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AIMR International Advisory Board Member

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What a person needs in order to become a world premier researcher

Ei-ichi Negishi

H. C. Brown Distinguished Professor at Purdue University / AIMR International Advisory Board Member

Ei-ichi Negishi, one of the recipients of the 2010 Nobel Prize in Chemistry, is the Herbert C. Brown Distinguished Professor at Purdue University. He first went to the United States at the age of 25 to pursue his graduate studies. Since then, he has been engaged in research activities at universities in the United States for more than 50 years. Even after receiving the Nobel Prize, Negishi has continued to pour his energy into research. We try to identify the source of his endless passion for research, while we ask him to give his views on the perspective that a researcher must have in order to conduct research that has an impact on the world, as well as the conditions that an institute should fulfill in order to be a major international research institute where outstanding researchers from around the world come together.

text by Yasufumi Nakamichi, photographs from Purdue University

"Going overseas, in and of itself, is not of great importance."

In order to become a globally recognized researcher, should a researcher go overseas to conduct his or her research? Professor Negishi's answer to this question was somewhat surprising at first, considering that he had appeared in various media interviews and pointed out the closed nature of Japanese universities and the importance of going overseas in one's youth based on his own experience. Of course, his answer did not necessarily imply that he was negating the merits of going overseas. He explained that one should go abroad at least once in order to gain a wider perspective. Nevertheless, he pointed out, armed with the wider perspective, it is of greater importance to choose the path one should venture on in the future at the global level.

He explained, "If you wish to become a world-class researcher, you should choose, at a postdoctoral level, the place that you wish to further studies or take up a job not by the country or specific academic institution but choose a mentor. Make sure that your mentor is someone who is at the world-class level in your chosen field. I think that is of the greatest importance. When you are choosing your mentor, if you find that the person who is at a world-class level in your field is in Japan, it would also be acceptable or even desirable for you to pursue your future in Japan."

Professor Negishi's stance when speaking about the importance of choosing a world-class "mentor" reflected the impression that his own experience going overseas at the age of 25 had left on him, and the immensity of the lessons he had learnt from his life-time mentor, Professor Brown, whom he had met there.

Taking a bold leap forward, and finding a lifelong mentor

Professor Negishi first encountered Professor Brown in a lecture at the University of Pennsylvania, where he had been pursuing his graduate studies.

After graduating from the University of Tokyo, Professor Negishi had joined the current Teijin Ltd. and conducted research on organic synthesis as an employee of Teijin. However, over the course of his research, he felt a need to gain even more in-depth knowledge about organic synthesis. It was at this time that he was given the opportunity to go to the United States and study at the University of Pennsylvania. Before he went there, Professor Negishi had had little experience in speaking English, and naturally felt uneasy about going overseas. However, his anxiety was overpowered by his excitement and anticipation. Laughing, he remarked that he had been reckless since he was a boy, as illustrated by the following episode.

"When I was five or six years old, my sister and I received ice skates. The edges of the skates are covered, aren't they? I was walking around the house with the covers on the skates, and in time, began to feel confident that I would be fine even without the covers. Finally, the ground was covered with ice. I bravely removed the covers from the skates, but the moment I stepped onto the ice, I fell hard. Remembering that incident even now, I feel that it was a perfect example of my reckless nature."

Even after he became a grown man, Professor Negishi did not change. The first time he went skiing at age 40, he boarded the ski lift alone without knowing how to descend. Since he excelled at skating, he had boarded the lift thinking that skiing was essentially similar to skating. However, he truly felt a sense of fear at the moment of descent.

"In that instant, I wondered what would happen if I broke my leg this time. Even so, I descended resolutely, prepared for the worst. As expected, I fell. That was my style."

However, everything did not come to an end after Professor Negishi took a leap and failed. Be it skiing or skating, the activity had become a part of himself as he engaged repeatedly in it with passion. For Professor Negishi that was the same case for his overseas studies. He worked very hard in English, armed himself with systematic knowledge in organic chemistry, and obtained test results that were as good as any of his peers.

It was during this time that he attended a lecture by Professor Brown, who would later become his lifelong mentor. Inspired by the lecture where Professor Brown explained a new synthesis method using boron, Professor Negishi became very determined to venture into the field of "organic synthesis via organometallics" as a researcher. After concluding his studies at the University of Pennsylvania, he returned to Teijin. However, he could not ignore his passion for fundamental research, and decided to cross the oceans once again to study under Professor Brown.

Learning from Professor Brown about the importance of pursuing failure

In 1966, Professor Negishi took up a position at Professor Brown's laboratory in Purdue University as a postdoctoral fellow. Two years later in 1968, he was appointed Assistant to Professor Brown (1968-1972). His time there had a significant impact on his research activities in later years.

"When tackling a research question, it is first important to review past research results, and think thoroughly about whether there are better ways to conduct the research. Logic is extremely important in this process. Pursuing logic thoroughly and thinking carefully would contribute to the generation of good, original ideas."

Once you have promising ideas, the next step is to try them out through experiments. However, it is extremely rare for things to happen in line with your expectations. In most circumstances, the experiments will not proceed as you expect them to. However, whether or not your experiments succeed is not of the greatest importance in and by itself. Rather, what you do when an experiment fails is more important. This was what Professor Negishi had learnt from Professor Brown.

"Experiments involve trying to do something that no one has ever attempted before, so they will be accompanied by many small failures. When that happens, Professor Brown taught me that it was more important to take thorough steps to clarify the truth. In other words, had the experiment failed because of a poor experiment design? If the design had been a good one, had the experiment failed because of something I had done erroneously? For example, had I allowed some water to enter even though no water should be allowed to enter, rendering the reagent unusable? Professor Brown would push me very hard to distinguish between these two categories of reasoning."

Thanks to Professor Brown, Professor Negishi became well drilled in this method of research, known as systematic search method.

"When I am faced with difficulties, I return to the experiment setting where the experiment proceeded well. Next, I introduce just one new factor. If this experiment does not go well, then I might be able to say for the first time that this new factor was not been suitable, provided that this new factor had been demonstrated and proved to be satisfactory in some other similar reactions or experiments. This is an extremely rigorous method to apply, but it is also very logical. In science, it is still very important to be logical."

Professor Negishi maintained a logical perspective and took thorough steps to investigate the reasons behind the failure of the experiment, and the repetition of this process led to the achievement of various results including the "Negishi coupling."

"I do not consider myself to be inferior to Professor Brown with respect to coming up with research ideas. However, Professor Brown is almost flawless when it comes to rigor in conducting experiments. Under his tutelage, I was also able to pick up these skills. In research, it is not sufficient to have just one of the two skills. It is meaningless to have only ideas, and it is useless to just be rigorous."

Hard work in the past provided support in the present

In 1972, after six years of research work in Professor Brown's research laboratory, Professor Negishi took up a position as Assistant Professor at Syracuse University. Professor Negishi described his days there as being steeped in a sense of inferiority.

"I had about 20 colleagues in the Chemistry department, all of whom were native English speakers. When I asked them where they had graduated from, all the answers were famous universities such as Harvard, Yale, Columbia, and Pennsylvania. No matter how I looked at it, I felt that they were all more intelligent than I was. I believed that I was probably at the lowest rung of the intelligence ladder."

It was Professor Negishi's experience in his high school days that provided him with support during this period.

Until he graduated from junior high, his only focus was on play, and he did not study at all outside the classroom. Even so, he continued to do well in school. In the first year of high school, he encountered his first difficulty. At the end of the first year, he was ranked 123 out of approximately 400 students in the same school year.

"I still remember clearly that I was ranked 1, 2 and 3," he commented with a laugh.

Since then, he has straightened himself out. Even though he had not studied at all outside of class, he was surprised that there were still about 300 students ranked below him. Until then, he had been a serious student only in the classroom, but he began for the first time studying outside the classes as well.

"I began to study with a blind single-mindedness. I would wake up early in the morning, study a little at home, and go to school about one hour earlier to prepare my work in the library."

In addition to the hard work in class, he also studied hard outside of the classroom. He then began to show definite improvement by taking a few top place in several mock tests. In 1953, he successfully gained admission into the University of Tokyo at the age 17. This experience provided Dr. Negishi with strong mental support during his days at Syracuse University.

"I remembered my days in high school when I had also been burdened by a sense of inferiority. However, by switching to a forward-looking perspective, I managed to overcome that difficulty. That is why I have to remain patient. There is a Japanese saying about perseverance, which says that three years on a cold stone will warm it. If I persevere for three years, what would happen after that? I thought that if things did not work out after three years, I would change my plans."

Take up the challenge, achieve results, and gain confidence through those achievements. This cycle would give him courage to tackle even more challenges.

"After three years, few of the colleagues whom I had perceived as elites could compete with me. I was actually quite surprised and puzzled, but I gladly accepted the apparent facts."

An idea alone is not even worth a dime

In 1979, Professor Negishi returned to Purdue University as a Full Professor. Beginning with the discovery of the Negishi Coupling in 1976, he had by then added numerous other achievements to his track record. In 2010, Professor Negishi was awarded the Nobel Prize in Chemistry.

Today, Professor Negishi is involved in a project about artificial photosynthesis. Despite being past 75 years of age and having received the Nobel Prize, which is the highest honor a researcher can receive, he continues to take on new research projects. What motivates him?

"That would simply be because research is really interesting. If it goes well, there is no hobby that can be more interesting than research."

Once research becomes interesting, it is possible to generate various ideas and a unique idea will come up based on experiments and data. Such ideas are truly original in his head. However, Professor Negishi continues. Regardless of how good the idea may be, it is still less than half of what constitutes "research." If the idea is simply kept in his head, it would be as good as being worthless.

"I always say, 'Idea is everything, but idea alone is not even worth a dime.' Even a wonderful idea is worth less than 10 cents during the time that it remains as an idea. In my case, as various ideas emerge in my head, I simply want to transform them into something realistic. This is my motivation for continuing with my research activities."

What is an international research institution?

Professor Negishi has achieved breakthrough successes in his research by gaining a wider perspective overseas, choosing the best "mentor," and verifying logical ideas through systematic experimentation. Although he had found his own lifelong teacher in the United States, he feels that one should pursue one's future in Japan if the world-class level researcher of one's chosen field is in Japan. We asked Professor Negishi to talk about his impression of Japanese research institutions today.

"Overall, I think that Japanese research institutions are getting closer to reaching the highest international standards. However, compared to Europe and the United States, there is still only a small number of preeminent leading researchers."

There are only a small number of preeminent leading researchers. According to Professor Negishi, that may be the result of an underlying problem in the existing Japanese system.

"Japan has traditionally placed great importance on seniority by length of service or by age. When young but outstanding researchers attempt to reach the ranks of professorship, there are often strong objections. Thus, young researchers who are rejected by the Japanese system in such ways often end up in professor positions in universities overseas, mostly in the United States."

In Japan today, various initiatives have been put in place to improve such situation. In particular, the WPI program including AIMR aims to carry out reforms of the old Japanese system, in order to attract outstanding researchers from around the world. Professor Negishi rates AIMR's initiatives highly for its attempts to step out of the box. However he pointed out that the most important factor in becoming a world-recognized international research institution lay in nurturing as many outstanding individuals as possible based on a fair evaluation system, and not on the traditional seniority-based system.

"When you have young researchers who have extremely excellent credentials, I feel that the organization should provide them with support, which includes recruiting them, and attempt to stretch their capabilities further rather than treating them as nails that need to be hammered down. Of course, I believe that competition is important, but competition has to be fair."

Professor Negishi also gave his nod of approval toward AIMR's internationalization initiatives, which includes using English as the official language and providing total support in administration and in other areas in English.

He commented, "I think that without such initiatives, the institutions will eventually fall out of the running. English is no longer the language of the United States or the United Kingdom. It is now the language of the world."

It is important for an individual to gain an international sensibility by choosing to pursue his or her studies or job in the global market. In addition, the organization should use English as the official language, and provide support for outstanding young researchers through fair recruitment and competition. These two factors are the conditions for the institutions to gain recognition from the world.

Ei-ichi Negishi

Born in 1935 in Changchun, in the former Manchuria. Graduated from the Faculty of Engineering, University of Tokyo. He joined TEIJIN Ltd. in 1958 as a researcher, but obtained a Fulbright Smith-Mund All-Expense Scholarship in 1960. He received his Ph.D. degree in Science from University of Pennsylvania in 1963. After three years research work at TEIJIN, he joined Prof. H. C. Brown's group at Purdue University in 1966 as a Postdoctoral Associate and then as Professor Brown's assistant in 1968. He then became an Assistant and Associate Professor at Syracuse University (1972-1979). Since 1979, he has been Professor at Purdue University. Since 1999, he was appointed Herbert C. Brown Distinguished Professor of Chemistry, Purdue University. In 2010, he received the Nobel Prize in Chemistry together with Akira Suzuki and Richard Heck.

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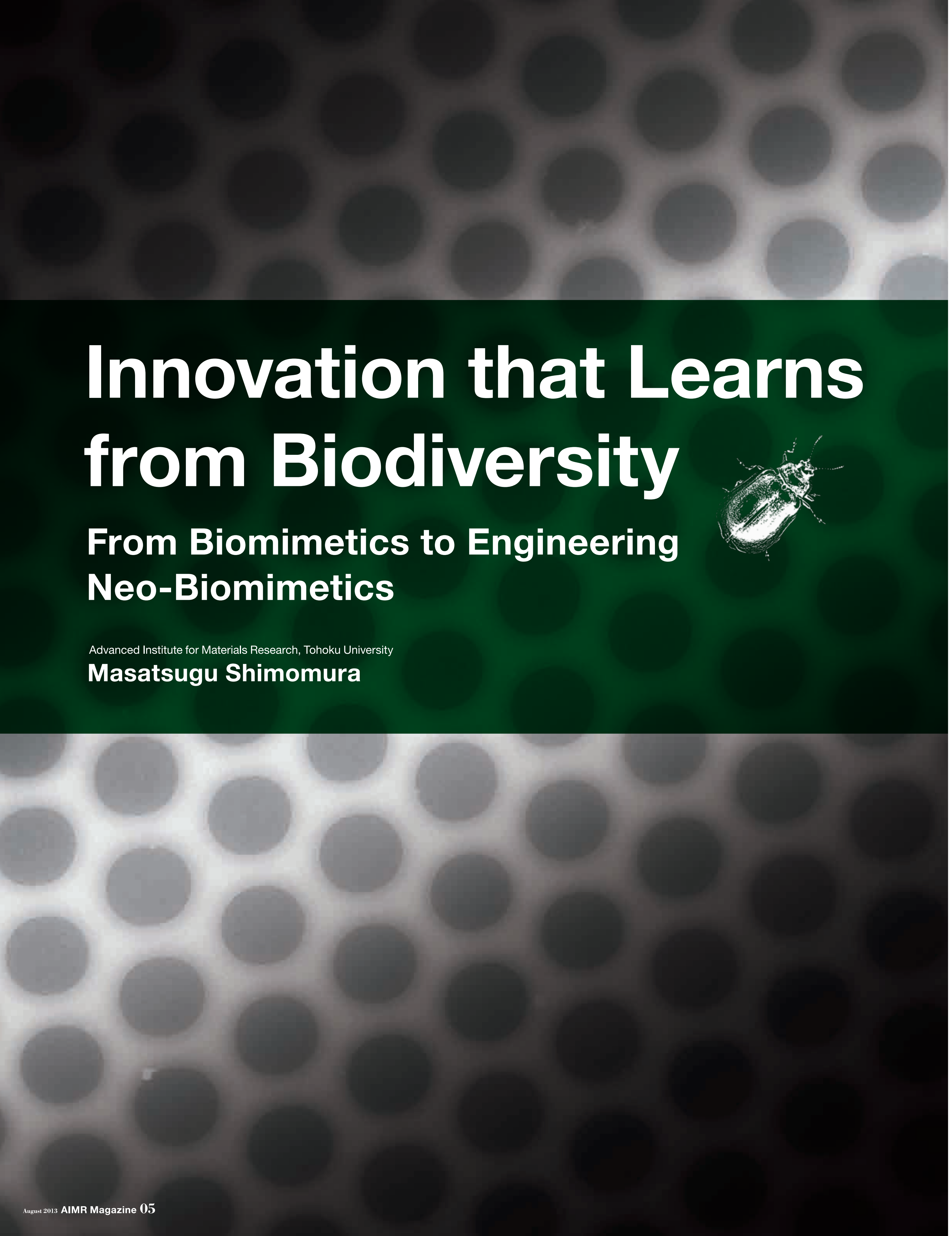


Innovation that Learns from Biodiversity

From Biomimetics to Engineering Neo-Biomimetics

Advanced Institute for Materials Research, Tohoku University

Masatsugu Shimomura

Economic forecasting by a zoo?!

The British economic paper, the Financial Times, ran an article on its online publication on 12 August 2011 about economic forecasting activities at the San Diego Zoo in the United States. While readers may have suspected that it must have been a mistake for a zoo to release economic forecasts, or that it was simply an income and expenditure report for the zoo, it turned out to be a genuine report about overall economic trends. The report predicted that a certain type of technology would generate US$300 billion annually for the United States in gross domestic product after 15 years, and create employment for 1.6 million people by 2025. Furthermore, the report claimed that this technology would have the ability to solve issues currently confronted by mankind, such as environmental and energy-related problems. Commenting on this report, the Financial Times even called this a paradigm shift that was comparable to the Industrial Revolution. What was the technology that could elicit such a comment from an international financial newspaper, and on top of that, be reported by a zoo? It was none other than biomimetic technology.

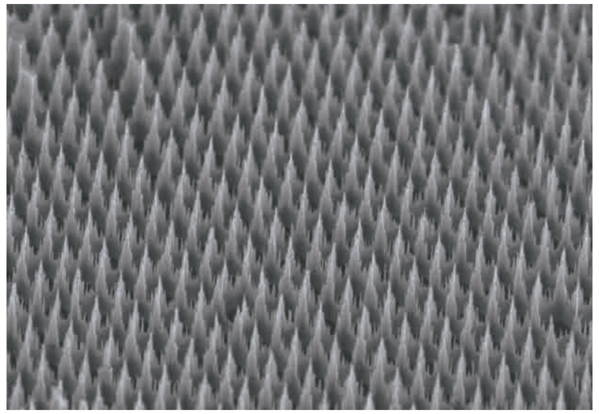
Biomimetics-simultaneously old and new

Biomimetics, as the name suggests, is the development of new technologies and materials that mimic living organisms. This technology has in fact been applied to the creation of materials that we are familiar with from a long time ago; one of these materials is the hook-and-loop fastener. This is known as Velcro in Europe, and Magic Tape in Japan. This product was developed in the 1940s by a Swiss named George de Mestral, who had been inspired by how burdock seeds surrounded by burrs stuck to clothes and the fur of animals. By imitating the shape of the burrs, he succeeded in creating a fastener that could be fastened and removed indefinitely. In the second half of the 1950s, American scientist Otto Schmidt created an electrical circuit for removing noise by mimicking the nervous system of the squid. Schmidt had proposed to name technological development that harnesses biological functions as “biomimetics,” and his suggestion was taken up.

Water-repellant material developed by imitating the superhydrophobic properties of lotus leaves and moth eyes.

Thereafter, various forms of technological developments arose through biomimetics in fields such as chemistry and mechanical engineering. Examples included the invention of artificial muscles, and the development of sonars that imitated the echolocation function of bats. In Japan, the development of the high-speed shinkansen trains was strongly influenced by biomimetic technology. The noise that was created by air resistance posed a problem to increasing the speed of the shinkansen train. An increase in speed was accompanied by an increase in air resistance, and in turn, greater noise. In particular, the noise created in tunnels, and the noise generated by pantographs that come into contact with the electric cables sticking out from the train body, were major problems. To counter these problems, the first train carriage was made into a pointed shape in imitation of the beak of the kingfisher when it dives into the water to capture its prey. This helped to reduce the amount of resistance when the train entered a tunnel, and succeeded in reducing the volume of noise that was generated. The pantograph was also structured to resemble the feathers of owls flying silently to avoid drawing attention from the small animals that they prey on, thereby achieving a soundproofing effect for the train. These are widely known examples of biomimetics, which puts to use the unique shapes of living things and the accompanying functional features.

After the year 2000, increasing attention was placed on biomimetics research in the field of materials, and people gradually began to put these studies to practical use. For example, scientists succeeded in developing a water-repellant material that did not require the use of the chemical substance Teflon, by imitating the water-repelling properties of the lotus leaf. There were two factors behind the success of this development—one was the popularization of the electron microscope which helped scientists gain an understanding of the microscopic asperities on the surface of the lotus leaf, and the other was the development of microfabrication technology known as nanotechnology, which allowed engineers to recreate the small asperities at the nano level. The development of various other materials through the imitation of unique biological properties was also reported. These included adhesive tape that did not make use of adhesive materials, but rather, applied the adhesive properties on the legs of insects and gecko, as well as non-reflective film that did not make use of metallic film, but applied the non-reflective properties of moth eyes. All of these were materials that had been developed by carefully observing nano-sized structures on the surface of living things using electron microscopes and recreating these structures through the application of nanotechnology. However, regardless of the degree of development achieved in electron microscope technology and nanotechnology, we would not have been able to develop these new materials without the knowledge of the unique and diverse functions that living things possessed. Such knowledge had been accumulated through taxonomy and natural history, and this formed the background to the release of the "economic report" by the San Diego Zoo. Much information concerning the unique functions of living things has been accumulated in zoos, botanical parks, and museums. By linking this information with nanotechnology, such information will become a treasure trove of ideas for new materials.

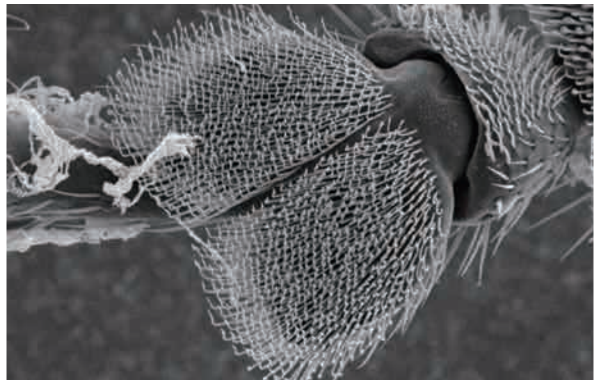


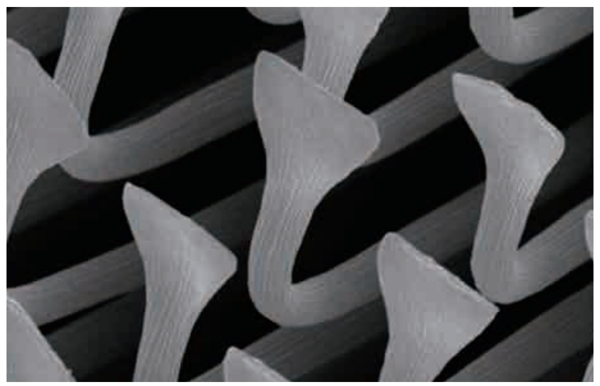
Micrographs of silicon nano-pillar array, which has both non-reflective and superhydrophobic properties (taken by Yuji Hirai, lecturer at Chitose Institute of Science and Technology).

A future carved out through biodiversity and the wisdom of mankind

The diversity of living things is the result of adaptation to the environment over a long process of evolution. We could also call it the biological technology system. This is clearly different from the substances, energy, and manufacturing methods used in the technology systems of mankind. Since the Industrial Revolution, humans have used fossil fuels and nuclear power as energy sources, and iron, aluminum, silicon, and rare elements as raw materials. Driven by high temperatures, high pressures, and lithography, they have created products from these energy and material sources. While this has propelled the development of human civilization, it has also created energy and environmental problems. On the other hand, the technology system of living things makes use of solar power and chemical energy. It mainly uses organic compounds that are mostly carbon-based and general-purpose elements such as hydrogen, oxygen, and phosphorous, to create products at ordinary temperature and pressure through molecular association and self-organization. Compared to human technology systems, the manufacturing systems employed by living things are significantly cleaner and environmentally friendly. In other words, by elucidating biological technology systems which generate the unique structures as well as functions of insects, plants, and other living things, we could be holding the solution to the environmental, resources, and energy problems brought about by human technology systems.

Nanotechnology, which is one of the most developed human technology systems, is required in order to elucidate such biological technology systems. This is an ironic situation, but environmental and energy problems have become desperately pressing issues for mankind. In particular, the events of 11 March 2011 have once again raised the issue of this century for mankind—the sustainability of the Earth's environment. We are learning from biological technology systems, which had brought biodiversity and adaptability to the environment, and combining it with the wisdom of mankind to create a new technology system. We have named it engineering neo-mimetics, and aim to create and develop this field of studies in order to realize a sustainable society. To that end, we are conducting research from day to day and establishing a global research network.





Leaf beetles that can walk in reverse on glass surfaces (Bottom-right: Provided by Shigehisa Hori, Historical Museum of Hokkaido), and micrographs of the adhesive hairs on the tops of their legs (Top two: Provided by Tateo Shimozawa, Honorary Professor, Hokkaido University). The adhesive hairs, shaped like flexible springs, are applied in the production of adhesive tape that can be reused repeatedly without the use of any other adhesives.

Masatsugu Shimomura

Born in Fukuoka in 1954. Graduate of Faculty of Engineering, Kyushu University. Formerly visiting researcher at the Institute of Organic Chemistry at the Johannes Gutenberg University Mainz; Assistant Professor at the Faculty of Engineering at the Tokyo University of Agriculture and Technology; Professor at the Research Institute for Electronic Science at Hokkaido University; head of the Nanotechnology Research Center at Hokkaido University; team leader of the Frontier Research System at RIKEN; and Professor at the Institute of Multidisciplinary Research for Advanced Materials at Tohoku University. Since 2007, he has been an AIMR Principal Investigator at Tohoku University. Doctor of engineering.

EVENT REPORT

Keep Curiosity, Keep Creativity

"The discovery is a lucky event meeting prepared mind."

These were the reflections of Dr. J.G. Bednorz, recipient of the 1987 Nobel Prize in Physics, when he reflected on the prize-winning discovery of high-temperature superconductors using ceramics.

Dr. Bednorz visited AIMR as a guest of Science Café on a Saturday in February, and delivered a talk at a special stage set up at the Atrium on the first floor of the AIMR Main Building. Dr. Bednorz talked to the audience about the story leading up to the Nobel Prize win.

Having chosen superconductors as his research theme, Dr. Bednorz had searched for materials that could retain a high state of conductivity even at a temperature of 1°C. He brainstormed countless ideas together with his colleagues, and devoted himself to experimentation work, which was followed by repeated failures. He spoke to the audience about his days of trial and error that were overcast by clouds of uncertainty, when he had been plagued by worries about whether something was missing, or whether they were proceeding in the completely wrong direction. However, they persisted in conducting experiments, and grasped tightly onto any tiny signs of a discovery. Finally, they discovered a high-temperature superconductor using ceramics, an idea that no one had even conceived of. Their discovery then gave rise to a superconductivity fever that swept the world. Dr. Bednorz and his colleague were awarded the Nobel Prize the year following the discovery, which was a recognition given at unprecedented speed. This was a testament to the great excitement that their discovery had aroused in the world. The audience also commented that the talk had given them greater insight into the story that created the superconductivity fever, and generated much excitement.

Finally, Dr. Bednorz was asked to give some advice to future scientists, to which he responded, "Keep a strong sense of curiosity and imagination. Take up new challenges. Do not be afraid of failure. Learning from failure gives people confidence, and helps them to continue tackling challenges in unknown territories."

Study "abroad" at Katahira—Second session

An international exchange program for high school students, conducted only in English, was held for the second time at the AIMR Main Building on 22 June 2013.

On the back of the popularity of the program last year, the number of participants increased significantly this year to 42 high school students from five schools. Assistant Professor Packwood from AIMR explained that it was possible to make use of probability models to understand data obtained through the collision of neon atoms on the surface of liquids. One of the high school students asked whether it was possible to conduct the experiment using helium atoms. To this, Assistant Professor Packwood explained that helium atoms are too small for the application of Newtonian mechanics, so the models would become too complicated. Despite the fact that the lecture was conducted without interpretation, questions and answers that probed deep into the contents of the lecture flew back and forth.

After the lecture, the students were divided into small groups to conduct interviews of non-Japanese researchers. The groups then gave presentations about their interviews, with topics ranging from why their interviewees had become researchers, the reasons for choosing their research themes, and what they liked about Japan. At the end of the program, the following feedback was received from the participating students: "There were quite a number of English-speakers around me, and I felt the lack of my own English ability quite keenly. However, this has inspired me to work even harder in the future." Also, "The opportunity to discuss topics that were of interest to the researchers and to myself left a deep impression on me." Even after the program had ended, the students continued to consult with the researchers about their future paths and plans, enjoying the interaction until the very last possible moment.

NEWS & INFORMATION

Professor Kurihara receives "Distinguished Women in Chemistry or Chemical Engineering Award" from IUPAC

Professor Kazue Kurihara (AIMR Principal Investigator) has been selected as a recipient of the "IUPAC 2013 Distinguished Women in Chemistry or Chemical Engineering Award."

This award, initiated in 2011 as part of the International Year of Chemistry celebrations, is presented by the International Union of Pure and Applied Chemistry (IUPAC) to female chemists around the world who have contributed to the fields of chemistry and chemical engineering. This is the second time the award is being given out, and 11 renowned female chemists, including Professor Kurihara, were accorded this honor. Professor Kurihara was recognized for her outstanding research work throughout her career, including research on intermolecular and surface interactions using surface force measurement, as well as research on interfacial phenomena at the molecular level. The award ceremony will take place during the IUPAC Congress in Istanbul, Turkey, in August 2013.

Associate Professor Hitosugi receives the Gottfried Wagener Prize

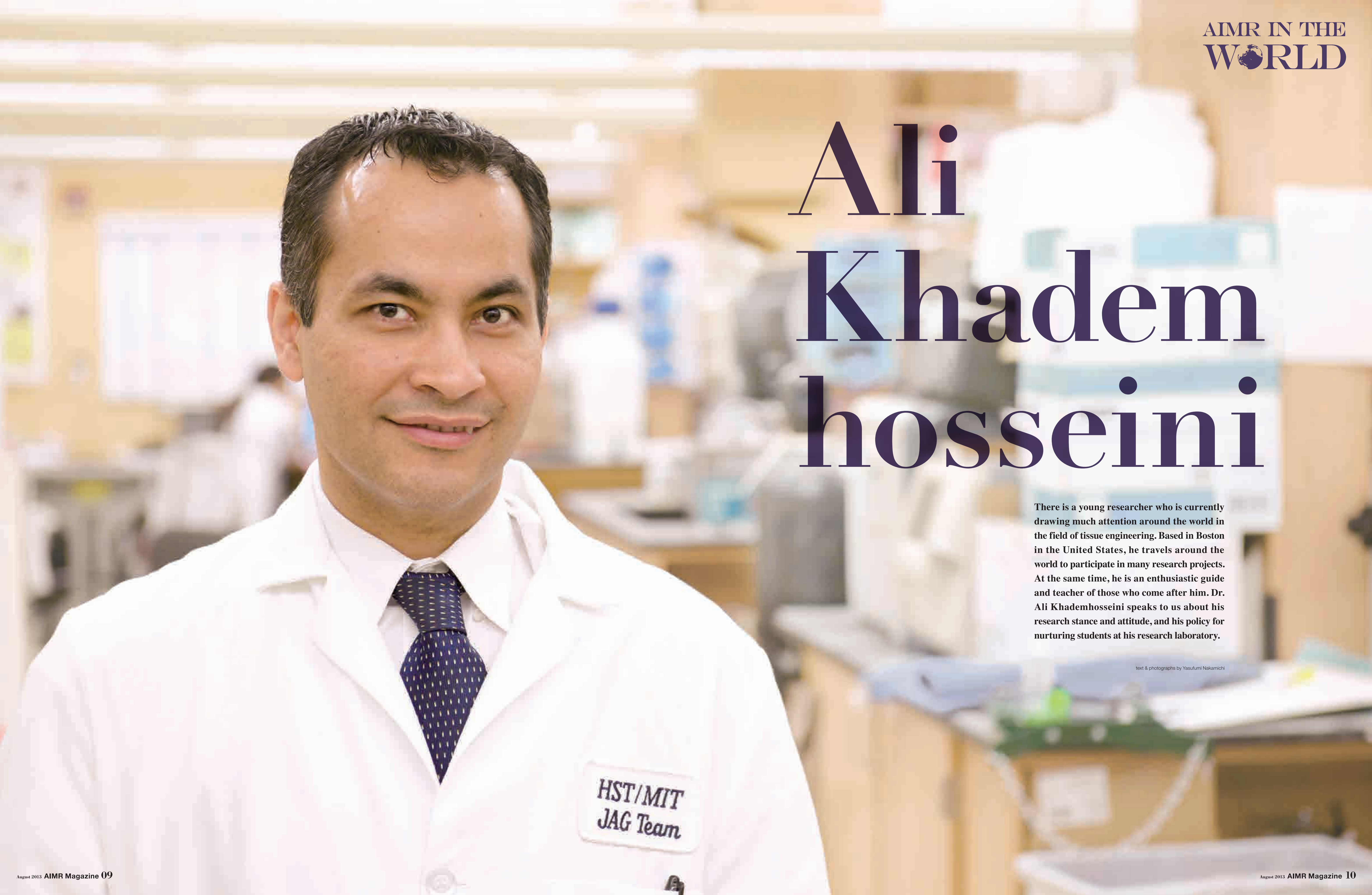
Associate Professor Taro Hitosugi has been awarded the Gottfried Wagener Prize 2013 in the 5th German Innovation Award. The award ceremony was held on 18 June at the Residence of the German Ambassador in Tokyo. This award was initiated with the aims of providing support for young competent Japanese researchers, and promoting industry-academia cooperation between Japan and Germany. Associate Professor Hitosugi was recognized for his research achievements in the development of titanium dioxide transparent conductors, which is a transparent conductor that does not make use of the rare resource, indium.

Regarding his award-winning research, Associate Professor Hitosugi explained, "I believe the realization of greater efficiency in environmentally-friendly devices can play a very significant role in societies that place an importance on sustainable development."

Professor Ikuhara and Assistant Professor Souma receive MEXT prizes

Professor Yuichi Ikuhara (AIMR Principal Investigator) received the 2013 Prize for Science and Technology (Research Category) of the Commendation for Science and Technology from the Minister of Education, Culture, Sports, Science and Technology. This award is presented to those who have produced distinguished achievements in the field of science and technology in Japan. Professor Ikuhara was recognized for his research on the atomic structure/electric state and the generation mechanisms of materials properties in local structures, such as interfaces, surfaces and dislocations.

Assistant Professor Seigo Souma was also a recipient of the Commendation for Science and Technology from the Minister of Education, Culture, Sports, Science and Technology. He received the Young Scientists' Prize. Assistant Professor Souma was commended for his achievements in the development of a spin-resolved photoemission spectrometer, and his research on the electronic structure of functional materials.



Ali Khademhosseini

There is a young researcher who is currently drawing much attention around the world in the field of tissue engineering. Based in Boston in the United States, he travels around the world to participate in many research projects. At the same time, he is an enthusiastic guide and teacher of those who come after him. Dr. Ali Khademhosseini speaks to us about his research stance and attitude, and his policy for nurturing students at his research laboratory.

text & photographs by Yasufumi Nakamichi

Culture of cells to create tissue structures such as blood vessels, muscles, and ultimately, a heart. This may sound like a dream, but such tissue fabrication technology is on the way to becoming reality. Once realized, the transplanting of organs would not anymore be from others to patients that require organ transplants. It may enable organ transplants through the production of functional tissue from the patient's own cells. The research and studies that back up this technology are stem cell research, which includes research on iPS cells, as well as the field of study known as tissue engineering.

Tissues such as blood vessels and the heart cannot be produced simply by culturing cells. A certain type of structure, known as scaffolds, is required in order to bring cells together to create a three-dimensional form. In the field of tissue engineering, research is currently underway to develop and improve scaffold materials, and to culture various tissues. Dr.Ali Khademhosseini, Junior Principal Investigator at AIMR, is one of the researchers who is currently drawing much attention in this field worldwide.

"Stem cells are an extremely important material that form the basis for creating the shape of a tissue. They are the building blocks of tissues, however, you cannot build a house only with building blocks. The blocks have to be combined in the correct way so that the house can be built. In order to assemble the house (tissue), tissue engineering technology is required", he explains.

Dr. Khademhosseini is involved in the development of scaffold materials for the creation of the three-dimensional tissue structures by controlling the movement of cells. He travels back and forth between Sendai and Boston, mainly working at Harvard Medical School. His laboratory places a particular focus on the culture of tissues using a scaffold material known as hydrogel.

"Our research laboratory has developed a material called GelMA based on hydrogel. GelMA is characterized by an extremely high level of biocompatibility. Using this technology, we are attempting to control cell behavior so as to create the ideal tissue architecture. Our goal is to create tissues such as cardiac muscles, bone, liver, and blood vessels. While the results are not complete, we have already released reports on some successful cases. If such technology proves to be possible, we would be able to harness it not only for organ transplants, but also for drug testing. By adding drugs to the cultured tissues, we will be able to conduct even more accurate tests on the toxicity of the drug, and its efficacy on treating diseases." speaks Dr.Khademhosseini, passionately about the potential of tissue engineering.

He began to study tissue engineering during his PhD at MIT. He had majored in chemical engineering at the University of Toronto. However, many of the technologies that he had studied had already been put to use in industries. What were the fields of research that still had potential for future development? While pondering this question, biology came to mind, and he began to develop an interest in the field of tissue engineering, which also required the application of his chemical engineering knowledge. After receiving his Master's degree at the University of Toronto, he began to conduct research under Robert Langer, an eminent Professor at MIT.
Dr.Khademhossini says, "I had known about Professor Langer's work while I was pursuing my Master's degree. This is because Professor Langer had been the one who had established the field of tissue engineering, and I have had many opportunities to witness the results of his research. Impressed and inspired by his great achievements, I really wanted to join his lab for my PhD, and so decided to pursue further studies at MIT."

Under the Professor, he picked up not only specialized knowledge and technologies, but also learned about research stance and attitude from his mentor.

"One of the greatest characteristics of the Langer Lab was that it was highly multidisciplinary. The atmosphere was one of many researchers working together to conduct research. Carrying out research together with young, outstanding, and highly motivated researchers with different fields of specialization allowed us to tackle problems while discussing various approaches to solving the problems. This would lead us to completely fresh solutions that were different from anything we had learned before. Studying at the Langer Lab had proven to be of immense help to me in running my own lab."

In his lab at AIMR, multinational and multidisciplinary researchers discuss various research topics.

The truly important discoveries are made at the boundaries of the research field

Dr. Ali Khademhosseini has one requirement for students and postdoctoral researchers who join his laboratory. It is to ' become independent researchers '.

"I would like each member of my lab to consider how they can contribute to various fields of research, think about how they can solve major issues, and be able to come up with grand visions. To that end, they have to become independent who are constantly full of ideas, and who are able to work proactively on multiple projects that straddle several disciplines."

The issues covered by the projects that the Khademhosseini Lab is engaged in are complicated, and most of these cannot be solved without a combination of members from multiple disciplines, including biology, chemistry, materials science, and engineering. Young researchers may come to face many barriers, and find difficulties in continuing with their work. Dr.Khademhossini emphasizes that these are the very challenges for the young researchers.

"A good researcher realizes that the truly important discoveries are made not in a specific field of research, but rather, take place at the boundaries of different disciplines. My lab brings together many young researchers from various disciplines. While tackling their own research problems, these researchers befriend others who come from different environments and learn how to communicate with them. I believe this would serve them well in resolving the problems that confront them, and in helping them to become better scientists."

Dr. Khademhosseini says that there is something he pays attention to when giving advice to young researchers who are facing problems.

"People who are facing problems have to be aware that the key to solving those problems rests in themselves. This is something that I learned from Professor Langer. People have to understand that they should have a desire for solving the problems on their own."

While he sometimes dishes out research advice directly to his students, simply providing them with solutions will not help these students to develop.

He notes, "Independent researchers make the effort to search for people with the most ideal experience in order to solve their problems, and look for solutions by holding discussions with these people. It is important to go through this problem-solving process repeatedly, every day, from the student and posdoc phases. When faced with a problem, solve it. By doing that repeatedly, you will learn about the problem-solving process, which involves understanding the problem, coming up with various possible solutions, and selecting the most appropriate method from among these possibilities. Once you have familiarized yourself with this process, you will be able to deal with any problem that comes along."

This policy applies to his lab both in Boston and Sendai. The Khademhosseini Lab in AIMR comprises members of different nationalities and different fields of specialization. The members conduct research independently, and in a proactive manner. They visit other AIMR laboratories to join discussions, and conduct joint research, which has lead to produce several wonderful achievements. Dr. Khademhosseini points out,

"Despite differences in the number of people, both the laboratories at AIMR and Boston bring together top-level researchers in different disciplines. Just as in Boston, AIMR provides a space for researchers to meet and discuss. Through discussions about the same theme from different perspectives, they are able to produce interesting and unique results."

When researchers from different disciplines come together to tackle the same problem, they contribute to the development of new technologies and discoveries. Dr. Khademhosseini feels that AIMR provides a superb environment for conducting such cross-disciplinary fusion research, even in comparison with Boston where international research institutes such as MIT and Harvard are based. Furthermore, he believes that AIMR has advantages that are unique to the institution simply because of its smaller scale.

"The entire research institute has narrowed down the issues that it should be engaged in, and all the members of the institution work together as one toward that goal. This is not possible for an organization of a larger scale. AIMR has designated three projects as "Target Projects" for all members of the research institute to work together on. I think that this is a very effective way of conducting fusion research."

The high level of motivation that AIMR has toward fusion research is something that Dr. Fujie, Research Associate also gets a strong sense of in his research work at the Khademhosseini Lab.

"I am involved in the geometric modeling of the shape of each individual cell that makes up a living organism with researchers in theory and mathematics at AIMR. Through this research, we aim to develop methods for evaluating the quality of the tissues that are fabricated, as well as efficient methods of fabricating transplant tissues. Research that captures living tissues as "materials" that are not in a state of equilibrium is an extremely new challenge and endeavor. It is precisely the gathering of researchers with specialization in various fields at AIMR that makes it possible for us to take on this challenge."

Dr. Ali Khademhosseini, in collaboration with many outstanding young researchers, is involved in various projects that aim to apply the results of tissue engineering to the sites of medical treatment. In closing, he spoke about the future of tissue engineering.

"The day will come when tissues created artificially are used in regenerative medicine. To achieve the success, there are so many things that we need to discover. Not only do we have to know more about living things, we also have to develop new technologies and materials in order to gain better control over cells. Therefore, the field that we study calls for knowledge of materials science, as well as an understanding of biological systems based on mathematics. The tie-up between materials science and mathematics at AIMR holds the key to unlocking the potential for solving our problems. Through my research in this field, I hope to save patients who are suffering from illness and disease, and create better and richer lives for people."

Ali Khademhosseini

Born in Tehran, Iran in 1975. He is an Associate Professor at the Harvard Medical School and at the Harvard-MIT Health Sciences and Technology. He is also concurrently a Principal Investigator at AIMR. After graduating from the University of Toronto in Canada, he received his doctoral degree from MIT. His previous experience includes serving as Assistant Professor at Harvard University. The successful young researcher has already produced numerous achievements in the field of tissue engineering, and received more than 30 awards to date.

Column

A short detour

MATERIALS

This corner contains essays that cover topics relating to materials science research at AIMR, including fundamental facts, history, research trends around the world, and advanced research at AIMR.

Part 2
A Journey of Contemplation

Gold was discovered in California around 1848. At the same time, the Western part of the North American continent, including California, was ceded by Mexico to the United States, triggering a spate of migration into California especially in 1849. These events comprise the time in history known as the "Gold Rush," and the settlers became known as the forty-niners (49ers). It is also widely known that the American football team based in California was named after these settlers. Sendai has a team named 89ers as well; perhaps the expression "~9ers" has a powerful ring to it. There was, in fact, something that happened in the field of materials science that created the same kind of excitement as the Gold Rush. It was the discovery of high-temperature superconductors in the 1980s, and the superconductivity fever that came after that discovery. Even researchers and students who had nothing to do with superconductors, such as the author of this article, as well as members of the general public who were not engaged in research, developed an interest in materials science thanks to media reports at that moment.

In 1911, Dutch physicist Heike Kamerlingh Onnes discovered the phenomenon of superconductivity by cooling mercury to a temperature close to absolute zero, using the helium liquefaction technology that Omnes had developed by himself. He found that the electrical resistance of the mercury became zero when absolute temperature was 4.2 degrees. If superconductivity could be achieved at normal temperature, it is expected to be of great use. With that in mind, many researchers began to search for materials that could be used as superconductors at even higher temperatures. However, there was little success in their endeavors even until the end of the 1970s. In the last issue of this magazine, I described materials science as a treasure hunt. However, when the treasure hunt lasting close to 70 years had yielded no results, learning that researchers may have then lost their motivation to hunt for the treasure, it was then that the breakthrough came. Dr. Johannes Georg Bednorz and Dr. Karl Alexander Müller discovered that a certain type of ceramics, which typically did not allow electricity to pass through, could become a superconductor at a higher temperature than other materials that had been used prior. In the short period of one year after the publication of their paper, the pair was awarded the Nobel Prize in Physics. This was an unprecedented event in the history of science. This triggered the superconductivity fever—a second round of the superconductor treasure hunt. Dr. Bednorz, who is a member of AIMR's International Advisory Board, took the rostrum at the Science Café this February during his stay in Sendai, and spoke about this historical discovery from his personal perspective.

Thus, while the search for materials is as exciting as a treasure hunt, it is the desire to know the truth and the spirit of inquiry that lie at the core of what makes this process exciting for the scientists themselves. An example would be the intellectual curiosity that seeks to elucidate the causes and mechanisms behind the phenomenon of superconductivity. Of course, scientists are happy if they succeed in finding good materials as a result of their research. However, it is the scientific process that they truly take delight in. These processes could be viewed as the groundwork that they lay in order to obtain good materials, but it means more than that for the scientists. Rather, it is the desire to be the first to understand something that no one else in the world has yet discovered. At AIMR, these "explorers" who enjoy the journey of contemplation and thought are constantly engaged in creating experimental equipment, taking measurements, developing formulae, carrying out theoretical calculations, synthesizing new materials, and thinking throughout these processes, in order to elucidate the wonders of materials. Materials science is not simply the discovery of new materials; rather, the generation of new scientific principles lying at the heart of this field of study.

Susumu Ikeda

Born in Saitama in 1967. Ikeda graduated from Tohoku University's Faculty of Science in 1990. After working at a cement company, he received his Ph.D. degree from the Graduate School of Science, the University of Tokyo. He became an Assistant Professor at the Graduate School of Frontier Sciences at the same university, and then moved on to become an Assistant Professor at AIMR. In 2010, he was appointed Associate Professor, and in 2011, took on a second position as the Deputy Administrative Director (for Research).

NEW STAFF

Benoît Collins

"I have loved mathematics since the days of my childhood. No matter how difficult it may be, an attractive math problem would still have sufficient appeal to keep me going without giving up, until I have gained a complete understanding of how it works."

So says the young mathematician who joined AIMR's Mathematics Unit as a Junior Principal Investigator in April 2013. He also spoke about the advice he had received in his teens from a physicist whom he had consulted with regard to his future course. With a laugh, Collins said, "When I told him that I loved mathematics, he advised me to study physics instead, because mathematicians tend to become locked up in their own world." Although Collins ultimately decided to pursue a future in mathematics, these words have remained with him even today. He explained, "Over the course of my research, I constantly try to think about what fields I can apply my own research to, so that I would not confine myself only to the world of mathematics."

To Collins, AIMR provides an extremely attractive research environment for researchers. "Although AIMR is based in Japan, it is truly international. Researchers can conduct research that straddles various fields of study. I believe that it is possible to produce a significant quantity of research results in a short period of time here. Going forward, I would like to invite many researchers from around the world to be a part of the research that is being conducted at AIMR."

Benoît Collins is currently conducting research at both AIMR and at the joint research facility in Canada, and travels back and forth between the two places. "Working both in Sendai and in Canada can sometimes be difficult, but it may also be inspiring for my research work. In that sense, it is not a painful burden for me." Smiling, he added, "It helps that my family is also based in Japan."

Benoît Collins

AIMR Junior Principal Investigator

Benoît Collins, 35, was born in France in 1977. After obtaining his doctorate degree from Pierre and Marie Curie University (Paris VI), he became a JSPS research fellow (Kyoto University) and then joined the University of Ottawa as an assistant professor. In 2011, he was appointed associate professor at the University of Ottawa. Since April 2013, Collins has also taken up the concurrent post of Junior Principal Investigator at AIMR.

text by Yasufumi Nakamichi