Department of Electrical and Electronic Information Engineering

Electronic Materials

Electrical Systems

Integrated Electronics

Information and Communication Systems

Electronic Materials

Photonics Laboratory

Staff	• Professor	**Mitsuo FUKUDA**	(E-mail：fukuda@ee.tut.ac.jp)
	• Associate Professor	**Takeshi ISHIYAMA**	(E-mail：ishiyama@ee.tut.ac.jp)
	• Assistant Professor	**Yuya ISHII**	(E-mail：yishii@ee.tut.ac.jp)
Laboratory URL	http://www.photon.eee.tut.ac.jp/		
Key words	Surface plasmon, Photonic integrated circuit, OEIC, Optical equipment, Optical sensing, Semiconductor nanostructure, Nanowire, Transparent conductive film, Optical and electronic material, Nanofiber		

We undertake basic and applied research of light, the basis of photonics, and photons and electrons. We undertake development of nano-photonic devices using near-field light and surface plasmons that can confine light beyond the diffraction limit of light; technology that transfers signals that are the basis of light frequencies in the nano region; light-emitting elements using silicon and zinc oxide; and applied research for medical, food, agricultural and environmental measurements using semiconductor lasers.

Theme 1 ▶ Development of surface plasmon devices

With the aim of developing next-generation (silicon-based) opto-electronic integrated devices at the nanoscale beyond the diffraction limit of light, we undertake research and development of devices that use surface plasmons(Figure 1).

(1) We undertake research of nanoscale optical resonators (optical accumulators), surface plasmon detectors and modulators.

(2) In order to achieve communication using light frequencies at the nanoscale, we undertake R&D on nanoscale optical communication technology via surface plasmons.

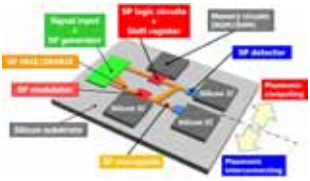


Figure 1 Target plasmonic integrated circuits

Theme 2 ▶ Study in nanostructures with new optical and electronic properties

In optical and electronic materials such as semiconductors, we undertake research to find materials and structures with new characteristics through atomic level control. Further, through scaling to the nanoscale, we discover nanostructures with new optical properties and electronic properties, and aim to apply them to the nanophotonics and nanoelectronics fields.

(1) Light-emitting materials research through semiconductor nanostructures (Figure 2): We undertake research on nanostructure growth in silicon, the basic material for electronics, and oxide semiconductors that have light-emitting properties. We advance improvements in performance through use of nano-hole templates and light-emitting impurity doping.

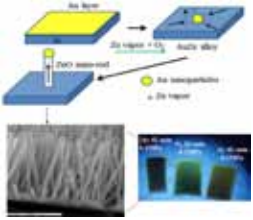


Figure 2 ZnO nanorods and their green luminescence

(2) Research on transparent conductive films and light element materials: We conduct research on optical element materials that combine transparent conductive films and semiconductor nanostructures, focused on indium tin oxide (ITO).

Theme 3 ▶ Development of optical equipments

We develop various optical devices that can be applied to medical or agricultural fields using optical fibers, LEDs and semiconductors, etc (Figure 3).

(1) Using the properties of invisible infrared light, we undertake R&D on living body observation devices and devices for detecting foreign objects in food. Through confirming the principles of foreign object detection for organic matter such as hair and insects which have been hard to detect up to now, and developing new devices, we are nearing achievement of observation of the bones in the palm and blood vessels, etc., and wing tips, and detection of organic foreign objects in food.

(2) Using optical coherence tomography (OCT), we are developing devices to image processed food, fruit and vegetables, etc. without damaging their internal structure.

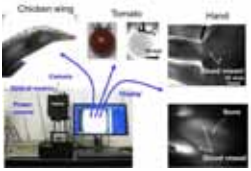


Figure 3 Observation devices and observation for living bodies and inside food

Advanced Materials Science Laboratory

Staff	• Professor **Atsunori MATSUDA** (E-mail : matsuda@ee.tut.ac.jp) • Assistant Professor **Go KAWAMURA** (E-mail : gokawamura@ee.tut.ac.jp)
Laboratory URL	http://ion.ee.tut.ac.jp/
Key words	Sol-Gel, Mechanical Milling, Anodization, Fuel Cells, All-Solid-State Lithium Ion Batteries, Metal-Air Batteries, Solar Cells, Superhydrophilic/Superhydrophobic, Photocatalyst, Plasmonic Nanoparticles

We undertake research on manufacture of and applications for functional materials. The materials are prepared by means of liquid phase syntheses such as sol-gel, ball-milling, anodization, etc.

Theme 1 ▶ New Generation Fuel Cells

We have developed novel electrolyte composed of phosphoric acid doped polybenzimidazole and inorganic solid acid complex for fuel cells. The inorganic solid acid complex is prepared by ball milling method and the composite electrolyte thus obtained exhibits high thermal stability and high proton conductivity at 100 °C and up. The electrolyte is also mechanically strong and flexible as seen in Fig. 1. The maximum power density at 160 °C and under anhydrous condition is 400 mW cm-2.

Fig. 1 Photo of electrolyte for fuel cell

Theme 2 ▶ Synthesis of Plasmonic Nanostructures for Photocatalyst and Solar Cells

We have synthesized several kinds of plasmonic nanostructures composed of noble metal nanoparticles and nano/meso-porous metal oxides prepared by sol-gel, anodization, etc. Fig. 2 shows transmission electron microscope (TEM) images of Au deposited mesoporous SiO2-TiO2. Au was deposited with selected shapes of sphere and rod. These materials show high performance of photocatalysis under sunlight because they absorb the photons very efficiently. Fig. 3 shows SEM image of Ag nanoparticle-deposited TiO2 nanotube arrays. This can be used as photoanode of dye-sensitized solar cells to capture more photons by plasmonic effects of Ag nanoparticles.

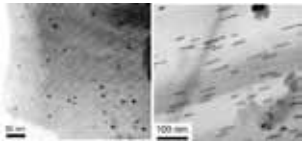


Fig. 2 TEM images of Au nanosphere (left) and Au nanorod (right) deposited mesoporous SiO2-TiO2 photocatalysts

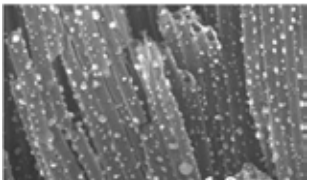


Fig. 3 SEM image of Ag nanoparticle deposited TiO2 nanotube array electrode for solar cell

Theme 3 ▶ All-Solid-State Li Ion Secondary Battery

We have developed novel synthetic method for a precursor of Li3PS4 solid electrolyte for Li ion secondary battery. The precursor was composed of Li3PS4 and ethyl acetate in a molar ratio of 1:2, as determined by thermogravimetric-differential thermal analyses (TG-DTA). Upon drying at 160 °C, the precursor decomposed to form crystalline Li3PS4 with a high ionic conductivity of 3.3 × 10−4 S cm−1 and low activation energy of about 31 kJ mol−1. Fig. 4 shows a scanning electron microscope (SEM) image of Li3PS4 solid electrolyte which is derived from the newly developed precursor.

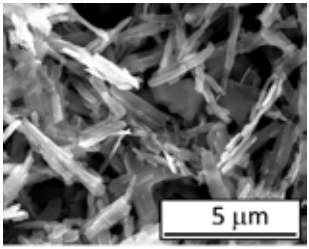


Fig. 4 SEM image of Li3PS4 solid electrolyte derived from the newly developed precursor for Li ion battery

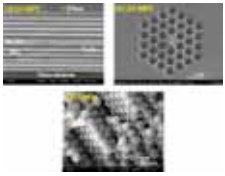
Spin Electronics Group

Staff	• Professor	**Hironaga UCHIDA**	(E-mail：uchida@ee.tut.ac.jp)
	• Associate Professor	**Yuichi NAKAMURA**	(E-mail：nakamura@ee.tut.ac.jp)
	• Associate Professor	**Hiroyuki TAKAGI**	(E-mail：takagi@ee.tut.ac.jp)
	• Associate Professor	**Pang Boey LIM**	(E-mail：may2lim@cie.ignite.tut.ac.jp)
	• Assistant Professor	**Taichi GOTO**	(E-mail：goto@ee.tut.ac.jp)
Laboratory URL	http://www.spin.ee.tut.ac.jp/		
Key words	Magnetics, artificial magnetic lattice, magnetophotonic crystal, spin, photonics, nanostructure, spintronics, magnonics, spin caloritronics, thermoelectric conversion, plasmonics, magnetic materials		

Electrons, which play the leading role in electronics, have a property called spin. Spin is the origin of ferromagnetism and plays an important role in electrical and electronic information engineering fields. By controlling the orientation and extent of this spin, it is possible to control various physical quantities such as light, high-frequency electromagnetic waves or ultrasonic, offering attractive functions. Recently, a new field of engineering that seeks to apply semiconductor materials with spin dependence (magnetic semiconductors) and spin information current (spin current) is being formed, and the research called spin caloritronics related to the interaction of heat and spin is advancing.

Theme 1 ▶ Development of spin functional materials

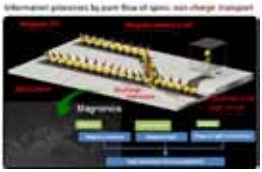
We develop magnetophotonic crystals (original to our group) that can localize light spatially and increase the non-reciprocal optical response and thin-film materials that use bonds with plasmons. We also develop new materials with spin functions such as thermoelectric multilayered materials, magnetic hologram, and magnonic crystal magnetic oxides using sputtering and PLD / MBE methods; heterostructure film formation using lasers, while considering process technology development and application devices.



Magnetophotonic crystals

Theme 2 ▶ Development of optical and high frequency spin system

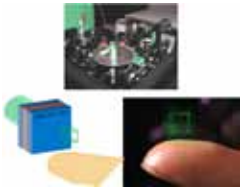
Large-capacity holographic data storage with collinear interference systems have been recognized as a world-first international standard from our research result. Currently, we are working to develop high density holographic data storage systems with rewritable recording systems using artificial magnetic lattice media with polycrystalline spin materials of nanoscale particle size. Further, using magnonic crystals that manipulate spin-wave, we are developing completely new magnonic devices using spin-wave, such as a magnonic circuit using ultra-low damping magnetic oxides.



Magnonic system using flow of spin wave

Theme 3 ▶ Development of integrated spin device

We developed the world's fastest solid spatial light modulator (SLM) using the magneto-optical effect at approximately 10 ns per pixel. Currently, we are further developing this device, and developing integrated spin devices such as a solid SLM that works in the visible short wavelength region. Additionally, we are developing a magneto-optical holographic display as the ultimate 3D display to reproduce the wave front state of object light.



Developed hologram writing/ reading system and three-dimensional display using

Theme 4 ▶ Spin caloritronics applications

Aiming to realize thermoelectric power generation, in addition to exploring raising the performance of oxide thermoelectric materials and novel materials, we are developing an actual thermoelectric conversion module. In addition, regarding the recently discovered spin Seebeck effect (magnetic Seebeck effect), starting with the fundamental study of spin current measurement using the inverse spin hall effect, we are aiming to develop spin control devices based on heat and new thermoelectric power generation modules using the spin phenomenon.

Theme 5 ▶ Plasmonic composite structure

In magnetic garnet composite structure with Au particles, which is one of artificial magnetic lattices, Faraday rotation is enhanced at a wavelength where surface plasmon resonance is excited. A composite structure with randomly arranged Au particles has the almost constant resonant wavelength, which shows enhancement of Faraday rotation. However, a composite structure with periodically arranged Au particles shows different optical and magneto-optical responses. By using the finite-difference time-domain (FDTD) simulation, we discuss obtained properties. Furthermore, application of the plasmonic composite structures are investigated.

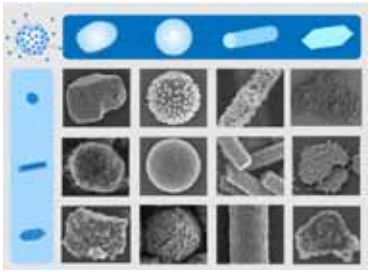
Processing and Instrumental Mechanics Laboratory

Staff	• Professor **Hiroyuki MUTO** (E-mail : muto@ee.tut.ac.jp)
Laboratory URL	http://ion.ee.tut.ac.jp/
Key words	nano-composite, functional / structural ceramics, composite particles, discrete element method, finite element method, nano-indentation, superplastic deformation

To further advance various electronic devices, it is essential to develop materials with properties that surpass existing properties. Up to now, as a method to both improve properties and enable new ones, our laboratory has proposed novel fabrication technique for nanocomposites that can optimally design microstructures using electrostatic attractive force, and studied improvements in mechanical, heat and electrical properties. Additionally, since there is an urgent need for the establishment of technologies that can universally and scientifically perform evaluative analysis of the properties of the resulting materials, we are studying to establish property evaluation technology.

Theme 1 ▶ Functional composite ceramic materials based on their nanostructure control

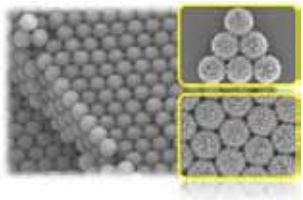
The mechanical and functional properties on composite materials, such as strength and fracture toughness, etc., can be enhanced by controlling microstructure. However, in some cases, the expected performances are difficult to obtain by using the conventional mechanical powder mixing technique. In this study, various kinds of functional composites can be fabricated by novel nano-assembly technique.



Composite materials via proposed technique

Theme 2 ▶ Development of functional composited particles

This study is to prepare novel functional composite particles via electrostatic adsorption technique. Various kinds of composite particles can be obtained by nano-sized materials such as carbon nanotube, adsorbed on matrix particle. This technique is expected to serve in electrochemistry application, high-effective catalysts and optical devices.

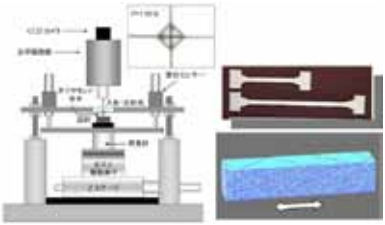


Ordered structure of functional composite particles

Theme 3 ▶ Deformation and flow of advanced materials

This project is to discuss the deformation and flow on the polycrystalline materials (such as ceramics typically) at not only room temperature but also high temperatures. The novel testing procedure and theoretical analysis including computer simulation are proposed in this study.

a. Analysis of the mechanical property of thin films by nano-indentation technique.
b. Surface mechanical property evaluation by scratch test
c. Superplastic deformation on nanostructured materials



Evaluation techniques in our laboratory

Electronic Materials

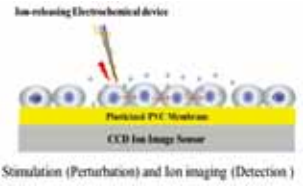
Electroanalytical Chemistry Laboratory

Staff	• Associate Professor **Toshiaki HATTORI** (E-mail：thattori@ee.tut.ac.jp) • Assistant Professor **Ryo KATO** (E-mail：ryo_kato@crfc.tut.ac.jp)
Laboratory URL	http://www.electroanal.ee.tut.ac.jp/
Key words	Ion sensor, ion imaging, electrochemical device, chemical stimulation, polyelectrolyte, chemical observation, living cells and tissue, bio-friendly system

Our laboratory researches micro electrochemical devices and array type ion image sensors, and investigates the application of polyelectrolytes for electrochemical devices. The aim and concept is to fabricate a bio-friendly system for chemical observation of cells and tissues.

Theme 1 ▶ Development of Micro Electrochemical Devices to Release Ions

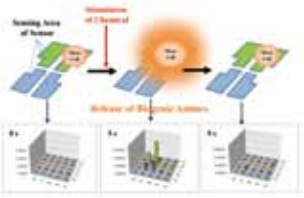
Living action of cells and tissues is due to a conversion and/or a transfer of chemical substances. In order to analyze the action of a tissues, controlled techniques is required; only a cell is stimulated in local, and then the change of chemical substances by the stimulation transfer is monitored. We are developing micro ion-release electrochemical devices to the chemical stimuli. The electrochemical ion-release device is an important tool to stimulate a cell chemically without other effects.



bio-friendly system
An electrochemical system observes living cells by a chemical stimulation.

Theme 2 ▶ Development of Electrochemical Ion Image Sensor

Ion selective electrodes (ISE) and semiconductor ion sensors (ISFET/CCD ion sensor) can measure a specific ion immediately. We have developed ISEs for polyelectrolytes and non-ionic chemicals that had been regarded as difficulty of its detection from Nernst equation. Recently, using a CCD-type ion image sensor that was developed by Professor Sawada in TUT, we are developing chemical imaging of several metal ions and biologically-important organic ions. The image sensors can monitor living cells and tissues non-invasively.



mast cell stimulation
The ion image sensor monitors the concentration change of biogenic amines released from mast cells by a chemical stimulation. 3D images show each sensor response around a mast cell stimulated.

Theme 3 ▶ Application of polyelectrolytes

Polyelectrolytes act as substances with unique functions. We had developed analytical methods for various synthetic and natural polyelectrolytes (chitosan, heparin, chondroitin sulfate, and polyhexanide hydrochloride, etc.) using titration, electrochemical analysis (voltammetry and potentiometry), and capillary electrophoresis. In addition the reaction of polyelectrolyte with proteins has been analyzed. Now, we develop electrochemical devices using polyelectrolytes.

polyelectrolyte ternary complex
A polyelectrolyte ternary complex releases calcium ion by electrolysis.

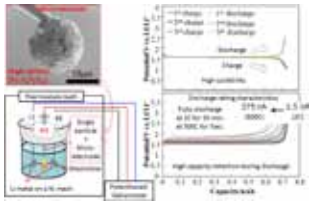
Clean Energy Conversion Laboratory

Staff	• Professor **Yoji SAKURAI** (E-mail：sakurai@ee.tut.ac.jp) • Associate Professor **Ryoji INADA** (E-mail：inada@ee.tut.ac.jp) • Assistant Professor **Tomohiro TOJO** (E-mail：tojo@ee.tut.ac.jp)
Laboratory URL	http://www.cec.ee.tut.ac.jp/
Key words	Lithium-ion batteries, Multivalent ion batteries, All-solid-state batteries, Battery materials, measurement

In order to provide integrated solutions to resource energy and environmental issues and meet societal demands such as for diversification, low environmental impact and decentralization of power sources in the desired ubiquitous network clean energy society, long life secondary batteries and high efficiency fuel cells with low environmental load and high energy density are essential. R&D on new materials, processes and evaluation technologies that will be the foundation of these power sources will become more and more important in the future. This laboratory is broadly deploying R&D that contributes to high safety, low cost, high performance and high reliability of electrochemical energy conversion devices, while looking to their use in clean vehicles such as electric and fuel cell vehicles and the renewable energy generation field.

Theme 1 ▶ Research for next-generation high-performance secondary batteries

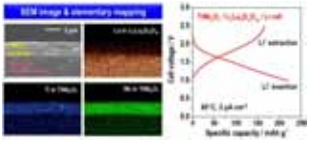
We are putting our attention on environmentally friendly, low cost electrode materials, making clear the material physico-chemical properties, battery operating conditions and various reaction process correlations that occur within batteries such as charge transfers, mass transfers and side reactions. We are also conducting research to improve the performance of lithium-ion batteries by clarifying battery reaction mechanisms. We are also working on research for new battery types such as multivalent ion batteries.



Charge-discharge property of new battery material using single particle measurement system.

Theme 2 ▶ Research for oxide-based all-solid-state battery

All-solid-state lithium-ion batteries, using nonflammable inorganic solid Li-ion conductor as an electrolyte, is expected as one of the next generation energy storage devices, because its safety and reliability are much superior to present lithium ion batteries with flammable organic carbonate liquid electrolyte. However, development of solid electrolytes with both high ionic conductivity and minimizing interfacial resistance between solid electrolyte and electrodes are critical issues to be solved. In our laboratory, oxide solid electrolyte with high ionic conductivity and chemical stability against electrode materials are developed. In addition, aerosol deposition (AD) method, which is polycrystalline ceramic film formation process under room temperature, is applied for novel fabrication process of all-solid-state batteries.



Film electrode formed on oxide solid electrolyte by AD (left) and its charge and discharge property (right).

Theme 3 ▶ Research of new measurement technologies for batteries

There is a trend for lithium-ion batteries to be used in more large scale applications, but fires or explosions may occur if a fault occurs due to the high energy density, and together with recent large-scale recalls, the battery safety has become an issue for society. In this research, we develop battery measurement technologies to detect problems in the production and use of batteries in advance and that can non-destructively identify battery degradation causes.

Electrical Systems

Plasma Energy System Laboratory

Staff	• Professor	**Hirofumi TAKIKAWA** (E-mail：takikawa@ee.tut.ac.jp)
	• Associate Professor	**Yoshiyuki SUDA** (E-mail：suda@ee.tut.ac.jp)
	• Assistant Professor	**Toru HARIGAI** (E-mail：harigai@ee.tut.ac.jp)
Laboratory URL	http:// www.pes.ee.tut.ac.jp	
Key words	Vacuum plasma, atmospheric-pressure plasma, diamond-like carbon, eco-energy, nanocarbon, energy devices	

Theme 1 ▶ Effective utilization of renewable energy and eco-energy

Securing sufficient energy and protection of the global environment are important issues for human. In order to deal with these issues, we are working on research to effectively utilize clean energy (solar energy and wind energy) from the Sun that is the enormous plasma and eco-energy (cogeneration) from energy recovery system such as exhaust heat utilization.

(1) Eco-energy system design and its high-efficiency operation
(2) Utilization and application of weather measurements and solar panel systems
(3) Energy environment control on the cultivation of plants


Solar panels of TUT

Theme 2 ▶ Development of apparatus using generation and control of plasma and its applications for industrial use

We have investigated generation and control technologies of vacuum arc plasma that generates high-energy ions and atmospheric-pressure plasma that generates chemical active radicals. Especially, we have developed apparatuses and processes aimed at industrial use.

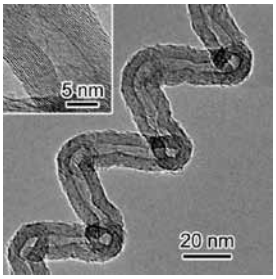
(1) High-performance filtered arc deposition apparatus based on electromagnetic field control and its process development
(2) Composition control and quality analysis of diamond-like carbon (DLC) film
(3) Development of vacuum and atmospheric-pressure plasma apparatuses, and its application to surface treatment by physical vapor deposition and chemical vapor deposition (PVD/CVD) processes
(4) Development of forming, shaping and removing processes for functional protective films


Apparatus for generating high-purity carbon plasma beam

Theme 3 ▶ Nanocarbon synthesis and its application development

We have synthesized nanocarbon using the arc discharge method and thermal chemical vapor deposition (CVD) method. We have developed nanocarbons for applications such as energy devices for eco-energy systems, electronic devices, and so on.

(1) Synthesis of helical carbon nanofibers using the catalytic CVD method
(2) Development of direct methanol fuel cells using nanocarbon
(3) Development of super capacitors using mixed nanocarbon
(4) Development of field electron emission sources using fibrous nanocarbon
(5) Development of solar cells using nanocarbon



Transmission electron micrograph of carbon nano-coil

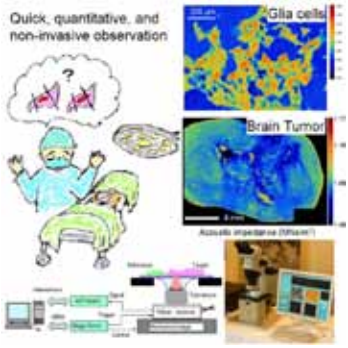
Applied Measurement Laboratory

Staff	• Professor **Naohiro HOZUMI** (E-mail : hozumi@icceed.tut.ac.jp)
Laboratory URL	http://icceed.tut.ac.jp/hozumi/
Key words	Ultrasonic microscope, biological tissue, acoustic impedance, high voltage, insulation diagnosis, ageing

We develop new measurement techniques based on electrical engineering, and propose applications. We design and assemble measurement equipments by ourselves. Information processes like signal processing and image processing are carried out as well. The output of the research are applied to fields of medicine, electric power, environmental technique, automobile, steel, food, and material. We conduct collaborative researches with companies and institutes in these fields.

Theme 1 ▶ Ultrasonic techniques for medical use

We are developing an ultrasonic microscope that can image local acoustic impedance of a biological tissue. It can observe without introducing any contamination to the tissue, and without staining the tissue. At this moment we can observe live cultured cells as well as cross section of tissue. Its resolution is as good as several micrometers.



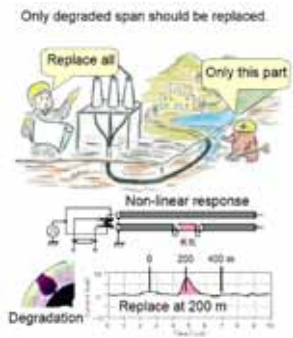
Ultrasonic microscope for medical and biological use.

Theme 2 ▶ Diagnosing techniques for industrial use

We are developing a new technique for locating the degraded point in a power transmission cable. The "water tree degradation", which is a significant mode of degradation of underground transmission cable can be detected by transmitting a sharp high voltage pulse and measuring its response. We proved that 5 m of degraded part inserted in 400 m of sound cable could be located.

Theme 3 ▶ Assessment for high voltage insulation system

We are developing a new measurement method for high voltage insulation. Internal electrification that significantly distorts internal electric field may lead to dielectric breakdown. By using ultrasonic technique, the internal charge density distribution can be measured by applying a very high voltage. The technique is highly appreciated in the field of high voltage power transmission.



Location of degradation in underground power cable.

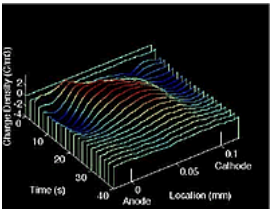
Laboratory for Measurement and Diagnostic System on Dielectric and Electrical Insulation Phenomenon

Staff	• Associate Professor **Yoshinobu MURAKAMI** (E-mail : murakami@ee.tut.ac.jp) • Research Assistant **Tomohiro KAWASHIMA** (E-mail : kawashima@ee.tut.ac.jp)
Laboratory URL	http://www.dei.tut.ac.jp
Key words	Measurement and diagnosis for dielectric and electrical insulation phenomena, electrical breakdown, conduction current, space charge, electrical tree, flashover, functional insulating material

Dielectric and insulating materials are important elements that support the reliability of power equipment and electronic components. The electric stress in the electronic components like LSI is also higher than that in ultra-high voltage power equipment, so anything phenomena like the flashover, the spark discharge and the nonlinear properties may occur in the even electronic components driven by the low voltage. No understanding of the high field phenomena may bring to great damage to the device, but the excellent applications may be discovered if you understand that effectively. We have performed the research including the related research to clear the dielectric and electrical insulation phenomena under the high field using measurement and/or diagnosis of the insulating materials by detecting the electrical signal the ultrasonic, the light, and electro-magnetic wave. Additionally, many functional insulating materials where insulation is not the primary purpose, such as medical percutaneous absorption tape, are used in everyday life. Our laboratory undertakes research related to improving and evaluating performance and engineering applications focused on these “insulating materials” and “a little conducive insulating material”. We also undertake development of thermal conductive insulating materials for the applications such as automotive power modules.

Theme 1 ▶ Electrical Breakdown, Conduction Current, Space Charge

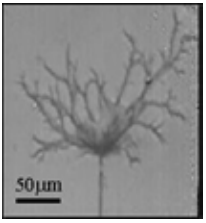
If a dielectric or insulating material are subjected to a high electrical field, the breakdown which the insulation properties are lost may occur. Even without a high field, the breakdown may occur in conditions such as high temperature and high humidity. Lightning is an electrical breakdown phenomenon in the air, and in the case of gas or liquid insulation system, even if the breakdown occurs, the insulation properties recover basecally, but in solid insulating materials used for an electrical device commonly, in principle they do not recover. Insulation performance is important as one of the factors that determine the life span of an electric device. We measure the conduction (leakage) current and the internal accumulation (space) charge where these are closely related to the breakdown, and we perform the research related to the mechanisms of the dielectric and electrical insulation under high field including the breakdown of various insulating materials. We also develop the electrode systems for breakdown test and space charge measurement systems with various added functions.



Charge movement captured by ultra-acoustic wave

Theme 2 ▶ Partial Discharge, Creeping discharge, Electrical Tree

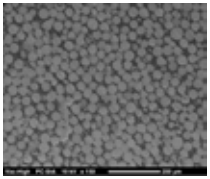
If there are microscopic void-like defects in the insulating materials, weak discharge (partial discharge :PD) occurs. In principle, PD is not total breakdown, so it is rare for breakdown to occur immediately, but the insulating materials deteriorate due to PD, and over the long term there is a possibility of breakdown. With the application to inverter drive fed motors, the rapid rise times of inverter surges may also cause partial discharge. Further, if PD deterioration etc. progresses locally, local dendritic path grow and branch into hollow channels in solid dielectrics (Electrical Tree) may arise. This electric tree also causes long term insulation deterioration. At our laboratory, in addition to gaining understanding of PD characteristics, we are also working to gain understanding and elucidate the electrical treeing mechanism.



Electrical tree in polymer

Theme 3 ▶ Development of functional composite insulation materials

The use of thermal conductive insulating materials with both higher heat dissipation and acceptable insulation properties are essential in applications such as automotive power modules. Higher heat radiation is required in addition to a high level of insulation, but generally these properties are mutually contradictory. In this research, we give attention to an electrostatic adsorption method that can design optimal microstructures of filler and matrix polymer, and are developing thermal conductive composite insulating materials with a good balance of acceptable breakdown strength and higher thermal conductivity.


Composites materials produced by electro static adsorption method

Integrated Circuit Group

Staff	• Professor **Kazuaki SAWADA** • Associate Professor **Takeshi KAWANO** • Lecturer **Kazuhiro TAKAHASHI** • Assistant Professor **Daisuke AKAI** • Assistant Professor **Ippei AKITA** • Assistant Professor **Tatsuya IWATA** (E-mail : info-icg@int.ee.tut.ac.jp)
Laboratory URL	http://int.ee.tut.ac.jp/icg/
Key words	Smart sensors, high-performance sensors, CMOS, MEMS/NEMS, RF devices, nanodevices, agricultural sensors, biosensors, gas sensors, neural interfaces, nanophotonics, silicon, Al_2O_3, ferroelectric thin films

We conduct interdisciplinary engineering research projects on MEMS, NEMS, sensors, integrated circuits and systems, aiming to industry and academic leadership positions in these fields. Our students, researchers, and faculty are developing a wide range of micro/nanoscale devices at the internationally recognized top rank facility of our campus EIIRIS-2/VBL (class 100 clean room). In this facility, our laboratory members are allowed to use freely the complete set of CMOS, MEMS, and nanodevice fabrication tools, enhancing their engineering experience.

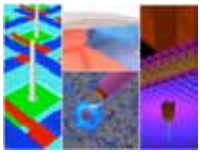


Fig.1

Theme 1 ▶ Neural interface micro/nanoscale devices (Kawano)

To understand how the brain works, the goal of our research team is to develop micro/nanoscale electronics for the brain. Our current research projects include i) 3D micro-/nanoscale needle electrode arrays for extra-/intracellular recordings, ii) 2D flexible and stretchable devices, and iii) optical waveguides for optogenetic applications. Starting with our world's smallest needle technology, we have succeeded in detecting high quality neuronal signals from cerebral cortices of rodent and monkey, etc. (Fig. 1).

Fig.2

Theme 2 ▶ High-performance sensor devices using intelligent substrates (Akai)

We develop high functionality, high-performance sensor devices using epitaxial alumina substrates (intelligent substrates). We develop infrared image sensors and ultrasonic image sensors using ferroelectric thin films (Fig. 2).

Fig.3

Theme 3 ▶ Function integrated Smart microsensors (Akita)

In the near future, the age of microsensors being used everywhere close to you may arrive. In such a future, in addition to integration of sensing and information processing circuits, it is also necessary to realize ideal sensor devices (smart microsensors) with integrated wireless external communication and power supply functions. We are developing sensors and circuit systems with various functions (amp, ADC, digital circuit, wireless circuit, antenna, power circuit) (Fig. 3).

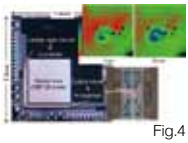


Fig.4

Theme 4 ▶ Intelligent biosensor devices (Sawada, Iwata)

We are researching creative biosensor devices that combine integrated-circuit technology (CMOS and CCD image sensor technology), MEMS and bio-chemical technology. In particular, we are researching and developing image sensors (Fig. 4) that can detect various ions from DNA and biological substances and visualize their 2-dimensional distribution and concentration. Further, based on this technology combined with enzymatic reaction, we are developing biomolecule sensors that can detect only specific substances (glucose, etc.), and sensors that can detect fluorescence and force at the same time as pH.

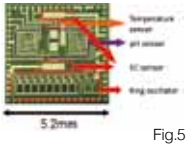


Fig.5

Theme 5 ▶ Multi-modal sensors for environmental and agricultural applications (Sawada, Iwata)

We are researching multi-modal sensors (Fig. 5) that integrate CMOS circuits with several types of chemical sensors. For example, in the growth of crops there are various complex relationships with the pH in the soil and the CO_2 concentration, light and temperature in the air. By measuring these with the multi-modal sensors it is possible to "diagnose" the conditions comprehensively. These sensors can greatly contribute to the safe and stable supply of food, and the agriculture and livestock sector has high expectations.

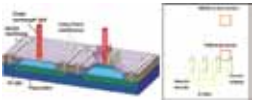


Fig.6

Theme 6 ▶ Intelligent Bio-MEMS devices (Takahashi, Sawada)

We develop sensors that can detect biomarkers that are the diagnostic indices of various diseases quickly and accurately from one drop of blood or urine, aiming to realize rapid onsite diagnosis for simple examination and first aid of illnesses in the home. We are reducing the size and adding multiple elements to sensors that fuse optical MEMS (microelectromechanical systems) and integrated circuit technology, aiming at exhaustive disease diagnosis by detection of multiple biomarkers (Fig. 6).

Fig.7

Theme 7 ▶ Variable plasmonic metamaterials (Takahashi)

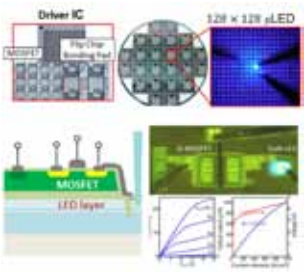
We fabricate metal periodic nanostructures at the same extent as light wavelengths, and develop artificial optical materials and plasmonic metamaterials with optical properties that do not exist in the natural world. We embed nanostructures in polymer thin films, aiming to create display elements and electronic skins that can be pasted on that to freely change their coloring using micro-actuator.

Opto-Electronic Group

Staff	• Professor	**Akihiro WAKAHARA**	(E-mail：wakahara@ee.tut.ac.jp)
	• Associate Professor	**Hiroto SEKIGUCHI**	(E-mail：sekiguchi@ee.tut.ac.jp)
	• Assistant Professor	**Keisuke YAMANE**	(E-mail：yamane@ee.tut.ac.jp)
Laboratory URL	http://www.int.ee.tut.ac.jp		
Key words	Micro-Display, Solar Cell, Thermal Stable LD, Crystal Growth (III-V-N on Si, GaN), OEIC		

Theme 1 ▶ Development of Monolithic Opto-Electronic Integrated Circuit

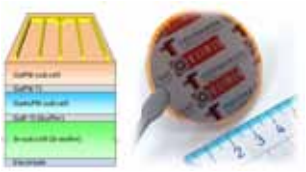
In the last decade, the significance of heterogeneous integration devices/systems has been progressively increasing because of the anticipated limit on further miniaturization of Si-based LSIs, and GaN-based materials are understandably one of the candidates for that component. In Particular, the heterogeneous integration technique on the Si-CMOS platform is an important topic for a breakthrough to POST-CMOS technology. In this subject, a monolithic integration process of Si-MOSFET and GaN-μLED using Si/SiO2/GaN-LED wafer has been developed. The n-channel MOSFETs (nMOSFETs) and μLED are successfully fabricated as a top-Si layer and GaN-LED layer respectively using a CMOS process line.



Opto-Electronic Integrated Circuit using GaN-LED and Si-LSI

Theme 2 ▶ Development of Monolithic III-V-N/Si Multi-Junction Solar Cell

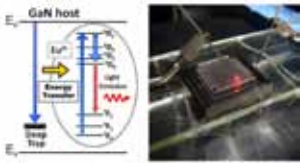
Integration of high-quality III-V compounds on Si substrates are of importance for a wide variety of light emitting/absorbing device applications while it allows significant saving of substrates. The monolithic integration approach using lattice-matched III-V/Si hetero-epitaxy enables a simple fabrication process of dislocation-free device structures on entire Si substrates. In this subject, we propose a GaPN/ GaAsPN/Si multi-junction structure in which lattice constants for all layers are matched to a Si bottom cell for highly efficient and cost effective solar cells.



Monolithic III-V-N/Si Multi-Junction Solar Cell

Theme 3 ▶ Research for thermal-stable optical devices using rare-earth doped GaN

Electronic materials embedded with rare-earth (RE) ions are widely applied in optoelectronics devices, such as solid-state lasers, phosphors and optical-fiber amplifiers. The RE ion luminescence shows a sharp line emission and thermal stability of the emission wavelength. If the RE ions can be embedded into a semiconductor, excitation of RE ions through current injection is possible, thus enabling next-generation optical devices such as thermal-stable laser diodes, quantum operation devices and opto-spintronic devices. In this subject, we study the growth of RE doped GaN and its application.



Thermal-stable optical devices using rare-earth doped GaN

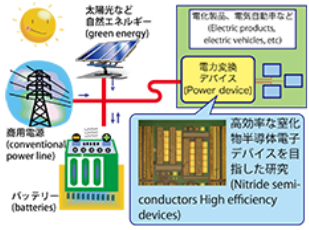
Advanced Electronic Device Laboratory

Staff	• Associate Professor **Hiroshi OKADA** （E-mail：okada@ee.tut.ac.jp
Laboratory URL	http://www.int.ee.tut.ac.jp/oeg http://www.eiiris.tut.ac.jp
Key words	Electron device, compound semiconductor, GaN, harsh environment electronics, power electronics, nano materials

Our interest is a development of novel electron devices beyond the present microelectronics by using compound semiconductors such as gallium nitride (GaN). Towards integrated device/system for power electronics and harsh environment electronics, device fabrication technologies are also investigated using clean room facility.

Theme 1 ▶ High performance electron device based-on nitride semiconductors

So far, semiconductor devices are regarded as components for "low power electronics." However, recent advances in technology for GaN-related materials open up a new field of “heavy electronics” or “power electronics,” where high voltages beyond 100 V are controlled in higher temperature environments. These advances are promising for compact and high efficiency semiconductor devices which are indispensable for hybrid vehicles and electric vehicles. Realization of high tolerance devices for use in harsh environments is also expected. In this laboratory, we focus on power electronics and electronics for harsh environments, and investigations are made to develop advanced semiconductor devices based on nitride semiconductors and nano materials.



Power electronics for daily life.

Theme 2 ▶ Investigation of novel electron device by heterogeneous integration

Nitride semiconductors possess relatively wide band gap energy and chemically stable nature. These properties are suitable for operations of electron devices made with nitride semiconductors in tough environment such as in high temperatures nearby the engine in vehicles, irradiation environment in space, and so on. Novel sensors and electronic devices can be expected by hybriding nitride semiconductors and other characteristic materials or nano structures including well developed silicon circuits. These unique integrated devices are expected to enhance the field of engineering since these are useful to detect physical information in harsh environment.

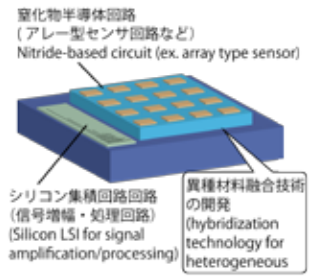


Image of heterogeneous integrated device/system

Wave Engineering Lab. and Electromagnetic Wave Engineering Lab.

Staff	• Professor	**Takashi OHIRA**	(E-mail：ohira@tut.jp)
	• Associate Professor	**Masaya TAMURA**	(E-mail：tamura@ee.tut.ac.jp)
	• Assistant Professor	**Naoki SAKAI**	(E-mail：sakai@ee.tut.ac.jp)
Laboratory URL	http:// www.comm.ee.tut.ac.jp		
Key words	Electrified road electric cars, underwater wireless power transmission, communication for high-frequency filters, battery-less sensor systems, non-linear device measuring instruments, DOA finders, wireless secret key sharing		

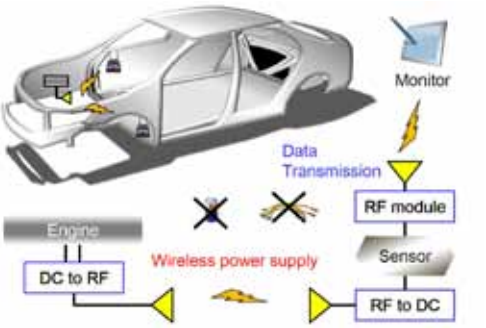
The wireless technology makes us free from the confines due to wires. In addition to the current information transmission systems for broadcasting and communication, prospective applications are emerging if we can exploit the wireless technology for energy transfer. Our laboratory is engaged in research and education covering a wide scope from creating basic theories to pragmatic system development. Graduated students are expected to be a professional engineer who contributes to the global society by the sophisticated wireless technology.

Theme 1 ▶ Electrified roadway, Future vehicle city

We propose a new concept of electric motor vehicle named EVER, which can continuously run on electrified roadways without consuming charged onboard energy. This technology simultaneously overcomes four major problems: weight, cost, charging time, and cruising range of battery-based EVs. To develop this technology, we focus on the wheels of the vehicle to pick up high-frequency energy from a feeder line buried under the road surface. The line is excited with high frequency while the EV is running, the energy propagates on the line, goes through the wheel, and finally reaches the motor. This technology will contribute to mass deployment of EVs replacing fossil-fuel engines, and to the ecological world with minimum CO_2 emission.

Theme 2 ▶ Battery-less sensor systems

For the conventional sensor system, the power supply and data transmission are done by the wiring harness, or data is wirelessly transmitted to the master by the battery. In this case, they are very difficult to handle in enclosed spaces such as car interiors or high temperature furnaces, or in inaccessible or difficult to manage places. However, if energy can also be supplied wirelessly, these issues can be solved. Therefore, in this research we are developing fusion modules to realize wireless power supply to sensors installed in enclosed spaces and intercommunication.



Example of battery-less sensor networks to vehicle

Custom Computing Systems Laboratory

Staff	• Professor **Shuichi ICHIKAWA** (E-mail：ichikawa@tut.jp) • Assistant Professor **Naoki FUJIEDA** (E-mail：fujieda@ee.tut.ac.jp)
Laboratory URL	http://www.ccs.ee.tut.ac.jp/ich/index.html.en.latin1
Key words	Special-purpose Computing Circuits, FPGA Applications, Computer Security, Parallel Processing, High-performance Computing, Embedded Systems

Our laboratory deals with a wide range of research from software to hardware based around “high-speed processing.” We explore the methods to improve performance using dedicated circuits (in hardware themes), and using parallel and distributed processing (in software themes). We are also promoting research on information security and computer security, whose importance has been increasing in recent years.

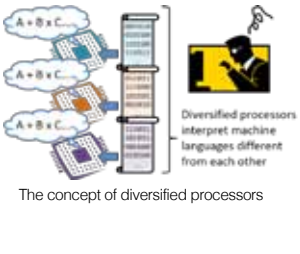
Theme 1 ▶ Reconfigurable logic circuits and special-purpose computation circuits

Field Programmable Gate Array (FPGA) is a kind of reconfigurable logic devices in which the internal logic circuit can be arbitrarily rewritten. We design, implement, and evaluate dedicated circuits for various applications, which range from academic to practical. We design the dedicated circuits in Hardware Description Language (HDL), implement circuits using CAD software, and evaluate their performance on FPGA boards. For an example, we have implemented hard-wired sequence control circuits by translating PLC (Programmable Logic Controller) software into HDL description. One of the proposed circuits achieved 8,050 times higher performance than the equivalent software implementation on a PLC. In addition, we are working on data-dependent hardware that makes circuits smaller and faster by fixing a part of input as constant. This idea corresponds to “partial evaluation” or “specialization” in software.

A demonstration version of control machinery using FPGA.

Theme 2 ▶ Information security and computer security

We utilize FPGAs to implement and evaluate components for secure systems such as encryption circuits and random number generation circuits. We are also studying secure processors which incorporate the features to protect software. One of our research on secure processors is based on diversification. The reason why a computer virus spreads and infects many computers is that their processors interpret the same machine language. If they interpret different machine languages, malicious software for a specific processor will no longer affect the other processors. The concept of such diversified processors can be compared to the myth of the Tower of Babel. FPGA technologies are well suited to this diversification technology. We apply our idea to the soft processors written in HDL to demonstrate the practicality of diversified processors.



The concept of diversified processors

Theme 3 ▶ Parallel processing technology

In recent parallel processing, the performance of each processing element may differ widely. For a simple example, different kinds of personal computers may be used in a PC cluster. We are studying the load balancing techniques for such heterogeneous systems to derive their maximal performance automatically. We are also working on optimized application software mainly for embedded systems. The target applications include, for example, scientific computation, image processing, and positioning systems.

Load balancing on a heterogeneous cluster system.

Wireless Networks Laboratory

Staff	• Professor **Hideyuki UEHARA** (E-mail：uehara@tut.jp) • Assistant Professor **Yuichi MIYAJI** (E-mail：miyaji@ee.tut.ac.jp)
Laboratory URL	http://www.comm.ee.tut.ac.jp/
Key words	Wireless access controls, wireless multi-hop communications, sensor and ad-hoc networks, array signal processing

Wireless systems hide limitless possibilities that can enrich our lives, as said by the father of wireless communications, Guglielmo Marconi, “It is dangerous to put limits on wireless.” We are aiming to realize new communication networks through wireless access and multi-hop communications, based on communications theory, network architecture and signal processing. Specifically, we undertake research on access control for effectively sharing limited radio resources, network control for cooperative connections and signal processing for high quality communications, for distributed autonomous systems such as sensor and ad hoc networks.

Theme 1 ▶ Wireless Networks

In wireless networks, especially distributed autonomous networks such as sensor and ad hoc networks, it is crucial to keep connectivity high for delivering more data with low latency, and also to save energy for longer time operation. We are aiming to design and build medium access control and topology control protocols so as to utilize and manage wireless resources efficiently for the use of the emerging IoT or trillion sensors universe.

Cluster formation for wireless sensor networks.

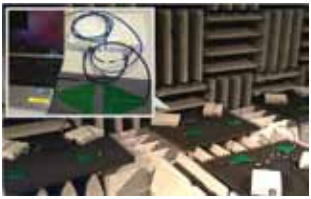
Theme 2 ▶ Sensing Systems

A sensor which converts physical quantities to electrical signals can be a sensing system and create new services when a lot of sensors are assembling together and connecting each other, besides having processing and communication functions. We are aiming to develop new sensing systems exploiting radio wave propagation characteristics such as localization for mobile objects including sensors and persons, and also for resonator’s location estimation in wireless multi-hop power transfer systems.

Location estimation for wireless multi-hop power transfer systems.

Theme 3 ▶ Full Duplex Multi-hop Communications

Communication traffic is rapidly growing as widely spreading wireless tools and sensors, which causes wireless resources a critical shortage. In-band full duplex communications can double the capacity in principle than half duplex communications used in current wireless LAN etc., however it must suppress self-interference. In addition, no protocols have been designed for multi-hop communications. We are aiming to develop a self-interference canceler and access protocol for in-band full duplex multi-hop communication systems that can efficiently utilize wireless resources by spatial-temporal control.



Wireless multi-hop communication testbed using two directional transceivers.

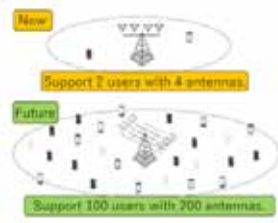
Communications and Signal Processing Laboratory

Staff	• Associate Professor **Keigo TAKEUCHI** (E-mail：takeuchi@ee.tut.ac.jp)
Laboratory URL	http://comm.ee.tut.ac.jp/csp/en/
Key words	Massive MIMO, compressed sensing, belief propagation, spatial modulation, energy efficiency, multiuser decoding, spatial coupling

For future wireless communications, groundbreaking schemes are needed to satisfy high performance requirements. In order to realize such a paradigm shift in the field of communications, an interdisciplinary point of view is important in our research. One sometimes recognizes that a problem is essentially the same as a problem that has been already solved in another research field, while there is no superficial relationship between the two problems. Our goal is to realize novel communication schemes by applying such achievements from other fields to the field of communications. Also, we are aiming to deliver our achievements on communications to different research fields in order to contribute to academic and industrial progress in a wide range of fields including communications.

Theme 1 ▶ Massive MIMO

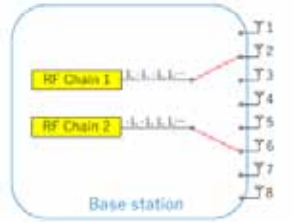
Multiple-input multiple-output (MIMO) systems are wireless communication systems that use multiple transmit and receive antennas for information transmission. In massive MIMO systems, base stations equip a large number of antennas to support many users simultaneously. Conventional receivers cannot be used to process all user signals jointly and efficiently. In our laboratory, we are aiming to construct efficient reception schemes for massive MIMO on the basis of an iterative method called belief propagation and of its modification proposed in the field of compressed sensing.



Massive MIMO

Theme 2 ▶ Spatial Modulation

The signals 1, -1, or 0 (no transmission) are transmitted in spatial modulation, while 1 or -1 is sent in conventional modulation. Since information is conveyed by signal 0 (no transmission), spatial modulation is an energy-efficient transmission scheme. A problem is an efficient blind estimation of the positions at which signals 0 have been sent. In our laboratory, we utilize a similarity between the problem and that considered in the field of compressed sensing to construct efficient reception schemes.



Spatial modulation

Theme 3 ▶ Multiuser Decoding

Decoding and multiuser detection have been separately developed in coding theory and communication theory, respectively. In multiuser decoding, on the basis of a combination of the two fields, joint detection and decoding are performed to realize a significant improvement in decoding performance. In our laboratory, we are aiming at improving the performance of multiuser decoding by applying spatial coupling, which was an idea to improve the performance of belief-propagation-based decoding up to the optimal performance.