Laboratory Introduction 2018

Nara Institute of Science and Technology

Contents

Message from the President

Naokazu Yokoya, President

Nara Institute of Science and Technology (NAIST) is a national 'independent graduate school' institution established in 1991, focusing on the advancement of information, biological and materials sciences. Since then, we have not only promoted research in these fields, but also carried out human resource development through graduate education curriculum based upon world-class research. To this date, NAIST has sent out approximately 7,300 master's and 1,400 doctoral graduates into society, and they now play key roles as active researchers and engineers throughout various fields around the world. This focus on contributing to education, research and development in the forefronts of science and technology is a distinguishing feature of NAIST.

Looking back at the 26 years of education and research performed since NAIST's beginnings, we can see how our activities have been consistently recognized in the education and research achievement evaluations of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). For example, NAIST was chosen by MEXT as one of the prestigious 22 institutions to participate in the *Program for Promoting the Enhancement of Research Universities* (2013) to further strengthen the research prowess of institutions with considerable achievements. Furthermore, in 2014, NAIST was selected as one of 37 universities to participate in the *Top Global University Project*. This government-funded project is supporting NAIST in enhancing institutional internationalization to cultivate globally-minded professionals, and to lead Japanese higher education.

Today, globalization is being called for across all areas of society. NAIST has responded to this by strengthening globalization activities in education and research. To further develop education, NAIST has established international offices in Indonesia and Thailand to serve as academic collaborative centers. Currently almost a quarter of NAIST's student population consists of students from diverse countries and areas, and we plan to further support the growth of our global community. In relation to research, NAIST is expanding its strategic collaborative pursuits with institutions in North America, Europe and other regions. Our faculty members are leading two satellite laboratories at partner universities in France and USA, as well as three joint research laboratories within NAIST in collaboration with American, Canadian, and French institutions.

NAIST's collaboration with private industries and other non-academic institutions is also a significant priority for innovation. For example, NAIST is currently working with three corporations in Collaborative Research toward Future Innovation projects to create novel collaborative research.

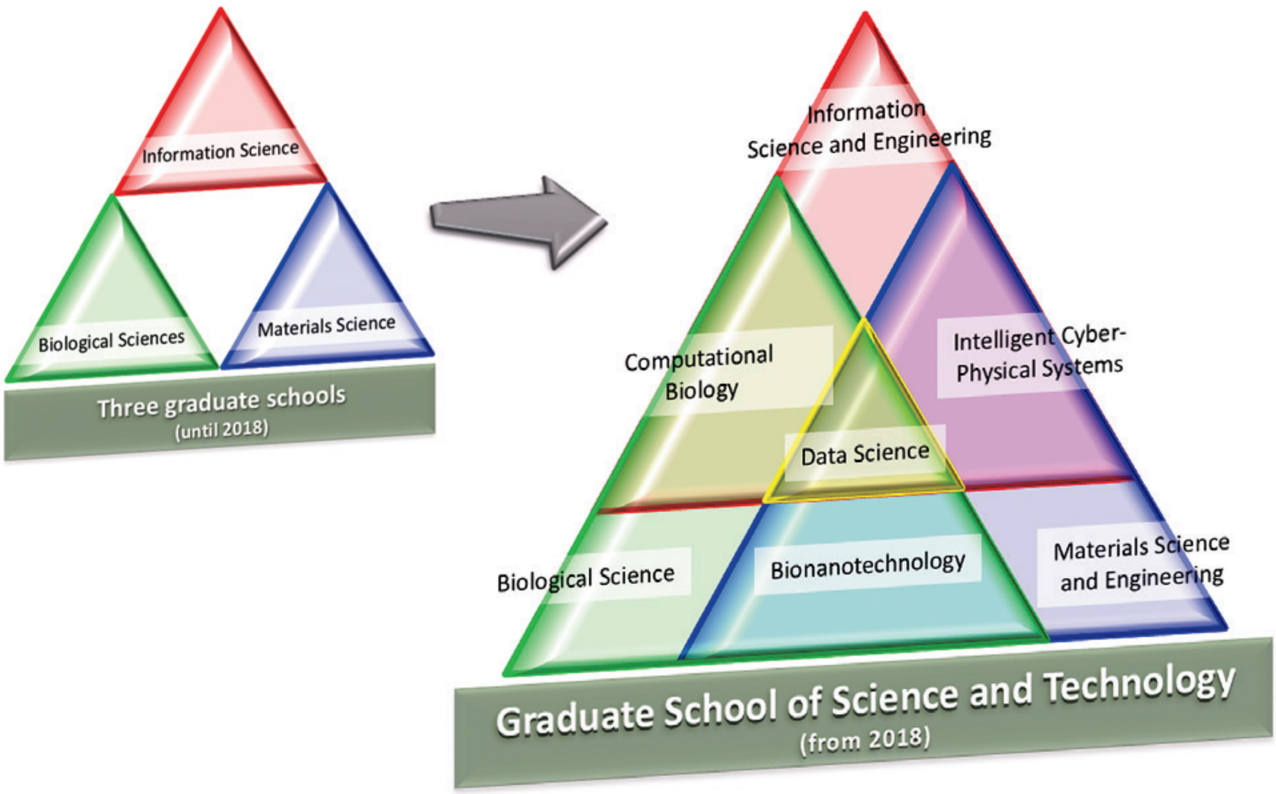
Science and technology are currently facing a revolutionary era. For the 26 years since its foundation, NAIST has continuously redefined the 'forefronts of science and technology'. In order to respond flexibly to ever-evolving developments of science and technology, we have focused on producing talented researchers and engineers who will lead tomorrow's discoveries and innovations. NAIST is to be shifted to a one graduate school system in April 2018 for further enhancing interdisciplinary research and education. In our pursuit of a growing global presence, this transition is the largest challenge NAIST has faced since its establishment.

As the President of NAIST, I am proud to lead NAIST to continue to strive towards the challenges that lie ahead, and *-out grow our limits-* to better the future through discovery and innovation in the years to come.

Transition to the Graduate School of Science and Technology

With its focus on leading graduate education in the fields of information, biological and materials science since 1991, NAIST will make a transition to the Graduate School of Science and Technology, offering seven new programs as of April 1st, 2018.

The integrated graduate school not only merges the existing three graduate schools into one, but also further expands interdisciplinary and multidisciplinary research and education. The three core disciplines will remain in the Programs of Information Science and Engineering, Biological Science, and Materials Science and Engineering. Amongst them are the Programs of Computational Biology, Bionanotechnology, and Intelligent Cyber-Physical Systems which cover interdisciplinary/multidisciplinary areas, and the Program of Data Science which encompasses all three disciplines.



Program of	Program Outline
Information Science and Engineering	A focused information science program
Computational Biology	An interdisciplinary information and biological science program
Biological Science	A focused biological science program
Bionanotechnology	An interdisciplinary bioscience and materials science program
Materials Science and Engineering	A focused materials science program
Intelligent Cyber-Physical Systems	An interdisciplinary materials and information science program
Data Science	An interdisciplinary information, biological and materials science program

Information Science

Laboratories

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Dependable System



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Research Areas

1. Distributed algorithms

We focus on designing algorithms to improve the dependability and performance of various distributed systems such as the Internet, ITS, IoT, blockchain (bitcoin), sensor networks, and nano-scale systems.

- Fault-tolerant distributed systems
- Wait-free distributed algorithms
- Self-stabilizing algorithms
- Mobile agent and robot algorithms
- Population protocols for nano-scale systems
- Dynamic distributed algorithms

2. Hardware Design

We are conducting research on hardware dependability which spreads broadly across robust computing, VLSI design, CAD, testing, photovoltaic systems, security, and power converters using new wide-bandgap semiconductors.

- VLSI design for testability
- Reliable design and testing for memory
- Hardware Trojan detection
- Circuit and system mechanisms for high field reliability
- Test optimization through machine-learning-based analysis
- Circuit simulation of power converter
- Device modeling of SiC devices
- Optimization of photovoltaic system power generation

Key Features

Today's information society is supported by various levels of advanced technology such as applications, systems, computers and VLSIs. The Dependable System Laboratory is pursuing research on safe and secure systems including distributed systems with hundreds of computers and VLSIs with billions of transistors. "Dependability" is a concept from the user's point of view, when systems can be used reliably and securely.

In order to achieve dependable systems, we need to consider various aspects of these systems from the user's point of view. For example, whether all the systems are completely tested before shipping, whether the systems can function correctly in the presence of faults, whether the systems can predict and avoid system failure caused by transistor aging, whether the system can handle malicious users, and whether the photovoltaic systems can efficiently generate power with partial shade or faulty cells. This laboratory performs research to improve dependability through various approaches.

The Dependable System Lab also fosters skills for logical thinking, presentation, design and analysis of algorithms, CAD tools, machine learning, software programming (C/C++, Java, Python etc.) and hardware programming (Verilog/VHDL) through our research.

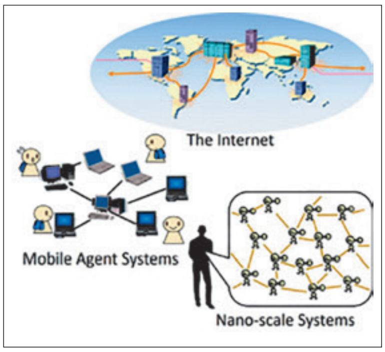


Fig. 1
Various types of distributed systems

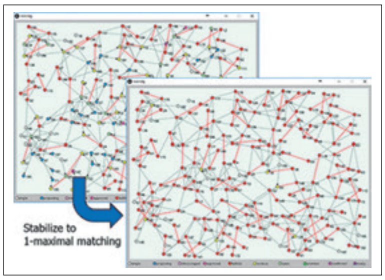


Fig. 2
Self-stabilizing algorithms

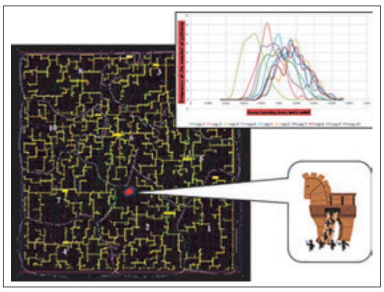


Fig. 3
Hardware Trojan detection

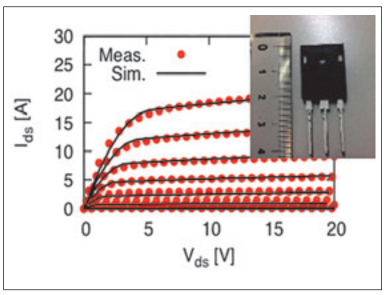
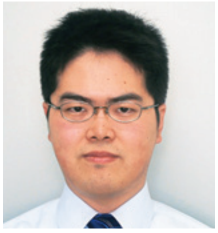


Fig. 4
Power device modeling

Computing Architecture

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Research Areas

1. High performance, low-power and near-data-intensive memory array accelerators

Research and development of highly efficient computing systems, accelerators and LSIs for image processing and big data processing, such as graph processing and machine learning

- Acceleration of graph processing and stencil computation on modern 120-core environments and commercial accelerators (GPU and Xeon Phi)
- Large-scale FPGA-based accelerators for image and graph processing
- LAPP: A high performance accelerator LSI with processing element arrays using standard scalar instruction sequences
- EReLA: A dependable and high performance accelerator LSI with redundant execution functionality on processing elements arrays
- EMAX2: A memory-centric accelerator LSI for graph processing and stencil computation
- EMAX4: A high performance accelerator platform with heterogeneous commercial LSIs
- EMAX5: A large-scale CGRA for image recognition
- PyCoRAM: A productive programming model with high-level synthesis and hardware resource abstraction for FPGA-based accelerators
- Pyverilog: A toolkit for static analysis of hardware description, and its applications

2. Ultra small dependable processors for printable sensors

Research on small and ultra-dependable processor architecture for next generation LSIs using new materials

- OROCHI: A heterogeneous multi-ISA processor with hardware-centric dynamic instruction translation
- DEP: Dependable processing element architecture through self-sustaining circuit recovery
- RM: An emulation-based small computing system for legacy software
- EMIN: Efficient emulation technology on 8-bit small computers for modern 32-bit software
- REMIN: A dependable CPU with dynamic instruction translation to avoid circuit failures
- FCOMP: An 8-bit ink-jet film computer executing 32-bit operating systems with emulation technology
- NCHIP: An analog neural network for image recognition

3. Extremely defect free computers

Research and development of highly dependable computers with resistance to cosmic radiation. We use a real alpha-ray source for our LSI evaluations

- DARA: A dependable CPU achieved through cooperation of multiple independent pipelines
- BDMR: Reliable processor architecture

Fig. 1
High Performance, Low-Power and Near-Data-Intensive Memory Array Accelerator

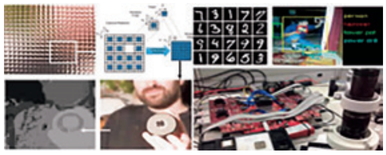

Fig. 2
Accelerators for Light-field Image Processing and Image Recognition

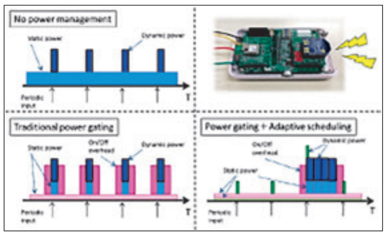

Fig. 3
Energy Efficient Scheduling for Smart Sensor Nodes

Research Areas (Cont'd)

4. Asymmetric processor architecture for irregular applications

Research on complicated processor architecture for irregular applications containing many pointer chain accesses and recursive calls

- CAMP: A crazy CPU created by reusing past computation results and speculative parallel executions using CAM (Content Addressable Memory)

5. IoT system architecture

Research on next generation IoT system architecture with trillion sensor nodes.

- Design methodology for next generation IoT systems
- Spatiotemporal task/data/communication optimization
- Edge computing on advanced sensor nodes
- Adaptive task scheduling for near real time applications
- Dependable sensor networks for trillion sensor nodes

6. Next generation WiFi for IoT

Research and develop a low-cost low-power wireless communication transceiver for IoT applications. The transceiver follows IEEE 802.11ah standards. In this research, we focus on two layers: Physical (PHY) and Medium Access Control (MAC). The research basically has two stages: (1) software simulation on software (using Matlab, C) to check the Bit Error Rate (BER) performance, throughput (data rate), etc. of system; (2) hardware circuit design (using Verilog, Simulink, ModelSim, FPGA, etc.)

- VIT_DEC: A low complex K-best Viterbi decoder for error correction
- FEC_CONCAT: concatenating several FEC types such as LDPC, BCC, etc.
- Energy simulation of IoT sensor networks
- BER/PER simulation and hardware prototypes of the 802.11ah PHY layer
- 802.11ah MAC protocol

Key Features

In our laboratory, we study state-of-the-art technologies for next-generation computing paradigms. Our goal is to realize environment-friendly, high-performance, and robust computer systems under energy constraints. From a wide viewpoint (from new theories to LSI implementations), we promote cutting-edge research and the highest degree of education within various research themes, particularly: high-performance, low-energy and dependable computation, and hardware/software co-design.

Research Collaboration

Socio Next, Konica Minolta, Huawei

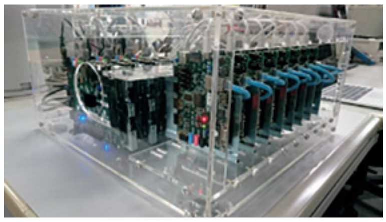

Fig. 4
FPGA Design Framework

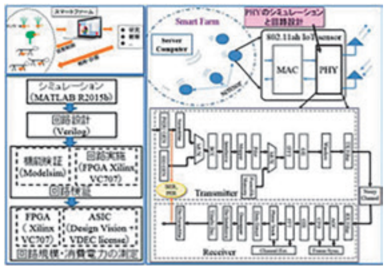

Fig. 5
Next Generation Low-power WiFi for 801.11ah

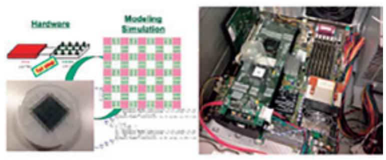

Fig. 6
Analog Neural Network LSI

Ubiquitous Computing Systems


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Research Areas

Ubiquitous computing systems utilize a lot of sensors and embedded/mobile devices in a harmonious manner and efficiently provide users with sophisticated services by recognizing real world contexts. Our lab conducts data collection, data analysis, and application development for solving the various challenging issues of real world. The main themes are as follows:

Smart homes

- Recognizing living activities in smart homes using various sensors
- Context-aware appliance control systems
- Smart appliances
- Elderly monitoring systems using BLE devices
- Smart concierge for supporting daily life

Smart life

- E-health support for diet and calorie control
- Human's internal state estimation with IoT devices and wearable sensors
- Smart gadgets for health support and stress monitoring

Smart city

- Participatory sensing platform and applications
- Edge-based IoT platform for realizing real-time services through local distributed computing
- Disaster response systems based on DTN and computation offload mechanisms
- Efficient car sharing systems with behavior change

Key Features

We are conducting research using a smart home facility built within the university. This facility provides an actual home environment where various home appliances are deployed as in an ordinary household. In addition, this facility is equipped with special sensors including a high-accuracy indoor positioning system, wireless power meters, door sensors, and others. We are collecting data while subjects are actually living in this facility and develop various methods including activity recognition and automatic appliance control using the collected sensor data.

Each student selects research topics according to his/her own interests through several brainstorming meetings with advisers. Advisers provide students with kind and careful direction to advance their research as well as suggestions to improve their programming, writing, and presentation skills. Students receive various opportunities to present their research results at domestic/international workshops and conferences.

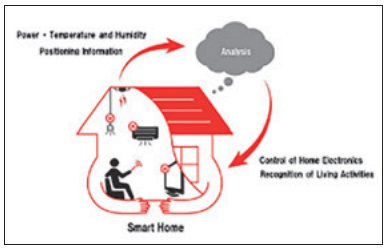

Fig. 1
Smart Home

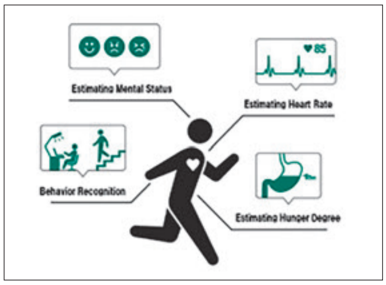

Fig. 2
Smart Life

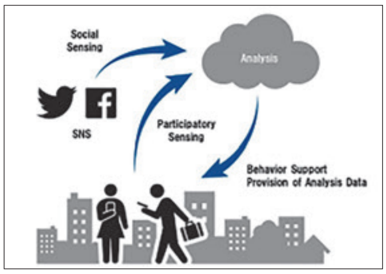

Fig. 3
Smart City

Mobile Computing

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Research Areas

1. Distributed computing

- Video multicast streaming and grid computing via P2P overlay networks
- Fault-tolerant and autonomous adaptive algorithm design

2. Mobile computing

- Portable terminal low-power-consuming video streaming (Patent granted)
- Cooperative downloading and streaming by multiple portable terminals in ad hoc networks
- Low-power-consumption information gathering in wireless sensor networks, optimal sensor deployment in 3-dimensional environments, and underwater sensor networks
- Delay tolerant network applications
- Pedestrian and vehicle urban sensing
- Mobile data offloading

3. Ubiquitous computing

- UbiREAL, a simulator for virtual ubiquitous environments composed of sensors and consumer electronics (http://ubireal.org/)
- Consumer electronics intuitive remote controller with 3D graphic interface
- Power-saving support systems in smart homes
- Disaster emergency rescue support systems using ad hoc networks (http://etriage.jp/)

4. Intelligent Transportation Systems (ITS)

- Efficient information delivery via vehicle-to-vehicle and vehicle-to-road communication
- Navigation systems for tourists
- Traffic jam reduction via whole city traffic signal control and mass vehicle scheduling
- Pedestrian detection and alert system using directional antennas and vehicle-to-vehicle communication

Key Features

We work with a variety of research topics to realize distributed pervasive systems. Each master's course student starts his/her two year study by choosing an interesting research issue. Staff with different areas of expertise actively work with students to discover new perspectives towards each problem. We move forward through cooperation in pursuit of novel research results. Most master's course students attend domestic and international conferences to present their achievements. We encourage students to take such opportunities to let people know how important, difficult and interesting their work is.

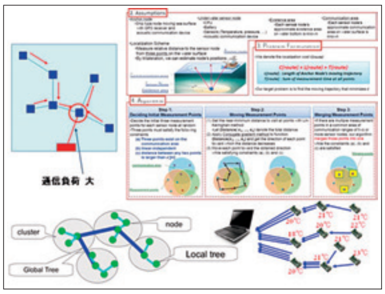

Fig. 1
Optimal sensor deployment in 3-dimensional underwater sensor networks

Fig. 2
Adjusting parameters for stereoscopic 3D video playback

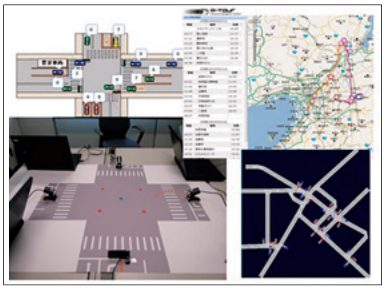

Fig. 3
Cooperatively capturing and sharing video between vehicles

Software Engineering


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Research Areas

1. Software data mining
- Software quality analysis and cost estimation
- Visualization and substantiation for software analytics
- Natural language processing in software development
- Data-driven software development

2. Open source software engineering
- Open source software reliability models
- Expert recommendation models in open source development
- Communication analysis in open source development
- Toward understanding open source ecosystems for user support
- Software repository mining and integration in open source systems

3. Human factors in software development
- Measuring human brain activities to assess the program understanding processes
- TaskPit: A software development task measurement system
- Social analysis and game theoretical modeling

4. Software protection
- Software obfuscation
- Software watermarking and birthmarking
- Software tamper-proofing

Key Features

The software engineering laboratory uses both theoretical and empirical approaches to address various problems related to software development, human computer interaction and software lifecycle management. We fully exploit the potential of students' curiosity and creative thinking and, together with conventional research theories and technologies, explore new topics in software engineering.

While actual software development often relies on project managers' intuition instead of sufficient evidence, our goal is to develop an empirically-guided software development environment where the software development process and product data are measured and decisions are based on the data. We also address current hot topics in software engineering such as open source software engineering, global software development and software protection.

Fig. 1
Software Analytics Virtual Environment

Fig. 2
TaskPit: A software development task measurement system

Fig. 3
A software engineering data analysis system

Software Design and Analysis

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Research Areas

1. Modeling and management / improvement of the software development process

- Process modeling / analysis / improvement
- Project information visualization & management support
- Social network analysis for open source projects
- Project re-player (virtual re-play of projects)
- Development process simulation

2. Repository mining

- History analysis of source code (code clones / design patterns)
- Infinitesimal grain degree process analysis of software maintenance
- Extracting topics from developers' mailing lists

3. Software design & verification

- Super-upper process design
- Searching / detecting design patterns
- System and software assurance
- Software risk analysis

4. Cloud infrastructure design

- Virtual computing environment deployment
- Software defined network (SDN) deployment
- Experiments on widely distributed systems
- High performance computing support
- Resource management

Key Features

In the Software Design & Analysis Laboratory, we conduct research on the methods and technologies which support the design / development of software and cloud computing systems. Our main focus is on the analysis and improvement of the software development process. Software technology is increasingly present in our daily lives, including various software embedded machinery and electronic devices for homes or mobile telephones and social infrastructures represented by cloud computing systems.

Fig. 1
Social network analysis tool for Open Source Software developments

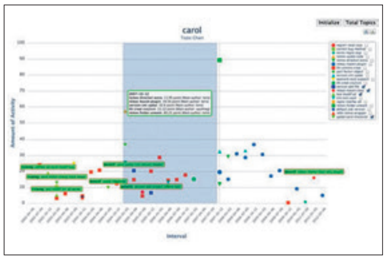

Fig. 2
Software development history visualization tool using topic extraction method

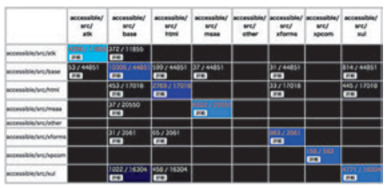

Fig. 3
Scatter plot for code clone analysis

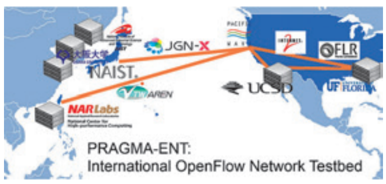

Fig. 4
Demonstration environment for international OpenFlow network

Cyber Resilience




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Research Areas

We investigate all technical areas of cybersecurity: security standards, malware analysis, security risk assessment, malicious drone detection, DDoS attack detection, memory forensics, phishing, cloud computing security, IPv6 transition mechanism security, etc.; all in order to make the Internet a more resilient infrastructure.

1. Towards making the Internet cyber-resilient

- Information infrastructure attack prevention and mitigations techniques
- Reliable communication over mobile networks
- Trusted identity management for modern applications and services
- Workload measurement and characterization
- Construction and management of resilient infrastructures
- Security risk assessment (cloud computing, IoT, etc.)
- IPv6 transition and verification methodologies

2. Impacting society through cyber-resiliency

- Critical infrastructure security and resiliency
- Secure information distribution based on users' situation
- Gamification of cybersecurity
- Privacy protection
- Internet user experience quality improvement
- Learning the effects of cyber-resiliency on humanity

Key Features

The Internet has evolved to become essential to, arguably, all fields of industry and academia. At its inception, the Internet was used for basic electronic communications where users stored, processed, and transferred small amount of data. Currently, the Internet encompasses more advanced technologies like social networks, cloud computing, big data, Internet of Things (IoT), augmented and virtual reality etc., in summary, it is becoming the world economy. Simultaneous to the universality of the Internet and its rapid growth, cyber threats are augmenting and globally proliferating at an exponential rate. Additionally, cyber threats are conquering domains like industrial control systems (ICS) that were, until recently, bereft of any types of internet-related security issues. In the Laboratory for Cyber Resilience, our goal is to build an Internet that, while intrinsically vulnerable, can contain any types of cyber-attacks and use the heuristics of the latter to build robust, dependable and more resilient architectures in order to make the cyber platform an environment that promotes efficiency, innovation, economic prosperity, academic development, safety, security and civil liberties.

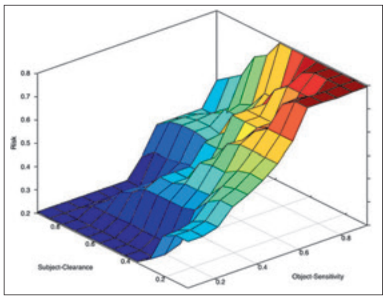

Fig. 1
Evaluation of a Risk-Adaptive Authorization Mechanism

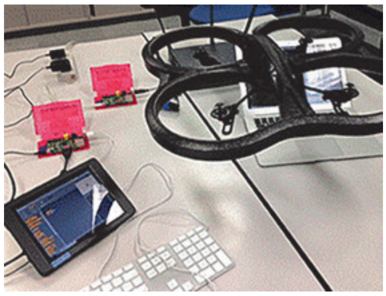

Fig. 2
Malicious drone detection

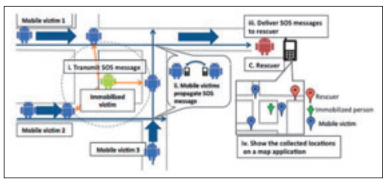

Fig. 3
Immobile victim's message propagation among visible victims' device and delivery to the rescuer

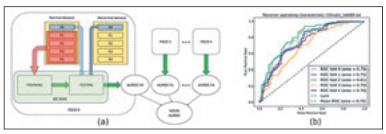

Fig. 4
AUROC value from a pair of normal dataset – VMM-based Anomaly Detection System

Information Security Engineering

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Research Areas

1. Electromagnetic information leakage

Research on the risk assessment of security degradation due to information leakage (Fig. 1) using electromagnetic signals generated from information terminals; we are also conducting research on a technology for countering this phenomenon (Fig. 2).

2. Intentional electromagnetic interference (IEMI)

Research on the risk assessment of security degradation due to electromagnetic disturbance in hardware and also on technology for countering this phenomenon (Fig. 3).

3. Intentional modification of internal circuits

Research on risk assessment of security degradation due to malware implemented by intentionally changing the internal circuits of information equipment, and also on technology for countering this occurrence.

4. Developing secret key-sharing frameworks and protocols based on information theory

Research on a cryptographic protocol, which is secure in terms of information theory. This stream of research is different from that on cryptosystems that base security on the difficulty of performing calculations, such as RSA public key and AES block cryptosystems.

5. Large-scale electromagnetic field simulation

Research on large-scale electromagnetic field simulation necessary for clarifying information security degradation mechanisms due to leakage or interfering electromagnetic waves, and for risk assessment at the design stages of equipment (Figs. 4 and 5).

6. Reliability of information communication systems

Research on approaches for designing information communication system equipment, which has little electromagnetic signal leakage from the viewpoints of environmental electromagnetic engineering (EMC) and electromechanical devices (EMD), and which is tolerant even to electromagnetic disturbance (Fig. 6).

Key Features

In the Information Security Engineering Laboratory, we conduct research on methods to ensure hardware safety, which is the bedrock of system information security. We also conduct research to ensure the security of the entire system, including the upper layers.

Fig. 1
Remote Visualization of Screen Images Using EM Emanation

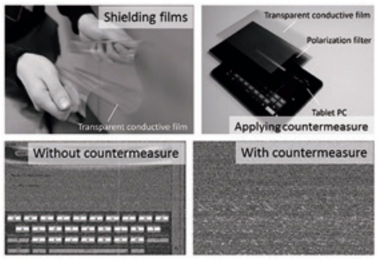

Fig. 2
Development of countermeasure to prevent EM display stealing from tablet PCs

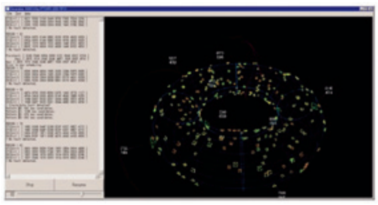

Fig. 3
Visualization of information leakage due to intentional electromagnetic interference

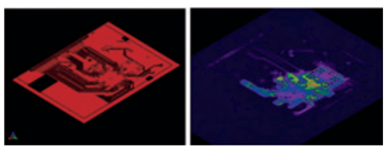

Fig. 4
Visualization of information leakage path based on large-scale EM field simulation

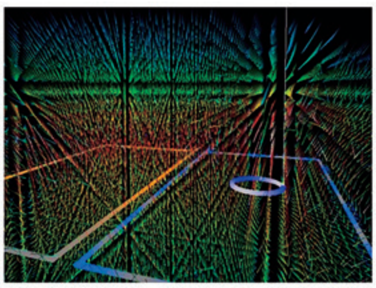

Fig. 5
Visualization of near fields disturbed during attack against a cryptographic module

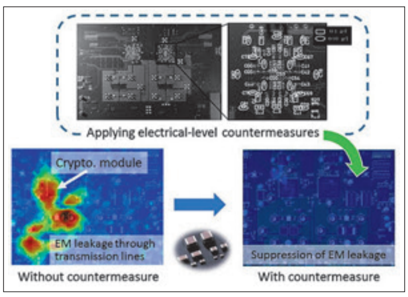

Fig. 6
Development of cost-effective countermeasures based on information leakage map

Internet Architecture and Systems




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Research Areas

1. Pervasive Computing / Ubiquitous Computing

In an environment which everything in real space is connected to the network (IoT, M2M environment) an information system analyzes and understands the sensor data and then controls remote devices and presents useful decision making information.

- Public transportation big data analysis (ex. driving analysis)
- Indoor localization utilizing environment sensors and smartphone mounted sensors together
- Fog computing (Optimization of computing resource allocation for smart city)

2. Disaster relief computing / networking

In large-scale disasters where the communication infrastructure may be cut off, the use of satellite communication systems becomes extremely important. We are conducting R & D on communication methods that make maximum use of limited resources of low bandwidth / high latency satellite lines. At the time of the initial disaster occurrence, on-site staff need to devote themselves to disaster response, and we are also discussing ways to provide an environment where terminals can be used as they are normally.

3. Operations technology for data centers and networks

We are working on operations technologies for data centers that are developing higher performance and higher density with the spread of cloud computing. In particular, we study the following technologies of data management for online storage for storing and sharing data in networks, resource management, and operations support for cloud service infrastructure and routing control for network traffic.

- Network storage system adaptation to data properties (object storage, distributed storage, access control)
- Technologies for virtual machine placement, data placement, traffic control and operations support considering energy saving and load balancing
- Next-generation traffic engineering for safe and effective data transport (IPv6 site multihoming, network auto configuration)
- Technologies for IPv4-IPv6 transition and IPv6 deployment

4. Cyber Security

Devices which are connected to the Internet are always threatened by malware and DoS attacks.

With the spreading of IoT or M2M technologies, it is important to consider the vulnerabilities of various devices such as automobiles, robots, sensor nodes, etc. as well as servers and PCs.

- DoS attacks on industrial network and devices
- Car security
- Malware analysis

5. Transmission system using IP network of super realistic feeling space

Utilizing the method of transmitting super high definition 4K / 8K video and stereophonic sound using ultra high speed IP networks, we are studying video / sound / IP networks with the goal of forming a super-realistic space comparable to real space in remote places.

- Utilization of uncompressed video data for high quality / low latency
- IP network routing control methods for high reliability
- Adaptive use of video data compression
- Approaches for medical use, museums, planetariums, etc.
- Digital library system applications

Key Features

In our laboratory, students can study a variety of topics concerned with computer networks, from the network layer to the application layer. The strength of our laboratory is that students have opportunities to perform their research using actual computer network environments because all faculty members are engaged in the Information Initiative Center (ITC) of NAIST. Additionally, in some cases we develop devices to create appropriate research environments. Our laboratory welcomes students of all levels of expertise, providing seminars on basic theoretical and practical studies as well as advanced areas.

Fig. 1
Pervasive Computing / Ubiquitous Computing

Fig. 2
Disaster relief computing / networking

Fig. 3
Operations technology for data center and network

Fig. 4
Cyber Security

Fig. 5
Transmission system using the IP network of super realistic feeling space

Computational Linguistics




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Research Areas

1. Making natural language processing resources publicly available

We believe that publicly available software and resources are important for the advancement of computational linguistics. Therefore, fundamental work in building essential resources such as dictionaries and annotated corpora is performed. Various widely used software tools are also maintained for core natural language analysis. Examples include:

- Software: Japanese Morphological Analyzer ("Chasen"), Dependency parser ("Cabocha"), Predicate Argument Structure Analyzer ("Syncha")
- Resources: NAIST Text Corpus, NAIST Japanese/English/Chinese dictionaries

2. Learning-based natural language processing and knowledge acquisition

Machine learning approaches are investigated to acquire linguistic rules automatically from large-scale text data. This approach enables us to build highly accurate and robust statistical natural language taggers and parsers. We also perform research in lexical and expert knowledge acquisition from scientific documents.

3. Applications

We explore novel applications that are enabled by computer processing of natural language. For example, our work in language learning assistance studies how computers can be used to help humans learn second languages. Our Scientific Document Analysis effort focuses on extraction of expert domain knowledge, automatic summarization and trend analysis of scientific fields by detailed analyses of scientific articles. Also, we have explored textual entailment, sentiment analysis, and information extraction.

Key Features

Natural languages are highly complex systems embodying various kinds of exceptions and subtle linguistic phenomena among beautiful grammatical structures. They are also systems for representing and describing our knowledge. To analyze and interpret languages computationally, one needs various theories and tools. Our lab organizes many research projects and reading groups focusing on areas from fundamentals to applications. Each group presents surveys of cutting-edge research topics and reads books and journals, while each project holds meetings on the research progress of its members. By participating in these reading groups and research projects, we encourage students to gain extensive knowledge on natural language processing that cannot be studied otherwise.

Fig. 1
Online demo of information extraction of restaurant reputations: Customer review positive/negative opinions extraction and summary

Fig. 2
A reading group session discussion

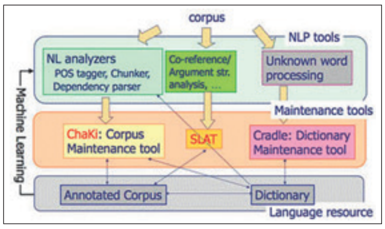

Fig. 3
Overview of corpus management and annotation tools

Augmented Human Communication


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"Go Beyond the Communication Barrier" and "Next Generation Big Data Analytics"

The AHC Laboratory performs research and education on a wide variety of technologies that support human-to-human and human-to-computer communication with the final goal of enhancing human communication abilities. Our research areas include multilingual speech translation, human-machine dialog systems, communication quality of life (CQoL), user-adaptive speech recognition, and brain measurement and analysis.

NAIST launched its big data analytics project in April 2014. Big data including multi-dimensional social, biological, and material information are targets for data analytics and mining. The project also encourages close collaboration with industry. The AHC-lab plays a central role in the project. (For details, please see http://bigdata.naist.jp/)

Research Areas

- Speech-to-speech translation

Speech-to-speech translation has been a long-standing dream, allowing for the possibility of seamless communication between people that speak different languages. Speech-to-speech translation recognizes the user's speech, translates it, and synthesizes a voice in the target language. Our current research project focuses on simultaneous speech translation of news and lectures. [Fig. 1]

- Spoken dialogue systems with verbal and non-verbal information

Our spoken dialogue system research aims to develop a computer avatar/agent that can communicate with humans intelligently and naturally. We focus on new statistical dialogue models for natural dialogue using intonation, emotion, personality, face and gesture information as well as verbal information. Individuality modeling is a study of what makes each person different. We study the individuality present in the human voice, face, expression, and dialogue modalities. [Fig. 2]

- Multilingual statistical speech processing

Speech recognition and synthesis are fundamental technologies for realizing natural human-computer interaction. We study statistical methodologies such as hidden Markov models, Gaussian mixture models, deep neural networks, and recurrent neural networks. We are extending these models for emotional speech, conversational spontaneous speech and multilingual speech.

- Cognitive communication/brain analysis

Our research on cognitive communication analyzes brain activity to detect real-time communication difficulty using Electroencephalograms (EEG). We also perform research on education and support those with communication disabilities such as Autism. [Fig. 3]

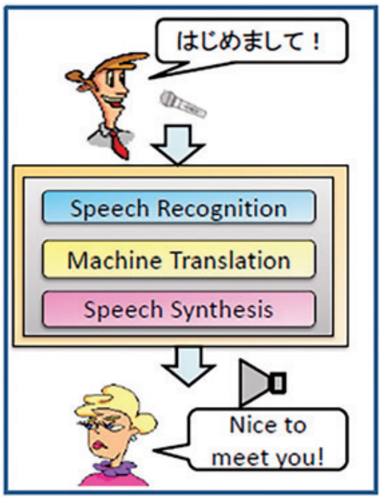

Fig. 1
Speech-to-speech translation

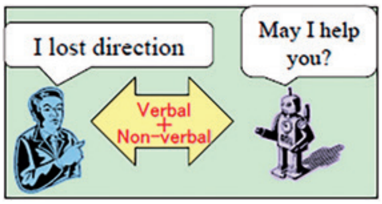

Fig. 2
A spoken dialogue system

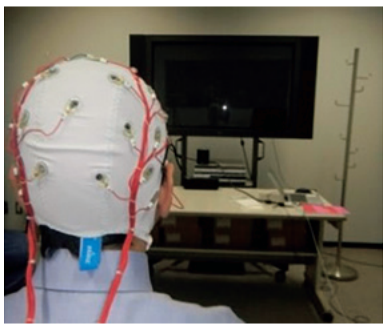

Fig. 3
An EEG measurement system

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Research Areas (Cont'd)

- Natural language processing and understanding

Natural language processing aims to process human language (such as English or Japanese) using computers. Our research into natural language processing focuses on creating natural language interfaces between humans and computers, thus allowing computers to understand natural language queries and commands so that they may answer questions or follow directions.

- Multimedia web information analysis

Huge amounts of multimedia information have been accumulated on the web. We conduct research on technology to analyze multilanguage and multimodal information and utilize it to enhance communication. [Fig. 4]

- Multimodal concept learning

Computers need not only understand language, but also understand objects, motions, and their connection with the words in language. Our research covers the concept of making computers study speech, language, image and motion linked together.

- Big data analytics

Big data analytics is one of the hottest topics in the area of information science. A variety of information, sensors, social network services, and lifelogging have become available through the development of telecommunications, and techniques of big data analytics are expected to add new values to such information in the real world. Our project addresses the problems of big data analytics by using real data provided by several research projects collaborated with research laboratories and schools inside NAIST, government offices, and private companies. We tackle real-world problems using techniques of data engineering and machine learning. The overall goals of this project are the extraction of knowledge from data and the development of data analysts and data scientists. [Fig. 5]

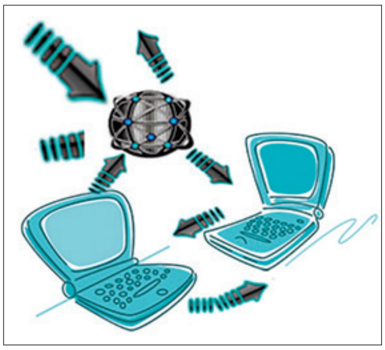

Fig. 4
Web information analysis

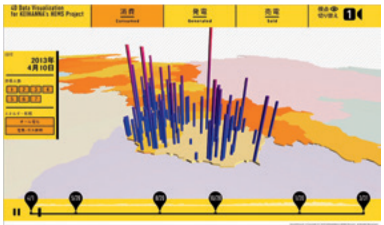

Fig. 5
Big Data Analytics

Key Features

As a Super Research Group, SRG, we collaborate with other research laboratories within NAIST and other international research laboratories. We participate in the InterACT consortium with 8 research universities including CMU/KIT.

The AHC-lab provides an international research environment for students where all students can experience interaction and collaboration with students and faculty from all over the world.

Network Systems

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Research Areas

1. Digital TV on mobile receivers

In Japan, high definition television (HDTV) is provided using digital terrestrial television (DTTV) broadcasting. In addition to HDTV, a narrow band digital television service dedicated to handheld terminals, known as "One-Seg TV", is popular now. After the termination of analog TV services, multimedia broadcasting services have started using the vacated VHF analog TV band. However, it is difficult to improve reception reliability in mobile and handheld environments. This laboratory is working on developing low power-consumption and reliable handheld digital TV receivers using array antennas and radio signal processing techniques.

2. Mobile communication systems

With recent research and development activities, the bit rate of mobile communication systems, such as cellular systems and wireless local area networks (W-LAN), is increasing rapidly. However, its reliability is not satisfactory for error intolerant purposes, such as surveillance, networked robots, etc. In order to solve this problem, our laboratory studies key technologies including OFDM (Orthogonal Frequency Division Multiplex), MIMO (Multiple Input Multiple Output), diversity, and multihop mesh networks. We are working on implementing these technologies into specific systems such as W-LAN, WiMAX, and Zig-Bee.

3. Radio on fiber and distributed antenna systems

We are studying the Radio on Fiber (RoF) technique in order to construct a heterogeneous backhaul infrastructure for various types of broadband wireless signals such as LTE, WiMAX, mobile multimedia contents broadcasting, etc. In this regard, we also investigate sophisticated signal processing capabilities of distributed antenna system (DAS) in multi-user, MIMO scenarios for achieving further performance enhancement.

4. Wireless sensor networks

Although radio wave-based sensor systems, such as RADAR and GPS, are capable of measuring positions over a wide area, their function is limited. To enhance their applicability, we propose various kinds of sensing networks using radio waves, for example, rain rate estimation using millimeter-wave mesh links, intruder sensing in leaky coaxial cable infrastructure, and positioning sensors for medical applications using RFID tags.

5. Wireless power transfer

There has been an increasing demand for wireless power transfer (WPT) for mobile nodes. Although many WPT systems have been developed and are widely used, it is difficult to transfer power to moving nodes using WPT. In conventional WPT using electromagnetic coupling, the distance between the transmitter and receiver is limited to few tens of centimeters. The motion of the power reception nodes leads to a decrease in the power transfer efficiency due to impedance mismatching.

Network Systems Laboratory is now working on developing a wide-area WPT system using a parallel feeder line. This system is capable of accommodating mobile receiving nodes including vehicles.

Key Features

We do not only evaluate systems through theoretical analysis and computer simulation, but also implement them onto hardware using FPGA (Field Programmable Gate Array) and embedded systems. Students learn theories of signal processing and communication systems. In addition, they experience embedded system programming and digital circuit design.

Fig. 1
Highly reliable wireless communication system research and development

Fig. 2
Wireless sensor network container yard in Tarragona

Fig. 3
ESPAR antenna assisted receiver

Interactive Media Design

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Research Areas

Our vision is to introduce Augmented Reality (AR) into the everyday lives of the entire population. AR is a technology that enhances human vision with computer-generated graphics. In order to achieve our vision, it is imperative to merge three currently distinct research fields, computer graphics, computer vision, and human-computer interaction, into one.

1. AR display technology
- High quality graphical rendering (Fig. 1)
- Projection-based displays (Fig. 2)
- Head-Mounted Display design

2. AR user interface technology
- AR assistance systems based on sensing
- AR based communication between humans
- Interface technology for ubiquitous display environments
- Haptic for AR (Fig. 3)
- Intelligent interface technology for senior citizens
- Designing novel interaction methods for AR (Fig. 4)

Key Features

Our laboratory has a rich international flavor, with many international students and visiting international researchers gathering from every corner of the world. Therefore, we communicate in English in most meetings and events. We have various custom systems and special equipment and actively pursue creative research.

Dissertation supervision is carried out through frequent discussions in research sub-groups, as well as in weekly lab meetings. In addition to supervising dissertations, we have weekly lunch talks about topics of interest and occasionally arrange research retreats.

Research Equipment

- Ubiquitous display system
- 270 inch display with touch interface
- AR development environment
- A variety of latest Head-Mounted Display systems (Fig. 5)
- Steerable projector system
- 3D digitizer & 3D printer
- Room-size visuo-haptic AR system

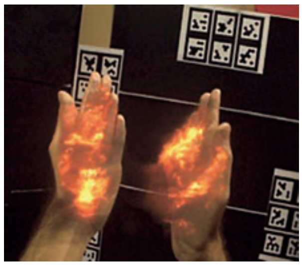

Fig. 1
High quality rendering technology for AR

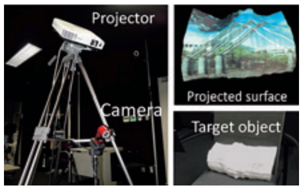

Fig. 2
Projection-based AR

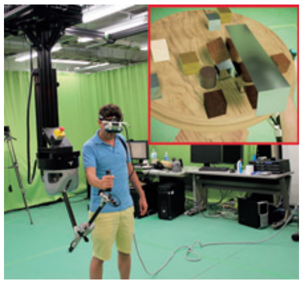

Fig. 3
Haptic feedback for AR

Fig. 4
Designing novel interaction methods for AR

Fig. 5
A variety of recent head-mounted display systems

Cybernetics and Reality Engineering

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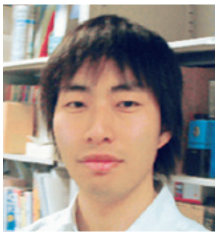

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Research Areas

Cybernetics is an academic field that unifies humans and systems. Reality engineering is used in the meaning of a superordinate concept bundling virtual reality (VR), augmented reality (AR), mixed reality (MR) and so on. In this laboratory, we are studying all of these, especially sensing, display and interaction technologies (Fig. 1).

Humans have acquired new capabilities by inventing various tools long before computers came up and mastering them as if they were part of the body. In this laboratory, we conduct research to create "tools of the future" by making full use of human and environmental sensing, sensory representation, wearable computing, context awareness, machine learning, biological information processing and other technologies. In particular, by manipulating various sensations such as vision, we aim to live more conveniently, more comfortably, or more securely by offering "personalized reality" which empathizes each person. Through such information systems, we would like to contribute to the realization of an inclusive society where all people can maximize their abilities and help each other.

Our laboratory has newly been established in April 2017. We will continue to try new challenges, inheriting the assets of Vision and Media Computing Laboratory. (Following topics include those of the former organization)

1. Sensing: Measuring people and the environment

We are studying various sensing technologies that assess human and environmental conditions using computer vision, pattern recognition, machine learning, etc.

- Estimation of drowsiness and degree of concentration from blinking and body movement
- Estimation of user's psychological state from gaze behavior
- HMD calibration and gaze tracking using corneal reflection images (Fig. 2)
- Three-dimensional reconstruction from video and sensor fusion (Fig. 3)
- Image restoration based on similarity and mesh defect repair of 3D shape models

2. Display: Manipulating perception

We are studying technologies, such as virtual reality and augmented reality, to freely manipulate and modulate various sensations such as vision and auditory, their effects, and their display hardware.

- Super wide field of view optical see-through HMD (Fig. 4)
- View expansion with a fisheye video see-through HMD
- Exaggeration of facial expressions using an eigenspace method (Fig. 5)
- Diminished reality / Object removal using image restoration technology (Fig. 6)
- A non-grounded and encountered-type haptic display using a drone

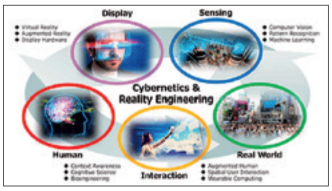

Fig. 1
Research fields

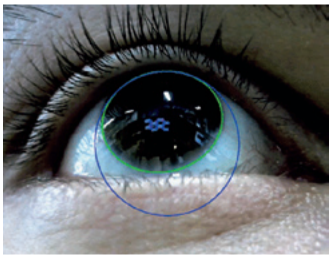

Fig. 2
HMD calibration and gaze tracking using corneal reflection images

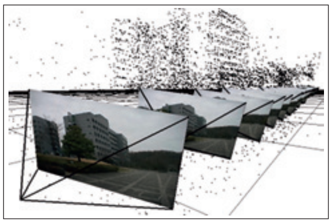

Fig. 3
Three-dimensional reconstruction from video

Fig. 4
Super wide field of view optical see-through HMD

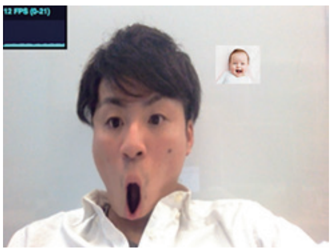

Fig. 5
Exaggeration of facial expressions using an eigenspace method

Research Areas (Cont'd)

3. Interaction: Creating and using tools

We combine sensing and technologies to study new ways of human interaction and interaction between humans and the environment.

- An AR pet with emotions that recognizes people and its environment
- An AR assembly support system that automatically recognizes assembly status
- An AR furniture arrangement system that automatically shifts to the optimal viewpoint (Fig. 7)
- A human motion reproduction system using augmented reality (Fig. 8)
- A remote robot manipulation interface with augmented free viewpoint image synthesis (Fig. 9)

Research Equipment

- A variety of HMDs, a spherical immersive display (Fig. 10)
- Omnidirectional camera systems, a laser range finder (Fig. 10)

Research Grants, Collaborations, Social Services, etc. (2016)

- MEXT Grants-in-Aid (Kakenhi) (B, C, Young B)
- Collaboration (Panasonic)
- MIC Strategic Information and Communications R&D Promotion Programme (SCOPE)
- JSPS Program for Advancing Strategic International Networks to Accelerate the Circulation of Talented Researchers (CMU, JHU, TUM)
- JASSO Student Exchange Support Program (University of Oulu)
- Steering / Organizing Committee members of international conferences on augmented and virtual reality

Fig. 6
Diminished Reality

Fig. 7
An AR furniture arrangement system that automatically shifts to the optimal viewpoint

Fig. 8
An AR human motion reproduction

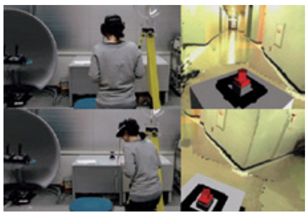

Fig. 9
Free viewpoint remote robot manipulation

Fig. 10
Part of research equipment

Optical Media Interface




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Research Areas

1. Computer Vision

We analyze the behavior of light reflection on a surface, and scattering inside an object. This analysis should become a basic technology of material estimation and 3d shape reconstruction.

2. Computer Graphics and Feeling of Material

To reveal a mechanism of human visual perception, we develop human visual interface to represent reliable material appearance and feelings.

3. Computational Photography

We are developing a method to generate images according to computation of light distribution captured by a specialized camera. To compute the distribution of the light captured by a specialized camera, we develop a method to generate an image which cannot be obtained from a conventional camera. Using this computation, we are able to generate an image taken by simulated virtual camera with physically impossible settings. This enables us to provide an image which we have never produced before.

4. Sensing System Development

Light transportation in 3D space contains various kinds of significant information, but a camera can only capture a 2D image of the scene, which is just a subset of the light transportation. Therefore, constructing optical measurement devices with specialized mirrors and lenses, we pursue the capturing of light transportation.

Key Features

The research topics in our laboratory include Computer Vision to understand scenes according to visual information obtained by a camera, and Computer Graphics to generate rich visual information for humans. We aim to realize new interfaces that enable humans and machines to interact through optical media based through cutting edge research.

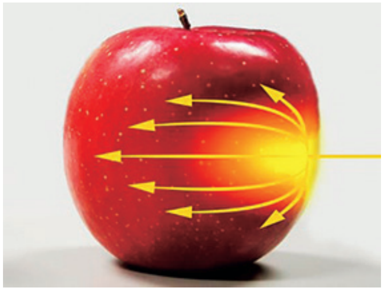

Fig. 1
Light transport analysis inside a target object

Fig. 2
Different materials, different appearances

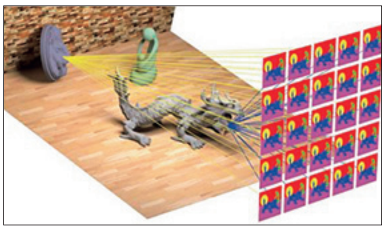

Fig. 3
Light field acquisition for computational photography

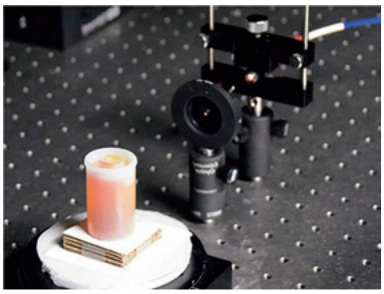

Fig. 4
Optics sensing system

Ambient Intelligence


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Research Areas

Ambient intelligence is a kind of intelligent environment and space corresponding to the real world, which helps and facilitates our daily life. Our lab aims to create core technologies of ambient intelligence for a safe, secure and comfortable life based on real-world sensing, knowledge structuring and interaction for humans.

1. Real-world sensing

In order to acquire real-world information for ambient intelligence development, information from actual scenes is collected by various sensors. Information about human behavior is essential for human life support using ambient intelligence platforms. Our laboratory is trying to analyze human behavior by integrating various kinds of data achieved through various measuring sensors installed in real environments.

2. Knowledge structuring

For a service robot to support human activity, it is necessary to structure knowledge of the environment (the position and behavior of humans, status of the actual area, etc.) in advance. This knowledge is structured from huge amounts of data through real-world sensing and information on the internet, utilizing analyzation with pattern recognition techniques and configuration structures, etc.

3. Interaction

Ambient intelligence provides users with appropriate multimodal interaction determined by structured knowledge in order to support users' activities. Our laboratory is not only developing augmented reality interaction, which is an intuitive visual information display technique, but also Human-Robot Interaction (HRI), that can provide visual, audial and physical stimulus. User's reactions after the interaction are also observed to update the knowledge of the ambient intelligence.

Key Features

By cooperating with communication media and objects, like robots for human support, and providing useful and helpful information of the environment to these, ambient intelligence significantly contributes to novel and useful services. Additionally, due to our carrying out of user studies not only in experimental rooms at NAIST, but also at actual scenes such as shopping malls etc., the development of more practical and reliable services is expected.

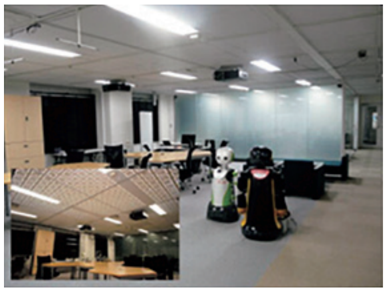

Fig. 1
Experimental environments: human and robot positions are measured using laser range fingers or invisible markers

Fig. 2
Interaction robots

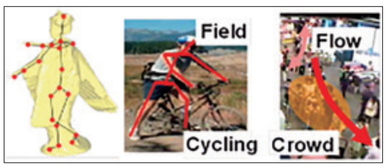

Fig. 3
Human motion and behavior understanding in various scenarios

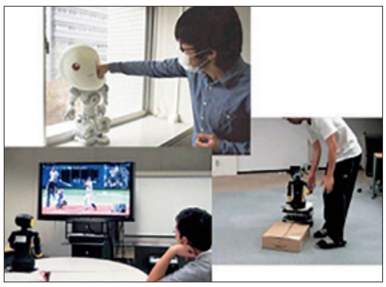

Fig. 4
Examples of Human-Robot Interaction (HRI) research

Social Computing

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Research Areas

1. Medical application based on NLP

Electronic medical records are now replacing traditional paper medical records, and accordingly, the importance of information processing techniques in medical fields has been increasing rapidly. Besides, the uses of information and communication technology (ICT) in medical fields are said to be 10 years behind those in other fields. ICT enables us to analyze voluminous medical records and obtain knowledge from the analysis, which would definitely bring more precise and timelier treatments in this field. Such assistance has much potential in saving more lives and further improving life quality. Our goal is to promote and support the implementation of practical tools and systems into the medical industry, so that we can support physicians and medical staff in their decision-making and treatment. Additionally, we are gathering people interested in such issues to share our knowledge, so that we can facilitate communication between different specialties and have discussions between them to clarify issues to be solved, while defining necessary fundamental technologies.

2. Web mining for healthcare

Social Network Services (SNS) potentially serve as valuable information resources for various applications. We have addressed and will be addressing web-based disease surveillance systems. To date, most web-based disease surveillance systems assume that the web immediately reflects real disease conditions. However, such systems, in fact, suffer from time lags between people's web actions and real-time situations. We have taken this time gap into consideration and have been applying various technologies not only from our familiar NLP field, but also from other fields, such as simulation modeling and psychological modeling. Findings from this study will also directly contribute to healthcare.

3. NLP as language ability test

We have investigated the relationship between cognitive ability and language ability, and are focusing on the creation of indicators to detect and screen language related diseases, such as Mild Cognitive Impairment (MCI), dementia, Autistic Spectrum Disorder (ASD), and many others. Recent medical studies on early detection methods (such as blood testing and detailed memory testing) have improved detection capabilities, but such methods are physically and/or mentally invasive. Instead, we are aiming for low or even non-invasive methods. Natural Language Processing (NLP)-based analytical methods have the potential of detecting cognitive ability deterioration quickly and easily.

Key Features

Our laboratory has been recently established to develop a new academic field, which can oversee the entire range from basic science to real-world applications. Our core technology is natural language processing, but we aggressively employ and collaborate with other fields in order to produce extensive applications mainly in the medical and healthcare fields. Fig. 3 displays an example of our targets, involving medical fields, clinical fields, psychology, architecture, and much more.

Join us, and let's break new ground together.

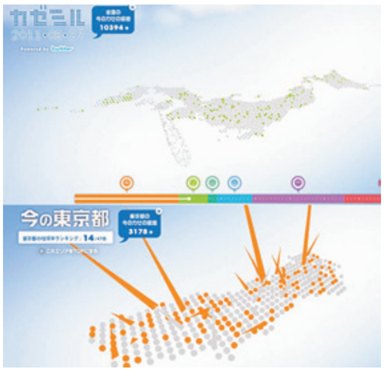

Fig. 1
Web-based disease surveillance system "KAZE-MIRU"

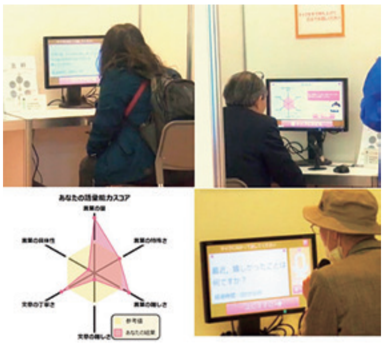

Fig. 2
We built a collection of elder's narratives.

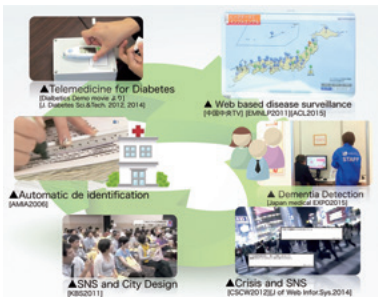

Fig. 3
Our fields

Robotics

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Outline of our Research Topics

A robot is an intelligent system that follows real-world dynamics while it interacts and communicates with human beings. Such a system requires sensing the real-world environment in real time (*real-time sensing*). In our laboratory, we develop real-time sensing technologies, such as robot vision and tactile sensing, and integrate them into intelligent systems.

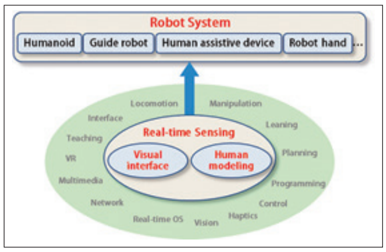

Fig. 1
Overview of our research

Research Areas

1. Visual interface

Understanding the environment and generating robot motion play an important role in intelligent interaction among people, robots, and computers. We develop methods to recognize daily life environments so as to facilitate activities of people and robots.

- Modeling of human/environment in space-time …(A-1)
- A service robot and interface …(A-2)
- Human-robot interaction …(A-3)
- Control, motion generation and machine learning …(A-4)

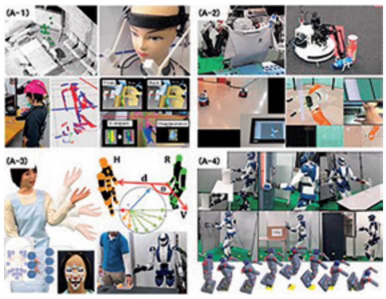

Fig. 2
Research area A: Visual interface

2. Human modeling

We measure, analyze, and model human beings to understand human skills, as well as policy/strategy while carrying out various tasks. Our research topics include a human-sized robotic hand, evaluation of usability based on musculoskeletal models, power assistance, haptic devices, and the evaluation of surgical skills.

- A musculoskeletal model and its application …(B-1)
- Haptic perception modeling and haptic device …(B-2)
- A functional electric prosthesis hand …(B-3)
- A realistic electric prosthesis hand …(B-4)

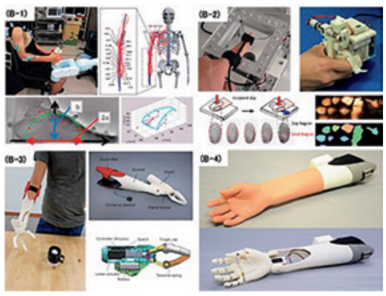

Fig. 3
Research area B: Human modeling

3. Application

We construct various robot systems for applications in real-world environments. Research outputs on visual interfaces and human modeling are fundamental components to construct such systems.

- A humanoid robot: HRP-4 …(C-1)
- An upper body humanoid robot: HIRO …(C-2)
- An android robot: Actroid …(C-3)
- Mobile robots: Pioneer 3DX …(C-4)

Fig. 4
Robots in our laboratory

Collaborators & Research Activities

AIST, Georgia Tech., CMU, KIT, Tokyo Univ. of Science, Nara Medical Univ., National Inst. of Fitness and Sports in Kanoya, ATR, Osaka Urban Industry Promotion Center, Robotics Society of Japan, etc.

Intelligent System Control





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Research Areas

1. Control systems design

- Advanced robust/adaptive control

We study advanced theories in post-modern robust/adaptive control and their applications including current investigations into various schemes of feedforward learning control (feedback error learning). System identification and state estimation are also topics of interest.

- Networked dynamical systems

The goal of this research is to provide a better understanding of the dynamical processes taking place over complex networks, as well as developing effective strategies to control their behavior. Applications of this research direction can be found in a wide variety of contexts, from social networks to networked infrastructure and cyber-physical systems.

2. Machine learning for robotics

- Motor skill learning for humanoid robots

We are developing novel methods that enable robots to learn complex motor skills (e.g., biped walking, putting on T-shirts and clothing assistance) by optimal control and reinforcement learning.

- Truly autonomous robots

The ultimate goal of this research is to develop next generation autonomous robots that autonomously find multiple objectives, select what the robot wishes to achieve from among them, and acquire dynamic motions to achieve the selected objective.

- Constructing practical myoelectric interfaces for robot control

We construct myoelectric interfaces robust to postural changes, sweating, and muscular fatigue, using surface electromyograms (sEMG) via modern machine learning methods.

Key Features

We welcome motivated students from various fields including mechanical/electrical engineering, mathematical/physical science, as well as computer science. The faculty guides students individually, taking into account their backgrounds, and assists them in mastering mathematical system approaches by the end of their course. Thereby they acquire a wide range of technical skills from fundamental theories to applications. The students in our lab are highly motivated, diligent, cooperative and eager to learn from others. We anxiously await such students from all over the world.

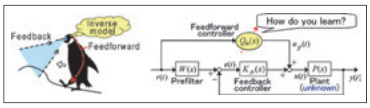

Fig. 1
Feedback error learning control

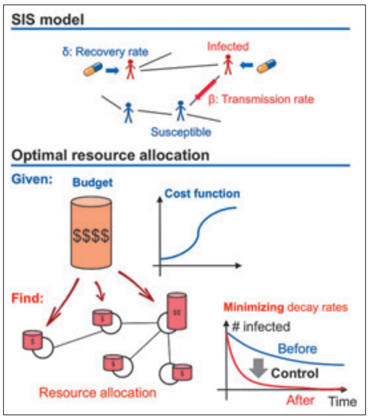

Fig. 2
Quantized control of mechanical system

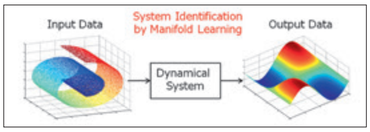

Fig. 3
System identification by manifold learning

Fig. 4
Motor skill learning by enforcement learning

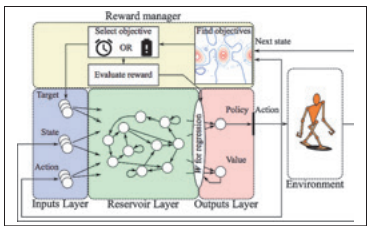

Fig. 5
Distributed lighting system and distributed generation network system

Large-Scale Systems Management

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Research Areas

1. System analytics and simulation

- Large-scale system modeling
- Markov analysis
- Queueing theory
- Simulation tools and techniques for large-scale systems
- Mechanism design
- Distributed virtual currency and smart contracts

2. Human-behavior-aware network systems

- Automation of hazard area estimation and evacuation guidance
- Crowd guidance for congestion alleviation
- Navigation for people with walking difficulty
- Delay tolerant networking

3. Network design

- Next generation networks
- Cognitive radio
- Cloud computing
- Controllable P2P contents distribution systems
- Game-theoretic approach

4. Algorithms for large-scale data processing

- Hadoop distributed processing systems/frameworks/clusters
- Task scheduling and file systems for cloud
- Online algorithms
- Large-scale graph and network algorithms
- Advanced data structure

5. IoT security

- Physical layer authentication
- Physical layer secret key generation
- Access control

Key Features

The Large-Scale Systems Management Lab research aims to develop mathematical modeling and simulation techniques for design, control and architecture of large-scale systems such as computer/communication networks, with which the resulting systems achieve high performance, low vulnerability and highly efficiency energy. Our research focus is on network-science oriented design frameworks, fundamental technologies and highly qualified services, particularly for large-scale computer/communication network systems. The laboratory was established in June 2012, and we welcome students from abroad who have strong interest in theories and simulation skills for designing smart services over large-scale complex systems including data centers, cognitive radio networks, and energy-harvesting networks.

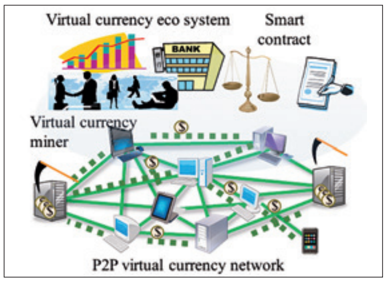

Fig. 1
Distributed virtual currency and smart contract network

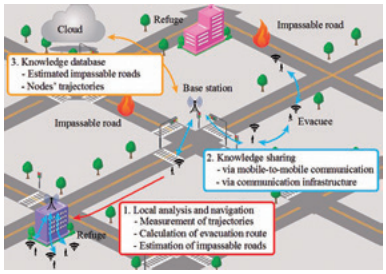

Fig. 2
Hazard-area estimation and evacuation guidance using trajectories of mobile terminals

Fig. 3
Cognitive radio

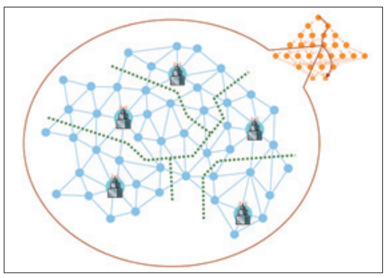

Fig. 4
Large-scale graph algorithms

Mathematical Informatics


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Research Areas

We study mathematical models for life sciences, from cell biology and neuroscience to medical science and social interaction. Our interdisciplinary research covers computation (machine learning), science (mathematical biology) and engineering (signal processing).

1. Machine learning

- Statistical learning theory
- Statistical signal processing based on Bayes theory
- Neural network theory
- Information geometry and information theory
- Factor analysis and sparse models

2. Mathematical biology

- Math models for cell biology
- Neural models of epilepsy and other diseases
- Neural mechanisms of empathy
- Behavior analysis using smart sensors
- Cognitive interaction design and social interaction

3. Signal processing

- Advanced driver assistance systems
- Adaptive signal processing theory and applications
- Reinforcement learning theory and applications
- Non-invasive human-machine interfaces

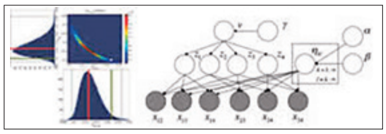

Fig. 1
Mathematical models in computation

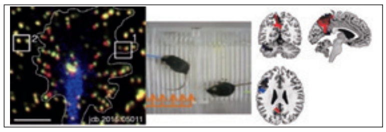

Fig. 2
Mathematical models in science

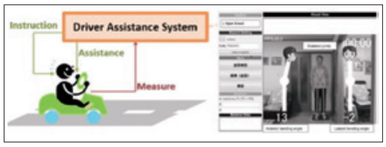

Fig. 3
Mathematical models in engineering

Key Features

Mathematical informatics is interdisciplinary; faculty and students in our lab have a variety of backgrounds, such as mathematical engineering, electric and electronic engineering, mechano-informatics, statistical science, physics, psychology, social science and medical science. We welcome students from any background since "mathematical models are everywhere", as far as they are interested in mathematical models.

Imaging-based Computational Biomedicine


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Research Areas

We integrate biomedical imaging with information science approaches such as statistical learning, computational simulation, and augmented reality to create knowledge and foster innovation in the field of computational biomedicine. We currently have four main research areas (Fig. 1):

- Virtualized human anatomy (Fig. 2)

We create models of human anatomy for each subject from 3D biomedical images. By integrating 3D image analysis and statistical learning, we also create models of variability in anatomical shape and image appearance throughout a population. We call these computational anatomy models. We also construct computational models of, for example, physical or physiological functions to seek comprehensive understanding of a subject's body.

- Diagnosis and treatment planning (Fig. 3)

We develop systems to support critical decision-making in diagnosis and therapeutic planning. These systems integrate patient-specific biomedical simulations with virtualized human anatomy and statistical predictions from clinical databases (known as "medical big data").

- Image-guided therapy (Fig. 4)

We are developing a surgical navigation system to provide surgeons with intraoperative guidance through real-time fusion of the surgical field and virtualized human anatomy. Our goal is to develop "intelligence" in surgery based on statistical learning and computational simulations. This will enable the prediction of changing conditions of patients during operations in order to perform optimal surgical procedures.

- Postoperative assessment (Fig. 5)

Medical treatment quality assurance requires proper assessment of the surgical outcomes. We develop ways to quantitatively evaluate the motion of patients who have had surgery on their skeletal structure, such as in orthopedic and craniofacial operations, where detecting subtle changes in locomotion is crucial in predicting long-term outcome.

Key Features

Our laboratory features a highly integrated research environment for information science, biomedical imaging, clinical medicine, and other related technologies. We have a number of medical and technical collaborators, including companies, working together within Japan and throughout the world. We fully utilize our unique environment and our network of researchers to pursue our work in imaging-based computational biomedicine.

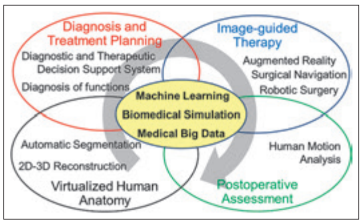

Fig. 1
Research areas in our lab

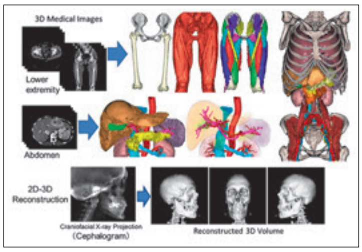

Fig. 2
Virtualized human anatomy

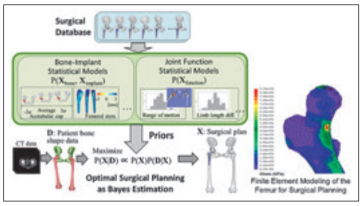

Fig. 3
Diagnosis and treatment planning

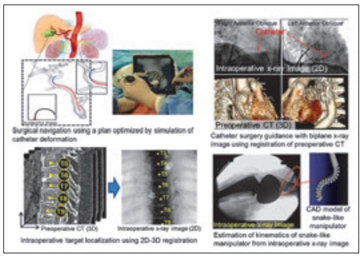

Fig. 4
Image-guided therapy

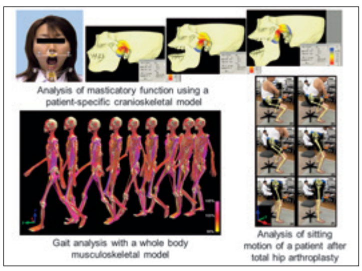

Fig. 5
Postoperative assessment

Computational Systems Biology


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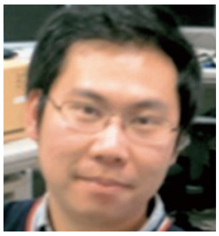
Assoc. Prof.
Md.Altaf-Ul-Amin


Assoc. Prof.
Naoaki Ono


Affiliate Assoc. Prof.
Tetsuo Sato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Research Areas

1. Systems biology

Biology has been significantly advanced by reductive approaches. Huge biological data sets, such as more than 1,000 genome sequences, have caused a paradigm shift into a holistic approach to understanding living things as systems. We study these approaches by modeling several biological systems to elucidate cellular mechanisms.

2. Network analysis

With the development of omics technologies, it has become imperative to systematically analyze all biological components (genes, mRNA, proteins and metabolites). To meet this challenge, we have developed a clustering algorithm (DPClus) to extract highly connected clusters.

3. Transcriptomes

A transcriptome is defined as a total set of transcripts in an organism. To elucidate transcriptome networks, we study transcriptome analyses using microarrays and new generation sequencers with the use of BL-SOM and novel methods.

4. Metabolomes

Cells consist of a few thousand molecules. Of those, metabolites are mainly produced by enzymatic reactions. The objective of metabolome analysis is to comprehensively identify which particular metabolites affect cellular networks. As a metabolome analysis platform, we have developed a species-metabolite database, KNApSAcK, covering almost all reported metabolites. To date, 50,048 metabolites and 101,500 species-metabolite relationships have been accumulated.

5. Bioimaging and informatics

Bioimaging has become an essential tool for understanding biological phenomena at the micrometer scale and also for medical diagnostics. Due to significant progress in microscope and detection technologies in the last decade, advanced observation methods have been realized, such as three-dimensional observation at the micron scale and super-resolution microscopes with resolution of several 10nm. We develop various microscope and analysis systems based on such emerging technologies.

- Three-dimensional and super-resolution microscopes
- A micro-nano manipulation system with optical tweezers
- fN force measurement and cell palpation systems

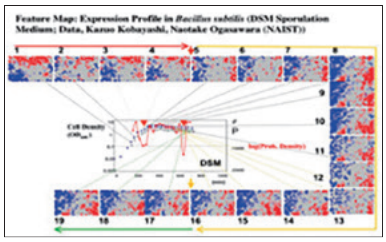

Fig. 1
Feature map: expression profile in Bacillus subtilis

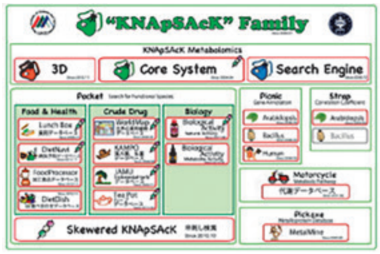

Fig. 2
Main page of "KNApSAcK Family" (http://kanaya.naist.jp/KNApSAcK_Family/)

Research Areas (Cont'd)

6. Medical imaging

A cardiac MRI in clinical imaging for coronary arteries and decision support technology for motion compensation has been developed. Diffusion Tensor MRI (DT-MRI) and tractography techniques are being investigated for the analysis of human brain cognitive functions.

- MRI
- Medical image analysis

7. Volume visualization in biology

We have developed a high speed volume rendering method for visualizing high resolution microscopic 3D images such as two-photon microscopy techniques.

- Volume graphics
- Neuron tracing
- Microscope image analysis

8. Medical engineering and informatics

In collaboration with medical hospitals and other institutions, we develop various medical engineering technologies based on information technology.

- Electromyogram and motion analysis
- Rehabilitation engineering
- Hospital information systems

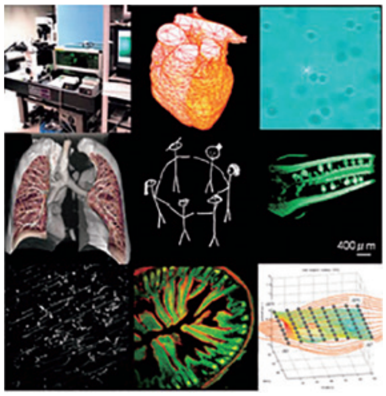

Fig. 3
Examples of biomedical imaging taken by various imaging schemes

Key Features

We work in an interdisciplinary field between information technology and bio-medical science. Our aim is to further both bio-medical science and information technology. Students study a wide variety of technologies, such as signal and image processing, imaging technology, optics, and nanotechnologies. We have developed techniques to identify gene function and disease mechanisms at high resolution.

Our laboratory members, who have come from a wide variety of backgrounds, aim to elucidate the robustness and diversity of biological systems through chemo- and bio-informatics. In our lab, students study a wide range of areas and attain broad perspectives. We always discuss important issues regarding research to enhance each other's knowledge.

Robotics Vision


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Takeo Kanade

Assist. Prof.
Yang Wu

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Research Areas

1. Assistive technology for disabled/older people

We focus on exploring computer vision possibilities for better enhancing robotics systems or wearable devices for better serving and helping disabled/older people, not just for safety purposes, but also for improving their quality of life and better engagement in the society. We start with helping blind people "see" the attitudes and emotions of people who they are talking with using wearable cameras. Future research will cover other practical needs of different groups of people.

Fig. 1
Assistive technology for disabled/older people

2. First-person vision with wearable cameras and mobile computing

First-person vision lets computers/robots see what we see, in exactly the same viewpoints and potentially the same time spans, and therefore it may be a better way to understand human vision, interest, intension, and behavior. We use wearable cameras and light mobile computing devices (e.g. smartphones) to capture and process this data, and communicate with other resources. This research is expected to better solve many traditional computer vision problems including segmentation, detection, tracking and recognition, and also further many new applications.

Fig. 2
First-person vision with wearable cameras and mobile computing

3. Scalable visual recognition for dealing with large amounts of data

As the big data era comes, we are able to share and access to large amounts of data, and connect countless amounts of sensors and devices. For computer vision, the critical research of visual recognition also goes from small-scale restricted data to large-scale real-world problems. We work on a representative task called large-scale across-camera person re-identification (with many cameras and people) to support large-scale real video surveillance systems. At the same time, we also look into more general problems such as image categorization and object recognition for investigating generic scalable visual recognition models. The research is also beneficial for our research on first-person vision.

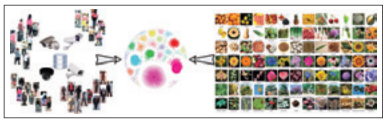

Fig. 3
Scalable visual recognition for dealing with large amounts of data

Key Features

As one of the first two international collaborative laboratories established in NAIST, this laboratory is different from any other research or collaborative lab that you can find in the Graduate School of Information Science. It is unique in:

- Being led by Prof. Takeo Kanade and closely collaborating with Carnegie Mellon University
- Gathering active and talented researchers with very diverse nationalities
- Targeting innovative research with global and long-lasting impact
- Effectively connecting NAIST researchers and international peers

Communication (NTT Communication Science Laboratories)

Prof.
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Assoc. Prof.
Tomoharu Iwata

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Research Areas

1. Data mining from relational data including large and complex networks

We study basic technologies mainly based on statistical machine learning to understand huge, irregular and ever-growing relational data including complex networks, such as the Web and SNS, and then make effective use of them for knowledge navigation.

2. Understanding real world situations through sensor networks

We are interested in observing and interpreting the real world through a variety of sensing devices such as acceleration sensors, light sensors, GPS, cameras, and microphones.

Key Features

Our research activities include various phases, including proposing new theories and modeling, developing effective algorithms and data structuring, and applying techniques to new interesting applications. We are interested in processing various data, such as Web and language data, speech sounds, images, and sensor data. Our everyday efforts are aimed at the world's first proposal and verification of new techniques, or the world's best performance of certain tasks. Students can use rich computer and human resources of NTT Communication Science Laboratories such as large clusters of high-performance servers. Each student receives a desk and personal computer and studies together with a group of researchers with which discussions occur naturally. More heated, in-depth discussions are also frequently conducted in discussion rooms.

Network-Human Interaction (Advanced Technology Research Laboratories, Panasonic Corporation)

Prof.
Tsuyoshi Inoue

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Research Areas

1. Integrated brain signal sensing technology for quantification of human cognitive status

2. Interactive robot control technology for human-occupied areas

3. Learning-based teaching methods of manipulators with sensory feedback

Key Features

"Humanware" is the core concept of this laboratory. It essentially refers to the capacity and dispatch of information results in humans. It aims to achieve human-like intelligent information processing, five-sense communication, and soft-flexible robotics/mechatronics. The basis of conventional information and communication technologies is mathematics, and the main R&D targets are computers and information equipment. In the near future, R&D of total systems and frameworks will be necessary, and this laboratory explores new research areas concerning information technologies combined with human, social, and physical science.

Computational Neuroscience (ATR International)

Prof.
Mitsuo Kawato

Assoc. Prof.
Jun Morimoto

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Research Areas

We aim to understand the human brain and to achieve new machine intelligence (artificial intelligence) based on brain information processing functions. We conduct research and educate students on computational neuroscience and cutting-edge machine intelligence with such methodologies as brain decoding, brain machine interfaces, neurofeedback, and robot learning at ATR, an internationally recognized computational neuroscience center.

Key Features

1. Machine intelligence for humanoid robot control
The framework for finding optimal behavioral policy can be formulated as a goal-directed decision-making problem. Using data-driven reinforcement learning algorithms, we construct machine intelligence for humanoid robot control to solve this decision-making problem.

2. Decoding brain signals
Brain signals resemble codes that encode cognitive and behavioral states. We address understanding how cognitive and behavioral information are encoded and processed in the brain using computational modeling and machine learning based on large-scale neural data. With decoded brain signals, we also develop brain-machine interfaces and brain-based communication systems.

3. Brain-Machine Interface (BMI) in daily life
By measuring brain activities in daily living environments, we develop inference techniques of such mental states as stress and empathy. Based on these, we approach the neural basis of cognitive functions in natural situations for the social applications of neuroscience, including human resource development.

4. Analysis and modeling methods for human brain imaging data
To understand how the brain generates behaviors and thoughts, we develop analysis methods for human brain data. We emphasize multiple integration measurements to overcome the limitations of each individual brain measurement.

5. Neurofeedback
We integrate psychophysical, neuroimaging, and computational neuroscientific approaches and propose novel neurofeedback methods, developing effective methods for BMI, medical treatment, and communication applications.

6. Computational models of decision-making
Our goal is to understand how humans make decisions. Reinforcement learning models and economic theorems allow us to build neural computations for human decision-making. We apply them to solve social, economic, and medical problems.

7. Adaptive shared control for BMI exoskeleton robots
Since robots are expected to work closely with humans, the development of a shared control strategy is becoming an increasingly important research direction. We are constructing an adaptive shared control strategy for our brain-machine-interface (BMI) exoskeleton robot.

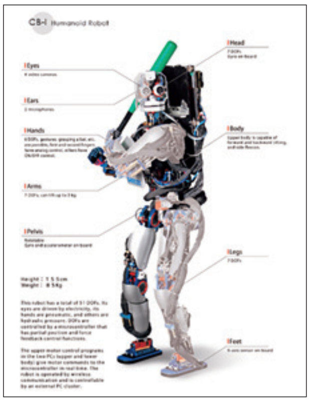

Fig. 1
Machine intelligence for humanoid robot control

Fig. 2
Decoding brain signals

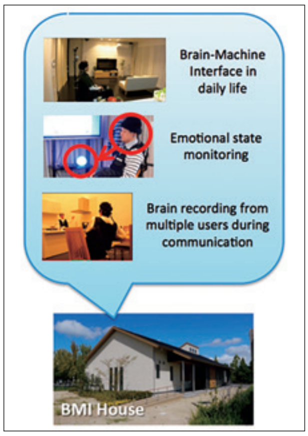

Fig. 3
Brain-Machine Interface (BMI) in daily life

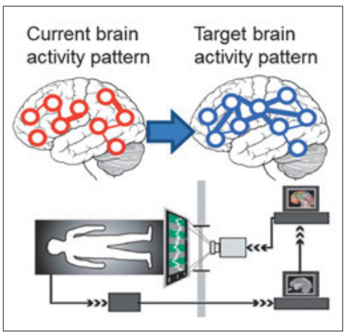

Fig. 5
Neurofeedback

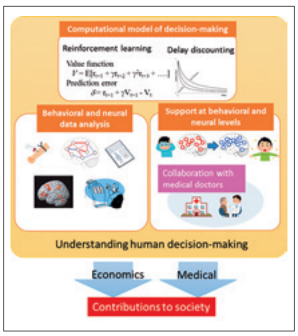

Fig. 6
Computational model of decision-making

Fig. 7
Adaptive shared control for BMI exoskeleton robots

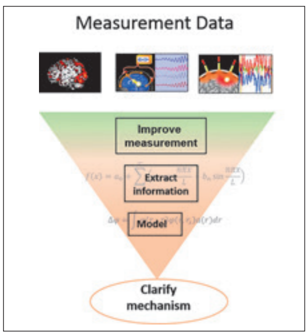

Fig. 4
Measurement data

Symbiotic Systems (NEC Corporation)

Prof.
Norihiko Taya

URL: http://isw3.naist.jp/Contents/Research/cl-04-en.html

Research Areas

We research symbiotic technologies to link society, environment, objects, information and energy with people. Also, we design new system architectures to realize a safe and rich society and more comfortable lifestyles. Currently we are creating new elemental technologies such as:

1. Open community co-creation systems
2. Work-flow analysis with various sensor data
3. Intellectual productivity measurement and support systems
4. Sensing of individual emotion and behavior characteristics
5. Wearable bio-sensing
6. Behavior diffusion simulation based on social dynamics
7. Systems for enhancing community activity

Key Features

1. Interdisciplinary collaboration
We pursue new technology through collaboration with experts in informatics, psychology, cognitive science, sociology, library science, economics, business management, media design, interactive arts, media science, etc.

2. Open and global research environment
We invite many researchers and internship students from Europe, Oceania and Asia to the open laboratory at NEC. Students of our laboratory learn about various research fields and foreign languages, while gaining a global point of view.

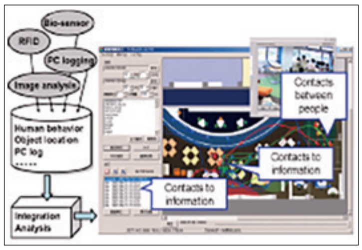

Fig. 1
Human behavior data analysis system for intellectual productivity measuring

Fig. 2
Laboratory devices such as remote communication systems, behavior sensors, etc., to accelerate co-creation

Human Interface (Fujitsu Laboratories Ltd.)


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Assoc. Prof.
Yuchang Cheng

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Research Areas

1. We develop Human Centric AI technology. One of the Human Centric AI technology's goals is to support smooth monolingual / multilingual text-based conversation using instant messenger or chat systems. Our focus is actuation technology which enables users to express user's senses, intentions and/or emotions correctly.
2. We also research methods to quantify and evaluate the "quality of conversation", which is a subjective impression of conversations. The AI uses the methods to improve communication quality for instant messenger users by providing suggestions to the speakers.

Key Features

Our laboratory belongs to Fujitsu Laboratories Limited, located in Kawasaki City, Kanagawa Prefecture. We research and develop various human interface technologies that enable smooth communication between persons using artificial intelligence (AI). The AI that Fujitsu envisions is a "collaborative, human centric AI," and we are aiming for the realization of AI that will support greater business growth and efficiency for our customers.

Multimedia Mobile Communication (NTT DOCOMO, INC.)

Prof.
Yukihiko Okumura

Assoc. Prof.
Tetsuro Imai

URL: http://isw3.naist.jp/Contents/Research/cl-05-en.html

Research Areas

Broadband multimedia mobile wireless communication systems

- Variable bit rate transmission techniques
  Power and bandwidth efficient resource allocation schemes for variable bit rate transmission, which is required for multimedia communication systems.
- Radio relaying schemes for MIMO wireless networks
  Radio repeaters expand coverage area without degradation in power and frequency utilization efficiency performance.

Key Features

Our laboratory is located in Yokosuka, Kanagawa. Students who plan to join our laboratory complete course work provided by the Network Systems Laboratory in the first year of the master's program. In the second year, students move to our laboratory in Yokosuka to start working with us.

Optical and Vision Sensing (Core Technology Center, OMRON Corporation)

Prof.
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Assoc. Prof.
Yoshihisa Ijiri

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Research Areas

Vision sensing technology for factory automation, social systems and consumer products

1. Physics-based vision
3D sensing, vision-based 3D measurement/object detection, camera calibration

2. Computer vision
Object detection/recognition, character recognition, machine vision algorithms

Key Features

Students in our laboratory:

- Extract research topics that are closely linked to product commercialization. Research topics are directly derived from customers' problems in each application field.
- Frequently discuss ideas with company engineers
- Collaborate with overseas internship students

Molecular Bioinformatics (National Institute of Advanced Industrial Science and Technology)

Prof.
Yutaka Ueno

Prof.
Kazuhiko Fukui

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Research Areas

1. Interacting protein molecule simulation using atomic coordinates
2. Bioinformatics tool integration for workflow analysis
3. Biological molecule structural analysis from electron microscopy images
4. A domain specific language for molecular model scripting animations

Key Features

- Graduate students' individual research projects and collaboration studies in bioinformatics areas are hosted at laboratories in the National Institute of Advanced Industrial Science and Technology (AIST).
- Experiencing a wide variety of research methods and techniques, and working with researchers from both biology and informatics fields.
- Various software systems for bioinformatics research projects developed in AIST in the last decade demonstrate the computational studies required for future problem solving.

Other Topics

- Software development for modern high performance computing
- Applications of haptic user interface devices for molecular modeling

Digital Human (National Institute of Advanced Industrial Science and Technology)

Prof.
Mitsunori Tada

Assoc. Prof.
Akihiko Murai

URL: http://isw3.naist.jp/Contents/Research/cl-08-en.html

Research Areas

Our laboratory is a part of Digital Human Research Group, Human Informatics Research Institute, National Institute of Advanced Industrial Science and Technology (AIST) under METI, located in Odaiba, Tokyo. Since our 2001 inception, we have promoted research projects with about 30 Japanese and international researchers and students from many fields to create computational models of human functions. We research the human appearance including its internal structure and functional neuro-musculoskeletal systems from the standpoints of modeling, computation, and measurement/visualization technologies. We work toward systems that adapt to individuals and their environments and support them suitably using digital human technology, a crucial function that has yet to be fully realized.

Prof. Tada works on modeling normalized/individual digital humans based on dimensional databases and statistics, and the development of motion measurement/analysis systems. Assoc. Prof. Murai works on modeling human neuro-musculoskeletal systems and the understanding of human motion generation/control mechanisms.

This course recruits students for the following research topics, which are part of ongoing research projects. Additionally, students may also propose related themes for their own research.

1. Digital human modeling

We lead research of modeling technology to reconstruct the human appearance and function on computers from anatomical knowledge and medical images of skeletons, muscle, and organs. This year, we will model detailed limbs, the trunk, and abdominal cavity based on the ongoing volumetric digital human model.

2. Understanding of human motion generation/control mechanisms

We measure human motion with optical motion capture systems and force plates, compute the joint angle and torque by kinematics and dynamics, and analyze the motion generation/control mechanisms based on robotics and statistics. This year, we will measure and analyze daily/athletic performance with the volumetric digital human model, applying statistical analysis and the feature extraction to analyze and modify these motion data.

Fig. 1
Digital human modeling based on anatomy and measurement

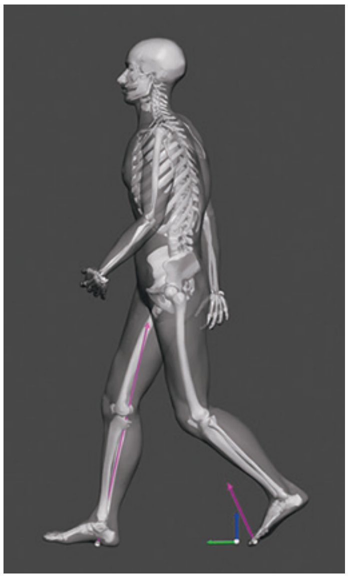

Fig. 2
Understanding human motion generation/control mechanisms using a digital human model

Fig. 3
Real-time motion measurement, analysis, and visualization

Technology of Radiological Science (National Cerebral and Cardiovascular Center Research Institute)

Prof.
Takahiro Higuchi

Assoc. Prof.
Kazuhiro Koshino

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■ MAIL: { thiguchi, koshino }@ncvc.go.jp

Research Areas

We develop image-based diagnostic tools to investigate the pathophysiology of diseases in the brain, heart and other organs (kidney, lungs, liver, pancreas etc.), using nuclear medicine and molecular imaging techniques with PET (Positron Emission Tomography), SPECT (Single Photon Emission Computed Tomography) and MRI (Magnetic Resonance Imaging).

We aim to develop advanced high performance imaging techniques/devices, new tracers and image processing programs based on computer science, to quantitatively assess physiological functions in clinical application and pre-clinical animal studies.

1. Clinical diagnostic imaging
- Rapid and quantitative PET systems for cerebral ischemia
- Quantitative and standardized SPECT imaging
- MRI and data analysis for morphometry and neuroimaging

2. Molecular imaging for pre-clinical studies
- New therapy and drug evaluation
- Development of animal models of diseases

3. Key technology development for diagnostic imaging
- Image processing: Image reconstruction, motion correction, image registration
- Image analysis: Quantitative assessment of physiological functions (perfusion and metabolism, tissue viability, inflammation and receptor binding), modeling of input function for completely non-invasive imaging, morphometry on MRI images
- Tracer development for physiological functions

Key Features

Our laboratory is in a national center for advanced and specialized medical care and research, with scientific researchers working in a variety of fields such as computer science, physics, medicine, pharmaceutics and chemistry. We collaborate with clinical doctors, medical equipment companies, pharmaceutical companies, and domestic and international researchers.

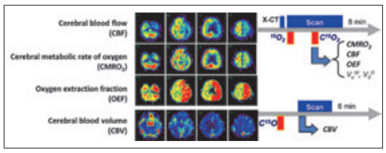

Fig. 1
Functional images obtained by our rapid and quantitative PET system.

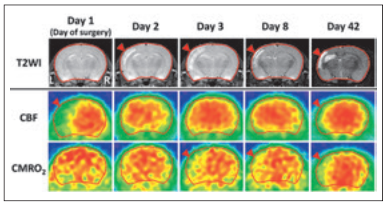

Fig. 2
Longitudinal observation of ischemic rat using a low invasive and hybrid PET and MRI imaging system.

Fig. 3
Imaging equipment dedicated to small animals in our laboratory.

Secure Software System (National Institute of Advanced Industrial Science and Technology)

Prof.
Yutaka Oiwa

Assoc. Prof.
Reynald Affeldt

URL: http://isw3.naist.jp/Contents/Research/cl-10-en.html

Motivation

Safety and reliability of software and computer-based systems, based on both scientific theory and practical applications

Research Areas

1. Development process and tools for ensuring software reliability
- Quality management and improvements for software testing
- Analysis of software implementation/design
- Software development processes
- Software security assurance/certification

2. Fundamental theories/technologies for software safety
- Semantics and design of programming languages
- Software testing, model checking and formal analysis

3. Theoretical/practical aspects of computer security
- Software protection, intrusion detection
- Security protocols and cryptography

Network Orchestration (National Institute of Information and Communications Technology)

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Assoc. Prof.
Eiji Kawai

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Research Areas

1. Virtualization technologies for network infrastructure
- Switch/router virtualization
- Software Defined Networking (SDN)
- Networking for cloud computing

2. Next- and new-generation network infrastructure technologies
- IPv6 and beyond-IPv6 technologies
- Infrastructure technology for service-oriented networks such as mobile networks, sensor networks, content-centric networks, etc.

3. Orchestration technology for large-scale network infrastructures
- Management of wide-area and virtualized networks
- Wide-area and virtualized network advanced traffic engineering
- Multi-domain networks

Key Features

The Network Orchestration Laboratory is a collaborative laboratory with the National Institute of Information and Communications Technology (NICT). In particular, we are developing the JGN-X network testbed, a nation-wide experimental network infrastructure founded by NICT. JGN-X provides high-speed international connectivity to the United States, China, Korea, Singapore, and Thailand, and forms part of a global R&E network infrastructure. Those students who are interested in real-world ICT infrastructure technologies find great opportunities to conduct research not only utilizing the facilities of JGN-X, but also applying their products to JGN-X.

High Reliability Software System Verification

(JAXA's Engineering Digital Innovation Center (JEDI), Japan Aerospace Exploration Agency)

Prof.
Masafumi Katahira

Assoc. Prof.
Naoki Ishihama

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Research Areas

Recent embedded systems and infrastructure systems are recognized as the basis for accomplishing national and human safety. Assurance of high reliability in those systems is one of the most critical issues to increase the safety of the whole social system.

Based on the proven studies and practices concerning high reliability and safety in the field of space systems established by JEDI in JAXA, our "High Reliability Software System Verification Laboratory" is focused on research into software verification methodologies to achieve high reliability and safety in software that must function properly under extreme environmental conditions.

Assurance methods for verification completeness, such as End-to-End point of view for complex distributed software systems, are a recent key issue. In our lab, the main topics are reliability and safety verification methodology and reliability and safety assurance methodology.

The research outcomes are expected to be applied to practical uses for systems that require high reliability, not only in space systems but also in social core infrastructures.

1. Reliability and safety verification methodology

- Verification methods for robustness

We research and develop the assurance methods for verification completeness, and the key technologies for robustness verification including the non-functional specifications.

- Automated verification methods

We first research the analysis of system configurations, operational conditions and system error pattern models. Based on those concepts, algorithms and methodologies for the automated generation of verification cases and the automated success criteria of verification results are developed.

2. Reliability and safety assurance methodology

- Assurance methods for verification completeness

We research technology to evaluate verification completeness of whole End-to-End software systems based on verification information produced by various software systems.

- Assurance methods for defect propagation

We formulate systematic defect modes in the whole software system, then research and demonstrate the evaluation method of propagation effects into whole systems.

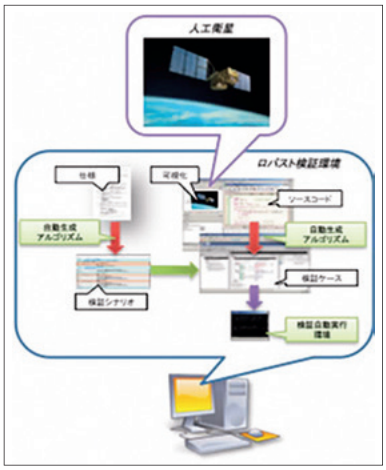


Fig. 1
The concept of robustness verification and automated environments

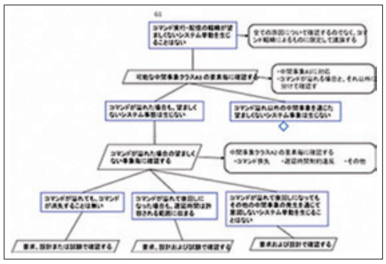


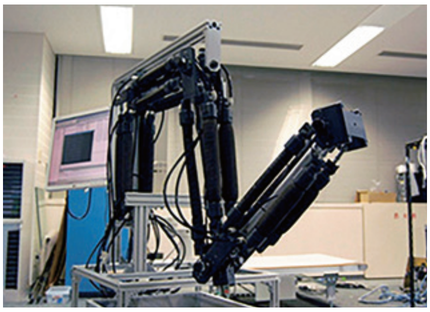
Fig. 2
An example of assurance methods for verification completeness using assurance cases

Key Features

In the first half of the graduate program, students complete required coursework on NAIST's campus, and in the last half, determine their of the thesis themes and join the research of various technologies to produce high reliability and safety in systems, such as independent verification and validation called IV&V, a model-based verification and system assurance, through project based studies and internships in JAXA. Most of the knowledge and skills experienced in our laboratory are highly concerned with science and industry, not only in the space domain but also in a broad range of industries, such as the automotive industry. Internships in JAXA Tsukuba Space Center are held during this period. For necessary topics, international collaborative studies with other international space agencies such as NASA are also performed.

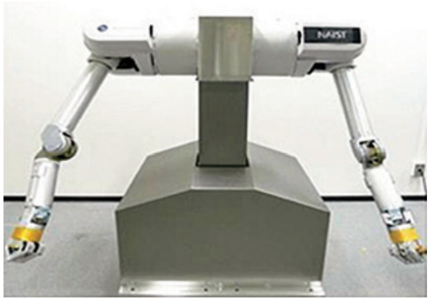
Fig. 3
JAXA Tsukuba Space Center

Cutting-edge Research Facilities



7-DOF manipulator controlled by pneumatic artificial muscles
(Mathematical Informatics Lab)

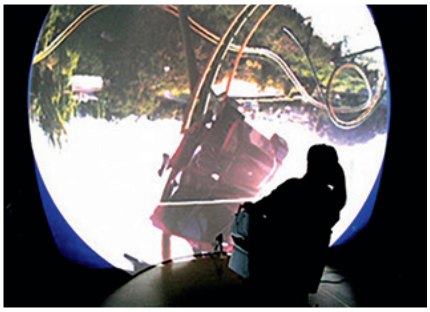
Multi-tilt camera system
(Ambient Intelligence Lab)



Advanced dual robot arm-hand system
(Intelligent System Control Lab)

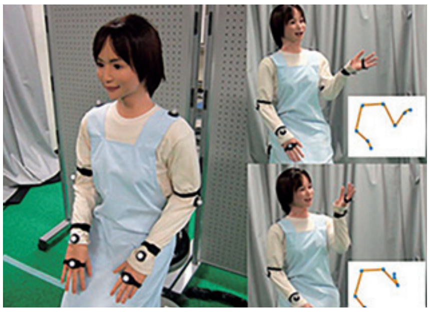
Tele-presence transmitter
(Network Systems Lab)

CAVE with treadmill
(Vision and Media Computing Lab)

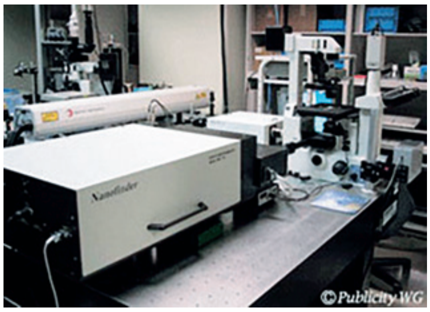


Immersive dome
(Vision and Media Computing Lab)

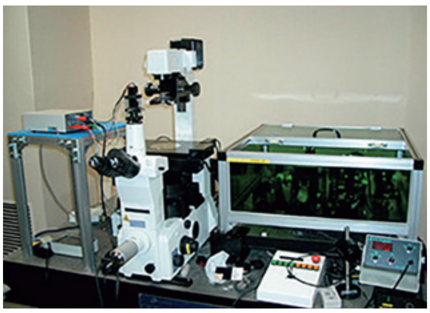
HIRO-NX
(Robotics Lab)



Behavior media system
(Robotics Lab)



Bioscience measurement equipment



Evanescent microscope

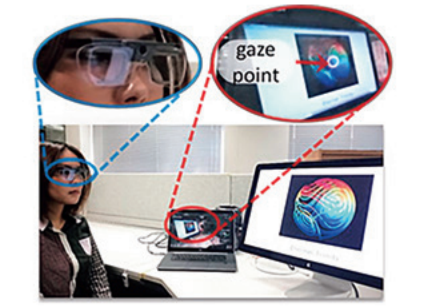
Ultra-short pulse laser microscope spectrometer

Super-high definition image interactive system

Computation server
(Information Initiative Center)

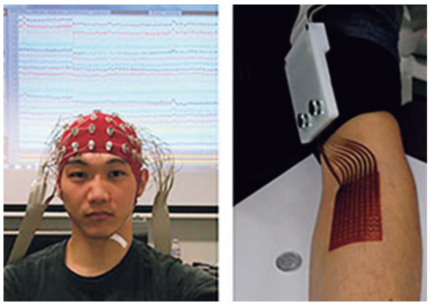
Cloud computing service system
(Internet Architecture and Systems Lab)

Humanoid Robot HRP-4
(Robotics Lab)



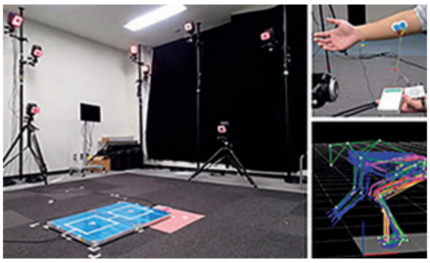
Glasses-type eye tracking system

Table-mounted eye tracking system

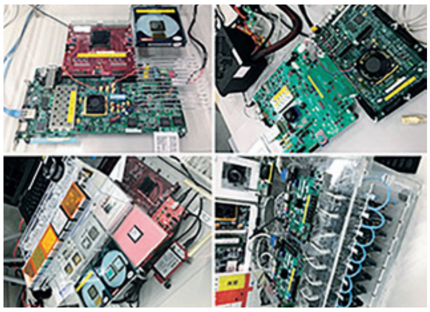


Multi-channel EEG/sEMG system

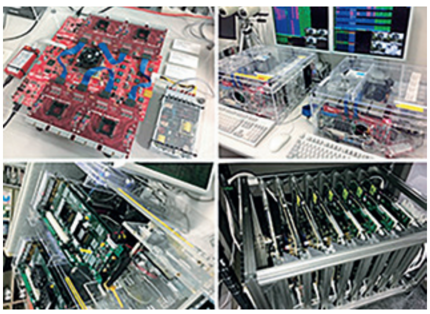
Driving simulator system



Optical motion capture system /EMG system /Force plates / Musculoskeletal simulator



Experimental equipments for IoT acceleration
(Computing Architecture Lab)



FPGA systems for large-scale applications
(Computing Architecture Lab)

Large-scale simulation environment
(Computing Architecture Lab)

Large-scale document processing system
(Computational Linguistics Lab)

Ubiquitous display
(Interactive Media Design Lab)

Virtual infrastructure system
(Software Design and Analysis Lab)

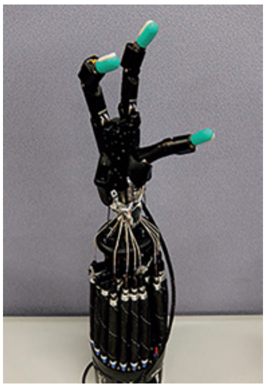
Near-infrared spectroscopy system
(Software Engineering Lab)

Data analysis system
(Software Engineering Lab)

Electroencephalogram (EEG)
(Augmented Human Communication Lab)

GPU server system for deep learning
(Augmented Human Communication Lab)

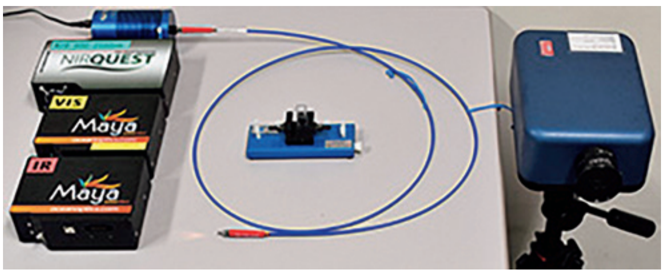
Bigdata processing system
(Augmented Human Communication Lab)



Dexterous robot hand
(Intelligent System Control Lab)

Satellite communication vehicle
(Information Initiative Center)

Smart home facility
(Ubiquitous Computing Systems Lab)



Hyper-spectral camera and spectroscopes

Multimodal Communication Robot

(Augmented Human Communication Lab)

Weight-bearing Open MRI System

(Imaging-based Computational Biomedicine Lab)

Biological Science
Laboratories

Information Science

Biological Science

Materials Science

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Outline of Research and Education

We conduct extensive research, from basic to applied, concerning the cellular function, signal transduction and regulation of gene expression in higher-plants, making effective use of molecular genetics and imaging technology on Arabidopsis thaliana, tobacco, and tomatoes.

Major Research Topics

1. Dynamic reorganization of microtubule cytoskeletons in response to environmental stimuli and during plant growth

- Pattern formation of bio-polymer networks
- Regulators of microtubule dynamics
- Left-right asymmetry establishment in cell shape
- Stress-induced reorganization of microtubule arrays

2. Natural product biosynthesis and regulation

- Transcriptional regulation of defense metabolism
- Jasmonate signaling
- Identification of novel enzymes and transporters
- Plant metabolic engineering

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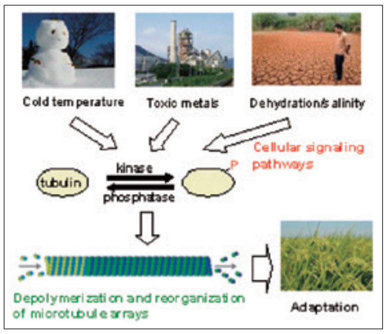

Fig. 1
Environmental stresses remodel the microtubule cytoskeleton by phosphorylation of tubulin subunits.

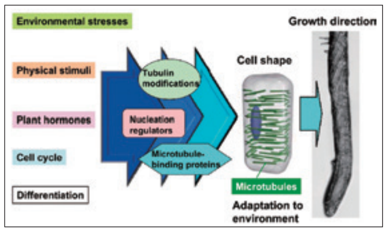

Fig. 2
The plant microtubule cytoskeleton remodels in response to developmental and environmental signals, and controls plant cell shape.

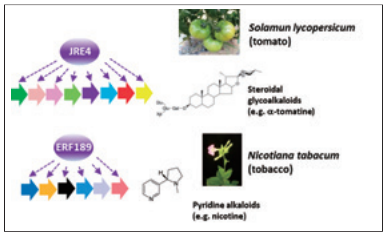

Fig. 3
Conserved transcription factors, JRE4 and ERF189, required for induced production of defense natural products in tobacco and tomatoes.

Plant Developmental Signaling



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Outline of Research and Education

Microscopic observation of plant sections allows one to realize the beautiful patterns of cells, each with a different shape and size (Fig.1). These cells are not only diverse in appearance, but are functionally specialized to play specific roles in each organ. These tissue patterns are produced from a single cell, the zygote. One of the most fundamental questions in plant developmental biology is how complex plant structures are derived from a single cell.

Our research group is trying to identify basic principles of plant development using model plant species. We aim to understand both intercellular and intracellular signal transduction pathways underlying the pattern formation and cell differentiation of roots and embryos, as well as cell reprogramming that triggers embryogenesis.

Major Research Topics

1. Cell-cell communication in tissue patterning

Due to the presence of rigid cell walls, plant cells are generally unable to alter their direction or position in the organ primordia. Therefore, timing and orientation of cell divisions, as well as cell fates, are determined by interpreting the positional cues of surrounding cells. Such developmental mechanisms rely on the presence of intimate cell-cell communication pathways. Our recent studies have revealed the presence of novel signaling pathways that allow regulatory molecules such as transcription factors and microRNAs to travel from cell to cell (Fig.2). We are currently focusing on the generality of such cell-cell signaling pathway in root and embryo patterning.

2. Cell reprogramming and pattern formation during embryogenesis and germ cell formation

Embryogenesis of the Brassica family, including the model plant Arabidopsis, proceeds in a highly coordinated manner (Fig.3). Similar to innovation of iPS cells, activation of an embryo- and germ cell-specific developmental program is initiated only after the reprogramming of somatic cells to the embryonic status. We have recently discovered a key reprogramming factor in Arabidopsis and bryophytes, and are currently investigating their mechanism of action. We are also constructing a translational approach that utilizes this reprogramming factor to propagate useful plant lines without waiting for the transition to the reproductive growth phase.

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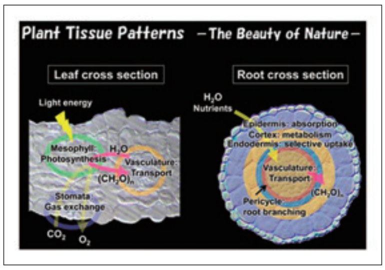

Fig. 1
(Left) In leaves, specialized cell types such as mesophyll, stomata, and vascular cells, are spatially arranged to maximize photosynthetic ability. (Right) Root tissues are organized into a concentric pattern that facilitates water and nutrient uptake, as well as their metabolism and translocation.

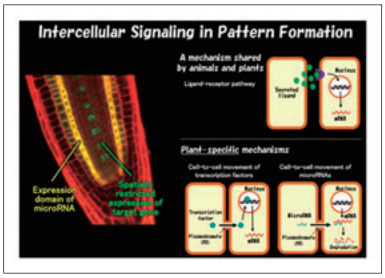

Fig. 2
Plant cells are connected with a cytoplasmic continuum termed plasmodesmata (PD). PD allows passage of regulatory molecules, such as transcription factors and small RNAs, thereby serving as a channel to transmit developmental signals.

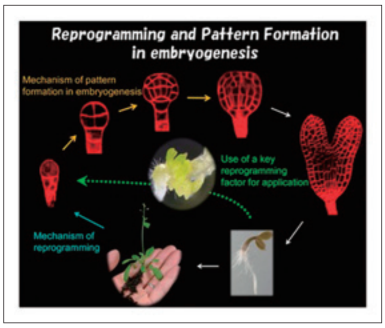

Fig. 3
Pattern formation in embryogenesis is triggered by cell reprogramming and proceeds in a highly coordinated manner. We study the mechanisms underlying embryonic pattern formation and reprogramming, as well as application of the reprogramming factors for efficient propagation of useful plants.

Plant Metabolic Regulation




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Outline of Research and Education

Our laboratory engages in research and education pertaining to the biotechnology needed to resolve the issues facing human beings in the 21st century, such as food, environment, and energy. Especially we are exploring the mechanisms of gene expression regulation for woody cell differentiation using omics technology to develop novel biotechnological tools for the establishment of a sustainable society.

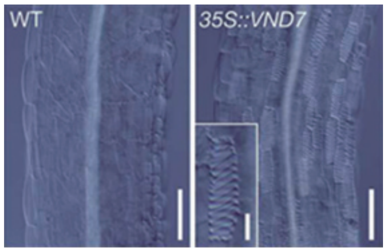

Fig. 1
VND7 acts as a key regulator of xylem vessel differentiation. Overexpression of VND7 induces transdifferentiation of epidermal cells into xylem vessel elements with spiral structures of secondary wall thickening (arrows) in hypocotyl. Bar=100 μm

Major Research Topics

1. Molecular mechanisms governing xylem cell differentiation

We identified a key regulator of the xylem vessel differentiation, Arabidopsis VND7 (Vascular-Related NAC Domain Protein7), which is a plant-specific NAC domain transcription factor (Fig.1). To understand the molecular mechanism by which xylem vessel formation is regulated, we have been characterizing VND7 and its homologs through various approaches (Fig. 2).

2. Molecular and cell biological approaches to improve woody biomass

We are also conducting genomics, transcriptome, proteome and metabolome studies to reveal the molecular system of plant biomass biosynthesis, using not only model plants but also non-model practical plants.

3. Highly-efficient transgene expression systems of higher plants

In order to transcribe foreign genes in plant cells more effectively, we are studying the factors that contribute to transgene-silencing, the relationship between chromatin/nucleosome structure around the promoter region and gene expression, identification and characterization of matrix the attachment regions, and improvement of transcriptional terminator regions.

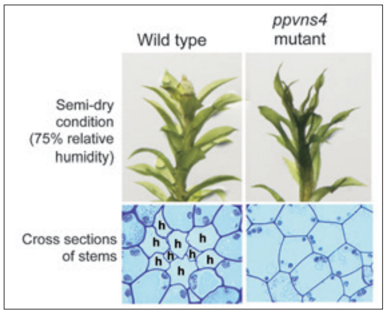

Fig. 2
Moss *Physcomitrella patens ppvns* mutants, a knock out mutant for one of VND-homologous genes, show the malformation of hydroids (h) in stems, thus leading to decreased water transport activity accompanied wilting phenotype under semi-dry conditions.

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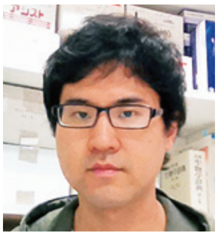
Plant Growth Regulation





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Outline of Research and Education

Plants continuously produce organs throughout their life. This feature renders them distinct from animals, in which organ formation ceases soon after embryogenesis. We are studying DNA polyploidization and stem cells that support sustained plant growth. We focus on the molecular mechanisms of DNA polyploidization that increases cell volume and organ size, and how plants preserve stem cells. We aim to understand the regulatory system underlying continuous plant growth, and to develop technologies to increase plant biomass and food production.

Major Research Topics

1. Mechanisms of induction of DNA polyploidization

In many plant species, cells start endoreplication after the cessation of cell division. This is an alternative type of the cell cycle, lacking mitosis and cytokinesis. As a result, DNA content in individual cells is elevated. The resultant DNA polyploidization causes enlargement of individual cells and organs (Fig. 1); thus, it greatly contributes to plant biomass production. However, the induction mechanisms of endoreplication have remained largely unknown. We recently found that regulation of chromatin structure as well as the cell cycle play essential roles in triggering endoreplication. Therefore, we are studying the epigenetic control of endoreplication, and developing technologies to induce DNA polyploidization, which may increase crop yield and woody biomass production (Fig. 2).

2. Maintenance of plant stem cells

The sequoia, the largest tree on the earth, has a life span of more than 3,000 years. It continues to grow throughout its lifespan, indicating that pluripotent stem cells function for a long time period under changing environmental conditions. How plants generate, proliferate, and maintain stem cells in tissues, however, remains elusive. We are studying the mechanisms of how the stem cell niche is regenerated through reprogramming, and how stem cells are replenished when they are lost owing to environmental stresses (Fig. 3). Our study will shed light on the pluripotency of stem cells and the process of tissue regeneration.

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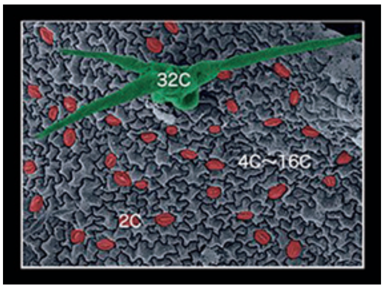


Fig. 1
Epidermal cells of an Arabidopsis leaf. Each cell type has different DNA ploidy; stomatal cells (2C, red), trichomes (32C, green), and the other cell types (4C-16C). As the DNA content is elevated by endoreplication, the cells are enlarged.

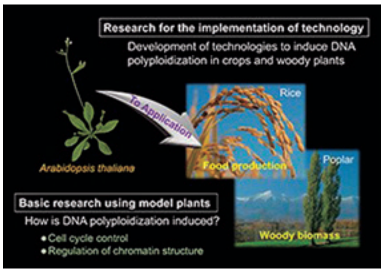


Fig. 2
Development of technologies to increase the yield of crops and woody biomass by induction of DNA polyploidization.

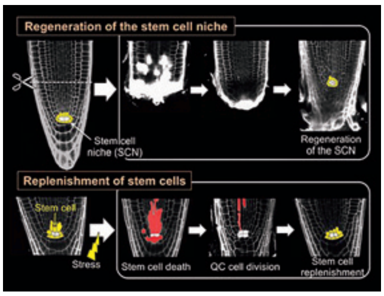
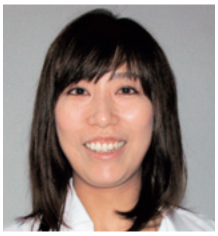


Fig. 3
Regeneration of stem cells in roots.
(Top) When the stem cell niche is removed by cutting the root tip, plants regenerate the stem cell niche through reprogramming.
(Bottom) Environmental stress causes stem cell death, which is followed by division of quiescent center (QC) cells (white cells) to replenish stem cells.

Plant Stem Cell Regulation and Floral Patterning



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Outline of Research and Education

We are interested in a holistic view of gene regulation in plant reproduction, which leads to developmental robustness and coordination. We explore signaling and epigenetic control in stem cell maintenance, environmental response and fertilization. To reveal molecular mechanisms, we use *Arabidopsis* as a model plant for genetic, reverse-genetic, biochemical and genomics approaches, as well as Brassicas and rice, to study conservation and diversification. Our students work at the frontiers of plant molecular genetics, developing their research, presentation and writing skills.

Major Research Topics

1. Floral stem cell homeostasis

Flowers originate from self-renewing pluripotent stem cells in the floral meristems (Fig. 1). The maintenance and differentiation of stem cells are regulated by a well-coordinated interplay of **cell-cell signaling** and **epigenetic regulation**, leading to spatiotemporal-specific gene regulation. We study downstream cascades of the receptor kinase signaling pathway controlling stem cell homeostasis.

2. Stem cell termination and cell specification

In flower development, the stem cell activity is terminated in multistep pathways mediated by multiple transcription factors. We study transcriptional/epigenetic mechanisms and hormone signaling controlling stem cell termination and cell specification (Fig. 2).

3. Environmental response and acclimation

We study how plants memorize environmental temperature and light conditions and reveal the molecular mechanisms that confer the plasticity and robustness of the cascades under various environmental stimuli. These studies will serve as a basis of plant growth optimization for improved crop plant yields (Fig. 3).

4. Mechanisms of dominant/recessive relationships in plants

Pollen determinant genes functioning for self-incompatibility are governed by a complex dominance hierarchy. We study the mechanisms of these dominant/recessive relationships regulated by a small RNA-based epigenetic mechanism and its evolution in *Brassicaceae*.

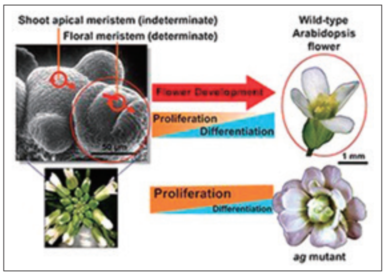

Fig. 1
Arabidopsis flower development
In flower development, the stem cell activities in the floral meristem are terminated (determinate), while the shoot apical meristem continues to grow.

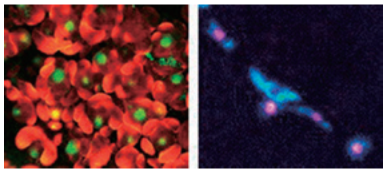

Fig. 2
Imaging of key transcription factors in floral meristems (left) and a differentiated myrosin cell (right)

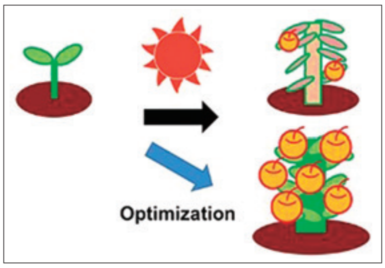

Fig. 3
Plant growth optimization
By revealing the mechanisms of floral stem cell regulation and environmental responses, we will develop a molecular basis for plant growth optimization for higher crop yield.

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Plant Immunity

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Outline of Research and Education

In nature, plants cope with a wide range of microbes that reside on the surface of or within plant tissues. Plants disregard or tolerate the presence of these plant-inhabiting endophytic microbes at non-damaging levels, despite an elaborate innate immune system to detect and repel microbes. We hypothesize that plants distinguish pathogens from non-pathogens by sensing "danger" signals (DAMPs) generated upon pathogen challenge in addition to microbial signals (MAMPs). We aim to decipher the molecular principles and mechanisms underlying plant immunity to infectious microbes, with major focuses on signaling crosstalk between MAMP and DAMP receptors, defense-related transcriptional reprogramming and infection strategies of pathogenic and endophytic microbes. We also study the mechanisms by which a subset of endophytic microbes facilitates host adaptation to adverse conditions. We believe that our studies will reveal important insight into general principles of plant-microbe interactions, and thus offer new effective approaches to controlling plant health and growth in sustainable agriculture.

Major Research Topics

1. Danger sensing and signaling in plant-microbe interactions

2. Transcriptional reprogramming and priming in plant immunity

3. Modulation of plant immunity in fluctuating environments

4. Endophytic and pathogenic microbes in plants

5. Plant-associated microbiomes

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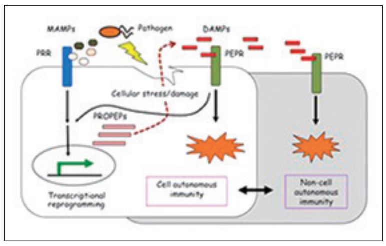


Fig. 1
Layered MAMP- and DAMP-receptor signaling provides an important basis for pathogen resistance.

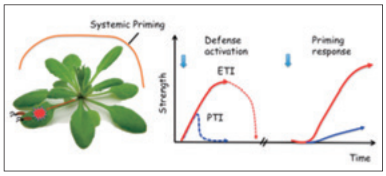


Fig. 2
Transcriptional reprogramming and priming in plant immunity. Following the initial defense activation (left arrow) upon recognition of pathogen-associated patterns (PTI) or effectors (ETI), defense-related genes become primed to allow faster and/or greater responses upon second stimulation (right arrow). Histone modifications provide a basis for this immune memory that is sustained in the generation and can be inherited by the next generation

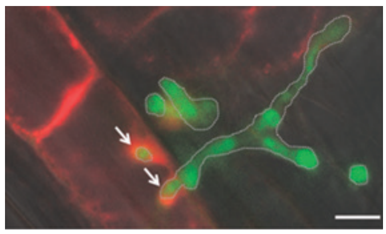
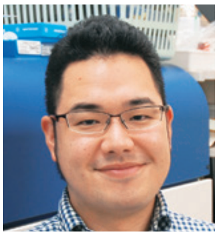


Fig. 3
Root colonization of endophyte Colletotrichum tofieldiae (Ct). Confocal microscope images of Ct constitutively expressing cytoplasmic GFP (green, labeled by dotted lines) and A. thaliana expressing VAMP722-mRFP (Red). Intracellular hyphae inside a root cortical cell are enveloped by PIP2A-mCherry-labeled host membranes (arrows). 8 day post inoculation. Bar = 10 μm.

Plant Secondary Metabolism

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Outline of Research and Education

Plant secondary metabolism (also called "specialized metabolism") produces compounds having several bioactivities such as resistance factors against various environmental stresses in plants, as well as health benefits for humans. Secondary metabolites are widely diversified in their chemical structures in nature (Fig. 1), since plants have adapted to environmental niches during long evolutionary periods using varied strategies such as gene duplication and convergent evolution of some key genes which contribute to chemical diversity. The Plant Secondary Metabolism Laboratory focuses on, i) the analysis of the natural diversity of secondary metabolites, and ii) the functional genomics approach for metabolic genes using translational analysis of omics studies (genomics, transcriptomics and mass spectrometry-based metabolomics). The specific goal is the identification of key factors of natural chemical diversity and regulatory roles in plant secondary metabolism which enable genome wide metabolic cross-species comparison for metabolic engineering of beneficial compounds.

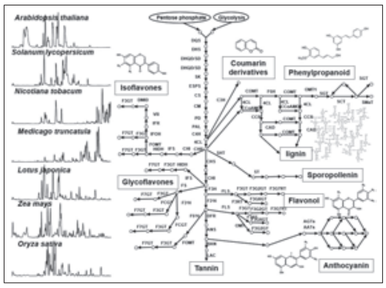

Fig. 1
Metabolic network of plant polyphenolic biosynthesis and their chemical diversity between plant species

Major Research Topics

1. Functional genomics approach by omics-based translational analysis

Currently, after completion of full-genome sequencing of over 100 plant species, the complete biosynthetic framework needs to be applied for integrative approaches with other omics data such as genomics and transcriptomics. However, genome information is not sufficient to compute the size and framework of a species' metabolism. Therefore, we screen qualitative differences of metabolite levels between tissues, stress treatments and wild accessions for "elucidation of biosynthetic framework" based on gene expression levels predicted from metabolite data (Fig. 2). On the other hand, recent technical developments allowing affordable whole genome sequencing, omics studies and availability of several resources such as knockout mutant library, quantitative trait locus (QTL) lines and wild accessions, have resulted in a dramatic increase in the number of approaches such as metabolic phenotype screening, network/modeling analysis, QTL and *genome-wide association studies* (GWAS). We employed these approaches supported by metabolomic studies to refine biosynthetic framework of plant secondary metabolism including natural variance, tissue and species specificity, in order to discover key genes involved in the creation of chemical diversity.

2. Cross species comparison on the neo-functionalized genomic region

Recent technical developments allowing reasonable whole genome sequencing as well as a better inventory of species-by-species chemical diversity have greatly advanced our understanding as to how these pathways vary across species. The range of genetics based strategies for characterization of key genes described above provide several genes and genomic regions involved in neo-functionalization of plant secondary metabolism. We therefore focus on the species specific duplicated genes in these key syntenic regions in order to find neo-functionalized genes having novel functions in plant secondary metabolism.

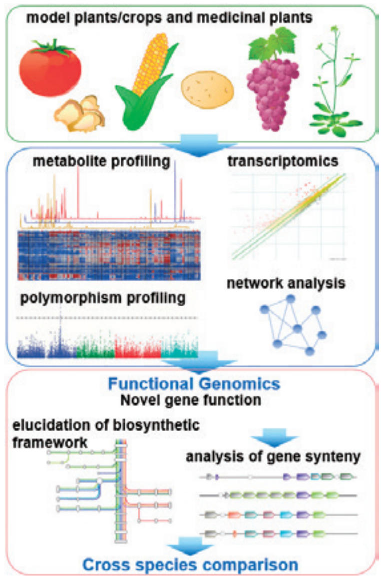

Fig. 2
Omics-based translational analysis using model plants and crops

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Plant Symbiosis

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Outline of Research and Education

Parasitic plants - major agricultural constrains in the world

Parasitic plants are able to parasitize other plants and rely on their hosts for water and nutrients. Several parasitic plants in the Orobanchaceae family, such as *Striga* (Fig. 1) and *Orobanche* spp., cause enormous damage to world agriculture because they parasitize important crops and vegetables. We are investigating molecular mechanisms underlying plant parasitism using the model parasitic plants *Phtheirospermum japonicum* and weedy parasite *Striga* spp. By combining molecular, genetic, cell biology and genomic approaches, we aim to understand the nature of parasitism and eventually develop novel control methods for weedy parasites.

Fig. 1
Sorghum field infested by *Striga* spp. (pink flowers) in Sudan

Major Research Topics

1. Identification of genes involved in haustorium formation

Parasitic plants form specialized invasive organs called "haustorium". The haustorium invades host roots, and eventually forms a vasculature connection between the host and the parasite to assimilate host nutrients (Fig. 2). To identify the genes involved in haustorium formation, forward and reverse genetic tools in *P. japonicum* were established. Screening of *P. japonicum* mutants which lack haustorium formation and identification of the causal genes by next-generation sequencing (Fig. 3) will isolate the essential genes in the haustorium formation. Furthermore, the genes upregulated during haustorium formation will be reverse-genetically analyzed.

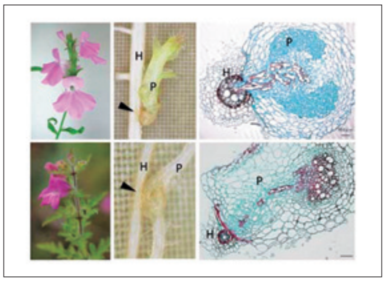

Fig. 2
Obligate parasite Striga hermonthica (upper panels) and facultative parasite Phtheirospermum japonicum (lower panels). Photos of flowers (left), host invading parasitic plant root (middle) and cross section of haustorium (right). H: host, P: parasite. Arrowheads indicate haustoria.

2. Plant-plant communication via small-molecular weight compounds

Parasitic plants recognize their hosts via small-molecular weight compounds secreted from the host plant (Fig. 4). For example, the obligate parasite *Striga* germinates in response to the plant hormone strigolactone, and its haustorium formation is induced by derivatives of cell wall lignin. However, some of our ***P. japonicum*** mutants do not respond to the known cell wall-derived chemicals, but are still able to form haustoria and parasitize hosts. We are trying to identify novel haustorium inducing compounds.

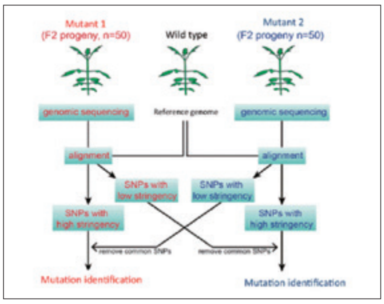

Fig. 3
Identification of the mutant causal genes using a next-generation sequencer

3. Comparative genomics of parasitic plants

Recent progress in next-generation sequencing technology enables us to acquire the complete genome sequence of any plant. We sequenced the whole genomes of *Striga* and *P. japonicum*. By examining these genome sequences, we found that parasitic plants have experienced evolutionary events such as expansion of specific gene family and horizontal gene transfers from hosts. How did the plants obtain new genes, increase the copy numbers and eventually acquire a new trait? What is the genetic diversity among *Striga* species in Africa? We analyze genome evolution using bioinformatics tools.

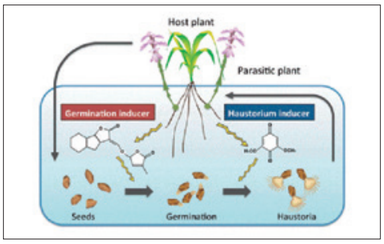

Fig. 4
Chemical communication between host and parasitic plants

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Molecular Signal Transduction

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Outline of Research and Education

Signal transduction is indispensable for organ development and homeostasis. Hormones and neurotransmitters induce a variety of cell responses mediated through membrane receptors and intracellular signaling pathways. Impairment of the signal transduction often causes disease. And with this, many drugs targeting these signal components are widely used today. Our laboratory is interested in cellular signaling systems with special emphasis on heterotrimeric G proteins. In our laboratory, faculty and graduate students are dedicated to cutting-edge scientific research and work towards a better understanding of how the human body functions and the alleviation of human disease.

Major Research Topics

1. **Cellular functions and regulatory mechanisms of G protein signaling**
2. **Molecular mechanisms of self-renewal, differentiation, and migration of neural stem cells**
3. **Monoclonal antibodies against orphan adhesion GPCRs involved in tumorigenesis and neural function**
4. **Regulation of primary cilia formation and function in mammalian cells**
5. **Molecular mechanisms of epithelial morphogenesis and cancer**

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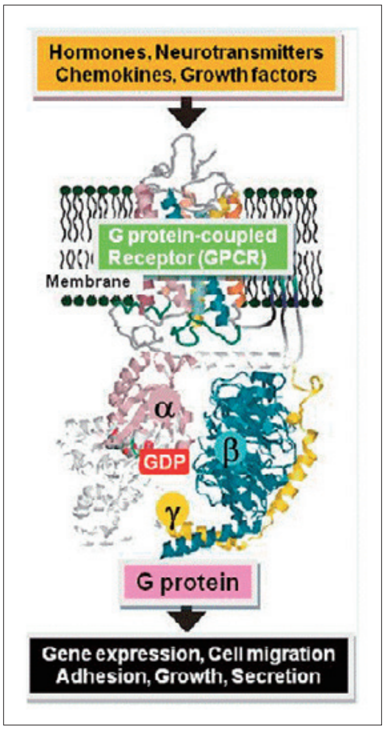

Fig. 1
Signal transduction mediated by G protein-coupled receptor

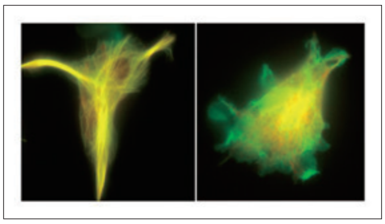

Fig. 2
G protein/PKA signal-regulated dynamics of a cytoskeleton in neuronal progenitor cells

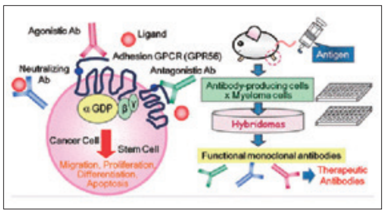

Fig. 3
Monoclonal antibody against orphan GPCR as a tool for signal analysis

Functional Genomics and Medicine

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Outline of Research and Education

Since completion of the genome sequencing of a variety of organisms including mice and humans, a main task has become elucidating the functions of the sequenced genomes. For this purpose, biomedical researchers inactivate particular genes of interest in mice and analyze the phenotypes of the mutated animals, thereby revealing the functions of the inactivated genes. We will devote our efforts to the investigation on the higher cognitive functions in the immune and nervous systems in mice and humans.

Major Research Topics

1. Elucidation of the physiological functions of PD-1

Since the discovery of PD-1 by Y. Ishida et al., in 1992, the negative immuno-regulatory functions of the PD-1 molecules expressed on the surface of activated T lymphocytes have been described. Recently, cancer immunotherapy based on the blockade of the PD-1 pathway has been successfully performed in clinics (Cell 162, 937, 2015). We try to elucidate the yet undiscovered functions of PD-1 in the self-nonself discrimination of the immune system.

2. mRNA localization in mouse sensory neurons

mRNA localization is a widely employed mechanism to target protein synthesis to specific cellular sites. It is particularly important for neuronal development and function. In mammalian olfactory sensory neurons, odorant receptor (OR) mRNAs are localized in the axon terminal. We currently investigate the molecular mechanisms of the OR mRNA localization in mouse olfactory sensory neurons and we have revealed the involvement of RNA binding proteins. We also explore how mRNA localization contributes to physiological functions and/or development of the olfactory tissue by using transgenic and knockout mouse models.

3. Development of novel gene-trapping strategies

Previously, it was almost impossible to inactivate transcriptionally silent genes in ES cells by random gene trapping. Almost 10 years ago, we developed a novel gene-trapping strategy named UPATrap that is based on the suppression of NMD, and allows for such difficult gene disruption for the first time. We are upgrading UPATrap technology in order to randomly disrupt long non-coding mRNA genes as well as protein-coding ones. We also produce mutant mice using newly developed techniques and analyze their phenotypes.

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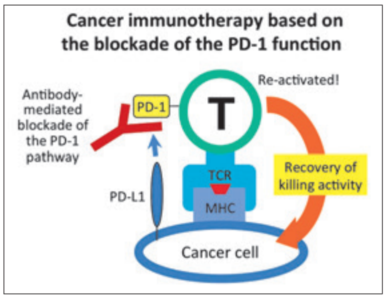

Fig. 1
Modulation of the PD-1 activity leads to effective T-cell immunity against cancer cells.

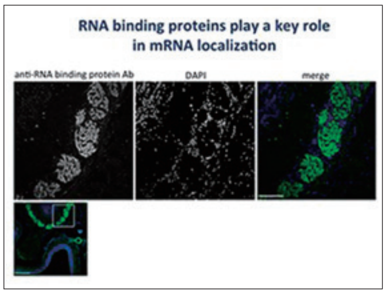

Fig. 2
Immunostaining of an RNA binding protein on the section of mouse olfactory tissue. We have found that some RNA binding proteins are highly enriched in the glomeruli of the olfactory bulb, where the axon terminal of olfactory sensory neurons exist.

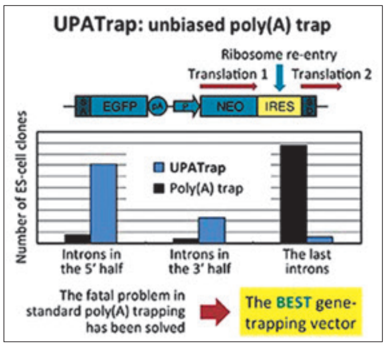

Fig. 3
The UPATrap method for the random insertional mutagenesis of transcriptionally silent genes in target cells.

Tumor Cell Biology

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Outline of Research and Education

We focus on the molecular mechanisms controlling proliferation, differentiation, and death of mammalian cells, and study the connection between cell cycle progression and oncogenesis, as well as differentiation, proliferation, and leukemogenesis in hematopoietic cells. These findings can be applied to regenerative medicine and cancer research. We use the following experimental systems:

- in vitro culture systems using mouse and human cell lines
- in vitro differentiation systems using ES cells and primary cultures
- mouse model systems using knockout and transgenic mice

Major Research Topics

1. Cell cycle control and oncogenesis

- Cell cycle control and oncogenesis: During the cell cycle, whether cells should proliferate or stop growing and prepare for differentiation is decided at the G1 phase. Therefore, we investigate the function of molecules that promote or inhibit the progression of the G1 phase such as cyclins, Cdks, Cdk inhibitors, and Rb tumor suppressor gene products (Fig. 1).
- Checkpoint control: The checkpoint mechanism is a means of monitoring and controlling the progression of the cell cycle. The central role in this checkpoint mechanism is played by the tumor suppressor gene product, p53. Recently, members of the p53 gene family, p63 and p73, have been identified. We are interested in the role of these molecules not only in oncogenesis, but also in the developmental program including morphogenesis (Fig. 1).
- Cancer and the cell cycle: Since cancer cells grow abnormally, they generally have abnormalities in the cell cycle control. We analyze the key molecules involved in cell proliferation, G1 regulation, and checkpoint control, and investigate the mechanisms involved in the abnormal growth of cells and cellular oncogenesis.

2. Leukemogenesis

We investigate the molecular mechanisms underlying leukemogenesis, focusing on AML (acute myeloid leukaemia), MDS (myelodysplastic syndromes), and CML (chronic myeloid leukaemia).

3. Hematopoietic stem cells

We perform studies on hematopoietic stem cells present in the bone marrow, with the aim of developing in vitro amplification methods for hematopoietic stem cells. The results of these studies can be of benefit to regenerative medicine as well as leukemia research.

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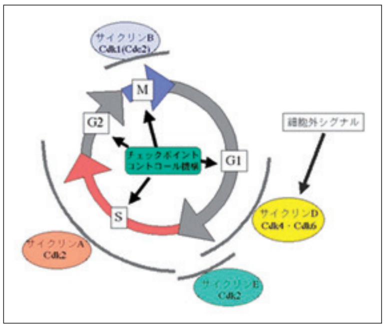

Fig. 1
Cell cycle and cyclin/Cdk complexes

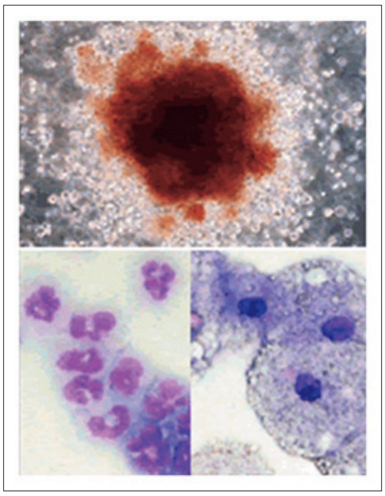

Fig. 2
A group of erythrocytes and leukocytes (upper), neutrophils (lower left) and macrophages (lower right), which were induced to differentiate from ES cells in vitro

Fig. 3
A chimeric mouse generated by infusion of genetically modified ES cells

Molecular Immunobiology

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Outline of Research and Education

Our body has an immune system to fight against microbial pathogens such as viruses, bacteria, and parasites. There are two arms of the immune system; innate and adaptive immunity. The innate immune system is the first line of host defense that detects invading microbial pathogens and plays a critical role in triggering inflammatory responses as well as shaping adaptive immune responses. In spite of its role in host defense, aberrant activation of innate immune responses is closely associated with exacerbation of inflammatory diseases, autoimmune diseases and cancer. Our aim is to uncover molecular mechanisms that control innate immune responses using tools of molecular and cell biology, bioinformatics and genetically modified mice, and seek a way to control immune diseases.

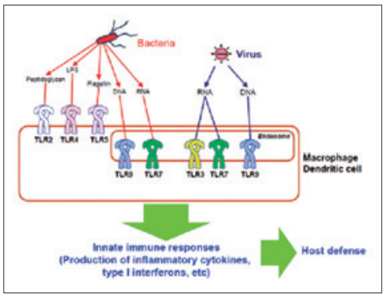

Fig. 1
Recognition of microbial components by Toll-like receptors (TLRs)

Major Research Topics

1. Analysis of innate immune signaling pathways

The innate immune system employs germline-encoded pattern-recognition receptors (PRRs) for the initial detection of microbes. PRRs distinguish self from non-self by recognizing microbe-specific molecular signatures known as pathogen-associated molecular patterns (PAMPs), and activate downstream signaling pathways that lead to the induction of innate immune responses by producing inflammatory cytokines, type I interferon (IFN) and other mediators. Mammals have several distinct classes of PRRs including Toll-like receptors (TLRs), RIG-I-like receptors (RLRs), Nod-like receptors (NLRs), AIM2-like receptors (ALRs), C-type lectin receptors (CLRs) and intracellular DNA sensors. Among these, TLRs were the first to be identified, and are the best characterized. The TLR family comprises 13 members, which recognize distinct or overlapping PAMPs such as lipid, lipoprotein, protein and nucleic acid (Fig. 1). We are focusing on the recognition mechanism of microbial components by PRRs and their signaling pathways, and understanding their roles in immune responses.

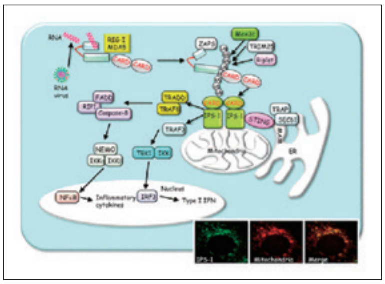

Fig. 2
Signaling pathways through RLRs, cytosolic sensors for RNA viruses

2. Analysis of RLRs

RLRs such as RIG-I and MDA5 are cytoplasmic RNA helicases that detect infection of RNA viruses. Upon detection of RNA virus, RLRs trigger intracellular signaling pathways by recruiting a mitochondria-localized adapter IPS-1, which further activates the transcription factors NF-kB and IRF3 that control expression of antiviral genes, including IFN and inflammatory cytokines (Fig. 2). We seek to understand molecular mechanisms underlying RLRs-mediated antiviral innate immune responses.

3. Analysis of sensing mechanisms of endogenous molecules by PRRs (Fig.3)

Recent evidence has shown that innate immunity can react with endogenous molecules derived from necrotic cell death and this reaction is associated with inflammatory diseases. In addition, innate immunity also senses environmental factors such as asbestos and pollen, and causes cancer and allergic responses, respectively. We are seeking the recognition mechanisms of these molecules by innate immunity and its role in diseases.

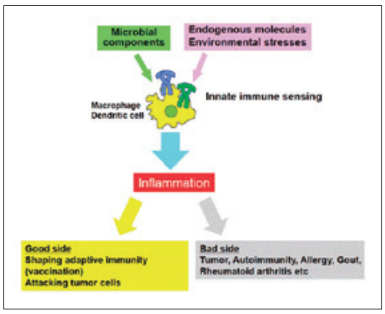

Fig. 3
Recognition of non-infection agents by innate immunity and its relevant in diseases

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Molecular Medicine and Cell Biology



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Outline of Research and Education

The cellular membrane is the essential component of cells that distinguishes the inside and the outside of cells. While the membrane receives all of the stimulus affecting the cells, how it behaves is not well understood. Our lab focuses on the membrane-binding proteins connecting the membrane to the intracellular signaling for varieties of cellular functions including proliferation and morphological changes. The roles of lipid composition of the membrane, including the saturation or unsaturation of fatty acids, are examined using the membrane-binding proteins.

Major Research Topics

1. Elucidating cell-shape dependent intracellular signaling

The intracellular signaling cascade became understood by observing molecule-molecule interactions. However, the spatial organization of these signaling cascades had not been well studied. We found the BAR domain superfamily proteins that remodel membrane shape and then, presumably, dictate the intracellular signaling cascades. Thus, the important questions are how the BAR domain superfamily proteins are regulated, and how they assemble the downstream molecules.

2. Searching for new membrane binding proteins

Given the importance of membrane lipids as essential components of cells, we suppose there are many lipid-binding molecules that have not been clarified. We are searching for novel lipid-binding proteins using a variety of methods.

3. The importance of fatty acids in the membrane

Another point for understanding the cellular membrane is the importance of fatty-acid tails of lipids. Although the importance of saturated or unsaturated lipids in nutrients is well-known, the mechanism behind this importance is not understood at molecular levels in cell biology. We examine how fatty acids are important in intracellular signaling including that for cancer, using the proteins listed above.

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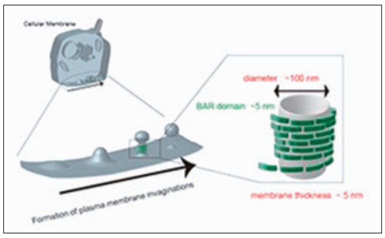

Fig. 1
Location of BAR domain functions in cells. The BAR domains function as polymers at submicron-scale invaginations, such as clathrin-coated pits and caveolae, as well as in protrusions, including filopodia and lamellipodia. The typical scales for clathrin-coated pits and caveolae are 100-200 nm and 50-100 nm in diameter, respectively. The BAR domains have typically been approximated as arcs of 20-25 nm in length with a diameter of 3-6 nm. The membrane thickness is typically approximately 5 nm.

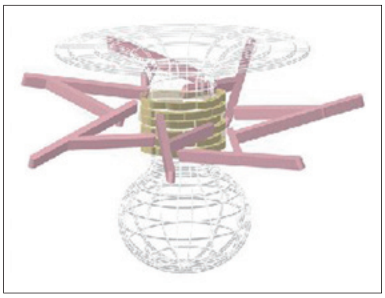

Fig. 2
Wire-frame model of the clathrin-coated pit. The BAR proteins are shown in yellow, and the actin cytoskeleton is shown in magenta. The membrane is in wire-frame. The actin filaments are thought to be finely organized on the nano-scale membrane invaginations of the clathrin coated pits.

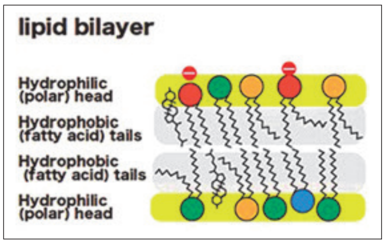

Fig. 3
Schematic diagram of the cellular membrane. Each lipid molecule consists of one hydrophilic head and two hydrophobic fatty-acid tails. There are varieties of combinations of the head, such as serine, ethanolamine, etc., and various saturated and unsaturated fatty acids, such as palmitic acid (saturated), oleic acid (monounsaturated), etc.

Stem Cell Technologies

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Outline of Research and Education

Pluripotent stem cells, such as embryonic stem (ES) cells and induced pluripotent stem (iPS) cells, have the abilities of unlimited self-renewal and multiple differentiations into all the tissue cells of the body. Therefore, these stem cells find potential application in regenerative medicine and drug discovery, and it is very important to strictly regulate this potent differentiation ability to induce multi-step differentiation of these stem cells toward functional tissue cells. During mammalian development, cells differentiate to form precise 3D structures of organs. Understanding of this process may contribute to the development of in vitro differentiation methods. Our goal is to understand the mechanisms of stomach and lung development to perform in vitro differentiation of pluripotent stem cells into these tissue cells. Moreover, we plan to develop in vitro disease models of these organs and technologies for regenerative medicine in the near future.

Major Research Topics

1. Generation of gastric tissues and their disease models

Although the stomach is a major organ in our body, the mechanisms of its development are not well known. During early development, a primitive gastric tube developed from early endoderm is converted to stomach primordium, and further matures to fundus and antrum tissues covered with gastric glands. Recently, we developed an in vitro differentiation method of mouse ES cells to whole stomach tissue (Fig.1). We think that this method could be a powerful tool to study the mechanisms of stomach development as well as serve as a unique model for various diseases such as gastric cancer (Fig.2). We are currently investigating the mechanisms of gastrointestinal development, and studying these mechanisms using our in vitro model.

2. Differentiation of lung tissue and tissue regeneration

The lungs emerge as lung buds from the early gastric tube during development. These primordia proliferate, morphologically divide into multiple branches with the mesenchymal layer, and further differentiate into several kinds of epithelial cells to fulfill respiratory functions (Fig.3). Recently, differentiation methods for these lung tissues have been investigated in the scientific community. We are also studying novel differentiation methods for these respiratory tissues.

3. Stem cells in tumors

Patients with pancreatic cancer have a low survival rate because of a lack of early detectable symptoms and poor prognosis. Recent observations suggest the presence of a small number of stem cells in various cancers, which hamper effective cancer therapy. In our laboratory, we study the regulatory mechanisms of these cancer stem cells to decrease their functional potential.

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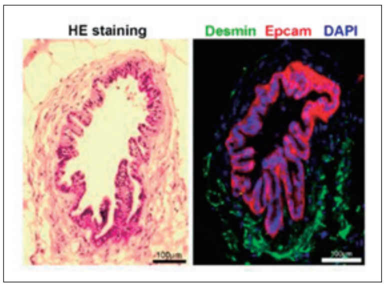

Fig. 1
Stomach tissue differentiated from mouse ES cells *in vitro* by 3D culture method. (Left) HE staining of the differentiated stomach organoid (day 56). (Right) Immunofluorescent staining of stomach organoid with Epcam antibody (red), Desmin antibody (green), and DAPI (blue) for epidermis, mesenchyme, and nuclei, respectively. Stomach organoid with gastric glands and mesenchyme can be differentiated from ES cells *in vitro*.

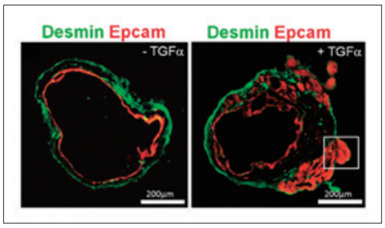

Fig. 2
A stomach disease model using *in vitro* differentiation method. (Left) Healthy control model. (Right) Ménétrier's disease model with massive gastric folds. This disease model can be generated by addition of TGF-α after day 28 of *in vitro* differentiation.

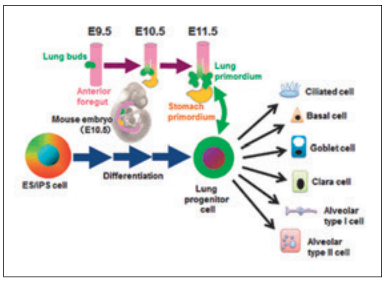

Fig. 3
During lung development, lung progenitor cells are generated in lung buds and can differentiate into various functional epithelial cells of the lung. These lung progenitor cells can be differentiated from pluripotent stem cells *in vitro*.

Developmental Biomedical Science

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Outline of Research and Education

One of the central questions of classical developmental biology is to understand how a limited number of genes produce a diversity of cell types. The developing central nervous system is composed of a number of different cell types, and we seek to elucidate the molecular mechanisms leading to this diversity by employing chick and mouse embryos as model organisms.

We are also interested in the homeostasis of functional neurons. We have been utilising model mice that have been shown to develop particular inherited retinal diseases, and propose novel therapeutics for these related dystrophies.

Overall, our research program aims to be influential in cell and developmental biology and will furthermore be scientifically and technically cross-disciplinary across basic biology and clinical biomedical sciences.

Major Research Topics

1. Transition of the intrinsic characteristics of neural progenitor cells during development and pattern formation

The neural tube is the embryonic tissue of the central nervous system, where a number of functional neurons are produced and precisely assigned. This pattern formation is mainly governed by a handful of extracellular molecules including BMP, Wnt and Sonic Hedgehog (Shh). These molecules are collectively called morphogens, and induce different neuronal subtypes in a graded manner. On the other hand, the intrinsic characteristics of neural progenitor cells change over time, and respond to the same inducing molecules differently. We are particularly interested in the relationship between the inducing activity and the cells' mode of response.

2. Detailed analysis of the Shh signalling pathway

There are many unique aspects of the intracellular signaling pathway induced by Shh. For instance, the Shh pathway is introduced into the cells through the protrusive structure on the surface of cells, called cilium. In addition, Shh target genes start to be expressed only after 6 hours, which is much slower than other signaling pathways. We attempt to identify the proteins that regulate the speed of the signal transduction, and further to reveal the relationship between the speed of the signal and the patterning of the neural tube.

3. Homeostasis of functional cells

How functional cells are maintained is also an important question. We recently demonstrated that the membrane protein Prominin-1 (Prom1) has an essential role in maintaining established photoreceptor cells, and that Prom1-deficient mice show severe retinal degeneration. In addition, our recent study suggests that Prom1 is involved in many more dystrophies in a number of other organs. We therefore aim to propose a novel therapeutic method by analysing these model mice.

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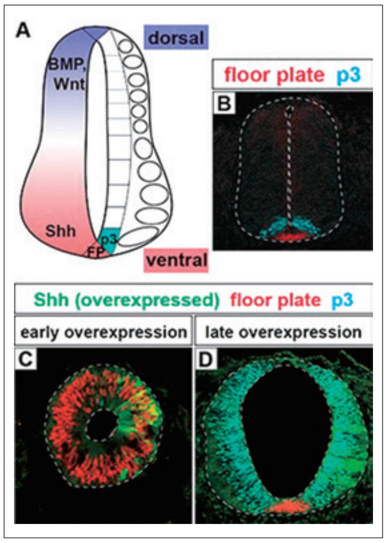

Fig. 1
(A) The cross section of the trunk neural tube. The neural tube is divided into at least 13 subdomains along the dorsal-ventral axis. (B) The floor plate and the p3 interneuron progenitor domains can be separated by immunohistochemistry. (C,D) The phenotype of the neural tube upon forced expression of Shh. The neural progenitor cells tend to differentiate into the floor plate cells (C), while they differentiate into the p3 cells when Shh is overexpressed at the late stage (D). This finding suggests that the neural progenitor cells respond to the same signal differently over time.

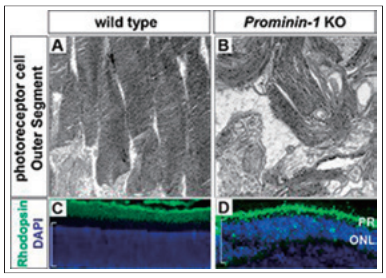

Fig. 2
Eye phenotype in the Prominin-1 (Prom1) deficient mice. The outer segments are degenerated (A,B), and Rhodopsin proteins are misplaced in the photoreceptor cells of the Prom1-knockout eyes (C,D).

Organ Developmental Engineering


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Outline of Research and Education

In mammals, until the eight-cell embryo stage, fertilized eggs have totipotency, meaning that each cell can differentiate into all kinds of cell. In blastocyst-stage embryos just before implantation, the cells' fates are divided into the trophectoderm (TE), which will develop into placental tissue, and the inner cell mass (ICM), which has pluripotency in that its cells will develop into three germ layers, including germline cells. Embryonic stem cells (ESCs) were established from ICM, promoting the study of regenerative medicine and led to the discovery of induced pluripotent stem cells (iPSCs). We combine these early embryos, ESCs/iPSCs, and developmental technology with the aim of performing basic studies that will lead to regenerative medicine using animal models.

Major Research Topics

1. Model of organ formation using xenogeneic chimeras

Xenogeneic chimeras containing both mouse and rat cells were generated using blastocysts and ESCs (Fig. 1 and 2). When we injected rat ES cells into blastocysts of nu/nu mice lacking a thymus, we could produce a rat thymus in chimeric animals. This indicates the formation of an organ from ES cells in xenogeneic conditions. Although this rat thymus could educate T-cells (Fig. 3), it was smaller than that of a mouse, and the functions of the educated T-cells were unclear. On the other hand, we could detect rat spermatozoa in mouse ← rat ES chimeric testes. Rat pups were generated from rat spermatozoa in the xenogeneic chimeric testes by intracytoplasmic injections, and the normal germline potential of rat spermatozoa in the xenogeneic chimeric testes was demonstrated. Findings of the functions of organs, tissues, and cells developed in xenogeneic chimeras are valuable for future translational research.

2. Trials of novel animal models

Gene knockout animals can easily be generated using genome editing systems such as the CRISPR/Cas system. Using the combination of this system and ESCs/iPSCs, complicated gene modification can be performed. We aim to produce novel animal models using these technologies.

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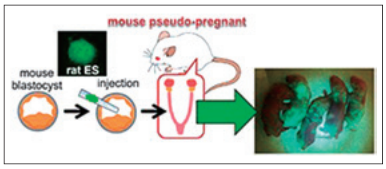

Fig. 1
Production of xenogeneic chimera
GPFP-expressing rat ES cells were injected into mouse blastocysts (mouse ← rat ES chimera). We could obtain viable mouse ← rat ES chimeras upon transplantation into the mouse uterus.

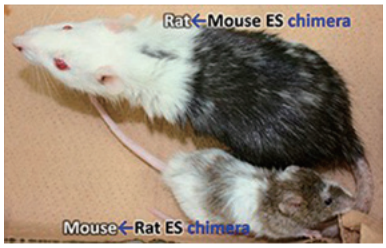

Fig. 2
Two kinds of mouse and rat xenogeneic chimeras
A rat-sized xenogeneic chimera which produced mouse ES cells injected into rat blastocysts (upper). A mouse-sized xenogeneic chimera which produced rat ES cells injected into mouse blastocysts (bottom).

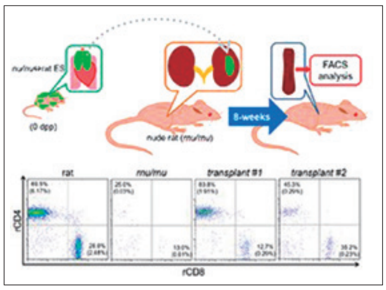

Fig. 3
The function of rat thymus in xenogeneic chimera
When rat thymus from a xenogeneic chimera was transplanted into renal subcutaneous tissues of nu/nu rat, rat T-cells were educated.

Microbial Molecular Genetics



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Outline of Research and Education

At our laboratory, we have been studying how genetic information is precisely transmitted from parent cells to daughter cells and, conversely, how mutation is induced by inaccurate transmission of genetic information. To approach these questions, it is important to understand molecular mechanisms of genomic stability and molecular functions of DNA replication machineries. We also put strong emphasis on the international education of young students who are highly interested in basic issues related to DNA transaction (3R: Replication, Repair and Recombination) and the molecular mechanisms of biological evolution. We want to assist our laboratory members in becoming globally active individuals who act and think independently.

Major Research Topics

1. Mechanisms of spontaneous mutation and its suppression (Fig.1)

- Onset of DNA replication errors and their repair (References 1 & 4)
- Generation of DNA damage due to oxygen radicals and its repair (References 1 & 3)
- Spontaneous mutation induced by cellular growth environment

2. Molecular mechanisms for genetic stability (Fig.2)

- Control mechanisms for genetic recombination
- Roles of DNA damage response and cell cycle checkpoint control (Reference 7)

3. Molecular functions of DNA replication machineries (Fig.3)

- Biochemical activities of DNA polymerases (References 2, 5, 8, 10-12 &14)
- Replication fork arrest and its recovery processes (Reference 10)
- Dynamics of replication fork movement on genomes (References 6, 9,13, & 15)

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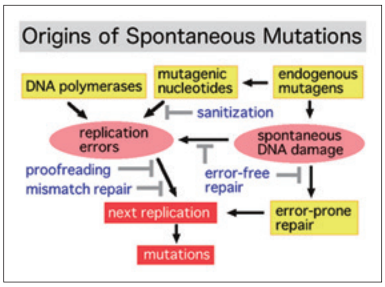

Fig. 1
Multiple mechanisms suppress mutations. However, spontaneous DNA lesions serve as major causes of mutation under normal growth conditions.

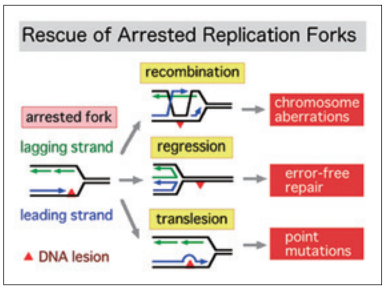

Fig. 2
When DNA replication occurs without repair of DNA lesions, replication fork progression is inhibited, potentially leading to genetic instability. Mechanisms to rescue arrested forks include recombination, regression of forks and translesion DNA synthesis.

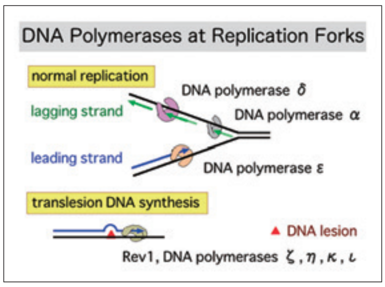

Fig. 3
Multiple DNA polymerases ordinarily work together for efficient DNA replication, thereby suppressing replication errors. Special DNA polymerases work in both eukaryote and bacteria to copy damaged DNA (translesion DNA synthesis).

Systems Microbiology

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Outline of Research and Education

Escherichia coli is undoubtedly one of the most studied organisms in the world. A vast amount of accumulated biological knowledge and methodologies makes this organism one of the ideal platforms to analyze cells at the systems level. Our lab is one of the leading groups performing post-genomic, systems and synthetic analyses using *E. coli* as a model system.

1. Genetic interactions

Normally cell systems can tolerate many kinds of perturbation, e.g. environmental changes and genetic mutations. In *E. coli*, most single gene knockout strains do not exhibit substantial phenotypic changes. This characteristic is called "robustness" and is caused by the function of a network of compensatory backup systems. This is one of the main reasons why the computational design of a cell system has been unsuccessful so far. Genetic interaction analysis is one of the most reliable ways to identify and characterize cellular pathways. To determine the cellular network system in *E. coli*, we are performing high-throughput systematic genetic interaction studies using double-gene knockout strains.

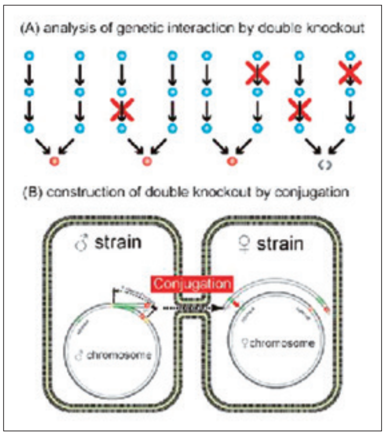

Fig. 1
(A) The concept of synthetic lethal/sickness analysis: Red circles represent essential metabolites for cells. If cells have redundant routes to produce essential metabolites, double deletion methods may identify such redundant steps of genes (enzymes). (B) The conjugation method to generate double knockout strains by combining single knockout strains

2. Bar-code analysis

If each single gene knockout strain has a specific tag, and if we have a way to distinguish their tags from a single cell, then mixed cultures of all the deletion strains can be analyzed simultaneously to monitor population dynamics under competitive growth conditions. For this purpose, we developed a new single gene knockout mutant library carrying 20nt DNA sequences as a bar-code. To validate our approach, we are currently analyzing population changes during growth in a liquid medium for up to three weeks by monitoring the bar-code frequency of each of the deletion strains using deep sequencing methods.

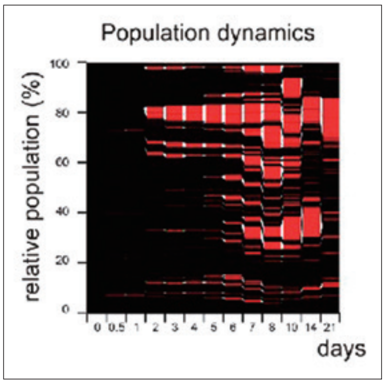

Fig. 2
The X axis shows time points of samplings and the Y axis represents population ratio of all deletion strains.

3. Genome size design and cross-species transfer of DNA by conjugation

We have developed a very efficient method to construct double knockout strains using F-plasmid-based DNA-conjugation. The F- (*incF*) plasmid has a narrow host-range but *incP* and *incW* plasmid families have much wider host-ranges. We are expanding our conjugation vector system from the F-plasmid to the *incP* and *incW* plasmids to enable the transfer of large DNA molecules from E. coli into other microbes. Our long-term goal is to design genome-sized DNA molecules within constructed vectors and establish transfer systems to conjugate them into target micro-organisms.

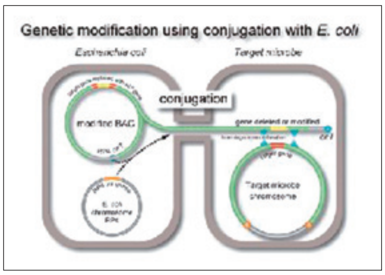

Fig. 3
Wide host-range incP family plasmid RP4 can deliver large plasmid DNA by cross-species conjugation.

Major Research Topics

1. Genetic interaction networks

2. Quantitative metabolic network analysis

3. Development of artificial chromosome and cross-species transfer systems of huge DNA

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Cell Signaling

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Outline of Research and Education

Our research aims to elucidate intracellular signaling networks that sense and transmit diverse extracellular stimuli, with particular focus on the signaling pathways involved in cancerous cell proliferation and metabolic syndromes such as diabetes. To identify and analyze novel components of the signaling pathways, the studies utilize the fission yeast *Schizosaccharomyces pombe* (Fig.1), which has been successfully used as a genetically amenable model system to investigate cellular regulatory mechanisms conserved from yeast to humans. Students in our laboratory are encouraged to design multifaceted approaches that logically combine research tools in molecular genetics, cell biology and biochemistry. Originally established in 1998 at University of California-Davis, our laboratory has been training researchers that serve the international scientific community.

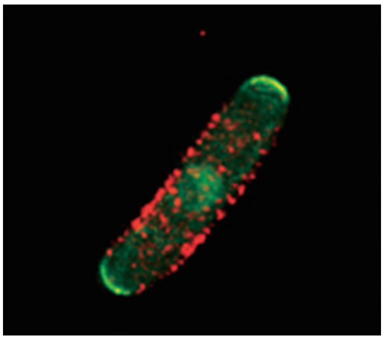

Fig. 1
Fission yeast *Schizosaccharomyces pombe*

Major Research Topics

1. TOR (Target Of Rapamycin) signaling pathway

TOR kinase forms a protein complex called TORC2, which mediates insulin-induced activation of Akt kinase and cellular uptake of glucose (Fig.2). Defects in insulin signaling result in type 2 diabetes and therefore, comprehensive understanding of this pathway is crucial for the development of informed strategies to treat the disease.

2. Stress-responsive MAP kinase cascade

Stress-activated protein kinase (SAPK) is a member of the MAP kinase family that plays pivotal roles in cellular stress responses, including those of cancer cells exposed to cytotoxic therapies. Our goal is to discover cellular "stress sensors" that transmit signals to induce activation of SAPK.

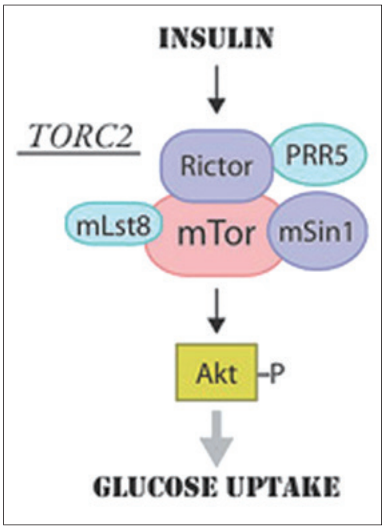

Fig. 2
TOR complex 2 (TORC2) mediates insulin signals that induce cellular uptake of glucose.

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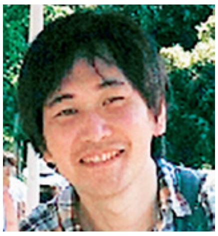
Applied Stress Microbiology



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Outline of Research and Education

Our research involves "Applied Molecular Microbiology". Our laboratory aims at basic studies in microbial science, particularly cellular response and adaptation to environmental stresses, and its practical applications in new biotechnology. To understand microbial cell functions, we analyze and improve various mechanisms of microorganisms from molecular, metabolic and cellular aspects. Our novel findings can be applied to the breeding of useful microbes (yeasts, bacteria), the production of valuable compounds (enzymes, amino acids) and the development of promising technologies (bioethanol, etc.).

Major Research Topics

1. Stress response and tolerance in yeast *Saccharomyces cerevisiae* (Figs.1, 2, 3, 4)

We are interested in cellular response and adaptation to environmental stresses in the yeast Saccharomyces cerevisiae, which is an important microorganism as a model for higher eukaryotes. Yeast is also a useful microbe in the fermentation industry for the production of breads, alcoholic beverages and bioethanol. During fermentation, yeast cells are exposed to various stresses, including ethanol, high temperature, desiccation and osmotic pressure. Such stresses induce protein denaturation, reactive oxygen species generation, and lead to growth inhibition or cell death. In terms of application, stress tolerance is the key for yeast cells. We analyze the novel stress-tolerant mechanisms found in yeast listed below.

- Proline: physiological functions, metabolic regulation, transport mechanisms
- N-Acetyltransferase Mpr1: arginine biosynthesis, antioxidative mechanisms
- Nitric oxide (NO): synthetic mechanism, physiological roles
- Ubiquitin (Ub) system: protein quality control, Ub ligase Rsp5 regulation.

2. Development of industrial yeast based on novel stress-tolerant mechanisms

Through our basic research on novel stress-tolerant mechanisms, we construct industrial yeasts with higher fermentation ability under various stress conditions and contribute to yeast-based industries for the effective production of bread dough and alcoholic beverages, or breakthroughs in bioethanol production.

3. Endoplasmic reticulum (ER) stress and unfolded protein response (UPR)

We are pursuing the molecular mechanism by which ER stress triggers the UPR in yeast cells.

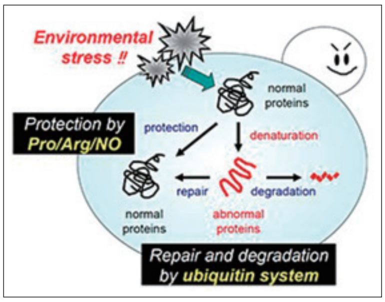

Fig. 1
Novel stress-tolerant mechanisms in *S. cerevisiae*

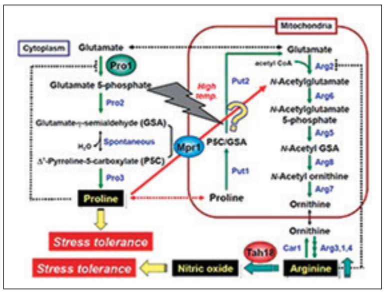

Fig. 2
Metabolic pathway of proline and arginine in *S. cerevisiae*

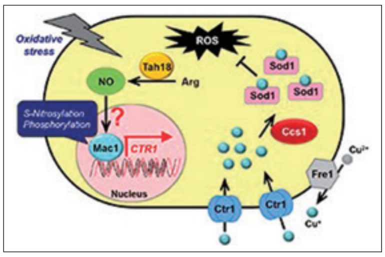

Fig. 3
NO-mediated antioxidative mechanism in *S. cerevisiae*

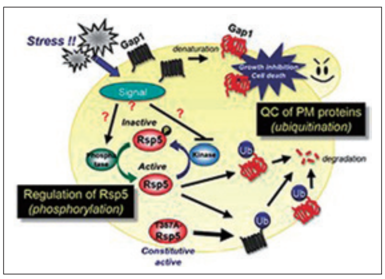

Fig. 4
Ubiquitin system under stress conditions in *S. cerevisiae*

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Development of industrial yeast based on novel stress-tolerant mechanisms

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ER stress and UPR

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Environmental Microbiology

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Outline of Research and Education

Human beings have placed a heavy burden on the environment through modern mass production/consumption of petrochemical products which are not circulable. Microbes live in all environments and are deeply involved in the global homeostasis. Recently, we have discovered a microbe that degrades a plastic which was thought not to be biodegraded. Why do microbes possess such unique abilities? How did they attain them? To answer these questions, we study microbial molecules and assemblies. We believe that our studies will lead to solutions for the sustainable development of society.

Major Research Topics

1. Elucidation of a bacterial PET metabolism

Poly(ethylene terephthalate) (PET) is a material used for plastic bottles and polyester fibers. A bacterium that we discovered named *Ideonella sakaiensis* can degrade and metabolize PET. The fact that this bacterium nutritionally utilizes PET has been revealed through discoveries such as unique PET hydrolyzing enzymes. By unraveling bio-information such as genomes and transcriptomes and using genetic and biochemical methods, we aim to fully understand the molecular mechanisms involved in PET degradation.

2. Visualizing microbiology

Microbial research has been focused on analysis of cells that can be observed with an optical microscope, or molecules that can be followed by their presence such as enzymatic reactions. However, in recent years, it has been found that many microbes secrete much smaller structures than their cells. To open this new microbial world, we are trying to clarify the functions of these nanostructures using electron and super-resolution microscopes.

3. Plastic fermentation

I. sakaiensis can eat PET. In other words, it has a metabolic system that can degrade and convert PET into energy and cellular components. We are attempting to breed the strains that produce high value compounds from waste PET products by modifying and/or enhancing their metabolism.

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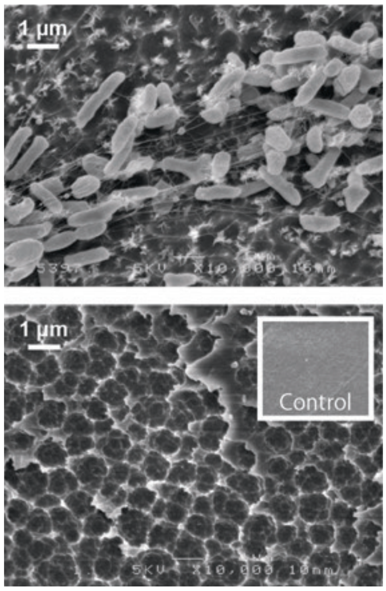


Fig. 1
A scanning electron microscopic image of *I. sakaiensis* cells grown on PET film (upper). The degraded PET film surface after washing out the adherent cells (lower).

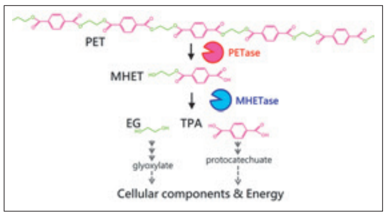


Fig. 2
Predicted PET metabolism by *I. sakaiensis*. Two unique enzymes, PETase and MHETase, are able to efficiently convert PET into its monomers.

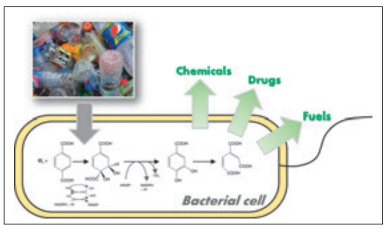
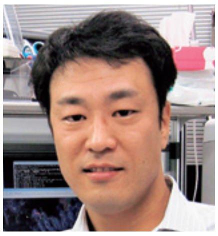


Fig. 3
Metabolic engineering to ferment waste plastic bottles into valued compounds.

Structural Biology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Outline of Research and Education

Proteins are folded into specific three dimensional (3D) structures, which are essential for imparting functions such as molecular recognition and catalysis. Without precise knowledge of their 3D-structures, we are unable to understand how proteins execute their respective molecular functions and, in turn, unable to rationally design inhibitors or drugs. Thus, the experimental determination of protein 3D-structures represents the hallmark of structural biology. Structural biology in our laboratory is performed using X-ray crystallography to determine the 3D-structures of proteins and molecular complexes at atomic resolution, and biochemical/biophysical analyses are performed to delineate the mechanisms by which proteins function at the atomic, molecular, and cellular levels.

Our overall goal is to contribute to the understanding of the nature of life. Our long-term objective is to understand the molecular functions of proteins and other biological macromolecules and their complexes in terms of molecular structures. Our efforts are directed towards defining the manner by which protein interactions and 3D-structures determine specificity and how structural changes enable functional switches in living cells.

We expect our lab to be an international one and we welcome foreign students to study protein structures and functions with us.

Major Research Topics

1. Structural molecular medicine

Drug-target proteins and other proteins important in medical research such as cancer, teratogenesis and infectious diseases

2. Structural cell biology

G proteins, and their regulators and effectors, which play central roles in intracellular signal transduction regulating cell motility, adhesion and morphogenesis

3. Structural molecular biology

Enzyme engineering in biodegradable plastic synthesis

4. Structural plant biology

Proteins that play pivotal roles in plant hormone signaling, such as receptors and master regulators

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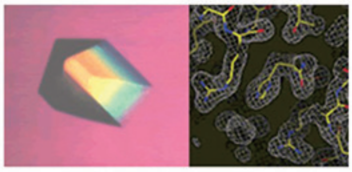

Fig. 1
A crystal of histidine protein phosphatase (left), crystallized in our laboratory and part of its electron density map at 1.9 Å resolution obtained from X-ray crystal structure analysis

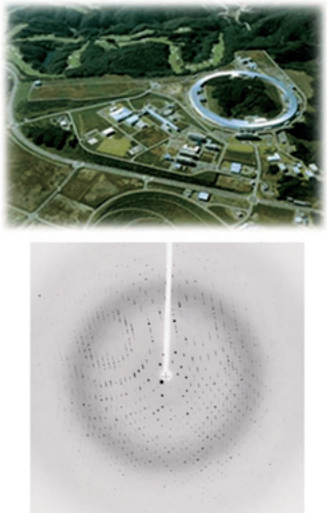

Fig. 2
The SPring-8 synchrotron radiation facilities at Harima, Hyogo. We perform X-ray intensity data collection at SPring-8 for structure

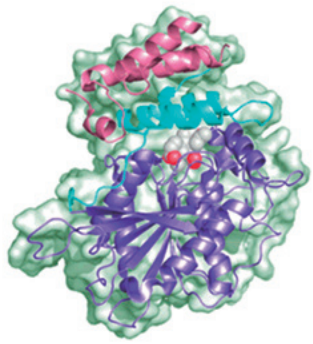

Fig. 3
The ternary complex of gibberellin (space-filled model in white and red)-bound receptor GID1 (blue and cyan) trapping its downstream effector protein DELLA protein (pink) from our recent Nature article [5]

Membrane Molecular Biology

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Outline of Research and Education

In the cell, a variety of membrane protein complexes is involved in the fundamental biological processes. The Sec membrane protein complex embedded in the cytoplasmic membrane in bacteria or the endoplasmic reticulum membrane in eukaryotes is the essential machinery for translocation of newly synthesized proteins across the membrane (Fig.1). In bacteria, the protein transport to the periplasm via a hetero trimeric complex called Sec translocon, composed of SecY, SecE and SecG, is driven by ATP-dependent motor SecA and proton-dependent motor SecDF cooperatively (Fig. 2). We have determined crystal structures of all of the Sec factors and performed structure-directed functional studies, which have enabled us to propose conformational changes of Sec proteins during protein translocation. However, the details of the molecular mechanisms remain unclear. Sec structures of other forms and at high resolution are required to fully understand Sec protein translocation processes. In our laboratory, we perform structural biological analysis, including a new technique for visualizing protein translocation (Fig.3). Our results will lead to understanding of not only protein transport across the membrane, but also the transport mechanisms of various materials including drugs.

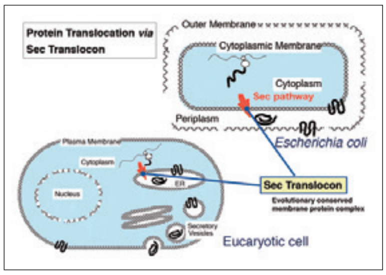

Fig. 1
Conserved protein translocation across the membrane

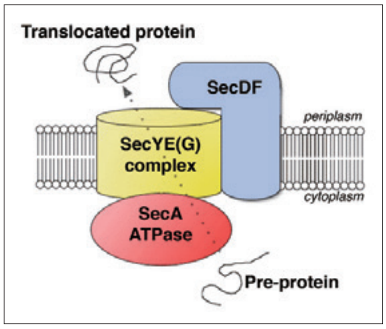

Fig. 2
Bacterial Sec machinery. SecYEG complex provides the pore for protein movement that was driven by two motors, SecA and SecDF.

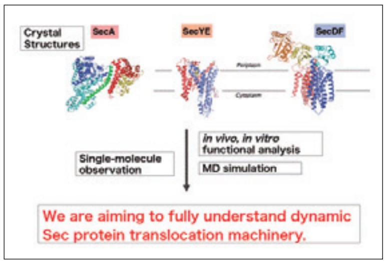

Fig. 3
Our strategy for visualizing protein translocation

Major Research Topics

1. Protein transport across cell membranes

2. Molecular function and dynamics of membrane proteins

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Gene Regulation Research

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Outline of Research and Education

Organisms are composed of various cells arranged in a well-coordinated manner. A fertilized egg repeats cell division and differentiates into the animal body in embryogenesis, in which various phenomena take place in a pre-determined order controlled by the inherent "biological clock" in each living body. We attempt to clarify the principles of animal morphogenesis through investigating the mechanisms of the "biological clock" that controls various life phenomena during embryonic development.

Major Research Topics

Research on somitogenesis in vertebrates as a model system for the biological clock

A mouse's body is composed of a metameric structure along the anteroposterior axis. For example, the spine is made up of the accumulation of multiple vertebrae, each of which is similar in shape. Such metamerism is based on the somite, which is a transient structure in mid-embryogenesis. Somites are symmetrically arranged on both sides of the neural tube as even-grained epithelial spheres that give rise to vertebrae, ribs, muscles and skin.

The primordium of the somite, located at the caudal tip of the mouse embryo, extends posteriorly. The anterior extremity of the somite primordium is pinched off to generate a pair of somites in a two-hour cycle, resulting in the formation of repeats of a similar size structure. On the basis of this finding, it has been considered that there is a biological clock, which determines the two-hour cycle, in the primordium of somites. The expression of several genes oscillates in the primordium of somites, corresponding to the cycle of somite segmentation, which serves as molecular evidence of the biological clock. We are exploring the mechanisms of the biological clock on the basis of such oscillatory gene expression.

Transcription factor Hes7 is specifically expressed in the primordium of somites (Fig.1) and in a cyclic manner (Fig.2). Through genetic and biochemical experiments, we have shown that Hes7 is involved as a principal factor in the mechanism for the biological clock that determines the two-hour cycle (Fig.2, Fig.3). We are conducting studies to understand the biological clock in a comprehensive manner.

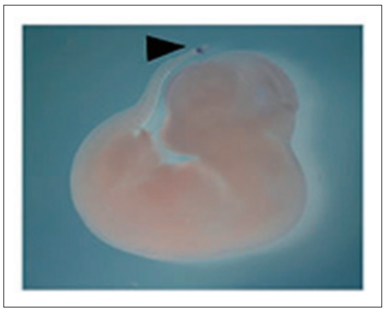

Fig. 1
Transcription factor Hes7, serving as a molecular clock, is specifically expressed in the primordium of somites.

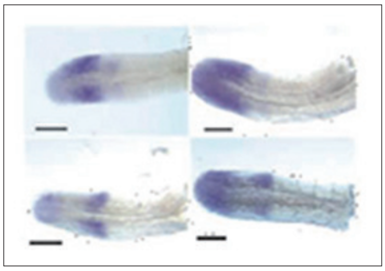

Fig. 2
The expression of Hes7 oscillates in the primordium of somites.

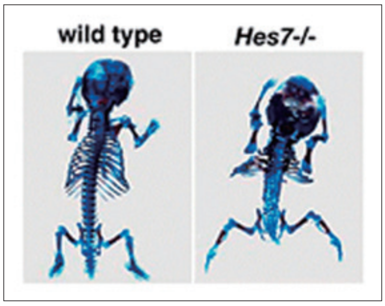

Fig. 3
In Hes7 knockout mice, somite segmentation does not occur cyclically and the metameric structures along the anteroposterior axis are lost.

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Systems Neurobiology and Medicine



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Outline of Research and Education

During morphogenesis, biological systems self-organize their simple shapes into more complicated and beautiful ones. The goal of our studies is to fully understand this miraculous phenomenon of cellular morphogenesis. There are fundamental questions to be answered. Symmetry breaking (change of a symmetric shape to an asymmetric one) is an essential process of morphogenesis: theoretical models suggest that feedback loops and lateral inhibition may be involved, but how do cellular molecules indeed give rise to these processes? Generation of mechanical forces is required to create cellular shape, but how? How do cells sense cellular length and size in order to regulate their size and morphology? Transport and diffusion of intracellular molecules would create inhomogeneous distribution: Do they play a role in cellular pattern formation? Is stochasticity utilized in cellular morphogenesis? All these questions are fascinating to us.

To untangle these issues, our laboratory focuses on neuronal morphogenesis and the proteins Shootin1a, Shootin1b and Singar1, which we identified via proteome analyses. We analyze the molecular mechanisms for cell migration, neuronal polarization, axon guidance and synaptogenesis, using up-to-date methods including systems biology and mechanobiology. We expect that these analyses will give us a new window into therapeutic strategies for nerve injury, Alzheimer's disease and cancer metastasis.

Major Research Topics

1. **Molecular mechanisms of neuronal network formation**
2. **Generation of mechanical forces for axon guidance and neuronal migration**
3. **Sensing of cellular length and size**
4. **Actin waves and novel mechanisms of protein transport**
5. **Brain morphogenesis and diseases**

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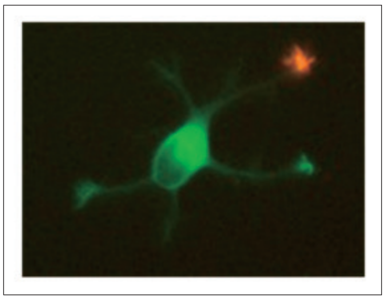


Fig. 1
Shootin1 is a key molecule involved in neuronal symmetry breaking.

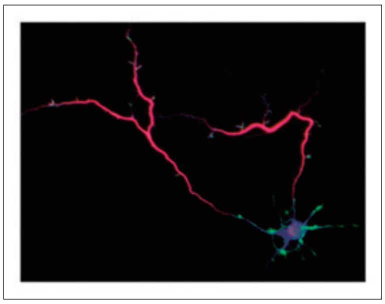


Fig. 2
Singar knockdown leads to formation of surplus axons.

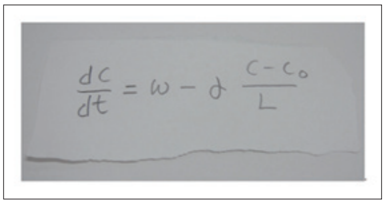


Fig. 3
An equation to describe neurite length sensing by shootin1

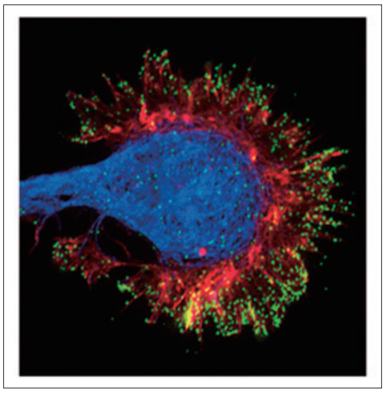
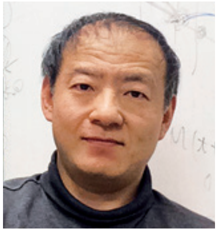


Fig. 4
Signal-force transduction through shootin phosphorylation at growth cones

Computational Biology

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Outline of Research and Education

Our laboratory aims to extract the principle between biological molecules and target biological function and phenotype by computationally analyzing experimental data. We quantitatively associate molecules with function and phenotype to elucidate the underlying mechanism as a set of interactions among various physical quantities. Biological molecules and biochemical interactions actually play an important role in the regulation of biological function and phenotype. Many of functions and phenotypes are expressed in quantities different from molecular concentration, and some of them actively interacting with molecules. In other words, biological system functions as the interactions of multimodal quantities beyond the biochemistry! We aim to understand biological functions and phenotypes as aspects of the multimodal system. To achieve this goal, we collaborate with experimental researchers and analyze experimental data using mathematics and computer programs.

Major Research Topics

1. Systems biology on cell morphogenesis and migration (Fig.1)
- System between morphogenesis and molecules regulating cytoskeleton formation and mechanical force
- Cell taxis depending on substratum stiffness
- Neuronal axon guidance depending on membrane potential

2. Systems biology on tissue formation (Fig. 2)
- Cell communication and synchronization for development of vertebrates (Fig. 2)
- Angiogenesis based on cell morphogenesis and migration

3. Estimation of essential components by machine learning (Fig. 3)
- Molecular system identification using membrane potential time series
- Computer-assisted diagnosis using human breath gas
- Estimation of essential kinases using inhibitor compounds

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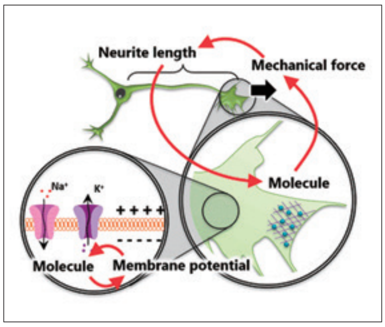

Fig. 1
Examples of system consisting of membrane potential and molecules, and system consisting of neurite length, mechanical force, and molecules. Signal transduction between various quantities are derived from experimental data. System can be reconstructed by integrating these signal transductions.

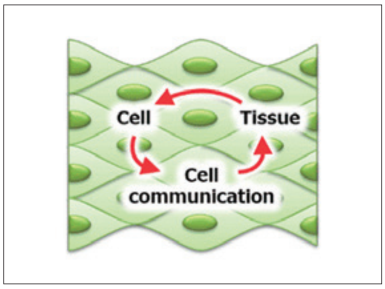

Fig. 2
Tissue formation can be regarded as the system consisting of cell, cell communication, and tissue itself. We aim to understand tissue formation as an aspect of this system.

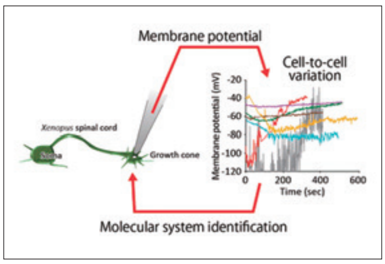

Fig. 3
Identification of molecular system from membrane potential time series. Measuring membrane potential is relatively easier than observing cell-cell interaction. Computation enables us to estimate intracellular molecular system from membrane potential.

Humanophilic Innovation Project

Information Science — Biological Science — Materials Science


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Outline of Research and Education

We promote seminal research for the creation of human life support systems in the "Humanophilic Innovation Project". With this approach, we endeavor to create novel interdisciplinary research integrating the fields of material, biological and information science, and to produce researchers and engineers capable of solving the complicated problems facing the world and in the future. These achievements will be applied to develop new support systems for social activities such as agriculture and nursing care, in order to address the needs created by a low birth rate and an aging population.

Major Research Topics

1. Development of monitoring technology for biological activity
- Development of micro photonic device systems for organisms
- Application of monitoring technology with portable devices

2. Development of ecological device systems
- Construction of nano devices using organic super molecules
- Production of green materials using synthetic biology

3. Creation of human life support systems
- Application of ubiquitous computing systems
- Integration of achievements in monitoring technology and ecological device systems

References

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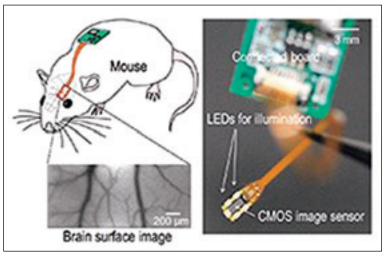

Fig. 1
Development of monitoring technology for biological activity. Monitoring brain activity and action of a mouse with a micro photonic device.

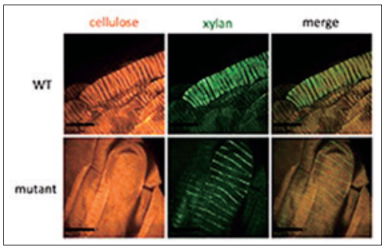

Fig. 2
Development of ecological device system. Micrographs of a cell wall of Arabidopsis mutant's modified production of cellulose as a green material by genome breeding.

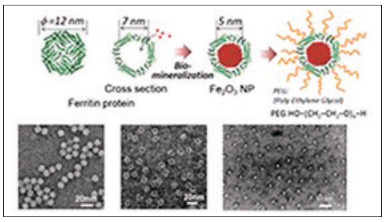

Fig. 3
Development of ecological device systems. Controlling density of the organic super molecule ferritin for development of new eco devices.

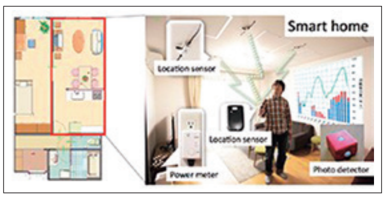

Fig. 4
Creation of human life support systems. Demonstration of a context awareness system and monitoring of human activity in a "smart home".

Cell Growth Control *(with the Center for Developmental Biology, RIKEN)*

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Outline of Research and Education

The processes of animal development, including organ and body size, are genetically predetermined, but these processes are also influenced by environmental factors such as nutrition and temperature. The close link between cell and tissue growth control and environmental cues ensures that developmental transitions occur at the appropriate times during animal development. Our lab's research aims to shed light on the molecular basis for growth control and developmental timing at the cellular and tissue/organ level using the fruit fly Drosophila melanogaster and mammalian cell cultures as model systems. We combine biochemical and genetic approaches, along with quantitative and qualitative imaging and cell-biological analysis, to identify and characterize the relevant signal transduction pathways.

Major Research Topics

1. Molecular mechanisms of division arrest in neural stem cells

2. Molecular mechanisms of systemic growth and developmental timing

3. Molecular mechanisms of amino acid signaling

References

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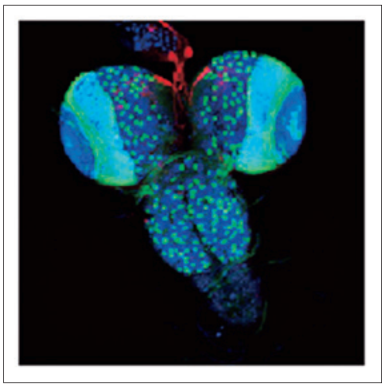

Fig. 1
Larval central nervous system in Drosophila. Neural stem cells (green) and insulin-producing cells (red) are shown.

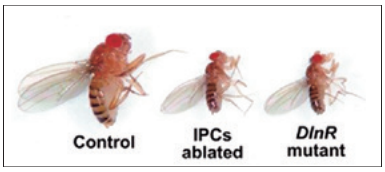

Fig. 2
Drosophila mutants defective for systemic growth. Down regulation of the insulin signaling leads to the formation of small flies. The picture shows brain insulin-producing cell (IPCs) ablated flies and Drosophila insulin receptor (DInR) mutant flies.

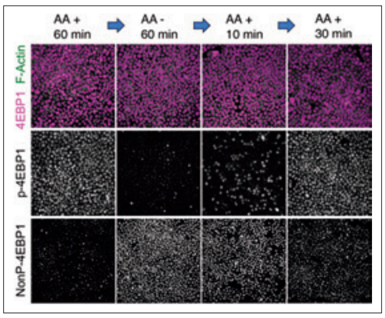

Fig. 3
Amino acid response in cultured mammalian cell lines. The phosphorylation level of 4EBP1, a downstream target of the TOR kinase, is used as a readout of amino acid (AA) dependent activation of the TOR. Top panels indicate total 4EBP1 levels. Middle panels indicate phosphorylated 4EBP1, while lower panels indicate non-phosphorylated pools of 4EBP1.

Molecular Microbiology and Genetics (with Research Institute of Innovative Technology for the Earth (RITE))

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Outline of Research and Education

Global warming resulting from elevated CO_2 and global energy supply problems have been in the limelight in recent years. As these problems originate from rapid economic expansion and regional instability in parts of the world, broad knowledge of global economic systems as well as R&D is necessary to solve these problems. Fundamental research employing microbial functions to tackle the adverse effects of global climate change and mitigate energy supply problems is carried out in our laboratory.

Major Research Topics

1. Biorefinery

A biorefinery is the concept of production of chemicals and fuels from renewable biomass via biological processes. Biorefinery R&D is considered of national strategic importance in the U.S.A. (Fig.1). A biorefinery can be divided into two processes: a saccharification process to hydrolyze biomass to sugars, and a bioconversion process to produce chemicals and fuels from the sugars. Based on a novel concept, we have pioneered a highly-efficient "growth-arrested bioprocess" as bioconversion technology to produce chemicals and fuels (Fig.2). It is based on Corynebacteria that are widely used in industrial amino acid production. The key to high efficiency is the productivity of artificially growth-arrested microbial cells, cells with which we evaluate production of organic acids and biofuels. To efficiently produce these products, the cells are tailored for the production of a particular product using post genome technologies like transcriptomics, proteomics and metabolome analyses (Fig. 3).

2. Bioenergy and green chemicals production

Having established the fundamental technology to produce bioethanol from non-food biomass, we are now partnering with the automobile and petrochemical industries to explore commercial applications. We have also developed the platform technology to produce biobutanol, the expected next-generation biofuel, as well as a variety of green chemicals such as organic acids, alcohols and aromatic compounds from which diverse polymer raw materials used in various industries are produced.

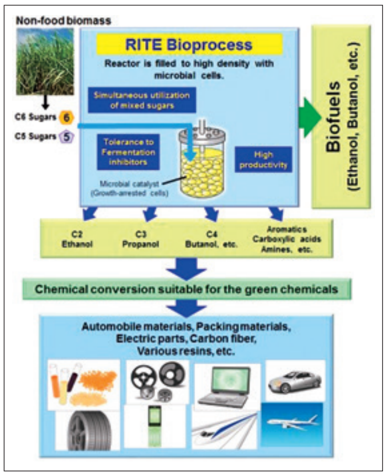

Fig. 1
The biorefinery concept

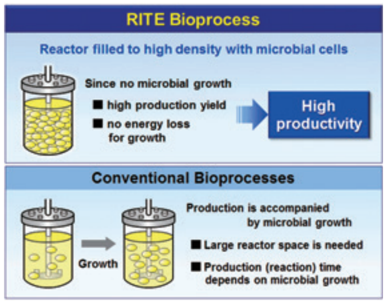

Fig. 2
Novel features of the RITE Bioprocess

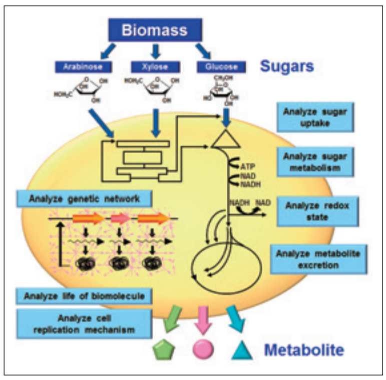

Fig. 3
Breeding of recombinant strains using system biology

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Medical Genomics


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Outline of Research and Education

Our current research focus is circulating tumor DNA (ctDNA), which is cell-free DNA released from dying cancer cells (Fig.1). Because ctDNA enables detection of cancer cell DNA of various lesions using only a small amount of blood (~1 ml), there are huge expectations for clinical applications including early detection. We use next-generation sequencing (NGS) to detect ctDNA. We offer students the opportunity to study experimental basics and bioinformatics of NGS.

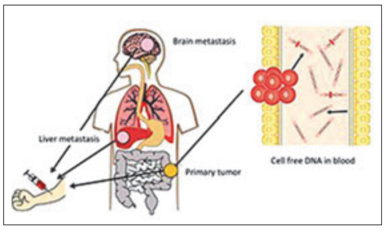

Fig. 1
Circulating tumor DNA

Major Research Topics

1. Noninvasive genotyping of *EGFR* for lung cancer therapy

Gefitinib (Iressa) is a molecular target agent for lung cancer to inhibit tyrosine kinase activity of *EGFR*. It is effective only for lung cancer with activating *EGFR* mutations, and patients are selected through a genetic test. Gefitinib is a good example of "personalized medicine" (Fig. 2), a new concept of medicine, i.e., choosing therapy based on genetic information of each patient. An important concern in clinical practice is that tumor samples are often difficult to obtain by biopsy. In particular, biopsy for advanced or resistant cases and repeated sampling is extremely difficult.

We developed a noninvasive detection system for *EGFR* mutation in ctDNA based on NGS (Kukita et al., 2013). The mutations are sought in more than 100,000 reads of the *EGFR* fragments. We conducted a multi-institute prospective study to evaluate the performance of the detection system, and demonstrated that the system was sufficient for practical use (Uchida et al., 2015). This study was done in collaboration with the Department of Thoracic Oncology, Osaka Medical Center for Cancer and Cardiovascular Diseases.

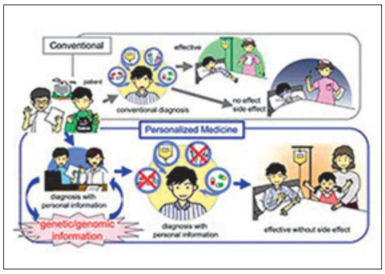

Fig. 2
Personalized medicine

2. Development of methodologies for cancer detection

The accuracy of current sequencing technologies has limitations when detecting rare mutations in multiple loci. To overcome this problem, we developed a new sequencing method named NOIR-SeqS (non-overlapping integrated read sequencing system) (Fig. 3) (Kukita et al, 2015). The system employs the barcode technology, and achieved 60-100 fold increase of accuracy from that of the standard NGS. We applied NOIR-SeqS to ctDNA, demonstrating its feasibility for practical use.

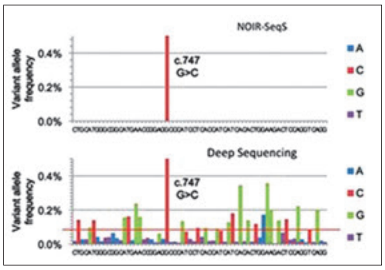

Fig. 3
Detection of a mutation in *TP53*. Top, NOIR-SeqS; bottom, conventional next-generation sequencing

References

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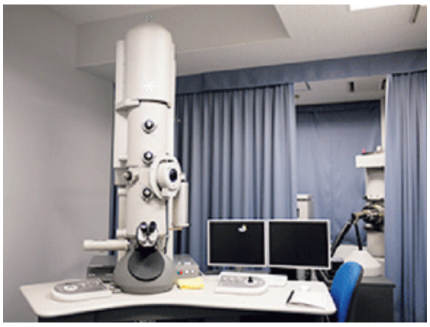
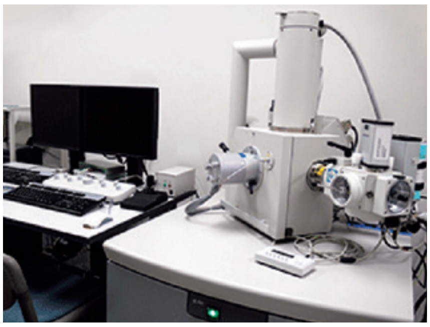
Abundant Research Facilities

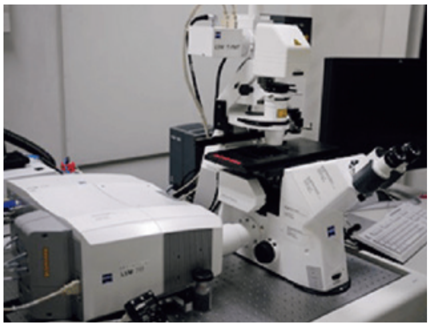
Each division is equipped with a variety of state-of-the-art equipment.
Shared equipment, among the most advanced available for biological science research in Japan, is provided at numerous locations within the division.



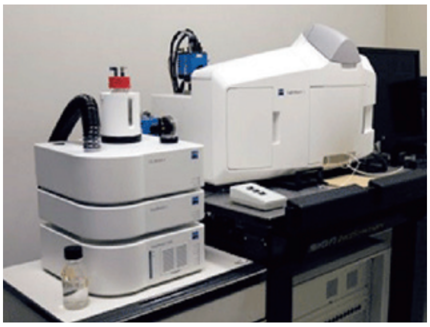
Transmission Electron Microscope



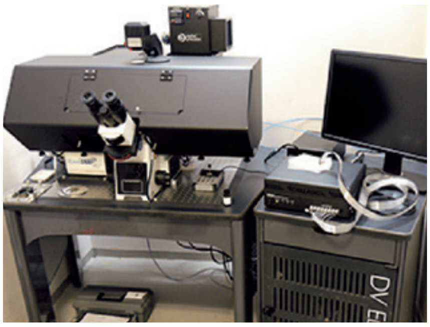
Scanning Electron Microscope



Confocal Laser Scanning Microscope

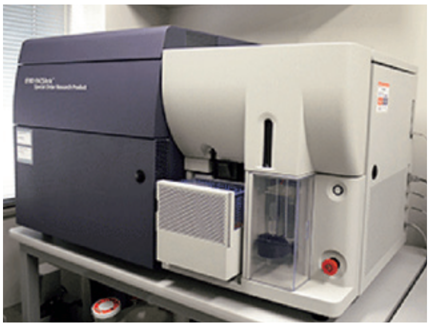


Light Sheet Fluorescence Microscopy

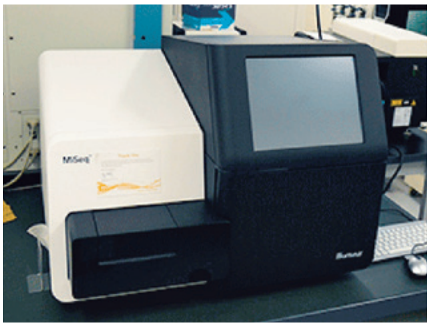


High Resolution Fluorescence Microscopy Imaging System

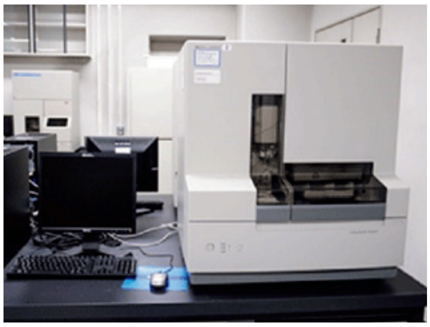
Molecular Interaction Analysis System



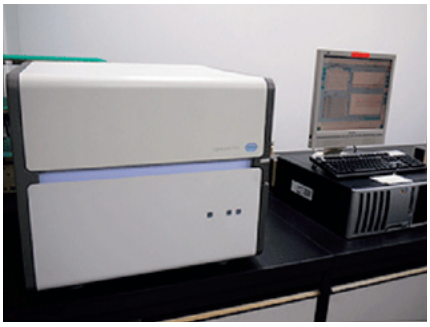
Flow Cytometer



Next Generation Sequencer

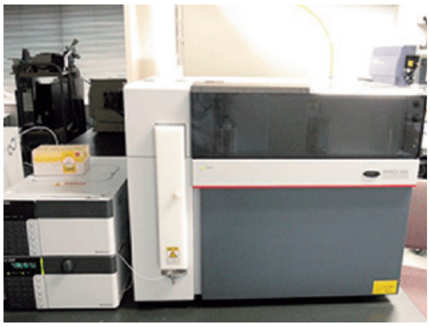


DNA Sequencer

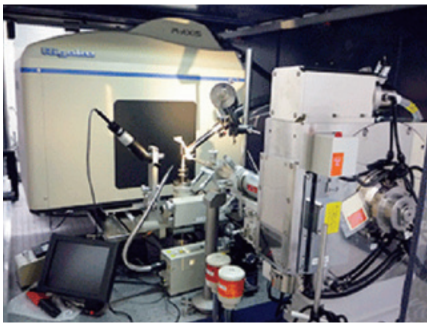


Real-Time PCR System

Triple Quadrupole Mass Spectrometer



Protein Sequencer



Ultra High-Intensity Microfocus X-ray Generator・Macromolecular Crystallography Diffraction System

Cell Preservation Container

Botanical Greenhouse

Animal Experimentation Facility

Radioisotope Facility

Materials Science

Laboratories

List of Laboratories

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Advanced Polymer Science	Michiya Fujiki			87
Photonic Device Science	Jun Ohta	Takashi Tokuda	Kiyotaka Sasagawa, Toshihiko Noda, Makito Haruta	88
Information Device Science	Yukiharu Uraoka	Yasuaki Ishikawa	Mutsunori Uenuma, Mami Fujii, Juan Paolo Bermundo	89
Synthetic Organic Chemistry	Kiyomi Kakiuchi	Tsumoru Morimoto	Hiroki Tanimoto	90
Supramolecular Science	Shun Hirota	Takashi Matsuo	Satoshi Nagao, Masaru Yamanaka, Hulin Tai	91
Photonic Molecular Science	Tsuyoshi Kawai	Takuya Nakashima	Yoshiyuki Nonoguchi	92
Photofunctional Organic Chemistry	Hiroko Yamada	Naoki Aratani	Mitsuharu Suzuki, Hironobu Hayashi	93
Sensing Devices	Takayuki Yanagida	Noriaki Kawaguchi	Go Okada, Naoki Kawano	94
Organic Electronics	Masakazu Nakamura	Hiroaki Benten	Hirotaka Kojima, Jung Mincherl	95
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Biomimetic and Technomimetic Materials Science	Gwénaël Rapenne		Kazuma Yasuhara	98
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Functional Polymer Science (with Santen Pharmaceutical Co., Ltd.)	Takahiro Honda, Hiroshi Enomoto	Komei Okabe	104
Ecomaterial Science (with Research Institute of Innovative Technology for the Earth)	Katsunori Yogo, Kazuya Goto	Hidetaka Yamada	105
Sensory Materials and Devices (with Shimadzu Corporation)	Keishi Kitamura, Masaki Kanai	Shigeyoshi Horiike	106
Advanced Functional Materials (with Osaka Research Institute of Industrial Science and Technology)	Yasuyuki Agari, Yutaka Fujiwara	Masanari Takahashi	107

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Quantum Materials Science

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Education and Research Activities in the Laboratory

Electrons, when confined in a nanometer-sized space (1 nanometer = 10^{-9} m), remarkably begin to behave like waves. For example, an organic molecule can be considered as a quantum state in which electrons are confined in a nm space consisting of atoms connected together. Semiconductor nanoparticles show colors different from those of bulk solids due to this quantum size effect.

The Quantum Materials Science Laboratory studies molecules, crystals, nanoparticles, and ultrathin films of both organic and inorganic materials, utilizes various optics-based experimental approaches to clarify material properties from the viewpoint of quantum physics, and aims to create new functional materials that will be used in optical information-communication or environment-conscious devices in the future.

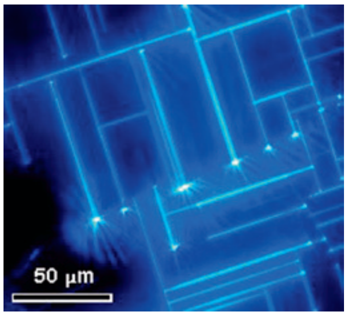

Fig. 1
A molecular crystal-based organic laser

Research Themes

1. Molecular electronics and photonics
By controlling molecular alignment and crystal growth, we develop efficient light-emitting materials specifically aiming to realize organic lasers.

2. Coherent control in various quantum systems
Using ultrafast lasers, we are attempting to observe and control quantum coherence in various quantum systems, such as solid para-H_2, strong coupling cavity polaritons, and coherent phonons.

3. Photo-physical properties of nanostructured materials
We are working on optical functionality of nanostructured materials such as environment-conscious nanoparticles and impurity-doped nanoparticles.

4. Metamaterial photonics
By assigning distinct functions to different artificial units much smaller than the wavelengths of light, we aim to create artificial materials (metamaterials) mimicking an intriguing property for light.

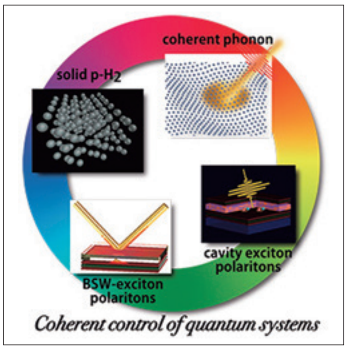

Fig. 2
Targets of coherent control

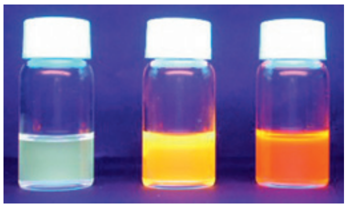

Fig. 3
Luminescence from impurity-doped semiconductor nanoparticles

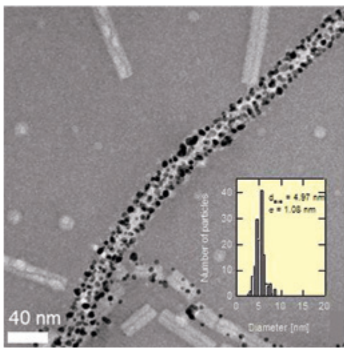

Fig. 4
TMV/gold nanoparticle complexes

Recent Research Papers and Achievements

1. P. Riego, S. Tomita, K. Murakami, T. Kodama, N. Hosoito, H. Yanagi, and A. Berger, *J. Phys. D: Appl. Phys.* **50**, 19LT01 (2017).
2. V.-C. Nguyen, H. Katsuki, F. Sasaki, and H. Yanagi, *Appl. Phys. Lett.* **108**, 261105 (2016).
3. H. Katsuki, K. Ohmori, T. Horie, H. Yanagi, and K. Ohmori, *Phys. Rev. B* **92**, 094511 (2015).
4. A. Ishizumi, S. Fujita, and H. Yanagi, *Opt. Mater.* **33**, 1116 (2011).

Surface and Materials Science

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Education and Research Activities in the Laboratory

1. Research purpose and target

All materials, when smaller than one nanometer in size, begin to exhibit different properties from those under normal conditions as exemplified by iron and gold: iron becomes nonmagnetic, while gold becomes highly reactive. These materials are the new microscopic materials essential for resource saving, energy saving, element strategy, and nanotechnology. They can be manufactured and analyzed on the surface of a solid at the atomic and electron levels. The Surface and Materials Science Laboratory studies atomic and electronic structures of surfaces and nanomaterials using unique approaches such as a two-dimensional photoelectron spectrometer, aiming to clarify the physical properties of nanomaterials and to create new functions from atomic and electron viewpoints. Our research targets include superstructures on semiconductor surfaces, magnetic thin-films and strongly correlated electron systems, as well as organic and biological molecule adsorbing surfaces vital to catalysis and molecular electronics.

2. Educational policy

We provide education not only on experiments but also on what is important as a researcher and a professional engineer, including having an active attitude toward obtaining knowledge through research, originality training, acquisition of technical skills to enhance laboratory techniques (such as shop practice, machine control, and data analysis), and cooperation with laboratory members. Students are expected to improve or create apparatuses before graduation. It is important for students to not only learn how to think systematically through seminars or lectures, but also to have contact with external researchers as well as the regular educational staff in the laboratory. We conduct joint research with several external research institutions including the synchrotron radiation facilities of SPring-8 and the Ritsumeikan University SR Center, and actively dispatch our students overseas.

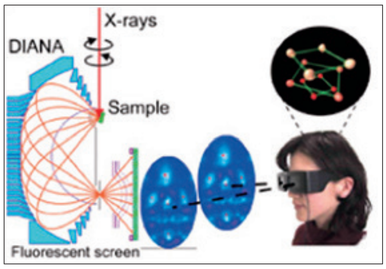

Fig. 1
A stereoscopic view of atomic arrangement through our two-dimensional photoelectron analyzer (DIANA) used as an atomic stereo-microscope

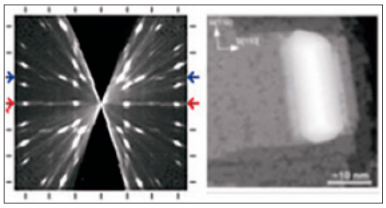

Fig. 2
An STM image and 3D reciprocal lattice map of a 3D elongated island of α-FeSi$_2$(110) on Si(001))

Research Themes

1. Atomic structural analysis by stereoscopic viewing, RHEED, STM, photoelectron diffraction/holography
2. Energy bands on surfaces and their modification by electric field and strain
3. Atomic analysis of surface molecular reactions
4. Surface nanomaterials physical property analysis
5. New analyzers development
6. Electronic and atomic structure analysis of strongly correlated materials

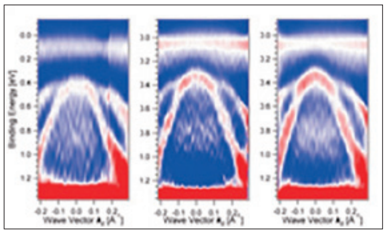

Fig. 3
Strain effect on Si band structure

Recent Research Papers and Achievements

1. H. Matsuda, et al, *J. Electron Spectrosc. Relat. Phenom.* **195** 78 (2014).
2. O. Romanyuk, K. Hattori, M. Someta, and H. Daimon, *Phys. Rev.* **B 90** 155305 (2014).
3. Sakura N. Takeda, et al, *Phys. Rev.* **B 82** 035318 (2010).
4. L. S. R. Kumara, M. Taguchi, et al, *J. Chem. Phy.* **141** 044718 (2014).

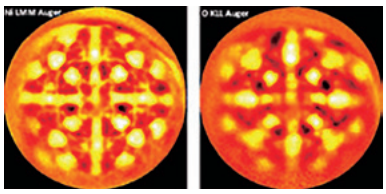

Fig. 4
A photoelectron diffraction pattern of anti-ferromagnetic NiO

Advanced Polymer Science

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Education and Research Activities in the Laboratory

The Advanced Polymer Science Laboratory is devoted to breaking common sense and knowledge, textbooks, established theory, and historical knowledge, aiming to realize unique chiroptical photophysics of polymeric materials. The issues we focus on are as follows:

1. Research outline

Generation, amplification, inversion and transcription of helix structures by chemical and physical origin

2. One-pot synthesis, green-sustainable processes, renewable bioresource processing of functional polymers and hybridized materials

3. Education in the laboratory

We aim to cultivate capable researchers and engineers who will work in the area of polymer-related science and engineering through ground-breaking outcomes in relation to the design, synthesis, analysis, and function of polymers. We focus on educating students to independently think about new concepts and to propose new ideas through daily reciprocal interaction, as well as in seminars and meetings hosted by related academic communities.

Research Themes

1. Mirror symmetry breaking at polyatomic systems and elucidating the origin of life on Earth
2. Detecting ultraweak molecular interactions
3. CPL-functioned polymeric materials using catalyst-free zero-step synthesis
4. Liquid-phase physisorption of π-conjugated polymers at inorganic/polymer interfaces

Recent Research Papers and Achievements

1. Laibing Wang, Lu Yin, Wei Zhang, Xiulin Zhu, and Michiya Fujiki, "Circularly Polarized Light with Sense and Wavelengths to Regulate Azobenzene Supramolecular Chirality in Optofluidic Medium", *Journal of the American Chemical Society* (ACS), 2017 (DOI: 10.1021/jacs.7b07626).
2. Sang Thi Duong and Michiya Fujiki, "The origin of bisignate circularly polarized luminescence (CPL) spectra from chiral polymer aggregates and molecular camphor: Anti-Kasha's rule revealed by CPL excitation (CPLE) spectra", *Polymer Chemistry* (RSC), **8**, 4673-4679 (2017). [highlighted as cover page].
3. Michiya Fujiki and Shosei Yoshimoto, "Time-evolved, far-red circularly polarized luminescent polymer aggregates endowed with sacrificial helical Si–Si bond polymers", *Materials Chemistry Frontiers* (RSC), **1**, 1773-1785 (2017).(invited paper).
4. Sibo Guo, Nozomu Suzuki, and Michiya Fujiki, "Oligo- and polyfluorenes meet cellulose alkyl esters: Retention, inversion, and racemization of circularly polarized luminescence (CPL) and circular dichroism (CD) via intermolecular C-H/O=C interactions", *Macromolecules* (ACS), **50**, 1778-1789 (2017).
5. Kai Kan, Michiya Fujiki, Mitsuru Akashi, and Hiroharu Ajiro, "Near-ultraviolet Circular Dichroism of Achiral Phenolic Termini Induced by Nonchromophoric Poly(L, L-lactide) and Poly(D,D-lactide)", *ACS MacroLett* (ACS), **5**, 1014-1018 (2016).
6. Nor Azura Abdul Rahim and Michiya Fujiki, "Aggregation-induced scaffolding: photoscissable helical polysilane generates circularly polarized luminescent polyfluorene", *Polymer Chemistry* (RSC), **7**, 4618−4629 (2016) [highlighted as cover page].

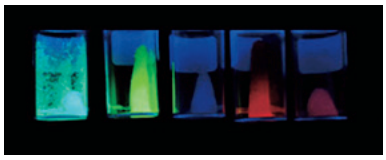

Fig. 1
Zero-step room-temperature synthesis of full-visible photoluminescent polymer particles

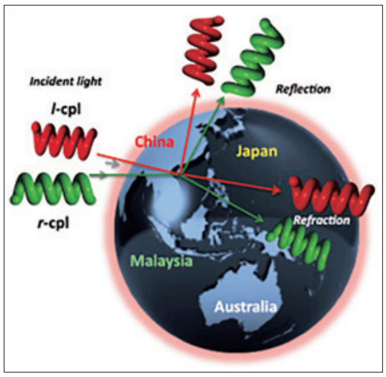

Fig. 2
International students and collaboration with our lab

Photonic Device Science

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Education and Research Activities in the Laboratory

1. Laboratory outline

The Photonic Device Science Laboratory researches and develops new optical functionality-based material science and device functions for fast, flexible processing of image information that promises to play a leading role in an advanced information society and a "super aging society." Specifically, we work on applying photonic LSI technology, which integrates semiconductor circuit technology and photonic technology, toward biological and medical field applications as shown in Fig.1. Our typical research fields include bio-medical photonic LSIs and artificial vision devices.

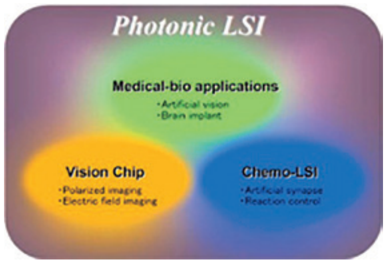

Fig. 1
Research fields of the Photonic Device Science Lab

2. Research activity and policy

With our research subjects crossing over various research fields, we actively pursue cooperative interdisciplinary studies. For example, we are conducting joint research on artificial vision with the Department of Ophthalmology of Osaka University Graduate School of Medicine and an ophthalmologic apparatus manufacturer and also performing joint research on bio-medical photonic LSIs with the Functional Neuroscience Laboratory of NAIST.

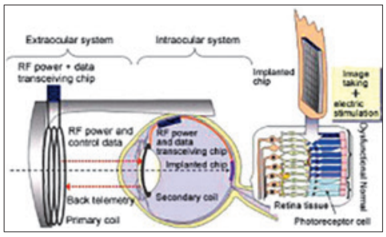

Fig. 2
Retinal prosthesis device

3. Education

The majority of students in the laboratory are requested to work on research subjects involving other fields. We provide introductory seminars, study meetings, and many opportunities to interact with researchers within and outside the university so that they can pursue their research smoothly and broaden their research perspectives.

Research Themes

1. Bio-medical photonic materials and devices
2. Micro-chemical photonic devices
3. Advanced image sensors and their application systems

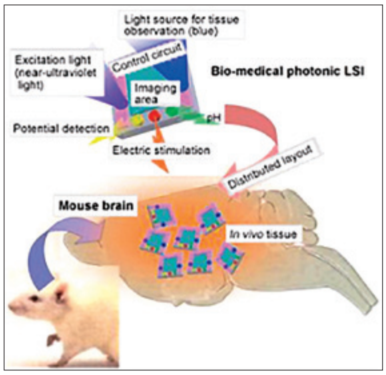

Fig. 3
Brain implantable microimager

Recent Research Papers and Achievements

1. J. Ohta, Y. Ohta, H. Takehara, T. Noda, K. Sasagawa, T. Tokuda, M. Haruta, T. Kobayashi, Y. M. Akay, M. Akay, "Implantable Microimaging Device for Observing Brain Activities of Rodents," Proc. IEEE, vol. 105, no. 1, pp. 158-166, Jan. 2017
2. K. Sasagawa, T. Yamaguchi, M. Haruta, Y. Sunaga, H. Takehara, H. Takehara, T. Noda, T. Tokuda, and J. Ohta, "An Implantable CMOS Image Sensor with Self-Reset Pixels for Functional Brain Imaging," IEEE Trans. Electron Dev., vol. 63, no. 1, pp. 215-222, 2016.
3. H. Takehara, Y. Ohta, M. Motoyama, M. Haruta, M. Nagasaki, H. Takehara, T. Noda, K. Sasagawa, T. Tokuda, and J. Ohta, "Intravital fluorescence imaging of mouse brain using implantable semiconductor devices and epi-illumination of biological tissue," Biomedical Optics Express 6, pp. 1553-1564, 2015.

Information Device Science


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Education and Research Activities in the Laboratory

Many daily necessities around us, such as TVs, computers, and mobile phones, are composed of silicon-based semiconductor devices. The Information Device Science Laboratory conducts research on information function devices that will support the next-generation information society. Key features of our research include the introduction of various new materials on silicon substrates, our own unique designs, and production of semiconductor devices that make the most effective use of their characteristics. Thus, we are working on producing semiconductor devices with innovative functions on the basis of skilled manufacturing.

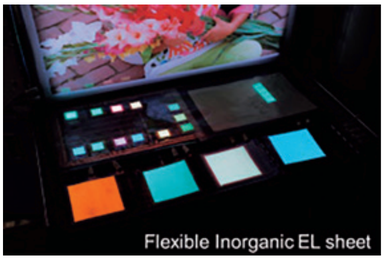

Fig. 1

Research Themes

1. Next-generation high-tech information terminals
2. LSIs with new functions based on biological supramolecules
3. Printed/flexible displays using wide band gap materials
4. Printing technology for energy harvesting devices (solar cell, thermoelectric devices)
5. Emerging devices (Graphene transistors, power devices based on GaN)

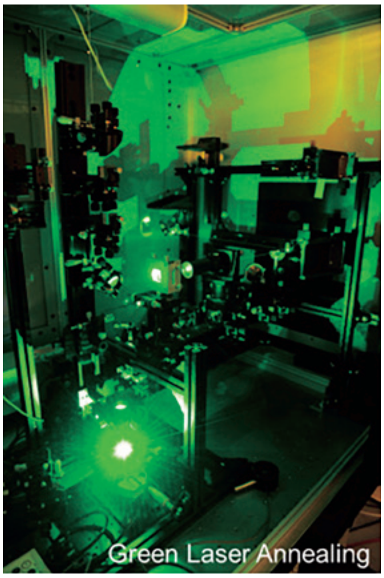

Fig. 2

Recent Research Papers and Achievements

1. J. Bermundo, Y. Ishikawa, M. N. Fujii, H. Ikenoue, and Y. Uraoka, "H and Au diffusion in high mobility a-InGaZnO thin-film transistors vis low temperature KrF excimer laser annealing", Applied Physics Letters **110**, 133503 (2017).
2. Kahori Kise, M. Fujii, S. Urakawa, H. Yamazaki, E. Kawashima, S. Tomai, K. Yano, D. Wang, M. Furuta, Y. Ishikawa, Y. Uraoka, "Self-heating induced instability of oxide thin film transistors under dynamic stress", Appl. Phys. Lett., **108**, 02501 (2016).
3. Mutsunori Uenuma, Yasuaki Ishikawa and Yukiharu Uraoka, "Joule heating effect in nonpolar and bipolar resistive random access memory", Applied Physics Letters **107**, 073503 (2015).
4. Juan Paolo Bermundo, Yasuaki Ishikawa, Mami N. Fujii, Michel van der Zwan, Toshiaki Nonaka, Ryoichi Ishihara, Hiroshi Ikenoue, Yukiharu Uraoka, "Low Temperature Excimer Laser Annealing of a-InGaZnO Thin-Film Transistors Passivated by Organic Hybrid Passivation Layer, Applied Physics Letters, (2015).
5. Takahiko Ban, Mutsunori Uenuma, Shinji Migita, Naofumi Okamoto, Yasuaki Ishikawa, Ichiro Yamashita and Yukiharu Uraoka, "Ultra-short channel junctionless transistor with a one-dimensional nanodot array floating gate", Applied Physics Letters, **106**, 253104 (2015).

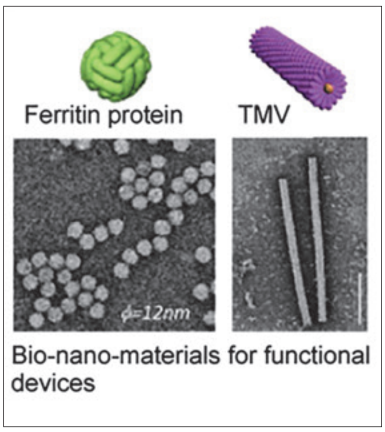

Fig. 3

Synthetic Organic Chemistry

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Education and Research Activities in the Laboratory

Our philosophy in the Synthetic Organic Chemistry Laboratory is to cultivate, through the study on organic synthesis, abilities to (1) understand one another's research background, (2) make independent, logical research plans, and (3) consider and evaluate obtained results accurately to achieve rational conclusions (with a deep insight into the truth), in order to produce human resources possessing broad perspectives, flexibility and adaptability, and creativity, all of which are essential for researchers. Furthermore, in order to enhance students' presentation skills, we encourage them to present their research in various meetings and symposia.

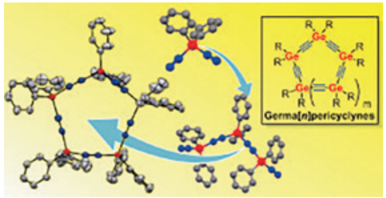

Fig. 1

Research Themes

Research in our laboratory focuses on photochemistry, natural product chemistry, and organometallic chemistry towards organic synthesis. We are interested in developing new photochemical and catalytic reactions to synthesize compounds of interest to the pharmaceutical industry, especially reactions that are stereoselective. We are also interested in the synthesis of natural products and functional organic materials utilizing developed methods. We are currently focused on our own research centered on the following themes:

1. Development of new methodologies for the synthesis of various functional polycyclic organic compounds, such as biologically active compounds and functional organic materials (Fig. 1).
2. Development of asymmetric photoreactions and devising a new microreactor system using a capillary reactor for organic synthesis (Fig. 2).
3. Development of new environmentally-friendly green organic synthesis processes using organometallic catalysts (Fig. 3).

Fig. 2

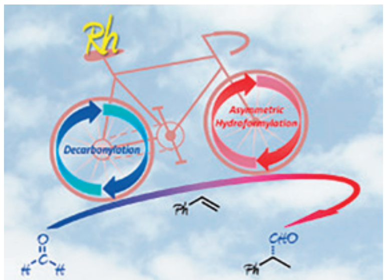

Fig. 3

Recent Research Papers and Achievements

1. H. Tanimoto, J. Mori, S. Ito, Y. Nishiyama, T. Morimoto, K. Tanaka, Y. Chujo, K. Kakiuchi, *Chem. Eur. J.* **2017**, Accepted, DOI: 10.1002/chem.201701359 (Cover Picture).
2. S. Hikage, Y. Nishiyama, Y. Sasaki, H. Tanimoto, T. Morimoto, K. Kakiuchi, *ACS Omega* **2017**, *2*, 2300.
3. T. Furusawa, H. Tanimoto, Y. Nishiyama, T. Morimoto, K. Kakiuchi, *Chem. Lett.* **2017**, *46*, 926.
4. T. Furusawa, H. Tanimoto, Y. Nishiyama, T. Morimoto, K. Kakiuchi, *Adv. Synth. Catal.* **2017**, *359*, 240.
5. H. Tanimoto, T. Shitaoka, K. Yokoyama, T. Morimoto, Y. Nishiyama, K. Kakiuchi, *J. Org. Chem.* **2016**, *81*, 8722.
6. M. Nakano, Y. Nishiyama, H. Tanimoto, T. Morimoto, K. Kakiuchi, *Org. Process Res. Dev.* **2016**, *20*, 1626.

Supramolecular Science


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Education and Research Activities in the Laboratory

In living organisms, a variety of biomolecules such as proteins, DNA, and sugars form unique supramolecular assemblies to maintain biofunctions. Based on chemical knowledge of the functions and structures of these bio-supramolecules at the molecular level, our laboratory focuses on elucidation of the function mechanisms and design/applications of bio-supramolecules using various spectroscopic analysis methods, protein engineering techniques, and organic syntheses.

Research Themes

1. New bio-supramolecule creation

We develop new protein supramolecules and polymers for functional biomaterials based on a new concept in which a protein molecule is used as a structural unit. (Fig.1)

2. Functional protein creation by protein design

We design artificial proteins with multi-active sites exhibiting antibacterial activity and ligand binding properties. (Fig. 2) These proteins are attracting attention in the biotechnology and pharmaceutical science fields.

3. Elucidation and inhibition of protein denaturalization processes

Accumulation of proteins with unusual structures in tissues causes various diseases such as Alzheimer's disease, Parkinson's disease, and mad cow disease (conformation disease). We investigate denaturalization of these proteins at the molecular level and develop strategies to inhibit the denaturalization.

4. Reaction mechanism elucidation of metalloenzymes

To utilize the energy production system in nature, we elucidate the H_2 production and decomposition mechanisms of a metalloenzyme, hydrogenase, using spectroscopic methods.

5. Functional analysis of interaction fashions between biomolecules for medicinal chemistry

To understand and regulate bioreactions, we develop methods for bioreaction regulation based on interactions between biomolecules from the perspective of medicinal chemistry and chemical biology.

6. Functional protein creation through synthetic chemistry approaches

We aim at developing novel biocatalysts and artificial protein, or "molecular design-based functional biomolecules", and apply these biomolecules for organic syntheses and regulation of naturally occurring bioreactions. This strategy is based on complementary advantages of synthetic chemistry and biochemical approaches such as genetic engineering methods. (Fig. 3)

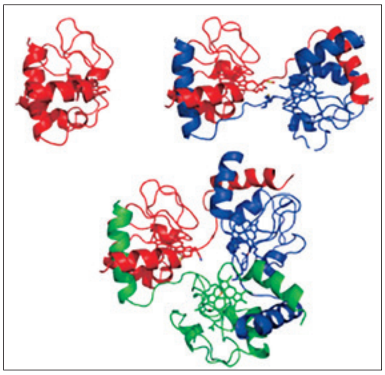

Fig. 1
Elucidated structures of cytochrome c supramolecules

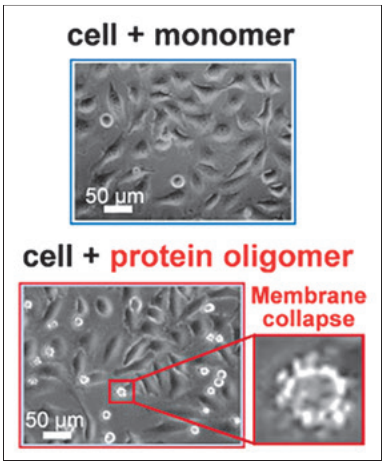

Fig. 2
Creation of antibacterial protein supramolecules

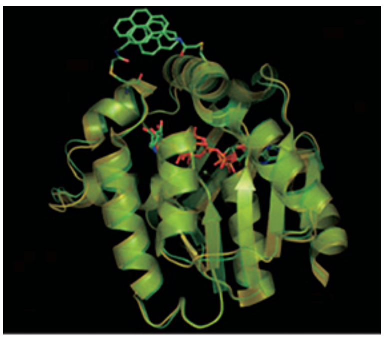

Fig. 3
X-ray crystallographic structure of an artificial fluorescent protein constructed by a combination of genetic and synthetic methods

Recent Research Papers and Achievements

1. K. Yuyama, M. Ueda, S. Nagao, S. Hirota, T. Sugiyama, H. Masuhara, *Angew. Chem. Int. Ed.*, 56, 6739-6743 (2017) (selected as Hot Paper).
2. H. Kobayashi, S. Nagao, S. Hirota, *Angew. Chem. Int. Ed.*, 55, 14019-14022 (2016).
3. Y.-W. Lin, S. Nagao, M. Zhang, Y. Shomura, Y. Higuchi, S. Hirota, *Angew. Chem. Int. Ed.*, 54 511-515 (2015).
4. A. Fujii, Y. Sekiguchi, H. Matsumura, T. Inoue, W.-S. Chung. S. Hirota, T. Matsuo, *Bioconjugate Chem.*, 26 537-548 (2015).
5. T. Matsuo, K. Yamada, M. Ishida, Y. Miura, M. Yamanaka, S. Hirota, *Bull. Chem. Soc. Jpn.*, 88, 1222-1229 (2015) (BCSJ Award).

Photonic Molecular Science


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Education and Research Activities in the Laboratory

Research activity of this laboratory is focused on "Photonic Molecular Science", a new research field covering molecules, polymers, coordination compounds and low-dimensional nanomaterials with advanced photo-functionality. We accept students who have been educated in related fields such as chemistry, applied physics, material science and electronic engineering in Japanese and overseas universities. Students are trained in organic and inorganic syntheses and characterization methods, which are essential for developing future advanced materials and devices with photo-functionality. We welcome ambitious students with high motivation, flexibility, and positive attitudes to address new scientific challenges while taking advantage of their educational backgrounds and scientific interests in materials science.

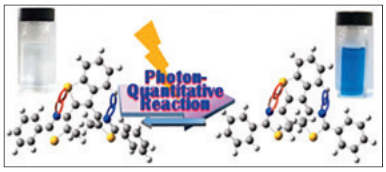

Fig. 1
Schematic illustration for photoisomerization reactions of our unique photochromic molecule, which exhibits photoreaction with quantum yield of unity, a "photon-quantitative reaction"

Research Themes

1. Photoresponsive molecules based on terarylene structures for photon quantitative reactions, photoacid generators (PAGs), ultra-efficient oxidative cycloreversion, and photoswitching of circularly polarized luminescence (CPL)

2. Nanoparticles chemistry through surface molecular design for self-assembly, chiral chemistry, and composite materials

3. Supramolecular functionalization of carbon nanotubes for thermoelectric energy conversion

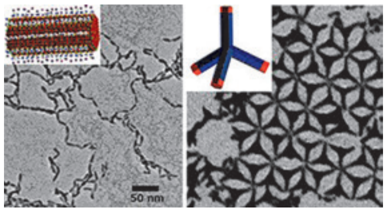

Fig. 2
TEM images of Self-assembling structures of amphiphilic semiconductor nanoparticles with rod-(left) and tetrapod-(right) shape.

Recent Research Papers and Achievements

1. T. Nakashima, K. Tsuchie, R. Kanazawa, R. Li, S. Iijima, O. Galangau, T. Kawai et al., "Self-Contained Photoacid Generator Triggered by Photocyclization of Triangle Terarylene Backbone", J. Am. Chem. Soc. 137 7023-7026 (2015).
2. J. Kumar, H. Tsumatori, J. Yuasa, T. Kawai, T. Nakashima, "Self-Discriminating Termination of Chiral Supramolecular Polymerization: Tuning the Length of Nanofiber", Angew. Chem. Int. Ed. 54, 5943-5947 (2015).
3. Y. Taniguchi, T. Takishita, T. Kawai, T. Nakashima, "End-to-End Self-Assembly of Semiconductor Nanorods in Water by using an Amphiphilic Surface Design", Angew. Chem. Int. Ed., 55, 2083-2086 (2016).
4. Y. Nonoguchi, M. Nakano, T. Murayama, H. Hagino, S. Hama, K. Miyazaki, R. Matsubara, M. Nakamura, T. Kawai, "Simple Salt-coordinated n-Type Nanocarbon Materials Stable in Air", Adv. Funct. Mater., 26, 3021-3028 (2016).

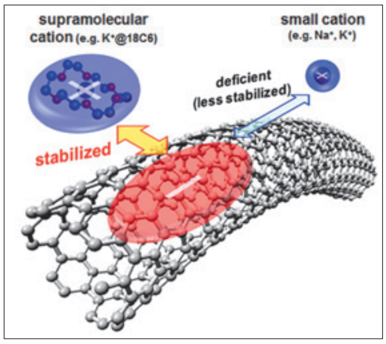

Fig. 3
A representative concept for supramolecular n-type doping of carbon nanotubes.

Photofunctional Organic Chemistry




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Education and Research Activities in the Laboratory

The Photofunctional Organic Chemistry Laboratory was established on January 1, 2011.

We focus on the development of functional organic materials including organic semiconductors for photovoltaic cells and organic thin-film transistors, highly fluorescent dyes, etc. on the basis of organic synthesis. In particular, acenes and porphyrinoids are our current target compounds. Students at our laboratory are encouraged to work independently and freely on their own original research themes.

Research Themes

1. Development of high-performance molecular semiconductors for solution-processed organic electronic devices

We are trying to engineer well-performing organic semiconducting thin films for use in electronic devices such as organic solar cells. To this end, we employ a unique deposition technique called "precursor approach" (Fig. 1), and are preparing new compounds—typically derivatives of acenes and benzoporphyrin—that can be processed by this method (Fig. 2). We have been conducting joint research "3D Active-Site Science" (JSPS Grant-in-Aid for Scientific Research on Innovative Areas).

2. Development of graphene nanoribbons

We are investigating the surface-assisted graphene nanoribbon (GNR) synthesis that allows width, edge structure, and heteroatom incorporation to be modulated with atomic-level precision (Fig. 3). Our group is currently involved in, among others, collaborative projects of "Tailor-Made Synthesis of Graphene Nanoribbons for Innovative Devices" (JST CREST).

3. Creation of unique carbon frameworks with remarkable optical/electronic properties

We have created various novel functional polycyclic aromatic hydrocarbons (PAHs). These compounds have near-infrared absorption properties, intensive light emission, or remarkable redox properties (Fig. 4). We have also been attempting to make porous crystalline materials.

Recent Research Papers and Achievements

1. K. Takahashi, M. Suzuki, K. Nakayama, H. Yamada *et al.*, Side-chain engineering in a thermal precursor approach for efficient photocurrent generation, *J. Mater. Chem. A*, **2017**, *5*, 14003. (Selected as an Inside Front Cover)
2. M. Suzuki, K. Nakayama, H. Yamada *et al.* Photoprecursor Approach Enables Preparation of Well-Performing Bulk-Heterojunction Layers Comprising a Highly Aggregating Molecular Semiconductor, *ACS Appl. Mater. Interfaces*, **2016**, *8*, 8644.
3. H. Hayashi, J. Yamaguchi, H. Jippo, R. Hayashi, N. Aratani, M. Ohfuchi, S. Sato, and H. Yamada, Experimental and Theoretical Investigations of Surface-Assisted Graphene Nanoribbon Synthesis Featuring Carbon–Fluorine Bond Cleavage, *ACS Nano*, **2017**, *11*, 6204.
4. A. Matsumoto, M. Suzuki, D. Kuzuhara, H. Hayashi, N. Aratani, H. Yamada, Tetrabenzoperipentacene: Stable Five-Electron Donating Ability and a Discrete Triple-Layered *β*-Graphite Form in the Solid State, *Angew. Chem. Int. Ed.*, **2015**, *54*, 8175. (Selected as a Hot paper)

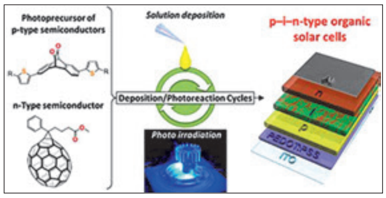

Fig. 1
A photoprecursor method for solution-processing of organic thin-film devices

Fig. 2
Photo-irradiation process on making of organic thin-film devices

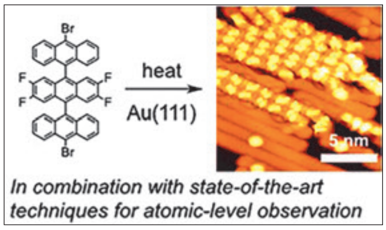

Fig. 3
On-surface Synthesis of Graphene Nanoribbon

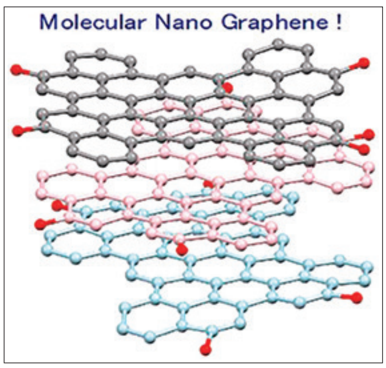

Fig. 4
Novel functional PAH

Information Science

Biological Science

Materials Science

Sensing Devices

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Education and Research Activities in the Laboratory

1. Measurements of ionizing radiations (for example, X-rays, γ-rays, charged particles and neutrons) using scintillators and dosimeters are our main focus of research.
2. Key areas of our studies are radiation physics, inorganic luminescent materials and photo-physics. It is preferable if the prospective student has a good understanding of physics described in the textbooks below.
   · Solid state physics: Introduction to Solid State Physics (C. Kittel)
   · Basic quantum mechanics: Principles of Quantum Mechanics (P. A. M. Dirac)
3. In our group, students are exposed to a wide range of experiments every day, and they learn and achieve experimental techniques to measure various ionizing radiations using inorganic phosphor materials. Typically, these phosphors (inorganic single crystals, ceramics and glasses) can be synthesized in the lab, and a variety of radiation-induced effects are characterized over a wide range of optical regions from VUV to NIR over a wide temperature range, 4-800 K. Successful students may be involved in collaborative research with major university and industrial partners in Japan and overseas.

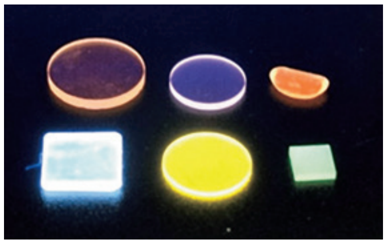

Fig. 1
Crystal, ceramic, and glass materials under UV excitation

Research Themes

1. Development of new scintillator materials and detectors for advanced radiation measurements

We synthesize inorganic crystal, ceramic and glass scintillators and characterize the fundamental scintillation properties. Successful materials will be further studied for state-of-the-art detectors.

2. Development of new dosimeter materials (OSL, TSL and RPL)

As for scintillator research, we synthesize inorganic crystals, ceramics and glasses for novel dosimeter materials. Our facilities offer comprehensive studies of different types of dosimetry. (OSL, TSL, and RPL)

3. Development of other phosphor materials

Besides radiation measurements, we also develop other types of phosphor materials, e.g., long persistent luminescence and stress luminescence.

4. Ionizing radiation detector applications

Promising samples are further advanced to develop detector instruments for medical, security and high energy physics applications.

Recent Research Papers and Achievements

1. Study of rare-earth-doped scintillators, T. Yanagida, Opt. Mat., 35 1987-1992 (2013).
2. Comparative study of ceramic and single crystal Ce:GAGG scintillator, T. Yanagida, K. Kamada, Y. Fujimoto, H. Yagi, T. Yanagitani, Opt. Mat., 35 2480-2485 (2013).
3. Development of X-ray induced afterglow characterization system, T. Yanagida, Y. Fujimoto, T. Ito, K. Uchiyama, K. Mori, Appl. Phys. Exp., 7 062401 (2014).

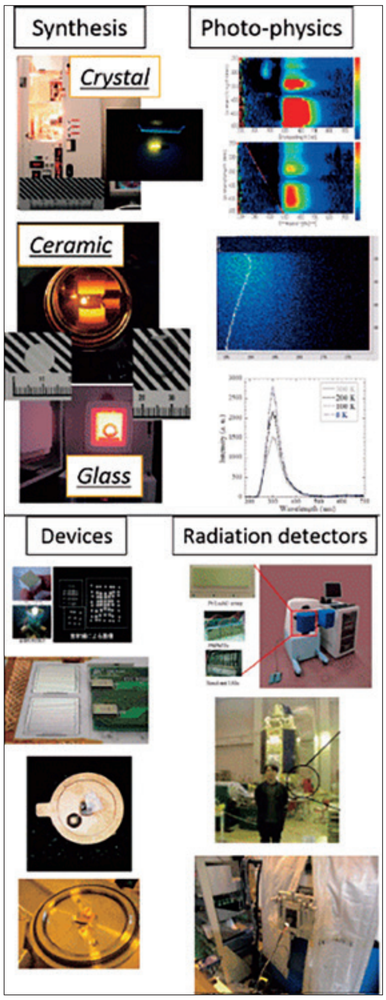

Fig. 2
Outline of studies in this group, from material synthesis to radiation detectors

Organic Electronics

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Assoc. Prof. Hiroaki Benten
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Education and Research Activities in the Laboratory

Let's imagine electronic equipment that is easy to carry in a rolled state, a piece of fabric that generates electricity from the human body or a paper-like solar battery that generates electricity by choosing the most available light. Adding such unprecedented electronic functions onto various "surfaces", human life will become more comfortable and prosperous. We are pursuing the realization of such novel electronic devices through studies elucidating unique interactions in organic solids and applying the findings to the device functions using knowledge of solid-state physics, electronics, surface science, polymer physics, and molecular science. Our laboratory utilizes unique approaches made possible by our original evaluation apparatus and theoretical calculations.

We determine individual research projects ranging from basic science to development of operable devices, depending on the interests and aptitudes of the students. We foster independent thinking and a top-level mindset necessary for a researcher through joint research with institutes in Japan and overseas. Thus, we aim to cultivate researchers with a broad knowledge of science and a keen interest toward industrial applications.

Research Themes

1. Creation of "soft" thermoelectric materials

We are attempting to create novel thermoelectric materials and innovative flexible thermoelectric generators to convert exhaust heat from the living environment and the human body into electricity. We have found that the thermal conductivity of a carbon nanotube composite decreases to 1/1000 by forming molecular junctions between nanotubes with a specially designed protein. (Fig. 1) We are also trying to elucidate and control the *Giant Seebeck Effect* in organic semiconducting solids discovered in our laboratory (Fig. 2) with the aid of advanced measurement techniques, theoretical physics, and computational chemistry.

2. Elucidation of carrier transport mechanisms in organic semiconductors

We develop original characterization techniques, such as AFM Potentiometry, and perform studies to deepen understanding of the structure and the electronic functions of organic semiconductors.

3. Development of next-generation plastic solar cells

We develop next-generation solar cells based on semiconducting polymers. To elucidate the mechanisms that lead to photon-to-current energy conversion, functional structures of the photovoltaic layer have been visualized at the nanometer scale by conductive atomic force microscopy. (Fig. 3)

4. Development of flexible THz imaging devices using organic transistor structures

We are performing fundamental studies on the interaction of free carriers in organic field-effect transistors with terahertz (THz) waves, aiming at the realization of flexible THz imaging devices that utilize the band-edge potential fluctuation in organic thin films. (Fig. 4)

Recent Research Papers and Achievements

1. H. Kojima et al., "Giant Seebeck effect in pure fullerene thin films", *Appl. Phys. Express* **8** 121301 (2015).
2. R. Matsubara et al., "Quantitative investigation of the effect of gate-dielectric surface treatments on limiting factors of mobility in organic thin-film transistors", *J. Appl. Phys.* **118** 175502 (2015).
3. M. Ito et al., "Enhancement of Thermoelectric Properties of Carbon Nanotube Composites by Inserting Biomolecules at Nanotube Junctions", *Appl. Phys. Express* **7** 065102 (2014).

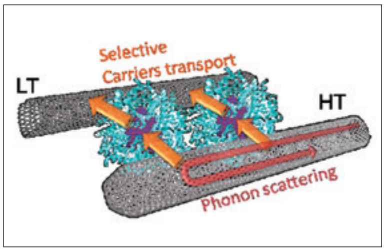

Fig. 1
A novel design of a thermoelectric nanocomposite using biomolecular junctions

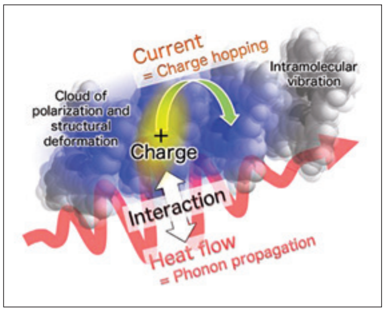

Fig. 2
Conceptual diagram of the Giant Seebeck Effect: a specific current-heat flow interaction in organic solids

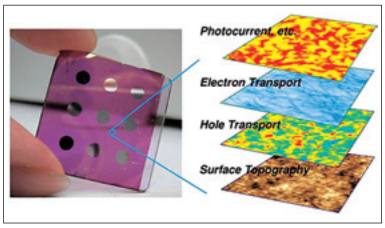

Fig. 3
Functional structures for photovoltaic conversion in plastic solar cells

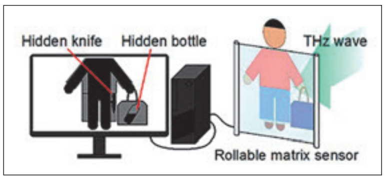

Fig. 4
An image of a baggage check with the rollable THz-wave imaging device

Bio-process Engineering

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Education and Research Activities in the Laboratory

The Bio-process Engineering Laboratory promotes developmental research on high-precision and fast manipulation methodologies for small biological materials, in which ultra-short pulse laser technology is utilized. When an intense femtosecond laser is focused in the vicinity of a micro-sized biological micro-object in a water medium, an explosion of water is induced at the laser focal point, and shock and stress waves due to the explosion are acted as an impulsive force on the sample (Fig. 1). We have developed several kinds of methodologies to manipulate single animal and plant cells utilizing this impulsive force. In addition, this laser manipulation technology has been combined with Atomic Force Microscope (AFM) and micro-fluidic chip technologies. The AFM is applied to quantify the impulsive force and to analyze the sample oscillation induced by the impulsive force (Fig. 2). A micro-fluidic chip is used to realize high-speed cell manipulation. For instance, these methodologies are applied to clarify biomechanical interaction between cells or proteins from a new perspective in order to further understand responsiveness of cells and living tissue under environment stress (Fig. 3). These activities aim to open new fields of life innovation and green innovation. The laboratory fosters human resources who have a broad knowledge of engineering and science from areas ranging from physics and chemistry to biology and medicine.

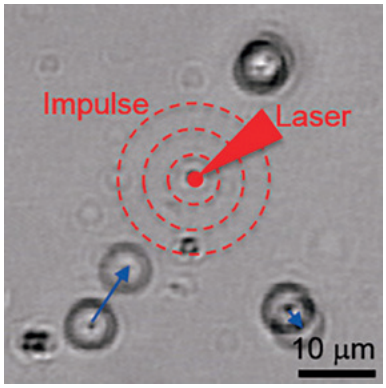

Fig. 1
Manipulation of microbeads by laser impulse

Research Themes

1. Kinetics of local explosions in water induced by ultrashort laser pulses, and its interaction with biological micro-objects
2. Development of new measurement methods to estimate internal stress in living tissues utilizing ultrashort lasers and atomic force microscopes
3. Development of new cell manipulation techniques in micro-fluidic chips
4. Exploration of the responsiveness of cells and living tissues to the environment stress and its application to cell manipulation

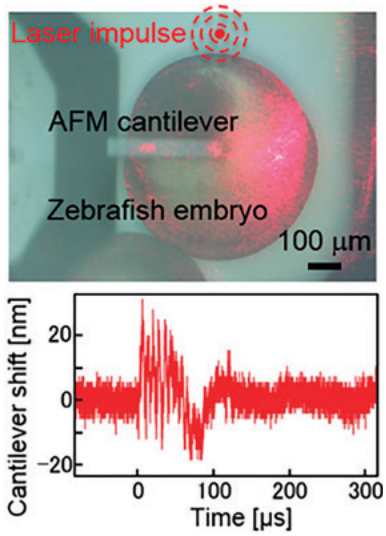

Fig. 2
Nanometer scale vibration of Zebrafish embryo induced by laser impulse and detected by AFM

Recent Research Papers and Achievements

1. K. Oikawa, S. Matsunaga, S. Mano, M. Kondo, K. Yamada, M. Hayashi, T. Kagawa, A. Kadota, W. Sakamoto, S. Higashi, M. Watanabe, T. Mitsui, A. Shigemasa, T. Iino, Y. Hosokawa, M. Nishimura, "Physical interaction between peroxisomes and chloroplasts elucidated by in situ laser analysis," Nature Plants, 2015, 1 15035.
2. Y. Hosokawa, M. Hagiyama, T. Iino, Y. Murakami, A. Ito, "Noncontact estimation of intercellular breaking force using a femto-second laser impulse quantified by atomic force microscopy," Proc. Nat'l Acad. Sci. USA, 2011, 108, 1777-1782
3. Y. Hosokawa, H. Ochi, T. Iino, A. Hiraoka, M. Tanaka, "Photoporation of biomolecules into single cells in living vertebrate embryos induced by a femtosecond laser amplifier," PLoS ONE, 2011, 6, e27677

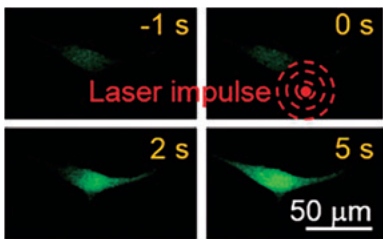

Fig. 3
Activation of cultured biological cells by laser impulse

Complex Molecular Systems



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Education and Research Activities in the Laboratory

The concerted actions of various molecules result in high-order functions that cannot be realized by individual molecules, as seen in various biological systems. The Complex Molecular Systems Laboratory, established on April 1, 2015, currently focuses on the complex molecular systems involving multicomponent biological molecules such as proteins. Weakly and/or strongly coupled proteins undergo regulatory dissociation and association in response to external stimuli, thereby exhibiting advanced biological functions. To determine the physicochemical properties of these molecular systems and to create new functional molecular systems, our laboratory employs various biophysical techniques, such as structural analysis using multiple probes (x-ray, neutron, and electron), spectroscopic measurements, protein engineering, and theoretical analysis.

Multidisciplinary knowledge is essential to clearly understand the characteristics of these complex molecular systems. We welcome students with various educational backgrounds such as physics, chemistry, material science, and biology. By enabling students to work on their own research theme independently, we encourage them to develop their own interests and to learn essential research skills, such as identifying problems to be solved, designing experiments that will yield solutions, and comprehensively interpreting experimental results.

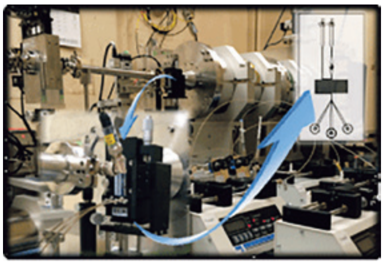

Fig. 1
Micro-fluidics based analyzer equipped for structure/interaction analysis of complex molecular systems

Research Themes

1. Development of analytical methods to investigate complex molecular systems (Fig. 1)
2. Investigation of the dynamical ordering of multi-component proteins (Fig. 2)
3. Creation of high-order self-assembled complex molecular systems (Fig. 2)
4. Detailed analysis of intramolecular actions in individual proteins responsible for the dynamical ordering of complex molecular systems in higher-class structural hierarchy (Fig. 3)
5. Development of rational molecular designs for novel synthetic proteins

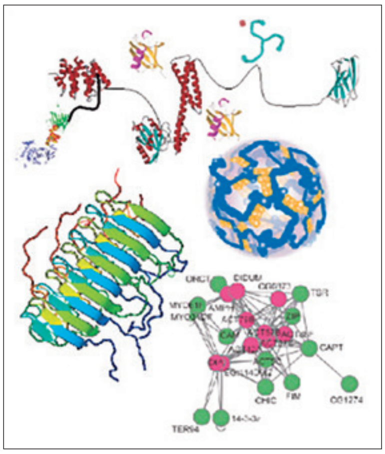

Fig. 2
Biological complex molecular systems

Recent Research Papers and Achievements

1. K. Yonezawa, N. Shimizu, K. Kurihara, Y. Yamazaki, H. Kamikubo, M. Kataoka. "Neutron crystallography of photoactive yellow protein reveals unusual protonation state of Arg52 in the crystal." *Sci Rep* 7(1):9361. (2017).
2. H. Kuramochi, S. Takeuchi, K. Yonezawa, H. Kamikubo, M. Kataoka, T. Tahara, "Probing the early stages of photoreception in photoactive yellow protein with ultrafast time-domain Raman spectroscopy", *Nature Chemistry*, 10.1038/nchem.2717 (2017).
3. Y. Yoshimura, N. A. Oktaviani, K. Yonezawa, H. Kamikubo, F. A. A. Mulder, "Unambiguous Determination of the Ionization State of a Photoactive Protein Active Site Arginine in Solution by NMR Spectroscopy", *Angewandte Chemie* **56**, 239-242 (2017).
4. F. Schotte, H. S. Cho, V. R. I. Kaila, H. Kamikubo, N. Dashdorj, E. R. Henry, T. J. Graber, R. Henning, M. Wulff, G. Hummer, M. Kataoka, P. A. Anfinrud, "Watching a signaling protein function in real time via 100-ps time-resolved Laue crystallography", *Proc. Natl. Acad. Sci. USA* **109** 19256-19261 (2012).
5. S. Yamaguchi, H. Kamikubo, K. Kurihara, R. Kuroki, N. Niimura, N. Shimizu Y. Yamazaki, M. Kataoka, "Low-barrier hydrogen bond in photoactive yellow protein", *Proc. Natl. Acad. Sci. USA* **106** 440-444 (2009).

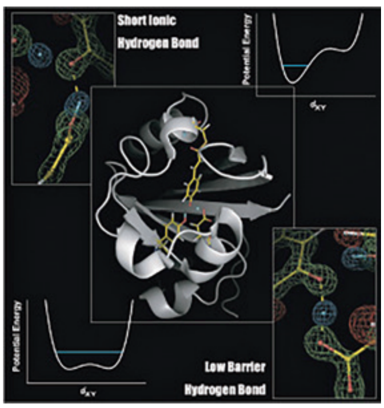

Fig. 3
Protonics in protein molecules

Biomimetic and Technomimetic Materials Science

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Assist. Prof.
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Education and Research Activities in the Laboratory

There are no physical limitations to the miniaturization of a machine down to the scale of a single molecule or conversely, to monumentalize a molecule until it becomes a machine. A molecular machine is a molecule designed to perform a function providing energy, data or/and orders to the molecule. Inspiration from mother nature and from modern technologies has given rise to the concept of biomimetic and technomimetic molecular machines respectively.

The Biomimetic and Technomimetic Materials Science Laboratory studies molecules which can act as machines at the nanoscale. Thanks to an input signal as an energy source (light, electron or chemical) these molecular machines can produce a controllable motion and then to a useful output.

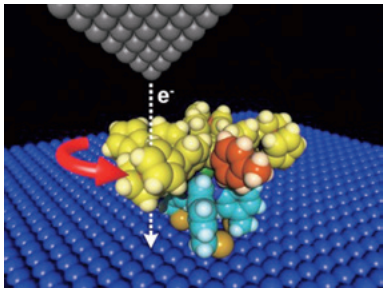

Fig. 1
A Molecular motor rotating clockwise or counterclockwise by request.[5]

Research Themes

1. Technomimetic molecular machines

Technomimetic molecular machines are molecules designed to imitate macroscopic objects at the molecular level, and also to transpose the motions that these objects are able to undergo. Our originality is in the design of molecular machines and devices operating at the atomic scale for molecular mechanical applications: gears, vehicles, motors, etc. We are designing, synthesizing, organizing and synchronizing such molecular nanodevices to develop energy, communication and information transfer at the nanoscale under the action of light, heat or electrons.

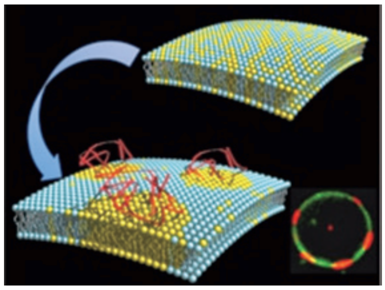

Fig. 2
Modulation of cell membrane structure by biomimetic molecular machines.

2. Biomimetic molecular machines

Membrane dynamics, such as morphological change of the cell membrane and molecular assembly in the membrane, are essential molecular mechanisms expressing and/or regulating various cellular functions. We design membrane-active agents which can trigger membrane dynamics and modulate biological functions learning from natural molecular machinery.

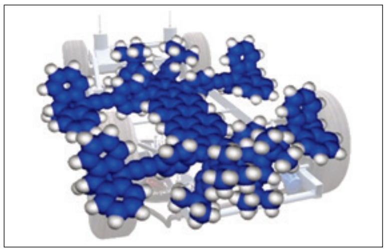

Fig. 3
Molecular nanovehicles which participated to the first Nanocar Race.[1]

3. Hybrid molecular machines

Hybrid molecular machines are based on biomimetic and technomimetic approaches to build new generation molecular machines and materials. Insertion of photo or electroactive molecular devices in membranes or in cells may induce some interesting biological activities.

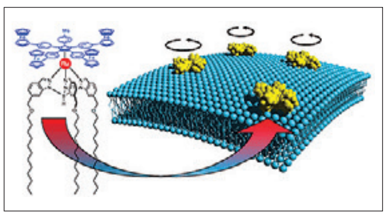

Fig. 4
A Hybrid molecular motor designed to be inserted in artificial or cell membrane.

Recent Research Papers and Achievements

1. G. Rapenne, C. Joachim, *Nature Rev. Mater.* **2**, 17040 (2017).
2. J.P. Dela Cruz Calupitan, O. Galangau, O. Guillermet, R. Coratger, T. Nakashima, G. Rapenne, T. Kawai, *Eur. J. Org. Chem.* 2451 (2017).
3. Y. Zhang, H. Kersell, R. Stefak, J. Echeverria, V. Iancu, G. Perera, Y. Li, A. Deshpande, K.-F. Braun, C. Joachim, G. Rapenne, S.-W. Hla, *Nature Nanotech.* **11**, 706 (2016).
4. M. Tsukamoto, K. Kuroda, A. Ramamoorthy, K. Yasuhara, *Chem. Commun.* **50**, 3427 (2014).
5. U.G.E. Perera, F. Ample, H. Kersell, Y. Zhang, J. Echeverria, M. Grisolia, G. Vives, G. Rapenne, C. Joachim, S.-W. Hla, *Nature Nanotech.* *8*, 46 (2013).

Nanostructure Magnetism

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Education and Research Activities in the Laboratory

In the Nanostructure Magnetism Laboratory, we use vacuum deposition and sputtering methods to produce metallic magnetic thin and multilayer films, and conduct basic research on magnetic phenomena specific to nanostructure thin films and the relationship between the structure of thin films and magnetism. The laboratory is characterized by research on “nanostructure magnetism” with synchrotron radiation X-rays. We are developing an X-ray magnetic scattering technique that enables element-specific magnetic structure analysis through the improvement of measuring methods, sensitivity enhancement and analysis precision.

Magnetic thin films and multilayer films with modulated structures at nanoscale can produce various magnetic structures and magnetization processes because of the effects of magnetic anisotropy in the individual magnetic layers, as well as the direct or indirect exchange coupling between the magnetic layers. Thus, we elucidate element-specific magnetic structures and vector magnetization processes by resonant X-ray magnetic scattering techniques, and reveal the generation mechanism of magnetic functionalities. In spin electronics, which is recently attracting attention, “magnetism in nonmagnetic layers” or “magnetism of conduction electrons” is related to the appearance of functionalities. The resonant X-ray magnetic scattering allows us to study the magnetism in nonmagnetic layers without being affected by the magnetism in ferromagnetic layers. We take advantage of these characteristics to advance our research on conduction electron magnetism.

In our laboratory, based on the specialized knowledge and experimental technology of solid state physics, especially of magnetism obtained from the above studies, we, for educational purposes, cultivate human resources with the ability to discover problems, explore solutions, discuss issues logically, give presentations on research results, and will demonstrate their ability in companies, universities, and research institutions after graduation.

Research Themes

1. Induced magnetic structures of nonmagnetic layers and their vector magnetization processes in the oscillatory interlayer exchange coupling systems such as Fe/Au and Co/Cu multilayers
2. Interface magnetism in the indirect exchange bias systems such as CoO/Cu/Fe and FeMn/Cu/Co trilayers
3. Induced magnetism of Pt layers in the Fe/Pt multilayers with perpendicular magnetic anisotropy

Recent Research Papers and Achievements

1. M. Lee, R. Takechi, and N. Hosoito, “Perpendicular Magnetic Anisotropy and Induced Magnetic Structures of Pt Layers in the Fe/Pt Multilayers Investigated by Resonant X-ray Magnetic Scattering”, *J. Phys. Soc. Jpn.* **86**, 024706-1-10 (2017).
2. S. Amasaki, M. Tokunaga, K. Sano, K. Fukui, K. Kodama, and N. Hosoito, “Induced Spin Polarization in the Au Layers of Fe/Au Multilayer in an Antiparallel Alignment State of Fe Magnetizations by Resonant X-ray Magnetic Scattering at the Au L_3 Absorption Edge ”, *J. Phys. Soc. Jpn.* **84**, 064704-1-8 (2015).

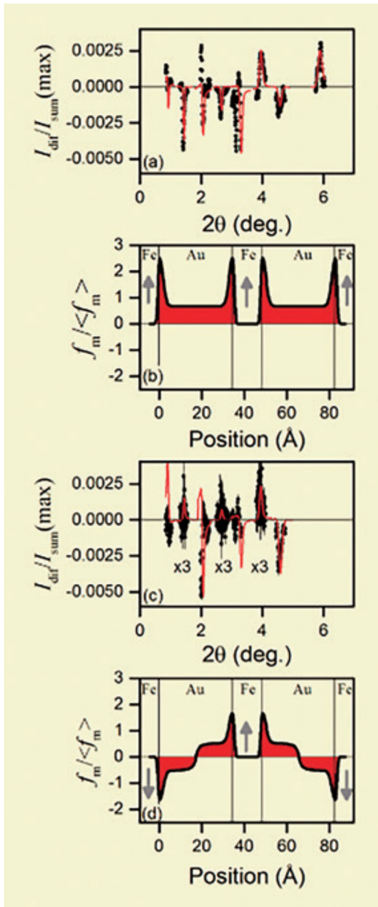

Fig. 1
Resonant X-ray magnetic scattering profiles in (a) parallel and (c) antiparallel states of Fe magnetizations measured near the Au L3 absorption edge, and induced magnetic structures of Au layers in (b) parallel and (d) anti-parallel states of Fe magnetizations.

Precision Polymer Design and Engineering

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Education and Research Activities in the Laboratory

We educate students and conduct research to design and create new and novel functional materials based on precise synthesis of polymers. For example, we develop functional materials that will contribute to highly reliable medical devices which may be used in regenerative medicine, new therapeutic methods, new drugs, DDS, etc. Therefore, molecular design, synthesis, and evaluation of functional materials are conducted based on knowledge and technology from a wide range of disciplines such as organic chemistry, polymer science, molecular biology, medicine, and pharmaceutical science.

Research Themes

1. Biocompatible coatings based on precisely designed polymers
2. Development of helical polymers for gene or drug carriers
3. Analysis of gene expression mechanisms in cells exerted by low-temperature plasma irradiation

Recent Research Papers and Achievements

1. Nurlidar F, Kobayashi M, Terada K, Ando T, Tanihara M; "Cytocompatible polyion complex gel of poly(Pro-Hyp-Gly) for simultaneous rat bone marrow stromal cell encapsulation" J Biomat Sci, Polym Ed. 2017 May 18. doi: 10.1080/09205063.2017.1331872
2. Kusumastuti Y, Shibasaki Y, Hirohara S, Kobayashi M, Terada K, Ando T, Tanihara M; "Encapsulation of rat bone marrow stromal cells using apolyion complex gel of chitosan and succinylated poly(Pro-Hyp-Gly) J Tissue Eng Regen Med, 2015 Jan 28. doi: 10.1002/term.1987
3. Totani M, Ando T, Terada K, Terashima T, Kim I-Y, Ohtsuki C, Xi C, Kuroda K, Tanihara M; "Utilization of star-shaped polymer architecture in the creation of high-density polymer brush coatings for the prevention of platelet and bacteria adhesion" Biomat Sci 2(9), 1172-1185, 2014
4. Kusumaatmaja A, Ando T, Terada K, Hirohara S, Nakashima T, Kawai T, Terashima T, Tanihara M, "Synthesis and photoproperties of Eu(III)-bearing star polymers as luminescent materials" J Polym Sci Part A: Polym Chem 51(12), 2527-2535, 2013
5. Kumagai S, Chang C-Y, Jeong J, Kobayashi M, Shimizu T, Sasaki M; "Development of plasma-on-chip: Plasma treatment for individual cells cultured in media" Jap J Appl Phys 55, 01AF01, 20162.

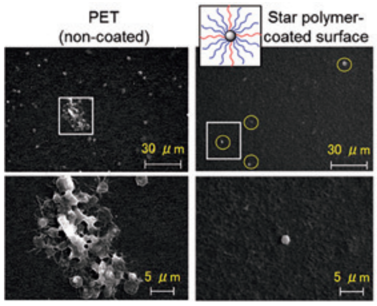

Fig. 1

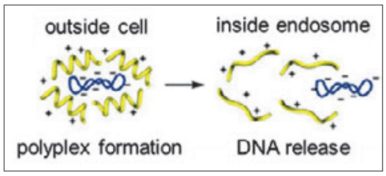

Fig. 2

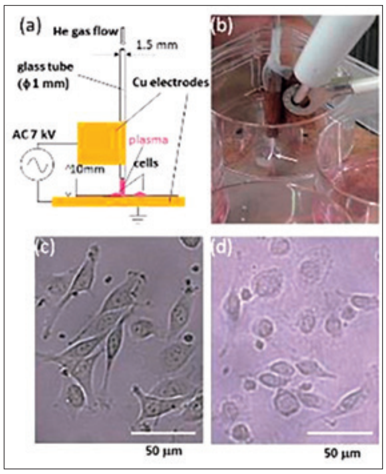

Fig. 3

Nanomaterials and Polymer Chemistry

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Education and Research Activities in the Laboratory

Based on the concept of "molecular technology", this laboratory was established in 2015 to conduct research on functional materials and nanomaterials in the field of polymer chemistry. Students who are interested in polymer synthesis and nanomaterials are welcome. The development of functional polymer materials requires knowledge of organic synthesis, analytical methods, and materials design, all of which are covered in the laboratory. We offer a thorough education to prepare students to become researchers through discussions, presentations, and participation in academic conferences and meetings.

Research Themes

We aim to create functional polymer materials through the application of "molecular technology". In this laboratory, high-performance polymers and functional polymers are prepared by various approaches such as molecular design, polymer structure control, and effective polymer-polymer interaction.

1. Biocompatible polymers / Bioabsorbable polymers

Trimethylene carbonate derivatives and N-vinylamide derivatives, for example, are selected as biomaterial applications. (Fig. 1)

2. Stimuli-responsive polymers

Thermal, pH, and light are used for stimuli-responsive polymer materials, which change their chemical and physical properties. (Fig. 2)

3. Nanostructure control

Nanoparticles, nanofibers, and nanofilms are design and prepared using polymer-polymer interactions, such as van der Waals and electrostatic interactions. (Fig. 3)

Recent Research Papers and Achievements

1. S. Fujishiro, K. Kan, M. Akashi, H. Ajiro*, "Stability of Adhesive Interfaces by Stereocomplex Formation of Polylactides and Hybridization with Nanoparticles", *Polym. Degrad. Stab.* **2017**, *141*, 69.
2. K. Kan, M. Akashi, H. Ajiro*, "Polylactides Bearing Vanillin at Chain End Provided Dual Dynamic Interactions: Stereocomplex Formation, and Nanostructre Control", *Macromol. Chem. Phys.* **2016**, *217*(24), 2679.
3. H. Ajiro*, S. Ito, K. Kan, M. Akashi*, "Catechin Modified Polylactide Stereocomplex at Chain End Improved Antibiobacterial Property", *Macromol. Biosci.* **2016**, *16*(5), 694.

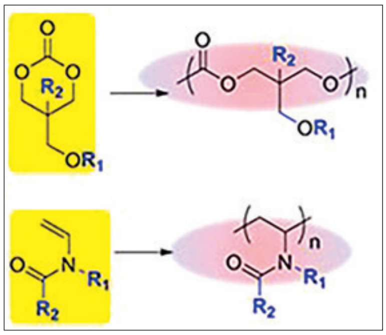

Fig. 1

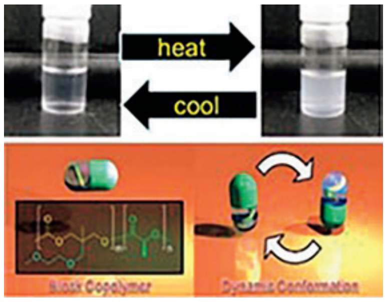

Fig. 2

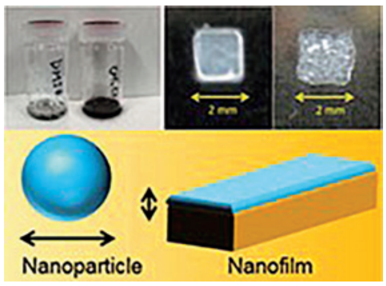

Fig. 3

Materials Informatics

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Education and Research Activities in the Laboratory

Theoretical and computational chemistry have contributed to a better understanding of the mechanisms and efficient molecular design for catalytic systems and functional materials. For the next challenge, we aim to devise a new research area by combining theoretical chemistry and informatics technology. Recently, along with the development of automated reaction path search methods, it has become possible to obtain big chunks of data regarding reaction pathways. Based on this data, we will extract the keys to determining reactivity and catalytic ability from a different viewpoint obtained by utilizing informatics technology, including machine learning and deep learning. Our material informatics strategy is applicable not only to chemical reaction systems but also to various functional materials. By using this strategy, we aim to construct a new methodology to accelerate the development of new functional materials.

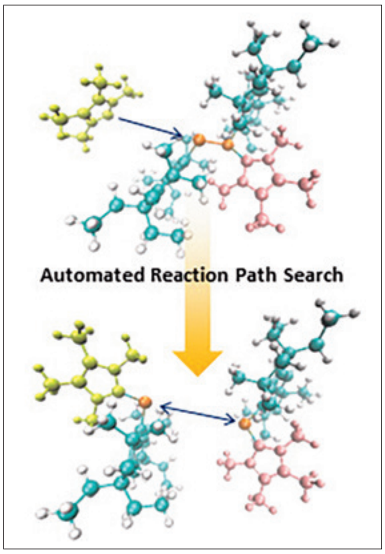

Fig. 1
Automated reaction path search by the "Global Reaction Route Mapping" strategy

Research Themes

1. Automated reaction path search for catalytic reaction systems

We explore the catalytic reaction pathways exhaustively by using a recently developed automated reaction path search method, called the Global Reaction Route Mapping (GRRM) strategy. This strategy gathers all the important intermediates and transition states automatically, which enables us to discuss the regio- and stereo-selectivity as well as reaction mechanism.

2. Mechanism studies and ligand design of lanthanide luminescent materials

Lanthanide materials are widely used for display, optical fibers, in vivo probes and sensors. To understand the mechanisms and predict the luminescent properties of these materials, we study the potential energy surfaces of ground and excited states using our unique approximation method.

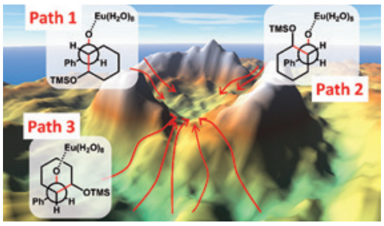

Fig. 2
Exhaustive sampling of the transition states of the stereo-determining step

3. Finding the keys for efficient material design using informatics techniques

The GRRM is very powerful tool to gather information about chemical reactions. However, it becomes difficult to analyze the calculation results because of a surplus of data in the intermediate and transition states. To analyze the data efficiently, we apply informatics techniques and aim to accelerate computational research.

Recent Research Papers and Achievements

1. N. Hayakawa, K. Sadamori, S. Tsujimoto, M. Hatanaka, T. Wakabayashi, T. Matsuo, "Cleavage of a P=P Double Bond Mediated by N-Hetrocyclic Carbenes", *Angew. Chem. Int. Ed.* 56, 5765-5769 (2017).
2. M. Hatanaka, Y. Hirai, Y. Kitagawa, T. Nakanishi, Y. Hasegawa, K. Morokuma, "Organic linkers control the thermosensitivity of the emission intensities from Tb(III) and Eu(III) in a chameleon polymer", *Chem. Sci.* 8, 423-429 (2017).
3. K. Honda, T. V. Harris, M. Hatanaka, K. Morokuma, K. Mikami, "Computational S_N2-Type Mechanism for the Difluoromethylation of Lithium Enolate with Fluoroform through Bimetallic C−F Bond Dual Activation", *Chem. Eur. J.* 22, 8796-8800 (2016).
4. W. M. C. Sameera, M. Hatanaka, T. Kitanosono, S. Kobayashi, K. Morokuma, "The Mechanism of Iron(II)-catalyzed Asymmetric Mukaiyama Aldol Reaction in Aqueous Media: Density Functional Theory and Artificial Force-Induced Reaction Study", *J. Am. Chem. Soc.* 137, 11085-11094 (2015).
5. M. Hatanaka, K. Morokuma, "How Can Fluctional Chiral Lanthanide (III) Complexes Achieve a High Stereoselectivity in Aqueous Mukaiyama-Aldol Reaction?", *ACS Catal.* 5, 3731-3739 (2015).

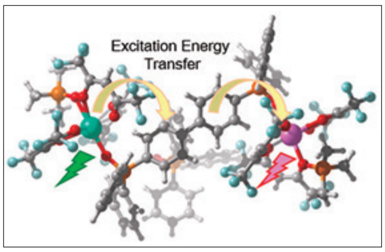

Fig. 3
Excitation energy transfer pathway of the thermometer using lanthanide luminescence

Mesoscopic Materials Science (with Panasonic Corporation)



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Education and Research Activities in the Laboratory

We aim to cultivate researchers who will carry out investigations on new physical phenomena and devices at the mesoscopic scale, and who will promote interdisciplinary research and open up new research areas. In the master's program, we first provide students with a basic education in order for them to grasp the reasons why our research is necessary for society, and why research in science and technology is essential for the development of humankind. Then, based on this education, students participate in our research activities in mesoscopic and nano fields, experiencing the joy of new discoveries and skilled manufacturing through experiments. Thus, we nurture researchers who can take on basic responsibilities in the development of new science and technology.

In the doctoral program, we not only provide guidance on specific research themes but also clarify the difference between science and engineering, thus providing students with adequate guidance so that they can, in a balanced manner, utilize both a scientific mindset that leads to paradigm shifts, and engineering knowledge that serves to realize scientific ideas.

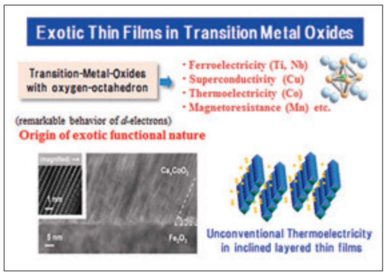

Fig. 1
A conceptual illustration of strongly correlated electronic materials and the layer-controlled thermoelectric thin film structure

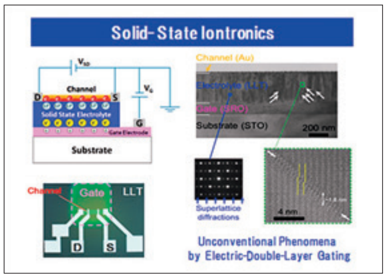

Fig. 2
A conceptual illustration of a solid-state iontronics device made of ion-conducting epitaxial thin film

Research Themes

We conduct research on exotic devices utilizing new physical phenomena in the mesoscopic region that take advantage of thin-film technology. Specifically, we are conducting research on novel energy conversion devices using strongly-correlated electronic materials and/or solid-state iontronics materials.

1. Strongly correlated electronic materials (Fig. 1)
Research of novel devices utilizing cross-correlated phenomena

2. Solid-state iontronics materials (Fig. 2)
Search for new phenomena using electric-double-layer derived in ion-conducting thin films

Recent Research Papers and Achievements

1. I. Fujii, S. Tagata, T. Nakao, N. Koyama, H. Adachi, and T. Wada, "Fabrication of (K, Na) NbO_3 films on $SrRuO_3$/(001)$SrTiO_3$ substrates by pulsed laser deposition", *Jpn. J. Appl. Phys.* **54** (10) 10NA13 (2015).
2. K. Wasa, S. Yoshida, H. Hanzawa, H. Adachi, T. Matsunaga, and S. Tanaka, "Structure and ferroelectric properties of high T_c $BiScO_3$–$PbTiO_3$ epitaxial thin films", *IEEE Trans. UFFC* **63** (10) 1636-1641 (2016).
3. T. Asano, Y. Kaneko, A. Omote, H. Adachi, and E. Fujii, "Conductivity modulation of gold thin film at room temperature via all-solid-state electric-double-layer gating accelerated by nonlinear ionic transport", *ACS Appl. Mater. Interfaces* **9**, 5056-5061 (2017).

Functional Polymer Science (with Santen Pharmaceutical Co., Ltd.)

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Education and Research Activities in the Laboratory

1. Educational Purposes

We cultivate human resources with the ability to identify and solve research challenges, as well as those who can contribute to society through research activities in drug discovery based on synthetic organic chemistry. We provide research and education aiming to develop human resources who dream of performing skilled manufacturing and spare no effort in achieving their dreams. Thus, we place emphasis on the understanding of research backgrounds and positioning, experimental design and techniques, result analysis, discussion, and how to derive conclusions.

2. Guiding Principle

We provide guidance to students so that they can acquire the basic experimental capabilities to obtain correct and reliable data and, at the same time, give consideration to safety and health during actual chemical experiments.

Research Themes

New Drug Delivery System Project

The Functional Polymer Science Laboratory, a collaboration course between Santen Pharmaceutical Co., Ltd. and Nara Institute of Science and Technology, has been conducting research activity since April 2005. Our current main research focus is on new drug delivery systems (DDS) for the treatment of various eye diseases. Within ocular DDS development there are many challenging subjects for pharmaceutical and ophthalmologic sciences remaining, such as improvement of intraocular migration and intraocular sustainability of drugs. DDS for the eye are categorized into two main segments, anterior and posterior chambers (Fig. 1 & 2). Now especially, sustained-release type DDS using inactive ingredients, such as an ascorbic acid ester derivative, are being studied to treat diseases of the posterior chamber of the eye (Fig. 3).

Recent Research Papers and Achievements

1. T. Honda, et al. Bioorg. Med. Chem. Lett. 18, 2939 (2008).
2. T. Honda, et al. Bioorg. Med. Chem. 17, 699 (2009).
3. H. Tajima, et al. Bioorg. Med. Chem. Lett. 20, 7234 (2010).
4. H. Tajima, et al. Bioorg. Med. Chem. Lett. 21, 1232 (2011).
5. T. Honda, et al. Bioorg. Med. Chem. Lett. 21, 1782 (2011).
6. N. Kojima, et al.: Development of a novel in situ depot system using low molecular weight gelators. General Oral Presentation (27R-pm04), The 135th Annual Meeting of the Pharmaceutical Society of Japan in Kobe (March, 2015).
7. K. Kudo, Heterocycles, 91, 1591 (2015).

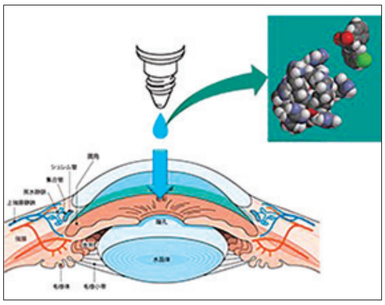

Fig. 1
DDS for eye disease (anterior chamber)

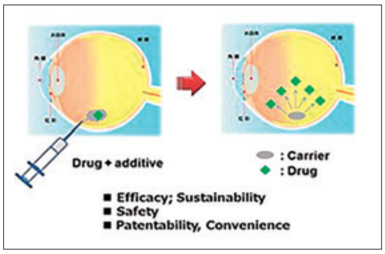

Fig. 2
DDS for eye disease (posterior chamber)

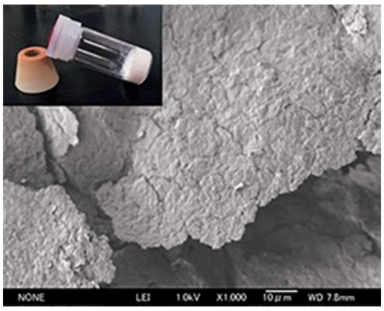

Fig. 3
Injectable gel for DDS using ascorbic acid ester derivative and its SEM image

Ecomaterial Science (with Research Institute of Innovative Technology for the Earth)

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Education and Research Activities in the Laboratory

The Ecomaterial Science Laboratory, staffed by researchers of the Research Institute of Innovative Technology for the Earth (RITE), provides research and education on fundamental technologies to solve the global warming issues. We endeavor to develop advanced materials for CO_2 capture and inorganic membranes for H_2 energy production. Specifically, solid materials (e.g. zeolite, mesoporous silica, MOF) have been investigated in order to reduce the energy requirements and cost for CO_2 capture. Concerning CO_2-free, H_2-based energy systems generated by any renewable sources, it is necessary to develop efficient processes for the dehydrogenation of chemical hydrides such as methylcyclohexane or ammonia. We evaluate silica, zeolite and palladium membranes for the processing of chemical hydrides.

In our laboratory, we normally provide our students with OJT (on-the-job training) education through the projects conducted in RITE. The students can deepen their understanding of social contexts, causes and countermeasures concerning global environmental issues. They also learn fundamental knowledge of material science in relevant subjects such as physical chemistry, organic/inorganic chemistry, synthesis, and chemical engineering.

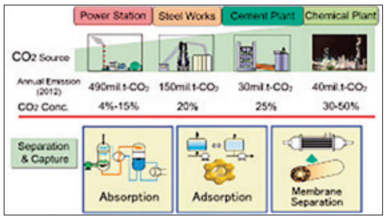

Fig. 1
CO_2 separation and capture technologies

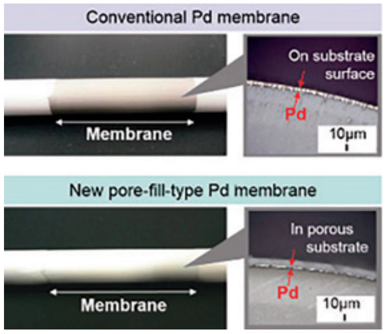

Fig. 2
Novel palladium (Pd) membrane for H_2 separation

Research Themes

1. Development of CO_2 capture technologies

Research on high-performance and energy-saving materials for gas separation in the fields of greenhouse gas mitigation, air quality control in space stations, etc.

· zeolite · mesoporous materials · polymeric materials
· metal organic framework (MOF)

2. Development of inorganic membranes for an H_2 energy society

Research on various separation membranes for use of inorganic materials.

· palladium (Pd) membranes · zeolite membranes
· chemical vapor deposition (CVD) based silica membranes

3. Computer-aided material development

Multi-scale simulations playing an important role in material developments.

· quantum chemical calculation · molecular dynamics (MD)
· process simulation

Recent Research Papers and Achievements

1. K. Kida, Y. Maeta, K. Yogo, "Preparation and gas permeation properties on pure silica CHA-type zeolite Membranes", Journal of Membrane Science, 522, pp. 363–370 (2017).
2. D. S. Dao, H. Yamada, and K. Yogo, "Response surface optimization of impregnation of blended amines into mesoporous silica for high-performance CO_2 capture", Energy & Fuels, 29, pp.985−992 (2015).
3. M. Miyamoto, T. Nakatani, Y. Fujioka, K. Yogo "Verified synthesis of pure silica CHA-type zeolite in fluorite media", Microporous and Mesoporous Materials, 206, pp.67-74 (2015).

Sensory Materials and Devices *(with Shimadzu Corporation)*

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Prof.
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Education and Research Activities in the Laboratory

We are advancing our research on sensor and device-related fundamental technologies such as microfabrication. We take advantage of these technologies to then conduct research on various devices such as electrophoresis chips, cell culture chips (Fig.1), microreactors, electro-osmotic pumps, and vapor-liquid separation chips. Additionally, we are also furthering research on molecular imaging technology (Fig.2) and X-ray image sensor systems (Fig.3) to be applied in the medical diagnosis field, as well as working on the integration of these technologies to realize highly functional ultra micro chemical analysis systems (μTAS: Micro Total Analysis Systems).

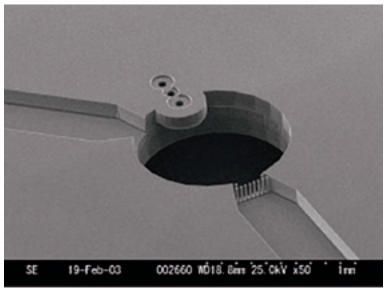

Fig. 1
Cell culture chips

Research Themes

Taking advantage of semiconductor manufacturing process technologies to apply micromachining to silicon and glass substrates of sub-micron dimensions, we develop functional devices with one-micron sized three dimensional structures that are used for chemical analysis and chemical manipulation (reaction or extraction).

We are also active in the medical diagnosis field, focusing on molecular imaging technology and X-ray imaging systems. We pursue the application of molecular imaging-related technologies such as the molecular design of molecular probes or microreactor based synthetic apparatuses, to medical diagnosis fields including cancer detection at its very early stage. X-ray imaging systems are an important technology in the medical diagnosis field and are investigating a large area 2D X-ray detector composed of a poly crystalline CdZnTe film, a thin film transistor array and read out electronics.

Our laboratory research themes include:

1. Microchemical analysis systems
2. Microreactors and micropumps
3. Molecular imaging
4. X-ray photoconductor materials: Poly crystalline growth and evaluation
5. X-ray imaging systems

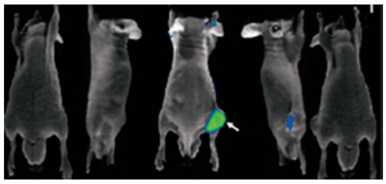

Fig. 2
Molecular imaging probe "Lactosome" for cancer (→ : cancer)

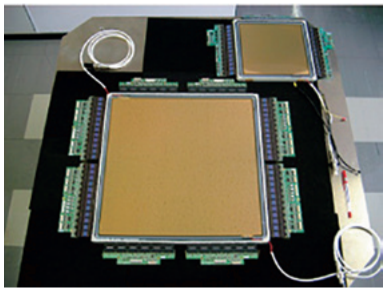

Fig. 3
An X-ray image sensor for diagnosis

Recent Research Papers and Achievements

1. Y. Kakimoto et al., "The Effects of Ar Plasma Etching and UV Ozone Treatment on Single-crystal CdTe", The 63th JSAP Spring Meeting, Tokyo Institute of Technology, Tokyo, Japan (2016).
2. T. Okamoto et al., "Deposition of Cl-doped CdTe polycrystalline films by close-spaced sublimation", Phys. Status Solidi. C12(6), 532–535 (2015).
3. T. Okamoto et al., "Deposition of polycrystalline Cd1-xZnx Te films on ZnTe/graphite and graphite substrates by close-spaced sublimation", Phys. Status Solidi. C11 (7-8), 1178-1181 (2014).
4. S. Okuyama et al., "Formation of CdS/CdZnTe, ZnS/CdZnTe hetero junction by solution growth method", The 61th JSAP Spring Meeting, Aoyama Gakuin University, Kanagawa, Japan (2014).
5. Y Yamakawa et al., "Development of a dual-head mobile DOI-TOF PET system having multi-modality compatibility", Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), Seattle, WA, USA (2014).
6. KK. Miyake et al., "Performance Evaluation of a New Dedicated Breast PET Scanner Using NEMA NU4-2008 Standards", Journal of Nuclear Medicine 55(7), 1198-203 (2014).
7. Y. Kimura et al., "Novel system using microliter order sample volume for measuring arterial radioactivity concentrations in whole blood and plasma for mouse PET dynamic study", Physics in Medicine and Biology 58(22), 7889-903 (2013).

Advanced Functional Materials (with Osaka Research Institute of Industrial Science and Technology)



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Education and Research Activities in the Laboratory

Polymers, ceramics and metals are materials used widely in industry. Their applications are widespread from structural uses to a variety of functional uses. We devote our efforts to develop these materials and their nanocomposites to be applied in advanced industry. We focus on the nanostructure control of the materials to realize next generation electronic, optical, and energy devices. Another important challenge is the development of environmental-conscious material processing technology. Our laboratory is located in the Osaka Research Institute of Industrial Science and Technology, Morinomiya Center near the downtown area of Osaka city. Our laboratory conducts intimate collaborations with engineers from private companies; this leads to the rapid application of the developed materials into practical devices.

Research Themes

1. **Highly thermal conductive materials and transparent and highly thermal emissivitive coating materials**
   Super hybrid materials made up of honeycomb structures with nanoparticles show 10 W/(m K) of thermal conductivity with electric insulation, although those with co-continuous phases, made by SPS method have been developed to attain super highly thermal conductivity (> 120 W/(m K). Furthermore, those with both a high thermal emissivity (> 0.9) and light transparency (haze<2%) have been developed, resulting in application to heat releasing materials in LED devices, communicators, robots and rockets.).
2. **Biomass polymer materials with unique properties**
   A group of environmental and functional polymer materials, poly(lactic acid) materials, was developed to obtain properties of similar flexibility, high elongation and transparency to polyethylene, although they were perfectly biodegradable. Additionally, poly(lactic acid) can be synthesized to have high adhesion strength and unique rheological properties, because of high brunch chains and approximately 1 of Mw/Mn.
3. **Highly reliable wiring fabrication on flexible polymer substrates**
   The core technology to fabricate wiring pattern is selective polymer metallization using plating. Along with plating technology, nanoparticle fabrication and the surface engineering of polymers are fully used to develop wiring with controlled nanostructures at the metal/polymer interface.
4. **Lithium ion batteries fully composed of ceramics**
   Our research is aimed at the development of an all solid state lithium ion battery with high safety standards and high rechargeable capacity without liquid leakage. Our approaches to fabricate this lithium ion battery are economically and ecologically viable techniques expected to be used in industry. Core techniques employed are the slurry coating, aerosol deposition and the spray pyrolysis methods.

Recent Research Papers and Achievements

1. T. Nagayama, T. Yamamoto, T. Nakamura, Y. Fujiwara, "Properties of electrodeposited invar Fe–Ni alloy/SiC composite film", *Surface and Coatings Technology*, **322C**, 70-75 (2017).
2. Y. Agari, K. Uotani, K. Mizuuch, H. Hirano, J. Kadota, A. Okada, "Preparation and Properties of Al alloy/PPS Hybrid Materials with Co-continuous Phases by Spark Plasma Sintering Method", Asia Thermophysical Properties Conference 2016 (Yokohama).
3. M. Takahashi, J. Tani, H. Kido, A. Hayashi, K. Tadanaga, and M. Tatsumisago, "Thin Film Electrode Materials Li4Ti5O12 and LiCoO2 Prepared by Spray Pyrolysis Method", 2011 IOP Conf. Ser. Mater. Sci. Eng., 18, 122004.

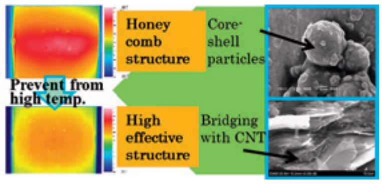


Fig. 1
Honeycomb structure of phenol resin particles with thermal conductive BN nanoparticles, or bridged structure of graphite plates with CNF has promoted thermal conductivity to increase immediately (two times).

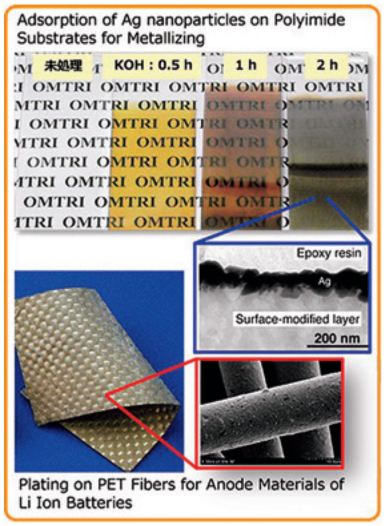


Fig. 2
Metallizing of Polymer Substrates

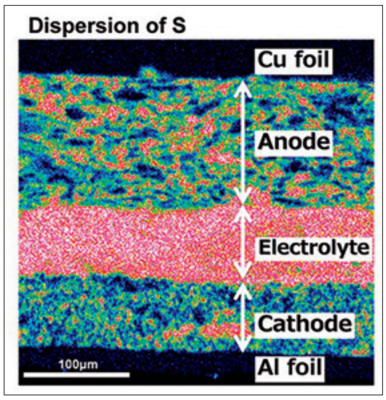


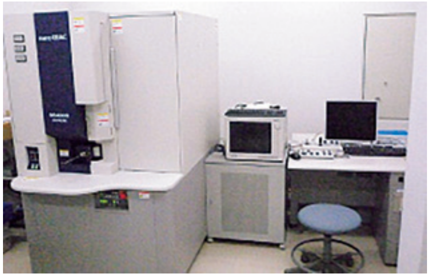
Fig. 3
A cross-section of an all solid state lithium ion battery. The layer by layer structure is composed of a cathode ($LiNi_{1/3}Co_{1/3}Mn_{1/3}O_2$with Li_3PS_4 and acetylene black), a solid state electrolyte (Li_3PS_4), and an anode (carbon with Li_3PS_4 and acetylene black).

Research Instruments

Transmission
Electron Microscope
(TEM)

Scanning Transmission
Electron Microscope
(STEM)

Low Vacuum Scanning
Electron Microscope
(LVSEM)

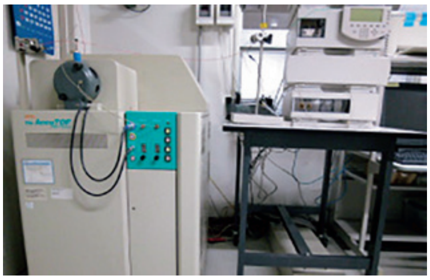


Nano-prober/EBAC

Scanning Probe
Microscope
(SPM)

Focused Ion Beam
(FIB)

Double-focusing
Mass Spectrometer



Electrospray Ionization(ESI)
High Resolution
Time-of-Flight Mass
Spectrometer

MALDI-TOF Mass
Spectrometer

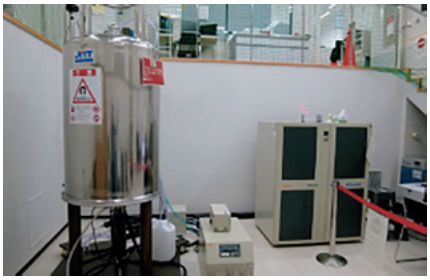
High Resolution
MALDI-TOF
Mass Spectrometer

DART Mass
Spectrometer

Wide-angle
X-ray Diffractometer
(WAXD)

Single Crystal
X-ray Diffractometer and
Structure Analysis System

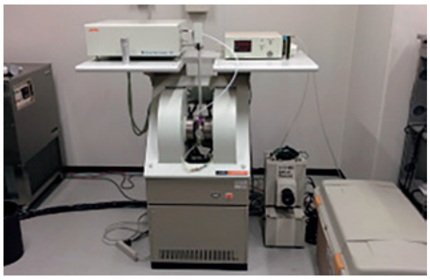
Small-angle
X-ray Scattering
Diffractometer
(SAXD)



600MHz
Nuclear Magnetic Resonance
(600MHz NMR)

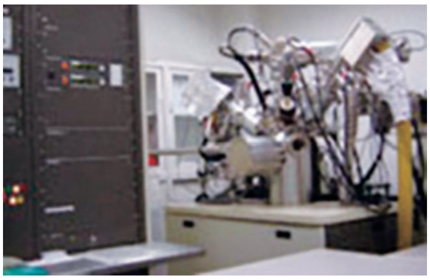
500MHz
Nuclear Magnetic Resonance
(500MHz NMR)

400MHz Solid-state
Nuclear Magnetic Resonance
(400MHz Solid-state NMR)



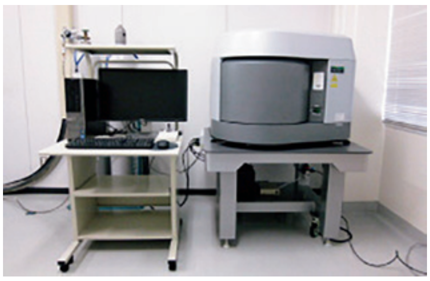
Electron Spin Resonance
(ESR)

Electron Probe
MicroAnalyser
(EPMA)



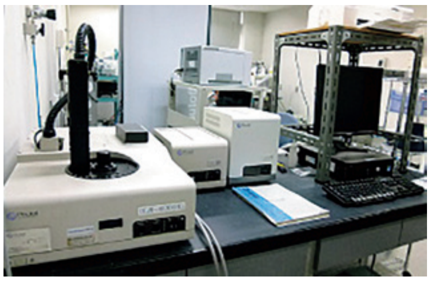
Secondary
Ion Mass Spectrometer
(SIMS)

X-ray Photoelectron
Spectroscope
(ESCA)



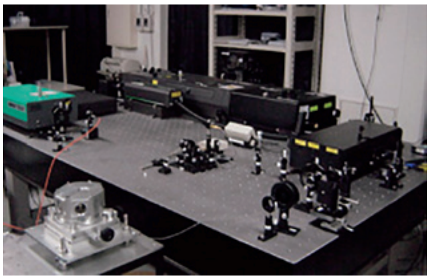
Micro Raman
Spectrometer

Circular Dichroism
Spectropolarimeter
(CD)



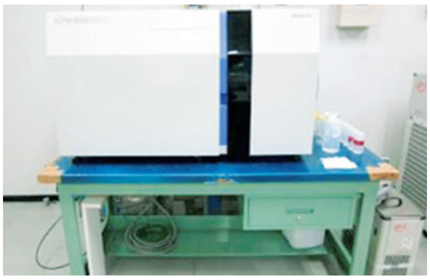
Dynamic Light Scattering
Spectrometer
(DLS)

Spectroscopic Ellipsometer



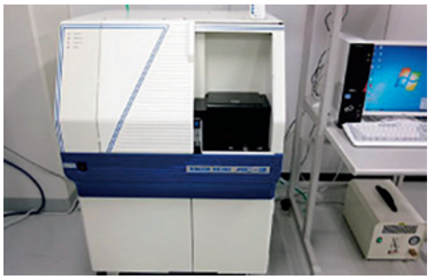
Photoluminescence Lifetime Measurement System

Elemental Analysis
(EA)



Inductively Coupled Plasma Mass Spectrometer
(ICP-MS)

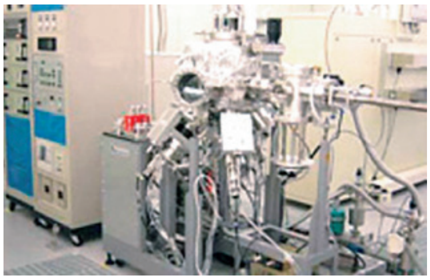
Differential Scanning Calorimeter / Simultaneous Thermogravimetric Analyzer
(DSC / TG-DTA)



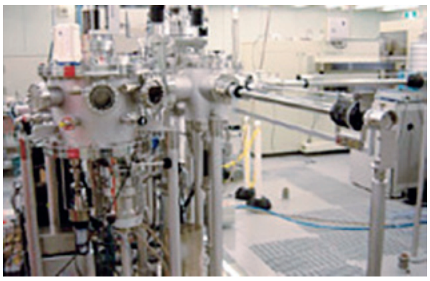
Photoelectron Yield Spectroscopy
(PYS)

Electron Beam Lithography Exposure

Projection Aligner



Oxide Complex Thin Film Coating Apparatus



High Purity Metal Sputter

Surface Profiler

NAIST®