Mechanical / Biomedical Engineering

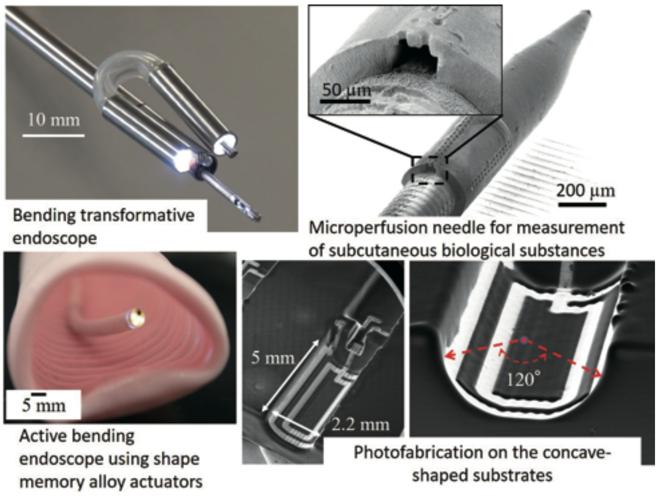
Haga/Tsuruoka Laboratory

Prof.
Yoichi Haga

Research Assoc.Prof.
Noriko Tsuruoka

Biomechanical Engineering,
Medical Nanodevice Engineering

http://www.medmems.bme.tohoku.ac.jp/

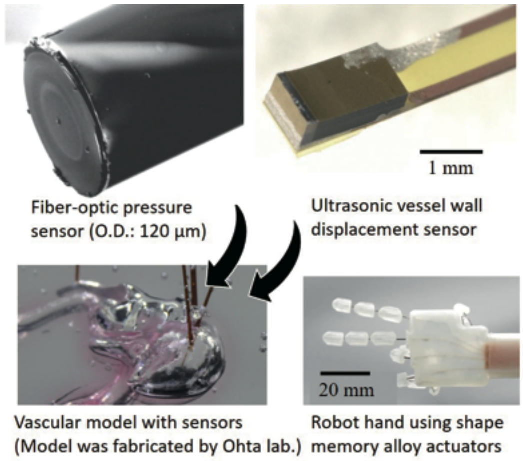


Bending transformative endoscope

Microperfusion needle for measurement of subcutaneous biological substances

Active bending endoscope using shape memory alloy actuators

Photofabrication on the concave-shaped substrates



Fiber-optic pressure sensor (O.D.: 120 µm)

Ultrasonic vessel wall displacement sensor

Vascular model with sensors (Model was fabricated by Ohta lab.)

Robot hand using shape memory alloy actuators

New generation medical devices realized by micro technology

Several medical devices and healthcare devices which have new features and advantages have been developed using several micro fabrication technologies, for example, MEMS (Micro Electro Mechanical Systems) technology. New diagnosis and therapy can be realized by minimally invasive medical devices with higher functions and multifunction. Biometric measurement, diagnosis and therapy in daily life can be also realized by small, thin and flexible healthcare and medical devices which are enabled by micro fabrication technologies. Required fabrication technologies have been also newly developed. We are aiming realization of medical machines which are useful for human.

High functionalized minimally invasive medical devices

Minimally invasive diagnosis and therapies from inside the human body are now widely performed using endoscopes, catheters and guide wires. Functions and precision of the medical devices are restricted by required sizes, shapes and flexibleness for use in the human body. Ultraminiature fiber-optic blood pressure sensor, small ultrasonic sensor, and new imaging systems have been developed for higher functionalization and multifunctionalization of endoscopes, catheters and guide wires.

Small, thin and flexible healthcare and medical devices

Biometric measurement, diagnosis and therapy in daily life can be realized by small, thin and flexible healthcare and medical devices. Small ultrasonic blood diameter sensor for blood pressure measurement without cuff and for quantification of stress reaction has been developed. Subcutaneous tissue fluid extraction system has been developed utilizing microperfusion needle for sensing biological substances, for example, glucose and lactic acid at several times in daily life.

Nonplanar photofabrication and assembly technologies

New micro fabrication technologies and assembly technologies which are required for realization of high functionalized minimally invasive medical devices and small, thin and flexible healthcare and medical devices have been also developed. Nonplanar photofabricaiton process which enable micro fabrication on the surface of round or concave shapes of several mm tube-shaped substrates has been developed. New equipment and micro assembly procedure have been also developed for the purpose.

Organ model with sensors for training and evaluation

Hollow organ models, for example blood vessel models, equipped with micro sensors (ultraminiature blood pressure sensors or small ultrasonic blood vessel wall displacement sensors) have been developed for training of operators of minimally invasive medical devices and for evaluation of effectiveness and safety of newly developed minimally invasive medical devices, for example, catheters, guide wires, endoscopes and vascular stents. Micro assembly procedure has been also developed.

Mechanical / Biomedical Engineering

Department of Biomedical Engineering / Department of Mechanical Systems Engineering

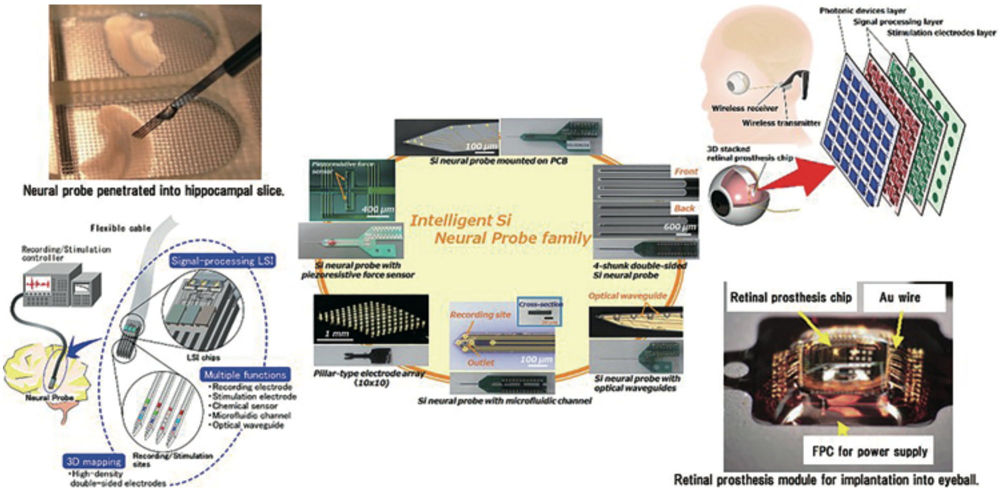
T. Tanaka/Kino Laboratory

Prof.
Tetsu Tanaka

Assist.Prof.
Hisashi Kino

Biomechanical Engineering
Medical Nanosystem Engineering

http://www.lbc.mech.tohoku.ac.jp/



Retinal prosthesis module for implantation into eyeball.

Research and development of biomedical micro/nano integrated systems based on semiconductor neural engineering

Semiconductor neural engineering is a discipline that uses semiconductor process/device/circuit technologies to further understand properties of neural systems and to create novel fusion systems of living body and machine. One of the goals in this laboratory is to establish semiconductor neural engineering and develop biomedical micro/nano integrated systems. Another goal is to educate the next generation of leaders in biomedical engineering through research including:

1. Intelligent Si neural probe and brain-machine interface
2. Fully-implantable retinal prosthesis system
3. Wearable and implantable high performance sensor system
4. 3D integration technology and analog/digital IC design

We collaborate with Fukushima laboratory.

Intelligent Si neural probe

Intelligent Si neural probes can be used to analyze both brain and neuron functions as a versatile tool for neurophysiology including optogenetics. The intelligent Si neural probe has various sensors, signal processing circuits, neuronal stimulation circuits, and so on. We have performed lots of collaborative research with many research institutes in the world.

Fully-implantable retinal prosthesis

More than 10 million patients have lost their visions due to eye diseases such as retinitis pigmentosa and age-related macular degeneration in the world. To restore the visual sensation of blind patients, we have proposed and developed a fully implantable retinal prosthesis. Our retinal prosthesis is small size, lightweight, and high resolution, which leads to a high quality of life (QOL) to the patients. We have already fabricated the retinal prosthesis chips with 1,500 pixels. Besides, we have successfully obtained EEPs from a rabbit by implanting the retinal prosthesis chip.

Wearable and implantable biosignal recording system

Biosignals such as EEG, ECoG, ECG, EMG, and pulse waves have different signal magnitudes and frequency bands. Therefore, to correctly record the biological signal, both the function and performance of the recording circuit need to be optimized. We have been developing an integrated wearable and implantable biosignal recording system including biosignal processing LSI, biosignal recording electrode, micro/mini-LED, photodiode, and various sensors.

3D integration technology & Analog/digital IC design

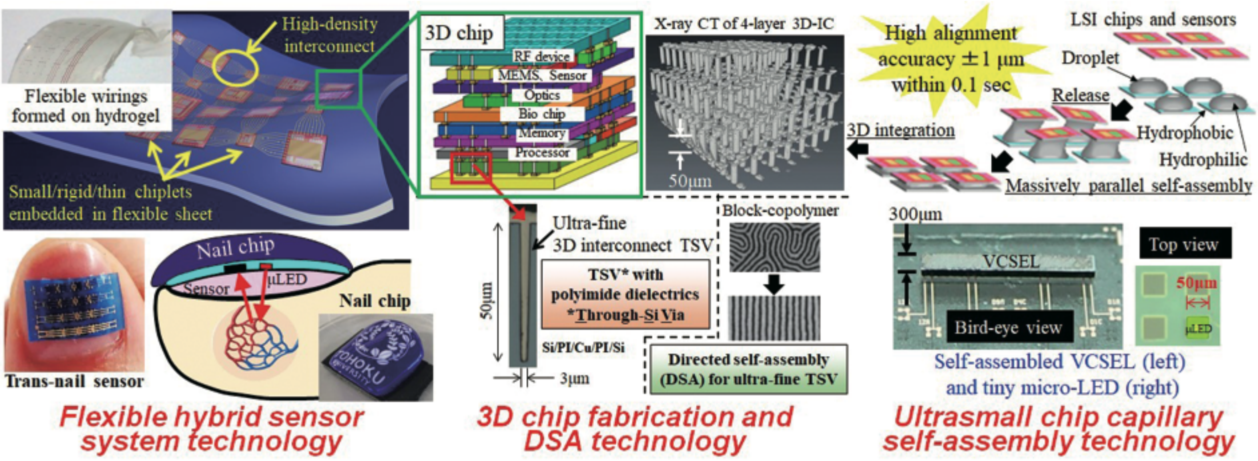
We have been developing 3-dimensional integration technologies and analog/digital IC design technologies to achieve high-speed and low-power LSI beyond conventional 2D LSI performances and to realize high-performance computing systems and advanced biomedical micro/nano integrated systems.

Fukushima Laboratory

Assoc.Prof.
Takafumi Fukushima

Biomechanical Engineering
Medical Nanosystem Engineering

http://www.lbc.mech.tohoku.ac.jp/



Holistic System Integration Based on Self-Assembly for a Future AI World

We are working on specialized education and research toward micro/nano integrated biomedical/healthcare systems based on wafer-level packaging that involves an interdisciplinary fields between physics, chemistry, mechanical and electrical engineering in addition to biomedical engineering. Our research activities aim to explore technological innovation to realize upcoming Internet of Everything (IoE) societies with real AI. In particular, our research focuses on holistic integration with LSI, MEMS, optics, bio chips, passives, and bendable/strachable devices to construct flexible/rigid, 2D/3D, and organic/inorganic hybrid systems. We collaborate with T. Tanaka/Kino laboratory

Flexible Hybrid Sensor System Technology

Flexible hybrid sensor system is an excellent combination of inorganic monocrystalline semiconductor chips with organic flexible polymeric substrates. High-performance and multi-functional wearable/implantable devices are integrated by our advanced flexible hybrid electronics (FHE) technology using embedded small/rigid/thin chiplets. We are fabricating various systems such as trans-nail photoplethysmography (PPG) sensor to know heart rate, bionic eye implant to cure retinal disease, flexible neural probes to analyze the brain function, and hydrogel-based patch to control glucose level.

3D AI Chip Technology

The human brain has 3D-stacked multi-layered structures that are electrochemically communicated through synaptic connections with extremely low power consumption without heat generation. For the next-generation brain computing chips, we are proceeding with the researches for high-performance 3D ICs that are electrically stacked through 3D interconnects called TSV (through-Si via) that is like neurons. Upcoming automatic driving systems and neuromorphic edge computing will be given by the 3D ICs in massively parallel signal processing with a huge number of TSV.

Capillary Self-Assembly Technology

Self-assembly is an innovative process in which a disordered system of pre-existing components forms an organized small structure or micro-patterns as a consequence of specific and local interactions among the components themselves without external direction. We have successfully self-assembled tiny chips (10 μm by 10 μm) and ultrasmall optical chips within 100 nm in alignment accuracy using liquid surface tension as a driving force. This massively parallel capillary self-assembly researches are toward advanced flexible micro-LED display application etc.

Directed Self-Assembly (DSA) Technology

DSA is a promising technology to make ultrafine-pitch nano-patterns induced by nano-phase separation of block co-polymers using simple coating and heating. Traditionally photosensitive materials called photoresists are employed to photolithographically make the fine patterns used for IC fabrication in semiconductor industry. Our extended DSA challenges are focusing on the formation of ultrafine-pitch nano-interconnections like synaptic connection with nanocomposites consisting of block co-polymers and metal compounds/nanoparticles etc.

Mechanical / Biomedical Engineering
Department of Finemechanics

Nishizawa/Yoshida Laboratory

Prof.
Matsuhiko Nishizawa

Assist.Prof.
Shotaro Yoshida

Biomechanics
Biodevice Engineering

http://www.biomems.mech.tohoku.ac.jp

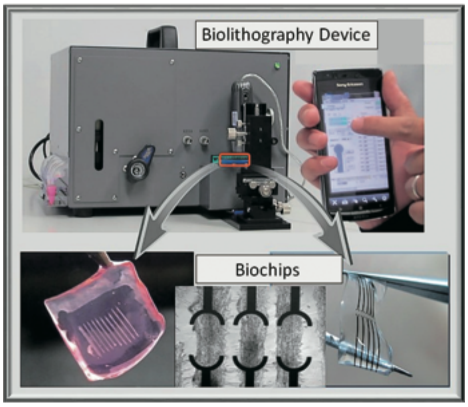


Figure 1. Biochips fabricated by our biolithography device are useful in drug testing and implants.

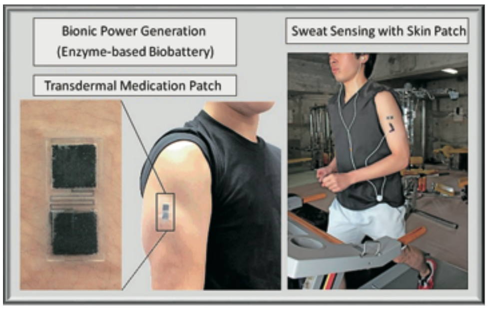


Figure 2. Power generation by an enzyme-based biobattery that activates biosensors and medication devices.

Biohybrid Devices with High Affinity for Human and Environment

We develop highly-sensitive and efficient biohybrid devices such as biosensors and biobatteries by utilizing proteins, cells, and biomaterials as parts of the devices. Our unique, key studies include development of fabrication process of soft/wet devices, and interfacing technology between electronic machines and iontronic biosystems. The biohybrid device technology enable state-of-the-art engieered systems with high affinity for human and enironment.

Biolithography: Manipulation of Proteins and Cells

We developed a biolithography technology for in situ manipulation of proteins and cells in a biosystem. The developed device also enables printing of flexible organic electrodes on a wet hydrogel for biosensing. The hydrogel-based biochip can be used for investigation of metabolic activities of exercising muscles as studies of diabetes and adiposity (Figure 1).

Wet Devices: Hydrogel-based Electrodes Fitting to Human

We developed hydrogel-based electrodes with 70% water content that fit to human skin and tissues for biosensing and electrical therapy of nerves and muscles. The totally organic, biocompatible hydrogel electrodes can be stored in a dried state, and used with added water for an implant sensor of brain functions.

Bionic Power Generation: Self-regulating Biobatteries

Our group achieved enzyme-based biobatteries with world-first high electrical density. The bionic power generation system is composed of totally organic biomaterials, and thus highly compatble to human and environment. We advance the technology to self-regulating biosensors and transdermal medication patch through improvement of generated power and lifetime of the biobattery by utilizing MEMS technologies (Figure 2).

Skin Medical Engineering: Therapy and Diagnosis of Skin

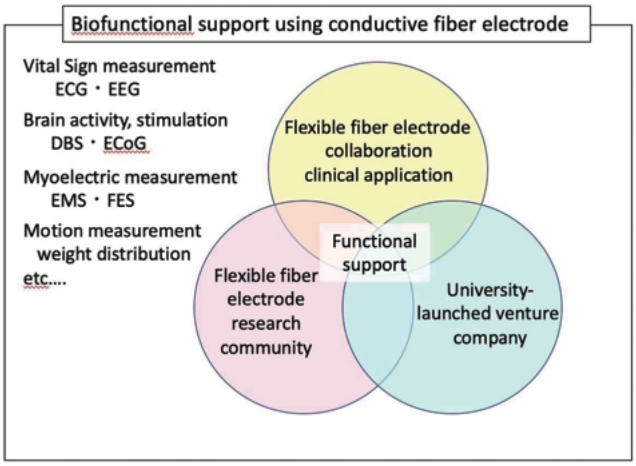
Human skin has transepidermal electric potential that supports various skin functions. The value of transepidermal potential is related to damage and diseases of a skin such as atopic dermatitis, and can be used as an indicator of skin condition. We develop biomedical devices for therapy and diagnosis of skin by integrating our technologies of wet device, bionic power generation, and a minimally invasive needle.

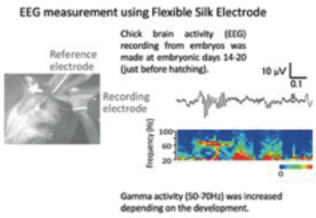
Torimitsu Laboratory

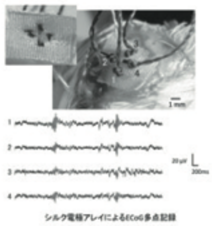
Specially Appointed
Assist.Prof.
Keiichi Torimitsu

Biomechanics, Biodevice Engineering

http://torimitsu-lab.jp







Establishment of neuro-machine interface for biofunctional support

The purpose of this research is based on understanding informational processing mechanism at synapse and its artificial formation of synapse. Establishment of interface between machine and neural system is the key. We have been studying conductive polymer modified fiber electrode for this purpose because of its high biocompatibility and flexibility. The electrode can be used not only for medical implant, bust also for health care, such as vital sign measurement. As the research is now on the phase of application, we organize a research community of flexible electrode and a venture corporation for further development in the field.

Conductive polymer fiber electrode for neural interface

Biocompatible flexible electrode was established using conductive polymer and fiber. As the electrode indicated high biocompatibility and flexibilty, it is suitable for measuring long-term brain activity and forming a neural interface. This could be helpful for medical treatment such as DBS (Deep Brain Stimulation) in Parkinson's disease. Ambient vital sign sensing is also possible for healthcare purpose.

Artificial synapse - neural machine interface

Most of the present supporting device for disabilty function is based on the musle electrical measurement and control. Because of our electrode indicated high biocompatibility, we can use it as an implantable electrode for neural control. Direct stimulation of the nerve acting like an artificial synapse is capable for producing precise control of behaviour. We are now studying a suitable system for longer sustainable neural connection.

Electrical circuit formation using fiber electrode

Fiber electrode is an unique material for establishing electrical circuit. We can control electrical acitivity using fiber structure. Structure dependence of the fiber on electrical characteristcs was studied. Results are indicated novel type of electrical circuit could be formed. As the structure is also good for cellular growth scafold, formation of electrical cellular interface is our future interest.

Real time weight measurement using fiber electrode

The fiber electrode can measure changes in weight and strain. We use this characteristics for measuring weight balance in our body when sitting on the chair and when lying on the bed in real time. We try to analyze posture conditions for helping correction to proper conditions in order to avoid pain.

Mechanical / Biomedical Engineering

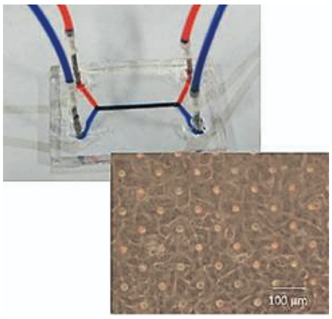
Department of Finmechanics / Department of Biomedical Engineering

Kaji Laboratory

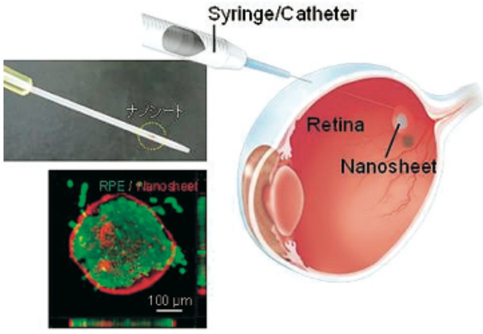
Assoc.Prof.
Hirokazu Kaji

Biomechanics
Biodevice Engineering

http://www.biomems.mech.tohoku.ac.jp



Retinal pigment epithelial cells cultured in a microfluidic device



Intraocular cell delivery system

Development of micro/nanotechnology and biomedical applications

In the field of biomedical engineering, micro/nanotechnology corresponding to the fragility of bio-derived materials such as living cells and proteins has been required. For example, technologies that can precisely and dynamically control the microenvironment of cultured cells are important in vitro, and technologies that deliver cells and drugs to the affected area in a minimally invasive and effective manner are important in vivo. Our laboratory aims to develop micro/nanotechnology applicable to the field of biomedical engineering and to apply such fundamental technology to medicine and medical devices, especially in the field of ophthalmology.

Micro/nanotechnology applicable to bio-derived materials

It is natural that the physiological environment is suitable for the functional expression of bio-derived materials such as living cells and proteins, and biomedical application of such materials requires micro/nanotechnology corresponding to their fragility. To date, we have developed bio-lithography technology that can pattern living cells and proteins on substrate surface under a culture environment, microfluidic devices that can control cell-cell interactions, and polymeric nanofilms as cell culture substrates.

Organ chip devices that mimic the ocular fundus tissues

As the top of blindness diseases are all retinal diseases that are complicated by many factors including aging, metabolism, and blood flow, development of treatments for those disease has become difficult. We are developing a three-dimensional culture model that mimics the ocular fundus tissues in a microfluidic device. Using such devices, we aim to accurately understand the pathological mechanism of eye diseases and to develop new treatments and drug screening methods.

Transscleral drug delivery system

As the frequency of visual impairment increases with age, visual information is very important to maintain the quality of life in super-aging countries such as Japan. The main factor of visual impairment is retinal diseases and development of effective drug delivery system to the retina has become an urgent issue. We are developing a minimally invasive drug delivery device that is placed outside the eyeball to transsclerally delivery drugs to the retina.

Intraocular cell delivery system

Drug therapy for intractable diseases such as retinal diseases is basically aimed at suppressing the progression of symptoms. Cell transplantation is necessary as a fundamental treatment for diseases of tissues such as the retina that do not have self-renewal ability. By using a biodegradable polymeric nanosheet as a transplant carrier, we are developing a method to effectively deliver a cell sheet into the subretinal space through a capillary needle.

Mechanical / Biomedical Engineering
Department of Finemechanics

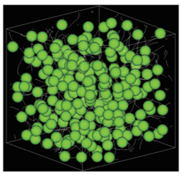
Ishikawa/Omori Laboratory

Prof.
Takuji Ishikawa

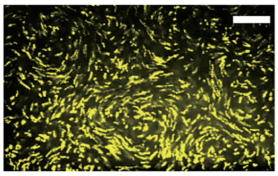
Assist.Prof.
Toshihiro Omori

Biomechanics, Biological Flow Studies Laboratory

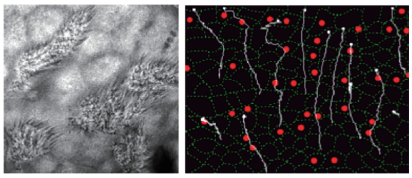
http://www.bfsl.mech.tohoku.ac.jp/index.html



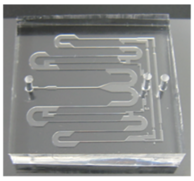
Collective swimming of microorganisms



Mesoscopic flow structure in bacterial suspension



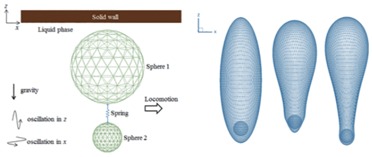
Mucus flow driven by tracheal cilia



Bio-chip for cell separation

Simulation of swimming bacteria

Circulating tumor cell



Micro-robot propelled by fluid oscillation

We study physiological and pathological flows, and utilize the knowledge for various kinds of health and enviromental issues.

Welcome to Biological Flow Studies Laboratory

Our research field is biomechanics, in which biological functions are clarified from mechanical point of views and utilized for engineering applications. We do experiment, theory and numerical simulation to overcome various kinds of health and environmental issues, such as cardiovascular diseases and red tides in the ocean.

Biomechanics of microorganisms

A red tide in the ocean occurs under certain tide, wind and algal swimming conditions, and causes serious damage in fish industries. Bacteria adhere to interfaces and form a biofilm, which causes damage on a machine and infection to a human. We clarify behaviors of microorganisms, and utilize the knowledge to solve environmental and engineering problems.

Biophysics

Left-right axis of a body is determined by weak ciliary flow in the node of an embryo. Bacteria sometimes swim collectively and generate turbulent like vortex structures, which significantly enhance mass transport in the suspension. We clarify biological functions generated by such flows, and utilize the knowledge for engineering applications.

Microfluidic devices

A microfluidic device is useful to separate cells from a small amount of sample. In order to improve diagnosis of breast cancer, we develop a microfluidic device to separate circulating tumor cells from blood. We also develop a device to separate motile bacteria and a wall configuration to prevent thrombus.

Micro-scale roboitic swimmers

A micro-scale robotic swimmer is a cutting-edge technology in micro-fabrication and drag delivery. We develop a mechanism of micro-swimmer by using fluid oscillation forces. By changing the direction of fluid oscillation, we can arbitrary control the motion of a micro-robot.

Mechanical / Biomedical Engineering

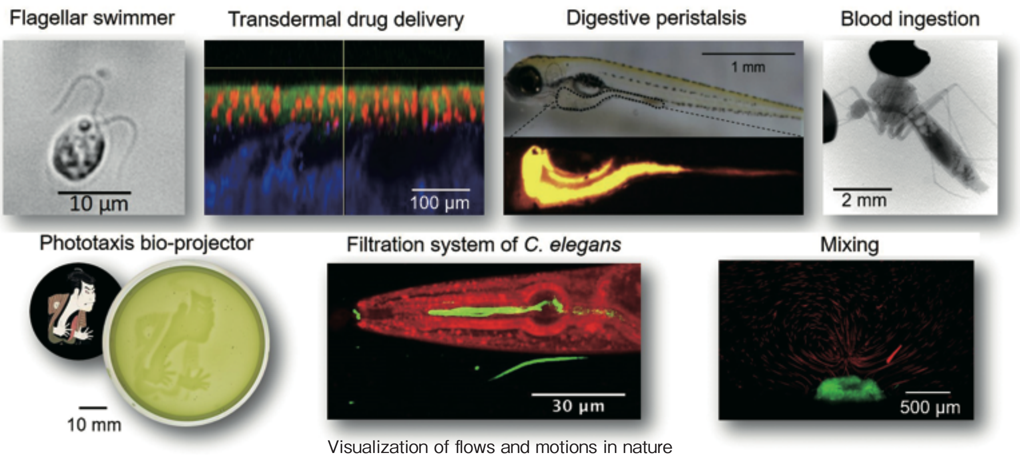
Finemechanics

Kikuchi Laboratory

Assoc.Prof.
Kenji Kikuchi

Biomechanics, Biological Flow Studies Laboratory

http://www.bfsl.mech.tohoku.ac.jp/index.html



Visualization of flows and motions in nature

Biological flow and Biomimetics using Visualization

Visualization is a userul tool for seeing invisible or unseeable flow, phenomenon, and motion which are difficult to see or cannot be seen. We have developed visualization technique and analysing for biological flows, diffusion, and motions of living things, and are conducting experimental research on various dynamics on living organisms. To better understand complex life phenomena needs theoretical analysis based on new insight from visualization experiments. We conduct interdisciplinary research across many disciplines for elucidating the mechanism of fluid-specific flow phenomena. This laboratory is operated in conjunction with the Ishikawa and Omori Labs.

In vivo bio-imaging as it is

We are developing a real-time observation technique that minimizes the load of stimuli and damage to the living organisms. There are optical limits to observing opaque cells and tissues with visible light. We are studying the internal fluid flow and the diffusion mechanism by observing the inside of the living body with non-invasive methods using ultra-short wavelength pulse laser, microfocus X-ray and confocal optical system.

Mechano-efficacy which promotes permeation and diffusion

Substances in the living organisms are further promoted to peameate and diffuse due to the fluid structure behind them. It is difficult to accurately predict and control the transport phenomenon in the living body because the substance concentration changes every moment due to metabolism and synthesis. We are studying methods for promoting the transport of drugs between cells and tissues with the controlling drug amount that permeate from the skin surface by mechanical stimuli.

Biomimetics using biological functions in engineering

The unique shapes and properties of living things may have functions adapted evolutionally to the environment. By understanding the characteristics of the living organisms dynamically and imitating and applying engineering (biomimetics), our quality of life would be better. We are researching the reduction of surface friction drag in medical equipment, aircraft, automobiles, swimming races, using hideden functions in nature.

Multimordal imaging using optical microscopy

We are developing a method to quantitatively acquire three-dimensional physical quantities using the laser-induced fluorescence method, image correlation method, and Raman scattering spectroscopy regarding the substance concentration, diffusion coefficient, advection speed, pH c , and temperature in a microscopic region. We are also studying multi-dimensional measurement methods with high spatiotemporal resolution specialized in elucidating biological phenomena.

Mechanical / Biomedical Engineering

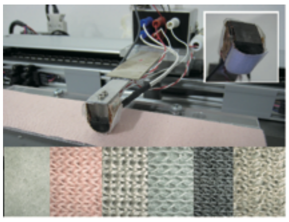
Department of Robotics/Graduate school of Biomedical Engineering

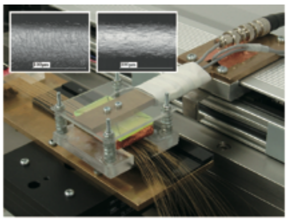
M.TANAKA Laboratory

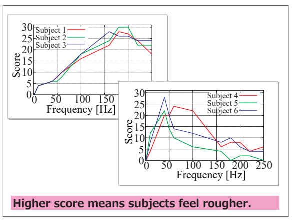
Prof.
Mami Tanaka

Biomedical Engineering for Health and Welfare, Medical Welfare Enginnering

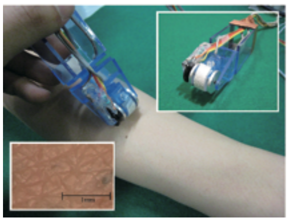
http://rose.mech.tohoku.ac.jp







Left: Intelligent artificial finger
Middle: Tactile sensor for touch feeling of hair
Right: Relationship between roughness feeling(vertical axis) and stimulus frequency(horizontal axis)



Left: Skin condition sensor
Middle: Braille reading sensor
Right: Contact stimulus sensor system

QOL technology based on tactile sensation technology

In medical, welfare and health field, improvement and enhancement of quality of life (QOL) is important. And development of medical welfare equipment using the advanced mechatronics technology is expected. In order to progress medical and welfare engineering, the creation of novel sensors and actuators and the advancement of system design and information processing technologies is necessary. Our laboratory focuses on human perception systems and aims to create new QOL technology by utilizing the skillful tactile sensation functions.

Elucidation of tactile perception mechanisms

Human perceive tactile sensations such as texture, softness, and warmth by performing touching motion such as stroking, pushing, and touching an object with fingers and hands. Tactile sensation is an essential sensation in human daily life, and one of the important indicators for developing various products. However, the tactile sensory mechanism has not been fully elucidated. In our laboratory, various experimental systems have been established to elucidate the perception mechanisms.

Development of tactile sensor system

We have been developing tactile sensor systems that measure human touch feeling. Based on knowledge about tactile perception mechanisms, we design sensor materials, measurement mechanisms, signal processing, and construct suitable sensor systems. By using the tactile sensor system, we measure not only fabric materials such as clothes but also human skin. In addition, we measure contact stimuli that affect wear comfort by using a tactile sensor using polymer piezoelectric films.

Development of Braille reading sensor system

We have been developing a sensor system that reads Braille for the visually impaired. A polymer piezoelectric film is used for the Braille reading part. The sensor system reads the electrical signal generated by contacting the film with the convex parts of Braille and distinguishes Braille characters by using difference of the electrical signal. In addition, from the viewpoint of usability, we have been designing a sensor structure to be used easily.

Development of palpation sensor

Palpation is a simple examination. However, evaluation by palpation is subjective, because palpation utilizes the tactile perception. And it is difficult to share the obtaining sensations by palpation. Therefore, a palpation sensor is demanded. We have been developing a palpation sensor that detects and evaluates the lump inside the body by scanning the object with a force measurement probe. It is expected to be useful for telemedicine and reducing the psychological burden on patients.

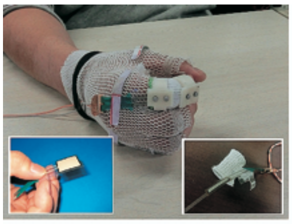
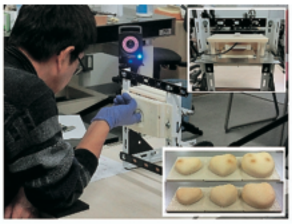
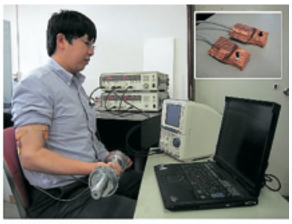
Mechanical / Biomedical Engineering
Department of Robotics

OKUYAMA Laboratory

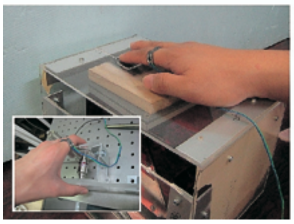
Assoc.Prof.
Takeshi Okuyama

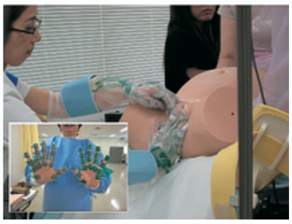
Biomedical Engineering for Health and Welfare, Medical Welfare Enginnering

http://rose.mech.tohoku.ac.jp

Left: Finger joint angle sensor
Middle: Prostate palpation simulator
Right: Mechanomyogram measurement





Left: Fingertip force sensor
Middle: Scratch motion sensor
Right: Midwives' delivery assistance measurement

Human sensing for medical and welfare engineering

In medical and welfare field, fingers and hands are used for palpation, surgery, and rehabilitation assistance. In order to acquire the exquisite skills using the fingers and hands, they need a lot of training and experience in clinical practice. Therefore, in order to learn the technique more effectively, quantification of fingers and hands motion during procedure is required. In our laboratory, we have been studying on human sensing systems and analysis methods of human motion by using the advanced mechatronics and information processing technology. The quantified motion information is utilized not only to educate novices, but also to develop seveal sensors.

Wearable sensor system for finger motion measurement

We have been developing an electroactive polymer sensor to measure finger joint angle, and a ring-type fingertip force sensor. The former is a simple structure that covers a finger joint with the electroactive polymer film that induces voltage by bending deformation. The latter is a method to estimate fingertip force from tendon tension. These sensors are devised so as not to interfere with tactile sensation and natural human motion, and are expected to be applied in various fields.

Assessment of muscle condition by using muscle vibration

To realize safe and effective rehabilitation, we have been developing methods for evaluating muscle activity such as fatigue of the muscle, focusing on the mechanomyogram and musculoskeletal vibration characteristics that occur when the muscle contracts. We have measured mechanomyograms and electromyograms at multiple points simultaneously, and confirmed that the frequency characteristics of mechanomyogram change due to muscle characteristics and muscle fatigue.

Measurement and analysis of human scratching motion

Quantification of human scratching behavior induced by itching is important in the treatment of skin diseases. In our laboratory, we have been developing several measurement systems of the scratching behavior. In particular, we have been developing a wearable microphone sensor that measures scratching sound and aiming at a system that can evaluate mechanical characteristics (contact force, etc.) during scratching by analyzing the scratching sound.

Measurement technology to quantify skillful procedure

We have been quantifying the skilled motion by using the various finger movement measurement techniques. For prostate rectal palpation, we have been developing a prostate palpation simulator that can measure motion and extract the features of skilled doctors' motion. Also, concerning midwives' delivery assistance procedure, we have quantified the characteristics of the skilled midwives by analysis of the pressure distribution on the midwife's hands.

Mechanical / Biomedical Engineering

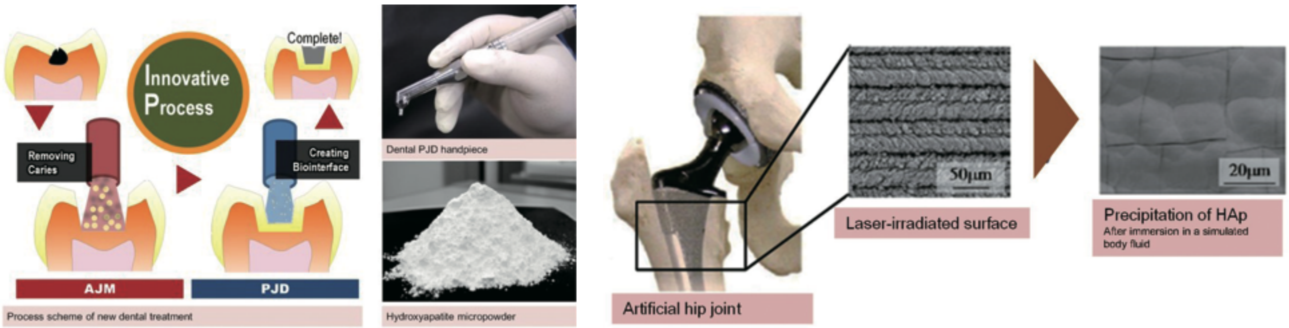
Graduate School of Biomedical Engineering / Department of Mechanical Systems Engineering, Graducate School of Engineering

Prof.
Tsunemoto Kuriyagawa

Kuriyagawa Laboratory

Bio-Medical Interface Fabrication

http://www.pm.mech.tohoku.ac.jp/



Innovative dental treatment with powder jet deposition technology

Innovation in Biomedical Engineering brought via Functional Surface

Surface is the starting point for almost all phonomena such as chemical reactions, optical reflections, and wear. We has been proceeding functional creation processing with fabrication of surface microstructures based on the advanced manufacturing technology such as ultraprecision processing. We have been attempting to improve biocompatibility and activate osteoblasts by modifying material surfaces.

Innovative dental treatment with HAp film formation

We achieved to form hydroxyapatite films on human enamel via powder jet deposition (PJD) technology that can be applied under room temperature and atmospheric pressure; i.e. it is free from preheating and vacuuming. PJD can reconstruct the tooth substance; thus this can be applied not only to cavity protection but also preventive and aesthetic dentistry.

Development of osteoaffinity implants

The biomaterial requires high compatibility to the biological tissues including cells and bones. We have been applying surface modifying techniques for achieving biocompatible surfaces. We, as of now, confirmed that laser processing can confer biocompatibility on surfaces of titanium alloy.

Creation of biocompatible and biomimetic surface

Interactions with living cells and tissues vary depending on the geometrical shape and chemical composition of the material surface. Focusing on this phenomenon, we have been working on surface creation based on biomimetic ideas. For example, the objective is to create a surface where cells and tissues can stick quickly or cannot completely. We aim to bring a new breakthrough to the medical and biotechnology fields by making full use of these methods.

Additive manufacturing for creating functional surfaces

Additive manufacturing (AM) can create complex shapes as long as the 3D shape information of the targeted structures can be prepared. Using this advantage, AM is expected as a manufacturing technology for tailor-made implants in the medical field. We have been working on the development of innovative processes that elucidate the microscopic phenomena that occur in the 3D printer modeling process and add new functions accordingly.

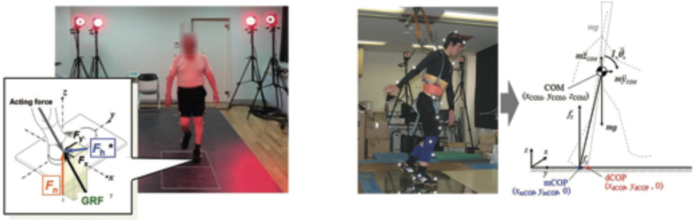
Mechanical / Biomedical Engineering
Biomedical Engineering

Yamaguchi Laboratory

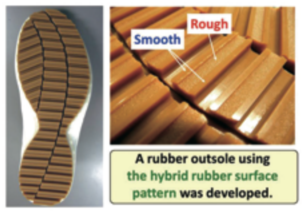
Assoc.Prof.
Takeshi Yamaguchi

Life Support Engineering, Biomedical Engineering for Health and Welfafe

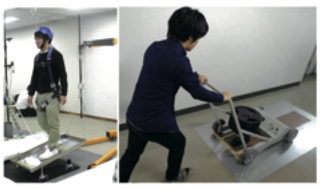
http://www.glocaldream.mech.tohoku.ac.jp/en/index.html



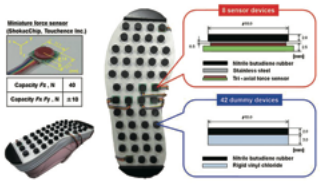
Biomechanics of gait and fall risk evaluation



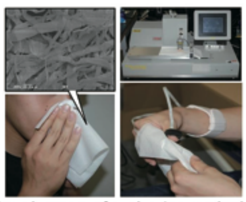
Development of high slip resistant shoe sole



Portable shoe-floor friction tester



Development of sensor shoe device



Development of evaluation method for texture of tissue paper

Life Support Engineering for Safe and Secure Society

In order to realize an independent living of elderly people and disabled people and a safe and secure life, the construction of new engineering filed that supports life and livelihood i.e. life support engineering. Our laboratory promotes education and research concerning life support engineering through studies on investigation of fall mechanism, development of footwear and floor for fall prevention, development of evaluation method of gait stability, and development of high-performance sport equipment and livingware, etc.

Biomechanics of gait for prevention of slip-related fall

Falls are becoming an increasingly critical issue in elderly individuals aged over 65 years. We aim to investigate the mechanism of falling due to induced slip during walking based on kinetic and kinematic analysis of gait. In addition, we study the friction coefficient needed at shoe-floor interface and gait to prevent slips during walking.

Development of high slip resistant shoe sole and floor

We have developed shoe sole materials and shoe sole pattern for high slip resistance on the floor covered with water, oil, or powder. We developed contact area observation system and succeeded in the development of novel pattern which remove fluids or powder from the shoe-floor interface efficiently. As a result, we have succeeded in commercialization of the high slip resistant working shoes for restaurant kitchen or food factory.

Gait analysis using sensor shoe device

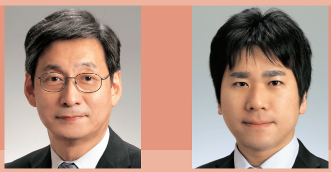
We have developed gait anaysis systmem using a shoe device mounted miniature tri-axial force sensors. By using this shoe device, it is possible to design shoe sole pattern according to the distribution of local ground reaction forces (GRFs) in the shoe-gournd contact area during walking. We also try to estimate the whole body center of mass (COM) using GRFs obtained by the shoe device, which will enable gait analysis without motion capture and force pates.

Industry-academia collaboration

Our laboratory tries to return the research results to society by industry-academia collaboration. For more detail, please see our web site.

Mechanical / Biomedical Engineering
Institute of Fluid Science

Hayase/Miyauchi Laboratory



Prof.
Toshiyuki Hayase

Assist.Prof.
Suguru Miyauchi

Cooperative Courses
Integrated Simulation Biomedical Engineering Laboratory

http://www.ifs.tohoku.ac.jp/sme/index_e.html

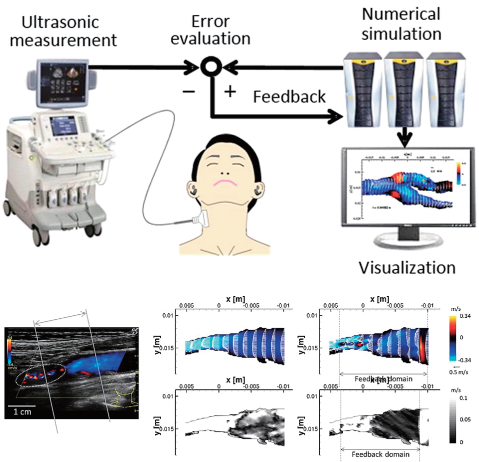


Figure 1 Two dimensional ultrasonic measurement integrated blood flow analysis system

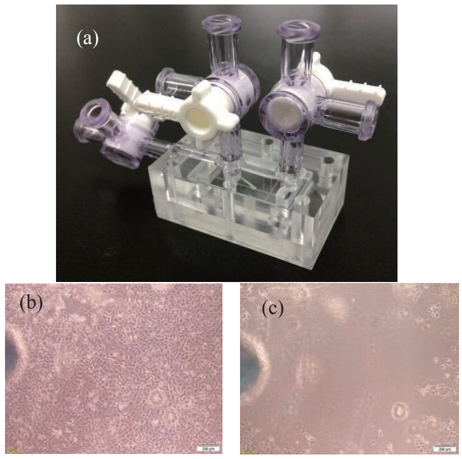


Figure 2 (a) The sample container in which endothelial cells are cultured , and distributions of the cells (b) before and (c) after the flow load experiment

Measurement Integrated Blood Flow Analysis

To elucidate initiation and growth mechanisms of circulatory diseases such as cerebral stroke and cardiac infarction, this study performs research for obtaining the complex blood flow information in vivo with high accuracy and high speed using measurement integrated simulation, which combines measurement and numerical flow simulation. Figure 1 shows the two dimensional ultrasonic measurement integrated blood flow analysis system for clinical purpose developed in our lab. This system can analyze complex velocity profile in a carotid artery, which is common site of the arteriosclerosis, and wall shear stress acting on a blood vessel wall.

Flow Analysis of Left Ventricle with Aortic Stenosis

Valves at inlet and outlet of a heart prevent back flows of the blood , and disfunctional state of the valves is called valvular heart disease. The load on the heart becomes large due to ineffective transport of the blood by the valvular heart disease, and surgery is required in a severe conditon. This study focuses on the aortic valve located between the left ventricle and aorta, and clarifies the influence of the aortic stenosis on the blood flow field in the left ventricle.

Inclined Centrifuge Microscopy for Erythrocyte Friction

Complex interactions between erythrocytes and the glycocalyx on the endothelial cells are considered to occur in microcirculation, and elucidation of the interactions lead to understanding of mechanisms of circulartory diseases and development of new diagnosis devices. This study investigates the interactions by measuring the frictional characteristics using the inclined centrifuge microscopy and by simulating the erythrocyte behaivor in the inclined centrifuge microscopy

Flow Analysis of Tumor Micro Environment

Neovascular network around the tumor has singularity to normal tissues such as abnormal blood vessel shape and increased permeability of blood vessels. These properties make the enough amount of the anticancer drug transport difficult. This study develops a flow analysis method for tumor network which can treat complex blood vessel shapes and permeability of the fluid through the blood vessel wall.

Fluid Mechanical Effect on the Endothelial Cell Damage

Endothelial Cells that cover an inner wall of blood vessels play vital roles in maintaining homeostasis of the circulatory system, and damage to these cells is known to lead to vascular diseases such as atherosclerosis. However, the cause of damage to Endothelial Cells is not yet known. This study investigates survival and damage of the cells in various flow conditions using the endothelia-cultured channel (Figure 2).

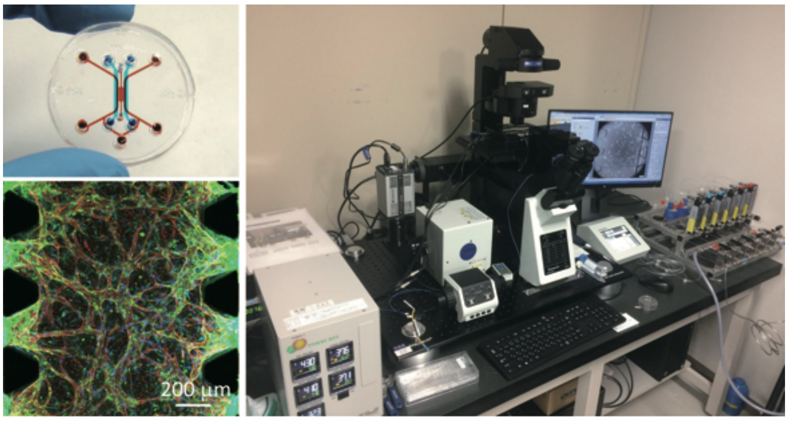
Mechanical / Biomedical Engineering
Institute of Fluid Science

Funamoto Laboratory

Assoc.Prof.
Kenichi Funamoto

Integrated Simulation Biomedical Engineering Labolatory

http://www.ifs.tohoku.ac.jp/sme/index_e.html



The 3-in-1 organ-on-a-chip (upper left), a microscope image of microvascular network formed inside the chip (lower left), and the time-lapse imaging system for observation of three-dimensional cellular dynamics (right).

Reproduction of *in vivo* microenvironments and control of cell behaviors using microfluidic devices

Cells respond to mechanical stimuli caused by motion and blood flow and chemical stimuli by biochemicals, and failures of such cellular functions possibly result in diseases or damages. An *in vivo* oxygen tension is lower than the atomospheric one, and has spatial and temporal variations. Therefore, for elucidation of *in vivo* phenomena and innovation for treatment techniques, it is critical to understand individual cell responses and cell-cell interactions under heterogeneous oxygen tension. We create microfluidic devices which reproduce *in vivo* microenvironments, and investigate mechanisms of cell behaviors and their control under various conditions.

Development of 3-in-1 organ-on-a-chip

In order to reproduce physiological and pathological microenvironments, we develop “3-in-1 organ-on-a-chip” which simultaneously controls oxygen tension and mechanical and chemical stimuli to cultured cells. Oxygen tension is controlled by supplying gas mixtures to the gas channels in the device. Simultaneously, mechanical stimuli (pressure and shear stress) and chemical stimuli (biochemicals and drugs) are applied to the cells.

Measurement and control of cancer cell migration

In tumor microenvironment, heterogeneous oxygen tension is observed due to hyperprolipheration of the cells and formation of immature vascular network. Temporal and spatial variations of oxygen tension activate migration of cancer cells and angiogenesis by vascular endothelial cells, leading to cancer progression and metastasis. This study investigates responses of cancer cells to hypoxic exposure and controls their behaviors.

Evaluation of vascular endothelial permeability

A vasular lumen is covered by a vascular endothelial cell monolayer. The vascular endothelial permeability is related to various pathological conditions, such as occurance of hemorrhage and development and progression of atherosclerosis. We investigate variations of vascular endothelial permeability by hypoxic exposure, with a focus on temporal changes of oxygen tension which are known to instantly change gene expressions.

Reproduction of placental function

An adequate functionality of placenta is essential for healthy fetal growth and maintenance of maternal health condition. Although a lot of animal experiments have been conducted to clarify the effects of maternal nutrient and health conditions on fetuses, there exists a fundamental issue that a placental structure varies by species. Hence, a placenta-on-a-chip is developed to reproduce human placnetal function *in vitro*.

Mechanical / Biomedical Engineering
Institute of Fluid Science



Prof.
Makoto Ohta

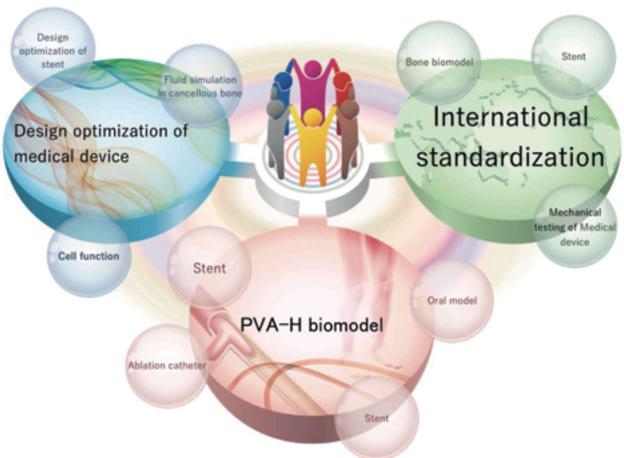
Assist.Prof.
Hitomi Anzai

Specially Appointed
Assist.Prof.
Simon Tupin

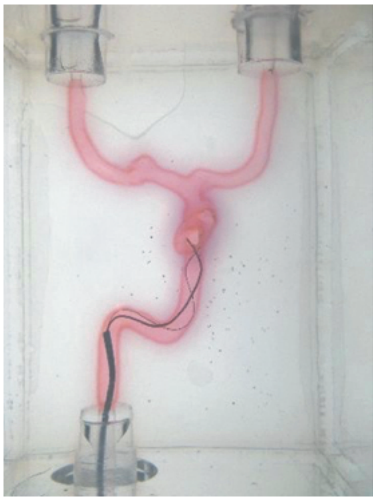
Ohta/Anzai/Tupin Laboratory

Biomedical Flow Dynamics

www.ifs.tohoku.ac.jp/bfc



Arterial PVA-H model



Laboratory activities

Tissue model (Biomodel) for mechanical testing of Medical Device

Cardiovascular disease including stroke or heart attack occurs occasionally. To treat the disease minimally invasive operation using medical devices such as catheters is attractive. To develop the minimally invasive operation, mimicked tissue model called as Biomodel is useful. We have developed a tissue model made of PVA-H (Poly (vinyl alcohol) hydrogel). The advantage of this model has similar friction of surface to the blood vessel with a wide range of mechanical properties from soft to hard. Then the medical device such as stent or coil is correctly deployed. And the model is transparent, and you can see the flow in the model with the device.

Optimization of medical device of stent

We have skills for design optimization of medical device using combination of CFD (Computational Flow Dynamics) and optimization method. Especially, we have proposed an optimized design of stent to reduce blood flow into an aneurysm and find out the roll of each stent strut to reduce the flow. Our method is based on automatic detection of optimized design for flow. You will use these skills to modify your medical devices.

Flow visualization around the medical device using PIV

Flow visualization is useful for to evaluate the function of medical device. We have developed flow visualization methods using either CFD or PIV (Particle Image Velocimetry). PIV is a technique using tracking particles with high speed camera. We have accepted several medical devices such as stent graft for leakage, coils, clot retriever, endscope and so on. We also accepted foreign companies. We will choose either CFD or PIV based on your phase of development.

Bone model for drilling

Drilling bone is a common surgical skills in dentistry or orthopedics. We developed a biomodel of bone with tribological characterization of drilling behavior on acrylic composite materials for intending to propose a substitute to natural bone. You will use the bone model for performing mechanical tests of your medical devices relating to orthopedics such as bone screw, bone saw, and bone drill.

Standardization activities

Implants always contact with human tissues. Mechanical characteristics of the implant is affected by the mechanical properties of tissue. We focus to establish standardization of tissue model for mechanical testing of implants, for training and for pre-operation. We established ISO 19213, ISO/WG14 and associated with a consortium of model of AIST. You can join us in the group or consortium.

Mechanical / Biomedical Engineering
Institute of Fluid Science

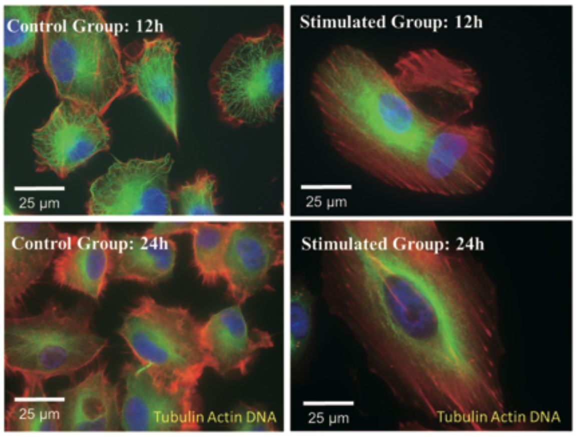
Sato/Uehara Laboratory

Prof.
Takehiko Sato

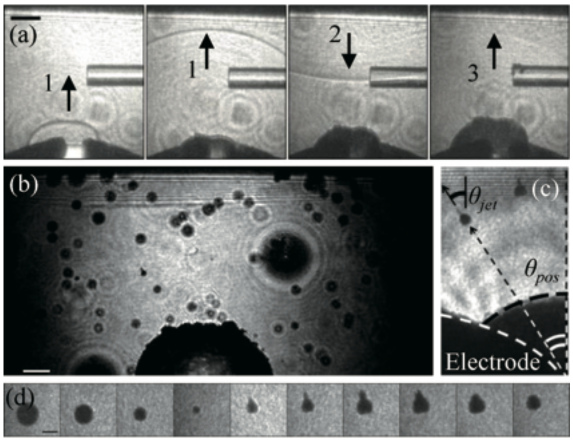
Assist.Prof.
Satoshi Uehara

Collaborative Course
Biological Nanoscale Reactive Flow Laboratory

http://www.ifs.tohoku.ac.jp/bionano/index.html



Change of Cell Response by Plasma Stimuli



Direction Control of Cavitation Microjet by Multiple Pressure Wave Associated with Discharge

Fundamentals and Applications of Plasma Medicine

We aim at clarifying how various stimuli generated by plasma flow affect living organisms, establishing fundamental theory of plasma medicine, and developing new plasma medical method. We study about the development and control of the generation method of chemical, mechanical, electric, thermal, optical stimuli of plasma flow, and clarification and control of the transport mechanism of the generated physical stimuli to the living organisms. We are conducting those researches through the new academic point of view which combines fluid mechanics, plasma mechanics, and biological mechanics. Also, we deal with the clarification of the cell response mechanisms of activation and inactivation of living organisms, development of apoptosis induction method against cancer cells, and the development of cell proliferation method using cell activation.

Response Change of Cells and Viruses by Plasma

Researches of killing and inactivation of bacteria and viruses by plasma, apoptosis induction by plasma stimuli are actively conducted. Until now, the effect of chemically active species generated by plasma has been gaining attention. In our lab, we conduct the observation of the cell responses by plasma stimuli and its detailed analysis in order to clarify the electric effect which is as important as the chemical responses. (left photo)

Clarification of Propagation Mechanism of Underwater Plasma Flow and its Biological Application

We try to clarify the streamer propagation process which gives a great influence on the chemical species generated in the underwater plasma flow, and deal with the application to the plasma medicine. In our lab, we measure the high-speed streamer propagation using ultra high-speed camera which has a nano-second time resolution. We aim at clarification of charge movement associated with the streamer and the behavior of the bubbles generated at the time of discharge, and the development of cell response induction technology by the control of the charge transfer.

Clarification of Thermal Flow Field and Chemical Reaction Field of Gas-Liquid Plasma

We try to clarify the fundamental phenomena of the interaction between plasma at the gas-liquid interface and the liquid, and deal with the application to the plasma medicine. Especially, we develop the efficient chemical transport method to the living organisms by clarifying the generation mechanism of plasma-generated flow and the transport phenomena of chemical species.

Development of Generation Method of Microbubbles and Microjet by Plasma

We advance the development of the generation and measurement method of fine bubbles by underwater plasma, and the development of the generation method of microjet using the generated bubbles. As shown in the right photo, we advance the research of the intracellular material introduction method by the microjet which is controlled by using multiple shock waves generated with the underwater discharge.