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The University of Tokyo Global COE Program : Global Center of Excellence for Mechanical Systems Innovation

Global Center of Excellence for Mechanical Systems Innovation

GMSI Newsletter

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Conversation

Tiny chemical plants for medical and environmental measurement applications

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A conversation with collaborating researchers

Tiny chemical plants for medical and environmental measurement applications

Microscale and nanoscale 'chemical chips' evolve as micromachining technology advances

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Graduated from the Department of Pure and Applied Sciences in the University of Tokyo's College of Arts and Sciences in 1980, and joined the Hitachi Energy Research Laboratory as a research staff member that same year. He earned his PhD in engineering in 1989, and became a Professor in the University of Tokyo's Faculty of Engineering in 1998 after rising through the ranks as Assistant Professor, Lecturer, then Associate Professor. Prof. Kitamori became the Vice-Dean of the University of Tokyo's School of Engineering in 2008. His areas of specialization include analytical chemical measurement and integration of chemical systems on microchips. His major publications include *Bunseki Shuho no Saizensen* ('Frontiers of Analytical Methods'), *Hayawakari Microkagaku Chip* ('Guide to Microchemical Chips') and *Integrated Chemistry* (in Japanese).

Prof. Nakao earned a Master's Degree from the Department of Engineering Synthesis in the University of Tokyo's School of Engineering in 1983. He joined Hitachi Metals in the same year, working in its Magnetic Materials Research Laboratory. Prof. Nakao was later seconded to HMT Technology Corporation in California in 1989 to help start a magnetic disk production facility. He later earned a PhD in engineering from the University of Tokyo in 1991 and became an Associate Professor in the Department of Engineering Synthesis in the University of Tokyo's School of Engineering in 1992. In 2001 he became a Professor in the School of Engineering. Prof. Nakao's research covers various fields, such as nano- and micromachining, intelligent machining, and miniaturization of scientific devices. He makes media appearances as an expert in the field of failure analysis, and has several major publications including *Shippai no Yobōgaku* ('Failure Prevention'), *Shippai ha Yosoku Dekiru* ('Failures are Predictable'), *Shippai no Hyakusen* ('One Hundred Failure Case Studies') and *Seisan no Gijutsu* ('Production Technology').

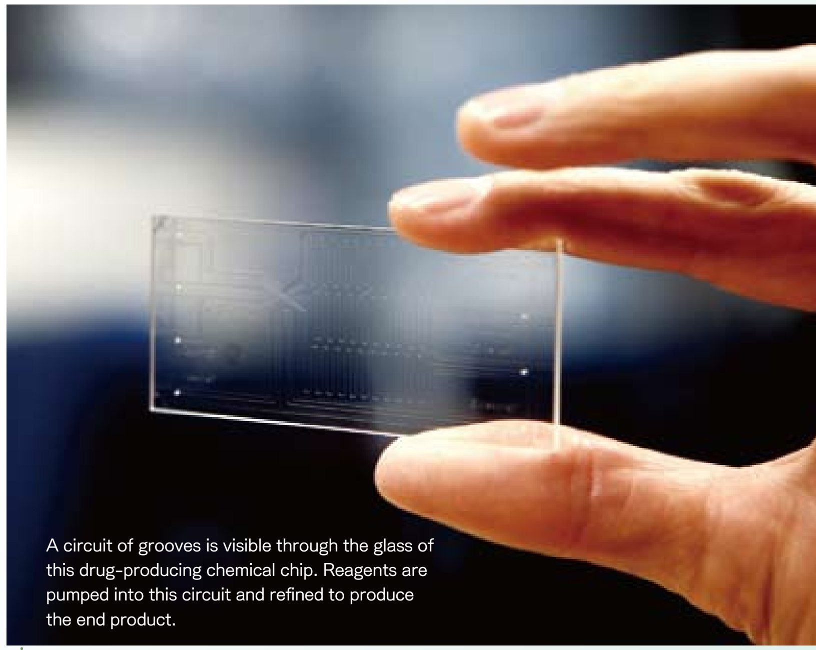
Micro- and nanoscale lab-on-a-chip (LOC) devices known in Japan as 'chemical chips' or 'Kitamori chips' are made by scoring small grooves inside microscope specimen slides. They can be used in various types of research. Chemical chips represent the combined research efforts of laser spectrograph expert Professor Takehiko Kitamori and Professor Masayuki Nakao, a leading authority on micro- and nanomanufacturing. These tiny chemical plants are promising for a wide array of applications such as chemical mass-production, immunological blood analysis and environmental measurement. GMSI Newsletter asked Professors Kitamori and Nakao about the events leading to the development of chemical chips, and what they see for the future.

Micro- and nanoscale chemical chips act like tiny chemical plants

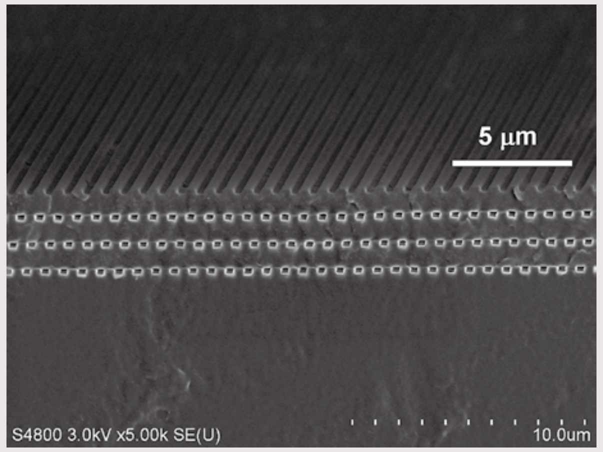
I understand you've partnered on research projects before, is that right?

Kitamori: Yes, a typical example was developing a drug synthesis chemical chip. It's a container that manufactures drugs by enabling chemicals to react inside it to separate and purify the products. We created it by scoring miniature grooves of about 100 microns deep inside a glass specimen slide measuring 3 by 7 centimeters and 0.7 millimeter thick. A miniature pump is used to pump several chemicals into the grooves. You can think of it as a tiny chemical plant. The grooves have a volume of only a few hundred nanoliters, so you only need to use one-billionth or a few ten-millionths the volume of reagents you'd need to use if you were synthesizing chemicals in flasks or beakers. The smaller volume of reagents needed is not only cheaper but also easier to warm and cool, which speeds up the chemical reactions. The tiny scale also makes reactions less prone to being contaminated by impurities, and eliminates the risk of explosions or other hazards. There's really no downside. A single chemical chip can only synthesize a minute quantity of drugs, but there are already plants that use arrays of 7,500 of them in tandem to generate chemical reactions. They're producing something like 150 tons of drugs a year. A blood analyzer driven by a chemical chip was released on the market last October.

The chip's development was a team effort of many years between Professor Nakao and myself. You see, when you look at the grooves on the chip with the naked eye, all you can see is a single line, but there's actually a very complex structure inside this line that is designed to enable chemical reactions. This structure could never have been created without micromachining technology—the reason for our partnership. I started working on developing the chip about fifteen years ago. At first I had no idea what technology to use, so I approached Professor Nakao who was working in the field of nanomanufacturing.



A circuit of grooves is visible through the glass of this drug-producing chemical chip. Reagents are pumped into this circuit and refined to produce the end product.



A cross-section of a five-layer microsheet created by roll-to-roll nanoimprinting seen under a scanning electron microscope.

Nakao: Actually, after finishing graduate school I got a job for a while at Hitachi Metals. At the time I worked in hard disk production, so I didn't start out making miniature components. I got into this area 18 years ago when I went back to university at the age of 33. After a bit of thought on what research topic I should work on, I decided to start researching ways of creating smaller components. Micromachining tools didn't exist in those days, so I had to start by creating them. But now, nearly twenty years later, technology has advanced dramatically and everyone can apply semiconductor manufacturing technology to micromachining in the same way. Today there are places like Taiwan that can do micromachining to order if you give them the drawings for the chemical chip you want. So sub-micron level micromachining is no longer so incredible. The next boom now starting to happen is technology for creating patterns of just a few nanometers in size—one hundred times smaller than the sub-micron level. But what's so great about Professor Kitamori's research isn't the pattern size, it's that he developed devices with machined groove patterns tailored to individual applications.

How did you get the idea for your chemical chip?

Kitamori: Like Professor Nakao, I spent some time at Hitachi's Energy Research Laboratory after graduate school. While there, I worked on developing a laser spectroscope for analyzing minute quantities of substances with lasers. That was followed by work on a research project headed by leading laser beam researcher Tsuguo Sawada of the University of Tokyo. So I didn't start out planning to create a chemical chip.

When observing objects under a microscope, normally you place the specimen between thin specimen slides. We tried putting a minute amount of liquid between the slides and measuring it by shining a laser through it, but the method didn't work because the liquid was unstable. So we came up with the idea of scratching the slide to stabilize the liquid, and then successfully mixed two different liquids by making a Y-shaped scratch in a slide. That was the birth of the first chemical chip. When we tried using this method to mix non-mixing liquids, we found they flow side by side without any mixing, which made me wonder whether there might be a practical application for it. After a lot of trial-and-error, we became able to create a complex circuit using various combinations of Y-shaped scratches. In other words, we became able to make chemical chips act like semiconductors.

But making the scratches in the glass was difficult in the beginning. Having the work done by an outside company took six months, and the grooves would sometimes be clogged and useless, so I asked Professor Nakao for help. Another problem was that the surface tension would prevent the liquid from entering the grooves the way we wanted, or it would flow very fast due to capillary action as soon as it entered. We tried fixing these problems in various ways. One very primitive approach we tried at first was using twisted kite string to control the liquid flow speed.

Nakao: The properties of glass make it hard to work with. Glass is stable and unreactive, that's why it's used to make lab equipment. So it's very difficult to create machined glass objects by etching. Another difficulty is that the chemical chip has to be made by diffusion bonding two sheets of grooved glass onto each other, to join them by heat and pressure without melting. To bond the glass, you have to use a press to apply pressure to it without warping it. You have to maintain a constant temperature of about 650˚C so that the machined grooves don't deform, and the glass softens but doesn't melt. We had to create all these device development techniques from scratch just by trial-and-error. In those days we couldn't borrow an electron beam generator from another research lab to do the machining since the university's departments didn't lend research equipment to each other the way they do now. In retrospect, the difference in the way professors and associate professors are treated in the mechanical and chemical engineering departments created a lot of problems for us!

Kitamori: That's very true. We tried using materials other than glass, such as metals and ceramics, but since we need to shine a laser through it for observation we're currently still using glass. In the future, I think chips will be made of different materials depending on their application and price.

Chips produced by a combination of chemical and mechanical engineering

Do chemical and mechanical engineering require different research approaches?

Kitamori: I think chemistry research depends a lot on experience and intuition. Successful researchers need to develop a certain skill set and hone their intuition. When I was at Hitachi for example, I had to test the reactor water in a nuclear reactor. The reactor water was very close to pure water. I was trying to find impurities measured in the parts per trillion (ppt). At those levels, the results can vary just by how you wash the test tubes. It took me more than six months to acquire the skill of being able to wash the test tubes properly.

Another requirement is the intuition to be able to see opportunities in chance events. For example, the event that led to the development of the chemical chip was my getting an old microscope. The medical school was throwing it out, and I didn't want it to go to waste. I used it to try measuring liquids by passing a laser through them, and was amazed to find I could make measurements that would normally be impossible. The microscope was so old that its color aberration compensation was off, making these impossible measurements possible. It was this chance event that led to the development of the world's !!first!! thermal lens microscope, and to chemical chips—made from the specimen slides it uses.

What makes a thermal lens microscope different from other microscopes?

Kitamori: When you use a thermal lens microscope to shine a laser into a fluid, you get lens effects because the heat generated changes the lens's index of refraction. Examining the magnitude of the change lets you measure quantities of molecules. Of course, you need a large electron microscope to observe individual electrons 'by eye', but you can still detect molecules with a thermal lens microscope even though you can't observe them. The problem is that you can't identify molecules, and that's where chemical chips come in. The circuit in a chemical chip guides the liquids that pass through it to enable the chip to detect which molecule has passed through—Liquid A flows through the grooves and ends up on the left, while Liquid B ends up on the right. For example, you could create a chemical chip that only allows a particular protein linked to a specific allergy or cancer to pass through it, and use it to detect that specific illness. Chemical chips now have a precision measured in parts per trillion (ppt). A length of 1 millimeter in a distance of 25 times the circumference of the earth at the equator is just a few ppt—that gives you an idea of just how high a level of precision that is. And now researchers are working on increasing detection to levels measured in ppq—parts per quadrillion. Incidentally, liquids start to behave very differently than they normally do when you're talking about scales ranging from a few nanometers to tens of nanometers. For example, the groove walls can increase the viscosity of a liquid by a factor or four or five, reduce its dielectric constant by 90 percent, or activate its hydrogen ions and change the actual chemical reactions. This is the nature of the nanoscale we're trying towork with at the Center.

Will more research on the extended nanoscale generate more applications?

Kitamori: Yes. Right now chemical chips are being used to generate medicines, and as immunological analyzers that analyze ailments such as cancer, inflammation, allergies, myocardial infarctions, and hepatitis B. They can also be used as environmental analysis sensors. For example, researchers are working on using them to detect trace amounts of ammonia in clean rooms. The ammonia that emanates from human skin can sometimes cause manufacturing problems in LSI manufacturing plants. No ammonia sensor currently available is sensitive enough for this application, so chemical chips look promising here.We're now investigating the expanded nanoscale to research possible energy applications such as semiconductor cooling equipment.

Nakao: Meanwhile, I'm making chemical chips out of metal and diffusion-bonding stacks of one hundred of them to build devices that enable reactions in a water-cooled environment. I'm also working to bring the manufacturing cost down to ten yen per chip by making them from extrusion-molded plastic instead of glass, so you could say my areas of research are gradually shifting. One of the new areas I'm working on is nanoimprinting, a technology that uses a metal die to transfer micromachining to a plastic substrate instead of cutting grooves on it directly. The aim is to use this new method for extended nanoscale manufacturing. For example, we're working on transferring miniature patterns of around 100 nanometers in width to large items such as LCD screens.

Removing barriers between fields, honing Japan's strengths

I understand that both of you happen to have served as the head of the university's health and safety office, is that right?

Nakao: That's right. I'm the current head. I took over the position from Professor Kitamori. One of the most important tasks the position is responsible for is disposing of unknown reagents stored on university grounds. Unknown reagents are chemicals that were used for research in labs. They're an unwelcome legacy handed down to us by the university's 130-year history. You see, when a professor retires, we sometimes discover chemicals containing unidentifiable ingredients that were used in his research. The Faculty of Engineering alone has generated nearly 3,000 of these chemicals, and there are nearly 30,000 throughout the entire university. Since some of the chemicals are hazardous, we're now in the midst of analyzing and disposing of them, but we're not making much progress since there are so many of them. Right now I have about 30 students working part-time for me to analyze the substances. We can process about 1,300 chemicals a year. It would be great if we could use Professor Kitamori's chemical chip for this chemical analysis work.

Kitamori: That's right, hiring an outside organization to analyze the chemicals would cost tens of thousands of yen [hundreds of US dollars] per substance, or around two million yen ($20,000) for some of the hazardous substances. Nowadays, it's more expensive to dispose of chemicals than buy them! It would be great if we could use chemical chips for this application in future.

What is the outlook for the future, and what message do you have for young researchers?

Nakao: A key theme for the years ahead will be removing the barriers between fields to let researchers share ideas. I think the Center will really come of age in such an environment, and the growing array of multidisciplinary research partnerships will be very welcome. Fifteen years ago a research partnership like ours was rare, but the Center is going to revive the academic world by creating a research partnership boom. In the years ahead, I'd like to continue exchanging ideas with colleagues in many different fields, to create new value—make one plus one equal three instead of two. Another thing I'd like to mention is that as a failure analysis expert, I find that one-third of the failures in manufacturing sites are caused by communication errors. For that reason, I'd like to let people know how important it is to remove the barriers between academic disciplines and stimulate communication.

Kitamori: Chemistry is a field where unexpected discoveries are sometimes made by trial-and-error of various approaches. It's a field that becomes more interesting the more experienced you become, and in the coming years we're going to see many different types of chemistry knowledge used to help develop new engineering devices. There will be ever-greater opportunities for unexpected discoveries from multidisciplinary approaches. With Japan's science and technology facing an uncertain future, now more than ever, young researchers need to find the strength of character to create innovations that tear down the conventional barriers separating different academic disciplines and organizations.

Reported and written by : Madoka Tainaka
Photographs by : Yuki Akiyama

KIM, Seong Su
Project Researcher

Development of alternative cure cycle to minimize the thermal residual stress for composite materials

My name is Seong Su Kim, and I became an associate researcher on May 16, 2009. I earned Ph.D. degree majoring in mechanical design with advanced materials at Korea Advanced Institute of Science and Technology (KAIST) in Feb 2007. I have been working as a senior researcher of KAIST Institute for Design of Complex Systems (KIDCS). My Ph.D. research in the laboratory of Prof. Dai Gil Lee focuses on the development of the hybrid composite journal bearing for large vessels. My research interests lie in design of composite structures based on mechanics of composite materials, engineering tribology such as thermo-hydrodynamic analysis of fluid lubrication and frictional behaviors of self-lubricating materials, and development of diagnostic techniques that enable detection and quantification of damage. Further, I will concentrate all my efforts on developing bipolar plates for automotive fuel cells with carbon fiber composite. I will also contribute to achieving the goals of the GMSI program. I look forward to your support and cooperation.

1. Thermal residual stress of composite materials

Fiber reinforced composite materials are used in many aerospace, civil, and industrial applications. To produce these materials, strong and stiff reinforcing fibers such as graphite or glass are embedded in a lightweight, compliant matrix such as epoxy to create a material which takes advantage of the beneficial mechanical and thermal properties of both constituents. Composite materials are often selected over traditional engineering materials because they may possess higher stiffness-to-weight and strength-to-weight ratios. Additionally, the mechanical and thermal properties of composites can be customized through the appropriate selection of constituent materials, geometry, and processing conditions. The increased use of composites in structural engineering applications has led to concern about the reliability of these materials. In particular, residual stress introduced during fabrication is cited as one of the most significant problems in the processing of composite structures. These stresses can cause warping or "spring-back" of the composite structure and can significantly degrade the strength of the material, resulting in cracking, reduced fracture toughness and fatigue strength, and delamination. The primary causes for residual stress in composites are thermal stresses due to the different coefficients of thermal expansion of the constituents, and curing stresses which result from chemical shrinkage of the matrix material during processing of polymer matrix composites.

2. Cure monitoring using FBG sensor and Dielectric sensor

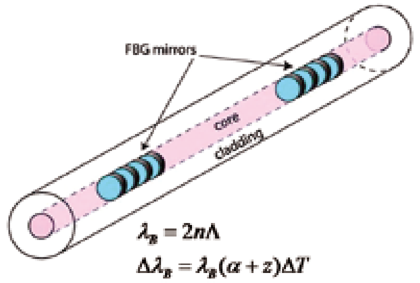
For these reasons, the curing process is the most critical and costly stage in the manufacturing of composite structures. An intelligent manufacturing process has to be able to recognize the features of the process by using in-situ sensors and then to activate the controller connected with the system actuators. To control the processing operation with feedback capability, real time in-situ information about the condition of the material must be available. Fiber optic sensor as shown in Fig. 1 offers a very powerful tool to perform remote, on-line, in-situ monitoring of composite manufacturing processes. The fiber optic is free from electromagnetic interference, and is characterized by high chemical and high temperature resistance. Moreover, to this aim, due to the capability of the fiber optic sensors to be multiplexed in a large number of independent channels, due to the fact that fibers are readily embedded in to the composite and due to their small size that make them minimally intrusive in the host structures; this approach provide useful tools to realize the so-called Smart Materials.

For the dielectrometry measurement, two electrodes embedded in composite materials are connected to an alternating electric field, where the composite forms a capacitor. The charge accumulated in the capacitor depends on the mobility of dipoles and ions presenting in the resin to follow the alternating electric field and varies with the state of cure. The degree of cure is related to the movement of dipoles and ions, which have high mobility when the epoxy resin is uncured. But the movement is restricted abruptly when the epoxy resin becomes gel state or solidifies. The degree of movement can be expressed by the dissipation factor D, which represents the ratio of the energy loss by movements of dipoles and ions to the supplied energy.

In this study, the dissipation factor D is measured in the carbon epoxy composite material using a commercial dielectrometer using an alternating current of 1 kHz frequency. As shown in Fig. 2, the dielectric sensor is composed of two very long electrodes with opposite polarity on the same plane.

The sensor is made of a thin copper plate of 25 μm thickness using a photo-lithographical etching, of which base film is made of a polyimide film of 50 μm thickness because the polyimide has constant dielectric property regardless of temperature. The sensing area of the sensor, the width of the electrode, and the gap between the electrodes are 9 mm × 25 mm, 100 μm and 100 μm, respectively.

For curing monitoring, the carbon-epoxy prepreg sheet is stacked on the aluminum plate. An FBG sensor, inter-digital dielectric sensor and a K-type thermocouple are embedded in the center of the specimen. The thermal residual strain, dissipation factor and temperature of the carbon epoxy composite during various cure cycles are measured using the devised measuring system.



$$\lambda_B = 2n\Lambda$$
$$\Delta\lambda_B = \lambda_B(\alpha + z)\Delta T$$
$$\Delta\lambda_B = \lambda_B(1 - P_e)\varepsilon$$

λ_B : *Bragg wavelength*, n : *effective refractive index*
Λ : *grating period*, z : *thermal – optic coefficient*
P_e : *photo – elastic const.*

Fig. 1 Schematic diagram of FBG sensor

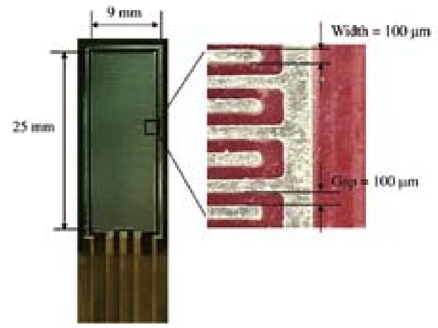


Fig. 2 Dielectric sensor

3. Development of alternative cure cycle to minimize the thermal residual stress

Based on the curing monitoring results, the alternative cure cycle with cooling and reheating for the composite structure as shown in Fig. 3 will be developed to reduce the fabricational thermal residual stress between the carbon fiber and epoxy. The thermomechanical properties of the high modulus carbon epoxy composite will be measured by a Differential scanning calorimetry (DSC) and rheometer to obtain the optimal time to apply the cooling operation.

The static flexural strength of the composite specimen will be measured by three-point-bending test to investigate the effect of cure cycle on the thermal residual stress. From the experiments, the optimum cure cycle with cooling and reheating which is not only reduced the fabricational thermal residual stress but also improved the strength and dimensional accuracy of the composite structures will be found.

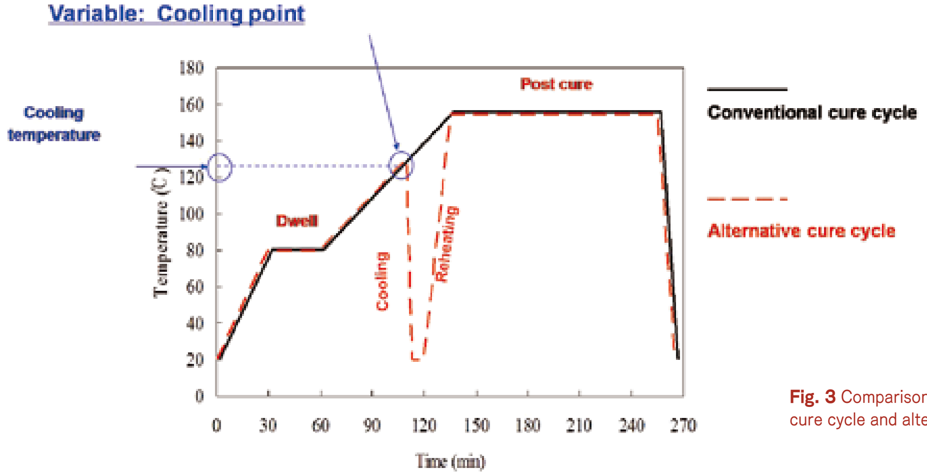


Fig. 3 Comparison between conventional cure cycle and alternative cure cycle

Long-term international internship report

Takashi Yokoyama, Fumitaka Kimura, and Aiko Yakeno

Department of Mechanical Engineering,
Sakai-Izumi Laboratory

Takashi Yokoyama

I started a PhD in mechanical engineering at the School of Engineering in October 2007,and am a member of the Sakai-Izumi Laboratory. In October 2008, I was chosen to be a GCOE program research associate. The objectives of my current research are to explicate and model the mechanism that generates looseness in bolt couplings.

Internship location

My internship took place at the Royal Institute of Technology (Kungliga Tekniska Högskolan, KTH) in Sweden's capital city of Stockholm. KTH is Sweden's center of science and technology research and education, with programs spanning a wide array of fields ranging from the natural sciences to mechanical engineering, architecture, urban planning, computer science and environmental engineering. Since it plays a key role in such a large number of disciplines, the school hosts many government- and corporate-supported research projects. It currently enrolls about 12,000 undergraduates and about 1,400 graduate students. The exchange programs and English lectures of its graduate schools attract many students from Europe and Asia. My internship was on the main campus, northeast of the Stockholm city center. It's an area of several universities and colleges that's conveniently close to Stockholm's main areas. The campus is next to a large park and has lush natural surroundings.

My department, the Department of Solid Mechanics, researches areas such as the mechanics of materials, fracture mechanics and contact mechanics. These areas are important for ensuring engineering product reliability, so many of the school's PhD candidates play a central role in collaborative projects with companies. Students receive guidance from professors and receive research assistance from outstanding technical staff when working on their research. But, because the department is relatively small and intimate, the members of the floor felt like a family. In the morning and afternoon, professors, students and staff would gather in the center of the space on the floor to discuss research or chat.

Research work

I've been working on explicating and modeling the mechanism that generates looseness when an external force acts on a bolt in the direction perpendicular to its axis. Since I could only spend two months at KTH, my work there was limited to examining the looseness that results when an external force acts around the axis of a bolt—an application of my previous research. In my previous research, I used finite element analysis to investigate the mechanism. At KTH, I was able to do new experimental work under the guidance of Professor Olsson and with assistance from the technical staff. With such a ready availability of guidance and assistance, I found the department well set up to provide support for all the experimental work being done there. The support system was very dependable, and there was always someone I could turn to for advice at any time.

KTH campus

Another highlight of my time at KTH were the opportunities that the department and Scania (a large truck maker and research partner) created for me to present my research. Bolt coupling looseness is often presented as a major problem in Japan, and the interest it received in Sweden showed me it's a problem encountered in other countries also. In fact, one student took a particular interest in my research and is doing a one-month exchange at the Sakai-Izumi Laboratory to investigate and research the same topic.

The center of Stockholm is surrounded by shoreline.

Stockholm and Sweden

Sweden has slightly more land area than Japan (450,000 km^2), but its population of about nine million is less than a tenth of Japan's. With its densely populated areas limited to tiny pockets of land (even Stockholm is compact), Sweden is mostly tranquil countryside hemmed in by forests and shorelines. Since the country is so far north, the number of hours of daylight it receives varies greatly from summer to winter. Between dawn and dusk, Stockholm gets about eighteen hours of daylight in summer, while getting only about six in winter. The country is snowbound in winter, and even Stockholm can reportedly get as cold as –20°C. Although I was lucky enough to be there in the summer, I can understand why the climate makes everyone try to spend the long summer daylight hours as productively as possible. Students and professors were at the university and already at work just after 8 am, and left just after 5 pm to enjoy sports and other recreational activities.

Stockholm's liveliest shopping district is the area around Sergels Torg, which has many department stores and shopping malls. On Sundays, many of the stores are apparently open for only a few hours in the afternoon, but the area doesn't close down completely and I was able to spend Sundays shopping in the city center. There are few English signs in the city, but most people can speak English, so I think anyone able to speak everyday conversational English would encounter few problems. Since traditional Swedish food is mostly home cooking, there are few restaurants offering Swedish food, but like Japan, Sweden has many restaurants serving food from around Europe and Asia. I was struck by the profusion of sushi restaurants, where salmon seems to be the local favorite—it's a fish also traditionally eaten in Sweden.

Local lifestyle

I lodged in a peaceful residential neighborhood called Stocksund in the north of Stockholm. Most of the greater Stockholm area is accessible by bus and subway, and I did all my work and pleasure travel on one-month passes good for both buses and trains. Adapting to the local habits, I rose and slept earlier than I would in Japan.

My days off were not confined to the Stockholm area. I managed to make a few trips to other areas of Sweden on long-distance trains and short-hop flights. My lodging was near the shore, and there was a pleasant area nearby for jogging and cycling. I also joined other students in my department in activities such as bowling and the annual Chocolate Festival, making my stay a short but enjoyable one.

Acknowledgements

Though Sweden is a long way from Japan, I found many similarities between our two nationalities, and had no problem getting used to the local lifestyle. My internship was in a department that's working on the same area as my laboratory, so I felt it understood my work, making my internship a very rewarding experience. I'd like to express my heartfelt thanks to the people at GMSI for giving me this opportunity, along with Professor Olsson and the many others at KTH who helped me. Thank you very much.

Department of Precision Engineering,
Higuchi-Yamamoto Laboratory

Fumitaka Kimura

I started a PhD in precision engineering at the School of Engineering in April 2009, and am a member of the Higuchi-Yamamoto Laboratory. At the same time I started my PhD, I was chosen to be a GCOE program research associate. I'm now researching actuator and sensing technology in the field of mechatronics.

Internship location

My internship was at the Swiss Federal Institute of Technology in Lausanne (Ecole Polytechnique Fédérale de Lausanne, EPFL), located in the city of Lausanne, Switzerland. EPFL is an engineering college. Besides its Lausanne campus in the French-speaking part of Switzerland, it also has a campus in German-speaking Zurich. It's a college with a highly international flavor, with the majority of its students a highly varied mix of world nationalities. The Lausanne campus is located in a quiet neighborhood near Lake Geneva. The college buildings have a terrific view of Lake Geneva with French towns and the Massif du Chablais in the Alps visible on its far side.

I was placed in the Laboratory of Robotics Systems 1 (LSRO1), an organization in the school's Microengineering Department. It's a research center with over 30 members, headed by Professor Hannes Blueler. Its members were at work on a wide array of robotics-related research, primarily for medical applications. The lab's students held lively discussions every day and got along very well with each other outside the campus as well. They often went to each other's houses to share their national cuisines, and went on trips together to the lake. There was a friendly atmosphere throughout the lab, something that seemed to be characteristic of EPFL as a whole.

Research work

I worked on research related to haptic devices enabling use in magnetic resonance environments. But instead of discussing the details of my research, I'd like to discuss the different research styles I found in Switzerland and Japan. In Japan, researchers carry out theoretical studies and actual experimental work simultaneously. But I was surprised to find the students in Switzerland spent most of their time on theoretical studies, then did all the experimentation at once in the second half of their stay. The Japanese approach is to experiment repeatedly, making fine-tuned adjustments as you go, while the Europeans felt it was enough just to confirm a behavior consistent with the theory, without worrying about details unlikely to affect the overall experimental behavior. I wondered if this difference arose from differences in national characteristics. I'm not saying one approach is necessarily any better than the other. Seeing a different approach greatly helped me understand how other researchers work, and will be helpful when working with foreign researchers in future. Also new to me was the way the students would attempt to answer any questions they had by discussing them with the other project members instead of looking up the answers in textbooks. I was struck by how much more discussion there was every day than there would be in Japan.

View of Lake Geneva from the third story of an EPFL building.

The peak of Switzerland's iconic Matterhorn.

Lausanne

Lausanne is a city on the shore of Lake Geneva on Switzerland's western edge, in its French-speaking zone. The lake forms the border between Switzerland and France, and its far shore is in France. (The French capital of Paris is about three-and-a-half hours away on the TGV high-speed rail service.) As the headquarters of the International Olympic Committee, Lausanne is known as the 'Olympic Capital'. It houses the world's only museum dedicated to the Olympics, with exhibits such as medals from the various games. Among the exhibits of interest to Japanese visitors are the shoes worn by Japanese marathon runner Naoko Takahashi. The city center contains the central rail station and Lausanne Cathedral, as well as a concentration of shopping areas and restaurants. Away from the center are residential areas containing small supermarkets. Many of Lausanne's residents seem to be dissatisfied with the limited selection of these supermarkets and instead do their shopping near the central station, using the city's two subway lines and the bus lines that originate from each station.

Lausanne's limited business hours were what most shocked me about the city. Supermarkets and restaurants close at 7 pm and only a few bars stay open later than that. These hours might explain why most of Lausanne's residents are morning people, at work before 8 am and back home just after 6 pm. Just before closing time, the supermarkets were filled with suit-clad customers lining up at the registers. These business hours must make it very hard for them to balance their work and personal lives. Over 90 percent of the shops are closed on Sundays, when the city center becomes a virtual ghost town. It was a very different lifestyle from the Japanese pattern of working till late, buying groceries on the way home, and doing large shopping trips on days off—something I found bewildering at first. On their days off, Lausanne's residents picnic by the lake or go to outdoor concerts in summer, and go skiing or have dinner parties in winter.

Local lifestyle

I rented a room in the home of a student in the same lab as me. He and his family were Japanophiles, and were very nice to me. On weekends they often invited friends and relatives to the home for parties. Of course seeing the local sights is always important, but I wanted to focus on building relationships, so ended up going to most of these parties instead. They gave me the chance to meet people not connected to the university who later invited me to events and trips, giving me the chance to make more lasting connections. Doing things with them let me experience a degree of local color difficult for a single traveler, and ultimately made my time much more fulfilling than it would have been traveling alone. Being able to stay with a local family was mostly what gave me the chance to meet so many people outside the university like that, and while it was hard at times, I'm very lucky to have had them accept me.

Acknowledgements

Now that I've come back to Japan and returned to my life in Tokyo, I find my perspective has broadened. I feel certain I've grown both as a linguist and as a person. I owe a debt of gratitude to everyone at GMSI for giving me this opportunity, and to the many people in Switzerland who helped me. Thank you very much.

Department of Mechanical Engineering,
Kasagi-Suzuki Laboratory

Aiko Yakeno

I started a PhD in mechanical engineering at the School of Engineering in April 2009, and am a member of the Kasagi-Suzuki Laboratory. At the same time I started my PhD, I was chosen to be a GCOE program research associate. I'm now researching the generation mechanism and control of wall turbulence.

How I became a GCOE research associate

I'm a first-year PhD candidate in mechanical engineering in the School of Engineering who is researching the generation mechanism and control of wall turbulence at the Kasagi-Suzuki Laboratory. I was selected to be a GCOE program research associate starting this academic year, and got the chance to go abroad on an extended internship program.

I didn't plan to get a PhD originally. Like most people, I wanted to work as an engineer in a company after finishing my master's degree. But once I started looking for work, I realized I hadn't even really figured out what company I wanted to work for and why, and started to doubt whether I really wanted to devote the rest of my life to just one company. So I talked to some of the lab instructors, to foreign researchers visiting the lab and to recent graduates, and got inspired to work on bigger, transnational projects such as global environmental issues. That led to my starting a PhD course and continuing research with the ultimate aim of making myself into a globally-oriented researcher.

Internship

I took part in a five-month overseas internship program to work on a project under a research partnership between the University of Tokyo and Imperial College of Science, Technology and Medicine in the UK. The language barrier and the differences between the Japanese and British research systems were tough things to deal with at first, but in the end I found the internship a very valuable experience overall, since it gave me many opportunities to talk to researchers in the UK. These discussions showed me how my research fits into the big picture, exposed me to the current topics of interest to European researchers, and gave me a close-up look at how they go about research work. While I found the UK university had some good points, I feel Japanese universities are superior in many ways. Japanese universities should adopt the good points of UK universities, and maintain a competitive edge by continuing to do what they do better.

The front entrance of the South Kensington campus of Imperial College.

Students often play cricket on this common near the University of Cambridge, known as Parker's Piece.

Japanese researchers tend to work closely with each other in the lab, but I found that in Europe the focus is more on the independence of individual researchers—even members of the same group. Seeing this difference gave me a glimpse of just how competitive research is on the global level. It made me see that researchers who want to achieve world recognition need to be great at what they do individually, and not just great members of a group. The experience showed me that my abilities and attitudes as a researcher already have a lot of room for improvement even though I'm still just a first-year PhD candidate. While completing my PhD at the University of Tokyo, I'd like to work on acquiring the skills I'll need to become a globally competitive researcher.

GCOE benefits, message to future participants

I was selected to be a GCOE research associate while working on my PhD. The financial assistance I received from the program enabled me to continue research as a student, which is something I'm very grateful for. I think a PhD does more than just expand your knowledge of a specific area, and GCOE research work provides a wealth of opportunities to become more globally-oriented. GCOE offers more than just financial assistance for overseas programs. Its open seminars presented by foreign researchers, discussions with exchange students, and other programs are all terrific opportunities for participants to broaden the scope of their awareness to the world at large instead of limiting it to just Japan. Finding out what will motivate you to continue pursuing your research is one of the keys to making your name as a researcher. The GCOE programs give researchers a larger, global perspective and inspire the passion needed to work tirelessly.

We tend to take it for granted while we're here, but the University of Tokyo is really a fantastic environment. In fact, the opportunities are so plentiful that if anything, recipients often overlook what's available to them rather than suffer a shortage of opportunities. So I think it's best not to limit your options.

Just graduating from the University of Tokyo's Faculty of Engineering or School of Engineering is enough to make you an expert in the eyes of the world, and be treated as one. Some alumni may want to work in humanities fields and some of the women may become mothers at some point. But no matter what we want to do, we need to find out what we're good at as quickly as possible, and aim to become the top of our field. I hope we can stay true to our objectives and rise to positions of leadership one day.

The University of Tokyo's GCOE research centers are organizations that foster world-class researchers. If you want to become a researcher with a global perspective, you should be aware that there is an environment and support system only too willing to help you achieve your goals.

Activity report

Activity Report for Second Half of Academic Year 2009 (October 2009 to March 2010)

International Symposia

March 12-13, 2010
4th TU-SNU-UT (Tsinghua University, Seoul National University and the University of Tokyo) Joint Symposium

Open Seminars

October 6, 2009 **The 31st GMSI Open Seminar**
Lecturer : S. J. Pennycook (Materials Science and Technology Division / Dr.)
Moderator : Yuichi Ikuhara (Institute of Engineering Innovation / Professor)
Title : New Directions with Aberration-Corrected STEM

October 29, 2009 **The 32nd GMSI Open Seminar**
Lecturer : Pierre Duysinx (Department of Automotive Engineering, Aerospace and Mechanical Engineering Dept., University of Liège / Professor)
Moderator : Shinji Suzuki (Department of Aeronautics and Astronautics / Professor)
Title : EU Strategic Roadmap:Europe's Emphasis on the High-Power Supercapacitor

November 6, 2009 **The 33rd GMSI Open Seminar**
Lecturer : J. Michael Ramsey (Departments of Chemistry and Biomedical Engineering, the Carolina Center for Genome Sciences, University of North Carolina / Professor)
Moderator : Takehiko Kitamori (Department of Applied Chemistry / Professor)
Title : Microfabricated Fluidic Devices for Biochemical Analysis

December 2, 2009 **The 34th GMSI Open Seminar**
Lecturer : Stephan Irle (Institue for Advanced Research, Nagoya University / Professor)
Moderator : Shigeo Maruyama (Department of Mechanical Engineering / Professor)
Title : Quantum Chemical Molecular Dynamics Simulations of SWNT Nucleation and Growth on Iron and Nickel

November 11, 2009 **The 35th GMSI Open Seminar**
Lecturer : Yogesh Gianchandani (The University of Michigan / Professor)
Moderator : Shinji Suzuki (Department of Aeronautics and Astronautics / Professor)
Title : Hybrid Micro-Technologies for Medical and Other Applications

November 27, 2009 **The 36th GMSI Open Seminar**
Lecturer : L. J. Allen (School of Physics, University of Melbourne / Professor)
Moderator : Yuichi Ikuhara (Institute of Engineering Innovation / Professor)
Title : Atomic Resolution Transmission Electron Microscopy

December 7, 2009 **The 37th GMSI Open Seminar**
Lecturer : Klaus Van Benthem (Department of Chemical Engineering and Materials Science, University of California Davis / Professor)
Moderator : Yuichi Ikuhara (Institute of Engineering Innovation / Professor)
Title : New Prospects of Aberration Corrected Scanning Transmission Electron Microscopy

December 9, 2009 **The 38th GMSI Open Seminar**
Lecturer : Thijs J. H. Vlugt (Process & Energy Laboratory, Delft University of Technology / Professor)
Moderator : Shigeo Maruyama (Department of Mechanical Engineering / Professor)
Title : Adsorption / Diffusion of Guest Molecules in Zeolites / MOFs Studied by Molecular Simulations

December 15, 2009 **The 39th GMSI Open Seminar**
Lecturer : Brian L. Wardle (Nano-Engineered Composite Aerospace STructures (NECST) Consortium Technology Laboratory for Advanced Materials and Structures (TELAMS), Department of Aeronautics and Astronautics, Massachusetts Institute of Technology / Professor)
Moderator : Shigeo Maruyama (Department of Mechanical Engineering / Professor)
Title : "Literally Big Nano : Bulk Nanostructured Materials for Aerospace and Infrastructure Applications"

December 22, 2009 **The 40th GMSI Open Seminar**
Lecturer : Takao Suzuki (The Boeing Company, Commercial Airplanes / Dr.)
Moderator : Shinji Suzuki (Department of Aeronautics and Astronautics / Professor)
Title : From Technology to The Airplane:The Quiet Technology Demonstrators

January 14, 2010 **The 41st GMSI Open Seminar**
Lecturer : Javad Mostaghimi (Plasma Engineering Centre for Advanced Coating Technologies, Department of Mechanical and Industrial Engineering, University of Toronto / Professor)
Moderator : Toyonobu Yoshida (Department of Materials Engineering / Professor)
Title : On the Dynamics of Droplet Impact and Solidification Process

January 14, 2010 **The 42nd GMSI Open Seminar**
Lecturer : Jun Nogami (Materials Science and Engineering, University of Toronto / Professor)
Moderator : Satoshi Shiratori (Department of Materials Engineering / Professor)
Title : Materials Engineering Research at The University of Toronto

January 18, 2010 **The 43rd GMSI Open Seminar**
Lecturer : Cindy Colinge (Tyndall National Institute / Principal Investigator, California State University Sacramento / Professor)
Moderator : Tadatomo Suga (Department of Precision Engineering / Professor)
Title : Low Temperature Direct Wafer Bonding : Mechanisms and Applications

January 18, 2010 **The 44th GMSI Open Seminar**
Lecturer : Helmut Baumgart (Old Dominion University / Professor)
Moderator : Tadatomo Suga (Department of Precision Engineering / Professor)
Title : Atomic Layer Deposition for Nanotechnology Fabrication with Applications in Microelectronics, Biosensors and Microfluidics

January 29, 2010 **The 45th GMSI Open Seminar**
Lecturer : Shashi P. Karna (US Army Research Laboratory, Materials Research Directorate / Dr.)
Moderator : Shigeo Maruyama (Department of Mechanical Engineering / Professor)
Title : New Concepts in As-Grown Single-Walled Carbon Nanotube Applications to Nanoelectronics

February 1, 2010 **The 46th GMSI Open Seminar**
Lecturer : Kanako Harada (Scuola Superiore Sant'Anna / Dr.)
Moderator : Mamoru Mitsuishi (Department of Mechanical Engineering / Professor)
Title : Reconfigurable Modular Robot for Endoluminal Surgery : Study in A Multidisciplinary Research Setting

February 18, 2010 **The 47th GMSI Open Seminar**
Lecturer : R. Bruce Weisman (Department of Chemistry, Rice University / Professor)
Moderator : Shigeo Maruyama (Department of Mechanical Engineering / Professor)
Title : Fluorescence of Single-Walled Carbon Nanotubes : Applications in Physics, Chemistry, and Bio-medicine

Evening Seminars

October 19, 2009 **The 9th GMSI Evening Seminar**
Lecturer : Brajendra Mishra (Department Head of Metallurgical & Materials Engineering, The Colorado School of Mines / Professor)
Moderator : Toyohisa Fujita (Department of Precision Engineering / Professor)
Title : Development of Multifunctional Nanocomposite Coatings Using Pulsed Close-Field Unbalanced Magnetron Sputtering

November 24, 2009 **The 10th GMSI Evening Seminar**
Lecturer : Makoto Usui (Future Architect Co. / Executive Senior Vice President, Shibaura Institute of Technology / Professor)
Moderator : Kiyoshi Takamasu (Department of Precision Engineering / Professor)
Title : Consumer-Centered Value Co-Creation and Progress in Service Innovation

December 21, 2009 **The 11th GMSI Evening Seminar**
Lecturer : Takehiro Inoue (Steel Research Laboratories, Technical Development Bureau, Nippon Steel Corp. / Ph.D.)
Moderator : Toshihiko Koseki (Department of Materials Engineering / Professor)
Title : Fracture Mechanics Research for Structural Support and Safety

January 25, 2009 **The 12th GMSI Evening Seminar**
Lecturer : Mikio Murozono (Clean Venture 21 Corp. / Dr.)
Moderator : Yukio Yamaguchi (Department of Chemical System Engineering / Professor)
Title : From Development to Commercialization of Mass-Produced Collector-type Spherical Silicon Solar Cells

February 23, 2009 **The 13th GMSI Evening Seminar**
Lecturer : Mutsuhiro Arinobu (Toshiba Corp. / Dr.)
Moderator : Yasuyuki Yokono (Department of Mechanical Engineering / Professor)
Title : Expectations of PhD Students from The University of Tokyo

Workshops

October 26, 2009 **GMSI Special Workshop**
Lecturer : Junichi Kobayashi (Akita Prefectural University / Professor)
Title : "Why a super collaborative graduate school is necessary"