The 21st Century COE Program
Mechanical Systems Innovation
The University of Tokyo

Newsletter

No.3E
November 1, 2004

The 21st Century COE Program
Mechanical Systems Innovation, The University of Tokyo

Biomedical Innovation Project

In our aging society, new medical treatments and health care technologies are crucial. The technologies of the future must provide a variety of mechanical systems capable of delivering advanced medical treatments for the maintenance of good health and for tailoring medical services to meet individual needs. Our biomedical innovation project, therefore, is conducting research on advanced medical support technologies by integrating nano and micro mechatronics with biotechnology. More concretely, we are now performing research on: (1) development of a remote medical diagnosis system and high precision minimally invasive surgical robot system using advanced data communications, control and robotics technologies, (2) development of contrast media for identifying malignant tumors by applying microelements such as molecular markers and nano-bubbles, which move with the flow and allow visualization of critical phenomena in the macro flow, (3) new, noninvasive tumor therapy systems using high-intensity focused ultrasound (HIFU), (4) a lithotripsy system using the collapse phenomenon of cavitating bubbles, (5) a low-invasive laser coagulation treatment using controlled heat transfer, (6) construction of bio-nano system using a DNA handling technology based on micro machining and measurement, and nano-micro mechatromics. Several of these research areas are introduced in more detail in the newsletter.

Medical information system

Remote medical system (Tele-microsurgery system)

Mamoru Mitsuishi, Professor
Department of Engineering Synthesis

“Remote medical systems” provide an environment where a medical doctor at a remote location can diagnose and operate on a patient. There are several kinds of remote medical systems, such as tele-pathology, tele-mentoring, tele-surgery and tele-education systems. These technologies reduce the stress on and workload of both the patient and doctor and allow for consultations between local and remote medical professionals, emergency care workers, home care specialists, and high-level medical educators. In our group, as an example of remote surgery, a remote, minimally invasive surgical system has been developed. Multi-axis force sensors are installed at the master manipulators for the left and right hands. The force detected at the slave manipulators can be fed back to the master manipulator. The viewing direction of the endoscope, which is supported by a slave manipulator, can be controlled from the master manipulator by switching the mode using a foot pedal. The slave manipulator has three arms. The left and right hands hold the forceps and the center arm holds the endoscope. All arms are designed so that the insertion point for the trocar is mechanically fixed in space. A cholecystectomy for a pig has been successfully executed 4 times between Tokyo and Fujinomiya by our group. The time delay was 390 ms and 50 ms, for visual and auditory information transmission (1.5 Mbps) and control information transmission (256 kbps), respectively. Our group is also developing a micro-neurosurgical system in the deep surgical field, a bone cutting robot for total knee arthroplasty, a robot to assist femur fracture reduction, a remote ultrasound diagnosis system, a hand surgery system and a tele-micro-surgical system.

Master manipulators for the remote minimally invasive surgery

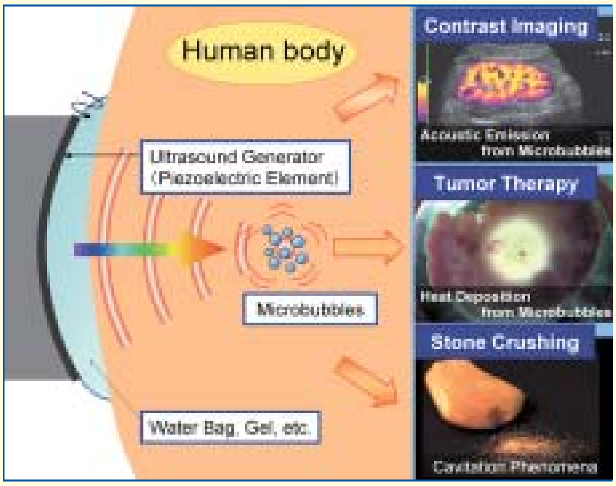
Slave manipulators for the remote minimally invasive surgery

Noninvasive or minimally invasive medical therapy

Non-invasive Treatment with Ultrasound

Yoichiro Matsumoto, Professor
Department of Mechanical Engineering

Recently, Ultrasound is widely applied for the less-invasive treatment, and microbubbles are also closely tied to the diagnosis or therapeutic use. For diagnostic applications, their large sound scattering property yields improved imaging, where the microbubbles are used as contrast agents. The harmonics responses from the bubbles assist in distinguishing the acoustic scattering of blood from that of the surrounding tissue.
For one of the therapeutic applications, the heat coagulation of tumor site has been investigated. HIFU (High Intensity Focused Ultrasound) has attracted much attention, and microbubbles in HIFU field can convert the mechanical energy of ultrasound into heat. The heat generated by the bubbles contributes an enhanced heating effect, and the treatment with lower power ultrasound can be realized.
The treatment of crushing renal stone has also been developed. The violent collapse of cavitation bubbles generated by ultrasound has the potential of inducing tissue traumas. The new method of crushing has been investigated: the cavitation is located only at the stone surface, and erodes only the stone, not the tissue. The fragments are sufficiently small to pass through the urethra.
The synergy of ultrasound and microbubbles has a potential to be applied to DDS (Drug Delivery System), gene transfer and so.

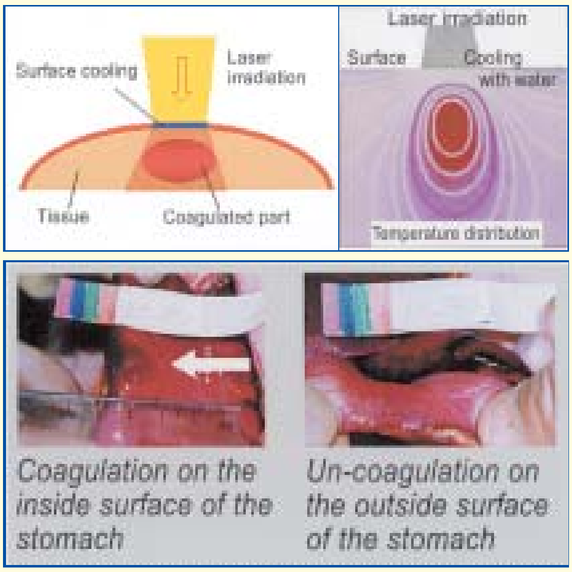


Synergy of ultrasound and microbubbles

A New Methodology for Spatially Selective Laser Coagulation

Masahiro Shoji, Professor
Department of Mechanical Engineering

A new low-invasive laser coagulation system is developed by irradiating the gastric wall from the serosal side combined with synchronous serosal cooling that can produce deep thermal coagulation without transmural damage. Basic analysis, fundamental as well as animal experiments were conducted to ascertain whether this system could coagulate the musoca and submucosa with acceptable injury to the muscular layer and serosa. Cauterization of the mucosa and submucosa with acceptable muscle layer damage was achieved in selected setting to find that this method is a promising, novel, minimally invasive treatment for submucosal cancer.



Spatially selective laser coagulation

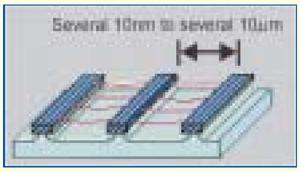
Nano and micro bio-engineering

Construction of bio-nano system using DNA
Realization of tailor-made medical therapy

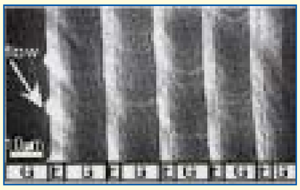
Masao Washizu, Professor
Department of Mechanical Engineering

DNA consists of four bases, A, T, G and C stacked at the spacing of 0.34 nm, and the genetic information is recorded by the sequence of the bases. DNA retains its structure, and reproduces itself, by the specific bindings between complementary bases, A-T and G-C. If a DNA strand is immobilized on a solid surface as a template, onto which the target molecules labeled with complementary DNA fragments are fed, the base pairs are spontaneously formed, and the target molecules will be aligned on the template as designed, at a resolution of 0.34 nm. Such a self-assembling technique will have applications in the construction of molecular electronics circuits, biochemical functional molecular units, or assembling of molecular machinery. The chemical stability of DNA, as well as the ease in its synthesis, makes the molecule the best candidate as the template for such molecular constructions.

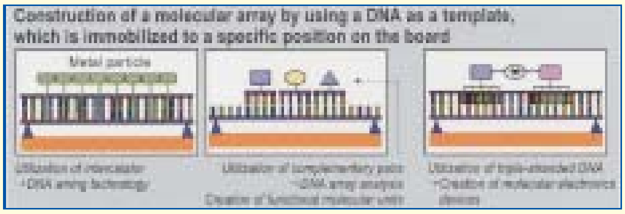
To investigate such possibility of DNA-based self-assembling technology, we are currently using our original electrokinetic DNA manipulation methodology in combination with microfabircation techniques to stretch and immobilize DNA strands in microstructures, and to perform dynamic interaction studies between DNA and foreign molecules. The clarification of the molecular process in single-molecule level will not only open a way for the molecular construction, but also provide basic knowledge for the improvement of hybridization-based gene analysis such as DNA chips.



DNA stretch-and-positioning using microstructure



Anchoring only at molecular ends to avoid steric hindrance



Construction of a molecular array by using a DNA as a template

Development of Cell-Engineering Devices / Fujii

Teruo Fujii, Associate Professor
Department of Environmental and Ocean Engineering

PDMS Cell Culture Device

The group of Prof. T. Fujii at the Institute of Industrial Science is working on the so-called 'Cell-engineering Devices' in collaboration with Prof. Y. Sakai's group at the Center for Disease Biology and Integrative Medicine. The idea of the device is to mimick the microfluidic environments in in vivo tissues by introducing microfabrication techniques. Three dimensional arrangement of the cells and active materials transport in the cultured tissues are expected to be realized in the newly developed devices.

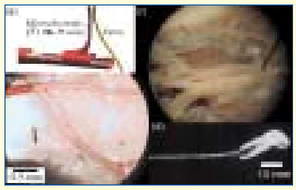
Hep G2 cells in the device (day 6)

Real-time multipoint measurement of brain functions using ultra-precise electrodes: Development of auditory function recovering technology

Masayuki Nakao, Professor
Department of Engineering Synthesis

The ultimate goals of our group are to elucidate the high-order function in the brain and to develop advanced medical technologies. Toward this purpose, we have been developing ultra microelectrode arrays on the basis of our microfabrication technologies, and have been applying them for mapping and microstimulation of the brain activities.
The left figure shows, for instance, the animal model of neural prosthesis that directly stimulates the cochlear nucleus in the brainstem and restores hearing to deaf patients. Using the model, we mapped neuronal activities in the auditory cortex, and compared the activities evoked by acoustic stimulation and those by microstimulation in the cochlear nucleus. We developed a surface microelectrode array for the cortical recording and spike microelectrode array for the cochlear nuclear microstimulation. Our recent experiments highly suggest that microstimulation at an adequate location and that with adequate stimulation strength can induce the pitch and intensity sensation, respectively, thus substantially showing the capability of the prosthesis.
The right figure(a) shows an intravascular recording with an ultra-thin wire array we are developing. In the recording, we introduce neural probes into cerebral vessels using a microcatheter and have the probes flow through capillaries toward the destination. The probes are required to introduce the probe to a spinal artery and measure the neural activities in the spinal cord. The right figure(d) shows the probe employing insulated platinum wire with a diameter of 1 mm, which was proved to be safe, and having platinum black electrodeposited at the tip, by which reduced electrical impedance yielded a sufficiently high S/N ratio.

Real-time multipoint measurement of auditory brain functions



Intravascular recording with an ultra-thin wire array

Activities of Mechanical Systems Innovation Program

〈Open Seminars〉

◎FY2004-1st Seminar
Date : June 15, 2004
Venue : Seminar Room, Frontier Sciences, Kashiwa Campus
Speaker : Prof. William Curtin (Division of Engineering, Brown University)
Subject : Mechanical Properties of Carbon-Nanotube Ceramic Matrix Composites

◎FY2004-2nd Seminar
Date : June 18, 2004
Venue : Lecture Room No.27, Faculty of Engineering Bldg.2, Hongo Campus
Speaker : Dr. Michael R. Bailey (Center for Industrial and Medical Ultrasound, Applied Physics Laboratory, University of Washington)
Subject : Behavior and Application of Cavitation in Lithotripsy and High Intensity Focused Ultrasound

◎FY2004-3rd Seminar
Date : June 21, 2004
Venue : Conference Room No.1, Institute of Industrial Science, Komaba Campus
Speaker : Prof. Urs Staufer (Institute of Microtechnology, University of Neuchatel)
Subject : Scanning Force Endoscope

◎FY2004-4th Seminar
Date : July 27, 2004
Venue : Conference Room, Faculty of Engineering Bldg.7, Hongo Campus
Speaker : Professor Ibrahim Sinan Akmandor (Department of Aerospace Engineering, Middle East Technical University)
Subject: Use of Novel Rotary or Thrust Augmentation Systems in Micro Vehicle Propulsion.

◎FY2004-5th Seminar
Date : July 29, 2004
Venue : Conference Room, Faculty of Engineering Bldg.7, Hongo Campus
Speaker : Prof. Ibrahim Sinan Akmandor (Department of Aerospace Engineering, Middle East Technical University)
Subject : Improvement of Power and Efficiency Using a Novel Compound Rotary-Gas Turbine Systems

◎FY2004-6th Seminar
Date : September 9, 2004
Venue : Lecture Room No.226, Faculty of Engineering Bldg.7, Hongo Campus
Speaker : Prof. Fei-Bin Hsiao (Institute of Aeronautics and Astronautics, National Cheng Kung University)
Subject : The Evolutionary Development of Unmanned Aerial Vehicles in National Cheng Kung University

◎FY2004-7th Seminar
Date : September 9, 2004
Venue : Lecture Room No.226, Faculty of Engineering Bldg.7, Hongo Campus
Speaker : Prof. Seung Jin Song(Department of Mechanical and Aeronautical Engineering, Seoul National University)
Subject : Micropropulsion Activities in Korea

The 21st Century COE Program Mechanical Systems Innovation, Newsletter No.3E

November 1, 2004
The 21st Century COE Program Mechanical Systems Innovation Office, The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, JAPAN
Phone and Fax/+81 3 5841 7437
URL/http://www.mechasys.jp/