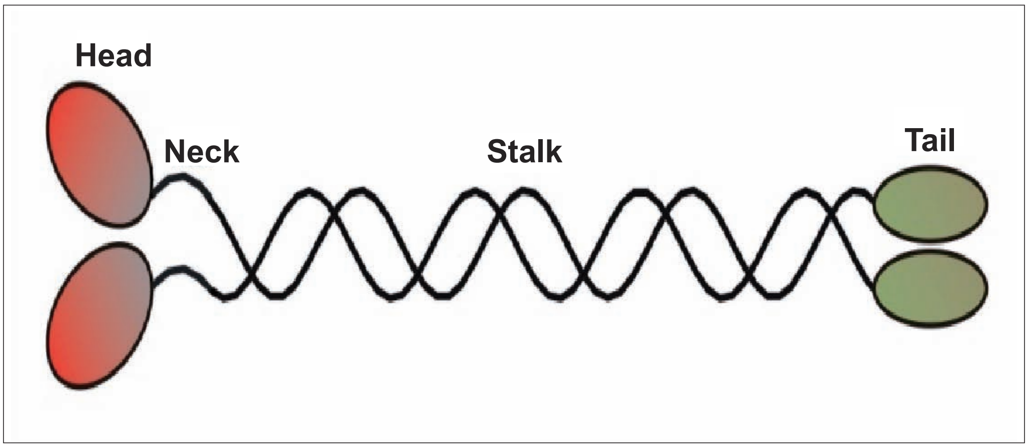
Volume 12

WPI-AIMR NEWS

April 28, 2011

Kinesin dimer structure



World Premier International Research Center
Advanced Institute for Materials Research

Tohoku University

Cover: Kinesin is a motor protein in the eukaryotic cell, hauling biological cargo as it steps along its associated filament (microtubules). Powered by Adenosine-triphosphate (ATP), kinesin can function as a self-assembled, highly efficient, synthetic nano-transporter. This makes it very attractive for the development of novel Nanoelectromechanical Systems (NEMS).

(Winfried Teizer, WPI-AIMR)

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Produced by the WPI-AIMR Communication Office

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The 2011 WPI-AIMR Annual Workshop and the Terrible Disaster on March 11

Yoshinori Yamamoto
Director, WPI-AIMR, Tohoku University

From February 22 to 24, the 2011 WPI-AIMR Workshop was held at Sendai International Center, and we had 216 participants from 9 countries. The symposium started with opening remarks from the President of Tohoku University, Professor Akihisa Inoue, and the congratulatory address by Professor Toshio Kuroki, the Program Director of six WPI centers (including AIMR) of JSPS. Then, the special session followed, in which Dr. J. G. Bednorz (1987 Nobel Laureate in Physics on high temperature superconductivity), Prof. P. A. Grünberg (2007 Nobel Laureate in Physics on giant magnetic resistance), and Prof S. Iijima (2009 Order of Culture, discoverer of the carbon nano-tube) gave lectures. After a short coffee break, the morning plenary session started with a plenary lecture by Alan Lindsay Greer who is a foreign PI of AIMR. During the two and half day symposium, 20 lectures by domestic and foreign PIs and by young researchers of AIMR were given together with 21 lectures by invited speakers. 83 posters were presented during lunch time of the first day. Active, fruitful, and positive discussions were made during the symposium. Dr. Heinrich Rohrer, who is the Chair of the International Advisory Board, listened to almost all of the lectures and gave constructive comments. I appreciate Heini's attendance and his constructive comments. I believe the symposium proceeded smoothly and we were able to hold a successful symposium. In fact, I have heard that of the four workshops so far, the 2011 annual workshop was the best one yet. After the workshop was over, we held the International Advisory Board meeting in the afternoon of February 24. The board members, Dr. Heinrich Rohrer, Dr. Georg Bednorz, Prof. Herbert Gleiter, and President Akihisa Inoue, attended this board meeting. We discussed past achievements, the several challenges ahead of us, and the future prospects of AIMR. We have concluded that the points raised by the program committee have to be solved pertinently and quickly, and improvement of AIMR structures is an urgent task for us.

The symposium was over successfully, and we were enthusiastic about the further improvement of the structure of AIMR and preparing the materials for the interim evaluation of AIMR. However, as you know, a huge earthquake of magnitude 9.0 struck us on March 11. At that time, I was in a lecture room at Aobayama campus listening to the presentations of young researchers to evaluate their achievements. At the very beginning of the earthquake, myself, the speaker, and the audience felt that we were once again experiencing an ordinary earthquake, that it would be a typical one, and that it would soon be over, because in the preceding few weeks we had had ordinary earthquakes very frequently. However, within a short while, everybody in the room felt that this earthquake was exceptionally strong, and some escaped from the building. I did not have time to escape, so I took shelter under the table. The length of the earthquake was exceptionally long; I thought it continued for perhaps a few minutes. As you know, a huge tsunami hit the coastal areas of the north east district of Japan, and many people were killed. This is a truly terrible disaster. I would like to extend my most sincere sympathies to those individuals and families that have been affected by the terrible tsunami. Fortunately, none of the AIMR researchers and staff members were affected by the tsunami and we are all safe, although we have had many problems and difficulties in everyday life. For example, infrastructure (including electricity, city water, and gas) has collapsed, and we have encountered shortages of food and petroleum due to the collapse of the transportation system.

Immediately after the onslaught of this terrible earthquake and tsunami, I received a number of E-mails from domestic and foreign friends/colleagues/students who felt strong concern for the safety of AIMR researchers. Some friends also kindly offered to help with disaster relief. I thank you all from the bottom of my heart for such offers. Now, two weeks and a few days have passed after this terrible disaster, and most infrastructure has been restored. The problems of food and petroleum shortages are being solved, day by day. I believe all of these problems will have been solved by the time this AIMR NEWS is delivered to you. Fortunately, the buildings of AIMR were not affected, but equipment and valuable instruments in laboratories were significantly damaged. The precise amount of these damages is now being figured out, but I estimate that total damages may exceed twenty million USD. The researchers and students of AIMR have begun to resume lab activity and research work. Their spirits are very high in spite of the damage to laboratories and the inconveniences they face in everyday life, which still remain at this time in Sendai. I believe the activity of AIMR must recover soon and even be enhanced in comparison with that before this terrible disaster. I would like to ask all of you for your continued strong support for AIMR.

(Written on 28 March)

Interviews

Interview with Professor Sumio Iijima,
Adjunct Professor, WPI-AIMR
Professor, Meijo University
Award of 2009 Order of Culture

"What is behind the Carbon Nanotube"

Administrative Director Iwamoto: Professor Iijima is renowned worldwide as the scientist who discovered the carbon nanotube. Thank you, Professor, for accepting our interview so soon after your special lecture at the AIMR Annual Workshop today.

Professor Sumio Iijima: Thank you.

Iwamoto: After graduating from the University of Electro-Communications, Tokyo, you entered graduate school at Tohoku University, and became a research assistant at the Research Institute for Scientific Measurements, which is one of the parent organizations of the current Institute of Multidisciplinary Research for Advanced Materials.

Iijima: I was an assistant for a little more than two years.

Iwamoto: What memories do you have of your years in Tohoku University?

Iijima: Well, I did not study much in my undergraduate years and was involved in a variety of club activities, so I did not even imagine that I would enter this field and be where I am now. I could not decide whether to start working after four years of undergraduate studies, or to move on to graduate school. When the fourth year ended, I made up my mind to enter graduate school. That was one of the many crossroads in my life. After that, I happened to join the Research Institute for Scientific Measurements; or rather, I was taken in. Again, I happened to be delegated work on the electron microscope. I never really took any active action arising from a volition or desire to do something; I was extremely passive. However, the electron microscope suited me perfectly, and I finally found something that I wanted to pursue.

Iwamoto: That is to say, your undergraduate days were spent largely on enjoying your student life.

Iijima: That is right. I had a good time.

Iwamoto: After you left Tohoku University, you went to Arizona State University in 1970, and you discovered the carbon nanotube in 1991.

Iijima: That is right. Since I had gone to the United States in 1970, the span between the two events was 20 years. In the very beginning, you said something to the effect that "Dr. Iijima is synonymous with the carbon nanotube." That always annoys me, and I will say, "Hold on a minute." The fact that I discovered the carbon nanotube in 1991 means that I had had a 20-year research career before the discovery; that is a rarely known fact, but what am I to do about it? Therefore, the discovery of the carbon nanotube had not been a sudden event. I think it is important to realize that I had had 20 years, and 26 years if I include my graduate studies, that is, a quarter of a century of preparation time. Without that time, I would not have made the discovery. Everyone is influenced by what has been done by the precursor in the past; that cultivates wisdom or builds up experience, and it moves people forward to the next stage of development. I think that was precisely what happened to me.

Iwamoto: Could you be a little more specific?

Iijima: Carbon nanotube was discovered on a certain day, suddenly. That is how it is perceived. If you look at the event carefully, you would find that it had been a chance discovery. "Serendipity" is a frequently used word these days. How did I discover the carbon nanotube? If we are to trace the events—as the carbon nanotube is extremely small, of nanometer size, the only instrument through which it can be seen is the electron microscope. Since I had begun working with the electron microscope in graduate school, I have had more than 20 years of training. Therefore, I had first picked up skills pertaining to the electron microscope before moving on to investigating various objects. One of those objects happened to be the carbon nanotube.

Iwamoto: I see.

Iijima: That is why I say that the accumulation of such experiences had led to the chance discovery. To me, I had made the discovery because it needed to be discovered. It was an inevitable discovery.

Iwamoto: I understand that the story behind the word "serendipity" says that the third prince of Sri Lanka, formerly known as Serendip, had found an interesting stone, which then turned out to be a precious stone.

As you said, serendipity is the ability to focus on something at a certain point in time and say, "This is it!" At the same time, as you mentioned earlier, there would have been more than 20 years of cumulative experience before that is achieved.

Iijima: Yes, that is what I believe.

Iwamoto: What was the background to your discovery of the carbon nanotube?

Iijima: First, what had triggered me and given me the will to pursue this? The background of our community and the research on properties at the time of the discovery are of great importance. There were several interesting and significant events pertaining to our research on materials and properties in the latter half of 1980. One of those had been the discovery of Fullerene, C_{60} molecules.

Iwamoto: The discovery by Kroto and Smalley.

Iijima: That was in 1985. Then, in 1990, mass synthesis method was discovered.

Iwamoto: Yes.

Iijima: With that, a method to create large quantities was discovered; at the same time, there was a new discovery that linked that to superconductivity. Prior to that, in 1986, high-temperature superconducting oxides were discovered, which also generated much interest worldwide; the world buzzed like bees around a hive. That is to say, there were many such discoveries, including the new discovery of superconductivity and Fullerene superconductivity. Before that, I had been involved in the first project conducted by the Research Development Corporation of Japan, the predecessor of the Japan Science and Technology Agency (JST) today, which had commenced in 1982. In order to participate in that research project on ultrafine particles, I had concluded my 12-year stay in the United States and came home, and worked on that project for five years.

Iwamoto: I see.

Iijima: The research base for that project was Meijo University in Nagoya, where I am located now. With that connection, I moved to NEC after the project ended. That was in 1987. There, I had actually first worked on diamond thin films and Fullerene. I had started out with the intention of studying the growth mechanism of Fullerene. However, in order to carry out research on Fullerene, I was also looking at various types of carbon materials in a random manner. One of those materials was something that resembled embers left behind from the process of Fullerene generation by one of the professors at Meijo University. I happened to get on my hands on it, and when I studied it through the electron microscope, I found the carbon nanotube. There is some complicated background involved, but this was the basic catalyst leading to the discovery of the carbon nanotube.

Iwamoto: Although I am sure that part of it had been a result of your inquiring mind and natural sense of curiosity, the discovery was ultimately a culmination of an environment combining factors such as superconductivity and the birth of Fullerene.

Iijima: That is right, and, Fullerene is carbon. In the 20 years leading up to the discovery, we had been studying various carbon materials similar to it, using the high-resolution electron microscope we had developed. In that sense, because of the rather substantial build-up in experience and knowledge up to that point, the research papers that I had published had already talked about something similar to Fullerene.

Iwamoto: I had not been aware of that.

Iijima: Although Fullerene was discovered in 1985, about five years prior to that, Fullerene was captured in a photograph I had taken by the electron microscope.

Iwamoto: That is wonderful.

Iijima: That is why Kroto and Smalley came all the way to look for me. When Smalley and

Kroto published their paper on Fullerene in 1985, people all over the world did not really believe them. That is to say, their first paper had been speculative, and had not contained any logical scientific data.

Iwamoto: I see.

Iijima: Specifically, it had been a mass spectrometry experiment. In mass spectrometry, it would be possible to tell, from the number of atoms, how many carbon atoms there are. In other words, the peak corresponding to a cluster of 60 has a certain number.

Iwamoto: Yes.

Iijima: What shape does the cluster of 60 take? We are completely unable to tell. There are people who say that they are linked in a chain, and some say they are curled up together. There was also talk of the cluster being shaped like a soccer ball—that had been Kroto's and Smalley's amazing speculation. Based on just "60," that is, the number of carbon atoms, they concluded that this atom had to be shaped like a soccer ball. However, as they had no evidence, their argument lacked persuasion. Because of that, they found themselves in a tough situation for five consecutive years. My work then made an appearance, and among the photographs I had taken five years back, one showed the round structure of carbon. Kroto and Smalley had found that photograph somewhere, and it became the only evidence proving their speculation correct. That was how this electron micrograph became extremely famous at that time. So when people called their research a speculation, they were able to say, "There is a photograph here. This is what it is like."

Iwamoto: In a sense, that was what they were looking for, wasn't it?

Iijima: Yes, although they had been searching for evidence through various different ways. Therefore, a long time before they became famous, the two of them had come all the way here while I was working at NEC in Tsukuba. It had been very important to them. While they were struggling, I had written to them, saying, "I have this photograph that serves as proof for your model, so let us write this paper together." However, they replied, telling me to write it alone. That is how I came to author a paper by myself, proving their hypothesis right.

Iwamoto: I see.

Iijima: However, that came to an end soon. What I mean is this: in 1985, the discovery of C_{60} was announced, and five years later in 1990, the superconductivity and mass synthesis that I mentioned earlier came onto the scene. Through the mass synthesis of Fullerene, it became highly possible to carry out crystal structure analysis. Next, the soccer ball structure hypothesis was firmly proven using X-ray diffraction. With that, the proof I had offered met its end.

Iwamoto: That is a pity.

Iijima: However, what is interesting is that it did not end there. The soccer-ball structure of carbon atoms is extremely rare, but the reasons behind that structure and the growth mechanism were still unknown then. Even now, we do not really have a clear idea.

Iwamoto: Is that so?

Iijima: Although various things are possible, the question is, why do carbon atoms cluster together in the same way as a soccer-ball structure?

Iwamoto: That is true. It really forms a perfect soccer ball shape.

Iijima: I wanted to understand that. That is why I took photographs of not just a single soccer ball, but of a multilayer structural—or a nested structural—spherical graphite ball. I thought that with my skills, I would be able to investigate and understand how the nested structure was formed. That is what I thought I would do.

Iwamoto: That is great.

Iijima: With that, I started looking at various carbon materials, and one of them turned out to be something resembling a nanotube. However, such a nanotube had not been seen in the world thus far. With my previous experience in various forms of research, the sudden appearance of something long and narrow piqued my interest. I think that would be what we call "serendipity."

Iwamoto: That was all the more so because of the twenty odd years of experience and knowledge you had accumulated.

Iijima: Among material structures, there are extremely few that are long and narrow. Perhaps this should also be called "serendipity." While I was pursuing my master in Tohoku University, I had carried out research on such elongated crystals. As part of my master and doctoral work, I had already learnt, during my master course, how to conduct crystal analysis for these elongated fiber-like structures using an electron microscope. During that time, I had studied fine whisker crystals of about 1 micron; these were elongated silver crystals. In a way, I had only replaced elongated silver filaments with the nanotube.

Iwamoto: That is to say, the carbon took the place of silver.

Iijima: That is right. Thanks to my skills in electron beam crystallography, I was soon able to understand how carbon atoms were linked.

Iwamoto: So this is all linked to a technique you had already picked up during your years as a master student.

Iijima: The most important point is that they were all linked, because furthermore, there was another material with an elongated structure, and that was asbestos. Asbestos is a natural mineral with a long and narrow structure. Assistant Professor

Yada at the Research Institute for Scientific Measurements where I was based then had been undertaking research on the crystal structure of asbestos using the electron microscope. My supervisor was Professor Tadatoshi Hibi, who headed the research institute for long years. Assistant Professor Yada, who later also became head of the Institute, had been working on a joint research project with the University of Oxford. As a student, I had observed his work from the sidelines. He had carried out structural analysis by studying the electron diffraction patterns of asbestos under the electron microscope. Silver filament is exactly the same in that it is also cylindrical and elongated, so the methods used were the same.

Iwamoto: So in terms of methods, they were the same.

Iijima: The research methods were the same, and in addition, there were various other factors. That is why, 20 years henceforth, when I suddenly came face to face with the nanotube, all my previous knowledge resurfaced immediately. I was deeply interested in that long, narrow thing, and picked it up for further study. That would be the substance of "serendipity" in my case.

Iwamoto: That is exactly what they mean when they say, "Rome was not built in a day." Could you give us a simple explanation of the impact of carbon nanotube discovery?

Iijima: Yes. I think there were two significant results.

The first was in basic science. The impact on condensed matter physics was huge. There are also various linkages and connections as to why this was so. Although material science researchers like myself used to focus on the study of large structures, we shifted to the study of extremely small things under JST's research project starting from 1982, such as the ultrafine particle research mentioned earlier.

Iwamoto: Would that be what we call "nanomaterial" today?

Iijima: That would be what we call "nanocrystal" today. At the time, the word "nanocrystal" did not exist, so we called it ultrafine particles. That research had started with the study of ultrafine particles. That is because there are various theories that hypothesize on the changes in physical properties that arise simply from the act of shrinking something large, such as gold. Therefore, it was also hypothesized that by shrinking a nanotube, we would be able to observe various interesting phenomena that we do not see while it is in a larger state.

Iwamoto: That is true. In the nanomaterial world, even when things are made from the same element, they display surprising properties when they are shrunk.

Iijima: Copper wires are typically used to transmit electricity to homes. Although that is not a nanomaterial, the way the electricity flows changes when the size of the wire is reduced to a significant extent. In our lingo, that would be the discovery of quantum size effects. That work started at the beginning of the 1980s, both theoretically and experimentally. For instance, we make various small silicon devices, don't we? With such techniques, we would be able to develop technology for making small things, new structures, and materials, and then using that technology, we would in turn be able to make interesting mesoscopic structures. That was why we began experimenting. The research would enable us to discover various new physical properties.

Iwamoto: The discovery of quantum size effects is really one of the key points when we talk about pure science, isn't it?

Iijima: However, because the nanotube was discovered, we were able to gain a more detailed and precise understanding of the things that happen in that tiny world, that nanometer world. For instance, there is quite a lot of research that involves predicting physical properties based on theoretical calculations, using a computer. In the case where silicon structures are the subjects of such research, we do not know precisely what happens when they are made narrower; we do not know what happens to the thickness, or what happens to the tip. We are unable to predict the details. However, in the case of the nanotube, we are able to obtain all the atomic coordinates, and are able to predict everything using computers. That is why computational science researchers whose research focuses on theoretical calculations jumped on this material and used it to test their own theories. The emergence of the nanotube benefitted everyone.

Iwamoto: It has enabled simulations and other such research.

Iijima: That is where it coincides with our experimentation. The interplay between these theories and experimentation had already made fair progress, and overall, as I mentioned earlier, the material science research that involves the observation of quantum effects also began to advance rapidly. That was how the discovery contributed to pure science, to basic science.

Iwamoto: In a sense, while we had a tendency of focusing only on the practical aspects of the discovery, it had in fact made a truly significant contribution to the development of science.

Iijima: As a result of that, for example, theorists predicted that if we made something thinner, it should become a metal or a semiconductor. While silicon is a semiconductor, there is no way that carbon materials could become semiconductors. However, it was predicted that it would be possible to turn them into semiconductors by making them into narrow tubes. Therefore, we could make transistors; it had been predicted. Then, we were told to make thin, single-layer carbon nanotubes, so we started making them. That took as long as two years. Using this single layer tube, an American researcher produced an actual transistor in the United States. Indeed, when we measured the electrical properties, it proved to be a great transistor.

Iwamoto: That is wonderful.

Iijima: Once a transistor that could surpass silicon ones emerged, related experiments also came onto the scene, and applied research progressed. Based on the principle that if it were possible to produce a transistor, it would also be possible to produce computers; such applications would be possible. As such, various forms of applied research commenced at the same time. This is the second impact.

Iwamoto: I see.

Iijima: Although applied research started a little later, both pure science and applied science saw significant advancements as a result of the discovery of this material.

Iwamoto: The electron microscope may be a basic tool to you, but you do not simply use an order-made equipment. Rather, you have to put in special effort to manipulate the equipment, is that right?

Iijima: Yes. High-resolution electron microscopy has a long history. The electron microscope we have today was invented in 1932 by Ernst Ruska, an engineer in Siemens, Germany. He was awarded the Nobel Prize for the invention. I had entered this field in 1963 when I came to Tohoku University, 30 years after the invention of the electron microscope. During that 30-year period, a form of "Romanticism" existed among scientists—how small could the things we could observe be? This was because we could already see a limit to what we could observe using an optical microscope, and a microscope that made use of electrons was the only thing that could surpass that limitation. Although Ruska then invented the electron microscope, the resolution was initially worse than that of an optical microscope. It was improved year by year, and in 1970, electron microscope technology improved to the extent that we thought it may actually be possible to see atoms.

Iwamoto: Was that what those times were like?

Iijima: The development of that technology took place mostly in Germany and Europe. Although electron microscope manufacturers in Japan did their best, their products performed really badly. When I entered this field, I used a commercial microscope, but could not produce any results with it.

Iwamoto: I see.

Iijima: Then, I used my own ideas and made various attempts to take high-resolution photographs. That went well. That is how I picked up the skills in Tohoku University, got to the United States, bought Japanese devices, and began high-resolution research.

Iwamoto: Indeed.

Iijima: Incidentally, at the time, although Siemens had been the world leader in this field, I began to produce images that were clearly better than those produced by Siemens equipment, using my Japanese microscope. That was part of the reason—specifically, resolution kept improving, and we became able to see atoms. The timing of my entrance into this field had matched the technological progress of such equipment perfectly. We could also call that a

coincidence; that had also been “serendipitous.”

Iwamoto: That is true.

Iijima: That is why timing is of great importance in research. We cannot encounter this kind of chance if we are earlier or later.

Iwamoto: However, this had not all been a coincidence. The knowhow that you had accumulated throughout your studies and career had also been key to bringing you here today.

Iijima: Yes, that is true.

Iwamoto: How wonderful. In that sense, the carbon nanotube really did originate from Japan, and can truly be termed the “original Japanese science.”

Iijima: That is right. In that sense I was very lucky. However, it was not the case that one just all of a sudden appeared. After releasing my findings, I was told that others had already been doing the same thing. Actually, similar research can be found at various times throughout history. Going back to the very beginning in 1952, a researcher from then the Soviet Union presented a thesis on something similar to nanotubes in Russian.

Iwamoto: 1952?

Iijima: The reason I know that is because that a carbon society in the United States did a feature on the subject and created a thorough document about who discovered carbon nanotubes. The document includes that information. But what is important is that, as scientists, when writing papers we write logically about what new thing that we were able to achieve using some certain structure. As I explained earlier about C_{60}, we must present this information based on logic.

Iwamoto: It must be based on logic and must include evidence. Is that right?

Iijima: This means that, if you know the result, you can use an electron microscope to take a picture of a nanotube and then use that to claim that you have discovered nanotubes. However, in order to assert that what you have found are actually nanotubes, a single picture is not enough. There exists a certain ambiguity concerning the authenticity of the discovery, and in science there is no place for ambiguity.

Iwamoto: You are exactly right.

Iijima: One must present supporting evidence. So, in the case of nanotubes one would need more than a single picture. I used an electron diffraction pattern and investigated it thoroughly. I found that under the electron microscope it appeared long and thin. This was actually the structure of graphite, and can better explain the thickness and how the carbon atoms line up. So, nanotubes were named after collecting that type of data and I was the first person to call them that. Before that people did not use such labels very often. Today, if you took this data and examined it within the context of a single picture you may be able to argue the existence of nanotubes, but at the time we did not have such data so it was not possible to safely state it in that way.

Iwamoto: Because it would still be considered speculation, or the evidence would be insufficient, right?

Iijima: That is right. So, I always tell younger people that, when discovering something new, it is important to record solid data so as to eliminate any ambiguity, make your findings solid, and then present it. Otherwise your findings will be flawed. There are cases where, even if you did a good job, you cannot assert your findings to others.

Iwamoto: I see. A finding is important in and of itself, but unless you ensure that your findings are strong enough not to be refuted by anyone, your discovery will be invalid. You just mentioned younger researchers. I apologize, as this is just a general question, but some people point out that recently younger researchers are not traveling abroad. What are your thoughts on young researchers?

Iijima: I do not think that is a general question. While this is not to speak of the majority of people, some people that become scientists will always be that way. That is why I think it is important to specifically develop an environment that sparks such interests. I mean to say that we should not just sit back and tell younger researchers to go abroad, rather, we need to provide education that generates interest in going overseas.

Iwamoto: I totally agree. There is no meaning in simply requiring them to go. It is important that they possess a certain interest and want to do something specific.

Iijima: Exactly. It is best to encourage them to try to focus on a single topic.

Iwamoto: At AIMR we encourage researchers to work hard on their own research while also working together with researchers in other fields to conduct joint research. That brand of cross-field exchange is really important.

Iijima: I agree, but it may depend on the field. I do not want to blow my own horn, but I studied electron microscope technology at Tohoku University and earned my PhD using certain research that I was working on. If you can use new technologies there is a lot you can apply it to. For instance, I did a lot in the field of mineralogy.

Iwamoto: Really?

Iijima: Conventional mineral experts do not possess the technology of high-resolution electron microscopy. That is why I wrote many papers with mineral experts. At the time there was no field that used electron microscopes to look at the minuscule parts of minerals and evaluate them. That field actually advanced rather far due to this technology. In addition, while my major is physics, I am now working in the fields of mineralogy and chemistry. Recently, I am also working really hard in the field of biology.

Iwamoto: I see.

Iijima: I am working a lot on the application of biotechnologies that use medicines and other carbon materials. With this mixture of areas I am left confused about how to describe my own field. Field-mixing, or interdisciplinary research, is advancing throughout the world.

Iwamoto: I believe so, too.

Iijima: So, in that sense, it is important to be involved in other fields as well. I believe that if you were to go to a university in the United States you would rarely find a single teacher for each subject. Physics, chemistry, and other fields—everyone is involved in many at the same time. That is the norm these days. There are not many people that specialize in a single field, such as physics or something else, even though it would be okay if there were.

Iwamoto: I see what you mean. I think that you have highlighted something important—it is good to maintain interest in various different things.

In your case, as you mentioned earlier, you reached various turning points at different times. I believe that your resume speaks for itself, showing that you went to Arizona, JST, NEC, and today you work for Meijo University and National Institute of Advanced Industrial Science and Technology (AIST).

Iijima: I experienced completely different types of educational systems through elementary school, junior high school, high school, university, graduate school, and even during my stint as a post-doc. I also attended a public university, private university, universities in the United States and United Kingdom, participated in research projects funded by the national government, and even worked with private enterprises. So to put things more boldly, we scientists are proactive, always searching for new encounters and chances. Rather than waiting in the same place for something to happen to ourselves, we take initiative and push forward. It is not that I like doing that; it is just the outcome of the situation.

Iwamoto: Scientific policy in Japan has finally started to emphasize mobility over the past 20 years. As you say, it is really important to experience many things and meet a diverse range of people.

Iijima: I think that is ideal for a scientist. However, my opinion is not the most important factor. The social environment of Japan also plays a part. For instance, perhaps people do not move around very much in the United States nowadays. Nevertheless, they possess the spirit of exploration—gaining motivation when they do move somewhere new, resetting at zero, and then starting off on a new challenge all over again. In Japan, this form of activity causes one to lose out in the end.

Iwamoto: I agree.

Iijima: So, to put it differently, the best thing to do is to stay where you are and continue things out to the end.

Iwamoto: You are right. I have heard that some young men that have been negatively evaluated because on their recruitment exams it was discovered that they moved around a lot. I think it would be good if society as a whole would better tolerate the notion that these guys, conversely speaking, have a vaster range experiences.

Iijima: Right. When I moved, my family accompanied. After going abroad for a long time and then returning to Japan, my children were considered “returnees.” As a result, when they went to an ordinary school in Japan they were subject to bullying. The rest of the group excluded them. Japanese society still possesses negative areas such as this. When thinking about that it makes me think that staying in one place may not be so bad.

Iwamoto: I went to France three times for a total of 13 years—I know exactly what you are talking about. As a scientist we need a diverse range of encounters, but there are still various social structure and other problems involved as well, especially when it comes to family.

Iijima: If you move your retirement allowance resets to zero. Japanese systems like retirement allowances, for example, can rarely be applied. Today, however, things have changed greatly, so that would probably not be a strong inhibiting factor anymore.

Iwamoto: Lastly, tell me about your hobbies.

Iijima: I have been into mountain climbing since high school. In fact, I climbed so much that I had no time to study at all. During my first year in college, I spent 100 days out of the year climbing mountains somewhere. In high school, I was the founder of our school’s mountain climbing club, and in college I joined the mountain climbing club and the orchestra as well. I play the flute and I began learning in college. There are a lot of things I want to do.

Iwamoto: I see. You are good at culture and sports.

Iijima: That is right. We only live once so I think it is important to involve yourself in an array of activities. When I was young, in my 20s, I got to climb mountains. But now that I am older I cannot do that anymore, but there are many things that I want to do each year.

Iwamoto: Do you still play the flute?

Iijima: I sure do. I do not have enough time to really practice, though. Now, I enjoy riding my bicycle.

Iwamoto: Your bicycle?

Iijima: Yes, I have a road bike.

Iwamoto: Then you must be a very serious rider.

Iijima: I am. In August of last year I fell over and fractured my femur. I had to stay in the hospital for two weeks, but I finally got better. It is important to take things in a reasonable way, because if you rush things too much you may end up running into a wall and hurting yourself.

Iwamoto: I know exactly what you mean. It may depend on the person, but there have been people that have run into a wall and as a result not been able to do what they like anymore. So, it is important to maintain many interests….

Iijima: Right. Professor Grünberg played the guitar very well at yesterday's reception. I feel like I meet a lot of people that are interested in music.

Iwamoto: Oh, really? I see. I cannot do….

Iijima: That is everything about me. I do not like to impose myself on others, but that is my story.

Iwamoto: Thank you very much for your time.

Interviewer: Administrative Director, W. Iwamoto

At Sendai Kokusai Hotel

February 23rd, 2011

WPI-AIMR 飯島澄男連携教授
（名城大学教授、2009 年度文化勲章受章者）に聞く
(Interview with Professor Sumio Iijima－Japanese version)

カーボンナノチューブの背景

岩本：飯島先生といえばカーボンナノチューブの発見者ということで、世界的に有名でいらっしゃって、今回はAIMRのアニュアルワークショップで特別講演をしていただいた直後にインタビューに応じていただきましてありがとうございます。

飯島：ありがとうございます。

岩本：先生は、電気通信大学を卒業された後、大学院は東北大学に進まれ、今の多元物質科学研究所の母体の一つの科学計測研究所で助手になられましたね。

飯島：助手で２年少しいました。

岩本：東北大学時代のことでの思い出は何でしょう。

飯島：そうですね。私は、学部のときにはあまり勉強しないで、いろいろクラブ活動をやっていたので、実際に今の世界に入るなんていうことは想像していませんでした。大学４年になって就職するか、大学院に行くかと迷って、結局大学院に行く決心をした。私の人生にはいろいろ分岐点があるのですがその一つです。それで、たまたま科学計測研究所に入った、というか入れられた。そこでたまたま電子顕微鏡をやることになったと。自分でこれがやりたいからというので積極的に動いているということはあまりなくて、非常に消極的です。しかし、電子顕微鏡は私にピッタリ合って、ようやくやりたいことに巡り合えたというわけです。

岩本：では、学部時代は、どちらかというと学生生活をエンジョイしていたわけですか。

飯島：そうです。エンジョイしていました。

岩本：東北大学を終えられてから１９７０年にアリゾナ州立大学に行かれましたが、カーボンナノチューブの発見は９１年ですね。

飯島：そうです。ですから、私が行ったのは７０年ですから発見まで２０年あるのですね。一番初めに、「飯島さんといえばカーボンナノチューブですね」と言われたのですが、私はいつもへそ曲げて、「ちょっと待ってください」と言うことにしています。９１年が発見ですと、私の研究歴がそれまで２０年あるわけです、それについてはだれもあまり知らないので、これをどうしてくれるんだよと。ですから、突然カーボンナノチューブが現れたというのではなくて、その２０年、大学を含めると２６年、４分の１世紀の準備期間があったということが重要だと私は思っているのですけどね。それをなくして発見はなかったわけですから。みんないろいろ前人の仕事に影響されつつ、そういうのが知恵となり、あるいは経験、体験が重なって次に進んでいくという、まさにそのパターンだと思います。

岩本：具体的にはどういうことでしょう。

飯島：カーボンナノチューブというのは、ある日突然発見されました。そういうことになるわ

けですね。これは偶然の発見です。セレンディピティなんて言葉が最近使われていますけれども。それを発見したのはなぜかと、どんどん突き詰めていくと、カーボンナノチューブとは非常にナノメートルサイズの小さいものなので、それを見ることのできるたった一つの道具が電子顕微鏡なんですね。私が電子顕微鏡を始めたのは大学院のときからなので、そのトレーニングが二十何年間あったんですね。まず電子顕微鏡の技術を習得して、そしていろいろなものを調べる。その一つが、たまたまカーボンナノチューブだったのですね。

岩本：そうですね。

飯島：ですから、そういう経験が重なってきて偶然見つかったということ。私からすると、発見されるべくして見つかったということです。必然の発見というわけです。

岩本：セレンディピティというのは、スリランカの旧称セレンディップで第３王子が面白い石を見つけたらそれが宝石だったとか、そういう話から来ているそうですね。

　先生がおっしゃるように、セレンディピティというのは、何かその瞬間にこれだといって着目する能力であると同時に、それができたのも、先ほどおっしゃった二十何年の蓄積があったからなのでしょうね。

飯島：そうだと思います。

岩本：そのカーボンナノチューブ発見の背景とは何なのでしょう。

飯島：まず、どうして私の意志がそこに行ったかというそのきっかけですけれども、発見当時の我々の物性研究の背景が非常に重要です。物質材料の研究というのは、１９８０年の後半に幾つかおもしろい大イベントがあったんですね。そのひとつがフラーレン、C_{60}分子が見つかったこと。

岩本：クロトー、スモーリーの発見ですね。

飯島：それが１９８５年。そして、１９９０年に大量合成法が見つかったんですね。

岩本：はい。

飯島：それは大量に作れる方法が見つかったんですけど、それと同時に、それが超伝導になるという新しい発見がありました。その前の１９８６年には、高温超伝導酸化物の発見があったので、それもまた世界がハチの巣をつつくような大騒ぎになったんです。ですから、新しい超伝導の発見、そしてまたフラーレンの超伝導の発見と、そういうのがたくさんあったのです。その発見の少し前に、今のＪＳＴの前身である新技術開発事業団が１９８２年に始まり、その第１号のプロジェクトに私は参加しました。その超微粒子の研究プロジェクトに参加するために、私は１２年のアメリカ生活を終えて戻ってきました。それで５年間続きました。

岩本：なるほど。

飯島：その研究の場所は、今私のいる名古屋の名城大学なんです。それが終わってからＮＥＣに移ったのです。それは１９８７年です。そこでまずダイヤモンド薄膜とフラーレンをやったのです、実際は。フラーレンの成長機構を調べてやろうとして始めたのですが、いろいろなカーボン材料を手当たり次第見ている間に一つだけ、名城大の先生がフラーレンを作った残りの燃えさしみたいなものをたまたま入手して、それを電子顕微鏡で調べたらそこにカーボンナノチューブ

があったというわけです。いろいろ複雑な背景があるのですけれど、それがきっかけなんです。

岩本：結局、もちろん先生のふだんからの探求心というものもあったんでしょうけれども、一方では、フラーレンの誕生といい、高温超伝導といい世界的なそういう環境が組み合わさって出てきたということですね。

飯島：そうです。フラーレンというのはカーボンですね。それと同じようなものを私はそれまでの２０年の間に、我々が開発した高分解能電子顕微鏡でいろいろな炭素材料を見ていたんですね。このように、それまでに随分経験、知識の蓄積があったので、私の発表した研究論文の中にフラーレンと同じようなものがすでにあったのです。

岩本：それは知りませんでした。

飯島：１９８５年にフラーレンが見つかりましたけど、その５年ぐらい前に。私の撮った電子顕微鏡写真にフラーレンが写っているのですね。

岩本：すばらしいですね。

飯島：そのため、クロトーとかスモーリーは、私のところにわざわざ来たこともあるのです。８５年にスモーリー、クロトーがフラーレンの論文を出したときに、世界中の人はあまり信用しなかったんです。というのは、彼らの最初の論文は、スペキュレーションで、科学的にロジカルなデータが並んではいなかったのですね。

岩本：わかります。

飯島：具体的に言うと、質量分析の実験なのですけれども、質量分析というのは炭素原子が何個あるかという、そういう原子の数は分かるんです。つまり６０個集まったクラスターに相当するピークは、なるほどあるのですね。

岩本：はい。

飯島：その６０個はどういう形をしているか。それは全くわからないのです。何か鎖状につながっているものでもいいし、丸まっていてもいい。サッカーボール状になると言いますけれども、そこが彼らのすばらしいスペキュレーションなのですね。それで、６０個という炭素原子の数だけから、この分子はサッカーボール状の構造であるに違いないと、そういうふうに結論したのですね。だが、それはエビデンスがないので、全然説得力がないのです。それで彼らは５年間ずっとピンチだったのです。それで私の仕事が出てくるのですが、私の５年も前に撮った写真の中に、丸い構造のカーボンの写真があるのですね。それを彼らはどこからか見つけて、その写真が唯一彼らのスペキュレーションを証明するエビデンスだったのです。そんなことで当時はこの電子顕微鏡写真は非常に有名だったのですよ。だから、みんながスペキュレーションというと、ここに写真があるじゃないかと、こういうものがそうだと言えた訳です。

岩本：ある意味で、彼らはそれを求めていたのですね。

飯島：そうです。もういろいろな方法で探していたのですが。なので、彼らが有名になるずっと前から、二人ともわざわざ私がＮＥＣの筑波にいたときに来ましたからね。結構重要視されていた訳です。彼らが苦戦しているときに、「私の写真があるから、これはあなた方のモデルの証明になるから一緒に論文を書こう」といって彼らに手紙を出しましたら、「これはおまえだけで

書け」と言われました。それで、私の単独のものとして、彼らの仮説を証明する、そういう形の論文を書いたのです。

岩本：ほう。

飯島：ですけれども、それは間もなく終わるのです。というのは、１９８５年にC_{60}の発表をして、その５年後の９０年に先ほどの超伝導、大量合成があって、フラーレンの大量合成によって結晶構造解析ができるようになったのですね。それで今度はＸ線回折法で、しっかり仮説と同じようにサッカーボール構造があると証明されたのですね。それで私の以前の証明は、それで終わりだったんですね。

岩本：それは残念でした。

飯島：しかし、そこで終わらないのが面白いところです。炭素原子がきれいなサッカーボール状に並んだというのは全く珍しい構造で、しかしそれがどうしてできるかということ、その成長の機構というのは分かっていないのです。今でもまだはっきり分かっていませんけれど。

岩本：そうですか。

飯島：いろんなものができるのですけれど、カーボン原子が飛んできてどうしてサッカーボール構造と同じ集まり方をしたのかという疑問です。

岩本：そうですね。本当にきれいなサッカーボール状ですものね。

飯島：それを理解しようと思ったんですね。それで、私は孤立したサッカーボールの写真だけではなくて、多層構造というか入れ子構造の球状グラファイトボールを写真に撮っていたわけです。入れ子構造のでき方は私の技術で調べればわかるだろうと、それを調べてやろうと思ったんですね。

岩本：すばらしいですね。

飯島：それでいろいろなカーボン材料を片端から見始めた中の一つがナノチューブみたいなものだった。しかし、そういうナノチューブなど世の中にまだなかったが、そこは前にやったいろいろな経験から、何か突然細長いのが出てきたので、それに興味を持った。ですから、そこが、セレンディピティということだと思うんですね。

岩本：それこそ二十何年の蓄積がおありになったからですね。

飯島：物質構造の中で、細長い構造を持つものは割合少ないのですね。次の発見もセレンディピティと言えるのでしょうが、私が東北大のマスターのときに、そういう長い結晶の研究をしていたのですね。マスター、ドクターの論文の仕事の一つに、銀の結晶の細長いもの、細くて１ミクロンぐらいのウィスカー結晶というのですけれど、そういう細長い繊維状構造を電子顕微鏡で結晶解析をするという技術を、既にマスターのときに習得していました。いわば、細長い銀のフィラメントをナノチューブに置きかえただけですから。

岩本：銀が炭素になったということですね。

飯島：そうです。その電子線結晶構造という技術があったので、どういうふうにカーボン原子がつながっているかというのはすぐわかったのです。

岩本：それはもうマスター時代のそういうテクニックが結びついたということですね。

飯島：さらに、みんな連結しているというのが一番重要なところなのですが、細長いのはもう一つありまして、それは石綿です。石綿は、細長い、そして天然に存在する鉱物の一種ですね。その結晶構造の研究を電子顕微鏡でしていたのが、私がいた科学計測研究所の矢田助教授だったのです。私の先生は日比忠俊教授という同研究所長を長くやられていた先生ですけれども、矢田先生も後で所長になりますけれども、その矢田先生がオックスフォード大と共同研究をしていました。私はそれを横で学生として見ていたのです。先生は石綿の電子線回析像を電子顕微鏡で調べて構造解析をしていたのです。それも全く同じような、円筒で長いということでは同じなので、手法は同じです。

岩本：手法という意味では同じですね。

飯島：研究の手法は同じなので、そういうこととかその他にもいろいろなことがあって。

それで２０年後にナノチューブに突然めぐり会ったときに、すぐにぱぱっといろいろな前の知識が蘇ってきて、その細長いものに非常に興味を持って拾い上げたとうことです。セレンディピティって何か実体はそんなところなのですよ。私の場合は。

岩本：でもそれは、ローマは一日にして成らずと言いますが、まさにそのとおりですね。

ところで、カーボンナノチューブ発見のインパクトを分かりやすく説明いただけますか。

飯島：そうですね。２つほど大きなインパクトがあると私は思っています。

一つは、基礎科学ですね。物性物理へのインパクトというのは、非常に大きかったですね。なぜかというと、これもいろいろつながりがあって、我々物質研究者は、いろいろ大きな構造体を研究対象にしてきましたが、１９８０年ごろから、非常に小さくしたもの、先程お話ししたように超微粒子の研究というのが、ＪＳＴのプロジェクトで始まりました。

岩本：今でいうナノ材料ですか。

飯島：今のナノ結晶です。あのころナノ結晶という言葉がなかったので、超微粒子です。超微粒子なのですけれども、その研究を始めたんですね。なぜかというと、大きなものは単に小さくすると、金でも小さくすると物性が変わることが理論的にもいろいろ予測されるわけです。ですから、ナノチューブも小さくすると、大きなときには観測できないおもしろいことがいろいろ起こるということは、予測されたわけです。

岩本：そうですね。同じ元素からできていても、サイズが小さくなるととんでもない性質を出すというのがナノマテリアルの世界ですね。

飯島：銅線、普通は家庭に来る電気の配線ですね。それをナノメートルまでいかなくても、とても小さくすると電気の流れ方が違う。我々の言葉で言うと量子サイズ効果が発現します。それで１９８０年代に入ってから理論的にも実験的にも行われて始めていたのです。例えばいろいろシリコンの小さなデバイスをつくりますね。そういうシリコン加工技術で小さなもの、新しい構造、材料を作るという技術が発達すると、それを使っておもしろいメゾスコピック構造が作れるようになって、それで実験し始めていたわけです。それによりいろいろ新しい物理が見えてきたのです。

岩本：本当に純粋科学という意味では、量子サイズ効果の発現というのは、キーポイントなわ

けですね。

飯島：ですけれども、ナノチューブが出てきたので、まさにその小さな世界で起こる、ナノメートルの世界で起こることが、より確実に精確にわかるようになったんですね。例えばコンピューターの理論計算で物性を予測するという研究が随分ありますが、その研究対象とする構造が、シリコンだと細くしただけで、太さがどうの、端がどうのとか、細かいことは分からないから、あまり細かいことは予想できない。ところがナノチューブの場合には、すべての原子座標が全部分かってしまっているので、コンピューターで完全に予測ができるようになってきたのです。なので、理論計算を中心にした計算科学の研究者がこの材料に飛びついていろいろ自分の理論をテストできるというので、ナノチューブの出現でみなさん潤ったわけです。

岩本：シミュレーションとか、そういうことができるわけですね。

飯島：それで我々の実験と突き合わせる。そういう理論と実験のキャッチボールがもう随分進んで、全体的には先ほど言った量子効果を観測するといった物性研究がぐっと進んだのです。それが、ピュアサイエンス、基礎科学への貢献です。

岩本：ともすると我々は実用の方にばかり目が行きがちですけど、そういった本当にサイエンスとしての発展に非常な貢献がされているわけですね。

飯島：それでその結果として、例えば細くすると、これは金属になったり、半導体になったりするはずだと理論家が予測したのです。シリコンは半導体ですが、カーボンの材料で半導体はないですね。けれども、細くしてチューブ状にしたことによって半導体になるということが予測された。ですからもうトランジスタができる。それでは細い“単層”カーボンナノチューブを作れというので、それを作り始めた。これには２年かかりました。この単層をつかって実際にトランジスタをアメリカの研究者が作った。なるほど電気特性を測るとすばらしいトランジスタになる。

岩本：すばらしい。

飯島：シリコンを凌駕するトランジスタができると。それで応用研究が進みました。ですから、トランジスタができるから原理的にはコンピューターもできるだろうと、そういう応用があるだろうということでいろいろな応用の研究も同時に始まったんですね。これが２つめのインパクトです。

岩本：そういうことですね。

飯島：応用研究は発見から数年後れて始まりましたが、ピュアサイエンスと応用とが、この材料が出たことによって随分といろいろ進んでいるはずです。

岩本：電子顕微鏡が先生にとって基本的なツールになるわけですけれども、別にオーダーメイドをそのまま使うわけではなくて、そこに先生がやはりいろいろ工夫される訳ですね。

飯島：そうです。高分解能電子顕微鏡にも長い歴史がありまして、１９３２年にドイツのシーメンスのエンジニアであるルスカ先生が今の電子顕微鏡を発明し、ノーベル賞をもらいましたけれどね。それで、私がこの世界に入ったのは、東北大に来た１９６３年ですから、発明から３０年もたっているのですけれども、その間どこまで細かいものが見えるかという科学者のロマンがあったわけですね。なぜかというと、光学顕微鏡ではもう見える限界がありましたから、それを

超えるのには、電子を使った顕微鏡以外になかったのですね。それで、ルスカが電子顕微鏡を発明したけれども、分解能は、初めは光学顕微鏡より悪かったのです。それから、毎年々々改良が進んで、１９７０年ごろに、ひょっとすると原子が見えるかもしれないというところまで電子顕微鏡のテクノロジーが改良してきたのです。

岩本：そういう時代ですか。

飯島：その技術開発はドイツとかヨーロッパが中心でした。日本の電子顕微鏡のメーカーも頑張っていたんですけれど性能が全然だめだったんです。それで私がこの世界に飛び込んだときに、市販の顕微鏡を使いましたけれど、それだけではなかなか性能が出ない。

岩本：そうでしょうね。

飯島：それで、私はいろいろ自分なりの工夫をして、高分解能の写真が撮れるようにいろいろやったのですよ。それがうまいこといったのですね。私は東北大で技術を習得して、アメリカに乗り込んで、日本の装置を買って、それで高分解能の研究を始めたんですね。

岩本：なるほど。

飯島：当時はシーメンスが世界を席巻していたのですけれども、私は日本の顕微鏡を使ってシーメンスよりはるかにいい像を出し始めたんですね。具体的には分解能がどんどん上がってきたので原子が見えたのですね。そういう装置の技術開発が進んできた、私が飛び込んだ時期がちょうど時間的にぴったり合ったんです。これもやっぱり偶然というか。それもセレンディピティなのですよ。

岩本：そうですね。

飯島：だから研究は、タイミングが非常に重要ですね。早くても遅くてもそういうチャンスにはめぐり合えないということです。

岩本：でも、そういう偶然だけではなくて、ここでも先生がずっとこうやって蓄積されてきたそういうノウハウがあったからそこまでいったんですね。

飯島：そうですね。

岩本：すばらしいです。そうすると、本当にカーボンナノチューブというのは、日本から発信された、まさに日本発の科学ということになりますね。

飯島：そうですね。そういう意味では非常にラッキーなのですけれども、でもこれも結構いろいろありまして、単独に一つだけぱっと突然現れたのではなくて、われわれが発表すると、他にもおれがこれもうやっていたよという、そういうのが続々出てくるのですよ。一番さかのぼると１９５２年、当時のソ連の研究者がカーボンナノチューブもどきの論文をロシア語で発表しているんです。

岩本：１９５２年。

飯島：なぜそれが分かったかというと、アメリカの炭素学会が、だれがカーボンナノチューブを見つけたかという、特集を組んで、しっかりしたドキュメントを作りましたが、そこでそう書かれているのです。しかし、何が重要かというと、我々はサイエンティストなので、論文に書くときに、先ほどの$Ｃ_{６０}$ではないけれども、論理的にこういう構造でこういう新しいものができ

たと。それを論理的にプレゼンテーションしなくてはなりませんね。

岩本：論理的でなくてはいけないし、エビデンスも必要という訳ですね。

飯島：なので、そうするとカーボンナノチューブの電子顕微鏡の写真を１枚撮って、これがナノチューブですと、結果を知っていればそう言えるのですが、事前にこれがナノチューブですと言うためには、写真１枚では不十分で、これはそうかもしれないけれども違うかもしれないというあいまいさがありますね。サイエンスには、そういうあいまいさがあってはいけないのです。

岩本：おっしゃるとおりです。

飯島：それをサポートするエビデンスを示さなくてはいけない。ナノチューブの場合にも１枚の写真だけではなくて、電子回折像をつけて、それをよく調べると、電子顕微鏡的には細長くなるけれども、これは実際にグラファイトの構造であって、太さがどうで、炭素原子がどう並んでいるかといったことまでもっと詳しく説明できるのです。ですから、そういうデータをそろえてカーボンナノチューブと言っているので、それを言ったのは私が初めてなのです。それ以前のものは、そういうことはあまり言っていなくて、写真１枚で、このデータを見れば今ではそうかもしれないけれども、当時は何もないので、そこまで言い切ってないのですね。

岩本：どうしてもスペキュレーションの域を脱しないとか、あるいは証拠が不十分だったりとか、そういうことになるわけですね。

飯島：ですから、何か新しいものを見つけたときには、あいまいなところを残さないようにしっかりデータをとって、完璧にして発表しろと若い人に言っています。そうでないと、不備なところがある。いい仕事をしてもそれを主張できない場合がある。

岩本：そうですね。結局、発見は発見で大事なのかもしれないけれども、それをだれからも論破されないようにしないことには、結局真理の発見ということにはならないわけですね。ちょうど今若い人のお話が出ましたので、一般論になって恐縮ですが、今の若い人は、外国に行かないとか言われるのですけれど、先生は若手研究者についてどうお考えですか。

飯島：これは一般論ではないと思います。科学者になる人は、いつの世にも多数派ではないけれどもいるはずですよね。なので、そういう興味を持つような環境を具体的に整えてあげるということだと思います。ですから、ただ海外に行けばいいというものではなくて、そういう興味を持つような教育が必要なのかなと思います。

岩本：そうですね。おっしゃるとおりです。ただ行ってこいだけでは意味がないのでしょうね。何かインタレストがあって、こういうことがやりたいということが重要でしょう。

飯島：そうですね、割と一つのことに集中できるような、そういうふうに仕向けるというか、それがいいのではないかなと思います。

岩本：私どもAIMRでは、研究者に、自分の研究も一生懸命やり、かつ異分野の研究者と共同して、融合研究をやってほしいと奨励しているのですけれど、そういった異分野との交流というのもやはり重要ですよね。

飯島：そうですね。分野にもよるかもしれませんが、手前味噌ですけれども私の場合には、東北大で電子顕微鏡の技術を習得して、ある材料でドクターを取りました。新しい技術ができると

いろいろ応用できます。私は鉱物学も随分やりました。

岩本：ええ。そうですか。

飯島：高分解能電子顕微鏡技術は従来の鉱物屋さんは持ってないわけです。だから、私は随分鉱物屋さんと論文を書きました。当時、電子顕微鏡で細かいところを見て鉱物を評価するという分野は全くなかったのですね。この技術ができたために、そちらのほうも随分発達したんですよ。また、私はもともと物理出なのですけれども、今やっていることはミネラロジーであり、ケミストリーであり、最近はバイオロジーも一生懸命やっています。

岩本：そうでございますか。

飯島：薬とか、カーボン材料を使ったバイオテクノロジーの応用というのを随分やっています。そうすると、自分が何だか分からなくなってしまいますが。融合領域というかインターディシプリナリーの研究というのが世界中で今進んでいますね。

岩本：そうですね。

飯島：、そういう意味では、おっしゃるとおりに他分野とのかかわりというのは重要です。多分アメリカの大学では、一人の先生が物理一つだけというのは本当に少ないです。物理であり、化学であり、みんなかけもちでまたがっています。そういうのが普通になってきました。ですから、あまり一つのところにといて、私は物理屋だとそういうつもりでいると……、そういう人もいてもいいのですけれど。

岩本：それはそれであるのかもしれないですけれど、やはりいろいろなことに興味を持ってですね。それはいいお話を伺いました。先生の場合、先ほど冒頭でもおっしゃいましたけれど、いろいろなところで転機があった　と。確かに略歴を拝見しても、アリゾナに行かれ、それから科学技術振興事業団、それからＮＥＣと。また今では名城大学とＡＩＳＴに勤務されています。

飯島：小学校、中学校、高等学校、大学学部、大学院、ポスドク、とにかくすべて違います。、更に国立大学、私立大学、米国と英国の大学、国の研究プロジェクト、民間企業にも行っているんです。ですから、よく言うと、我々科学者は、出会いを求めて、チャンスを求めてみずから動く。同じところにじっとしてチャンスを待つのではなくて私はむしろ自分で動いて、背水の陣で真剣勝負をしてくるという、そういうのが好きというわけではないけど、結果としてそうなっています。

岩本：日本の科学政策でも、ようやくここ２０年くらい流動性を強調するようになりましたけど、やはりいろいろなところで経験をする、いろいろな人に出会うというのは、重要でしょうね。

飯島：科学者としては理想的だと思うのです。しかし、これは私だけではなくて、日本の社会環境が関わってくるので、要するに、今アメリカでもあまり人が動かなくなっていますが、動くことによってモチベーションを持って、リセットして、新たに挑戦するという、そういう開拓精神がありました。日本の場合は、動くと損をする世界。

岩本：おっしゃるとおりです。

飯島：なので、じっとしてずっと最後までいくのが損せず一番得をするんですよ。

岩本：そうですね。ともすると採用試験などでこの子は随分いろいろなところを転々としてい

るなというと、マイナスに評価するということもかつては聞きました。そうではなく、むしろいろいろなところでいろいろな経験をしているということを社会全体が許容するようなものがあればと思いますね。

飯島：そうですね。そういう意味で私は、自分が動くのはいいけど家族も動きますから。外国に長いこと行って帰国子女で帰ってくると、普通の学校へ行くといじめに遭いましたからね。排除ですよね。そういうマイナスな面が日本の社会にはまだ残っているので、そこを考えると、じっとしていてもいいのかなと思うこともあります。

岩本：私もフランスに３回、通算１３年いたことになるので、よく分かります。科学者としていろいろな出会いが必要ですが、その一方で、ご家族を初め、また社会制度とかそういう問題も絡んできますね。

飯島：移ると、退職金はリセットしてしまう。例えば退職金みたいな日本の制度はなかなか当てはまらないのですけれど。今はだんだん変わってきたので、きっとあまり強い阻害要因にはならないかもしれないですね。

岩本：最後に、先生のご趣味を教えてください。

飯島：趣味は、私はとにかく高等学校から山岳部なんですよ。山登りをやっていて、それで全然勉強する暇がなかったのです。大学の学部の１年のときは、通算１００日どこかの山に行っていました。高校では山岳部を作りました。大学に入ってからは山岳部とオーケストラ（フルート）。フルートは大学から始めたのですが。やりたいことがいっぱいあるんです。

岩本：文武両道ではないけれども、そうですか。登山とフルート。

飯島：そうなんです。人生１回だとすると、やはりいろんなことをやらなくてはいけないと思っているのです。ですから、２０代の若いときには、岩登りもしなくてはいけないし。年がいったらそんなことはできないので、その年、年に、そうしたいろいろやることがあると思っています。

岩本：フルートは今でも演奏されますか。

飯島：やっていますよ。時間がないので少しだけ。今は自転車ですね。

岩本：自転車?

飯島：はい。ロードバイクの。

岩本：ではかなり本格的ですね。

飯島：本格的です。それで、去年の８月にひっくり返って、大腿骨を骨折しました。２週間病院にいて、ようやく今治ったところです。良い加減にやるのがいいのですよ。あまり詰めて、壁にぶつかると困ってしまうので。

岩本：ええ、その意味はわかります。どうしても、これも人によるんでしょうけれども、壁にぶつかってそこでだめになっていくという人たちもいますけれども、やはりいろいろなことに関心を持って……

飯島：そうですね。昨日のレセプションでグルンベルク先生、ギターをよく演奏されましたよね。結構音楽の趣味の人とはいろいろ出会いますね。

岩本：そうですか。なるほど。では、私はちょっと……

飯島：いやいや、それは私はこうだけれども、それは皆さん違うので、私は自分のことは全然人に押しつけませんけれども、私はこうやってきましたということです。

岩本：先生、本日は貴重なお話をいただきまして、ありがとうございました。

２０１１年2月２３日

仙台国際ホテルにて

岩本　渉

Interview with Professor Alexander Shluger, Principal Investigator, WPI-AIMR

"Deep understanding helps to design things"

Administrative Director Iwamoto (I): On reading your CV, I noticed that until you were student at university, you were in Latvia since your birth.
Professor Alexander Shluger (S): Yes.
I: At that time it was before the independence.
S: Of course, very much before.
I: That's right. The independence of Latvia was in 1991, wasn't it?
S: In August 1991.
I: In Latvia there are many excellent personalities, artists, scientists and in the area of political science near to my specialization, I remember Isaiah Berlin was also your compatriot, and needless to say a legendary film director, Eisenstein.
S: Eisenstein was in fact born in Riga, capital of Latvia. At that time this was a part of Russia.
I: Exactly.
S: Then, after the revolution, Latvia, for about twenty years was independent, between 1919 and 1939. Then, in 1940 it was again occupied on the basis of the Molotov-Ribbentrop treaty, which divided the Europe and became a part of the Soviet Union as a republic. After the War it stayed there for about fifty years, before becoming independent and then joining the European Union.
I: When you were a student in the Latvia State University, science education and research were influenced by the Soviet Union's style?
S: Well, I think Riga was a very important scientific center for many years both in Russia and in the Soviet Union, because it is one of the most western cities. For many centuries it was basically a German city and then a Swedish city. And then Peter the Great conquered Riga in the eighteenth century and it became a part of Russia. And at the same time, Saint Petersburg was founded on the Baltic Sea. It is not very far. Latvia is on the Baltic Sea, then to the north there is Estonia, Tallinn and then there is Saint Petersburg.
I: It's sometimes difficult for Japanese to understand the European geography and history.
S: Latvia and Riga used to be a huge industrial center. Some of the first airplanes, first cars, and many other industrial developments happened in Riga at the beginning of the 20th century. It used to have the biggest factories. There are still old Zeppelin hangars in Riga

where these big aircrafts were built and serviced. Riga became a very big scientific center also during the Soviet period.

The foundation of a big scientific center at Riga was only possible, because it was part of this huge state, and that it was funded by the Soviet government. When Latvia became independent, its scientific research shrank very significantly. Because it should be proportionate, somehow, to the budget. This is a country with a population of about two and half million.

I: Two and half million? Almost the double of the population of the city of Sendai…

S: Maybe. So we cannot have a huge budget. But in the Soviet times, it was the part of the huge country; therefore it was possible to have a scientific center in Riga with a large number of academic, scientific and research institutions.

I: Very interesting. That means Riga has a long tradition of innovation and industrialization.

S: We also had one of the great chemists, who also got the Nobel Prize in 1919.

I: What is his name?

S: Wilhelm Ostwald. He is one of the famous chemists many people know. He used to work at Riga University of Technology and at Leipzig University.

I: By the way, was your interest in science born at your childhood?

S: At the time when I was going to school, many important things were happening. For example, Sputnik was launched in 1957, and the first cosmonaut was in 1961. And also a lot of nuclear developments were going on, such as nuclear power stations and many discoveries in particle physics. So science was very romantic. And also there were a lot of very important scientists at that time, for example, Landau, Kapitza, Ginsburg and others. So this was a very exciting and interesting time.

I: I see.

S: I went to some special physics and mathematics school. Science certainly had romantic appeal at that time.

I: Indeed.

S: So many people wanted to become a scientist. I mean the same thing happened in Japan and in many other countries at that time, around the beginning of ’70s.

I: In Japan, as you know, the laureates of the Nobel Prize for Physics, like Yukawa or Tomonaga, were very famous when I was a child. So many talented pupils were interested in learning science and technology.

S: That’s right.

I: So you were interested at young age?

S: I graduated from a school which was specialized in physics and mathematics. So we had a very good physics teacher. He infused me with doing physics. I was very interested in that

and decided that this is what I would like to go for my qualification at Latvia State University. So I wanted to study physics.
I: So you got a bachelor at Latvia State University, and then you went to Moscow.
S: No, I did not, actually. I lived in Riga all the time. But the system in the Soviet Union was such that you could not get a PhD degree from the same university, usually. So this is a very different system from the British or American systems. You needed to go somewhere and have a public defense. This was a quite complicated process. One needed to present a thesis to some special committee and go to several seminars. Then the thesis was published and the abstract of the thesis distributed for a month to general academic community in the country, and then there was a public defense. So all this was handled by a number of approved committees. I just got my degrees from a particular committee, which happened to be in Moscow. The reason for that was that I graduated as a theoretical physicist, but I used to work in the Chemistry Department for many years. I wanted to have a degree, which would combine physics and chemistry.
I: So, you have a double background of physics and chemistry.
S: In the Soviet system, you do not get just a PhD, you get a PhD in something. So it can be chemical physics or physical chemistry or inorganic chemistry or physics and mathematics, things like that.
I: I see.
S: I mean it is quite narrow. I was awarded a PhD degree in chemical physics.
I: That is right.
S: Therefore I needed to go to some special place, and this was in Moscow, at that time, the only place where I could obtain this degree by defending my thesis.
I: Was your PhD focused on rather chemical aspects?
S: I used to work in a Chemistry Department in a group, which was mainly dealing with radiation chemistry. This was a very important topic at that time. How radiation affects water and other materials. My group was mainly composed of experimentalists who were studying effects of radiation on different solid materials. And they wanted that somebody gave them theoretical ideas and models of how things work. So I was developing theories of how radiation interacts with different types of materials. Incidentally, this was a very common topic in Japan. There were many famous scientists in Japan. Professor Toyozawa was one of them, who worked in this field at the time. Then later I collaborated with a very famous person in this field, Professor Noriaki Itoh, who used to work in Nagoya. Many people in that period were interested in nuclear energy or nuclear power stations in the United Kingdom, America, Japan and Russia. They were studying the effects of radiation on materials, to improve the safety of nuclear power stations.

I: Yes.
S: There are still very famous people working in this area in Latvia and Estonia, who made significant contributions to our understanding how radiation interacts with different materials.
I: Is your interest rather how to explain this mechanism of radiation?
S: My PhD thesis was on how to explain the effect of radiation on some particular materials using computational methods. That is called quantum chemistry.
I: And then you moved to UCL in 1995.
S: No, before that, in 1988, I got my second degree, Doctor of Science, which is the highest degree in the Soviet Union, and it is like habilitation in Germany. After that I could start traveling, so I went to Japan.
I: So was this your first visit to Japan?
S: Yes. First, I myself invited Professor Itoh, whom I mentioned above, to Riga.
I: Did he belong to the University of Nagoya?
S: Yes. Then he invited me to come to Nagoya. I first came to Nagoya in 1989 and spent two or three months with him there. He is retired now but still active. I had a very good collaboration with his group.
I: Excellent.
S: After that, I have been invited to go to the UK, also by the colleagues who were interested in radiation damage. One of them is Professor Marshall Stoneham. He is a very famous person in the field of radiation defects. He used to work at the Harwell Laboratory, which was a radiation center in the United Kingdom. Another one is Professor Richard Catlow, another theoretician, who worked at the Royal Institution. They invited me to come to the UK for a Royal Society fellowship. This was in 1991. I started to work with Richard Catlow at the Royal Institution of Great Britain. This is a very famous institution, where many famous scientists, such as Faraday and Bragg, used to work. I worked there for five years.

At the beginning of my work there, I have received a prestigious fellowship from the Canon Foundation in Europe. In celebrating its fiftieth anniversary, Canon has established a Foundation to promote exchange of researchers between Europe and Japan. It is still a very active Foundation and they give fellowships every year. I was one of the first people who received a fellowship from them. The condition for that fellowship was that you are supposed to spend half a year in Japan and half a year in Europe, and basically carry out some joint research between Japanese and European institutions.
I: It was a very excellent opportunity, wasn’t it?

S: Yes. Since I had this very good relation with Nagoya University, they awarded me this fellowship. I spent several months in Nagoya, and then I was coming to Nagoya to collaborate with Professor Itoh for many years. But I used to work at the Royal Institution until 1995. And in 1995, I have been appointed at the University College London.

I: Was it you who chose UCL?

S: No. Marshall Stoneham has been appointed as a professor at UCL to organize a theory group. And he invited me to join him at UCL as a Senior Research Fellow.

I: You began your work in a chemical field. Then, at the time – 1990-1995, you were a theoretician. In general, what decides a scientist to be an experimentalist or to be a theoretician?

S: I became a theoretician in about 1975. But I started actually as an experimentalist. During my studies at university, I found a radiation chemistry group and started to do some research work with them. Initially they suggested that I do some experimental work. Then they wanted me to try to do some theory. And there were some other theoreticians around, so they helped me to do that. So this is how it happened with a theoretical research. But I could as well do some experimental research.

I: Nevertheless, even as a theoretician, your research is also related to a very fine microscope like AFM. And it is needless to say that the computer is very essential for your work.

S: AFM is an experimental machine, so I do not use it. But I can model it theoretically. I can produce a model of what is going on in an AFM using a computer.

I: I understand.

S: When I started to do theoretical modeling around 1975, computers were very slow. But now, with the development of nanotechnology, computers are getting very powerful.

I: Yes, and very quick.

S: So we can model the full behavior of very complicated processes computationally, with a very good accuracy – Tsukada's group is a very good example of how it is done.

I: OK. Now I'll move to topics of your current research. Are you still interested in the mechanisms of defect processes?

S: Yes.

I: What does it mean more concretely?

S: Some simple theories, which you can find in many textbooks, are always based on idealized models. A simplified model of a solid is an perfect periodic lattice of atoms. This is a very useful model, but it explains only part of the picture. Now, if you take some of the atoms out, or put some impurities in, this changes the properties of a material, and can make it more useful for applications. (Looking around the room,) In this camera there is a processor which is made from silicon. The silicon would not work if it would not be doped with some impurities, which are defects with respect to the ideal lattice. So it is always with respect to perfect or ideal that we identify a defect. Actually when material is defective, it may be an ideal material for performing some function. All materials, which are used in real life for making, anything are often specifically made defective in order to make them to acquire some function or perform better: lasers, transistors, catalysts.

I: I see. When you say “defect”, it doesn’t have bad meaning at all.

S: No. It may have a very positive meaning.

I: Positive meaning, I understand.

S: Of course initially it started from a kind of negative meaning - damage. So when you talk about radiation, it is producing defects in materials - it knocks out some atoms, etc. When people think about a nuclear power station, they want the materials of the walls of the station and the reactor to perform their function. If they become defective by radiation, this can be bad. But radiation and many other processes can also be used to modify materials structure in order to make them to perform more useful functions.

I: It changes properties of this material itself, naturally.

S: Yes. In particular, materials used for solid-state lasers always include some impurities, which perform some laser function. Or, if you look at this fluorescent lamp, it also contains some material, which contains defects, which in turn allow this lamp to work.

I: It’s very interesting.

S: Science about how to make defects to perform some positive functions is a very important science. Kawasaki sensei and Ikuhara sensei actually study these functions experimentally using different techniques.

I: That’s right.

S: But if you look at what they do, in many cases they actually study defects inside their materials.

I: Very interesting.

S: This area has been around for a long time. But accuracy with which we can make predictions about properties of materials with some particular defects or impurities in them has been increasing. And theory plays a very important role in achieving that by calculating these properties and building up models. Experiment itself cannot produce an image how a defect looks like because individual defects often have atomic dimensions.

I: Yes. You will make a model…

S: Yes. We need to make a model, which explains or predicts experimental data. Producing such models may take a very long time.

I: Of course. For example, in WPI- AIMR there are no so many theoreticians while Tsukada sensei is here, and Tokuyama sensei is in BMG. Do you think that we should reinforce the theoretical groups, in AIMR?

S: In principle, any experimental research can benefits from collaboration with theoreticians. But this should be done in a kind of targeted manner.

I: Perhaps we should proceed, as you said, in a targeted manner, not only by increasing the number of theoretician.

S: Of course not only the number of theoreticians is important, but one needs to do it in a kind of proportionate way targeting some specific areas, which require or can benefit from theoretical research. It is not very easy to start new collaboration between theory and experiment, because it requires putting right questions, which both theory and experiment could address. Experimentation is initially very empirical.

I: Of course.

S: So people are just trying to uncover new properties and discover new things. Then it requires some understanding for further improvement. This is one side of this process. At that point, theoreticians are very important to provide such an understanding

I: That’s right.

S: But on the other hand, theoreticians also predict some new properties and phenomena, which can then be discovered or proved by experimentalists. In many cases they can play a leading role in facilitating discoveries.

I: You are right.

S: However, culture of collaboration between theory and experiment takes some time to develop. For example, in the group of Ikuhara sensei, there is a very good culture of collaboration between theory and experiment, because most of the experimentalists actually are also doing theoretical research. So there is no gap between them. But some other experimental groups, working in more empirical and technological areas may feel no need for theoretical research. So collaborating with them may be very difficult.

I: But they may need it.

S: I mean that deeper understanding helps to design things. So when you want to move from empirical research to designing your experiment and achieving deeper understanding, you certainly can benefit from collaboration with theory. But this collaboration may be initially more about discussions, more about new ideas, which can be checked experimentally, actually helping an experimental group to move forward.

I: You are right.

S: In London, where I am working, this culture is quite well developed. There are seminars, there are specific discussions, where theoreticians and experimentalists can interact and to help each other in finding new directions in research.
I: I agree with you. When I was working in the Japanese Ministry of Education, Science and Culture, I was responsible for promotion of high energy physics. In Japan, two great theoreticians, Kobayashi and Masukawa predicted the existence of more than six quarks which would explain the CP Violation, but we needed experimentation. So we converted the existing accelerator called TRISTAN into B Factory and we succeeded through experimentation to prove their theory. So this kind of interaction between prediction and experimentation and then, once again, perhaps the next formalization or modeling.
S: Yes, exactly.
I: This is very important. And as you said, at UCL, there is a kind of this culture of discussions.
S: This culture usually takes some time to develop because there should be some mutual interest and incubation period for theory and experiment to achieve mutual understanding. Actually Tsukada sensei was one of the pioneers of this approach in Japan.
I: That's right.
S: He has initiated many collaborations between theory and experiment in material science. He used to work with many experimental groups. I always admire his approach to these things because I have known him for about twenty years. He was one of the first in Japan to actually achieve that.
I: As you know, AIMR itself is making an effort to organize "a joint seminar" or "tea time." Do you think AIMR should encourage these efforts?
S: Of course fusion cannot be achieved very easily, just over night. In my case, I have four big projects going on in Japan. I am collaborating with AIMR, but also I have a very big collaboration with the Osaka University, the Kanazawa University, and the Tokyo Institute of Technology, and all of them are with experimental groups. They took years to develop.
I: Yes, right.
S: This collaboration is like a marriage - people should be interested in working together. So many things should come together for developing a kind of fruitful fusion between different groups. It cannot be arranged just out of necessity or by persuasion.
I: Yes, it's not like top down.
S: People should find some common ground. When I visit AIMR, one of the main things I am doing is talking to many people, trying to find this common ground and see what can be done between theory and experiment, how we can achieve our goals to do better science. This is a main reason why I need to be here - to find these collaborations. So far we have

been quite successful in finding these different links. Developing them further and going from starting collaboration, to papers and then to very high profile publications may take a long time.

I: Very good. Really, as you said, fusion is like a marriage. We must find it. If there is a discovery of charming points of each other, there will be collaboration or fusion.

S: You cannot marry somebody just after meeting for one day. So this requires meeting many times, talking to people, learning what they are doing, finding out some particular problems. Scientists can help each other to achieve some synergy. This applies, of course, also to starting collaborations between experimentalists and between theorists.

I: Really like a marriage.

S: And if you have found a joint problem, this requires a big effort actually to perform the work and to perform it to very a high quality. In particular, we have now very nice collaboration with the group of Dr. Louzguine on bulk metallic glasses. But before I came to Tohoku, I knew nothing about bulk metallic glasses; I didn't know they existed, actually. But when I learned about their research, and talked many times with Louzguine sensei and Chen sensei and others, I started to understand that there are very interesting problems. And so we started to do some research together. Now we have already two papers published. And this is a very fruitful direction. The same with the group Adschiri sensei.

I: I see.

S: I heard his talk and read his interview, and then I realized that he has very interesting ideas. So we met several times, discussed, and I am meeting him tomorrow again. We are talking each time I am visiting AIMR and our collaboration is rapidly developing. On the other hand, I also send my colleagues here to facilitate these collaborations.

I: You are right. Now, in our institute, there are two assistant professors, Dr. Thomas Trevethan and Dr. Keith McKenna.

S: Yes.

I: Your lab is one of the most active foreign PI's lab, I think. What do you expect your colleagues like Dr. Trevethan and Dr. McKenna to learn from Japanese university or Japanese context?

S: Science is very international, as you know better than me. Therefore there is no kind of specific Japanese science. This AIMR provides a very good opportunity for these young guys to grow and become independent researchers and find their collaborations. So my role is to encourage them to talk to many people here, to find some interesting ideas, and develop these ideas together with the colleagues here. Some of these colleagues have absolutely fantastic capabilities. For example, Dr. Iwaya used to work at UCL in London.

Then he came here and developed a unique Scanning Tunneling Microscope. And we want to collaborate with him because he has this unique machine to develop new science. And I think that this synergy between theory and high quality experiment and independence are the main things these young researchers can achieve at AIMR. Doing good science is the main goal.

I: You mentioned a very important point, the importance of independence of young researchers. Of course, traditionally in the Japanese university system, from professor to assistant, post-doc, there is a kind of hierarchy. There was some kind of very rigid system. Young researchers, normally, they had no so much independence in Japan. But here we try to encourage the young researchers to be independent.

S: The British system is very different. AIMR is also an interesting place where different cultures of scientific research come together, which may cause some misunderstanding or may cause some kind of anxiety on the part of foreign researchers because they do not expect certain things to happen.

In Britain, the system is rather horizontal. These two young people, Tom Trevethan and Keith McKenna, are very excellent researchers, actually some of the best we had at UCL, with a very good track record of publications, etc. They, in Britain, would be expected to be fully independent. So they would be expected to have their own funding, to build their own group, like Dr. Peter Sushko, who used to work at AIMR and is now back at UCL. Incidentally, he has arrived yesterday to visit AIMR again and he is giving a talk at a seminar tomorrow. He actually was one of the first associate professors, who started here at AIMR three years ago.

I: You are right.

S: Then, as a result of his excellent research, he has been awarded a very prestigious fellowship of the Royal Society in Britain and became a staff member at UCL. Now he has his own group of four researchers and students working with him. This is the way how the British system works. Basically if you are appointed to an Assistant Professor position, you will have the same rights and duties as a big professor. There are no professors working under other professors - all professors are equal.

I: Great.

S: You develop your independent carrier. So this is why, I think, for my colleagues Keith McKenna and Tom Trevethan, this is an excellent opportunity because here they are in a free fly, and they can talk to everybody and develop their own independent research, find some interesting ideas, and then develop them further with Japanese colleagues in their future life.

I hope that they can work here and make a good contribution to AIMR. But eventually they will find some permanent job somewhere and will carry on collaborating with AIMR, like Peter Susko. Peter is now a Lecturer in Britain, but he comes to AIMR, because he collaborates with Kawasaki's group and also Hitosugi's group. So this is a good place for him to come.

I: I am very impressed to hear that. I think AIMR is not an institution that only receives foreign researchers and where they stay quasi-eternally here. But rather we expect that these foreign young researchers grow up in their stay in Sendai and they will get another new job in foreign countries or their own countries, and continue to work with us.

S: But I think this should happen naturally, not by saying: you can be here for only two years and then you need to go. I think this should be done on the basis of mutual benefit, because this requires quite a long time for a young researcher, who starts from zero, to achieve some results. So sometimes two years may not be even enough. Researchers should be given time to develop their ideas, and then of course they will go, because at the end of the day, they need to get a permanent job.

I: Surely.

S: This will happen naturally anyway, but developing strong links and ties with the experimental and theoretical groups here at AIMR may take two, three or four years. Then it will pay back when they will return back to Europe, China or America. They will continue this collaboration. Peter Sushko is an extremely good example of that.

I: You are right. By the way, do you enjoy the life in Sendai?

S: Yes. I like to come here. We have excellent facilities and I have lots of friends. Atmosphere in Tsukada's group is very good. I enjoy collaborating with colleagues here. And I usually have a very fruitful time when I come here because I can do a lot of things.

I: Generally speaking, the city of Sendai or the department of Miyagi makes an effort to make familiar foreigners to the life here. Do you think it is sufficient? Or even AIMR's support for foreign researchers, it goes well? What do you think?

S: When I come here, I usually work. I receive a lot of hospitality and help from Tsukada sensei and his group as well as from Sakurai sensei. The staff of the AIMR office have been very kind at helping us at the beginning of our work in AIMR, especially with furnishing the flat and with the office supplies. I know that my colleagues from UCL, who visited AIMR in the last two years, received a lot of support from the AIMR office in their daily activities. I have already spent in Japan altogether more than three years of my life, so I know some things about Japan quite a bit. I can find my own way if I want to go somewhere. I usually do not need great help. I must say that I do very much enjoy hospitality at AIMR and the secretaries and the administration staff is always extremely kind and helpful.

I: Thank you very much.

S: Otherwise I would not be coming here so often. I do enjoy working and being here.

I: What is your hobby? You work very hard, I know, but for the hobby.

S: I like reading and hiking. I usually go with my wife, one or two times per year to some places where we can hike. Also, here, I enjoy hiking in the mountains and hills. This is one of the things which cheer me up.

I: I see. There are a lot of places you can enjoy in Sendai.

S: Yes. I usually walk a lot around here and enjoy this very green city. It is very nice. So every day I usually spend a couple of hours walking around, because the weather is now quite nice.

I: That’s right.

S: Concerning the daily life of foreign researchers at WPI-AIMR, it would be helpful to have a different system of a guest house, especially for AIMR.

I: What is a problem?

S: The guest house here can accommodate guests only for five days. So if I come for two weeks, or three weeks, I cannot stay in this guest house for the whole period. We also have a flat, which has been generously given to us by AIMR. It is a good flat, very spacious etc., but it is not very comfortable during winter when it is cold. Because we are not living here permanently, that flat does not have permanent heating or air conditioning. We have only small electric heaters, so it is not very comfortable to stay in the flat when there is snow outside, although my young colleagues, Tom and Keith, usually stay even during winter.

It would be useful if there would be some different system of a guest house. I used to work at Nagoya University for many years. They had an excellent guest house for foreign visitors, which had small flats with a kitchen etc., where people could stay for long time. It was not very expensive and was very useful. So basically you could come there and have comfortable stay anytime of the year. In Tohoku this is particularly important because winters can be quite severe.

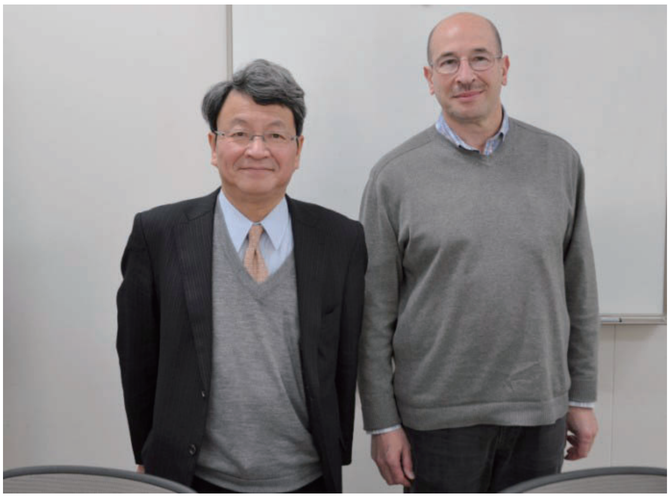
I: I see.

S: AIMR is an international center, where many people are supposed to come. If you come for a short time, you can stay in a hotel. But if you come for a long time, like several weeks or months, you need to have some accommodation which could be either a rented flat or a guest house or something else, which would allow you to live comfortably.

I: We are now constructing a new international residence at Katahira campus where a certain number of rooms will be reserved for AIMR researchers. With this, I think I can solve this problem.

S: That will be very helpful because I send several of my researchers here for a long time. Two of my young researchers have spent one month each or more here in AIMR only this year.

I: This is a very precious lesson for us. I really appreciate your taking time for this interview. Thank you very much.



Interviewer: Administrative Director, W. Iwamoto

At WPI-AIMR Annex Building

December 9th, 2010

Interview with Professor Thomas Gessner, Principal Investigator, WPI-AIMR

"From MEMS to Smart Systems Integration"

Administrative Director Iwamoto (I): Thank you, Professor Gessner, for accepting this interview. Of course, you are PI of WPI-AIMR since its creation three-and-a-half years ago. What is the purpose of your visit this time?

Professor Thomas Gessner (G): The purpose of my visit this time is that we organize the Fraunhofer Symposium here at Sendai for the sixth time. I have to give a lecture during this Fraunhofer Symposium and furthermore, there is a micro-integration workshop organized by Professor Esashi and the Japanese community. I will give a talk, too. And then, of course, I take this opportunity to discuss with our colleagues working at WPI-AIMR.

I: Very good. How many times have you been to Sendai?

G: I do not know exactly but I guess over 15 times.

I: Over 15 times? It is marvelous. Did your first contact with Tohoku University happen a long time ago?

G: The first contact with Tohoku University took place a long time ago with Professor Esashi, over ten years ago. Since then, I have met Professor Esashi in different kinds of international conferences and sometimes we were Chairmen of different kinds of conferences, but in the middle of 2005 or 2006, we had some closer relationships with Sendai and Professor Esashi.

I: Can you explain to me more in detail what is Fraunhofer?

G: In Germany We have different kinds of research organizations, outside of the university. We have Max Planck Society, Helmholtz Association, Leibniz Association, and Fraunhofer Gesellschaft. Max Planck, Helmholtz, and Leibniz are more focused on basic research together with PhD education, but also some kind of application of course. But Fraunhofer is an organization which has the mission to bring innovation to the industry.

I: Is it a big umbrella research institution? For example, Max Planck Society covers various fields of basic science, and as you said, Fraunhofer is mainly linked with the application.

G: And it should bring innovation in the industry in many different fields, and therefore, in Germany a total number of 60 Fraunhofer Institutes exists, and by the way, Fraunhofer ENAS is the 60th.

I: I see. I checked the Fraunhofer homepage in Japanese version. Fraunhofer has German acronym for each Institute such as EMB, Einrichtung für Marine Biologie which means Marine Biotechnology, and in your case it is ENAS.

G: It is Elektronische Nanosysteme which means Electronic Nano Systems.

I: You belong to Fraunhofer, but you are also Professor of Chemnitz University of Technology. Is ENAS itself now in Chemnitz?

G: We have what we call the Smart Systems Campus in Chemnitz. This is an innovative network with expertise in micro and nano technologies as well as in Smart Systems Integration. The partners of the Smart Systems Campus Chemnitz are Chemnitz University of Technology with Institute for Physics, Center for Microtechnologies (ZfM) and Center for Integrative Lightweight Technology (ZIL), Fraunhofer Institute for Electronic Nano Systems (ENAS), and Start-Up Building for new enterprises.

I: At first, concerning your research, when did you personally get interested in science and technology?

G: As a young man, just before final secondary school examinations, I read a lot of books dealing with science and technique. So, I studied physics and got my PhD in physics too. However, I was especially interested in applications, for that reason I started to work in industrial research right after PhD at ZMD center for micro electronics Dresden.

I: You got your PhD at the University of Technology of Dresden, and what was the main theme of your PhD?

G: My PhD topic was the development of nuclear radiation detectors by using Neutron Transmutation Doped (NTD) silicon. It is a silicon radiation detector and I developed this material and the detectors. This was my PhD's thesis.

I: I guess your interest is always how to apply it.

G: Yes, how we can apply this for different things.

I: That means from your childhood you were very interested in something like machines?

G: No, I was not. I guess I like to understand the basic thing like Physics but I would like to apply these in devices. If you look at my main material which I developed in my life, this is silicon - silicon for electronics, silicon for radiation detector, and silicon for Micro Electronic Mechanical System (MEMS).

I: So were you always very interested in this application of silicon and the tool for MEMS? Does it mean even now your research interest concerns how to develop MEMS for various fields?

G: I think we had in the past a big progress worldwide in development of components. We have electronics, chips, the MEMS components all very well-developed, but now it is time to make a new kind of systems and we call this the Smart System Integration. Smart systems go beyond MEMS/NEMS for physical, biological or chemical parameter measurements combined with signal processing and actuating functions. Smart Systems Integration addresses the demand for miniaturised multifunctional devices and specialised, connected and interacting solutions. Multidisciplinary approaches featuring devices for complex solutions and making use of shared and, increasingly, self-organising resources are among the most ambitious challenges.

I: What are examples?

G: Perhaps sensor electronics, wireless communication, and also the battery. You know the battery is a very interesting thing because this system can be autonomous. It does not need external energy supply. We have developed special printed batteries in our Institute. In fact, it is possible to do energy harvesting with a MEMS device.

In a device we can create a so-called seismic mass of silicon. If there is a movement, then you have kinetic energy, and you can transfer this energy – kinetic mechanical energy - into electric energy. This is a big topic in the field of energy harvesting and this is an example for an integrated system. This is our recent research topic.

I: I see. So it means that you want to create a kind of system that will prevent energy consumption. I remember in Professor Esashi's Laboratory they are working very hard with bulk metallic glasses to make a kind of sensor.

G: Yes, this is our topic in AIMR here and then of course, we would like to develop also component for systems. This is the goal here in AIMR because there is a big experience in Sendai regarding metallic glass. We are looking forward to applying the metallic glass for our systems.

One development of special MEMS actuator with metallic glass is micro-mirrors of metallic glass – it is completely new. We will investigate what are the benefits or the disadvantages of this material in comparison to silicon. This is the basic research, really. The second point is that we would like to stack different kinds of wafers. This is called wafer bonding and we would like to use metallic glass for wafer bonding.

I: How do you use this?

G: We need lower temperature than current state of the art for wafer bonding. Metallic glasses have fundamentally glassy structure and exhibit a Newtonian viscous flow in the supercooled liquid region which is between the glass transition temperature (T_g) and crystallization temperature (T_x). The atomic configuration can easily rearrange in the supercooled liquid state resulting in nice interdiffusion. The plastic fluidity performs superior wettability which improves interfacial integrity and achieves homogeneous bonding results. The supercooled

region and therefore the temperature range in which the material exhibits its soft status, can be tailor made by designing the composition of the metallic glasses. In addition to these applications, we are looking for another one which is the use of piezoelectric materials to generate electrical energy and the energy harvesting effect.

I: It will rather create the energy.

G: We call PZT a piezoelectric material composed of lead, zirconium, and titanium. If you have mechanical movement, then you can change this into an electrical voltage. This is called piezoelectric effect.

I: So all these, for example, micro mirror, wafer bonding, and the energy harvesting by PZT can be industrialized?

G: It can be in the future but the goal now is that within AIMR, we investigate the basics, to know the effects and if it is possible, we can do this in cooperation for example with Fraunhofer and Helmholtz.

Here we get the basic results by using small samples and if it is successful, we can proceed to the wafer level integration then in Chemnitz. Of course, at this Fraunhofer Symposium here tomorrow, we will speak with the Japanese industry. If the Japanese industry has interest in this research, we can help to industrialize the results.

I: AIMR insists on the importance of fusion of various fields and it will not only be at the level of basic research, but also at the level of industrialization.

G: This is also Professor Esashi's philosophy. We fit very well together.

I: As you know, Professor Esashi is a pioneer in Japan even in the scheme of university-industrial cooperation.

G: It is good.

I: When you obtained the PhD in Dresden, it was the time of what we call "Eastern Germany." Now your country is, of course, Germany. Has the situation changed very dramatically compared to 20 years ago?

G: Regarding the technical development and the universities in the former German Democratic Republic, the level was also very high on the technical side. I was especially involved in the microelectronics industry during that time and I was a project scientist to develop the interconnect system for the one-megabyte memory device. This was the state of the art of technology at the time, and I developed special metallization systems. The application of the devices and technology standard was fine, but the problem was the political system.

There was no open connection between the scientists. I was not allowed to go to international conferences. It was a closed shop. This was the problem of the system. After the German unification, all my dear friends in Dresden regarding this microelectronics, with

whom I worked together, have a wonderful career now in the new system. They have careers as scientist or entrepreneur. I am very happy that I can now cooperate worldwide.

I: I see. So that means even before 1989, of course, Dresden, Chemnitz, Leipzig, these are what we call "industrial zone," isn't it? So there was already tradition of technology but what you say is after the breakdown of the Berlin Wall, there is a spirit of entrepreneurship and openness to the world?

G: Yes, this is the case.

I: And it is important. So you have sent excellent young researchers like Dr. Yu-Ching Lin.

G: She stayed for one year in Chemnitz and learned about our work and then she moved to this laboratory and we have now around five scientists meanwhile in her group.

Another researcher will be coming in March to stay for seven months. So we will improve the cooperation.

I: Very good. In Chemnitz University of Technology, you have your own laboratory consisting of young researchers. What is the situation of researchers in your laboratories?

G: I have this university laboratory as well as Fraunhofer, so I have two systems. We are about 200 people within Chemnitz and our philosophy is the following: As we cooperate with the industry, we need also some senior scientists who have the experience and have gained the experience over the years.

So we have different kinds of people as the seniors, and then we have the young scientists including PhD students who are very innovative. We have a lot of PhD students here. These young guys create the ideas and the supervisors are these senior scientists; I cannot be supervisor for 200 people. So we have departments and we have a mix of PhDs and these experts. We also have post-doc, as like here. So there are post-docs, PhDs, young scientists and the seniors.

I: Are they from various countries?

G: We are mainly Germans. Of course, we have PhD students from all over the world, from Europe, outside of Europe, especially we see interest from Russian people to come to us, and then we have Chinese and Indians. We also have some students from Brazil in South America.

I: It is very international. Even in your laboratory in Chemnitz, do you have a kind of international atmosphere?

G: We have the internationally-oriented Graduate School and they speak English in this school and the lectures that are given by the professors and senior scientists are in English, but of course, they like to learn German. They are living in Germany but when we have scientific discussions, it is done in English.

I: I see. As for your personal background, where were you born?

G: I was born in a small city in Erzgebirge which means the Ore Mountains in English. It is not far from where I am living now, Chemnitz. It is in Saxony.

I: So is it in the Eastern side of Germany?

G: Yes, in the Eastern side. It is also in Saxony not so far from my place where I am working now. I studied in Dresden and worked the first time in Dresden, after that in Chemnitz.

I: I went to Dresden once and it is such a beautiful city with a big river and a splendid castle and I visited the Opera House. Dresden Staatsoper is very famous even in Japan. By the way, what is your hobby?

G: It is dancing.

I: Dancing?

G: Ballroom dancing. I go to exercises every week. We have one exercise time on Sunday afternoon and during that time I am usually in my city, but yesterday I was not in my city because I was in Sendai. However, usually I go with my wife to have exercise by dancing each week for two hours.

I: But what kind of dancing?

G: All kinds, Salsa, Samba, Waltz…It is good because it is good for health and fitness, moreover, it is a special thing that I can do with my wife together. It is a common experience.

I: This would be very good for me because even administrators like us are always enclosed in the office.

G: I was formerly a football player but I am not able to do this anymore, however, I like watching football sometimes.

I: Generally speaking, a hobby like dancing sometimes changes your mind or scientific and inspires something new?

G: No, it is only fun.

I: Still good. Finally, I want to ask you about what you expect more from WPI-AIMR?

G: In AIMR I have the opportunity to make this basic research, together with my colleagues, to investigate new principles, and new materials. It is a big chance for us. We do not have these kinds of materials now. We have had no experiences until now in our laboratory. The environment of the science labs with special homemade equipment gives us a chance to do this. And then there are, of course, relationships between different groups. That is also good. Dr. Lin is discussing with many groups, for example, about metallic glass, and so this is a beautiful thing.

I: The purpose of AIMR is, of course, that we must be world top level and also as I said, the fusion of the fields is very important.

In this sense, as you said, the collaboration between BMG and MEMS is very precious for us and the exchange of young researchers is highly crucial. You send many talented researchers, who are very helpful for us and we would like to send young researchers to your institution. This kind of collaboration is very important.

G: Yes, we can also think about more collaboration in the future after maybe another year, then perhaps we will have even better materials with good parameter and then we can apply this perhaps in our laboratories in Germany too.

I: Yes, today I am very glad to know that your research field will certainly contribute to what we call "Green Materials" or "Green Innovation." Nowadays, University is not considered like Ivory Tower. Today I can understand in depth that the collaboration with the external world is very important. Thank you very much for this nice talk.

Interviewer: Administrative Director, W. Iwamoto

At Administrative Office, WPI-AIMR

December 6th, 2010

News Update

Great East Japan Earthquake and WPI-AIMR

Wataru Iwamoto

The Great East Japan Earthquake, with a 9.0 magnitude, occurred at 14:46 JST on Friday, 11 March. The epicenter was approximately 130km east-south-east of the Oshika Peninsula of the Tohoku region, with the hypocenter at an underwater depth of approximately 24km. The National Police Agency confirmed more than 27,000 persons dead or missing.
I would like to extend our deepest condolences to the victims and sufferers of the devastating earthquake and the following catastrophic tsunami.

Fortunately, the safety of all the staff of WPI-AIMR was confirmed by 14 March. The electricity was cut immediately at the AIMR buildings, but then put into service in one week. Although the AIMR related buildings are intact, there has been damage to equipment and we hope that the governmental supplementary budget covers the cost of their restoration. The front page of our homepage has been converted to an “emergency version” since 15 March publishing the Director’s messages and sharing the measures taken by the Institute. From 18 March staff have been able to resume work as normal, but there are still some buildings where research cannot be undertaken.

There have been a significant number of emails of encouragement sent to the Director, researchers and the Administrative Office by Foreign PIs, Members of the International Advisory Board, Adjunct professors and invited speakers of the past symposia. Some of them kindly offered generous donations to AIMR and those who are affected. We highly appreciate this warm encouragement and these generous offers.

Now, the situation of the Fukushima Nuclear Power Plants cannot be foreseen, but as far as Tohoku University is concerned, the radiation monitoring of accidents at the Fukushima I Nuclear Power Plant measured at the Cyclotron and Radioisotope Center at Aobayama campus shows figures which have been interpreted as posing “No health risk.” As for lifelines, the main roads in Miyagi Prefecture, including Tohoku Expressway which leads to Tokyo, are now open and functioning normally. Sendai airport began its service on 12 April, and the JR Shinkansen which connects Tokyo and Aomori will resume running between Tokyo and Sendai on 25 April. Almost all of our staff have come back to Sendai and they are making great efforts to restoring their research environments. It will still take time. However, I am convinced that the human ties built through scientific collaboration cannot be cut by a natural disaster. We will raise the level of our research activity more than ever with the hope that “Good comes out of evil”.

(Written on 19 April)

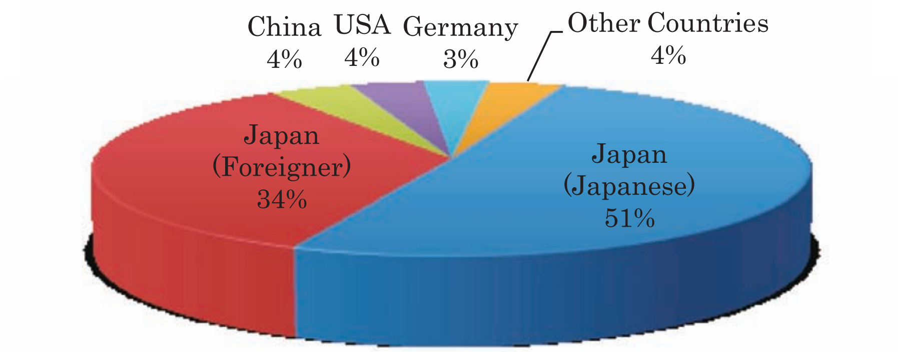
Tohoku University is accepting Earthquake Disaster Relief Donations. Please see for more details;
http://www.tohoku.ac.jp/english/contributions.html
or contact
Office of Tohoku University Earthquake Disaster Relief Donations,
Tohoku University
TEL: +81-22-217-5578 / FAX: +81-22-217-4846
E-mail： sinsai@bureau.tohoku.ac.jp

The 2011 WPI-AIMR Annual Workshop Report

The 2011 WPI-AIMR Annual Workshop was held on February 22 through February 24, 2011 at Sendai International Center in Sendai following a reception on February 21 at Sendai Kokusai Hotel. The main aims of the workshop were to stimulate current and future fusion research among WPI-AIMR researchers and between WPI-AIMR and world-leading researchers, and to make major progress in realizing the three major goals of WPI-AIMR, (1) invent and develop new and innovative functional materials, (2) establish a system befitting a World Premier Research Center, and (3) strengthen international cooperation and construct a world-recognized research center. Furthermore, the lectures focused on the theme of “Cutting-Edge Functional Materials for Green Innovation” which was set this year, in view of reflecting AIMR’s contribution in society. The Program Committee set up the special session, plenary sessions, parallel sessions and a poster session. The Organizing Committee and all the members of the Administrative Office contributed to successfully running the workshop.

The number of registered participants of the workshop was 216. Among the 184 participants registered from Japan, 74 researchers are those who are from abroad and working at WPI-AIMR and other research institutions in Japan. By contrast, 32 registered researchers were from abroad; 9 from China, 8 from USA, 7 from Germany, 2 from Switzerland and the UK, and 1 each from Australia, Denmark, France, and Israel. As a whole, about 50% of participants were foreign researchers.

[Participants by country of origin of institutions]



The total number of talks at the workshop was 123, which included 3 invited lectures in the special session, 7 invited talks and 12 talks by WPI-AIMR researchers (including foreign PIs) in the plenary sessions, 10 invited talks and 8 talks by WPI-AIMR researchers (including foreign PIs) in the parallel sessions, and 83 poster presentations.

In the special session, lectures were given by Dr. J. Georg Bednorz (1987 Physics Nobel laureate) of IBM Zurich Research Laboratory, a member of WPI-AIMR International Advisory Board, Dr. Peter Grünberg (2007 Physics Nobel laureate) of Research Center Jülich, and Dr. Sumio Iijima (a recipient of the Order of Culture of Japan in 2009) of Meijo University, Adjunct Professor at WPI-AIMR. For the plenary sessions and the parallel sessions, the world's leading scientists in the fields of AIMR research were invited. In the parallel sessions, current and forthcoming fusion research was highlighted, and sessions on (1) Bulk Metallic Glasses, (2) Material Physics, and (3) Soft Materials were arranged. A poster session was also organized for encouraging younger researchers and further discussing the Fusion Research. At the end of each session, fruitful discussions were held. In particular, Dr. Heinrich Rohrer (1986 Physics Nobel laureate), chair of WPI-AIMR International Advisory Board, followed all sessions and shared constructive comments.

We would again like to express our warmest appreciation to all the participants of the workshop. The 2012 WPI-AIMR Annual Workshop will be held in the last week of February, 2012.

For the complete program and the abstract booklet of the 2011 Annual Workshop, please visit our workshop website: http://www.wpi-aimr.tohoku.ac.jp/workshop/

The WPI-AIMR Young Researchers Mini-Workshop

Kazunori Ueno

The WPI-AIMR Young Researchers Mini-Workshop was held at Tohoku University on February 21, one day before the WPI-AIMR Annual Workshop. Dr. Bednorz, the Nobel Laureate, was invited to this Mini Workshop. At the Annual Workshop, few young researchers gave oral presentations due to the limitation of the time frame. The aim of the Mini Workshop is to give opportunity for young researchers to have oral presentations and discussions with Dr. Bednorz. Six presenters were selected who work on oxide and superconducting materials. More than 40 young researchers attended on the Mini Workshop and had fruitful discussions.

The first presenter, Dr. K. Iwaya reported on scanning tunneling microscopy (STM) on surface of $SrTiO_3$. He showed STM images with atomic resolution for TiO2 and SrO terminated surfaces, and discussed on surface reconstruction and superstructure of the topmost surface. Dr. K. Ueno reported on a high electron mobility transistor on $SrTiO_3$ single crystal, which works at low temperature. Dr. D. Hojo reported on Al_2O_3 thin films grown on woven cotton by low-temperature atomic layer deposition method. Dr. Y. Tanabe reported on magnetoresistance on iron pnictides doped with Ru, and discussed on Dirac cone state and electronic phase diagram. Dr. Z. C. Wang reported on transmission electron microscopy of $SrTiO_3$ related Ruddlesden-Popper Series. He discussed on insulator to metal transition and microstructure of the material doped with La. Dr. D. Maryenko reported on fractional quantum Hall states in MgZnO/ZnO heterointerface, and showed very high electron mobility in this system. Finally, Dr. Bednorz gave valuable comments to all the presentations. He appreciated all studies presented in the workshop, and encouraged young researchers in WPI-AIMR.

WPI-AIMR Outreach Plan in 2011

As reported in WPI-AIMR News vol.10, we have reinforced outreach activities from April, 2010 in order to facilitate communication and mutual understanding between WPI-AIMR and the public. It is needless to say that the research activities of WPI-AIMR have to meet accountability standards for the public.

In this year, we are programming the outreach events shown in the following list. Three volumes of outreach magazine *Tohoku WPI Tsu-Shin* will be issued keeping the same schedule of 2010. The mascot character introduces our researches in the magazine. We are planning to open the booth in some events for the public. After completion of our new building in Katahira Campus, we would like to start AIMR Science Cafe Series as one of the new challenges of our outreach activities.

Mascot character of WPI-AIMR

Plan of Outreach Activities in FY2011

June	Publication of *TOHOKU WPI Tsu-Shin* vol.4
June 11	Public lecture on materials science at Satellite Campus 2011, the Academic Consortium of Sendai (by Outreach Manager)*
July 10	The City of Academia “Sendai-Miyagi” Science Day 2011
July 27-28	Tohoku University Open Campus 2011
October	Publication of *TOHOKU WPI Tsu-Shin* vol.5
October 8-9	Katahira Festival 2011*
October	Tohoku University Innovation Fair 2011*
November 18-20	Science Agora 2011
February	Publication of *TOHOKU WPI Tsu-Shin* vol.6
Others	Starting AIMR Science Cafe Series in the new building of WPI-AIMR
	Joint Symposium by all WPI Centers at Kyushu University*

* The events marked with an asterisk are undecided at the moment, and there is a possibility that they may be changed.

Australian Colloid and Interface Symposium and AIMR

The Fifth Biennial Australian Colloid and Interface Symposium (ACIS) was held at Hobart, Tasmania, Australia from January 30th to February 3rd, 2011. The number of registered participants of the Symposium was 205, coming from Australia, Europe, America, and Japan.

On this occasion, Professor Kazue Kurihara, PI of WPI-AIMR was honored with the "A.E. Alexander Lecture Award." The A.E. Alexander Lecture Award was established in 1978 as a result of an appeal by the University of Sydney and the RACI Division of Colloid and Surface Chemistry to commemorate Professor Albert 'Alex' Alexander FAA FRACI, who was Professor of Physical Chemistry at the University of Sydney from 1957 to 1970. The Alexander Lecturer is an eminent scientist who has demonstrated outstanding achievement in the field of Colloid and Surface Science. The award lecture was ACIS and at The University of Sydney.

The ACIS-WPI Workshop was also held as a side event of ACIS on February 1st. Three WPI research centers, Advanced Institute for Materials Research (AIMR), International Center for Materials Nanoarchitectonics (MANA), Institute for Integrated Cell-Material Sciences (iCeMS) attended the Workshop. The purpose of the Workshop was to discuss new global research institutes in Japan and potential Australian involvement. This is the first joint initiative taken by plural WPIs to promote the WPI program abroad.

Administrative Director Wataru Iwamoto gave a presentation about the WPI program and AIMR, followed by an introduction of MANA by Professor Ariga, and then iCeMS by Professor Harada and Associate Professor Furukawa. Many participants were strongly interested in the presentation and they asked the speakers how to promote the relationship between WPIs and themselves.

Joint research between Japan and Australia has been enhanced at the level of individual researchers for a long time, however, there is still room for development at the institutional level.

In this sense, the workshop was a success and opened the door for the construction of our relationship with new partners.

7 Mar 2011

Volume 98, Issue 10, Articles (10xxxx)

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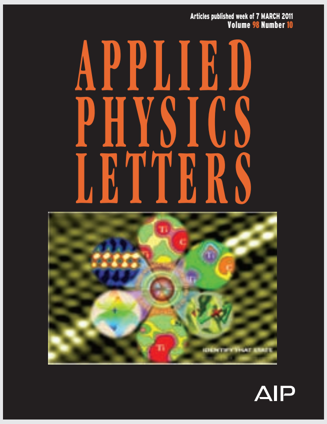

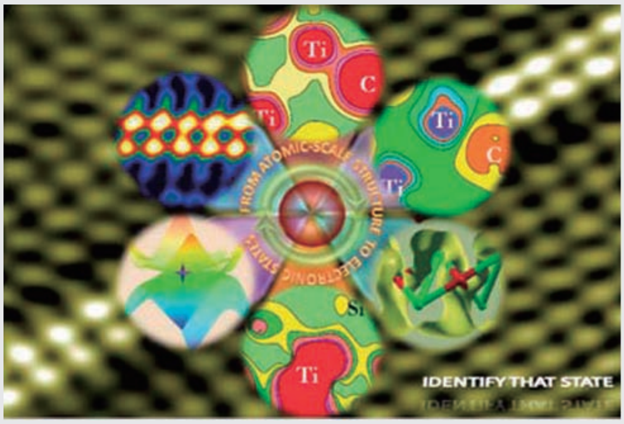

Appl. Phys. Lett. **98**, 104101 (2011);
doi:10.1063/1.3560505 (*3 pages*)

Zhongchang Wang, Susumu Tsukimoto, Rong Sun,
Mitsuhiro Saito, and Yuichi Ikuhara

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Applied Physics Letters / Volume 98 / Issue 10 / INTERDISCIPLINARY AND GENERAL PHYSICS

Appl. Phys. Lett. **98**, 104101 (2011); doi:10.1063/1.3560505 (*3 pages*)

Atomic-scale Ti_3SiC_2 bilayers embedded in SiC: Formation of point Fermi surface

Zhongchang Wang[1], Susumu Tsukimoto[1], Rong Sun[1], Mitsuhiro Saito[1], and Yuichi Ikuhara[1,2]

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[2]*Institute of Engineering Innovation, University of Tokyo, 2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan* map

(Received 11 October 2010; accepted 30 December 2010; published online 7 March 2011)

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Semiconductor heterostructures provide a fertile ground for fascinating physical behaviors that are not present in their respective bulk constituents. Here we demonstrate, by combining advanced transmission electron microscopy with atomistic first-principles calculations, that an atomic-scale Ti_3SiC_2-like bilayer can be embedded in SiC interior, forming an atomically ordered multilayer that exhibits an unexpected electronic state with point Fermi surface. The valence charge is confined largely to within the bilayer in a spatially connected manner, serving possibly as a conducting channel to enhance the current flow over the semiconductor. Such a heterostructure with unusual properties is mechanically robust, rendering its patterning for technological applications likely.

KEYWORDS and PACS

Keywords

density functional theory, electronic structure, Fermi surface, semiconductor heterojunctions, silicon compounds, titanium compounds, transmission electron microscopy

PACS

71.18.+y
Fermi surface: calculations and measurements; effective mass, g factor

71.20.Nr
Semiconductor compounds

71.15.Mb
Density functional theory, local density approximation, gradient and other corrections

ARTICLE DATA

Permalink

http://link.aip.org/link/doi/10.1063/1.3560505

PUBLICATION DATA

ISSN:

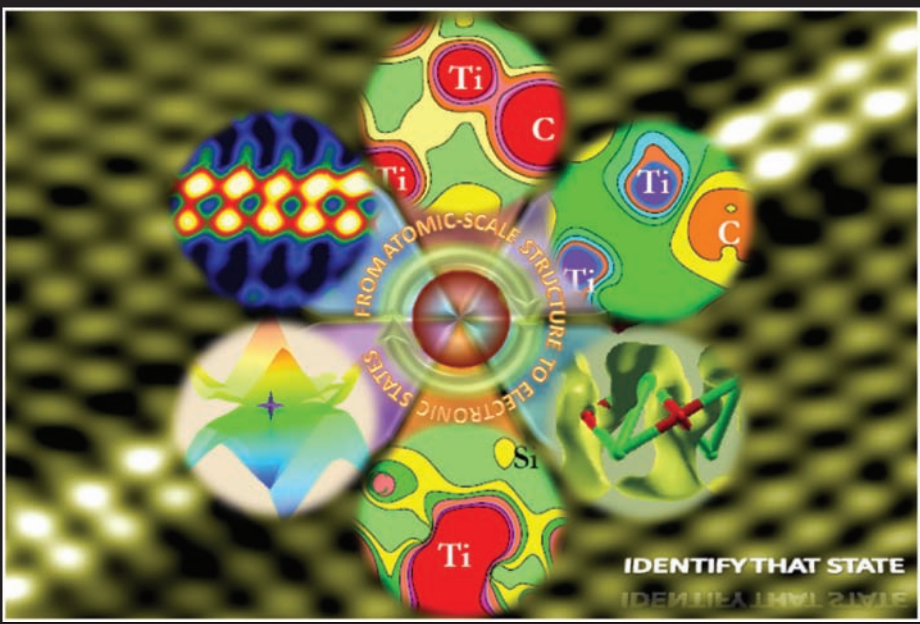
0003-6951 (print)
1077-3118 (online)

Publisher:

American Institute of Physics | crossref Member

Articles published week of 7 MARCH 2011
Volume 98 Number 10

APPLIED PHYSICS LETTERS



AIP

WPI Program and AIMR were presented in "Physics Today" in February.

Molecules to materials

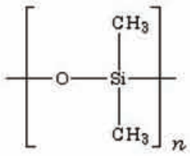
By Physics Today on February 16, 2011 1:29 PM | No Comments | No TrackBacks

I was happy the other day to receive a thick, info-packed newsletter from Tohoku University's Advanced Institute for Materials Research. As one of Japan's World Premier International Research Centers, AIMR has a twofold mission: to draw researchers from around the world and to do world-beating research.

The newsletter's title, "Molecules to Materials," succinctly and accurately describes one of AIMR's aims. It also got me thinking.

The notion of making materials from molecules isn't new. In the late 19th and early 20th centuries Nottingham University's Frederick Kipping developed a family of polymerized siloxanes, which he called silicone.

Silicone consists of crosslinked chains of alternating silicon and oxygen atoms. Attached to each silicon atom are two alkyl groups, such as methyl shown here.



The methyl groups mediate the crosslinking. By altering the length of the chains and the type of methyl group, Kipping and his successors have created a huge range of silicone materials—from free-flowing liquids to hard, stiff resins, all of which share siloxane's resistance to UV degradation and corrosion, low toxicity, and low coefficient of friction. My wife has a silicone madeleine pan. "It's great," she says.

Superhybrid materials

Following Kipping's example, chemists, material scientists, and physicists at AIMR and elsewhere are trying to make molecular materials that have useful properties. In principle, molecules are versatile building blocks. Chemical substitutions can tailor both a molecule's properties and how the molecule binds to other molecules.

Making molecular material that does what you want is tricky. The bonds that hold the molecules to each other can alter the molecules' properties. And even if you can identify a molecular arrangement that yields the properties you want, there's no guarantee that the resultant material is either robust or makable.

AIMR's Tadafumi Adschiri has devised a clever way to fabricate molecular materials. Like other researchers, he assembles his materials from nanoparticles whose size and chemistry have been picked to yield a material with a particular set of properties. And as Kipping was, he's interested in combining inorganic and organic molecules into hybrid polymeric materials.

To both make the nanoparticles and combine them with polymers, Adschiri uses supercritical fluids as solvents. Above its critical point—that is, the temperature and pressure at which liquid and gas phases coexist—a substance becomes a much better solvent. Supercritical carbon dioxide, for example, will readily dissolve caffeine, hence its use in the fanciest and most effective method of decaffeination.

Fluids that are immiscible below the critical point will readily mix when they're both supercritical. Adschiri exploits that feature to combine inorganic nanoparticles, whose ingredients dissolve in subcritical water, with organic nanoparticles and polymers, whose ingredients dissolve in subcritical oil.

Among the "superhybrid materials" that Adschiri makes with his supercritical process is a film that conducts heat but not electricity and the flexible, high-refractive-index film shown here.

The info-backed newsletter that inspired me to write this post opens with a message from AIMR's director, Yoshinori Yamamoto, entitled "Green Materials." Yamamoto wants his institute to be in the forefront of developing new materials for energy harvesting, energy saving, and environmental cleanup.

Of course, it's better if you don't have to clean up the environment in the first place. By using supercritical water and oil, Adschiri greenly avoids using environmentally hostile organic solvents.

Charles Day

SEARCH

RECENT ENTRIES

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“Nanoporous metal/oxide hybrid electrodes for electrochemical supercapacitors”

X. Y. Lang, A. Hirata, T. Fujita and M. W. Chen

WPI Advanced Institute for Materials Research, Tohoku University

Since being used in commercial devices as power-saving units in electronics in 1971, electrochemical capacitors, also called supercapacitors, have attracted considerable attention because of their unique combination of high power and long lifetime, as well as their wide-range applications from portable electronics to hybrid electric vehicles [1]. Although supercapacitors are naturally of high power delivery with an exceptional cycle life, their energy density is far below those of conventional batteries and the requirements of many important applications. For example, the stored energy density of conventional supercapacitors is only ~100 F/cm^3 (or 150 F/g) in specific capacitance. Pseudocapacitive metal oxides, such as manganese dioxide (MnO_2), could be used to make electrodes in such supercapacitors, offering higher levels of specific capacitance and energy storage via Faradic surface redox reactions, and circumventing the key limitation of conventional electrochemical double-layer capacitors with low energy density. However, the poor conductivity of MnO_2 (10^{-5} - 10^{-6} S cm^{-1}) limits the charge/discharge rate for high-power applications along with the limited cycle life and low power density, as the compromise of increased energy density, intrinsically restrict the applications of pseudocapacitors in practical devices [2].

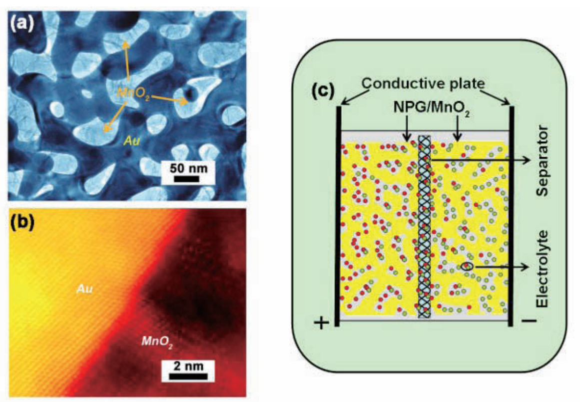

Figure 1 (a) Bright-field TEM micrograph of and the nanoporous gold/MnO_2 hybrid with the MnO_2 plating time of 20 minutes. (b) High-angle annular dark-field STEM image taken from a gold/MnO_2 interface region. (c) Illustration of the supercapacitor device constructed with the nanoporous gold/MnO_2 films as the electrodes.

In this research project we developed a novel nanoporous metal/oxide (Au/MnO_2) hybrid electrode material for high-performance supercapacitor applications [3,4]. This hybrid material was fabricated by electroless plating nanocrystalline MnO_2 into free-standing and three-dimensional nanoporous gold films at gas/electrolyte interface, and the loading mass of MnO_2 was controlled by plating time. Fig. 1(a) shows typical TEM image of nanoporous Au/MnO_2 hybrid film, legibly revealing that the nanocrystalline MnO_2 is uniformly plated into nanopores. Scanning TEM image of the Au/MnO_2 interface (Fig. 1b) demonstrates that the nanocrystalline MnO_2 epitaxially grows on gold ligament surfaces, forming a chemically bonded metal/oxide interface. The excellent contact between the nanocrystalline MnO_2 and gold ligaments can dramatically improve the electrical conductivity of the hybrid materials. Electrochemical measurement based on a two-electrode supercapacitor device (Fig. 1c) reveals that this hybrid electrode material possesses the highest energy density of ~1160 F/cm^3 (or 601 F/g) along with the outstanding power and energy densities as well as cycling stability by making use of nonFaradic surface ion adsorption (double-layer capacitance) coupled with Faradic surface redox reactions (pseudocapacitance). The high specific capacitances and charge/discharge rates offered by the hybrid structures make them promising candidates for the electrodes in supercapacitors that combine high energy storage densities with high levels of power delivery.

Pseudocapacitive MnO_2 can be used to make the electrodes in the supercapacitors because they are theoretically predicted to have a high capacity for storing electrical charge, while also being inexpensive and not harmful to the environment. In this project, we have achieved the exciting finding that the high conductivity and mechanical stability of nanoporous gold can great improve the performance of MnO_2 in the energy storage and delivery. Because gold is a very expensive noble metal, in our next plan we are going to reduce the amount of Au in nanoporous Au/MnO_2 hybrid materials, or replace nanoporous gold with much cheaper metals such as nanoporous Cu as skeleton to support nanocrystalline MnO_2 for electrochemical supercapacitors with both high energy storage densities with high levels of power delivery.

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“Long-lived Ultrafast Spin Precession Observed in Manganese Alloys Films with a Large Perpendicular Magnetic Anisotropy”

S. Mizukami[1], F. Wu[1], A. Sakuma[2], J. Walowski[3], D. Watanabe[1], T. Kubota[1], X. Zhang[1], H. Naganuma[2], M. Oogane[2], Y. Ando[2], and T. Miyazaki[1]

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[2] Department of Applied Physics, Graduate School of Engineering, Tohoku University
[3] I. Physikalisches Institut, Universittaet Goettingen

Spintronics utilizes a quantum mechanical object "spin" as well as "charge" of an electron. Nowadays, the most demanding spintronics application is a Gbit class magnetoresistive random access memory (MRAM) using spin-transfer-torque (STT) magnetization switching, and it is also regarded as one of the *Green Technologies* in this century. However, there is still a lack of a key material for a memory layer in magnetoresistive tunneling devices, which should have a high perpendicular magnetic anisotropy with magnetic easy-axis parallel to a film normal and a low magnetic friction as well as a large spin polarization. Especially, the low magnetic friction is very crucial for the STT-MRAM application.

The magnetic friction is a magnetic analogue of a mechanical friction that we usually experience in daily life. Magnetization (macroscopic spins) moves against the magnetic friction, that consumes electric power driving a rotation of magnetization. It is quite similar to a power consumption by a mechanical friction in an automobile or a motor. Several experimental and theoretical works indicated a correlation between magnetic friction and magnetic anisotropy, namely materials with large magnetic anisotropy tend to show large magnetic friction. Therefore, it is a challenging task to explore the key material and/or a new concept designing materials for STT-MRAM.

A Mn-Ga binary alloy has a tetragonal crystal structure [Fig. 1(a)] that is similar to that for a FePt alloy; the famous magnetic alloy for a permanent magnet. Most of alloys with high magnetic anisotropy have noble or rare earth metal elements but Mn-Ga alloys contain no heavy elements. Furthermore, a Curie temperature for Mn-Ga alloys is much higher than room temperature, and the large spin polarization has been predicted, nevertheless those contain no magnetic elements, *i.e.*, Fe, Co, and Ni [1]. We have succeeded to grow the good epitaxial films of Mn-Ga alloy exhibiting the large perpendicular magnetic anisotropy and to fabricate the magnetoresistive tunneling devices using ultra-high vacuum magnetron sputtering technique, and we also showed the high magnetoresistance ratio from *ab initio* calculations, so far [2].

In this letter, we demonstrated further the very low magnetic friction in this alloy films using the time-resolved magneto-optical Kerr effect (TRMOKE) [3]. Figure 1(b) shows the typical TRMOKE signals for the films. Sinusoidal oscillations correspond to magnetization (spins) precessions about an externally applied magnetic field. Spin precessions show ultrafast frequencies up to 280 GHz with no remarkable decays, that have never been observed in metallic ferromagnets. Gilbert damping constants (namely, magnetic friction coefficient) extracted from the data are smaller by a factor of ten than known materials with high magnetic anisotropy over ten Merg/cm^3. First-principles calculation also qualitatively supported the result. This finding contributes not only to develop STT-MRAM further but also to form the new concept for designing *Green Spintronics Materials* with no heavy elements [4].

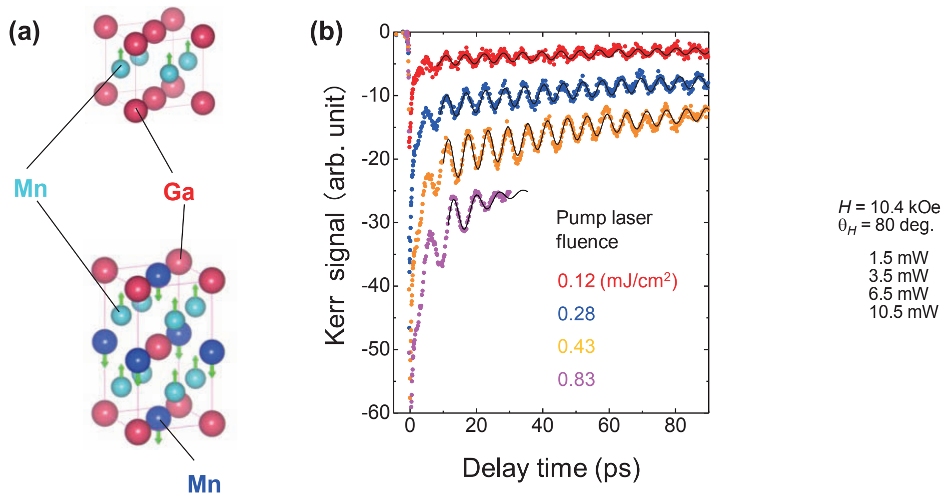

Fig. 1 (a) Schematics of crystal structure for Mn-Ga alloys and (b) typical TRMOKE signals.

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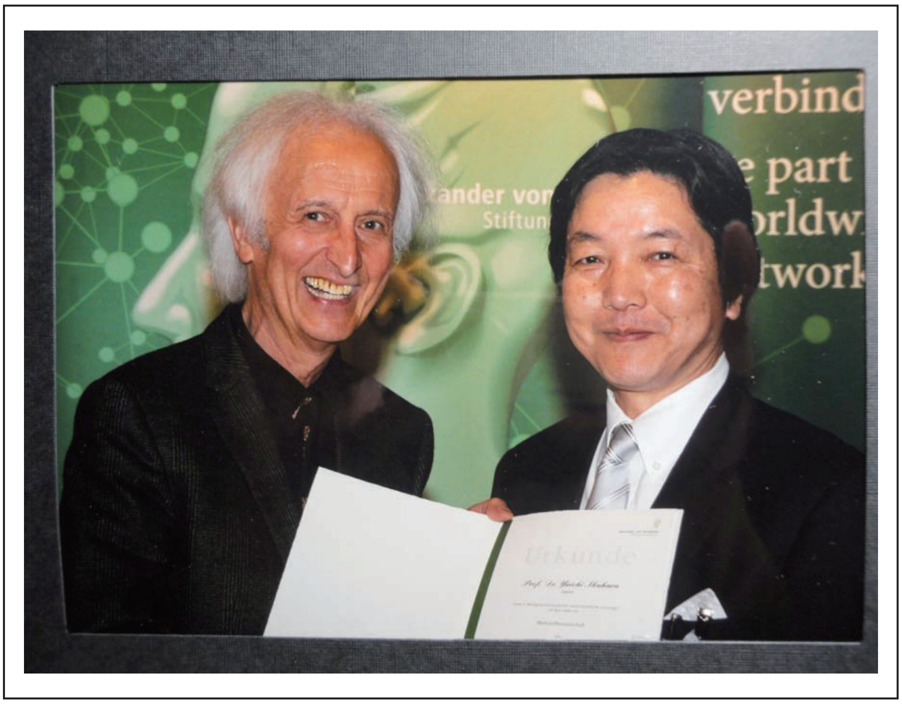
Professor Ikuhara (PI) received Humboldt Research Award



The award certificate was given by Prof. Dr. Helmut Schwarz, President of Alexander von Humboldt Foundation (March 25, 2011).

Prof. Ikuhara, PI of WPI-AIMR, won Humboldt Research Awards, bestowed by the Alexander von Humboldt Foundation in Germany, an organization that promotes academic co-operation between excellent scientists and scholars from abroad and from Germany. The award is granted in recognition of a researcher's entire achievements to date to academics whose fundamental discoveries, new theories, or insights that have had a significant impact on their own discipline and who are expected to continue producing cutting-edge achievements in the future. Prof. Ikuhara is well known and internationally recognized scientist in the field of interface science and grain boundary engineering in materials. His studies concerning grain boundary related phenomena took a world-leading role in this field of research. Prof. Ikuhara is the 3rd Japanese winner in the field of materials science. The award ceremony was held at Bamberg in Germany from 24th to 27th on March, 2011.

Award Information

Name	Position	Thrust	Name of Award	Awarding Organization	Date of Award
Zhongchang Wang*	Assistant Prof.	Materials Physics	Award for Encouragement of Research of Materials Science	The Materials Research Society of Japan	Jan 20
Daisuke Ishii*	Assistant Prof.	Device/System	Award for Encouragement of Research of Materials Science	The Materials Research Society of Japan	Jan 20
Kazue Kurihara	PI	Soft Materials	A. E. Alexander Lecture	Royal Australian Chemical Institute	Jan 31
Ali Khademhosseini	Junior PI	Device/System	Sloan Research fellowship	Alfred P. Sloan Foundation	Feb 15
Yuichi Ikuhara	PI	Materials Physics	Humboldt Research Award	Alexander von Humboldt Foundation	Mar 25

* Assistant Prof. Ishii and Assistant Prof. Wang also received "The 3rd WPI-AIMR Award" on April 21.
WPI-AIMR Award is given to the researchers working in WPI-AIMR at Sendai excluding PIs immediately when they won the prize from foreign and domestic research organizations, academic societies, academic journals, or administrative organizations, and Institute Director evaluates their work is worth awarding.

Dr. Wang

The Third Series of WPI-AIMR Joint Seminars FY2010

The third series of the WPI-AIMR Joint Seminars started from April, 2010. The aim of this seminar series was to enhance mutual scientific communications among research staffs in WPI-AIMR to promote further fusion researches and the seminars were organized and managed by younger research staffs in WPI-AIMR. The sessions were not constituted only by one way talks based on established research results, but also lively discussions and exchange of ideas.

Lineup of the third series of WPI-AIMR Joint Seminars (13th to 19th)

13th Seminar, Dec. 17, 2010

Tanigaki Group Organizer: R. Nouchi, Moderator: S. Souma

R. Nouchi "Overview of "Nanomaterials toward Green Innovation""

J. Xu "Guest Atom Motions in Type I Clathrate (Ba, Sr)$_8$Ga$_{16}$Ge$_{30}$: Promising Thermoelectric Materials"

Y. Tanabe "Single Crystal Diffraction and Structural Analysis of the Guest Atom Motion in Type-1 Clathrate X$_8$Ga$_{16}$Ge$_{30}$"

Y. Tanabe "Dirac-Fermion-Dominated Electronic Transport in Iron Pnictide Ba(FeAs)$_2$: Application for a Highly Mobile Carrier"

R. Nouchi "Characterization and Tuning of Metal Contacts to Dirac-Cone Systems and Organic Semiconductors"

14th Seminar, Jan. 14, 2011

Tokuyama Group Organizer: L. Xu, Moderator: T. Sato

L. Xu "Theoretical and Simulation Study of Structure and Dynamics in Glass-forming Liquids"

Y. Cho "Charge Interaction in Nano-scale Soft Matter"

M. Tokuyama "Universality in Self-diffusion among Distinctly Different Glass-forming Liquids"

15th Seminar, Jan. 28, 2011

Tsukada Group Organizer: K. Akagi, Moderator: T. Hitosugi

K. Akagi "Introduction : A Guide for Collaboration with Us"

I. Hamada "Ab Initio sStudy of eElectrochemical Reactions at a Solid/Liquid Interface"

A. Masago "Simulation for Scanning Probe Microscopy"

M. Araidai "Transport in nNano-scale sSystems"

16th Seminar, Feb. 4, 2011

Miyazaki Group Organizer: S. Mizukami, Moderator: S. Tsukimoto

S. Mizukami "Introduction to Spintronics in Miyazaki Group"

"Exploration of Magnetic Materials for Magnetic Random Access Memory - magnetic Properties and Spin Dynamics"

T. Kubota "Magnetoresistance Efect in Tunnel Junctions with Ordered MnGa Perpendicular Magnet Thin Film Electrode"

X. Zhang "Spin Transport in Organic-inorganic Hybrid Junction"

17th Seminar, Feb. 18, 2011

Yamada Group Organizer: T. Sato, Moderator: L. Xu

T. Sato "Overview of Material Science Studied by Neutron Scattering"

K. Horigane "Magnetic Structure of Mn2.5Ga Thin Film from Polarized Neutron Analysis"

S. Ji "Neutron Scattering Study on Geometrically Frustrated Magnetism in a Fe-oxychalcogenide"

T. Sato "Hydrogen in Materials Studied by Neutron Scattering"

18th Seminar, Feb. 25, 2011

Shimomura Group Organizer: D. Ishii, Moderator: K. Nakajima

D. Ishii "Overview of Self-Organized Materials for Functional Surfaces and Particles"

"High Adhesive Superhydrophobic Surface based on Self-Organization"

T. Higuchi "Structural Analysis of Phase Separation Structures of Block Copolymer Nanoparticles"

T. Kawano "Control of Stem Cell Functions by Physical Interaction with the Extracellular Matrix"

19th Seminar, Mar. 4, 2011

Yamaguchi Group Organizer: Z. An, Moderator: D. Ishii

Z. An "Introduction on the Development of Green Materials Based on Helicene Chemistry by Yamaguchi Group"

W. Ichinose "Synthesis and Aggregation of Amido-ethyl-amidohelicene Triblock Oligomers"

N. Saito "Synthesis and Hetero-double-helix Formation of Ethynylhelicene Oligomers"

K. Yamamoto "Stable Double-helix Formation of Ethynylhelicene Oligomer on Gold Surface"

S. Nakano (Kurihara Lab) "Effect of Electric Field on Confined Liquid Crystal"

Z. An "Aggregation/Deaggregation of Chiral Nanoparticles Induced by Aromatic Solvents"

H. Aikawa "Studies on the Relation Between Gel Properties and Their Components"

M. Shigeno "Enantiospecific Reversible sSwitching of Charge Injection Barriers"

The 13th Seminar (Tanigaki Group)
Nanomaterials toward Green Innovation

Organizer: R. Nouchi (Electronic Materials Lab., Materials Physics)

Materials whose characteristic size is on the nanometer scale show various kinds of novel physical properties which originate from the quantum mechanical behaviors of the nanostructures. To contribute to the target of AIMR "Materials for Green Innovation", Tanigaki group is pursuing thermoelectric materials for energy generation, superconductors for energy conservation, and organic semiconductors for environmental friendliness. In this seminar, we introduced three topics from our activities:

(1) Clathrate as a promising thermoelectric material

Good thermoelectric materials should exhibit high electrical conductivity and low thermal conductivity, but these two properties do not coexist in the majority of compounds. Type I clathrate is a very promising thermoelectric material under a phonon-glass-electron-crystal concept due to its unique host-guest structure, where anharmonic motions of the guest atoms suppress the phonon thermal transport while the host crystal structure ensures high electrical conductivity. Dr. Xu and Dr. Tanabe discussed guest atom motions in type I clathrate by means of x-ray photoemission spectroscopy, specific heat measurements, and single crystal diffraction.

(2) Dirac-cone systems with high-speed charge carriers

Dirac-cone states are very intriguing electronic states with an ideally massless fermion character, which ensures high charge carrier mobilities. This state was found in graphene, a single atomic sheet of graphite, and was recently shown to exist in the parent compound of FeAs superconductors. Dr. Tanabe introduced our recent observation of a linear magnetic-field dependence of the magnetoresistance of the FeAs superconductors, which indicates that the electronic transport is indeed governed by the Dirac-cone state. Dr. Nouchi discussed metal-contact effects on Dirac-cone systems, which is unavoidable when we fabricate electronic devices to exploit the high-speed charge carriers.

(3) Organic semiconductors toward flexible electronics

Organic semiconductors are expected to play indispensable roles in the future electronics because of their applicability for flexible, light-weight devices. It is well known that charge-carrier injection from a metal to an organic semiconductor determines the operation of organic electronic devices. Dr. Nouchi showed that helical molecules synthesized by Yamaguchi group, which can make a self-assembled monolayer on metal surfaces, impart switchable charge-injection properties to the metal-organic contacts.

The 14th Seminar (Tokuyama Group)
Theoretical and Simulation Study of
Structure and Dynamics in Glass-forming Liquids

Organizer: L. Xu (Theory Lab., Bulk Metallic Glasses)

Glass has a histroy of thousand of years and is an essential element in everyday life, such as window glass. However, the origin and mechanism of the steep increase of slowing down in dynamics from supercooled liquid to glass remains unclear. In the case of bulk metallic glasses, the phase behavior of substances rapidly becomes more complicated as the number of components involved increases, which makes the theoretical study and the prediction for practical applications more difficult. Thus, the development and investigation of simply system and the search for universalities are important for the understanding of the basic questions in supercooled liquids and material science. Our computer simulation results based on the studies of the thermodynamic, dynamic, and structural properties of a model system have shown that a new stable glass can be produced from systems with two different local structures in supercooled liquids, which is consistent with the experimental observations water and partially in metallic glass such as Ge and Ce-based alloys, thus provide a possible way for experiment to search for stable glasses via polyamorphism (glass-to-glass transition)[1]. Further, our theoretical studies based on mean-field theory shows that there exist two types of universalities in dynamic properties (e.g. self-diffusion) among distinctly different glass-forming liquids, such as BMG and window glass. One universality is that the dynamics of any atoms in different systems obeys a single master function of time if their self-diffusion coefficients have the same value [2]. The other universality is that the self-diffusion coefficients of any atoms obey a single master function of temperature [3]. Hence this fact enables one to predict a whole self-diffusion process of an atom contained even in a complex system if one can observe its only one self-diffusion data.

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The 15th Seminar (Tsukada Group)
Ab initio Surface/Interface Science
Aiming for Next Generation Devices and Measurement Techniques

Organizer: K. Akagi (Theory Lab., Materials Physics)

This seminer was planed to introduce our current researches and much more promote the interaction with experimantal reseachers. We made sure that each talk contains “what we are doing in our group”, “short review of the frontier in our research field”, “introduction of our own research(es) ” and “what we can do with the audience”.

After the introductory talk by Dr. Akagi, Dr. Hamada introduced his recent works on electrochemical reactions at solid/liquid interfaces based on *ab initio* calculations. How to model and simulate such complex catalytic reactions was shown for few examples and the difficult points of this kind theoretical approach were discussed.

Dr. Masago presented the simulation methods for scanning tunneling microscopy (STM), atomic force microscopy (AFM), Kelvin probe force microscopy (KFM), and some applications using them. He also announced that these methods are being implemented as a part of “advanced simulator for the Scanning Probe Microscopy (SPM)” [https://www.aas-ri.co.jp/spm/en/spm_eng.html], which will be released in the middle of this year.

The talk by Dr. Araidai was on theoretical treatments of electron transport in nano scale systems and related phenomena in open systems using so-called Non-Equilibrium Green's Function (NEGF) method. Preliminary result on spin transport property through a “metal/oxide/metal” multi-junction system was introduced as collaboration with Miyazaki group.

Dr. Tamura reported his recent studies on photovoltaic systems and molecular devices focusing on exciton dynamics in molecular aggregates, charge transfer at donor-acceptor hetero-junctions and polaron transports in organic thin films. Especially, he discussed how these complex systems can be modeled and treated using *ab initio* calculations and quantum dynamics calculations.

Finally, Dr. Akagi gave a talk on his approach for microscopic understanding of "water (or aqueous solution)/solid" interfaces based on the combination of first-principles calculation and classical molecular dynamics simulation. Some suggestive information derived from the analysis of structure and dynamics of hydrogen-bond network at the interfacial region were presented as a clue to understand the physical and chemical phenomena such as friction, lubrication and electrochemical reactions.

The 16th Seminar (Miyazaki Group)
Spintoronics Materials

Organizer: S. Mizukami (Spintronics Materials Lab., Device/System Construction)

Spintronics is a boundary research region that is new and wide in which both a magnetic technology and the semiconductor technology are the base. Therefore, it is impossible to deal only in an existing technological special region. In AIMR, Miyazaki group began to research on new magnetic materials for Gbit magnetic random access memory (MRAM) and also on inorganic-organic hybrid magnetoresistive junction for advanced flexible-spintronic devices, partially in collaboration with other groups in AIMR and a company.

Dr. Mizukami talked about his investigations of spin dynamics damping effect in various known magnetic alloys and multilayers. He reported that damping effect was too large in conventional magnetic materials with large magnetic anisotropy although damping determined most of power consumptions in MRAM. He claimed that it was crucial to develop new and special materials for MRAM application, and introduced such new materials, Mn-Ga alloys, investigated by Dr. Wu, who has succeeded to grow the $Mn_{2.5}Ga$ alloy epitaxial films using physical vapor deposition (i.e., magnetron sputtering) method. The $Mn_{2.5}Ga$ alloy films exhibited tetragonal structures, very small magnetization, and very large magnetic anisotropy, being advantageous for application although spin dynamics damping effect in the alloys were under investigation.

Tunnel magnetoresistance exhibited by magnetic tunnel junctions is one of the most important issues for MRAM application. Dr. Kubota talked about his experimental investigation of TMR effect in some series of Mn-Ga and MgO-barrier based magnetic tunnel junctions, especially focusing on the composition dependence of TMR. By considering band-dispersion curves obtained by first-principles calculations done by the theory group in AIMR, he discussed the potential of Mn-Ga alloys for MRAM application.

Dr. Zhang talked about his experimental investigation on magnetoresistive junctions using π-conjugated organic semiconductors (OSEs) as spacer. He reported the relatively larger and positive magneto-resistance (MR) ratio at low temperature was observed in his hybrid junction although spin transport mechanism is unclear yet. Finally, he claimed importance of fusion research in this topic, and several researchers gave him valuable comments.

The 17th Seminar (Yamada Group)
Structures and Dynamics of Spins and Hydrogen in Novel Materials

Organizer: T. Sato
(Advanced Spectroscopy for Materials Physics Lab., Materials Physics)

Atomic arrangements (structure) and dynamics (e.g. phonons etc.) strongly correlate with material properties, which lead to find those implications. Therefore, those studies are indispensable on material science. In order to study for them, neutron and x-ray scatterings are often employed. Particularly, neutron scattering is as a unique tool to study structures and dynamics of spins and hydrogen in novel materials. In this seminar, three different research topics studied by neutron scatterings were presented.

The first was about "Magnetic Structure of $Mn_{2.5}Ga$ Thin Film from Polarized Neutron Analysis presented by Dr. K. Horigane". It is of special importance to determine the magnetic structure of $Mn_{2.5}Ga$ thin film because of application for spintronics device. In this seminar, he determined the microscopic magnetic structure of $Mn_{2.5}Ga$ thin film by using polarized neutron analysis. From this analysis, magnetic structure of thin film is as same as that of bulk, however magnetic moment is smaller. This result is consistent with macroscopic measurement such as SQUID measurement.

The second was about "Neutron Scattering Study on Geometrically Frustrated Magnetism in a Fe-oxychalcogenide" presented by Dr. S. Ji. First, a basic concept of geometrically frustrated magnetism was introduced for general audiences of WPI members to help them to understand a fascinating field of solid state physic studying a ground state of glassy spins by neutron scattering techniques. Then, he presented his recent study on an Fe-oxychalcogenide which has attracted many attention regarding its interesting Mott-insulating behaviors and abnormal spin fluctuation of localized electon on a geometrically frustrated lattice. In this seminar, it was demonstrated how neutron scattering technique could investigate static and dynamic properties of spins in the compounds.

The final was about "Hydrogen in Materials Studied by Neutron Scattering presented by Dr. T. Sato". Identification of hydrogen in materials is highly required because hydrogen in materials leads a lot of interesting material properties. For the study, neutron scattering can provide precise determination of hydrogen site. In the seminar, he showed two different hydrides that were structural and dynamics investigations on a kind of hydrogen storage material $CaAlH_5$ studied by neutron diffraction and inelastic neutron scattering, and strucutral investigations a glassy alloy $(Ni_{36}Nb_{24}Zr_{40})_{1-x}D_x$ (x = 0, 0.15) studied by neutron total scattering.

The 18th Seminar (Shimomura Group)
Self-Organized Materials for Functional Surfaces and Particles

Organizer: D. Ishii (Bio Device Lab., Device/System Construction)

Functional surfaces and particles were prepared by self-organization process emerged in evaporating dual-solvent systems. In the case of immiscible system of dual-solvents such as chloroform and water, honeycomb patterned structure was fabricated on polymer surfaces templated by self-organization of condensed water droplet arrays [1]. On the other hand, in the case of miscible system of dual-solvents such as THF and water, nano-structured polymer particles were obtained by self-organization [2].

We could prepare various microstructures [3] made from the honeycomb-patterned polymer films, such as anisotropic-deformed porous films, honeycomb and particle hybrid, microling array, microdot array, microlens array, and the other structured films. We have tried not only to make precise surface structures by self-organization but also to fabricate functional surfaces made from the honeycomb-patterned polymer films. And also, we try to use the honeycomb film as extracellular matrix. Cell adhesion behavior is very important for cell culturing. By using the various honeycomb structured surface, we can control of cell adhesion and cell differentiation.

Another material is functional nanoparticle. Firstly, polymers are dissolved in a good solvent. And then, water as a poor solvent is added into the solution. After mixing the solution, good solvent is gradually evaporated. After evaporation, the polymer nanoparticles are obtained in the water solution. By choosing suitable solvent for the block copolymers, functional block copolymer nanoparticles having inner structures can be prepared by self-organization [4].

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[4] (a) T. Higuchi, et al., *Angew. Chem. Int. Ed.,* **47**(42), 8044 (2008). (b) T. Higuchi, et al., *Macromol. Rapid Commun.*, **31**(20), 1773 (2010).

The 19th Seminar (Yamaguchi Group)
Chemical Study on Helicene Chemistry: Development of Novel Chiral Green Materials

Organizer: Z. An (Organosoft and Hybrid Materials Lab., Soft Materials)

Chirality is an important concept in organic chemistry: Any molecule that is not superimposable on its mirror image is chiral, and possesses two stereoisomers, called enantiomers, with very similar but different properties. Chiral structures with right-handed or lefthanded helicity are named the *P*- and *M*-configuration, respectively. Our studies on chiral recognition phenomenon of helicenes show a tendency for pairs of the same configuration of the helicenes to form more stable complexes than pairs of enantiomeric helicenes via noncovalent bonding interactions. The observations are made in charge transfer complexation, crystallization, homocoupling reaction, layer structure formation, self-aggregation, and double helix formation [1]. In relation to the studies on such helical polymers with low molecular weight, we explored the bottom-up method to integrate small chiral helicenes as green soft materials, which will be applied to energy- and resource-saving based on the noncovalent bonding interactions of helicenes.

The chiral helicene molecules (< 1nm) are used as the building blocks in designing the soft green materials. A "bottom-up" method was developed to synthesize, characterize, separate, purify and functionalize the built-up macromolecules (1-10 nm) [2], which further aggregated (10-100 nm) or assembled (100 nm-10 μm) as chiral complex (10 μm-10 cm)[3]. Because these materials are designed with a step by step method, the high purification and orderly structure of these building blocks are advantages over natural or synthesized polymers, and their properties indicated reversible responsibility to the energy change (such as temperature, photo or magnetic) in a controlled manner. This approach employed in living things will be applied to green materials for energy- and resource-saving.

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Research Prospect

Nanomaterial Transport by Motor Proteins

Daniel Oliveira[1] and Winfried Teizer[1,2]

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[2]Department of Physics and Astronomy, Texas A&M University, College Station, TX, United States.

1. Introduction

Protein machines, also referred to as molecular motors, are the origin of nearly all biological movements within the eukaryotic cell. Conversion of chemical energy into mechanical work, harnessed by the hydrolysis of ATP, propels proteins' along cytoplasmic systems of fibers, such as microtubules. The kinesin protein (Figure 1) is a well known naturally occurring molecular machine capable of unidirectional cargo transport upon microtubule interaction, and consequently an attractive candidate as a constituent of a synthetic molecular machine. As illustrated in Figure 2, within the cytoskeletal network kinesin moves toward the (+)-terminus of microtubules (anterograde transport) having several functions including synapse activity [1,2].

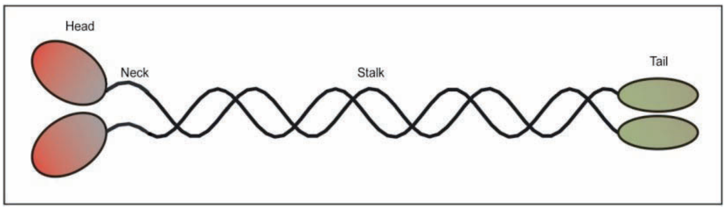

Figure 1. Kinesin dimer structure showing the heavy-chain (head domain) and the light-chain (tail domain).

Recent efforts to engineer tailor-made artificial nanotransport systems in order to carry out directional transport of nanoobjects in a cell-free environment are thus hardly surprising [3,4]. In a typical design, ATP-fueled kinesin motor proteins are immobilized on a glass surface while microtubules loaded with cargo are propelled over the motors. Alternatively, molecular shuttles can be assembled mimicking the natural cell`s intracellular transport mechanism where the kinesin protein moves over microtubules tracks (Figure 2). From a device engineering perspective, the latter approach for molecular shuttles is more appealing since multiple microtubules tracks with varying directions can be designed in the same device; moreover, bidirectional cargo transport can be achieved on the same track if different motor proteins are used (e.g., kinesin and dynein). Therefore, it is conceivable to utilize this concept for nanoelectromechanical systems. Kinesin motors have, in fact, been successfully used for applications such as biomedical sensors [5], bio-molecular motion [6], and nanoparticle transport [7].

Relying on very strong and specific covalent interactions (e.g., biotin-avidin) kinesin can be coupled to functionalized nanocrystals, and accordingly, the interaction of such a complex with microtubules tracks can be visualized and investigated. It is therefore anticipated that molecular shuttles can be engineered by manipulating not only the cargo to be transported by kinesin but also the microtubule track network. This work is expected to develop novel opportunities for nanosize transport, especially for drug delivery.

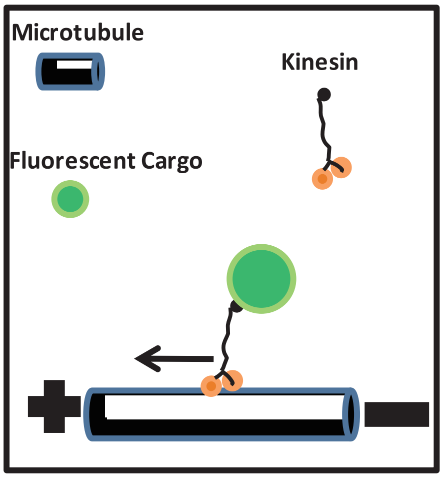

Figure 2. Kinesin-Microtubule Interaction for Cargo Transport.

2. Kinesin expression and kinesin-microtubule interaction observation

The first step toward the implementation of functional kinesin molecular shuttles is the construction, expression and purification of biotinylated kinesin dimers [8,9], currently performed in collaboration with Prof. Mitsuo Umetsu (WPI-AIMR at Tohoku University). Typically, the drosophila DNA fragment encoding the full-length kinesin heavy-chain motor domain is designed and modified by incorporating sequences of hexa-histidine and biotin tags. The recombinant kinesin protein is then expressed in Escherichia coli cells and purified by Ni-NTA chromatography. Following protein purification, the biotinylated recombinant kinesin protein is conjugated with streptavidin (or avidin) coated nanoparticles. Commercially available streptavidin-coated quantum dots (Invitrogen Corp.) are currently used for preliminary experiments on kinesin motility on microtubules. Microtubules (rhodamine-labeled) and fluorescent nanoparticles are then observed on an Olympus BX-51 fluorescence microscope, in collaboration with Prof. Tadafumi Adschiri (WPI-AIMR at Tohoku University).

3. Results and discussion

Two methods were used to quantify the relative amount of kinesin protein expressed in Escherichia coli, namely, sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), and Western Blot analysis of electrophoretic separated kinesin. Both methods rely on the electrophoretic separation of proteins based on their sizes, differing in how the sought protein is visualized. The later method estimates the molecular mass of a protein by comparison with a protein standard, whereas in the former, protein visualization is achieved using fluorescent-labeled antibodies specific to the target protein (here, a his-tag antibody). Figure 3-A shows the SDS-PAGE result for the expressed kinesin heavy chain in Escherichia coli purified in a Ni Sepharose column and separated by size exclusion chromatography using a Superdex 200 column. Following electrophoresis, the polyacrylamide gel was stained with coomassie brilliant blue dye to allow visualization of separated protein bands, as seen in the figure. The first lane in the SDS-PAGE corresponds to the molecular weight marker (New England Biolabs), whereas lanes 2-10 are different Superdex 200 elution fractions. Since the designed kinesin protein has a molecular weight of 48 kDa, observation of Figure 3-A seems to indicate the presence of kinesin in fractions 2-10. Kinesin expression was supported by the Western Blot technique, where eluted fractions shown in Figure 3-A where detected with a fluorescent-labeled his-tag antibody (Santa Cruz Biotechnology). As illustrated in Figure 3-B, the kinesin protein was confirmed to be present in fractions 2-10.

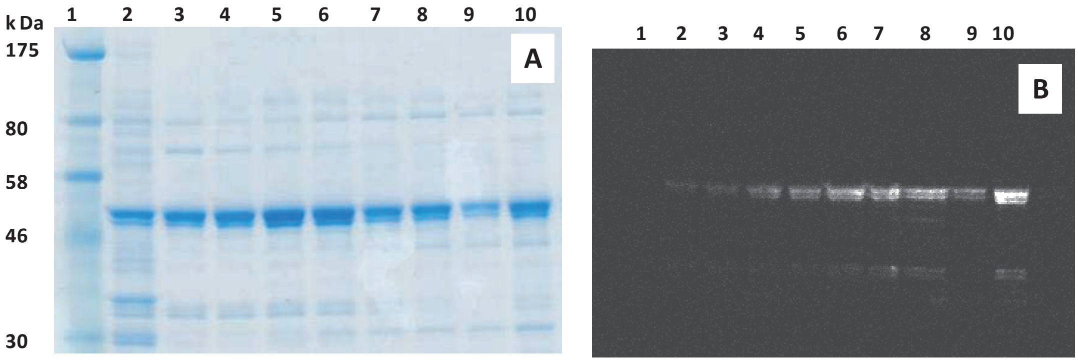

Figure 3. (A) SDS-PAGE: Lane 1, Molecular Marker; Lanes 2-10, Superdex 200 eluted fractions. (B) Western Blot with fluorescent labeled his-tag antibody: Lane 1, Molecular Marker; Lanes 2-10, Superdex 200 eluted fractions.

Following successful kinesin heavy chain preparation, the formation of microtubules was studied by controlling the polymerization of tubulin. A mixture of unlabelled tubulin and rhodamine-labelled tubulin was polymerized yielding stable fluorescent microtubules. Flow-cells constructed by the juxtaposition of KOH-cleaned cover slip and a microscope slide using double sided tape were used to observe microtubules with the fluorescent microscope. GTP (Guanosine-5'-Triphosphate) analogs are known to promote the polymerization of microtubules and also to prevent their depolymerization [10]; therefore, two GTP analogs where tested to study the difference, if any, in prepared fluorescent labeled microtubules, namely guanosine-5-[(,)-methyleno] triphosphate, and guanosine-5'-monophosphate salts. It turns out that microtubules prepared with the latter salt are considerably longer than the ones prepared with the former salt. The reason for this is currently under investigation. Since the major components of the constructed nanotransport system are fluorescent (rhodamine-labelled microtubules for tracks and fluorescent quantum dots to be transported by kinesin), fluorescence microscopy is an elegant choice to visualize such systems. Microtubules shown in Figures 4-A and B were obtained after guanosine-5'-monophosphate salts polymerization, and microtubules on Figures 4-C and D were visualized after guanosine-5-[(,)-methyleno] triphosphate polymerization. A clear size difference in microtubules polymerized with the two distinct promoters can be easily observed by the corresponding fluorescence images.

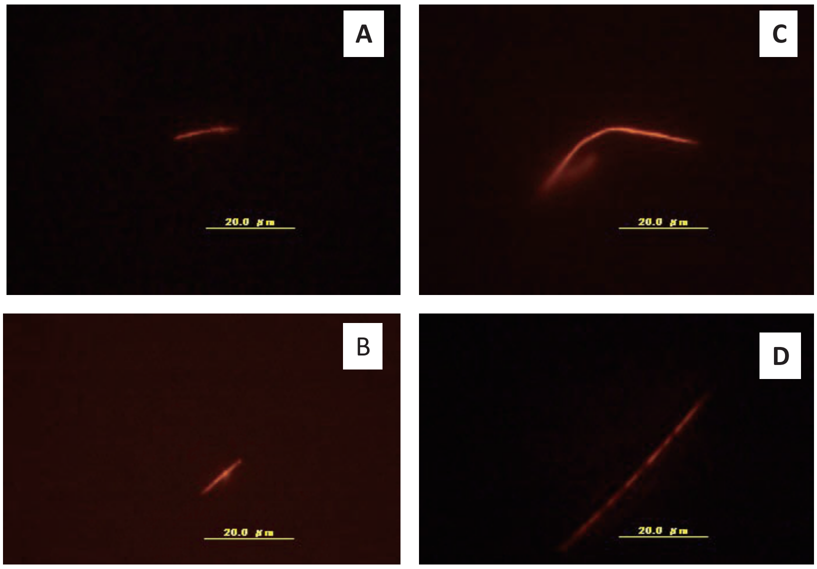

Figure 4. Microtubule fluorescent images. (A) and (B) microtubules polymerized in the presence of Guanosine-5'-monophosphate salts; (C) and (D) microtubules polymerized with Guanosine-5-[(,)-methyleno] triphosphate. Scale bar is 20 µm.

Following microtubule fluorescence observation, the kinesin-semiconductor nanocrystals complex, which consisted of biotinylated kinesin labeled with commercially available streptavidin-coated quantum dots (Qdot 605 nm, Invitrogen Corp), was assembled using a mixing ratio of 7 kinesin monomers per quantum dot. To visualize the kinesin-quantum dot conjugate interacting with the microtubule track, the same procedure described in Figure 4 was followed except that after injecting the microtubule solution, the kinesin/quantum dot complex was flushed into the flow cell. Because of the linear motion observed, Figures 5 A-C are interpreted to show quantum dot motion along microtubules, where pictures A to C correspond to fluorescent time elapsed images collected every 500 ms, respectively. Due to equipment limitation, we are not able at the present time to unambiguously rule out other interpretations since no microtubules were directly observed near the quantum dots. Efforts are currently being made to overcome the problems in the fluorescent observation of kinesin-quantum dot conjugates by (1) using semiconductor nanocrystals with different emission wavelengths, (2) altering the length of microtubules, and (3) varying the ratio of kinesin to quantum dots. It should be noted that the fluorescence images shown in Figures 4 and 5 were obtained with a relatively low resolution system, coupled with a standard CCD camera (DP71). We are in fact currently assembling a state-of-the-art microscope at WPI-AIMR capable of providing the high level of precision and accuracy required for the direct observation of microtubules and more importantly, kinesin/nanoparticle complex motion on microtubules networks. Such a system, which is expected to be fully operational in September 2010, consists of an inverted fluorescence microscope (IX71, Olympus) equipped with a Total Internal Reflection condenser (IX2-RFAEVA, Olympus); evanescent illumination will be provided by the 488 nm line of an argon ion laser. Fluorescent images will be acquired with an electron multiplier charge couple device (ImageEM C9100-13, Hamamatsu). With this new instrument, we expect to be able to resolve and distinguish microtubules and quantum dots simultaneously.

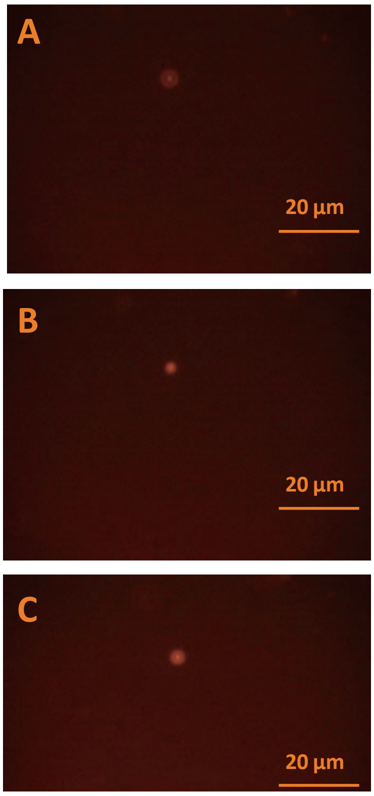

Figure 5. QD motion along microtubules. Images (A), (B) and (C) were collected with 500 ms intervals.

3. Summary

We have initiated an effort at WPI-AIMR in early 2010, which is aimed at understanding and constructing novel biomolecular systems for nanomaterials transport. Recombinant kinesin heavy chains have been expressed in Escherichia coli cells and confirmed based on their molecular weight by SDS-PAGE and Western blot. In addition, microtubules networks were systematically polymerized and their length could be manipulated by controlling the addition of specific polymerizing promoter reagents. Furthermore, the artificially created kinesin proteins could be conjugated with fluorescent-labeled quantum dots and visualized by fluorescence microscopy. Deeper insight into such nanoscale transport systems will be achieved once the Total Internal Reflection Fluorescence (TIRF) microscope is fully operational, providing the high level of precision and accuracy required to the direct observation of such phenomena.

Acknowledgements

We acknowledge crucial support by our collaborators in the laboratories of Prof. Adschiri and Prof. Umetsu.

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Engineering the Cellular Microenvironment

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Human physiology associates specific functions with each organ, for example, the liver acts as a filter for harmful substances contained within blood, it stores vitamins and minerals, and it produces cholesterol whereas the kidney filters blood and makes urine. These functions are specific to tissues even though the cells that make up tissues exhibit plasticity in their differentiated state. The earliest examples that exploit the instability of cells in tissues induced corneal epithelium to produce hair and transformed carcinoma cells into normal tissues (Figure 1) [1, 2]. These examples

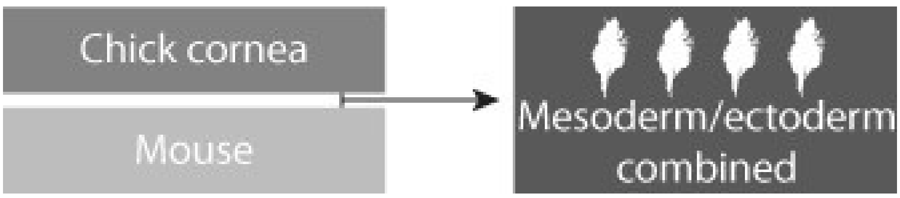


Figure 1. The role of the cellular environment. The embryonic recombination of mouse ectoderm with chick mesoderm produces an identity determined by the ectoderm; in this case, corneal epithelium grows feather appendages.

indicated that the cellular microenvironment played an essential role in the function of cells.

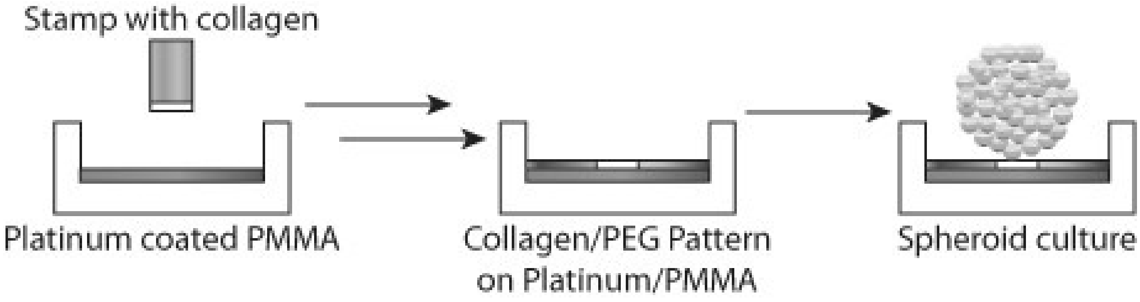
Materials and Methods for Engineering the Cellular Microenvironment.

Researchers can create tissue-like microenvironments using tissue extracts or synthetic hydrogels. These materials include alginate, collagen [3], laminin-rich ECM [4], Matrigel (extracted from Engelbreth-Holm-Swarm mouse sarcoma), and photosensitive hydrogels [5]. The purpose of synthesizing and using biocompatible materials and fabricating ordered structures from these materials is to control the location of cells within the structured material. A suite of rapid prototyping tools developed under the heading of 'soft lithography' makes the patterning and control of liquids and polymers at the microscale possible [6]. Combining soft lithography with the natural and synthetic materials for cell culture presents intriguing possibilities for controlling where cells grow in 3D, stimulating selective populations of cells, and engineering tissues from several types of cells.

Takeuchi et al. used an axisymmetric flow-focusing microfluidic device to fabricate hydrogel beads that contained cells [7]; the hydrogel beads self-assembled from a solution of peptides when exposed to ions. The combination of microfluidics, materials science, and cell biology exemplified in this work solved several problems for cell culture in 3D, namely, eliminating large chemical gradients that characterize millimeter-sized gels formed using conventional well plates and it simplified the preparation of beads that contain multiple types of cells. The same combination of microtechnology and biomaterials can provide control over the assembly of individual pieces of engineered tissue constructs. Sia et al. demonstrated the use of hydrogels that contain fibers of collagen that attach to neighboring hydrogels that contain fibers of collagen [8]. The ability to control how different and multiple phases of hydrogels interact at the molecular scale is likely to instruct the assembly of complex tissues using natural materials.

Several methods are available that produce aggregates of cells without using any material substitute for the ECM; these methods include suspending a drop of cells on an inverted substrate [9] and confining cells to chemically and topographically defined regions of a substrate (Figure 2) [10–12]. The design of micron sized tissues using aggregates enables the size of the tissue to be controlled, which maximizes aggregate size and prevents oxygen and nutrient deficiencies within the aggregate; multiple types of cells can assemble in aggregates and organize among themselves; and, unlike microfluidics, the forces that cells experience during aggregation are unlikely to affect their function.

Figure 2. Substrates that contain topography cause cells to aggregate into spheroids. A pattern of adhesive (collagen) and non-adhesive (poly(ethylene glycol), PEG) regions are fabricated in a microwell using a stamp. Cells adhere selectively to the collagen and the



Biological Phenomena Unique to Cell Culture in 3D.

What is probably most compelling in justifying the study of 3D cell culture is the manifest differences in behavior between cells cultured on two-dimensional substrata and those in three-dimensional matrices. The morphological differences between cells cultured in 2D and 3D are distinct. In 3D, fibroblast cells exhibit dendritic extensions or are bipolar and stellate (which morphology is observed is a function of how restrained and stiff the matrix is), however, on 2D substrata fibroblast cells are flat and are distinguished by stress fibers.

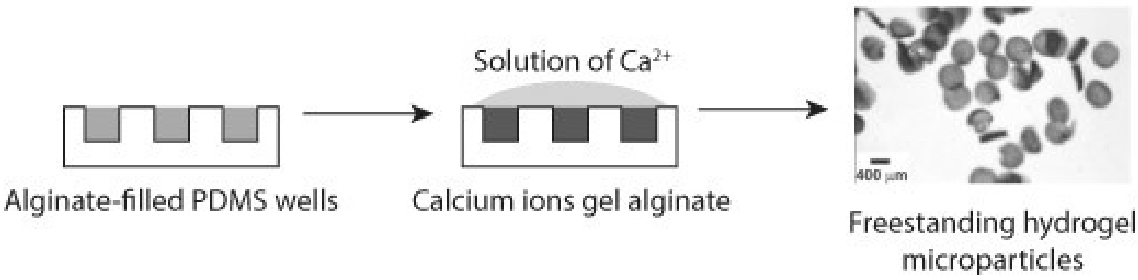
Bissell et al. developed a conceptual framework for thinking about the relationship between cells and their microenvironment using breast cancer as a model system [13, 14]. One of several outcomes from this framework was evidence that 3D cell culture models can be used to identify functional genes and proteins and validate targets for therapy. For example, the ß1-integrin receptor mediates cell-extracellular matrix interactions and increased expression of ß1-integrin correlated with poor survival in patients, however, down-modulation of ß1-integrin results in reversion of the malignant phenotype by arresting growth and restoring tissue polarity when propagated in a 3D microenvironment. Addition of ß1-integrin inhibitory antibody to tumor cells cultured in laminin-rich ECM gels decreased the rate of proliferation and numbers of cells and increased apoptosis.

The relationship between, for example, fibroblasts and collagen matrix is reciprocal: fibroblast cells remodel the matrix, which increases the tension within the matrix, which feeds back into the cells and alters the mechanisms that are used to further remodel the matrix. Primary hepatocytes, when cultured on collagen or basement membrane proteins, assume their differentiated shape and they express high levels of mRNA for liver-specific genes [15]; in contrast, the same cells cultured on plastic substrata exhibit a dedifferentiated, flattened shape, because the substratum is inelastic; liver-specific gene transcription also declines dramatically on flat substrata.

Aggregates of cells can be used to produce protein therapeutics in quantities several times greater than the amounts produced by suspended cells in protein-free media, however, it is unclear if this phenomenon can scale to compete with bioprocesses that are currently used for production of proteins [9].

Our Research Program.

Our lab focuses on problems that exist at the interface of microfabrication, materials science, microscopy, and cell biology and range from manipulating individual cells to organizing thousands of cells. We demonstrated the fabrication of monodispersed alginate gels that contained cells using biocompatible polymer membranes (Figure 3) [16] and we developed methods that modify the most popular material for microfluidics research (poly(dimethylsiloxane), PDMS) with fluorescent quantum dots for sensitive readout of temperature in microchannels [17] and with



paraffin wax, which rendered PDMS airtight [18].

Our recent work uses topographically defined substrates to create spheroid cultures of cells and organizes multiple types of cells cultured in collagen gels. These projects are part of our continuing efforts to demonstrate the simplest methods that can

Figure 3. Fabrication of individual pieces of hydrogel that contain bacterial cells using a microfabricated membrane. PDMS wells pattern the location and geometry of a solution of alginate, which is converted to a gel when exposed to a solution of divalent ions, for example,

culture cells in their natural environments and to characterize their behavior using accessible microscopy tools. We expect the outcome of our efforts to define methods that provide appropriate metabolites and nutrients for each type of cell in a multicellular engineered tissue.

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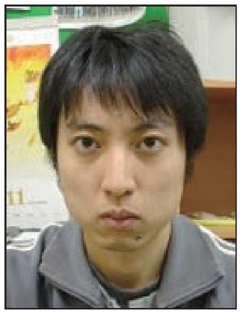

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Newly Appointed Adjunct Professors

Erratum

Newly Appointed Adjunct Professors, WPI-NEWS 11, December 24, 2011, page 122

The introduction of Newly Appointed Adjunct Professor misstated Professor Hideo Ohno's title. He is Adjunct Professor at WPI-AIMR.

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1991-1995 Professor, Faculty of Integrates Arts and Sciences, Hiroshima University
1995-present Professor, Research Institute for Electronic Science, Hokkaido University

1984-11-12 Guest Research Fellow, University of Heidelberg, Germany
1987-01-04 Guest Research Fellow, Department of Mathematics, Brigham Young University, USA
1988-01-03 Guest Research Fellow, Stichting Mathematisch Centrum, Netherlands
2002-01-03 TICAM Faculty Research Fellow, University of Texas (Austin), USA
2003-2005 Director, Research Institute for Electronic Science, Hokkaido University
2007-present Research Director of the JST Mathematics Program "Alliance for Breakthrough between Mathematics and Sciences"

RECOGNITION:

- ✦ Autumn Prize, Math. Soc. Japan (2002)
- ✦ Lecturer for Distinguished Colloquium Series of IAM-PIMS-MITACS, UBC, USA (2008)

CURRENT RESEARCH:

- Dynamics of patterns and waves
- Global bifurcation approach to nonlinear dynamics
- Collision dynamics of spatially localized patterns
- Adaptive behaviors of amoeboid locomotion

Toshikazu SUNADA

PRIMARY AFFILIATION:
Professor
Department of Mathematics, Meiji University
1-1-1 Higashi-Mita, Tama-ku, Kawasaki, Kanagawa, 214-8571, Japan
Tel: +81-(0)44-934-7462
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E-mail: sunada@isc.meiji.ac.jp

ACADEMIC:

1972 B.S., Tokyo Institute of Technology, Japan
1974 M. S.,The University of Tokyo, Japan
1977 Dr. of Science, The University of Tokyo, Japan

PROFESSIONAL EXPERIENCE:

1974-1975 Research Associate, Nagoya University
1975-1977 Research Associate, The University of Tokyo
1977-1979 Assistant Professor, Nagoya University
1979-1988 Associate Professor, Nagoya University
1988-1991 Professor, Nagoya University
1991-1993 Professor, The University of Tokyo
1993-2003 Professor, Tohoku University
2003-present Professor, Meiji University

1979-1980 Guest researcher at Bonn University, USA
1988 Guest professor at Institut des Hautes Etudes Scientifiques (IHES), France
2007 Organizer of a special project at Isaac Newton Institute at Cambridge
2008 Visiting professor of Max Planck Institute, Germany
2008 Andrejewski Lecturership at Humboldt University in Berlin under the auspices of the Walter and Eva Andrejewski Foundation as a distinguished scholar, Germany

[1] Member of the board of Mathematical Society of Japan (two times)
[2] Committee member of Kyoto Prize (three times)
[3] Member of the delegation to IMU (three times)
[4] Committee member of CDE in IMU (three terms)
[5] Head of a ``Good Practice" project in Meiji University supported by Ministry of Education
[6] Chairman of the scientific committee of Asian Mathematical Conference 2009 (AMC 2009) held at Malaysia
[7] Panel member of the European Research Council (an organization set up to promote outstanding, frontier research in all areas of science and humanities throughout Europe)

RECOGNITION:

✦Iyanaga Prize of Mathematical Society of Japan (1988)
✦Professor Emeritus of Tohoku University since 2003

CURRENT RESEARCH:

Topological Crystallography: Applying ideas in algebraic topology (theory of covering spaces and homology theory), discrete geometric analysis, and discrete algebraic geometry to a systematic enumeration of crystal structures

Ichiro TSUDA

PRIMARY AFFILIATION:

Professor
Research Institute for Electronic Science,
Hokkaido University
Kita 12 Nishi 6, Kita-ku, Sapporo 060-0812, Japan
Tel: +81-11-706-3824
E-mail: tsuda@math.sci.hokudai.ac.jp; tsuda@es.hokudai.ac.jp

ACADEMIC:

1977 B.S. in Physics, Osaka University, Japan

1982 D.SC. in Physics, Kyoto University, Japan

PROFESSIONAL EXPERIENCE:

1982 Post-Doc, Kyoto University

1982-1983 Research member of bioholonics national project. Research Development Corporation of Japan (the present JST)

1983-1988 Group leader of basic design group, bioholonics project. RDCJ

1988-1993 Associate Professor, Department of Artificial Intelligence, Faculty of Computer Science, Kyushu Institute of Technology

1993-1995 Professor, Department of Mathematics, Hokkaido University

1995-2005 Professor, Department of Mathematics, Graduate School of Science, Hokkaido University

2005-present Professor, Research Institute for Electronic Science (RIES), Hokkaido University

2008-present Director, Research Center for Integrative Mathematics, Hokkaido University

2009-present Project Leader, a Grant-in-Aid for Scientific Research on Innovative Areas “The study on the neural dynamics for understanding communication in terms of complex hetero systems (No.4103)”

1998-2001 Senior Visiting Researcher of COE, Electro Technical Laboratory(the present Advanced Industrial Science and Technology)

1999-2001 Visiting Professor, Fujitsu Endowed Chair "Sciences of Complex Systems" JAIST

2001-present Visiting Professor, Department of Intelligent Machine Systems Engineering, Graduate School of Engineering, Osaka University

2002-present Advisory board of The Research Center for Complex System Studies at Kalamazoo College, USA

2007-present Visiting Professor, Brain Science Institute, Tamagawa University

RECOGNITION:

✦HFSP Award (2010)

CURRENT RESEARCH:

・Chaotic Dynamical Systems, Complex Systems, Computational Neuroscience

Fred WUDL

PRIMARY AFFILIATION:

Professor of Chemistry and Materials,
Co-Director CPOS
Department of Chemistry and Biochemistry
University of California, Santa Barbara
CA 93108, USA
Tel: +1-805-893-5817
Fax: +1-805-893-3803
E-mail: wudl@chem.ucsb.edu

ACADEMIC:

1964	Bachelor of Science, University of California, Los Angeles, (UCLA) ,USA
1967	Ph.D., University of California, Los Angeles, (UCLA) , USA

PROFESSIONAL EXPERIENCE:

1968 - 1972	Assistant Professor, State University of New York, Buffalo, New York ,USA
1972 - 1974	Member, Technical Staff, Bell Laboratories, Murray Hill, New Jersey ,USA
1974 - 1982	Supervising Member, Technical Staff, Bell Laboratories, Murray Hill, New Jersey ,USA
1982 - 1994	Professor, Chemistry and Physics, University of California, Santa Barbara ,USA
1994 - 1997	Professor, Chemistry and Materials, University of California, Santa Barbara ,USA
1997 - 2006	Dean M. Willard Professor of Chemistry (formerly Courtaulds Professor of Chemistry), University of California, Los Angeles ,USA
2006 - present	Professor of Chemistry and Materials, University of California, Santa Barbara ,USA
2006 - present	Co-Director CPOS, University of California, Santa Barbara ,USA
2008 - 2009	Acting Associate Director of the California NanoSystems Institute, University of California, Santa Barbara ,USA

RECOGNITION:

- ✦ Peter A. Leermakers Lecturer (1988)
- ✦ Fellow of the American Association for the Advancement of Science (1989)
- ✦ Visiting Scientist at the C.N.R.S. "Postes Rouge" Orsay, France (1992)
- ✦ William Rauscher Lecturer in Chemistry Award (1992)
- ✦ Karcher Lecturer, University of Oklahoma (1992)
- ✦ Peter A. Leermakers Lecturer (1992)
- ✦ 3M Lecturer, University of British Columbia (1992)
- ✦ Arthur D. Little Award; Arthur C. Cope Scholar Award; Stouffer Award, USC (1993)
- ✦ Wheland Medal, University of Chicago; The "Giulio Natta" Medal, Rome; Clapp Lecturer, Brown University (1994)
- ✦ American Chemical Society Award for Chemistry of Materials; Bayer Lecturer, Cornell University (1996)
- ✦ Alumnus of the Year Award from Los Angeles City College (1997)
- ✦ Herbert Newby McCoy Award; Member, American Academy of Arts and Sciences (2001)
- ✦ D.Sc. (Honoris Causa), Universidad Complutense, Madrid, Spain (2004)
- ✦ Professor C.N.R. Rao Lecture Award of CRSI; Honorary Fellow, Chemical Research Society of India (CRSI) (2005)
- ✦ Merck-Karl Pfister Visiting Professor in Organic Chemistry, MIT (2006)
- ✦ Tolman Medal of the SCALACS (2007)
- ✦ Professional Achievement Award, University of California, Los Angeles (2008)
- ✦ Fellow of the Royal Society of Chemistry; Stephanie L. Kwolek Award, Royal Society of Chemistry (2010)

CURRENT RESEARCH:

- Currently we are interested in the optical and electro optical properties of processable conjugated polymers, as well as in the organic chemistry of fullerenes, and the design and the preparation of self-mending polymers. We have been studying single component re-mending polymers. Below we show the results of a mechanical properties study where the birefringence is correlated with deformation of the material.
- We continue to perform research on plastic solar cells with the goal of developing new materials to improve the efficiency of the solar cells within the concepts developed at UCSB over a decade ago, as well as employing possible new concepts.

Hitoshi SHIKU

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Associate Professor
Graduate School of Environmental Studies
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Fax: +81-22-795-6167
E-mail:shiku@bioinfo.che.tohoku.ac.jp

ACADEMIC:

1994 B.E. in Applied Chemisty, Department of Engineering, Tohoku University, Japan
1997 Doctor of Engineering, Tohoku University, Japan

PROFESSIONAL EXPERIENCE:

1996-1998 JSPS Research Fellowship for Young Scientist
1998-1999 Postdoctoral Fellow, The University of Kansas, USA
1999-2003 Senior Researcher, Yamagata Public Corporation for the Development of Industry
2003-2007 Assistant Professor, Graduate School of Environmental Studies, Tohoku University
2003-2007 Assistant Professor, Graduate School of Environmental Studies, Tohoku University
2007-present Associate Professor, Graduate School of Environmental Studies, Tohoku University

RECOGNITION:

✦Sano Award for Young Scientists, Electrochemical Society of Japan (2004)
✦Ichimura Academic Award (2009)
✦Young Scientist's Prize for the Commendation of Science and Technology by the Minister of Education, Culture, Sports, Science and Technology (MEXT) (2009)

CURRENT RESEARCH:

・Scanning Electrochemical Microscopy for Probing Respiration of Individual Mammalian Embryos
・Single-Cell Analysis Based on Scanning Probe Techniques
・Integrated Cell Cultivation Devices to Control Micro-Environmental Conditions

Global Intellectual Incubation and Integration Lab (GI^3 lab)

GI^3 Laboratory

In order to strengthen international fusion/joint research and construct a world "visible center", we started "Global Intellectual Incubation and Integration Laboratory (GI^3 Lab)" program in 2009. The original target of GI^3 Lab was to establish a global stream of young bright brains (young and excellent researchers and students) gathering at WPI-AIMR from all over the world. Now, we expand the target of GI^3 Lab to senior researchers, integrating existing IFCAM visiting professorship.

Briefly stated, GI^3 Lab will accept following researchers.

1. Senior Researchers: Visiting Professorship and Associate Professorship
2. Junior Researchers: Visiting Scientists

Ⅰ. Senior Researchers

Qualified researchers who may be interested in GI^3 visiting professorship should first contact the WPI-AIMR principal investigators (PIs) of the related research fields. Your contact PIs will initiate the further process to materialize the fusion/joint research.

(1) Tenure: For a period of one to three months.

(2) Financial: The salary varies, depending on the qualifications, based on the Tohoku University regulations. Roughly speaking, "full professor" receives 600,000 yen per month and "Associate Professor" receives 500,000 yen per month.

Ⅱ. Junior Researchers

We accept excellent young researchers and students who belong to foreign PIs' laboratories as WPI-AIMR visiting scientists. The PIs who would like to send them to GI^3 Lab should first contact the host PIs of the related research fields. The contact PIs will initiate the further process to materialize the fusion/joint research.

(1) Tenure: For a period of minimum a couple of weeks to a maximum of three months.

(2) Financial: We support living cost of about 100,000 yen per month and actual cost for accommodation.

For details, contact General Affairs Section at WPI Office:
wpi-shomu@wpi-aimr.tohoku.ac.jp

Global Intellectual Incubation and Integration Laboratory (GI^3 Lab) – April 2010 to March 2011

A. Senior Researchers <Visiting Professors/Associate Professors>

	Name	Host	Position	Term							Affiliation	Position	Nationality	Age	Research Topic
				From			~	Through							
1	GIOVAMBATTISTA, Nicolas	Tokuyama	Visiting Associate Professor	2010	6	28	~	2010	7	29	Brooklyn College of the City University of New York (CUNY), USA	Assistant Professor	Italy	38	Development of computer models to study polyamorphism in glassy
2	JABBARI, Esmaiel	Khademhosseini	Visiting Associate Professor	2010	7	16	~	2010	8	15	University of South Carolina, USA	Associate Professor	Iran	48	Effect of spatial pattern of osteogenic peptides on a biodegradable scaffold on mineralization and bone formation
3	LEE, Youn-Woo	Adschiri	Visiting Professor	2010	7	20	~	2010	10	19	Seoul National University, Republic of Korea	Professor	Korea	52	Fabrication of Nano Fusion materials by Supercritical fluid technology
4	ZHANG, Ze	Chen	Visiting Professor	2010	8	18	~	2010	9	17	Zhejiang University, P. R. China	Professor	P.R. China	57	Applications of Cs Corrected TEM upon Nanostructured Materials
5	PROCACCIA, Itamar	Tokuyama	Visiting Professor	2011	2	2	~	2011	3	1	The Weizmann Institute of Science, Israel	Professor	Israel	60	The statistical physics of amorphous solids

B. Junior Researchers and Students <Visiting Scientists>

	Name	Host	Position	Term							Affiliation	Position	Nationality	Age	Research Topic
				From			~	Through							
1	ALJERF, Moustafa	Louzguine (Yavari)*	Visiting Scientist (PhD Student)	2010	1	14	~	2010	4	14	Institute National Polytechnique de Grenoble, France	PhD Student	Syria	34	Mechanical and magnetic properties of metallic glasses
2	HAUBOLD, Marco	Esashi (Gessner)*	Visiting Scientist	2010 2011	3 1	17 4	~	2010 2011	4 1	5 28	Chemnitz University of Technology, Germany	PhD Student Scientist	Germany	27	・Grinding and polishing of lithium niobate substrate ・Deposition of gallium thin films(sputtering/vaporation) ・Integration of metallic glass structures into silicon MEMS using low temperature solid liquid interdiffusion (SLID) based on gallium and indium- evaluation of deposition and patterning techniques
3	CAO, Fei-Fei	Yamamoto (Wan)*	Visiting Scientist (PhD Student)	2010	6	15	~	2010	7	14	Institute of Chemistry, Chinese Academy of Sciences (ICCAS), P. R. China	PhD Student	P.R. China	26	Exploration on nanomaterials synthesis
4	TEOBALDI, Gilberto	Tsukada (Shluger)*	Visiting Scientist	2010	4 6	17 27	~	2010	4 7	30 6	University City College London, UK	Researcher	Italy	33	First-principles modelling of processes and STM/STS imaging at nanostructured surfaces
5	WATKINS, Matthew	Tsukada (Shluger)*	Visiting Scientist	2010	7	15	~	2010	8	5	London Centre for Nanotechnology, UK	Researcher	UK	33	Development of realistic tip models for simulating atomic force microscopy
6	MARTIN, Laura	Louzguine (Greer)*	Visiting Scientist (PhD Student)	2010	10	11	~	2011	1	21	University of Cambridge, UK	PhD Student	UK	24	Preparation of fully Biocompatible Bulk Metallic Glass
7	GABLER, Felix	Esashi	Visiting Scientist (Master Student)	2010	10	7	~	2011	3	11	Chemnitz University of Technology, Germany	Student	Germany	22	Development of deposition and structuring processes for application of metallic glasses for MEMS
8	LIN, Weichich	Esashi (Gessner)*	Visiting Scientist (PhD Student)	2010	11	1	~	2011	3	14	University of Cambridge, UK	PhD Student	Taiwan	33	Catalyst-Free Synthesis of Zinc Oxide Nanostructures by Microheaters in the Ambient Environment
9	ANNABI, Nasim	Khademhosseini	Visiting Scientist	2010	11	29	~	2011	2	2	The University of Sydney, Australia	Research Associate	Iran	30	・Development of a miniaturized microfluidic-based high-throughput cell toxicity to create an in vitro model of Parkinson's disease ・Fabrication of poly (ethylene glycol) (PEG) hydrogel containing concentration gradient of a model drug and its potential application for high throughput screening in drug
10	ROSCHER, Frank	Esashi (Gessner)*	Visiting Scientist	2011	2	12	~	2011	3	11	Chemnitz University of Technology, Germany	Scientist	Germany	26	Deposition of Metallic Glass thin films for the use as a normal low temperature bonding material

Note: * indicates the name of PI who dispatched the scientist.

GI^3 Activity Report of Felix GABLER
October 7th, 2010 - March 11th, 2011
Host: Professor Masayoshi ESASHI (Professor Thomas GESSNER)

During my stay at Esashi Laboratory in Tohoku University as a member of the WPI-AIMR Gessner Group I contributed to the cooperative german-japanese research project "NEMS/MEMS and Nanomaterial-enhanced Passive Components Compatible with Advanced Nano-CMOS for Future One-chip Tunable RF Systems". This frame project focuses on providing key technologies for future mobile wireless communication devices in the multi-GHz range.

My task was to study and design a "Low Temperature Cofired Ceramics (LTCC) Integrated RF Inductor with Nanoparticle Embedded Core" as part of the outlined frame project. This objective has been achieved by extensive software simulations with the sophisticated ANSOFT High Frequency Structure Simulator (HFSS). By means of the simulation results, different kinds of inductors have been designed and optimized for 2.4 GHz and 5.725 GHz respectively.

Another main issue was to carry out material measurements of the magnetic properties of promising high frequency soft magnetic materials like for instance nanocrystalline FeSiBPCu at multi-GHz range. These measurements have been realized under collaboration with the ECEI Laboratory of Prof. Yamaguchi. By including the measurement results into the software simulations, the possibility of enhancing the inductors performance by embedding soft magnetic materials into the LTCC substrate has been successfully confirmed.

The inductor designs have been successfully created and submitted to NIKKO Company for fabrication. Afterwards different kinds of soft magnetic materials will be embedded into the LTCC substrate. This will be done by the other members of GessnerGroup to continue the research project.

I would like to express my deepest thanks to all the members of WPI-AIMR and Esashi Laboratory for this opportunity and the great time in Japan.

GI^3 Activity Report of Wei-Chih LIN
November 1st, 2010 - March 14th, 2011
Host: Professor Masayoshi ESASHI (Professor Thomas GESSNER)

The major objective for the research project at the WPI-AIMR, Tohoku University is to develop a locally controllable method for synthesizing the zinc oxide (ZnO) nanostructures by the micro-fabricated microheaters. The research project is divided into the three issues that are the designs and fabrications of the microheaters; the experimental studies for the ZnO nanostructures synthesis and the analyses of the synthesized ZnO nanostructures.

The first section concentrates on the fabrication of the microheaters. Firstly, the geometries of the microheater are designed by the commercial software (Comsol) and fabricated, then, following with the MEMS processes. During the research period, three versions of the microheater fabrications are achieved in the Prof. Esashi's Lab and WPI cleanroom. Moreover, the optimized parameters in each process are acquired for the device fabrication. For instance, the sputtering parameters are investigated to deposit the Zn layer as an oxidized layer for ZnO nanostructure synthesis.

In the second part, the ZnO nanostructures are prosperous synthesized by the fabricated microheaters with applied voltages under various environments such us the different pressure and percentages of the oxygen and humidity. Furthermore, the appropriative synthesis parameters, which are the applied voltages (heat generation power) and the synthesized ambient, are gained through these experiments. Lastly, the characterizations of designed microheaters are studied by the IR camera and SThM probe for measuring the generated temperature to understand the relationship between the applied powers and ZnO nanostructures synthesis. Furthermore, the SEM, Raman and XPS spectrum are utilized to identify the geometries and crystal structures of the synthesized ZnO nanostructures.

Finally, the research results have been published to the WPI workshop and Nanotech, Tokyo 2011 and also are going to be submitted to the further conferences and journal papers. On the other hand, the research project is going to be continued in the Nanoscience Centre, Cambridge University.

GI^3 Activity Report of Dr. Nasim ANNABI
November 29th, 2010 - February 2nd, 2011
Host: Junior PI Ali KHADEMHOSSEINI

I was involved in two different projects during my research at WPI-AIMR in Tohoku University. The first project was about the development of a miniaturized microfluidic-based high-throughput cell toxicity to create an *in vitro* model of Parkinson's disease. This was achieved by generating concentration gradients of 6-hydroxydopamine along a microfulidic channel to trigger a process of neural apoptosis in pheochromocytoma PC12 neural cells cultured in the channel. The outcome of this project has been accepted for publication in Biomicrofluidics.

The second project was investigated the fabrication of poly (ethylene glycol) (PEG) hydrogel containing concentration gradient of a model drug and its potential application for high throughput screening in drug discovery studies. I was trained for the fabrication of microfluidic devices in the early stage of my research at WPI. Then, I collaborate with Dr. Serge Ostrovidov to produce results for a joint publication. In this project, a microfluidic gradient generator was used to create concentration gradient of okadaic acid (OA) as a model drug within the PEG hydrogel. The gradient hydrogel was then placed in close proximity of cell-coated surface to induce a gradient of cell viability through the release of OA from the gradient hydrogel. It was found that toxin was released from the hydrogel in a gradient manner and induced a gradient of cell viability. The miniaturized hydrogel containing drug concentration gradient developed in this study has potential to be used for drug discovery and diagnostics applications as it can simultaneously test the effects of different concentrations of drugs. It can also be used to screen molecular libraries for their effects on cell behavior such as proliferation, viability, differentiation and migration and overcome the problems associated by currently used cell-based *in vitro* assays. These assays are performed by seeding the cells within multi-well dishes and do not necessarily predict the function of drugs *in vivo*, which is resulted in a large number of failed drug candidates in animal experiments and clinical trials. The miniaturized microfluidic platform developed in our study may enable medical diagnosis in a more rapid and accurate manner and is of great potential for drug discovery and HTS cell-based assays. I am currently involved in preparation of a journal publication in collaboration with Dr. Serge Ostrovidov at WPI based on these results. We plan to submit this manuscript to the journal of controlled release shortly.

I acquired new experiences and skills on the fabrication of microfluidic devices during my visit at WPI; I would like to thank Prof. Khademhosseini and Prof. Yamamoto for giving me the opportunity to work at WPI and for their support during these two months.

GI^3 Activity Report of Dipl.-Ing. Marco HAUBOlD
January 4th, 2011 - January 28th, 2011
Host: Professor Masayoshi ESASHI (Professor Thomas GESSNER)

The objective of the research stay at the GI^3 Gessner Lab at Tohoku University follows two aspects for low temperature fabrication of semiconductor devices. On the one hand sputtered layers of metallic glass thin films have been evaluated. Therefore, a new sputter equipment for amorphous materials mainly was being introduced and set up at Micro-Nano Center (MNC) at Aobayama Campus. After several tests using RF and DC power, optimal parameters could be identified in order to deposit homogeneous layers of metals, required in MEMS/NEMS fabrication, such as titanium, copper or tin. These settings provided a basis for ongoing deposition investigations regarding zirconium based metallic glass thin films. XRD analysis of the produced layers showed significant peaks after the sputter deposition in comparison to the amorphous target. The observed profiles showed a partly crystallization of the layer which could be assigned to the alloy's components (e.g. zirconium, nickel). Within further investigations the crystallization could be avoided and the film's XRD measurement showed an amorphous character, comparable to bulk samples. The accomplished experiments are used as basic results for the application of metallic glass films within MEMS fabrication.

The low temperature bonding of semiconductor substrates was chosen as second research topic in order to meet today's and future's production conditions like the reduction of thermally induced stress in the case of heterogeneous material combinations and the minimization of energy consumption by the reduction of required process temperatures. In means of packaging techniques this approach demands for materials with a high reactivity at a low temperature, what is realized by solid-liquid-interdiffusion bonding (SLID bonding). Here, two or more metals are brought into atomic contact and are heated under applied mechanical pressure. The melting point of the resulting alloy is higher than the melting temperature of at least one involved element, following in a bond process below 200°C whereas the device can withstand 300°C or even higher temperatures. Potential low melting metals are seen to be indium or gallium, which are bonded with gold or copper. This topic is going to be investigated throughout one year by three different researchers who are seconded from Fraunhofer ENAS Germany to the Gessner GI^3 lab at Tohoku University. The focus of their work is the deposition, structuring and bonding of low melting metals on silicon substrates to achieve mechanically stable and reliable housings for semiconductor device. As a first step, suitable chemical baths for the electro deposition of indium were identified and evaluated in order to prepare the upcoming deposition processes.

GI^3 Activity Report of Dipl.-Ing. Frank ROSCHER
February 12th, 2011 - March 11th, 2011
Host: Professor Masayoshi ESASHI (Professor Thomas GESSNER)

Due to the strong demand for Smart System Integration new packaging concepts will be necessary for the near future to solve problems like integration of hybrid materials, integration of CMOS and MEMS, 3D Integration and many more. Consumer electronics and medical devices get more and more complex and therefore new materials have to be integrated to fulfill all expected tasks whereas the packaging of such Si based MEMS devices normally needs elevated temperatures above to form eutectics and intermetallic bonds. These temperatures lead to intrinsic stress and affect the functionality of the device or even induce heavy damage and yield losses when using materials with a big CTE mismatch.

During the period of stay a new technology for wafer level bonding, by using solid liquid inter-diffusion SLID, was launched. The focus was the electrochemical deposition of Indium on Si substrates and subsequent bonding tests of a Gold – Indium SLID Bond at temperatures as low as 200°C. Therefore 2cm x 2cm Si chips where prepared as substrates and coated with 150nm thick Au seed layer by sputtering for electro plating. A Indium sulfamate bath operating at room temperature was used for electroplating of Indium thin films. The bath was used in standard beaker equipment while an Indium anode provides new Indium material during electro plating. The cathode is the Au coated Si chip while the “Anode to Cathode ratio” was 1:1. First tests regarding the homogeneity of the so deposited Indium layers contained the evaluation of the deposition rate when using an AC or a DC source and different current densities. Optimizes parameters where found at 80mA DC for an area of 400mm^2. For further bond experiments patterned structures were necessary. Si substrates where coated with the photo resist and a subsequent lithography was used to pattern this resist with frame like shapes. This SLID bond process required, that a Indium layer lays between two Au layers to ensure the diffusion from Indium into the Gold by forming a Indium Gold alloy. Whereas this diffusion starts at ~160°C the metallic compound formed during bonding has a much higher melting point (>400°C) which makes this SLID bonding suitable even for devices operating at higher temperature.

The bond frames where deposited successfully by using the above mentioned sulfamate plating bath and optimizes parameters for electro plating of Indium. The bonding was tested on hot plates at 200°C and it was shown that SLID bonding with Indium and Gold, both deposited by using electro plating, is possible. Further studies and experiments on this topic will be done by the Gessner Group as a part of the Esashi Lab within the GI3 program as well as at Fraunhofer ENAS located in Germany.

Announcement

Junior Faculty/Post-doctoral Positions

Tohoku University
WPI-AIMR

Effective October 1, 2007, Tohoku University created a new Research Institute, the Advanced Institute for Materials Research (AIMR), based on an initiative of the Japanese Department of Education (MEXT) for World Premier International Research Center Initiative (WPI) to bring together scientists involved in research on nano-science and technology.
In the 21st century, material science, broadly defined as the study of how complex/novel properties arise in matters/materials from the interactions of individual components, will comprise of inter-discipline collaboration.
(http://www.wpi-aimr.tohoku.ac.jp)
Over the next few years, as many as one hundred new appointments at the levels of post-doctoral fellows and junior faculty will be available. All innovative researchers are welcome as active promoters of basic/applied sciences in the fields of physical metallurgy, physics, chemistry, precision mechanical engineering and electronic / informational engineering.

We are continuously looking for excellent applicants throughout the year.
Please submit

1) **a curriculum vitae,**
2) **research proposal (<3,000 words),**
3) **summary of previous research accomplishments (<2,000 words),**
4) **copies of 5 significant publications, and**
5) **2 letters of recommendation**

by email to:
aimr@wpi-aimr.tohoku.ac.jp
All files must be submitted electronically in pdf or Word format.

Applications from, or nominations of, women and minority candidates are encouraged. Tohoku University WPI-AIMR is an affirmative action / equal opportunity employer.

Graduate Student Scholarship in Materials Science/Engineering

WPI-AIMR
Graduate Student Scholarship

Effective October 1, 2007, Tohoku University created a new Research Institute, the Advanced Institute for Materials Research (AIMR), based on an initiative of the Japanese Department of Education (MEXT) for World Premier International Research Center Initiative (WPI) to bring together scientists involved in research on nano-science and technology.
In the 21st century, material science, broadly defined as the study of how complex/novel properties arise in matters/materials from the interactions of individual components, will becomes an essential and most important research topics (http://www.wpi-aimr.tohoku.ac.jp)
TU WPI-AIMR is now looking for young motivated Ph.D. graduate student candidates in the fields of physical metallurgy, physics, chemistry, mechanical engineering and electronic / informational technology. All innovative M. S. students are welcome as active promoters of basic/applied sciences in these fields.

Applications are continuously screened throughout the year.
Please submit

1) **a curriculum vitae,**
2) **research proposal (<1,000 words),**
3) **2 letters of recommendation,**
4) by email to:

aimr@wpi-aimr.tohoku.ac.jp
All files must be submitted electronically in pdf or Word format.

WPI-AIMR
Workshop Guideline

Tohoku University's new Research Institute, the Advanced Institute for Materials Research (WPI-AIMR) solicits several applications per year for International Workshops in the field of "broadly defined Materials Science."

Guidelines:

1) Organizers

Qualified research staff of academic institutions and public or private research establishments can submit the application for an international workshop to be held at WPI-AIMR or its Satellite branches, jointly with the WPI-AIMR principal investigator(s) whose research interest overlaps with the scope of the workshop.

2) Financial support

Under normal circumstances, WPI-IMR supports up to 2/3 of the workshop budget, while the organizer is expected to cover the rest.

3) deadline

The application must be received at least four months in advance to:
aimr@wpi-aimr.tohoku.ac.jp
All files must be submitted electronically in pdf or Word format.

Appendix

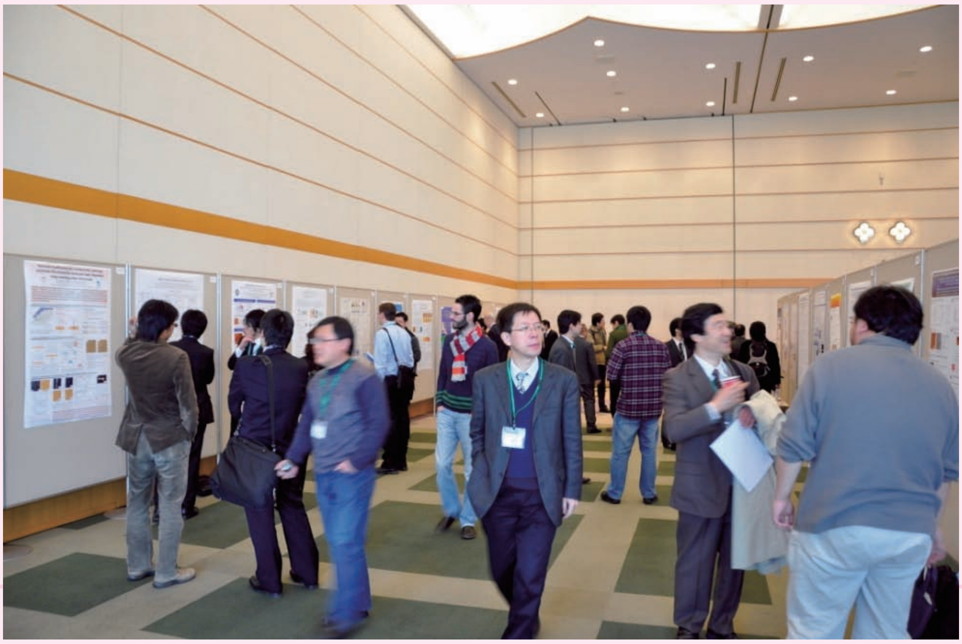
The 2011 WPI-AIMR Annual Workshop
February 22-24, 2011

The 2011 WPI-AIMR Annual Workshop
February 22-24, 2011

The 2011 WPI-AIMR Annual Workshop
February 22-24, 2011





The 2011 WPI-AIMR Annual Workshop
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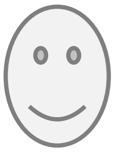

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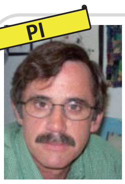

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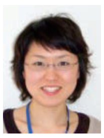

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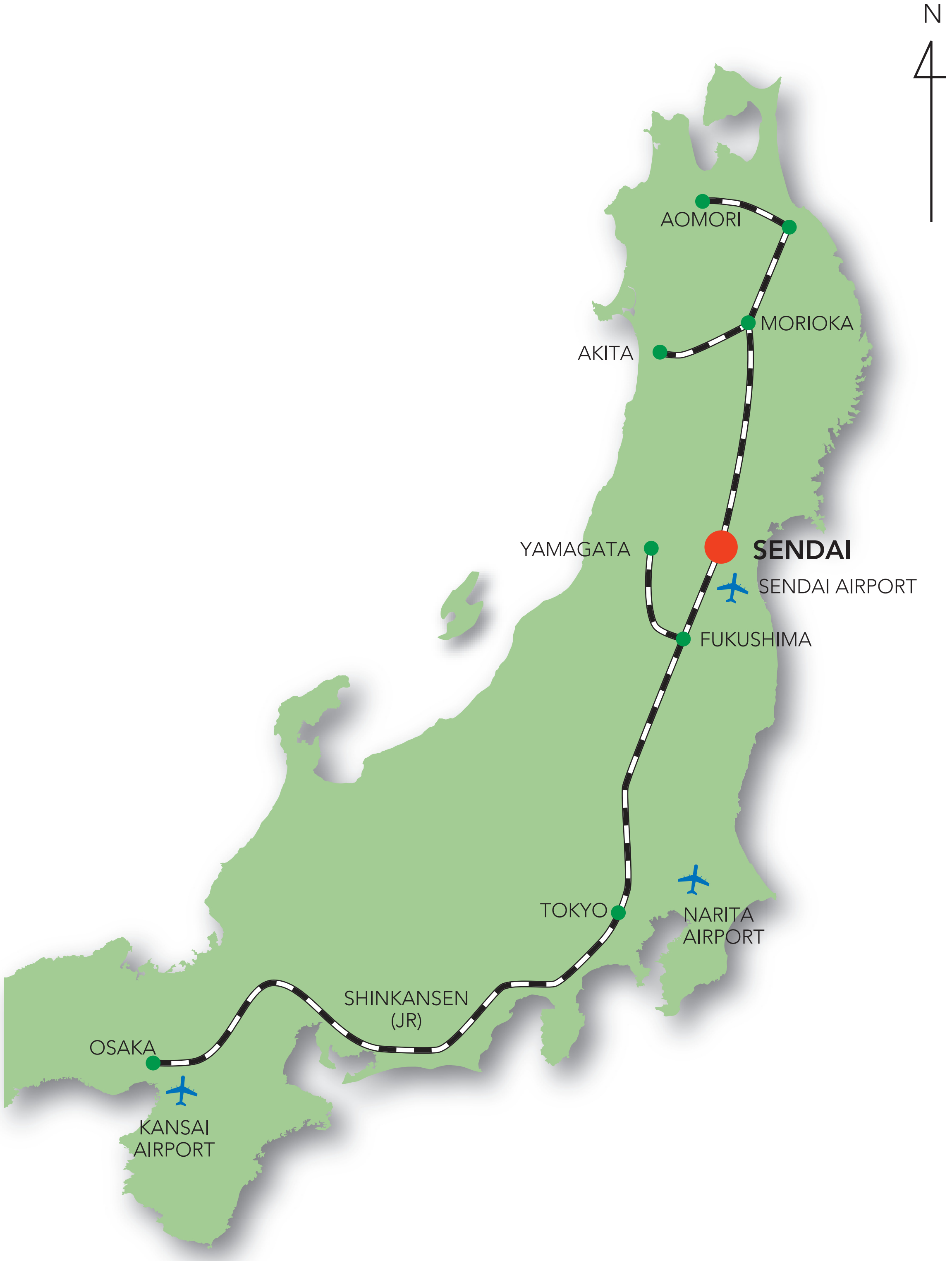

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