed at constructing molecular systems in which molecules and functions are highly integrated for the realization of novel electronic functions. Nanostructured entities such as molecular wires are also built utilizing self-assembling of molecules.

Magnetic Organic Superconductor



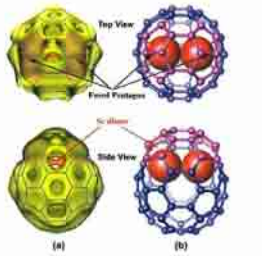
The structure and metal-superconductor switching phenomenon in the first antiferromagnetic organic superconductor consisting of magnetic anion layers and organic conducting layers. The periodical modulation of the external magnetic field produces the switching behavior caused by the coupled electrical (superconducto-metal) and magnetic (antiferro-ferro) transitions.

Creation and Application of Nano Structural Materials for Advanced Data Processing and Communication

Syntheses, Characterization and Application of Novel Carbon Nanotube Materials

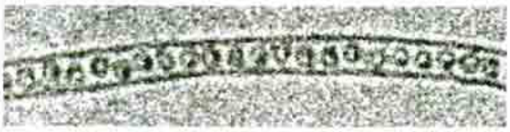
Hisanori Shinohara
Professor, Nagoya University

The current research project is devoted to synthesize and characterize novel carbon nanotube materials such as high-purity double-wall carbon nanotubes (DWNTs) and "nanotube peapods" materials. These nanotube materials are brand new nano-carbon materials which will be produced by the present research team. Since the DWNTs and peapods encapsulating various fullerenes and endohedral metallofullerenes are extremely promising nano-carbon materials for carbon nanotechnology, one of the main objectives of the project is to apply these materials to nano-electronic devices such as diodes, field effect transistors (FET) and memory devices.



Endohedral metallofullerene $Sc_2@C_{66}$

Double-wall carbon nanotubes (DWNTs) synthesized by the CCVD method

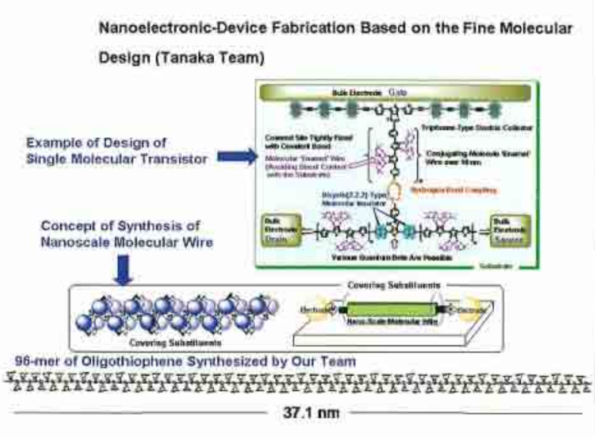


Nano-peapods: Single-Wall Carbon Nanotube Encapsulating $Gd@C_{82}$

Construction of Nano-electronic Devices Based on Precise Molecular Design

Kazuyoshi Tanaka
Professor, Kyoto University

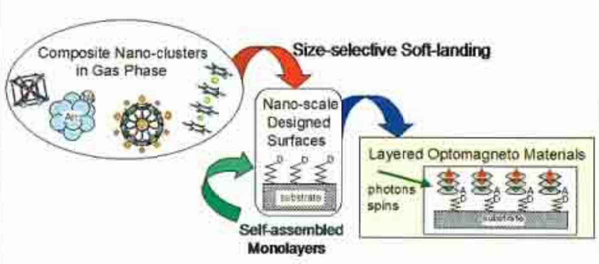
We are to construct harmonized organic-inorganic molecular systems by precise molecular design and bottom-up technology with the spirit of "fabrication of substances" aided by theoretical analyses. Our actual aim is to produce nano-electronic devices equipped with the external contact or probes and to establish carrier injection at the electrode-molecule junction. These research activities are expected to produce more intellectual assets in Japan toward construction of electronic devices utilizing small numbers of electrons.



Nano-scale Designed Surface Orientated Towards Novel Optomagnetomaterials

Atsushi Nakajima
Professor, Keio University

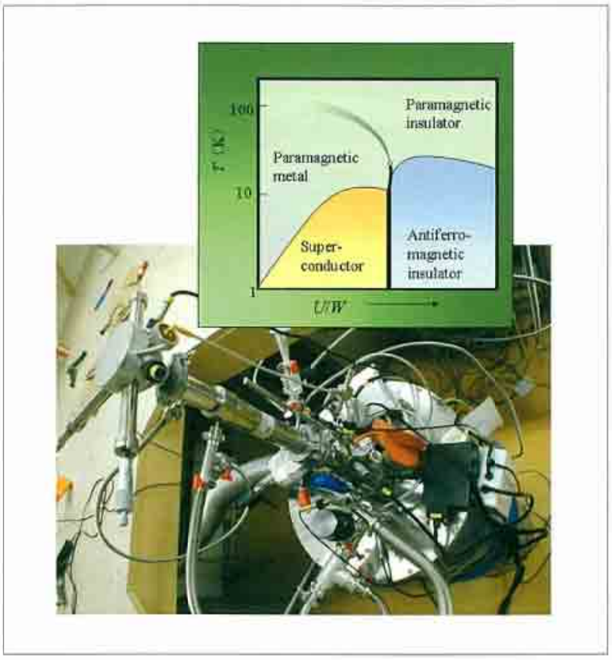
Composite nano-clusters exhibiting novel electronic properties will be created via gas-phase reactions that will control their chemical compositions. Two-dimensional nanoscale designed materials formed from the nano-clusters will be generated by size-selective soft-landing onto nano-scale designed surfaces. The electronic properties in these nanoscale two-dimensional designed materials will provide novel electronic/optomagnetic functions, which in turn will open up the creation of new optomagnetomaterials.



Coherence Control of Correlated Electron Systems

Naoto Nagaosa
Professor, The University of Tokyo

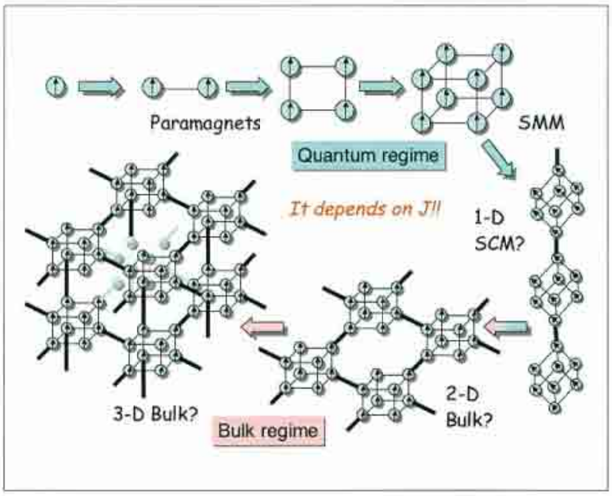
We aim at the control of the quantum coherence and various multicriticality of the internal degrees of freedom such as the orbitals and spins in the strongly correlated electronic systems, which show sensitive response and critical properties even at nano-scale. This aim will be accomplished in terms of (i) topological and (ii) critical phase control based on the concept of quantum Berry phase and multicritical phenomena. We will develop the novel functions of many electrons by the first principle band calculation, material design and experiments with both organic and inorganic systems being target.



Development and Application of Nano-Molecular Quantum Magnets

Masahiro Yamashita
Professor, Tohoku University

The aims of this project are first to synthesize nano-wire single molecular magnets, nano-ring single molecular magnets, and nano-dot-network molecular magnets by using the bottom-up method. Second, to discover new magnetic quantum phenomena arising from nano-sized magnets. Third, to investigate newly discovered phenomena between quantum magnets and bulk magnets. Finally, to develop new magnetic nano-devices based on the quantum magnets.



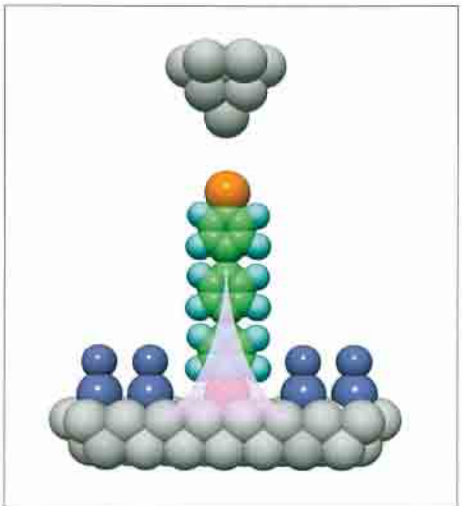
Creation and Application of Nano Structural Materials for Advanced Data Processing and Communication

FY2004

Contact Effects and Transport Properties of Single Molecules

Yoshihiro Asai
Group Leader, National Institute of Advanced Industrial Science and Technology

Molecular electronics is expected to have a large impact not only on information technology but also on medical, environmental and security applications such as bio-sensor, etc. Quantum simulation is indispensable for the research of molecular electronics, because of the small size of molecules. While it is composed of a single molecule, it is connected to macroscopic electrodes through the contact, where most of non-equilibrium effects might occur. Therefore, the contact effect is very important. We are going to study the contact effect on electric transport properties both theoretically and experimentally. Our findings would be useful for the development of molecular devices.

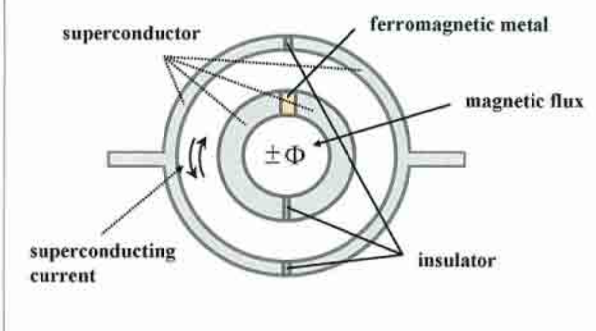


A schematic draw of electric conduction through a single molecule

Principles of Nano-devices Based on the Internal Degrees of Freedom of Electrons

Sadamichi Maekawa
Professor, Tohoku University

We study strongly correlated electron systems including transition metal oxides, organic compounds and micro-fabricated devices. In these systems, strong correlations between the internal degrees of freedom, i.e., the spin and the charge, cause their unusual properties. We perform numerical simulations of models of interacting electrons to investigate their physical properties. In collaboration with experiments, we construct the principles which govern nano-scale devices for spin-electronics and quantum computing. Based on these studies, we propose new materials and new devices with novel physical properties.



Superconducting qubit with π and 0 junctions

Research Area

Creation of Bio-Devices and Bio-Systems with Chemical and Biological Molecules for Medical Use

Abstract of Research Area

This research area covers studies to develop nanotechnologies for controlling bio-reactions and bio-informations, studies to create bio-devices and bio-systems, and studies of chemical and biological nano-structures for bio-devices/systems, which are applicable to medical use.

More specifically, this area includes research for creation of highly sensitive bio-devices and bio-systems for sensing of temperature, pressure and chemicals, creation of bio-devices and bio-systems for measuring and controlling bio-reactions and bio-informations, creation of chemical and biological nano-structures and nano-materials for bio-devices and bio-systems, and diagnostic and therapeutic applications of bio-devices and bio-systems; along with creation of drug delivery systems.

Research Supervisor:
Dr. Masuo Aizawa
President,
Tokyo Institute of Technology

FY2001

Generation of "Super Catalytic Antibodies" as Biological Nano-Materials for Health and Welfare

Taizo Uda
Professor, Prefectural University of Hiroshima

"Super Catalytic Antibody", though it has characteristics of antibody, can completely destroy the antigen with enzymatic function. In this study, the super catalytic antibodies as nano-materials capable of effectively attacking and destroying the targeted infectious microorganisms and tumor cells will be designed and produced using nano-scale technologies. The fruitful results from this study will contribute to the prevention, diagnosis and therapy for malignant cancer and infectious diseases.

Giant Porphyrin Arrays as Meso-Scopic Structural Motif of Molecular Electronics

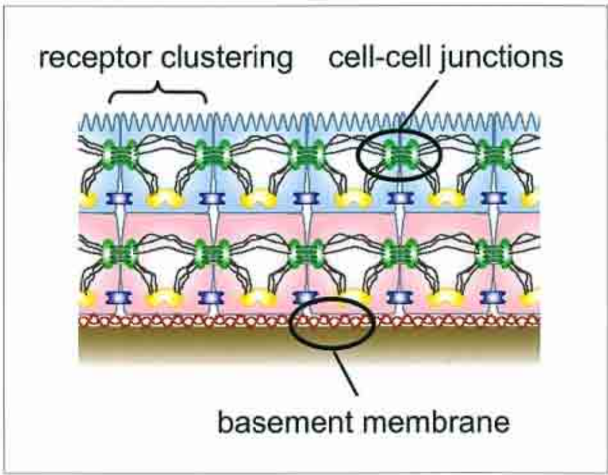
Atsuhiro Osuka
Professor, Kyoto University

Structurally well-defined Giant Porphyrin Arrays will be prepared and their single molecule detection will be preformed. These giant molecules will be assembled and organized through attachments to micro-electrodes and their meso-scopic properties and electron transport properties through metal-porphyrin surface will be thoroughly studied. Through these studies, the basis for future development of molecular electronics will be established.

Nano-Tissue Engineering Toward Next Generation Biosensors

Teruo Okano
Professor, Chief, Tokyo Women's Medical University

Cells and tissues have nanometer scale domains that are crucial for the specific functions. Novel materials will be developed in order to manipulate the nano-domains by integrating synthetic polymers, organic-inorganic hybrids, metals as well as semiconductors. Nano-devices will be also developed to detect cellular nano-responses in a real-time and non-invasive manner. These will open a novel way to utilize living cells as intelligent materials.



Creation of Bio-Devices and Bio-Systems with Chemical and Biological Molecules for Medical Use

Design of Multifunctional Quartz-Crystal Microbalance Multisensors for Quantitative Detection of Biomolecular Interactions

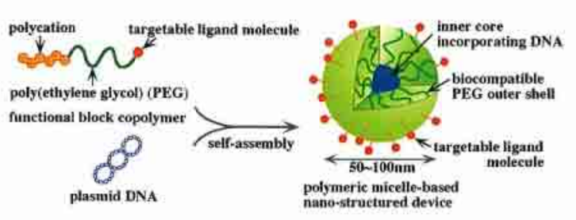
Yoshio Okahata
Professor, Tokyo Institute of Technology

We have studied that a quartz-crystal microbalance (QCM) was useful to detect single biomolecular interactions such as DNA hybridization and peptide-peptide interactions. In this project, we develop a multisensor systems of QCM and apply the multifunctional QCM for complicated biomolecular interactions such as DNA-polymerase reactions, protein-protein interactions, and protein binding to cell surfaces.

Development of Novel Nano-structured Device for Gene and Drug Delivery

Kazunori Kataoka
Professor, The University of Tokyo

Novel gene vector will be developed in this research project through controlled self-assembly of synthetic polymer and lipid molecules, allowing to achieve molecular diagnosis and therapy by delivering gene and various drugs to target organ and tissue in the body. Intelligent gene vectors thus prepared have an ability to respond physical stimuli including heat and mangetic field, and are expected to work as virus-inspired molecular nano-machine.

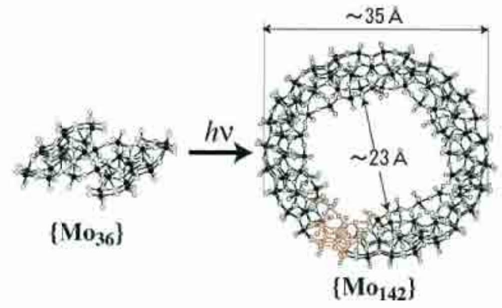


Novel Nano-sructured Device for Gene and Drug Delivery

Molecular Machinery based on Polyoxometalates as Nano-sized Clusters

Toshihiro Yamase
Professor, Tokyo Institute of Technology

Polyoxometalates as discrete metal oxide clusters comprise a class of inorganic complexes of unrivaled versatility and structural variation, and have applications in many fields of science. The fact that metal oxides ranging insulator to superconductor constitute a base for electronic devices and machines in the present industries makes the polyoxometalates promising as an industrial material in the twentieth century. It is aimed in the project to offer practical examples of functional nanotechnological innovations by bottom-up approach starting from individual polyoxometalate molecules in (photo) electronic applications and in the combination of nanotechnology and biotechnology, on the basis of our findings in the fields of photochemistry, optical and electronic devices, and biological activities. This would be the first realization of polyoxometalte-based nanotechnology to create the molecular machinery which leads to the burgeoning industry in the twentieth century.



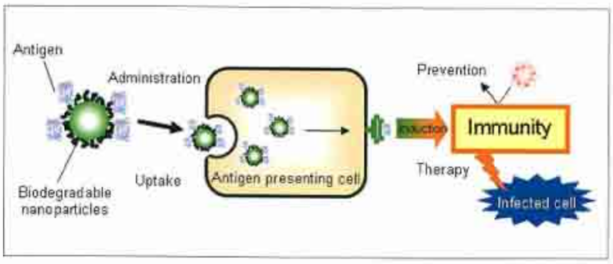
Photoinduced self-assembly to protein-sized synchrotron-storage-ring-like molybdenum blues

FY2002

Development of Anti-retroviral Vaccine Using Polymeric Nanoparticles

Mitsuru Akashi
Professor, Osaka University

This study is aimed at the development of anti-retroviral (human immunodeficiency virus type 1 and human T-lymphotropic virus type 1) vaccines using a core-corona type of nanoparticles capable of inducing excellent immunogenicity without any adjuvants. In order to achieve vaccination efficiently, we first design and synthesize suitable polymeric nanoparticles which have biocompatibility and/or biodegradability. Induction of anti-retroviral immunities will be accomplished by two different approaches. One is the direct administration of biocompatible and biodegradable nanoparticles immobilizing viral antigens on their surface to induce systemic immunity through mucous membranes. The other method is the administration of the antigens with fusogenic liposomes encapsulating the nanoparticles. It is expected that the results of this study contribute not only to the prevention and treatment of retroviral diseases but also to the establishment of nanotechnology-based medicine leading to the elimination of pathogenic cells.



Creation and Application of Nano Bio-Physico-Chemical Architectures

Takehiko Kitamori
Professor, The University of Tokyo

We have been developed the integration technologies of chemical processes and systems onto microchips. In this research project, novel nano-infrastructure will be constructed in the micrometer-scale structures utilizing the bottom-up nanotechnologies based on physical chemistry and biochemistry. Objectives of this project are elucidation of physicochemical properties in meso- and nano-space, artificial construction of order and class required for realization of bio-functions, and development of highly functional biochemical devices, such as disease sensors, bio-actuators, and artificial organ devices.

Creation of "Nanochemical Probes" and their Biomedical Sensing Application

Koji Suzuki
Professor, Keio University

The purpose of this research is to create novel "nanochemical probes" for biosensing such as nano-size micellar probes for fluorescent cellular imaging, adductive probes for ultra-sensitive mass spectrometry, and high resolution opto electrochemical nanoprobes and their application to biomedical sample analysis based on the integrated technologies of organic chemistry, biotechnology, optics, electronic chemistry, nanofabrication engineering and information processing. Our project team has lead to the worldwide advanced biosensing study with collaboration from different researchers such as chemists, physiologists, biologists and computer scientists in academia, industries and public institutions.

Creation of Innovative Artificial Nucleic Acids Capable of Control and Detection of Genome
— Based on the Most Advanced Technology for the Synthesis of Nucleic Acids —

Mitsuo Sekine
Professor, Tokyo Institute of Technology

This project was set up to create hitherto-impossible, highly sophisticated innovative artificial nucleic acid derivatives with new functions on the basis of our latest technologies such as the method for the synthesis of DNA without base protection and the method for precise recognition of bases with high resolution. Our studies will lead to a variety of new bio-related developments involving exploration of more advanced tools prescribed for the gene diagnosis and medical treatment which can bring about a major breakthrough to overcome previous serious problems these fields.

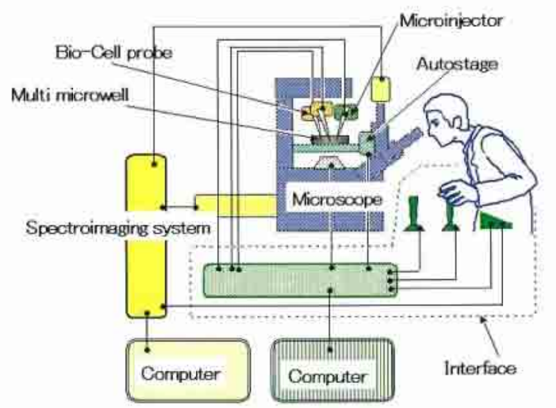
Creation of Bio-Devices and Bio-Systems with Chemical and Biological Molecules for Medical Use

The High Throughput Creation of Disease Model Cells and the Analysis of their Function

Hideaki Matsuoka
Professor, Tokyo University of Agriculture and Technology

Today a mass of genome information is available. Therefore there is a great need to investigate all diseases caused by the alteration of a particular known gene rather than to find the cause genes of a particular disease. Disease model cells (DMC) are just material that can meet this need. In this research project, various model cells will be made by the injection of gene alteration agents into oval cells, ES cells, and somatic cells of mouse. A supporting robot for the single-cell manipulation will be developed to facilitate the complicated procedures of nanoinjection and to establish a high throughput process for the DMC creation. The research results are expected to lead to the development of gene therapy methods and also to the screening of novel medicines.

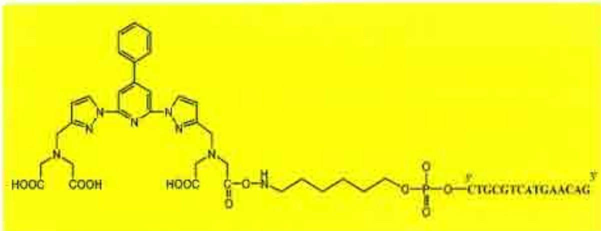
Single-Cell Experiment Supporting Robot



Delayed Fluorescence Bio-Imaging Using Metal-Complex Probes

Kazuko Matsumoto
Professor, Waseda University

A time-resolved fluorescence microscopy used with fluorescent lanthanide complex labels will be developed for observing life activities in living cells. With this microscopy system, the auto-fluorescence of cells are expected to be greatly suppressed and very clear images will be observed for longer period (several min to several tens of min) than the existing systems. The present system can be used as a tool for observing a range of life activities and phenomena. In the present study, imaging of mRNA is targeted, and a method for mRNA analysis by using FRET will be developed. The system will be a core intellectual property in biotechnology that is developed in Japan and launched from Japan to the world.



Amino-Modified Oligonucleotide with BPTA

FY2003

Novel Cell-selective Gene Delivery System Using Intracellular Signal-responsive Molecular System

Yoshiki Katayama
Professor, Kyushu University

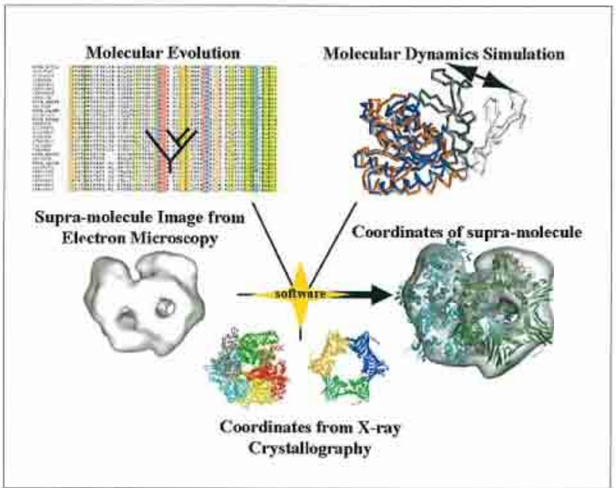
Gene therapy is one of the most promising medical teatments. However, its applicability has been restricted due to the luck of control techniques of delivered gene expression. We aim at establishing novel concept of gene delivery, which makes cellular-specific gene expression possible with our intracellular signal responsive gene carriers combined with novel gene delivery technique using bionanoparticle or neutrak plasma. These systems will be applied to some clinical models.

FY2004

A method to deduce atomic resolution structures out of low resolution supra-molecule images in biological systems

Kei Yura
Senior Scientist, Japan Atomic Energy Research Institute

The three-dimensional structures of supra-molecules in atomic resolution underlie the nano-technology. Accumulation of structural information enables us to advance new technology such as drug design. Although the X-ray crystallography plays a central role in determining atomic coordinates of proteins, it has difficulty in handling supra-molecules, complexes of many proteins, because of their size. A structural analysis based on single particle analysis using electron microscopes has been being developed for supra-molecules, yet the resolution in this method does not expand to atomic resolution. In our project, we will develop a computational technique to bridge the resolution gap between these two structure determination methods, which could mould the protein structures determined by X-ray crystallography into a crust of supra-molecules determined by electron microscopy.



Research Area

Creation and Application of "Soft Nano-machine", the Hyperfunctional Molecular Machine

Abstract of Research Area

This research area covers studies on mechanism, formation and application of "soft nano-machine", the hyperfunctional molecular machine, whose functions are based on the flexible interaction among constituent molecules and structural change of molecule on the nano level.

More specifically, this area includes (a) research to analyze the functional mechanism of soft nano-machine in living organisms and learn how to control it, (b) research for creation and application of soft nano-machines based on those functional mechanism, and (c) research on the highly efficient energy conversion, energy generation, information conversion and information transmission with soft nano-machine that consists of proteins and/or synthetic polymer molecules.

This research area is also expected to contribute to other strategic sectors, "Creation of Nanodevice / Material / System for Overcoming Integration / Function Limits in Data Processing and Communications" and "Creation of Nano Materials/ System for Realizing Environmental Conservation and Advanced Energy Recycling to Minimize Stress on the Environment".

Research Supervisor:
Dr. Hirokazu Hotani
Professor Emeritus, Nagoya University

FY2002

Quest for the Origin of the Flagellar Motility

Shin-Ichi Aizawa
Professor, Prefectural University of Hiroshima

Bacterial flagellar motor is a nano-sized rotary machine, driven by proton flow from outside to inside the cell. The molecular mechanism of energy conversion in the motor has been unknown, because the structural details of the torque generator is not reveled yet, and because the behavior of protons is beyond our detection techniques and un-describable. The needle complex, one of the supramolecular machines on the cell membrane, is a secretion apparatus for virulence proteins. Although the flagellar motor and the needle complex reveal completely different biological functions, they resemble each other in several respects: morphology, protein composition, DNA sequences of some of the component proteins, and the manner of protein secretion. One of the structural differences between the two is the presence of Mot proteins (components of the torque generator) in the flagellar motor and its absence in the needle complex, suggesting that these two nano-sized machines evolved in a parallel manner and differentiated at a certain point when the flagellar motor obtained the Mot proteins. We will be trying to solve the molecular mechanism of the flagellar motor by analyzing the origin of component proteins involved in torque generation. This approach to the flagellar motor will also give rise to an insight to the molecular mechanisms of the similar nano-sized machines on the membrane.

Creation of Nano Mechano-chemical Machines based on Protein Molecular Motors

Hiroyasu Itoh
Associate Senior Researcher, Hamamatsu Photonics K.K.

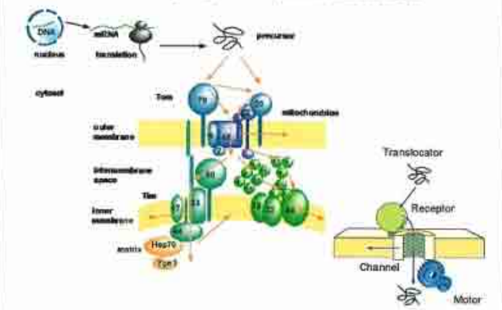
Living organisms contain molecular motors, made of a protein (or RNA) molecule(s), that directly transduce chemical energy into mechanical work. Our goal is to realize an unprecedented attempt at reversing these operations artificially, letting chemical reactions go backward by applying external force. We aim at designing nano mechano-chemical machines that drive chemical synthesis using mechanical power or that regulate chemical reactions through the action of mechanical force. Creation of such novel functions is a new departure for future biotechnology, and will also conduce to the understanding of mechanisms of natural molecular machines.

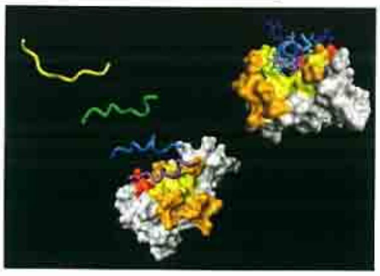
Molecular Mechanisms of the Functions of Protein Translocators

Toshiya Endo
Professor, Nagoya University

Protein translocators control topogenesis of proteins at the biological membrane systems. This study aims at revealing the molecular mechanisms of the recognition of membrane targeting signals, functions of protein-conducting channels, vectorial movement of proteins by translocator motors, and protein integration into the membranes. The expected results will contribute to the development of functional alteration of organelles and cell surface, of new drug delivery systems, and of technology of precise protein integration into membranes.

Protein targeting to and import into mitochondria





Principle and Assembly of Bio-nanomachines that Produce Vibration

Ritsu Kamiya
Professor, The University of Tokyo

Eukaryotic cilia and flagella are bio-nanomachines that produce rapid undulating movements and thereby carry out cellular swimming and material transport in microenvironments. This project is aimed at understanding the principle of the cilia/flagella movements and constructing vibrating nano-machines from defined protein components. Vibrating or undulating micromachines will find wide applications in medical and engineering fields - for example, as a tool for drug delivery or as nano-actuators.

Construction of an Artificial Cell Nucleus as a Gene-delivery System

Tokuko Haraguchi
Senior Research Scientist,
National Institute of Information and Communications Technology

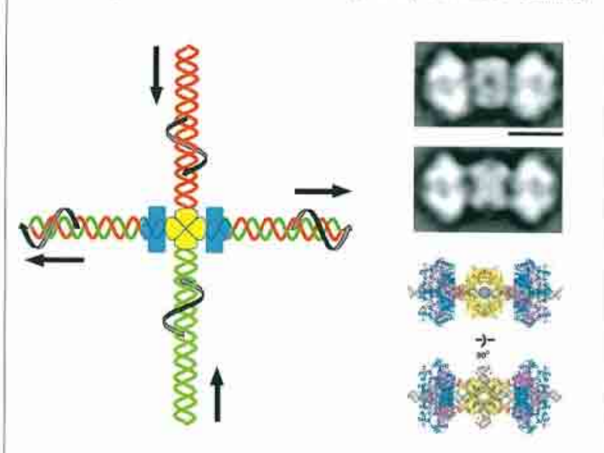
The cell nucleus self-assembles around chromosomes at the end of mitosis. Goals of our research project are to elucidate the mechanisms of nuclear envelope reformation, and to generate an artificial cell nucleus. Our research will contribute to the development of gene-delivery systems used for gene therapy and delivery of medicine.

Studies on the Molecular Motors Working along the DNA

Yoshie Harada
Chief, Tokyo Metropolitan Organization for Medical Research

The homologous recombination of the gene is carried out by protein complex including two DNA motors. DNA duplexes are unwound before the junction and rewound with the other partner strands while passing through the hollow opening of the DNA motors. Direct observation of the movement of this DNA motor complex enables us to uncover the coordinated mechanisms of DNA motors in the protein complex. The project is seeking to develop a nano-machine system which consists of multiple, cooperatively working proteins.

Homologous recombination of the gene by DNA motor complex



Creation and Application of "Soft Nano-machine", the Hyperfunctional Molecular Machine

Development of Observation Methods for Cellular Systems

Yoshinori Fujiyoshi
Professor, Kyoto University

We are aiming to undertake technical and methodological development for observation of cellular systems, such as spines, synapses and growth cones in neurons. This study could be expected to open a new field in cellular and neuronal studies based on structural biology and to develop new instruments for the field, because we have been developing a cryo electron microscope and PolScope both of which will come into the market.

Nano-machines Modeled after Fluctuations and Flexibility of Bio-systems

Toshio Yanagida
Professor, Osaka University

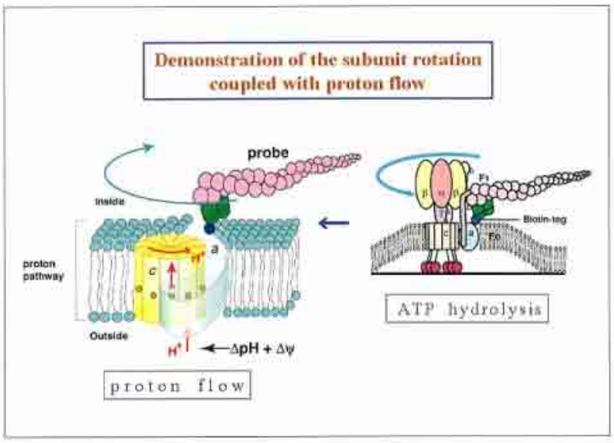
Biomolecular motors are nano-machines responsible for many motile processes in living organisms. These motors work efficiently using the energy from thermal fluctuations. This unique operation is what differentiates biomolecular machines from artificial machines. This project will explore the underlying mechanism of how these molecular motors and other molecular machines in bio-systems harness the energy from thermal fluctuations, using techniques of protein designing, single molecule imaging, nano-measurements, structural analysis with low-temperature electron microscopy, computer-simulation, and reconstructed motor systems. Bio-systems such as living cells are composed of various kinds of proteins and their assemblies. Their functions are highly flexible which can be altered to respond to changes in external stimuli and environmental conditions. Such versatility or "softness" of the bio-systems will be explained by the unique operations of protein molecules both experimentally and theoretically. Based on the results of these studies, an artificial muscle will be made as a model system of cell movements using polymer gels. Our ultimate goal will be to find an underlying basic principle for the relationship between the fluctuations and softness of bio-systems.

FY2003

Studies on the Mechanism of Proton Pump ATPase as Highly Efficient Nanomotors

Masamitsu Futai
Special Research Scientist, Microbial Chemistry Research Foundation

F-ATPase (ATP synthase) couples between chemistry (ATPase hydrolysis or synthesis) and proton transport by rotations of their subunits. We will study the detailed coupling mechanism, especially how ATP hydrolysis drives the rotation. We will also show how membrane potential and/or proton gradient drives rotation. We will also study subunit rotation of V-ATPase which is found in organelles including lysosomes and endosomes. Our studies will establish the molecular mechanism of the rotational catalysis by proton pumps.



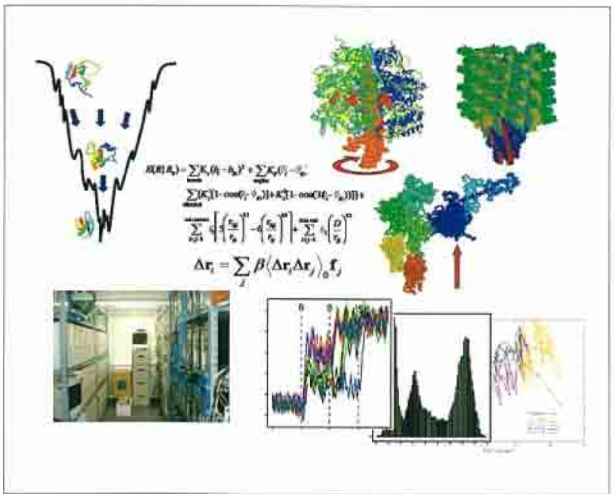
FY2004

Hierarchal modeling of bio-nanomachines: From dynamical structure to function

Shoji Takada

Associate Professor, Kobe University

For designing optimal soft-nanomachines, learning molecular principle of bio-nanomachines would be indispensable, for which new generation of theoretical modeling is necessary. This research project aims at theoretically uncovering how bio-nanomachines, such as molecular motors, exhibit their versatile functions. For the purpose, we first 1) perform dynamical structure modeling of bio-nanomachines using amino-acid sequences and available structures of their building-blocks. Next, we study functional mechanisms both at atomistic and at coarse-grained resolutions: Namely, we pursue 2) statistical mechanical modeling of dynamical function based on the global perspective of the energy landscape theory, and 3) atomistic-scale molecular dynamics simulation of dynamical function. Main targets studied are, F_0F_1-ATPase, actomyosin, and flagellum. We interpret experimental results of individual cases, make testable predictions, and contribute to design new experiments and ultimately to create new soft-nanomachines.



Research Area

Creation of Novel Nano-material/System Synthesized by Self-organization for Medical Use

Abstract of Research Area

This research project aims for the establishment of fundamental principles and methodologies for the synthesis of nanometer scale materials with novel functional properties by the well-designed control of molecular arrangement based on the concept of self-organization. Main research subjects to be studied in this project are as following.

(1) Development of the methodologies for the synthesis and evaluation of self-organized soft materials with the accuracy of nanometer scale.
(2) Precise understanding of the mechanisms of molecular recognition and information transfer in a nanometer regime.
(3) Design and synthesis of self-organized inorganic and organic materials with novel material properties.
(4) Developments of the new aspects of solution and surface sciences from the point of view of the bio-material science.

The results of this research project finally contribute to the advanced medical treatment as well as the information technology and environment technology.

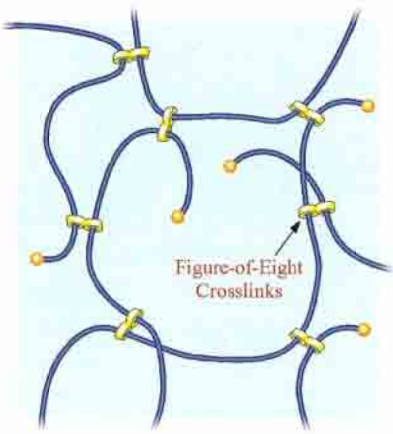
Research Supervisor:
Dr. Koji Kaya
Director,
WAKO Institute / Discovery Research Institute, RIKEN

FY2002

Production of Functional Biomaterials with Topological Gel for Medical Use

Kohzo Ito
Professor, The University of Tokyo

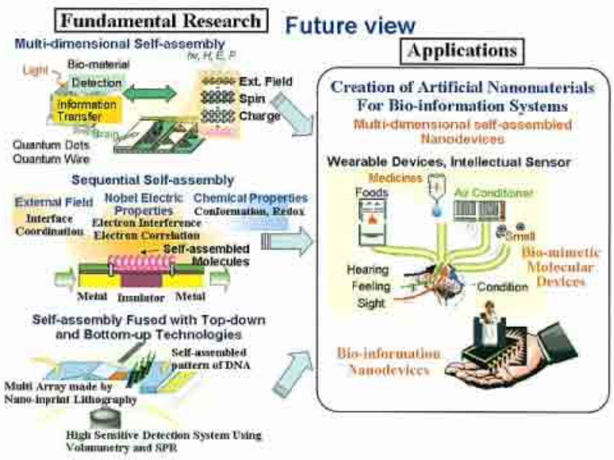
We have recently developed a novel kind of polymer gel, topological gel, which has figure-of-eight crosslinks moving freely in a polymer network. This new network structure automatically relaxes the inhomogeneous tension and stress in the gel on tensile deformation. The aim of this research is to produce biocompatible gel materials drastically changing the mechanical property through the control of the movement of the crosslinks by the external stimuli such as ionic environment, temperature, electric field and light.



Creation of Bio-mimetic Intellectual Material based on Programmed Self-assembly

Tomoji Kawai
Professor, Director, Osaka University

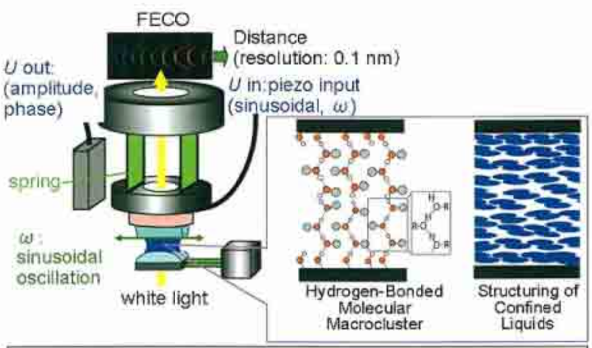
A living body is an extraordinarily elaborate and advanced "information material system," constructed based on a DNA program. The construction of a highly functional material device system with a mechanism of programmed self-assembly is a frontier of the 21st century's science technology. This research aims to clarify and establish the principle of "programmed self-assembly," which is the highest-priority issue in bottom-up nanotechnology, and the creation of artificial "bio-mimetic intellectual material" based on this principle.



Nanostructuring of Liquids at the Solid-Liquid Interfaces

Kazue Kurihara
Professor, Tohoku University

Liquid molecules, which are confined in a nanometer scale space and at the solid-liquid interfaces, exhibit quite different behavior from those in the bulk. This study aims at developing new methods for investigating the structuring of liquids confined at the solid-liquid interfaces and between solid surfaces. The new methods include the shear resonance measurement, which provides new insights into the structuring, and rheological and tribological properties of liquids confined in the nanospaces. Hydrogen-bonded molecular macroclusters, which we recently found on silica surfaces in apolar solvents, are also investigated from both of fundamental and applied point of views. Obtained knowledge should have important bearings on designing new nanomaterials for such applications as bio-medical and micromachines, and controlling friction and lubrication at the molecular level.

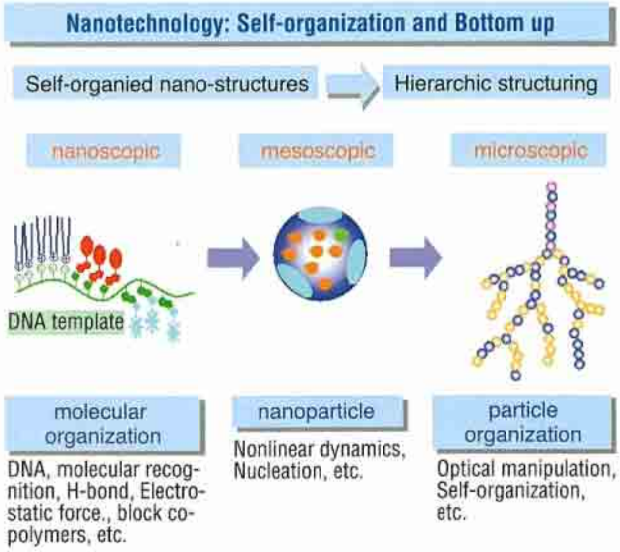


• This study aims at elucidating nano-structures of liquids at solid-liquid interfaces and in confined spaces.

Fabrication of Nanostructured Medical Devices Based on Self-organized Polymer Materials

Masatsugu Shimomura
Professor, Hokkaido University

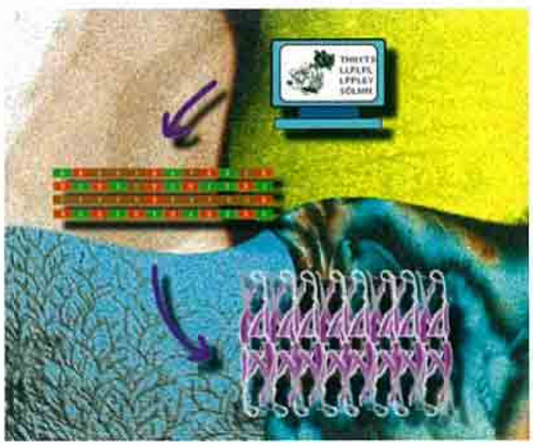
This research project aims to fabricate controlled polymer architecture with hierarchical structures from nanoscopic to macroscopic scales. Nanoparticles and mesoscopic polymer organizates prepared from DNA and biodegradable polymers are assembled into controlled three-dimensional structures by combining "bottom-up" optical manipulation technique and self-organization processes. The final goal of this research is to utilize the novel materials for tissue engineering, which regulate cell culture and growth.



Development of a Programmable Artificial Protein System for Nano-biotechnology

Kiyotaka Shiba
Chief, Japanese Foundation for Cancer Research

Our goal is to establish a novel system by which functional protein-based tissues and other materials are rationally designed and created. To accomplish this, we will use a unique protein engineering system in which periodic proteins are created through polymerization of designer microgenes. This system will serve as a platform for a broad range of biotechnologies, enabling exploration of new approaches to questions in areas of medicine, material engineering and semiconductive polymer science, among many others.

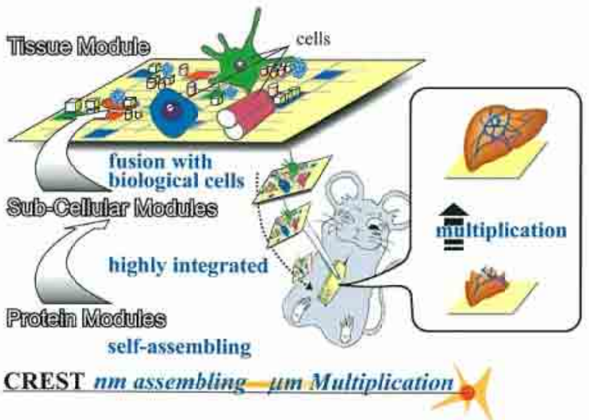


Creation of Novel Nano-material/System Synthesized by Selforganization for Medical Use

Protein Module: From Nano Assembling to Micro Multiplication

Fumio Tokunaga
Professor, Osaka University

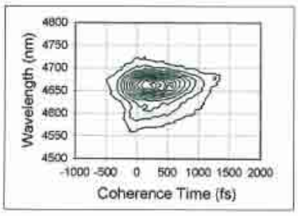
In biological body, hierarchical structures can be recognized in general; molecules, polymers, organelles, cells, tissues, organs, and so on. These components at each classified level have the specified functions and are located at the specific positions. "In biological systems", such components automatically assemble, construct the new units at the higher level to realize new functions. Our project aims to create artificial modules at the various levels, corresponding to biological systems, which induce the automatic assemble of the components and construction of structures at a higher level. The basis of our project toward a biological system is a protein module, where proteins are clustered. Protein modules are constructed by several original methods related to self-organized membrane and crystals. The protein modules are assembled with a highly ordered structure to construct a sub-cellular module by means of nano self-organization and laser nano/micro processing. The sub-cellular modules are patterns, leading to highly ordered structure. Its further integration will provide an artificial cell, what will undergo self-multiplication system.

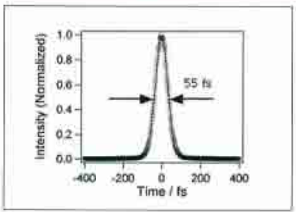


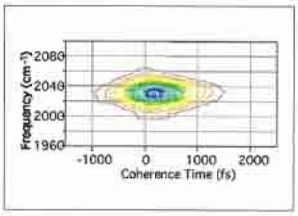
Reaction Dynamics in Nano-Scale

Keisuke Tominaga
Professor, Kobe University

We study reaction dynamics and functionality of self-organized systems by developing advanced molecular spectroscopy including ultrafast laser technique. Our particular interest in this research is to reveal cooperativity of multipule intermolecular interactions, diversity of dynamics, and selectivity and directionality of reaction on the basis of molecular science. In future, result of this research will be able to give principles and idea to develop nano-soft machine.



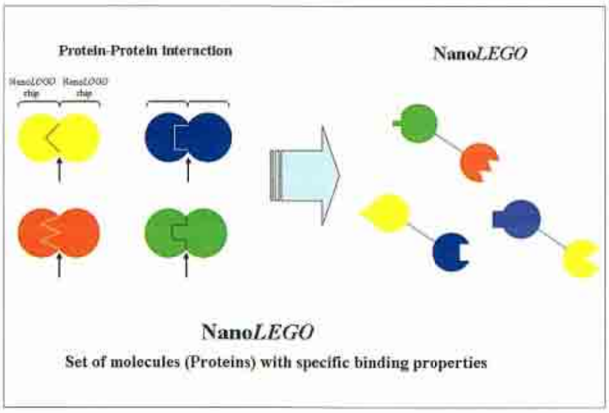




Development and Medical Application of "NanoLEGO" from Biomolecule Selected by Genome-wide Screening

Yoshihide Hayashizaki
Chief Scientist, RIKEN

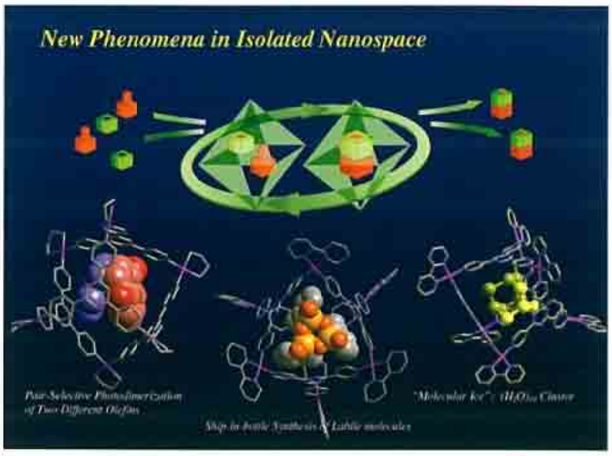
Protein-protein interactions (PPIs) play pivotal roles in the network of cellular biological processes, where enormous numbers of specific binding domains are observed. In this project, we conceive of the binding domains as "nano-scale chip" and design their fusion proteins in the purpose of developing new functional molecules that are self-organized in order and in a controllable way. We designate these functional molecules as "NanoLEGO". In our plan, we carry out large-scale protein-protein interaction assay and the interaction domain mapping using our mouse cDNA clones. We then design and express fusion proteins (NanoLEGO) using the identified domains. Further, their physical property and configuration of their complex are examined in nano-scale, which we expect to find functional biomaterials for medical use.



Development of Self-organizing Molecular Systems for Chemical Translation of Biological Functions

Makoto Fujita
Professor, The University of Tokyo

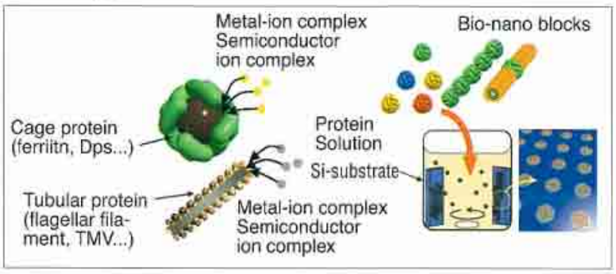
Precise self-organization at a molecular level takes an important role for biological functions. In reminiscent of such biological systems, we focus in this study on the self-organization of small molecules into highly ordered, hollow nano-assemblies where the observation of new chemical and physical phenomena are expected. Such molecular systems, being comparable with biological one in dimensions and functions, can be applied to medical technologies based on molecular level design.



Nano Integration Process by the Biomolecule Nanotechnology

Ichiro Yamashita
Chief Researcher, Matsushita Electric Industrial Co., Ltd.

This project will investigate the process of constructing organic or inorganic structures on solid surfaces. The project takes advantage of several features of biomolecules; namely their atomically identical structures, ability to self-assemble and ability to biomineralize. The mechanisms of biomineralization, self-assembly, and the interaction between biomolecules and solid surfaces will be studied and the results used to construct nanostructures on a solid surface. The knowledge obtained from this project will support future interdisciplinary research and the industrial application of biology and nanotechnology.



Research Area

Creation of Nano-Structured Catalysts and Materials for Environmental Conservation

Abstract of Research Area

The research area is directed towards the creation of new catalysts, materials, and chemical systems which can synthesize and treat chemical substances with high efficiency and selectivity and with less environmental impacts, and consequently will contribute to conserve and remedy the present environmental conditions.
More specifically, this area includes researches for; (a)Replacement of an environmentally unfriendly synthetic process by a process with less environmental impact by introducing catalysts whose nano-structures are finely controlled. (b)Creation of new nano-structured materials which possess a highly efficient separation and adsorption capacity, and a high stereo-selective surface and catalytic function. (c) Development of nano-structured catalysts to remove hazardous chemical substances selectively and efficiently in flue gases and waste waters by separation and decomposition. (d) Innovation in new systems incorporating those new nano-structured materials. (e) Creation of nano-reactors which have nanoscale reaction fields inside, and (f) Creation of materials with a well defined nano-structure.

Research Supervisor:
Dr. Makoto Misono
President,
National Institute of Technology and Evaluation

FY2002

Transition Metal Catalysts with Defined Nano-structure to Transform Organic Compounds in Water

Yasuhiro Uozumi
Professor, National Institutes of Natural Sciences

Transition metal nano-composite and/or nano-clusters will be prepared, in a tailor-made manner, in an amphiphilic polymer matrix from various transition metal complexes. The polymer-supported metal nano-composite would catalyze a given fine organic transformation in water under heterogeneous conditions to realize an environmentally benign and risk-free chemical process.

A SEM Image of Polystyrene-Poly(ethylene glycol) resin beads supporting Palladium Nano-particles.

Developments of Highly Functional Oxide Clusters for Green Chemical Synthesis

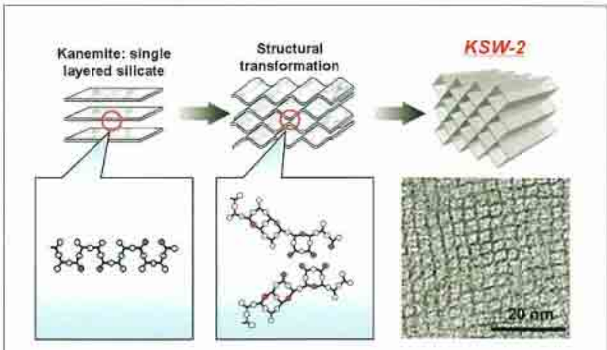
Toshio Okuhara
Professor, Hokkaido University

The object of this study is to design and develop new functional solid catalysts for green chemical synthesis. Two types of solid catalysts consisting of oxide clusters are designed with nano-size control of the structure; superacid catalysts for organic synthesis in aqueous media and highly difficult fine synthesis, and selective oxidation catalysts for alkanes with hydrogen peroxide and oxygen.

Creation of Highly Controlled Nano-space Materials

Kazuyuki Kuroda
Professor, Waseda University

The creation of novel nano-space materials, including microporous and mesoporous materials, with well-controlled compositions and structures is the scope of this research. On the basis of structural analysis by the electron crystallography, the capability of nano-space materials as catalysts for the environmental conservation will be evaluated. The functions of nano-space materials will be understood in a unified way in relation to their compositions and structures. The research challenges to create innovative nano-space materials of next generation, aiming at the environmental and industrial applications.

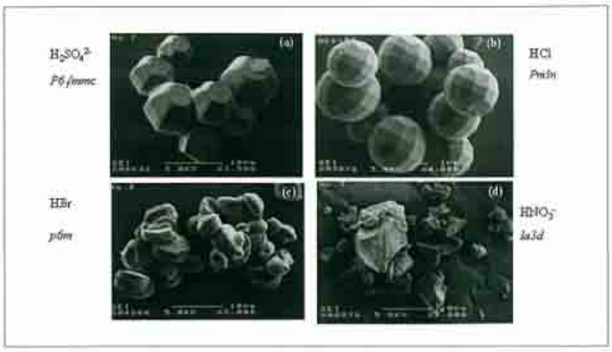


Formation process of novel mesoporous silica derived from a layered polysilicate
(Monolayered silicate → Structural change → KSW-2)

Creation of Green Catalysts through Free Interconversion of Organic-Inorganic Composite Phase

Takashi Tatsumi
Professor, Tokyo Institute of Technology

Utilizing the softness of the organic-inorganic composite phases directed by organic templates, we would strive to consciously convert the composites to novel zeolitic and mesoporous catalytic materials having desired porous structures and precisely controlled active species. The theory and mechanism of the morphological change in the silica-surfactant supermolecules and the mutual interconversion of the layered and 3-D structures of zeolites will be revealed. These well-designed nano-structured catalysts are expected to contribute to the development of green chemical processes.

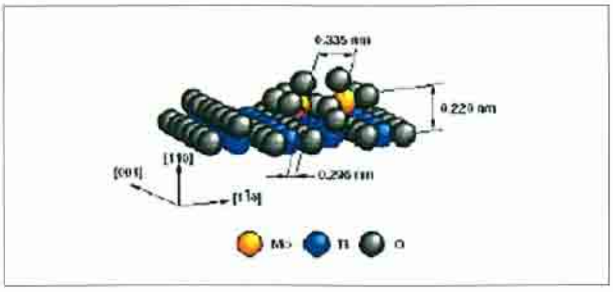


SiO_2 giving rise to 4 types mesophase in different anion conditions.

Creation of Highly Efficient Well-defined Metal Oxide Surfaces

Wang Jae Chun
Associate Professor, Hokkaido University

The objective of this research is the creation of new environment-friendly materials with high efficiency, high selectivity and self-control functions e.g. self-multiplication and self-restoration. We investigate physics and chemistry of single crystal metal oxide surfaces or chemically modified ones by suitable surface science techniques in an atomic or a molecular level. Moreover, it is expected that the new nano-analysis technique developed here will activate the nano-technology.

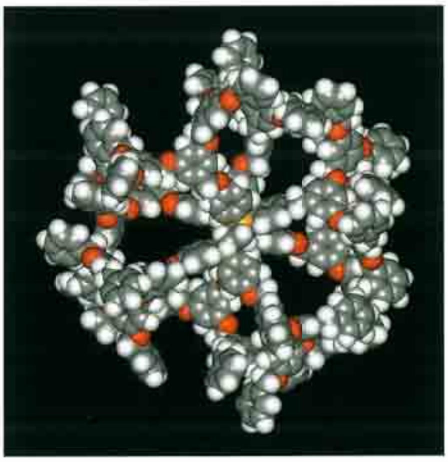


Well defined atomic structure on metal oxide surfaces determined by Polarization-dependent Total-Reflection Fluorescence X-ray Absorption Fine Structure technique.

Creation of Molecular Catalysts with Controlled Nanometer Space in Homogeneous Phase

Yasushi Tsuji
Professor, Hokkaido University

Well-defined nano space is introduced into homogeneous molecular catalyst system and supramolecular affinity of the nano area achieves highly selective reactions involving molecular recognition. This novel catalyst system realizes very efficient transformations to afford useful materials under mild reaction conditions near room temperature, and is definitely essential to maintain good world environmental conditions.



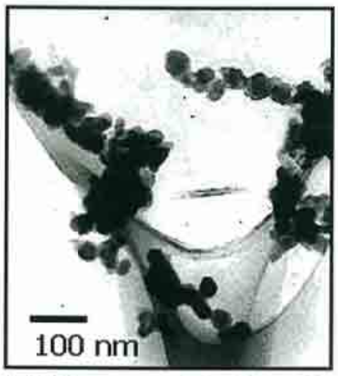
Optimized structure of novel nano-sized platinum (0) phosphine complex located at a core of second-generation dendrimer moiety (by CONFLEX/MM3-PM3/MOZYME -B3LYP/LANL2DZ calculation)

Creation of Nano-Structured Catalysts and Materials for Environmental Conservation

Nano-structured Catalytic Systems Using Perovskite-type Oxides

Yasutake Teraoka
Professor, Kyusyu University

The present research project concerns with the development of nano-structured catalytic systems using perovskite-type oxides for the exhaust gas treatment, fuel cell and battery electrodes, and oxygen-permeable membrane reactors. The basic strategy is to build up the catalytic systems of high performance and practical applicability by starting from the control of nano-structure and property of materials, and extending stepwise to meso- and macro-sturucture. We also aim at establishing a general methodology and scientific basis for the construction of catalytic systems and devices using mixed metal oxides based on the nano-technology.

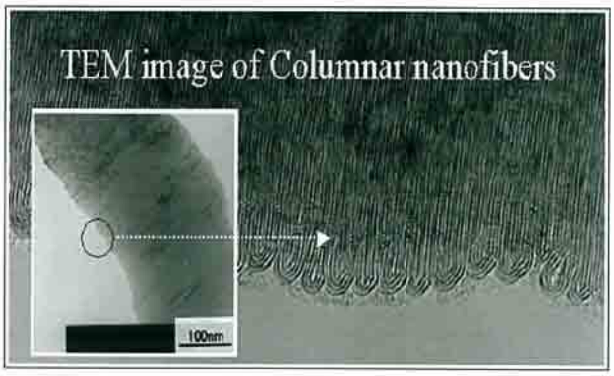


$LaMnO_3$ nano-particles formed by reverse uniform coprecipitation

Novel Catalytic Functions of Carbon Nano-fibers with Optimized Surface Structure

Isao Mochida
Professor, Kyusyu University

Our research team has succeeded to prepare a variety of carbon nano-fibers with designed diameters and alignments of hexagonal planes. We will develop novel catalytic functions over the defined surfaces of the carbon nano-fibers, recognizing their detailed structures. The surface themselves and catalytic substances such as material sulfides, oxides, carbides of fibrous nano-materials and micro organisms on the particular carbon nano-fiber surfaces are expected to develop superior and unique catalytic activities for environmental protection. Resolution on the interaction of the carbon nano-fiber surfaces with pollutants and catalytic materials may open novel windows of nano-catalytic chemistry. Preparation of carbon nano-fibers and novel nano-catalysts in a large quantity can provide new bases for industries of energy, materials, and environmental.



TEM image of columnar carbon nano-fiber

Selectivity Control Procedures and Their Use in Hydrocarbon Partial Oxidations Over Orderly Substituted Mixed Oxides at Nanometer Level Scale

Tatsuaki Yashima
Guest Researcher, Miyazaki University

Reactivity of hydrocarbons in the oxidation over metal oxides mainly depends on active oxygen species on the surface. To get a high yield and selectivity in the hydrocarbon partial oxidations, the control of total amount and migration of active oxygen species is important. We prepare two-dimensionally ordered mixed oxides at nanometer level scale on the surface. Every selected metal ion in the oxides has different affinity for oxygen in the gas phase. We expect the migration of active oxygen species over these prepared oxides are obstructed, which will cause the decrease of the amount of active oxygen species in the reaction area. Then, a high yield of oxygenates can be obtained. These selectivity control procedures will be also effective to get a high yield in other hydrocarbon partial oxidations such as propylene oxide formation.

FY2003

Nano-catalyst Based on Fine-controlled Metal Assembling

Kimihisa Yamamoto
Professor, Keio University

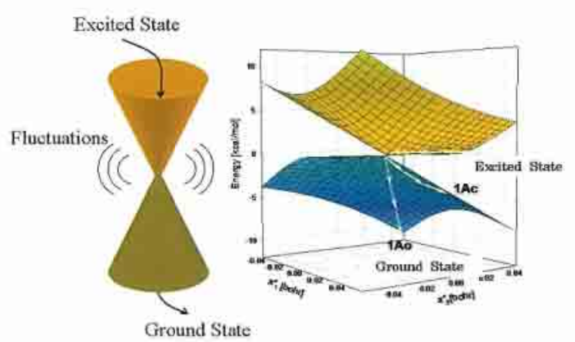
This project will focus on supra-molecules fine-decorated metal ions as leading-edge materials in order to create nano-catalysts based on fine-controlled metal assembling. The objective will be the development of new concepts for mono-dispersion clusters, sequential multi-electron transfer, etc., using the supra-molecules as a key material. In addition, the breakthroughs for energy and environmental science will be forthcoming by devising nano-catalysts for advanced fuel cells or air purification.

FY2004

Study of Nano-Environment to Realize the Optimum Molecular Properties

Shinichiro Nakamura
General Manager, Computational Science Laboratory,
Mitsubishi Chemical Group Science and Technology Research Center, Inc.

Aiming at the realization of the optimum molecular properties, theoretical and experimental studies are proposed. The properties induced by nano-environment will be investigated, by learning biological systems in which chemical energy is transformed to mechanical energy at extremely high efficiency. Subjects include molecular and solid state electronic structures, opt-electronic nonlinear properties, surfaces and interfaces design, and fluctuation analysis.



Conical Intersection, the bifurcation point of reactions

Research Area

Development of Advanced Nanostructured Materials for Energy Conversion and Storage

Abstract of Research Area

The research area covers the studies of nanotechnology for highly efficient energy conversion and storage, for creation of environmentally friendly technology for new energy and energy saving, and for creation of nano-ordered functional or structural materials with advanced physical properties for energy savings, which contribute to environmental improvement and conservation.

More specifically, this area includes researches for, (a) creation of nano-functional materials system and thermoelectric conversion devices for realizing high yield and selective material conversion processes and environmenally friendly energy systems, with very high energy efficiency, (b) creation of nano-functional materials/systems for high energy savings and new environmenally friendly systems such as solar batteries, fuel cells and heat reflecting and self-cleaning materials, (c) creation of high-functional nano-structured materials by controlling material composition, organization, structure and surface boundary on nanometer order, in order to realize highly efficient energy conversion and advanced use of energy, and (d) creation of process and evaluation technologies necessary for their construction.

This research area is also expected to contribute to other strategic sectors "Creation of Nanodevice / Material / System for Overcoming Integration / Function Limits in Data Processing and Communications" and "Creation of Functional Materials/ System that Utilize Nano Biotechnology for Realizing a Noninvasive Medical Treatment System".

Research Supervisor:

Dr. Akira Fujishima

Chairman,
Kanagawa Academy of Science and Technology /
Professor Emeritus,
The University of Tokyo

FY2002

Creation of Energy-conversion Devices Using Multi-dimensionally Ordered Matrices

Kiyoshi Kanamura

Professor, Tokyo Metropolitan University

Energy transducers derived from electrochemical reactions are represented by polymer electrolyte fuel cell, rechargeable lithium ion battery, and super capacitor. The creation of liquid-free devices requires another vigorous research than development of ordinary cells or batteries. This research aims the establishment of engineering and technologies on multi-dimensionally ordered materials. The establishment enables us to control not only the bulk structures of electrodes or electrolytes but the interface between electrodes and electrolytes, and would lead to novel solid-state energy-conversion devices.

Development of Highly Functional Nanotubular Materials and Their Application to Energy Conversion Processes

Tsuyoshi Kijima

Professor, Miyazaki University

This project was motivated by our recent discovery of platinum and polymer nanotubes of 6 nm outer-diameter. The research activities of this group are directed to the surfacatnt-templated synthesis and application of catalytic, proton-conducting, dielectric, hydrogen storage and other highly functional nanotubular materials. In particular, most efforts are devoted to the fabrication of Pt nanotube-bearing electrodes and nanotubular polymer electrolytes for fuel cells, nanostructured electric double layer capacitors as well as their assembled forms.

Development of Nano-structured Photocatalysts with Visible Light Response for Water Splitting

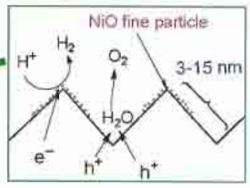
Akihiko Kudo

Professor, Tokyo University of Science

Visible light response photocatalysts in which charge separation and reactive sites for H_2 and O_2 evolution are controlled with specific nano-structure are developed in order to produce hydrogen from water using solar light. This research is expected to solve the global energy and environmental issues.

Visible light response photocatalysts in which charge separation and reactive sites for H2 and O2 evolution are controled with specific nano-structure are developed in order to produce hydrogen from water using solar light. This research is expected to solve the global energy and environmental issues.

NiO/NaTaO3:La photocatalyst with high activity for water splitting.

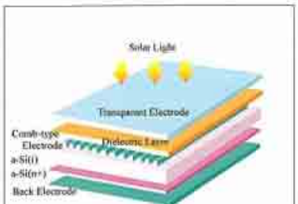


Reaction sites created with surface nano-structure.

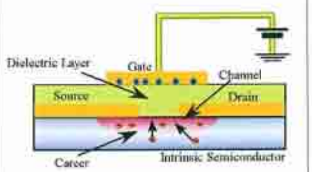
Development of Field Effect Induced Optically Functional Devices by the Integrated Nano-technology

Hideomi Koinuma
Research fellow, The University of Tokyo
Vice President, National Institute for Material Science

New possibility of electrical field effect is sought after in the development of high efficiency optical devices such as solar cells, transparent transistors, and photo catalysts, in view of the fact that carrier control can be achieved without using impurity doping which inevitably accompany the defects formation. Metal oxides and organic materials are mainly used as semiconducting components to extend the applicability of field effect. For high throughput experimentation to bring the speed in the research, an innovative combinatorial synthesis and characterization system will be designed and materialized.



Schematic Figure of Field Effect Solar Cell



Career Control by Field Effect

Creation of Thermoelectric Oxide Materials with Layered Structures through Nano-Block Integration

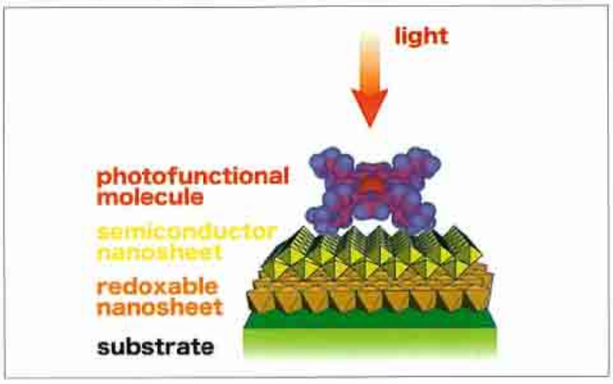
Kunihito Koumoto
Professor, Nagoya University

In order to create thermoelectric materials with high conversion efficiencies that can contribute to the effective utilization of energy in the future society, we attempt to simultaneously realize high electrical conductivity, large thermopower and low thermal conductivity in layer-structured oxides through integrating the functional blocks that are designed at nano length scale. Commercialization of thermoelectric power generation by use of dispersed heat sources such as automobiles would be expected to give great impact on the economic society.

Fabrication of Nanostructured Materials with Photo-functonalities Via Self-assembly

Takayoshi Sasaki
Director, National Institute for Materials Science

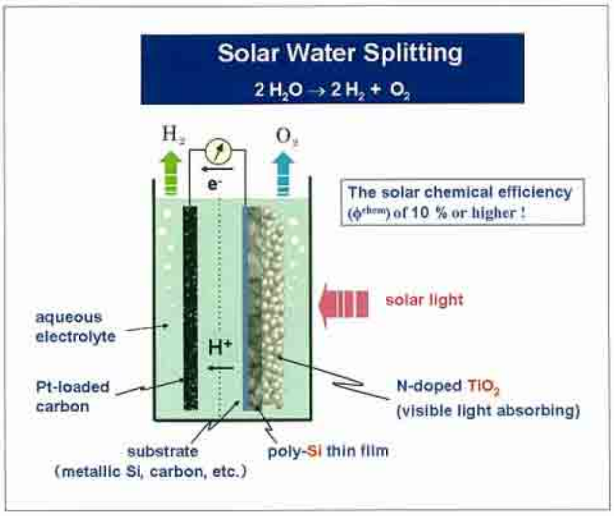
In this research project, we will develop a synthetic technique to self-assemble functional nanosheet oxides into tailored systems with hierarchical or gradient nanoarchitectures. This technique is expected to be applicable in design of new multicomponent nanosystems and nanodevices with a range of sophisticated functions including energy-conversion, storage and saving.



Efficient Solar Water Splitting by a Composite Semiconductor Electrode with Interfacial Nanostructuring

Yoshihiro Nakato
Professor, Osaka University

With an aim at high-efficiency and low-cost solar energy conversion, we will make research on solar water splitting by a composite polycrystalline Si/N-doped TiO_2 thin film semiconductor electrode. The ultimate target is the achievement of solar-to-chemical conversion efficiencies of 10% or higher by skillful interfacial nanostructuring. The success of this work opens a new possibility for the realization of large-scale (or global-scale) solar energy conversion systems.

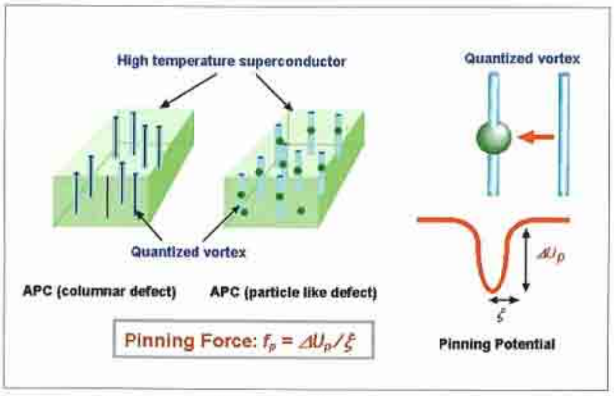


Development of Advanced Nanostructured Materials for Energy Conversion and Storage

Development of High Critical Current Superconducting Materials by Nano-Structure Control

Kaname Matsumoto
Associate Professor, Kyoto University

It is necessary to improve the critical current density of high-temperature superconducting wires several times for realizing high-efficiency electric and industrial apparatus such as superconducting power transmission cables, SMES, high-field motors and generators, to minimize stress on the environment of the earth. This research aims to introduce artificial pinning centers (APC) into superconductors by nano-structure control and to improve the critical current density strikingly by effective pinning of quantized vortices. As a result, it is expected that the applications of the high-temperature superconductors at 77 K will be accelerated dramatically.



The quantized vortex lines with the diameter of the nano-scale are formed in high-temperature superconductors under the magnetic field. If the vortex lines are moved by the Lorentz force, which is induced by the transport current, the zero-resistance disappears. This problem is solved by introducing the artificial pinning centers of nano-scale with various dimensionalities (particle-like, linear-like and planar-like crystalline defects) in the superconductors. Thus, superconductors can carry high non-dissipative currents as long as vortices are pinned.

Study on Electric-Energy Storage Devices Made by Nano-Scale Materials

Jun-ichi Yamaki
Professor, Kyushu University

Performance of lithium-ion batteries, capacitors, and other electric-energy storage devices is not only determined simply by macroscopic chemical composition of their electrode, but also strongly affected by nano-scale structure of electrodes. Therefore it is very important to investigate and control nano-scale structural parameters of the electrodes, such as nano-particle size of active materials, nano-size porosity and so on. In this study, by constructing and controlling a new nano-scale structure of electrodes, we aim to find new functions of the electrode and improve the performance of lithium-ion batteries, capacitors, and air batteries.

FY2004

Nano-simulation of Electrochemical Two-phase Interfaces

Tamio Ikeshoji
Director, National Institute of Advanced Industrial Science and Technology

In the fuel cell development, a lot of efforts to increase output currents, but not output voltage, have been made. Electrode catalysis is very important. Two-phase interface between electrode and Solution plays an important role. Structure and reactivity (including kinetics of electron) in its nano-meter region must be resolved. Recent advancement in the simulation methods and the computer performance make it possible to simulate these complex systems. This kind of simulations will contribute not only the fuel cell technology but also another technology developments in energy & environmental problems, censers, devices, and also nano-sciences.

Research Area

Creation of Innovative Technology by Integration of Nanotechnology with Information, Biological, and Environmental Technologies

Abstract of Research Area

Nanotechnology is expected to find applications in many areas of science and technology, including materials design, communication technology, biotechnology, and environmental technology. The projects in this program explore innovative applications and integration of nanotechnology in these diverse areas. To realize the full potential of nanotechnology, the scientific knowledge base must be broadened at the same time as we explore new applications in devices and systems. Recognizing the importance of exploring opportunities from both engineering and basic science approaches, we have included projects from widely ranging areas covering physics, chemistry, biology, and engineering. All the projects here are motivated by creative ideas of individual researchers and are being carried out by an individual or a small team of researchers.

Research Supervisor
Dr. Sukekatsu Ushioda
President,
Japan Advanced Institute of Science and Technology

RESEARCHER *2002–2005*

Extracorporeal Control of Nano-device Functions Aimed at Effective Cancer Therapy

Takao Aoyagi
Professor, Kagoshima University

The objective of this project is to develop an effective cancer treatment that combines hyperthermia and drug therapy. To achieve this purpose we will design a new device, using nano-magnetite that is chemically modified with sensitive thermo-responsive polymers. The polymers will be loaded with anticancer drugs through electrostatic interaction. This nano-device is heated by the inductive effect of radio frequency waves to cause a hyperthermic effect to tumor and simultaneously to release drugs regulated by thermo-responsive polymers. The combined action of this device is expected to cure cancer by efficiently damaging tumor cells.

Creation of Artificial DNA Devices for the Photo-regulation of Bio-reactions

Hiroyuki Asanuma
Professor,
Nagoya University

A gene that encodes a single protein is composed of millions of nucleotides. However, its expression is actually controlled by nano-ordered DNA devices involving at most several hundred nucleotides like a promoter or an enhancer sequence for RNA polymerase reactions. If these natural DNA devices are reorganized and modified chemically, we can create new systems that enable us to regulate various bio-reactions artificially. The purpose of this project is to create photo-switching bio-nano devices of artificial DNAs involving photo-responsive organic molecules, and their application to the photo-regulation of bio-reactions such as gene-expression. We have already synthesized several photo-responsive DNAs, and have successfully photo-regulated DNA and RNA polymerase reactions with these photo-switching devices. In the present project further sophisticated photo-switching devices will be developed to achieve effective photo-regulation of gene-expression and photo-triggered amplification of DNA (photo-PCR). With these photo-switching bio-nano devices, new systems and tools for the future biotechnology and therapy will be produced.

Creation of Innovative Technology by Integration of Nanotechnology with Information, Biological, and Environmental Technologies

Development of Quartz-crystal Resonator Type Molecular Recognition Chips using Micro/nanomachining Techniques

Takashi Abe
Associate Professor, Tohoku University

The main objective of this project is to develop a new generation of Quartz-Crystal Microbalance (QCM). A multi-channel device containing an array of QCM on a single-chip will be fabricated and characterized for applications to molecular recognition. The resultant technology will be applicable to microchips for clinical diagnostics, electronic nose, and ultrahigh sensitivity sensors used in detecting physicochemical phenomena in the nano-scale world.

Development of Scanning Interaction Spectro-microscope for Fabrication of Quantum Nano-structures

Toyoko Arai
Assistant Professor, Japan Advanced Institute of Science and Technology

This project will develop a new microscope that can distinguish individual atoms and molecules on a surface with an additional capability for fabricating quantum nano-structures. This novel instrument, "scanning interaction spectro-microscope (SISM)", will have three featured functions. The first is the imaging capability with atomic resolution as a noncontact atomic force microscope. The second is the analyzing power of surface electronic states relevant to chemical bonding. The analysis is based on "surface interaction spectroscopy on the atomic scale", which we have developed recently. Each atom and/or molecule on the sample can be distinguished by this analysis method. The third is the ability to manipulate atoms and molecules on the surface. This project is expected to develop a promising tool for future nanotechnology.

Development of a Super-critical Fluid Jet Technique and its Application to Elucidation of Molecular Recognition Mechanisms

Shunichi Ishiuchi
Assistant Professor, Tokyo Institute of Technology

Molecular recognition is a fundamental and important subject in nano-biology. This project is focused on neurotransmitters. To observe functional parts of biomolecules under non-collisional isolated conditions, we will develop a "super-critical fluid jet (SCF-jet)" technique that enables one to pick up biomolecules in a supersonic molecular beam. By applying laser spectroscopy, such as an IR-UV multi-resonance technique, to neurotransmitter-receptor complexes generated in a molecular beam by the SCF-jet technique, the mechanism of intermolecular interaction, that is molecular recognition, will be unveiled. The SCF-jet technique is expected to allow the synthesis of a multilayered film of functional supramolecules, such as dendrimers, by using the molecular beam epitaxy technique. This new analytical technique is expected to find applications in environmental chemistry.

Stress Control and Stress Patterning by Self-assembled Monolayer

Akiko Itakura
Senior Researcher, National Institute for Materials Science

Stress usually plays a negative role in materials processing, leading to deformation and breakdown of processed structures. However, stress can be utilized positively in modifying the surface reaction potential and increasing the surface reactivity. The goal of this project is to develop a technique for patterning of surface chemical reactions by means of surface stress modulation. This is achieved by controlling the stress of a self-assembled molecular film on a substrate surface by ion irradiation. This study will open a new approach to nano-patterning on surfaces by utilizing controlled stress.

Creation of Nanobio-analytical Systems using Nano/microfabrication Technology

Takanori Ichiki
Associate Professor, The University of Tokyo

This research project aims to create nanobio-analytical systems through the development of highly functional biochips using nano/microfabrication technology. Novel microfluidic devices with micro/nanostructures will be designed to enable direct manipulation and precise measurement of individual cells and biomolecules. We will develop fundamental tools for biological functional analysis that will have a significant impact in the field of biotechnology research, clinical testing, and drug screening.

Development of Single-molecular Sensors with a Protein Nano-pore

Tohru Ide
Researcher,
Japan Science and Technology Agency (JST)

Development of highly sensitive chemical sensors is required in many fields such as pharmaceutical research and genetic diagnosis. The purpose of this project is to develop ultra-sensitive sensors that utilize the single molecule detection techniques that we have developed. Protein pore-based stochastic sensing enables one to detect single analyte molecules. By combining this technique with single-molecule manipulation we will be able to sequence a single DNA molecule.

Development of Artificial DNA based on Precise Molecular Recognition and its Application to Nano-materials

Masahiko Inouye
Professor,
Toyama Medical and Pharmaceutical University

The purpose of this project is to develop artificial DNA by assembling synthetic molecular components. Detailed comparisons of the properties of artificial and native DNAs will clarify the structural essentials for information storage at the molecular level. We will also explore various applications of nano- and bio-materials.

Fabrication of Supraintegration Stages by Networking of Nanospaces

Tatsuya Okubo
Associate Professor,
The University of Tokyo

A class of novel materials with functions far beyond the state-of-the-art is indispensable for future global sustainability. Although the conventional materials design has been based on components in a single hierarchy, the materials and their systems for the future should be fabricated by controlling the size and shape of the components that belong to different hierarchies. Furthermore, the order in which the components are arrayed should also be controlled. We call this concept "Supraintegration." The aims of this project are to fabricate supraintegration stages by heterogeneously connecting nanospaces with different dimensions, and to create novel devices and systems through encapsulation of hierarchical guests in the networks. Such nanospace networks will provide us with practical stages for supraintegration. We aim eventually to propose schemes to create new products based on scientific findings from this project.

Multicolor Photochromism of Silver Nanoparticles Deposited on Titanium Dioxide —Fundamentals and Applications—

Yoshihisa Ohko
Research Scientist, National Institute of Advanced Industrial Science and Technology

Photochromic materials, which change their colors reversibly in response to incident light, can be applied to displays and memories. If they are multicolored, devices can be made with additional information content. We will investigate multicolor photochromism of silver nanoparticles deposited on TiO_2 photocatalytically by UV light.
The Ag-TiO_2 film, which is initially brownish gray, changes its color to that of the incident light when irradiated by visible light of various colors under ambient conditions. The film is bleached colorless when irradiated by white light, and returns to the original color after irradiation by UV light. Multicolor photochromism is thus achieved with this apparently uniform, easily prepared film. It has been difficult on the basis of conventional monochromic photochromism without combination of several different materials. The colors induced by visible light last at least one week in the dark, and one day under room light. If the film is irradiated with different laser beams simultaneously, absorption holes are formed at the wavelengths of the incident beam in 1 minute, similar to persistent hole-burning. This material can be used for a rewritable color copy paper or electronic paper and a high-density multi-wavelength optical memory.

Novel Sensing System based on 'Assembly and Fusion' of Nanoparticles

Shinya Onoue
Researcher,
Kyoritsu Chemical & Co., Ltd.

Inorganic nanoparticles with organic shells are regarded as one of the most promising sensor materials for metal ions, molecules, and complex molecular systems. In this project we will prepare various nanoparticles with abilities to induce "Assembly and Fusion" of the inorganic core, in order to obtain amplified spectroscopic signals. Highly sensitive sensing systems can be developed on the basis of such nanoparticle systems.

Creation of Innovative Technology by Integration of Nanotechnology with Information, Biological, and Environmental Technologies

Creation of Biosystem-Integrated Microdevices and their Application to Medicine

Masaru Kato
Assistant Professor,
University of Shizuoka

Biomolecules are involved in a variety of biological functions with highly controlled harmonization that enables maintenance of life. We have recently developed a novel biomolecule immobilization technique using micro-sized flow-through systems. In this technique the use of hydrogel allows encapsulation of biomolecules while maintaining their biological functions.

This project aims at creating multi-functional microdevices by integrating biosystems on a microchip using this new immobilization technique. We will explore the applications of this immobilization technique to a wide variety of biomolecules including not only proteins but also living organisms, cells, tissues, and organs. We will also investigate how different biological reactions can be integrated into a microchip. An effort will be made to take advantage of biological reactions such as recognition and catalysis for separation or detection of medically relevant biomolecules using the microdevices. Such microdevices are expected to contribute to diagnosis of diseases and high-throughput screening systems for drug development.

Construction of Functionalized Nano-scale Cavities in Synthetic Polymers by Tailor-made Molecular Assembly

Toshifumi Takeuchi
Professor, Kobe University

We propose a tailor-made molecular assembling technique that will enable one to prepare cross-linked macromolecules with "tailor-made" binding sites for a target molecule, in which the complementary cavities that fit the target molecule are constructed, allowing specific binding of the target molecule in accordance with its chemical properties and structural characteristics. The technique is based upon self-assembling of a given target molecule with polymerizable monomers bearing functional group(s) capable of interacting with the target molecule (functional monomers), followed by polymerization to freeze and maintain the alignment of the functional group(s) that are optimally set for binding the template molecule. After removal of the target molecule from the resulting polymer matrix, "tailor-made" binding sites for the target molecule will be constructed.

In this study, functional monomers for binding site construction and those bearing signaling function, and/or catalytic function will be assembled in order to construct desirable reaction sites for molecular recognition, catalytic reaction, and transduction of binding events to readable signals. The proposed technique will be essential for the development of functional materials bearing designed nano-scale reaction sites with pre-determined functions, and the resulting materials will be applied in a broad range of scientific fields including biotechnology, environmental science, and information sciences.

Realization and Application of Left-handed Materials using Ferromagnetic-metal Nanocomposite Films

Satoshi Tomita
Researcher, Japan Science and Technology Agency (JST)

The electromagnetic responses of materials are determined by the electric permittivity (ε) and magnetic permeability (μ). Materials with both ε and μ negative are called left-handed materials (LHMs). They are theoretically predicted to show extraordinary electromagnetic responses. However, no LHMs has yet been found in nature. In this project we will attempt to produce LHMs by using ferromagnetic-metal nanocomposite films. The results are expected to open a way to a new paradigm of electromagnetism of matter, making a significant breakthrough in materials science and technology.

Electronic Properties of Nano-sized One-dimensional Structures

Yukio Hasegawa
Associate Professor,
The University of Tokyo

For the development of nanotechnology, it is essential to characterize the electronic states and the electrical transport properties of nanometer-scale structures. By using a scanning tunneling microscope (STM) and an atomic force microscope (AFM), we will investigate the electronic properties of nanostructures under extreme conditions of low temperature and high magnetic fields, and explore their unique properties related to their size and dimensionality.

Exploration of Novel Photonic Potentials of Si-based Materials

Susumu Fukatsu
Associate Professor,
The University of Tokyo

Creation of an efficient light emitter using indirect band-gap semiconductors such as Si is an issue that has been addressed in many contexts and challenged enthusiastically over time. However, such efforts have often been plagued by the small oscillator strength and the selection rule of radiative recombination.

To overcome the difficulties, we will develop a new class of Si-based quantum nanostructures with highly luminous emission characteristics and a potential for interband lasing. We will demonstrate that nanostructuring is a promising way to transform Si into a realistic photonic material. The light-emitting capability of Si to be developed in this project will allow one to design novel device architecture with applications in optoelectronics, telecommunications, and biometrics.

Development of Phototriggered DNA Manipulation by Intelligent Nucleic Acids

Kenzo Fujimoto
Associate Professor, Japan Advenced Institute of Science and Technology

While many methods for enzymatic and chemical ligation of DNA fragments via native phosphodiester bonds or non-native linkages have been demonstrated, there are only a few methods for photoinduced non-enzymatic chemical ligation. The merit of photochemical ligation that avoids the need for additional reagent is obvious. Furthermore, their actions are controllable in space and time by the choice of proper irradiation methods. The photoligation methods can be used as a tool for DNA engineering and nanotechnology, and also as photoregulated diagnostic and therapeutic techniques. The aim of this research project is to develop a new technique of phototriggered DNA manipulation using intelligent nucleic acids.

Development of Optical Waveguide Amplifier Sensitized by Si Nanocrystals

Kazuyuki Moriwaki
Associate Professor,
Kobe University

Optical planar waveguide amplifiers are not practical at present, because of their low optical gain, unlike Er-doped fiber amplifiers (EDFAs). In this project a new planar waveguide amplifier will be fabricated, using an amplification medium containing Si nanocrystals in a conventional Er-doped SiO_2 film to enhance the Er luminescence intensity. If the practical planar waveguide amplifier is realized at the wavelength of 1.55 μm used in optical telecommunication networks, a variety of novel photonic devices can be developed, because a new functionality is added to passive silica-based waveguide components.

Creation of Innovative Technology by Integration of Nanotechnology with Information, Biological, and Environmental Technologies

RESEARCHER *2004–2007*

Computational Design of Proteins Binding to Specific DNA Sequences

Hidetoshi Kono
Senior Scientist,
Japan Atomic Energy Research Institute

Protein-DNA recognition plays an essential role in the regulation of gene expression. Regulatory proteins recognize specific DNA sequences, such as enhancer and silencer elements. Defects of such proteins are known to cause diseases. In this project, we will design DNA binding proteins which can bind to desired DNA sequences. The designed proteins can be useful for understanding the gene regulation and also be applicable for gene therapy.

Theoretical Studies of Current-induced Domain Wall Motion Aimed at Application to Novel Magnetic Memories

Gen Tatara
Associate Professor,
Tokyo Metropolitan University

Large capacity non-volatile memory devices are expected to revolutionize information technology. For the purpose of developing high-density non-volatile nanomagnetic memory devices, we will investigate the current-driven domain wall motions in nano-scale magnets, using both analytical and computational methods. The results will be applied to the design of novel high-density magnetic memories of the next-generation (such as MRAM), where information is written and read by use of current.

Analysis and Design of Plasmonic Optical Elements

Hiroharu Tamaru
Assistant Professor,
The University of Tokyo

Gold and silver nanostructures can confine light far beyond its diffraction limit through excitation of localized plasmon resonances. The aim of this project is to develop a means to design these nanostructures so that this strong light confinement effect can be controlled, as if we are using lenses in conventional optics. A dedicated FDTD simulation program will be developed to investigate the behavior of confined photons. The outcome should help in the design of nanoscopic optical devices and sensitive detectors.

Combined Digital and Analog Molecular Simulation of Polymer Dynamics

Yuichi Masubuchi
Associate Professor,
Tokyo University of Agriculture and Technology

This project is directed to simulation schemes for molecular design of polymers in advanced polymer processing. Control of long time relaxation of polymeric systems through molecular structure is a key technique for various advanced technologies. In this study a high-speed molecular simulator for polymers based on our unique theory will be developed. In addition visualization of individual polymers using fluorescent microscopy will be applied to construct model systems as analog simulators. Combination of these digital and analog simulators is expected to provide analysis methods of polymer dynamics in a wide range of complex systems such as filler composites, blend systems, micro channel systems, etc.

Computer Simulation of the Thermal Conductivity of Meta-materials

Koji Miyazaki
Associate Professor,
Kyushu Institute of Technology

Nano-structured materials with artificial physical properties (meta-materials) have recently been created using nano-technology. Meta-materials can be used to reduce the thermal conductivity of semiconductors and insulators, in order to improve the efficiency of energy conversion devices beyond the limitations of conventional bulk physical properties. In this project we develop numerical simulation methods for the prediction of the thermal conductivity of meta-materials.

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Creation of Ultrafast, Ultralow Power, Super-performance Nanodevices and Systems

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Creation and Application of Nano Structural Materials for Advanced Data Processing and Communication

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Creation of Bio-Devices and Bio-Systems with Chemical and Biological Molecules for Medical Use

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Creation and Application of "Soft Nano-machine", the Hyperfunctional Molecular Machine

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Creation of Novel Nano-material/System Synthesized by Self-organization for Medical Use

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