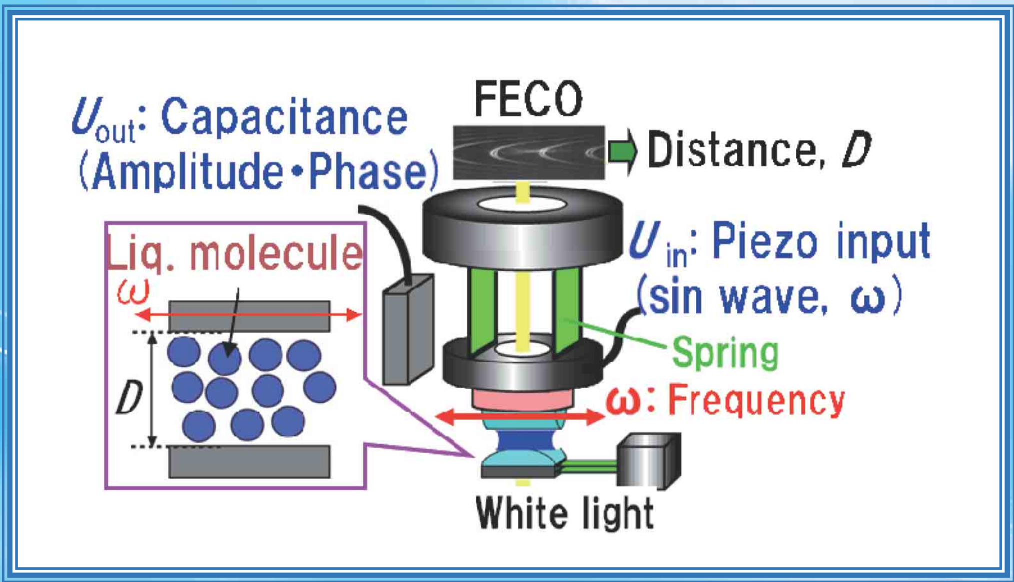
Volume 13

WPI-AIMR NEWS

August 31, 2011



World Premier International Research Center
Advanced Institute for Materials Research

Tohoku University

Cover:

RSM (resonance shear measurement) device for studying properties of liquids confined between solid surfaces by varying the separation distance between surfaces from 5 μm to the contact with 0.1 nm resolution. This original measurement can monitor changes in viscosity, lubrication, friction and structuring of confined liquids, and is a useful tool for nanorheology and nanotribology.

(Kazue Kurihara, WPI-AIMR)

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We welcome your comments, questions and involvement.
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Recovery from the Terrible Disaster on March 11 and New Deputy Director Professor Motoko Kotani

Yoshinori Yamamoto
Director, WPI-AIMR, Tohoku University

Nearly five months have passed since the terrible triple disasters happened on March 11—an extremely strong earthquake with a magnitude of 9.0, gigantic tsunami with heights of 10-20 meters (in some places greater than 30 meters), and the Fukushima Nuclear Power Plant problem. Now, things in Sendai have recovered to a level similar to that before the disasters. However, people in the coastal area are still experiencing serious problems. The activity of our AIMR institute, as well as of Tohoku University, has recovered to the same level as before. The situation at Fukushima is gradually being improved, but it will take a long time until the problem is settled completely. During the past few months, people all over the world have supported us both materially and spiritually, and I deeply appreciate all the offers you provided. It is a pleasure for me to say that now we are proceeding vigorously to recover from the disasters and to carry out the research activities and education at a much higher pace than before and with increased awareness about the earthquake.

Recently, Professor Motoko Kotani joined us as a deputy director. She is a well-known mathematician around the world. Please look at the Figure 1, which illustrates how the vector of AIMR research activities is changed by the injection of the mathematical perspective, in comparison with the conventional approach to materials science. In the first term of the WPI program (2007-2011), our team consisting of four research groups (BMG, material physics, soft materials, and device/system) has carried out world-class research of the highest level and performed extensive fusion research. For example, the creation of metallic nanoporous catalysts is an excellent example of fusion research between modern metallurgy and chemical science, and the development of MEMS devices is another example of fusion between device and modern metallurgy. Concerning both the outcome of those fusion research and accomplishments in each discipline, I think that the quality of science of AIMR has been at the world's top level. AIMR is a very unique materials research institute, in which seemingly totally different substances (metals and soft materials) are handled under one roof. This research condition has induced the unique fusion research mentioned above. In the second term of the WPI program (2012-2017), in addition to this unique fusion research, the introduction of mathematical science into the AIMR research groups is sure to not only enhance and catalyze fusion research but also create a new materials science. I believe that injecting math into the four research groups from 2011 changes the vector of both the research direction and activity, as shown in Figure 1, leading to a unique and leading hub for a new materials science in the world.

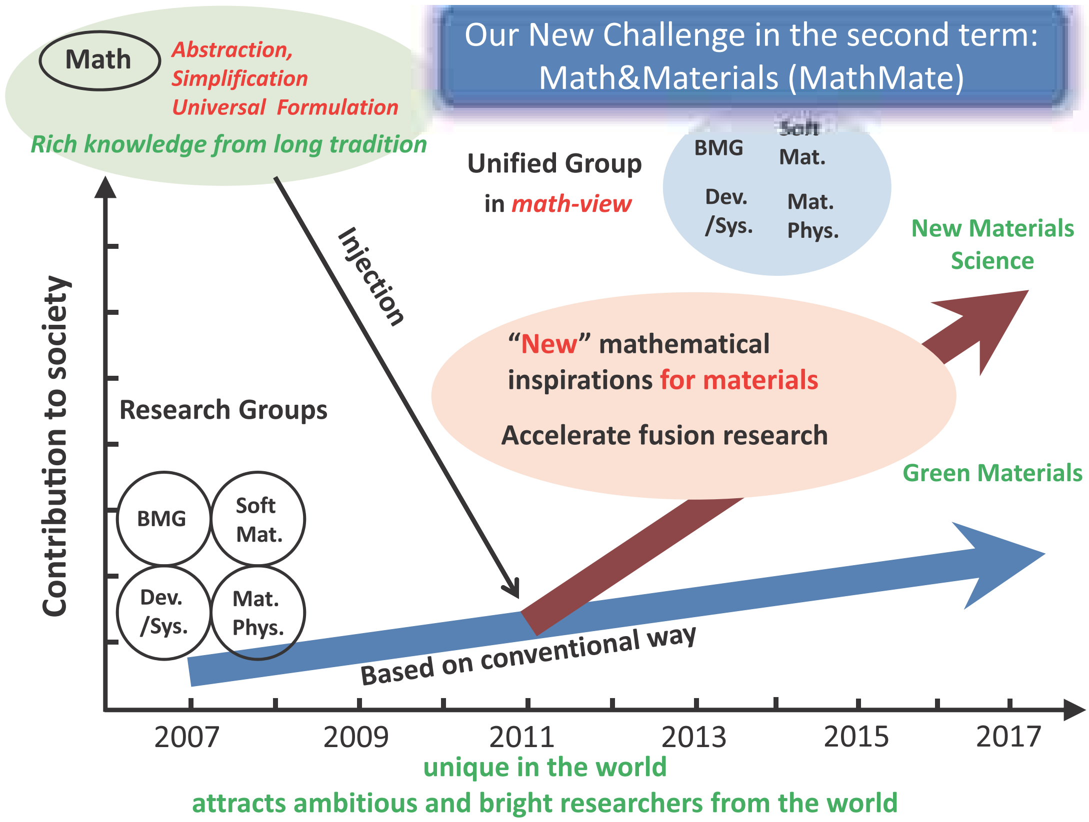


Figure 1

On August 10-11, reviewers for the interim evaluation came for a site visit in order to review the progress of AIMR's achievements and performance in science, fusion research, globalization and system reform. They gave us valuable advice and comments on our performance and future plan. I appreciate the strong cooperation and support of all the researchers and staff members of AIMR at the time when the site-visit review was being held in the new AIMR main building. I am sure that we will be able to create new materials science including mathematics in the second term (2012-2017) of the WPI program. This may be a challenging plan, but I believe that we will be able to build a world leading institute of materials science through such an entirely new challenge. I believe that the site-visit review process proceeded very smoothly without problems. Thank you very much for your assistance.

Interviews

Interview with Professor Motoko Kotani,

Deputy Director, Principal Investigator, WPI-AIMR

Mathematical Challenges at AIMR

Interests in Mathematics – from Harmonic Map to Discrete Geometric Analysis

Administrative Director Iwamoto (I): Thank you for taking time today. You joined WPI-AIMR as Principal Investigator at the end of March and are now working as Deputy Director. First of all, I'd like to ask where you are from.

Professor Motoko Kotani (K): I was born in Osaka and lived there until I was ten years old. Then, we moved to Kamakura City in Kanagawa Prefecture.

I: I see.

K: I went to Kamakura Junior High School affiliated with Yokohama National University, Tokyo Gakugei University Senior High School, and then the University of Tokyo. Because I went to a high school and a university in Tokyo, I feel like a quasi-Tokyo native.

I: Were you interested in science when you were a junior high school or high school student?

K: Yes.

I: Do you think your teachers had influences on that?

K: Yes, I think so.

I: Were you also interested in mathematics?

K: Yes, I became interested in mathematics when I was at junior high school.

I: In addition to your interests in mathematics and science, were you also involved in a lot of other activities such as club activities?

K: I preferred to read books or draw pictures alone rather than joining group activities.

I: Mathematics is a kind of study that you work alone diligently too, isn't it?

K: Yes, I think so. A mathematician is just happy without talking to anybody for a week or so

I: I guess the research style is very different from experimental researchers who work in a group. The library in the Mathematics Department is well stocked, which would help.

K: I think so, too.

I: You received a doctor's degree in 1990. What was the theme of your dissertation?

K: Differential Geometry, in particular harmonic map was my specialty. Harmonic map is, in simple words, a mathematical model of soap films and soap bubbles.

I: That was the theme for your doctoral dissertation, and what were your interests after that?

K: Next, I started working in Discrete Geometric Analysis, which has led me to my current research. There are two opposing concepts in mathematics, "Continuous" and "Discrete", and continuous spaces had been the main field of Geometry until at least the 20th century. However, in recent years there has been a trend to study discrete geometry.

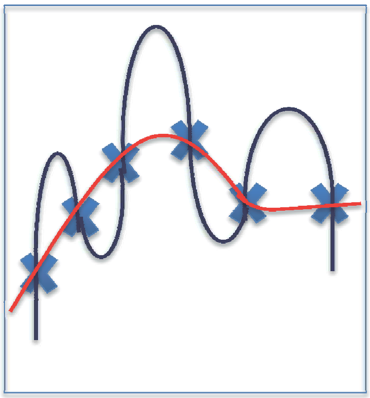
One of the backgrounds is the advancement of computers and the fact that it is now possible to handle a large volume of discrete data. It is not, however, a smart way to process a large volume of data one by one. A core structure should be extracted from the data; otherwise there would be no end to the process, even with a very advanced computer. What's needed is a smart method that can detect hidden structures in discrete data, and mathematics is very good at that.

I: So, traditionally only continuous object was studied, but now discrete object is studied too. Does it mean the data handled is detached from each other?

K: Yes. Data is generally discrete, isn't it?

I: Yes.

K: In science, we aim to extract meaningful information form a vast amount of data. You draw graphs based on experimental data. The data is actually plotted as dots. However, you do not get any meaning just through looking at these dots. So, you draw a curve to connect the dots, and then understand the trend of the data. Like this (see diagram). I've just drawn a curve readily, but is there any logic? If I draw differently, like this, it also goes through all the dots, but which one is correct? In science, the process of drawing curve must be justified. If there is no theory to justify it, it means that the process is based on experience and includes some arbitrariness. In order to avoid that, you ask yourself if more detailed analysis is needed around here, and if this part is really correct, or you come up with an assumption and insert different data to prove your conjecture. There is no end to it, and it will require more and more data. On the other hand, a small number of dots can capture the fundamental trend. If there is a theory that can determine how a curve goes through these dots, there is no need to create new dots between the existing dots.



I: I see.

K: This is where mathematics should be used. In other words, it is necessary to create a theory that explains how to draw a continuous curve to connect dots. Then, you will not need to take most of data.

I: I see. That's how you moved from harmonic map to discrete geometric analysis.

Aim of Research by CREST

K: My research proposal was approved by CREST Program in 2008. Before then I was studying so-called pure mathematics. Despite the background that I mentioned earlier, my research before 2008 was to find hidden structures in discrete data from a mathematical interest, rather than collaborating with other researchers in different fields. Then, I applied to CREST in 2008. This CREST is the first program that provided a large competitive research fund for mathematics, apart from Grant-in-Aid for Scientific Research.

I: Indeed.

K: Then, I wanted to apply in collaboration with materials science.

I: I see.

K: When I applied I took it easy and thought that I would carry on my research on pure mathematics and occasionally talk to the researchers in other fields; however, soon after I started I realized that there were a lot to learn and I had more opportunities to talk to the people in other fields. Around that time I started thinking about collaboration with other fields more seriously.

I: This CREST is supervised by Professor Nishiura at Hokkaido University, and your proposal "A Mathematical Challenge to a New Phase of Material Science -Based on Discrete Geometric Analysis-" was approved as one of the projects with high social needs. I often hear "pure mathematics" and "applied mathematics". Is your research regarded as applied mathematics?

K: It does not necessarily mean that I have switched to applied mathematics. I have just expanded my previous mathematical research. Traditionally pure mathematics and applied mathematics were considered to be pair concepts; however, recently it is regarded that they can be integrated to create a new academic study, namely, mathematical science. I do mathematical science with pure mathematics background.

I think mutually beneficial relationship between mathematics and other fields can be established. Mathematicians directly contact with other researchers in different fields and listen to their problems in order to stimulate and expand mathematics into a new direction. On the other hand, I hope the researchers in other fields will understand the advantages of mathematics.

I: I see. I understand.

Then, your current research for CREST is not something different from discrete geometric analysis that you mentioned earlier, but it is rather an extension of it.

K: Yes, it is more like a development and expansion (smile).

I: Professor Adschiri from WPI-AIMR is also participating in this CREST group. You and Professor Adschiri jointly published a paper about new metallic carbon crystal in 2009 (Phys. Rev.Lett.102,055703(2009)). So, you were already collaborating with materials science before the start of the CREST.

K: Yes, it is based on the research with Professor Sunada who is now Adjunct Professor of AIMR. Professor Sunada and I have been studying crystal lattices as a part of the study of discrete geometric analysis for about ten years since 2000. Later, Professor Sunada made a mathematical discovery of the K4 lattice in his own study. Based on mathematical requirements, there are only two crystal structures which satisfy natural properties; diamond lattice and K4 lattice. If one of the two is diamond, then does the other one - K4 lattice - really exist? Professor Sunada and I did not know the answer at that point. However, this was definitely significant issue and started discussing with various people in the university. Professor Adschiri was very much interested in this and we decided to try to compose it.

Of course, we didn’t think we could make it easily, so we started from simulations to determine the possibility. Then, Professor Sunada, Professor Adschiri, Professor Kawazoe, Professor Naito from Nagoya University and I had several discussions and conducted simulations, which resulted in the paper that you mentioned earlier. We came to a conclusion that although it may not be very stable it will be metastable and can be synthesized. So, we decided to make it, and I thought it would be good if we could do this as a subject in my CREST project.

I: So, your research on crystal lattices, which you mentioned arose from the mathematics world.

K: Yes. It is completely in the world of mathematics. I incorporated the viewpoint of harmonic map that I had been studying into discrete geometric analysis, and thought about what would be the most stable and balanced crystal structure based on the theory of harmonic map. That is the theme of the joint research with Professor Sunada: standard realization of crystal lattices. Standard realization is very useful in mathematics as it explains various issues. Therefore, I thought it would be useful in the real world.

I: I had a preconceived idea that you would abstract various data that was found in materials science, but based on what you’ve just told me, now I understand that the research came from the mathematics world.

K: We mathematicians are amateurs in the materials science field. It has its own great accumulated knowledge. Our understandings and opinions on this field will be just an amateur's suggestion. I would rather like to bring a brand-new viewpoint into the materials science to hopefully produce a new theory. Of course, this will not be an easy task.

Mathematics in AIMR

I: I remember that you emphasized at AIMR's meeting that mathematics will not be fused with materials science, but it will rather help other fields to be fused.

K: I think of the role of mathematics as a "catalyst". Each of the four groups in AIMR is forming a high peak. If we lower these peaks once then put them together, we can create an even bigger peak. To achieve this, it is necessary to input some catalysts in order to promote fusion. I think that is the role of Mathematics Unit in AIMR.

However, at the same time I would like Mathematics Unit to be stimulated by other fields and developed further. Then we may be able to start a totally new mathematics from there; that is also a motive for my participation.

I: I see. There are two purposes. Talking about the latter point of view, in the mathematics field, for example, the OECD report "Mathematics in Industry" was published and also "Mathematics as Deserted Science" was published in Japan in 2006. As a background, did you have a concern that it was necessary for mathematicians to send out information to the outside world?

K: Yes. It is of course necessary to do so, and I also think mathematics should change and expand. As with any academic field, there is a period for expansion in response to external stimulation, and a period for understanding itself based on its own value. I think mathematics has had a significant achievement in the latter direction in the last half century. However, as it becomes more and more advanced, I think it is becoming more restricted. This is my personal opinion and I suppose there are many people with different views.

I: The latest draft of the 4th Science and Technology Basic Plan also mentions about promoting mathematical science.

K: Yes, indeed. It is for the first time that mathematics is mentioned in the plan.

I: In addition, Ministry of Education, Culture, Sports, Science and Technology set up the Unit of Mathematical Innovation, and the government seems to start tackling it seriously. How about in other countries? You were invited to the Max Planck Institute in Germany and IHES in France. How mathematics is positioned in those countries?

K: I think Japan is rather behind in such matters.

I: I see. As Poincaré was from France, I guess mathematics is very popular there.

K: I think so. Mathematics is strongly linked to the science and technology policy and has a high status in France.

I: By the way, how do you describe the difference between theoretical physics and mathematics?

K: The traditional flow starts with pure mathematics and applied mathematics, followed by mathematical physics, theoretical physics and experimental physics, and then phenomena. Also, some theoretical physicists have a lot more focus on experimental physics while others focus on mostly mathematics. However, recent mathematicians are willing to change the traditional relation and be more involved in the study of phenomena. It is often the case that the same mathematical theory is used in various different academic fields, therefore, I expect if mathematics can be involved in these fields directly, various phenomena can be dealt in a uniform way. As the state-of-the-art science has become specialized, communication between different fields is not very easy at the moment; however, I think if those fields are put on the common foundation, namely mathematics, we can share a great source of ideas that has been developed individually in each field.

I: Does it mean that mathematics is used to translate and transfer highly specialized and advanced science issues? If so, mathematics will be a keyword in AIMR that is expected to accelerate fusion of various fields.

K: I think that is the role of Mathematics Unit.

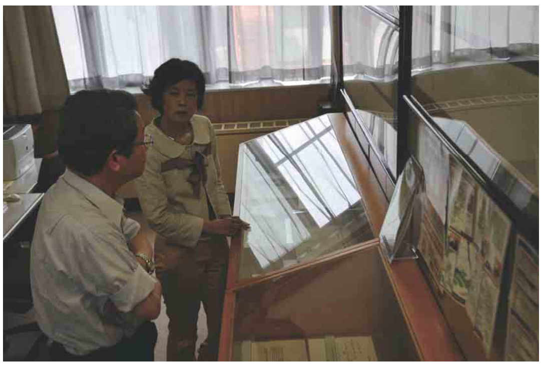
Expectations to AIMR

I: You have been in AIMR for a few months now. What do you think of the atmosphere?

K: According to other people, it seems to have changed a lot in one year. I think it seems to be improving to a great extent.

I: Yes. Currently the whole AIMR is working very hard. In addition to the hard work of PIs, all researchers, especially mid-career ones, are having discussions diligently.

K: I can feel there is willingness to discuss seriously and challenge the new directions in AIMR. I think AIMR can implement something very advanced that will make it a model for WPI.



I: I see. We hold tea time and joint seminars, and young researchers also hold study sessions. I would like to develop these activities further. Although fusion research is making a progress, there may be still a wall between laboratories.

K: Fusion of different fields is not an easy task. You hear a lot of interesting things from people in the different fields, which you think you may be able to develop using your methods. However, in reality it is rather difficult to spend energy on these things. You have your own research and are competing against the world, so you would like to use 100% of your energy for that. Even if you become interested in other things in your research, it is difficult to spend time on those, unless there is a strong force that can drive me towards them.

I: Yes, indeed.

K: I think WPI can create such systems. Research will not move forward if nobody thinks it is interesting. However, if there is an environment that enables us to challenge the issues that we have been interested in but have not taken any actions, things may move forward. This is a valuable opportunity and I would like to make it successful. It will be great if I can do so.

I: I agree with you. As you said, it is normal to compete against the world to reach the top of a certain field in academic world. It is of course important, but a new academic study may be produced as a result of fusion. You already have seen WPI in Kyoto University and Osaka University, and you know the University of Tokyo very well for a long time. What do you think of AIMR compared to these WPIs?

K: AIMR is more advanced in several aspects. There has been a trend to create a new academic study in research and the result has started to be produced. I think from the organizational point of view, it is ahead of others. One of the purposes of WPI program is to break the tradition of the university and reform the system for building the world's top research base. Tohoku University has set up an action plan called "Inoue Plan", and has been implementing various system reforms for five years. It is also actively promoting international collaborations and public relations. It also supports building independent environment for young researchers as well as new academic studies. These are the aim of the host university, and AIMR is characterized as a model for these activities. So, I guess the system reform is going comparatively well.

I: I think so too.

Nurturing Female Researchers

I: Changing the subject again, you won Saruhashi Prize in 2005, and also play an active part in Office for Women Researchers, Tohoku University. It is sometimes pointed out that the percentage of female researchers is low in AIMR. How do you think it can be improved?

K: I am often asked why it is necessary to nurture female researchers. There are several viewpoints, but I think it is important to nurture female researchers from the viewpoint of diversity. A breakthrough in research is a result of multiple rare events and the possibility of its occurrence is really minute. That is why it is important to keep the population rich and diverse. It is a waste of opportunity not to have many female researchers for traditional

reasons, as they consist of the half of the human resources. Similar to mathematics that we talked about earlier, it is an opportunity to incorporate a new female point of view, and nurturing female researchers will expand the possibility of the development of science significantly. The other viewpoint is the improvement of research environment. One of the missions of WPI is to create an ideal environment that attracts the world's top researchers. For this reason, creating a better environment for women can be a benchmark. An environment where you can concentrate on research and at the same can cherish your private life. A female friendly environment is not only beneficial for women but also for human beings.

I: Yes, indeed.

K: Especially for the researchers who come from abroad, support for their family life and children has to be in place before they can concentrate on their research and to conduct first-class research. Life-work balance is also important. Creating a female friendly environment will naturally create an ideal research environment. For these reasons, I am thinking of providing an environment and designing a system where female researchers can flourish.

I: Basically, issues of female researchers are not just the issues of themselves.

K: For example, Tohoku University has set up a daycare center for children. It is open at convenient hours for researchers, from early in the morning to late in the evening. There is also a support system to maintain research activities during child-rearing period. It is not difficult to do both research and child-rearing, if there is support from the university and understanding of the people around you. It is common for a father researcher to bring his children to his lab in other countries. I think such environment will improve the quality of research after all.

I: I think so too. It will improve both private lives and the quality of research. It is also important to switch on and off, as you mentioned.

K: Yes, a new idea will not come out if you cannot relax. When you are in the lab, you concentrate. Then when you are attending tea time, you relax and exchange new ideas and information. I think "work hard and play hard" attitude is important.

I: As you kindly suggested various proposals for the new AIMR building, such as combination rooms, common spaces, we would like to take them into account from the viewpoint of providing a better research environment.

Study and Passion

I: By the way, I did some research on your books to see if there was any book that a person with arts background like me can understand. Then I found *Book Guide Bunko de Yomu Kagaku* (Book Guide Science Series) published by Iwanami and read your article about recommended books on mathematics for university students. You entitled the article as "Were Not Our Hearts Burning Within Us?", which is a quote from Luke Chapter 24 Verse 32. Why did you choose this title?

K: Because I wrote about the "importance of passion" at the end of the article.

I: Yes, I remember. Passion.

K: These words are from the scene in Luke where the followers met Jesus Christ after his resurrection. The followers argued whether it was really him or not. And then, they asked each other "Were not our hearts burning within us while he talked with us?" So, they said they could believe it was him. In research, when you meet something that burns your heart, it is very important to pursue it, otherwise the research will not be the real thing. I introduced a book called *Sanpô Shôjo* (Mathematics Girl) in this article. It is a story of Japanese mathematics in the Edo period. A girl asks herself why she studies mathematics. Some people study it because it is a useful tool, and others do so in pursuit of beauty, such as culture or art. But she is neither of them. She reaches a conclusion that the reason why she studies mathematics is because she had met something that drives her passion and she just wants to pursuit it. I suppose research is something like that. There are many elements in research that contribute to human society, such as improving human knowledge, culture or our lives. However, after all, in order to conduct a good research you need to pursuit something that burns your heart and drives your passion. I think that is the real thing.

I: I see.

K: Something that burns your heart must have something very important in it, so pursuing that will naturally produce useful things for the world that also have cultural and academic values. This is what I think of the nature of research, and the reason why I chose that title.

I: I understand. It's very interesting. Although the world of academic study is driven by logic, passion, not logic, is necessary to get into the world or develop the world.

K: Yes.

I: This is also your message for young people.

K: Yes, it is.

I: From this point of view, do you think young researchers now are all right?

K: Of course. When I talk to the young researchers of AIMR, I can see they are highly motivated and very active too.

I: I agree.

K: Some researchers in my generation are rather shy and do not speak very much in international conferences, but the young researchers now take initiatives to talk about their research. It is often said that young people have inward-looking attitude or are not interested in science, but I do not feel that way at all. I think it is getting much better than my generation.

I: I see. It is true that there are more people who do not hesitate and are more proactive.

Thank you very much for taking your time today. It was very beneficial. Thank you again.

Interviewer: Administrative Director, W. Iwamoto

At Kotani Laboratory,

Science and Engineering General Research Building

June 28, 2011

WPI-AIMR 副機構長, PI　小谷元子教授に聞く
(Interview with Professor Motoko KOTANI－Japanese version)

AIMRにおける数学の挑戦

数学への興味—調和写像から離散解析幾何学へ

岩本：本日はお忙しいところ、有難うございます。先生には３月末にWPI-AIMRに主任研究者として加わっていただきまして現在は副機構長としてもお世話になっています。早速ですが、先生のお生まれはどちらでいらっしゃいますか。

小谷：大阪で生まれて１０歳ぐらいまでそこにいました。その後、神奈川県鎌倉市に引っ越してきました。

岩本：そうですか。

小谷：横浜国立大学附属鎌倉中学校から、東京学芸大学附属高校、東京大学に進みました。高校・大学が東京でしたから、その意味では東京圏育ちという気持ちでいます。

岩本：中学あるいは高校のころから科学にご興味を持たれたのですか。

小谷：はい。

岩本：それはやはり先生の影響が大きかったのですか。

小谷：そうですね。

岩本：やはり数学に興味を持たれたのですね。

小谷：中学校のときに数学が好きになりました。

岩本：その頃は数学や理科にもご関心もあったでしょうけれども、ほかにもいろいろクラブ活動などを結構おやりになったほうですか。

小谷：クラブ活動、団体で、みんなと一緒に何かやるよりは、自分一人で本を読んだりとか絵を描いたりとかのほうが好きでした。

岩本：数学というと、やはり一人でこつこつというイメージがありますよね。

小谷：そうですね。一人で誰とも口をきかずに１週間ぐらい平気でないと、なかなか数学はできないと思います。

岩本：そこら辺は実験系の研究者のようにグループでやるというのとはかなり研究のスタイルも違うということでしょうか。こちらの数学専攻の図書館も非常に充実していますものね。

小谷：そうですね。

岩本：９０年に博士号を取得されていますが、学位論文のテーマはどういうものでしたか

小谷：微分幾何学、特に調和写像の研究をしていたので、それに関するものです。調和写像とは、分かりやすく言うと、せっけん膜やしゃぼん玉を数学的に抽象化したものです。

岩本：それが博士論文のころのテーマで、その後はどう言うテーマに関心を持たれたのですか。

小谷：その後、離散幾何解析学を始め、これは、今の研究につながっています。数学で対照的に扱われる概念として「連続」と「離散」がありますが、少なくとも２０世紀までの数学は連続

な空間を主に扱ってきました。最近になって離散的なものを研究対象にしようという流れが生まれてきています。

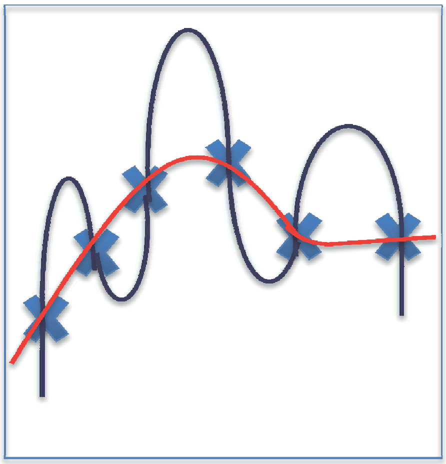
背景の一つは、コンピューターが発達し、大量の離散的なデータを扱えるようになったことがあります。大量のデータをしらみつぶし的に処理するのではなくて、そこから意味のある構造を取り出さないと、コンピューターの性能をいくら上げても切りがないわけです。離散的なデータに隠れた構造を見出すスマートな手法が必要です、数学は隠れた構造を見いだすことが得意です。これまでに築き上げられた数学の知恵を離散的な対象に適用できるようにする、そのような研究を離散幾何解析学といいます。非常に新しい研究分野です。

岩本：つまり連続的なものをずっと対象にしてきたわけだけれども、離散的ということは、要するにばらばらなものを扱うという訳ですか。

小谷：ええ。データって普通は離散的ですよね。

岩本：はい。

小谷：科学では、大量のデータから意味のある情報を取り出したいわけです。実験のデータから皆さんはグラフを書きますね。実際にはデータを点としてプロットしますが。点だけ見ていても意味がわからないので、それらの点を結んで線を引いて、これらのデータにはこういう傾向があると理解する。こんな風に。（図参照）でもこれは今、適当に引きましたけれども、ちゃんと理屈があるでしょうか。別のやり方でこうやって線を引いても、全部の点を通っているわけですが、これとこれのどちらが正しいのか。科学であるならば、線を引く手順がきちんと正当化されていなければいけないわけですね。正当化する理論がないと、その時々に経験に基づいて、ある意味恣意性が入り込みます。それを避けるために、この辺をもっと細かく解析しないと行けないとか、ここは本当にこれでいいのか、ひょっとしたらこうではないかと別のデータをとって埋めていって、やはりこうだなという。それでは切りがないし、データがどんどん必要になるわけですよね。一方で少数の点であっても、本質的な傾向を捕らえるもので、それらを通る線を決定する理論があればこの間の点をとる必要はないわけです。



岩本：そうですね。

小谷：そういうことを数学でやるべきなのです。言い換えれば、データを結ぶ連続な線はどういう理屈で引けばよいという理論を作る事。それがあれば大概のデータはとらなくてもよくなります。

岩本：なるほど。それで調和写像から離散幾何解析に移って行かれたのですね。

CRESTによる研究の目指すもの

小谷：２００８年にCRESTに採択されました。それ以前はいわゆる純粋数学の研究をしていま

した。今説明したようなことが背景にあるとしても、特に他分野の人と何か連携するのではなくて、数学の立場で、離散的なものに隠れた構造を見出そうというのが２００８年までの研究です。それで２００８年にCRESTの募集がありました。数学で科学研究費以外に大型の競争的資金がついたのはこのCRESTが初めてです。

岩本：そうですね。

小谷：それで、材料科学とのコラボレーションで応募したいと思いました。

岩本：そうですね。

小谷：応募の時点では、今までと同じように純粋数学をやりつつ、他分野の人の話も聞いてみようかなぐらいの軽い気持ちだったのですが、やり出したら結構いろいろ勉強することもでき、また、ほかの分野のかたと話をする機会も増え、そのあたりからだんだん他分野との連携ということを真剣に考えようになりました。

岩本：このCRESTは、北海道大学の西浦先生が総括されて、その中のいろいろな社会的ニーズの高い課題の一つとして、小谷先生の提案された「離散幾何学から提案する新物質創成と物性発現の解明」が採択されたわけですね。よく、純粋数学と応用数学と言いますが、もうこうした研究は応用数学に入ってくるということでしょうか。

小谷：以前は、純粋数学と応用数学は対立概念だったと思いますが、最近では、純粋数学と応用数学が一体化して数理科学という新しい学問を作るのだと考えられるようになってきています。

　私は、数学者が他分野のかたと直接接触をもち、彼らの問題を聞くことで数学が刺激を受けて新しい方向に広がる、一方で他分野の人にも数学の良さを分かって欲しいと思っています。必ずしも応用数学に転向したということではなく、それまでの数学をもう少し広げたというつもりです。

岩本：なるほど。わかりました。

　そうすると今取り組んでおられるCRESTの研究というのは、先ほどの離散幾何解析学から変わったという意味じゃなくて、むしろその延長線上にあるものということにもなりますね。

小谷：発展・展開という感じだと思います（笑）。

岩本：このCRESTのグループには本機構の阿尻先生もメンバーとして加わっておられますけれども、阿尻先生とはもう既に共著でニューメタリックカーボンクリスタルについての論文(Phys. Rev.Lett.102,055703(2009))を２００９年に発表されています。CRESTの始まる前ぐらいからそういった材料科学とのコラボレーションということを実践されていた訳ですね。

小谷：現在AIMRの連携教授になっている砂田先生との共同研究がベースになっています。離散幾何解析学の研究の一環として、結晶格子の研究を砂田先生と２０００年頃から１０年間ぐらい一緒にやってきました。その後、砂田先生単独のご研究でK4格子というものが数学的に発見されました。数学的な要請からくる自然な性質を持つ結晶を分類すると、ダイヤモンド格子とK4格子とたった二つの構造しかないのです。そのたった二つしかないうちの片一方がダイヤモンドで、じゃあもう片一方のK4格子は実在するのだろうか？　少なくともその時点では砂田先生も私も知らないものだったのです。しかし、これは絶対に意味があるものに違いないと思って、学

内でいろいろな人に聞いていくうちに阿尻先生が大変興味を持ってくださって、それでは作ってみようという話になったということです。

　作ってみるといっても、いきなり作れるかどうかもわからないから、とりあえずシミュレーションで可能性があるか調べてみようということで、砂田先生と、阿尻先生、川添先生、私と、名古屋大学の内藤先生で何度か議論を重ね、シミュレーションをやった成果が先程の論文です。非常に安定ではないかもしれないけれども、準安定であり、合成できる可能性もあるという結果になったので、では作ってみようということで、それをCRESTで実現できたらいいなと思ったのです。

岩本：そうすると先ほどおっしゃった一番初めの結晶格子の研究というのは、数学の世界の中で考えられたことだったのですね。

小谷：そうです。完全に数学の世界の話です。離散幾何解析学に、それまで研究してきた調和写像の観点を入れて、結晶構造の一番安定でバランスがとれた美しい形とはどのようなものになるかを調和写像の理論を使って考えたのです。それが砂田先生との共同研究である「結晶格子の標準的実現」です。数学の中では標準的実現は非常に役に立って、いろいろな問題が、それを使うことでうまく説明できました。だから、現実の世界でもきっと役に立つだろうと思いました。これは一例ですが、数学の知恵はきっといろいろな場面で役に立つだろうと思っているので、そのような場を展開したいのです。

岩本：私はどちらかというと材料科学でいろいろなものを見つけたことを抽象化してまとめていくという、そちらの流れのほうばかり先入観としてあったのですけれども、今のお話を伺っているとこれはむしろ数学の世界の中から生まれてきたものですね。

小谷：私たち数学者は材料科学では素人です。材料科学には材料科学のこれまでの深い蓄積があります。それを我々が理解して何か言うというのは素人がただ口出ししているだけだと思うのです。そうではなくて、今までに材料科学になかった新しい視点を数学から持ち込んで、新しい理論が産まれないかと期待しています。もちろん、そんなに簡単な話ではないとは思いますが。

AIMRにおける数学

岩本：この間も先生は、数学と材料科学が融合するわけではない、数学はむしろ各分野が融合するのを手助けしていくものとして考えてほしいということを力説されていましたけれども。

小谷：数学の役割は「触媒」だと思っています。AIMRの４つのグループはいずれも高いピークをなしているので、そのピークを一旦下げて、あわせることで、何かもっと大きなピークができるはずです。そのためには、触媒を入れて融合を活性化しないといけないですよね。それがAIMRにおける数学ユニットの役割と考えています。

　ただ、数学ユニットとしては、同時に数学が他分野から刺激を受けて発展することも考えています。そこから本当に新しい数学ができたらと、そういうことが参画の動機となっています

岩本：なるほど。二つあるわけですね。特に後者の点ですと、数学を取り巻く状況の話になり

ますが、例えばOECDのレポート“Mathematics in Industry”が発表されたり、国内でも２００６年に「忘れられた科学—数学」というレポートが出ましたが、背景として、数学者の中でももっと外に向かって発信する必要があるという問題意識があったのですか。

小谷：そうですね。外に向かって発信するということももちろんですし、また、数学が変わりたい、広がりたいということもあると思います。どの学問分野でも同じだと思うのですが、外から刺激を受けて広がる時期と、それからある程度自分の中の価値観に従って深める時期とがあると思います。数学はここ半世紀ぐらい深める方向で非常に高いアチーブメントがあったと思うのです。しかし、先端化が進み、もう少し裾野を広げないとちょっときゅうくつになりつつあるのではないかと、これは個人的な感想で、違う意見のかたも多くいらっしゃると思います。

岩本：第４期科学技術基本計画の最新の案文でも数理科学の推進について触れられていますね。

小谷：そうですよね。これは初めてのことです。

岩本：また文部科学省の中でも、数学イノベーションユニットができて、政府も本腰を入れてというところが見えますね。外国ではいかがですか。先生はドイツのマックスプランクに招聘されたり、あるいはフランスのIHESにいらっしゃいましたが、これらの国では数学の位置づけというのはいかがなのでしょう。

小谷：そうですね。このような流れではむしろ日本は後追いになっています。

岩本：そうですか。フランスというとポアンカレということで、やはり数学は盛んなんでしょうね。

小谷：そうですね。科学技術政策にも数学が深くかかわっていましたし、数学の地位が高いです。

岩本：ところで、理論物理と数学の違いは、どう考えたらよいでしょう。

小谷：伝統的にはまず純粋数学があり応用数学があり、それから数理物理があり理論物理があり実験物理があり、現象に係わるという、そういう流れだったと思います。また、理論物理の中でもかなり実験の人に近い人たちもいれば、ほとんど数学という人達もいます。そういう伝統的な係わりかたではなく、数学が直接現象に係わりたいという気持ちが最近の数学者にはあります。異なる学問分野で使われている数学は実は同じということは頻繁にありますので、直接に数学がかかわることで、いろいろな現象が統一的に扱えると言う期待です。今、最先端科学が専門化していて、お互いに言葉が通じにくくなっているけれども、それを数学という共通基盤に乗せることで、それぞれに開発して来たアイデアの宝庫をお互いに活用できるのではないでしょうか。

岩本：そういった極めて細分化された、科学の最先端のことを数学の言葉で翻訳し移転するというかことですか。そうすると、ますますもってAIMRの中でも数学という言葉が一つのキーワードになって、いろんな分野の融合みたいなものがさらに加速できると期待できるわけですね。

小谷：それが数学ユニットの役割だろうと思っています。

AIMRへの期待

岩本： AIMR自体に入られて数か月でいらっしゃいますが、雰囲気などどう思われますか。

小谷：皆さんのご意見を聞くと、ここ１年ぐらいで随分変わったと言われますね。いい方向に向かっているのかなと思いますが。

岩本：そうですね。確かに現在AIMR全体がいろいろ頑張っております。PIクラスも皆さん一生懸命やっていらっしゃいますけれども、特に中堅の研究者はかなりみんな熱心に議論しているように思います。

小谷：AIMRには、真剣に議論をし、新しい方向に挑戦しようという意気込みを感じます。むしろ他のWPIのモデルになるぐらい進んだことができるのではないかと思っています。

岩本：そうですか。ティータイム、ジョイントセミナーさらには若手研究者が一生懸命勉強会をやったりしているので、それをどんどん伸ばしていきたいなとは思っています。融合研究が進んでいる半面、まだ研究室間の壁というのもあるかもしれません。

小谷：異分野融合はそもそも難しいものです。他分野のかたの話を聞いたときに面白いなと思うことは幾らでもありますよね。自分の手法で発展できるなとは思う。でもではそれにエネルギーを使えるかというと実際にはなかなか難しいですね。自分が今やっている研究があって、世界と競っているわけですので、１００％力をそのことに使っています。その中で、他におもしろいと思ったことがあっても、どこまで力をさけるかというと、やはりそちらへ動かす強い力がないとなかなかそこまで行けないでしょうね。

岩本：そうですね。

小谷：その仕組みをつくるのがWPIだと思います。研究ですから面白いと思わなければ動きません。しかし、何かやればおもしろいのになあと思って今まで放ってあったことに挑戦できる環境を提供できれば、動くことがあるかもしれない。貴重な機会なのでぜひ成功させたいし、成功したらすごいことだと思います。

岩本：おっしゃるとおりです。先生がおっしゃったとおり普通、学問の世界ですとやっぱり世界と競ってある分野の頂点をねらう、それはそれでもちろん重要だし、ただ一方で融合したところからまた新しい学問というのは出てくるわけでしょうからね。先生は既に京都大学、大阪大学のWPIもご覧になっていますし、東京大学はもう前からよくご存じですが、それらと比較してAIMRはいかがでしょう。

小谷：AIMRは他よりも進んでいることがありますよ。研究面でも新しい学問を作ろうという気運が盛り上がってきていますし、成果も出始めています。組織面では、むしろ他をリードしているのではないでしょうか。WPIプログラムは、これまでの大学の伝統をやぶって、世界トップレベルの研究拠点を構築するための制度改革を行う事が目的の一つです。本学は井上プランというアクションプランを策定し、５年間様々な制度改革を実施してきました。国際連携や広報も積極的にやっています。若手の自立環境や異分野融合による新しい学問の構築の支援もです。ホスト大学が、このようなことを目指しており、そのモデルとしてAIMRを位置づけています。だから、制度改革が比較的うまく行っているのではないでしょうか？

岩本：そうですね。

女性研究者の育成

岩本： 今度はまたお話が変わりまして、先生は２００５年に猿橋賞を受賞されていまして、また２００６年からは東北大学の女性研究者育成推進室でも活躍されているわけですけれども、AIMRは女性研究者の割合が少ないというようなことを時々指摘されるわけですけれども、そのためにはどうしていったらいいと思われますか。

小谷：女性研究者育成は何故必要なのかとよく質問されます。いくつかの視点があるかと思いますが、研究の発展には多様性が必要であるという観点から女性研究者の育成が重要だと私は考えています。研究におけるブレークスルーは稀な事柄がいくつも重なって起こる、本当に細い可能性のものなのです。だからこそ、その土壌をなるべく豊かで多様にしておくことが大切です。歴史的な理由で研究者の中で女性がきわめて少ない、半分の人材を活用しないのはあまりにももったいない。これも先程の数学の話と同じですけれども、これまでになかった女性の視点を取り入れるチャンスなのですから、女性研究者育成は科学の発展の可能性を大きく広げます。もう一つは研究環境の改善という視点です。WPIのミッションの一つは世界トップレベルの研究者がそこに来たいと思う理想の研究環境を作ることです。その場合、一女性が働きやすい環境を作ることが一つの指標になるでしょう。研究に集中しながら、同時に生活も大切にする。女性が働きやすい環境は、実際には女性に特有のものではなくて、人間にとって働きやすい環境なのです。

岩本：そうですよね。

小谷：特に外国から来られた研究者は、家族の生活やお子さんの教育などがしっかりサポートされていて、初めて研究に集中し第一級の研究ができると思うのです。ライフ＆ワークバランスも重要です。女性にとって働きやすい環境を作ると自然に理想の研究環境ができる。そういうこともあって、女性研究者の活躍できる環境整備や制度設計を考えています。

岩本：つまり、女性研究者の問題というのは女性研究者だけの問題ではないということですね。

小谷：例えば本学には学内託児所を設けました。研究者が使いやすく朝早めの時間から夜も遅めの時間まで利用できます。育児中に研究のアクティビティを下げないための支援制度もあります。大学が支援し、周りの理解があれば研究と育児の両立は難しくないのです。お父さんが子どもを研究室に連れてきたり、外国だったら当たり前にやっていることですものね。そういうことが結局は研究のクオリティーを上げるような気がするのです。

岩本：そうですね。私生活もそうだし、研究のクオリティーという面でも上げていく。さっきおっしゃった緩急の使い分けというのも重要ですよね。

小谷：やはりリラックスしないと新しいアイデアって出ないですよね。研究室に入ったら集中する。ティータイムのような場ではリラックスしながら、新しいアイデアや情報交換を行えるという、そういうメリハリって必要だと思います。

岩本：今回、AIMRの新棟の件でも先生から交流スペース等についていろいろご提案をいただいていますが、それらについて、研究環境の整備という面で考えていかなくてはいけないと思っ

ています。

学問と情熱

岩本：ところで、先生の書かれた本で文科系の自分のわかる本はないかと探したら「ブックガイド文庫で読む科学」という岩波書店から出版された本を見つけ、その中に、先生が大学生向けに数学に関する本を推薦する文章を書かれているのを読みました。タイトルは、「心は燃えていたではないか」といって、これは、ルカの福音書２４章３２節からとられているのですけれども、なぜこのタイトルをつけられたのですか

小谷：文章の終わりの方に「情熱が重要」というようなことを書きましたもので。

岩本：ああ、ございましたね。情熱ですね。

小谷：ルカの福音書でその言葉が語られているのは、復活したキリストと弟子達が出会う場面です。弟子達が今の人は本当にあの人だったんだろうかと議論します。結局、あの人と話したときに心が燃えたではないかと。だから信じていいんだという話ですね。心が燃えるようなものに出会って、それを追求することが研究にとって大切だし、そうでなければ本物ではないというふうに思っています。「算法少女」という本を、この文章中で紹介しました。江戸時代の和算の話です。主人公の少女が、自分はどうして和算をやるのかと自問する。ある人は役に立つ道具として和算をやる、ある人は文化というか芸術というか、美しいものを追求するためという。自分はそのどちらとも違う。和算という情熱をかき立てられる対象に出会った、だからそれを追求するのだという結論に主人公の少女は達します。研究は、そういうものではないかなと私は思っています。人類の知恵とか文化・生活を豊かにするなど、研究が人類社会に貢献する要素はいくつかあります。しかし結局は、自分がそれに出会ったときに心が燃えるような思いをしたものを追求するのでなければきっといい研究はできないし、やはりそういうものが本物だと思うのです。

岩本：そうですね。

小谷：心が燃える思いのものというものの中にきっと本当に大切なものがあり、それを追求するとそのなかで世の中の役に立つことも自然に生まれてくるし、文化的にも学術的にも価値があるものが生まれる。研究とはそういうものではないかと思うので、そういうタイトルをつけたのです。

岩本：ああ、よく分かりました。そこは非常におもしろいですね。学問の中の世界は論理で動いていくわけでしょうけれども、学問の世界に入っていく、あるいはさらに進めていくというのは、やはり論理とは違う情熱がやはりないと無理ですね。

小谷：ええ。

岩本：それがまた若い人へのメッセージにもつながる訳ですね。

小谷：そうですね。

岩本：そういう点から見ていくと今の若い人というのは大丈夫と思われますか。

小谷：もちろんです。AIMRの若手の研究者など、身近にいる人と話をしてみると、モチベーションも高いし積極的ですよね。

岩本：そうですね。

小谷：海外の研究集会でも、私の世代だと物おじしてしゃべらないとかいう人が結構いたと思うのですが、今の若手研究者は自分でどんどん積極的にしゃべります。世間で内向き思考とか理科離れとかいろんなことを言われていますけれども、全然そんなふうには感じません。我々の時代よりも圧倒的によくなっているような気がします。

岩本：そうですね。確かに物おじしないでどんどん攻める人はだんだん出てきていますからね。

本日はお忙しいところ、有意義なお話をいただきました。どうもありがとうございます。

２０１１年6月２８日

東北大学理学系総合研究棟　小谷研究室にて

岩本　渉

Interview with Professor Li-Jun Wan, Principal Investigator, WPI-AIMR

"Importance of the Face-to-Face Communication"

Administrative Director Iwamoto (I): Thank you very much for accepting the interview immediately after your presentation on structure and the structural transition in organic nano devices at our Annual Workshop. You are our PI and you are the Director of the Institute of Chemistry of the Chinese Academy of Sciences with which AIMR has a very close relationship as our satellite.

First, can you tell me where you were born in China?

Professor Li-Jun Wan (W): I was born in Dalian in northeastern China. People always say the shape of Mainland China is like a rooster and the northeastern part is just the rooster's head.

I: So you were in Dalian until university.

W: Yes, in 1978, I entered the Dalian University of Technology.

I: When you were a child, were you already interested in science and technology?

W: Hardly, because I was born in the countryside, about 150 kilometers away from the center of the city.

I: So did you like literature instead?

W: Yes.

I: Your country has many classical novels like "Romance of the Three Kingdoms" (Sangokushi in Japanese) and "Water Margin" (Suikoden) about the 108 heroes.

W: Yes, you are right. I liked history and classical literature.

I: Recently I read a Japanese translation of "The Dream of the Red Chamber" (Kouroumu), and I was very fascinated by this beautiful love story.

W: Yes, this is a very famous novel. In China, we call "Four great classical novels", these three novels and "Journey to the West" with the monkey hero. "Saiyuki" in Japanese.

I: I would like to know how a literature youth like you got interested in science and technology.

W: I think it was after I entered university. When I was very young, almost all the schools and universities were closed, so I had enough time to learn history and some novels, but I did not have the chance to contact real science.

I: I see. Is it through experiments in scientific subjects at university that you got interested in the sciences, especially in the chemical field?

W: My major was material science when I was an undergraduate student. At first, I learned the traditional metallic materials. There was a boom for materials research and many new materials appeared in the world during the 1980s. In universities some traditional majors changed to Department of Material Science and Engineering, so we had the chance to learn about new materials.

I: Yes, I see. Until then, there was the Faculty of Metallurgy etc in a classical sense.

W: Also there were disciplines like casting and heat treatment.

I: But at that time, new materials and methodologies were developed and so we can say that this is a kind of the birth of actual Material Science.

W: In particular in material science, I think. The discourse maybe was interdisciplinary resource theory, compiled with metallic chemistry and physics. Therefore, I had the chance to learn chemistry, physics, and other new materials.

I: I see. After your undergraduate course, did you go straight to the master course?

W: No, I was at a factory related to surface treatment for almost two and a half years.

I: So you experienced working in the private sector.

W: Yes, and then I went back to Dalian University of Technology for my master's degree. During this period, I was still working on surface treatment like surface plating and metallic deposition. I studied the structure of the surface field. At first I studied the film structure and then imparted the interfacial production by using TEM (Transmission Electron Microscopy).

I: I heard that the Nobel Prize Laureate, Wolfgang Pauli, said, "God made solids, but surfaces are the work of the devil."

W: Then after finishing my master's course, I went to Dalian Maritime University where I started my research. At that time I used TEM to study film, surface and interface. As I said, this is because material science, in particular surface treatment, is very close to chemistry, like surface plating, electro-deposition and the electrochemical process.

I: I see. So knowledge of chemistry is very important for analyzing surfaces.

W: I had experience of using TEM for a long time and I am always interested in new technique. Around 1984 to 1987, a new technique was STM (Scanning Tunneling Microscope). Dr. Rohrer who is participating in this Workshop is the Father of STM. In China, I looked for it in the world, where there is a lot of this technique now. Then, I found Tohoku University and Professor Itaya.

I: So is it as a doctorate student that you came to Tohoku University?

W: Yes, we published the paper in the same journal "Journal of Vacuum Science and Technology".

I: At that time were you already acquainted with Professor Itaya?

W: Yes, I know him and his STM technique from journal. I used TEM to study the structure of film and the surface structure between film and the substrate. I published a paper in the journal. I read the paper from Professor Itaya in the same journal. He imaged electrode surface by STM. The results were very interesting.

I: How long have you stayed in Sendai?

W: I stayed in Sendai for a long time, continuously for seven years. The first year was from 1992 to 1993 as a visiting scholar in Itaya Laboratory, and then I entered my PhD course.

I: I see.

W: In March of 1996 I finished my PhD at Tohoku University.

I: Sendai, as you know, is linked with the Chinese writer Lu Xun, and he wrote a very moving essay on Professor Fujino.

W: Professor Fujino is very famous in China.

I: I have met many Chinese people who, not knowing the city of Osaka, know the name of Sendai because of Lu Xun.

W: He lived here for a long time. When I was in Sendai, I visited the apartment that Lu Xun lived in.

I: I see. What was the theme of your PhD paper?

W: In situ electrochemical scanning tunneling microscopy of molecular adlayers on Rh(111) and Pt(111)

I: So at that time, did you notice that these researches were very interesting to analyze?

W: Yes, as a first step I prepared the atomic flattened and clean surface of rhodium, palladium and iridium by the technique called flame annealing and quenching. The preparation of these atomically flat surfaces is not easy and I think that to this day, not many people can do this.

I: So this is a very sophisticated technique.

W: Yes. Then by using electrochemical STM we got in situ images which show electrochemical reaction process on rhodium surface or platinum surface in solution. The observation in electrolyte solution is the most important feature of our STM technique compared to other uses of STM. For example, the physicists use STM in ultrahigh vacuum condition. But most chemical reactions take place in solutions. Many people have interest in understanding chemical reactions in solutions.

I: So even using the STM, the physicists' approach and the chemists' approach is different.

W: Yes.

I: Great! Since 2009, you have been a member of the Chinese Academy of Sciences, haven't you?

W: Yes. I am very lucky.

I: No, you are worthy of it. I can understand this from your presentation at the Workshop. On the other hand, you presented the outline of the Institute of Chemistry which you lead as Director. I am surprised to know the great achievements in your Institute. In the Institute there are 97 professors, 450 Researchers and 900 PhD students.

W: Yes, there are.

I: I see. So this means that you receive the Ph D students from ordinary universities.

W: Yes. From individual universities all over China. They take an examination.

I: I see.

W: Then, they take a vigorous course, and get credits before going back to the laboratory for their research.

I: Your Institute is really a frontier research center. You have 3 State Key Labs, 7 CAS Key Labs, 2 ICCAS Labs and 3 Research Centers.

W: These are four very important fields that we focus on. Namely, Molecular Nanoscience & Technology, Organic/Polymer Functional Materials, Chemical Biology and Environment Energy and Green Chemistry.

I: What is interesting for me is Environment Energy and Green Chemistry.

W: This can be divided into three parts. First is environmental protection, in particular - How to control the pollution. Second is water treatment. By the way, yesterday, I read an article in a journal "Kahoku Shimpou (local newspaper in Tohoku region)," according to which some Japanese companies and institutes gathered together to discuss water economy, and in the future those Japanese companies want to work with some Chinese companies.

I: That is right. As you know, Japanese technology in water treatment is very developed. The Japanese government also wants to export this technology to various parts of the world.

W: I think this is very good.

I: And what is the third field?

W: We will focus on chemical energy, such as lithium-ion batteries, and solar cells with functional organic materials and semiconductors.

I: Excellent. Our Institute also wants to focus on green materials as you mentioned. So it is important not only to prevent pollution but also how to economize energy like with solar cells.

W: Most of the solar cells are now made from silicon and other inorganic semiconductors. But for chemists, there is still a great challenge in terms of organic solar cells.

I: I see.

W:There are several groups in our Institute working in this field to design and synthesize new inorganic molecule compounds. They use these new compounds to fabricate different solar cells.

I: On what elements are these new organic compounds based?

W: Just like some oligothiophene, xylophene and conjected xylophene molecules and other molecules with bigger pi electron systems.

I: That is very interesting. Also AIMR should make an effort to reinforce the soft materials. In China also, is there this approach? Not only hard metal; is the field of soft materials now very important?

W: We have a lot of people working in this field of soft materials. The research activities of many researchers focus on this field.

I: Does your Institute of Chemistry have close relations with other institutes?

W: Yes.

I: So, under the umbrella of the Chinese Academy of Sciences, are there interactions between the institutes?

W: There are. Our academy organized projects that included several institutes. For example, besides ours, there are also the Institute of Physics, the Institute of Material Research etc. and we have a number of collaborative projects.

I: So this means there is no wall, and collaboration is very easy. In Japanese universities, if one belongs to a faculty, sometimes it is difficult to have good collaboration, but in your case it is easy to do that.

W: We have collaboration.

I: Good! And I heard that the Institute of Chemistry also has relationships with foreign institutes like our AIMR.

W: Yes. For example, in Japan, we have official agreements with Riken, with Tohoku University, and with Institute for Molecular Science. Now, about 20 students from our institute are in Okazaki. We organized a winter school; the students flew here for winter school.

I: Winter school? Did Institute for Molecular Science (IMS) in Okazaki Research Institute organize this?

W: Yes. This is co-organized by the institutes of several Asian counties and regions such as our Institute, IMS and a Korean institute. This year we have winter school in Okazaki, next

year it is in Beijing and then to Korea, and also to Taipei. This year the school maybe includes Singapore.

I: Is this to attract young students to the study of chemistry?

W: And also to exchange emotions.

I: Yes, I think that for international collaboration, not only at the excellent researchers' level but also at the level of younger researchers like doctoral students or post-doctoral student's level is important. If a researcher stays for several years in a foreign country, that will also develop the individual emotionally.

W: Yes, you are right. First we can learn science and then we can understand foreign society and make friends. Friends are also very important.

I: I myself stayed in a foreign country for a total of 13 years. Naturally, I sometimes feel myself that I have another eye to look at Japan. If I have stayed all my life in Japan, I would not have known the different angles to see my society. That is also important, I think.

W: Since our Institute, as you said, collaborates with AIMR, we are exchanging researchers, including post-doc students

I: That's right. We are now discussing on the possible summer school for graduate students to stay in our Institute using our experimental facilities.

W: Although China is an open country now, we still have a lot of students who have no experience in foreign countries. They do not understand sometimes how life is in a foreign country, how the society is and how the city is likely to be. Everything is new for them.

I: That is right. Nowadays, many young Japanese researchers have a tendency to stay in Japan. Some say that this is due to the progress of the internet with which, they can collect information from all over the world.

W: Although we have internet, face-to-face is also very important. In China, we have a proverb that says "To see once is better than to hear about a hundred times".

I: We have the same proverb in Japanese. That is right, so now we want to encourage young Japanese researchers to go to China, the United States or the United Kingdom where we have satellites. As you said, face-to-face is very important and it is essential to know your activities on the spot.

W: It is important not only for exchanging science but also for understanding society. I have many friends in Japan. The visiting students from Japan stay in our institute as well as in my laboratory for one to two months. The young students become friends very quickly.

I: I see. This is very important.

W: Yes, I think in particular for Japan and China, because of the Second World War we still have some problems to be solved. So Japanese people may not understand the present China and the Chinese present situation. And the Chinese people also may not understand the Japanese very well.

I: That’s right.

W: Sometimes we will have some arguments about the policy, however, we can discuss it.

I: I think that in international relations there is, of course, a difference of views and opinions, but nevertheless, what is important is that we can discuss, and as you said, we have unfortunate problems in history, but nowadays we can communicate and we can make an effort to solve them for the future generation.

W: Of course. Japan and China are really close geographically and culturally. Therefore, we have many connections.

I: Yes, and we have imported many things from your country.

W: We also imported many things and introduced advanced technologies from Japan. The collaboration is very important. For me, first I am a scientist and also now, I am engaged in management as director. I would like to become a bridge that connects Japan and China, in particular for the younger generation.

I: Yes, thank you very much. At the senior researchers’ level, Professor Yamamoto and several PIs of AIMR went to your institute to participate in a joint symposium last October. I heard that it was very successful.

W: It was very successful, and at that time there were five professors from AIMR. Although they stayed in our Institute for a very short time, we were able to have enough discussions with our professors. On our side, our professors also have a very good impression about the research and the organization of AIMR.

I: Yes, and your Institute is a very important partner and satellite of AIMR. I would like to reinforce our relationship.

Finally, I would like to know what your hobby is?

W: If I have time, what I do first is reading and listening to classical music.

I: You like classical music? Who is your favorite composer?

W: Bach.

I: Bach? Great! I heard that there is a Chinese pianist who recorded the Goldberg Variations on piano.

W: Lang Lang maybe.

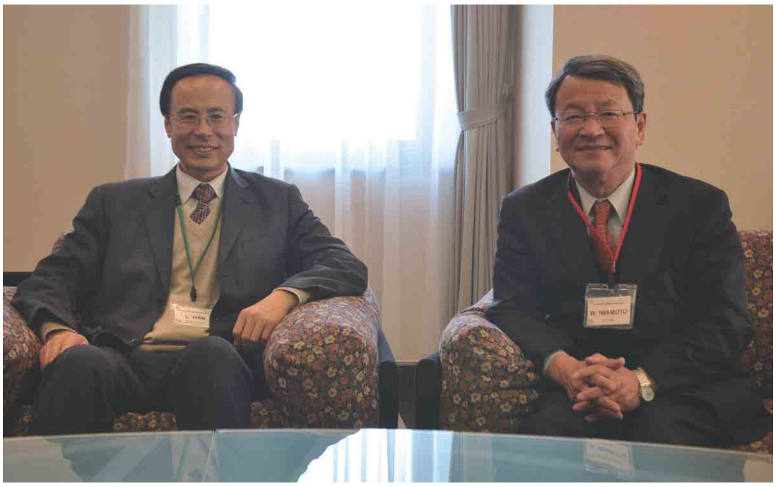
I: I forget… But Lang Lang is very popular in Japan. He is very talented.

W: Yes, romantic.

I: That’s right. In your country, there are so many excellent scientists and so many gifted artists.

W: We have a large population. We still have a long way to go to reach your level of development as a country. We are still a developing country.

I: But concerning Japan, as you know, some say we have lost our power since 1990, so we need to be revitalized. Thank you very much indeed for finding the time for this interview.



Interviewer: Administrative Director, W. Iwamoto

At Sendai International Center

February 23rd, 2011

Interview with Associate Professor Taro Hitosugi, WPI-AIMR

The Best of Man is like Water

Encounter with Science

Administrative Director Iwamoto (I): I recall that you grew up in Kanagawa Prefecture, and graduated from a high school in Kanagawa.

Associate Professor Taro Hitosugi (H): I graduated from a prefectural high school in Kanagawa. Before that, I lived in the US because my father was a semiconductor engineer. I think that is where I first came into contact with science and technology.

I: How old were you when you went to the US?

H: I lived in the Silicon Valley from third to sixth grade. It is the city where the headquarters of Apple Computer is located. I was sent to a local school when I was in the third grade, but I did not understand any English and did not have any friends, so I kept crying for about a week (laugh).

I: That is only natural.

H: But after a week I had already blended in with the new environment. You do not need language to communicate with one another when you are a third grader or so. You can naturally make friends by playing ball and other things. So I was soon Americanized.

I: That is right. Because your father was a semiconductor engineer, were you familiar with semiconductors and the like since you were little?

H: Yes, these things were in my head at least. I think my father had an influence on me on that point.

I: So you came back to Japan after you finished elementary school.

H: Yes. And there was the superconductivity boom at the end of 1986, when I was in high school. There were reports about superconductivity in the newspaper every day, and although I did not understand much, I thought science was interesting. I think that was one of the turning points in my fate.

I: Oh, I see.

H: The impression I had at that time that "science is interesting" later came to have a meaningful impact. At that time it was only drummed into my head, and the impact was not strong enough for me to decide my path back then.

Until then, the superconducting transition temperature, which is the temperature at which materials become superconductive, had not increased much for decades. However, the discovery made by Dr. Bednorz and Dr. Müller of the IBM Zurich Research Laboratory led to a major paradigm shift in the world of physics, in which the superconducting transition temperature exceeded the liquid nitrogen temperature (77 K) all at once. And many researchers ceased their previous research and made a dive into the research of superconductivity.

I: These things happened then.

H: Yes. At academic meetings in the US, discussions normally continue from 9:00 a.m. till around 6:00 or 7:00 p.m., but at that time they continued till 6:00 a.m. I hear that discussion sessions were held all night long. This shows how excited everyone was and how eager they were to hear the latest reports on superconductivity at that time.

I: That is surprising.

H: People had the rosy idea of putting it into practical use, which can be said to resolve many of the challenges we are facing today. For example, with respect to electric energy, electric power is now produced and consumed in Japan. If the superconducting technology is established, however, it will become possible to generate power in the Sahara by photovoltaic power generation to be transmitted to Japan without any loss. This is just one example of how we would be able to resolve the energy issue. Therefore, my final goal in my research is to achieve superconductivity at room temperature.

I: I see. So while you were in high school you decided that you would absolutely major in science.

H: Yes, although at that time I did not intend to become a researcher.

I: Then you entered the University of Tokyo, and studied industrial chemistry in your undergraduate course.

H: Yes, I studied in the Department of Industrial Chemistry. But during the four years of my undergraduate course, I did not study at all.

I: What were you doing?

H: I was playing rugby all the time. I was playing rugby so much that my professor said, "You are among the five people in the Faculty of Engineering with the worst grades," but I somehow graduated.

I: It is impossible to imagine you like that now.

H: Now that I think of it, what is important is the fact that I put all my energy into it for four years. Then, after I entered graduate school, I made a complete shift to studying.

I: So you concentrated on rugby during the undergraduate years.

H: I enjoyed it.

I: Did the University of Tokyo have a strong rugby team at that time?

H: It had quite a strong team then. It was like risking my life for it.

I: So you still have that kind of spirit.

H: Yes, I still have that spirit, really.

Company and University, and the Time Leading Up to the Decision to Become a Researcher

I: As was described in *Nature* (Vol. 466), after you completed your doctoral course, you first worked for a private company.

H: Yes.

I: And then you changed your path from a private company to a university. When you could have stayed at the university immediately after you obtained a Ph. D. from the graduate school, why did you choose to work for a private company?

H: At that time I wanted to see how my achievements would become truly useful in a tangible way. I wanted to make the technology I was involved in help improve people's lives and make people enjoy my technology. I thought I would be able to do such things if I worked for a company.

I: So you joined Sony Corporation.

H: Yes.

I: What kind of work did you mainly do at Sony?

H: I was first involved in the development of the optical disk. At that time we were developing new technologies that would go beyond the Blu-ray disk. So we had to think about what the market will be like in about 10 years, and develop products and technologies accordingly. We were in charge of optical disk development, so we had to envisage the future of the DVD. But then we reached a conclusion that in the future high-speed internet would be widely used at homes, and that very high density semiconductor memories would come into the market; and that therefore there would be no room where optical disks such as DVDs could succeed. And so our development was discontinued.

I: Is that the way it goes?

H: As it turned out, that is the exact social trend seen today. Digital distribution is on the increase, and computers without CD-ROMs are becoming more common. Hard disks are increasingly replaced by semiconductor memories. Right now we have the Blu-ray technology ahead of the DVD, but we cannot think of many suitable applications after the Blu-ray. It means that the optical disk technology will go out of use.

I: So you were of course carrying out your research, but the company had to focus on such market trends in 10 or 20 years. That was the kind of environment you were in.

H: Yes.

I: Were you with Sony for about four years?

H: Yes, for four and a half years.

I: And then you went back to the university again.

H: Before that, there was one event that marked my life. As you know, we are manufacturing experts. We are very good at thinking what kind of technologies should be combined and what kind of technology development is required to produce products. On the other hand, I also felt that it would be impossible to see what would really happen to the technologies in the future without paying attention to how the technologies were delivered to people after they were made into products. That feeling is still with me today. So I wanted to have the actual experience of spreading the technologies and products I created. Sony is a very interesting company that allows even Ph.D. holders to be transferred to product planning or marketing or sales.

I: I understand.

H: I already mentioned that the optical disk development project was discontinued. I am by nature a person who pushes ahead with things I want to do, so I said I wanted to do marketing or sales which I had never actually had any experience in, and I started doing sales activities to sell Sony products to the world. I was in charge of sales of small VAIO, which was like today's iPhone. I was making presentations at press conference myself, explaining "This is Sony's new product, and this is Sony's strategy!" and making statements in magazine and newspaper interviews. I was involved in sales promotion in such ways.

While doing this kind of work, I was always thinking of what kind of work I should spend my lifetime doing. And then when I was 30, I finally found out what I should spend my lifetime doing; I decided to devote myself to research. Looking at the wide range of functions from research to the frontline of sales allowed me to find out for the first time what position I would enjoy the most. So I decided to go back to research, and make it my lifetime's work. Of course, I think this decision was greatly influenced by the fact that the idea that science was interesting was drummed into my head when I was in high school.

I: Oh, I see. Your experience in a wide range of things contributed to your decision.

H: There is another important thing. As I mentioned before, we were indeed making products such as the iPhone when I was in Sony, but they did not become hit products like today's iPhone. It was very frustrating, and I tried to figure out the reason. I came up with a conclusion that I was trapped in and bound by the belief that I was not allowed to do things in certain ways. So now I am constantly trying not to set limitations on myself as much as possible.

I: What was the limitation that was in your head at that time?

H: Let's take the example of listening to music. Sony has a music company and therefore is very sensitive about copyrights. But the MP3 technology that triggered the success of the iPhone does not take the issue of copyright into consideration. Because we had a music company, we believed that we were not allowed to adopt technologies like the MP3 technology. That naturally made the product less user-friendly. That is one example of the limitations. Now I am telling myself never to set limitations on myself. If I succeed in something, it always serves as a restraint and it will become more difficult to achieve the next success.

I: There are no such limitations in research at universities by nature.

H: That is right. There are definitely fewer limitations than in companies. So I genuinely enjoy my research. Research at the university is fun. I always tell my students that if there is something they are interested in, they should take a shot at it and look for work they can spend their lifetime doing so they can live their lives to the fullest. I think there are quite a lot of people who are interested in something and want to do it, but cannot try it out and are reluctantly doing their current work with some dissatisfaction. I hope the students will not be like that, and that is the point of my message.

I: So it means that you should take interest in a variety of things to find out what you want to do for yourself.

H: Yes. I think you can have the greatest happiness if you can find out what you are going to spend your lifetime doing.

I: I agree. And then you became a researcher at the University of Tokyo and joined the AIMR about two months after its establishment.

H: That was in December 2007. If I am not mistaken, I heard that I was the first full-time researcher employed from outside Tohoku University. I also attended the opening ceremony of the AIRM that was held in November that year.

Characteristics of Research

I: Can you explain very briefly your research at the AIMR?

H: I can summarize it as an attempt to examine the characteristics of solid substances to achieve applications utilizing these characteristics. In simple terms, it is materials research for electrical products, to downsize and enhance the performance of mobile phones or to achieve higher speed and lower power consumption of computers, for example.

I: Therefore, it is important to measure the materials at an extremely micro level or examine their characteristics, among other things.
H: Yes.
I: I understand that the main tool you use for your research is the Scanning Tunneling Microscope (STM). You recently wrote a book called *Sosa Tonneru Kenbikyo Gijutsu* (Scanning Tunneling Microscope Technology) with Professor Hashizume as part of the *Butsuri-no-Sekai* (World of Physics) series of Iwanami Koza.
H: Yes.
I: Upon your recommendation, I read the first chapter of the book. People like Dr. Rohrer and Dr. Binnig appear in that chapter. You use the characteristics of waves and so on using the probe a sample.
H: We examine the atomic ordering or atoms themselves. Atoms are just so small at 10^{-10} meters, so people do not think that all things are made of particles. For example, water looks smooth, but it is also a collection of particles. The amazing technology that enables us to see each one of these particles became available in the early 1980s. And it caused a sensation in the fields of physics and chemistry.
I: Yes, and that was indeed the huge achievement made by Dr. Rohrer and Dr. Binnig.
So the microscope you have here in the AIMR is the STM?
H: Yes. The equipment we have on the first floor is the STM. We created laboratory equipment that we can boast to the world about, and we intend to press on with research using it.
I: I understand.
H: Things are comprised of atoms or molecules. So we are trying to understand them first, and then understand their aggregation. We are frequently discussing hierarchic structure at the AIMR, recently. It is the idea of viewing the clusters made up of atoms and molecules as a group, and viewing more than one cluster sticking together as a mass as well. We are heading for the direction of reestablishing materials science by breaking down the materials to such hierarchic structure.
I: In the end you are going to take a look at bulk properties.
H: Yes. In reality, at some level the materials start to have functions. We are trying to identify the origins of the functions and introduce a mathematical perspective, and establish new materials science by expanding this approach to more materials. These are the things we are discussing.
I: What you are working on now is very basic research. By the way, the AIMR has announced that the future direction of its output will be "green materials." How will your research contribute to this end in specific terms?

H: One of the several projects we are working on is the development of lithium-ion batteries. We are quite focused on this project.

I: What kind of research is it specifically?

H: An electric car with a nominal range of 200 km was recently brought to the market. But the actual range will be decreased to around 100 km if the air conditioner is turned on or if the car is caught in a traffic jam. A range of 100 km is not even enough for a trip from Sendai to Tokyo. In order to make electric cars that can travel 500 or 600 km, technology to increase the capacity of batteries becomes important. Moreover, it is important that the batteries can be charged instantaneously. It would be a big problem if it took hours to charge the batteries, so it is necessary that batteries can be charged promptly. We are working to develop a technology to achieve these things, and the materials hold the key to its success.

I: I see. These things are important.

H: The other project is the research on transparent conductors, which are used in light-emitting diodes, solar cells and liquid crystal displays. An innovative improvement of transparent conductors will enable brighter lighting with lower power consumption and lead to the improvement in the efficiency of photovoltaic power generation. These things will lead to more green society. It is important here that we are heading for the direction of not using scarce metals. As the phrase "rare metal (critical material)" often appears in newspapers, there is the risk that we are going to use up all the elements with small reserves on earth, and industries will no longer be able to continue. For example, if the current situation continues, the liquid crystal display industry will be dead when the supply of indium runs out. So, transparent conductors that do not use indium will play an important role. On such a backdrop, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) is promoting the Elements Science and Technology Project, and Ministry of Economy, Trade and Industry (METI) is pushing ahead with the Rare Metal Substitute Materials Development Project. The research on transparent conductors is part of such projects.

I: I understand. So in that sense, your research will contribute greatly to green materials.

H: Yes. Our research consists of three pillars.

I: The three pillars are the understanding of oxides by the STM, lithium-ion batteries and transparent conductors.

H: Yes. These are all oxides. We are carrying out projects to understand oxides on the atomic level to put them to use for society.

I: That is wonderful. One of the characteristics of the AIMR is the fusion research. You stressed the importance of the fusion of research in the May 2010 issue of "The Monthly Journal of MEXT". Specifically, which groups are you advancing the fusion research with?

H: We often carry out research with people in the chemistry field, such as the Teizer

Laboratory or the Adschiri Laboratory.

I: In concrete terms, what kinds of research are these?

H: For example, together with Assistant Professor Hojo in the Adschiri Laboratory, we are attempting to create new materials by combining the technology of producing tiny nanoparticles using liquids, which the Adschiri Group excels at, and the vacuum technology in which we have strength. Currently the Adschiri Laboratory is able to produce square nanoparticles of 10 nanometers or less, and we are trying to add a function to them. We are trying, for example, to attach material B to the nanoparticle of material A, and create a new dumbbell-like material of A-B as a material with a new function.

I: That is indeed the fusion research.

H: It would be quite a challenge if we had to bring results in one or two years, but we have been making gradual progress through such efforts.

I: Do you think that the AIMR provides you with a favorable environment in which to work on such a fusion research?

H: I think it is a very comfortable environment because each laboratory is making efforts to enable cross-laboratory research. The other thing I like about it is that the people on the Katahira Campus of Tohoku University attach great importance to horizontal ties. In other words, I have a lot of opportunities to get to know people, even in laboratories I do not know.

I: Do you feel that Tohoku University has more opportunities like that compared to other universities?

H: Yes. I feel that there are definitely more such opportunities compared with the University of Tokyo, where I worked before. I think this Katahira has the culture that enables people to get to know various kinds of people. People who have worked for both the University of Tokyo and Tohoku University say that Tohoku University is extremely good in that you can have more horizontal connections. I have connections not only within the AIMR but also with the Institute for Materials Research (IMR) and the Institute of Multidisciplinary Research for Advanced Materials (IMRAM). Maybe I get to know people at the pub in Ichiban-cho (laugh).

I: Do you especially feel that way about the Katahira Campus?

H: Yes, I love the Katahira Campus. People are very friendly. I get to know a lot of people. It starts with lending or borrowing the equipment for collaborative research, and then your relationships widen. Connections are vital for research.

I: Within the AIMR, various active discussions are held among associate professors or lecturers in particular.

H: Yes, very active discussions are held. Those of us, particularly the people in this building (the AIMR Annex Building) are all new here, and we have a strong sense of unity from the beginning, so we have a lot of exchanges.

Lessons Learned from the Earthquake Disaster—Safety and Security

I: You told me about the STM, but what happened to the microscope when the earthquake hit on March 11?

H: There was less damage caused to the microscope itself than expected. I first thought it was a serious situation, but as a result of precise examination, we found that there was little damage.

I think there were two reasons for this. For one thing, it was fortunate that it was located on the first floor. The other reason is that there are a lot of devices incorporated in the microscope to isolate vibrations because it is easily affected by vibrations. Specifically, the microscope is equipped with a vibration isolation device called active damping system, which works to suppress vibrations that can be constantly felt when cars drive in the street, for example. So I think it suppressed the strong shaking, and it was able to avoid the worst shaking successfully. The STM that weighs 1.5 tons moved about 5 cm on the anti-vibration plate, but actually there was minimum damage.

I: That was good.

H: Yes, I really think it was good. The situation on the fifth floor was terrible, though.

I: Then the STM on the first floor can actually be used now.

H: Yes. However, we cannot conduct any experiment because of the continued aftershocks, since the STM is very vulnerable to the shaking of the ground. So although the equipment may be repaired, that is not the end of our battle. In short, we cannot conduct any experiment until the aftershocks are over. So time is very important.

I: Yes, that is the problem.

H: That is the very tough part. Further, in the laboratory on the fifth floor, gas cylinders that were fixed to the floor as part of the earthquake countermeasures fell, and various laboratory equipment and measurement instruments also fell, which are currently under repair. But we can manage things as long as they can be resolved with money. The problem is the time. A vast amount of time is being spent on recovery.

I: Because various kinds of research are advanced in the world in the meantime.

H: Yes. The most important aspect of the damage caused by the recent earthquake is that it has a great influence on a researcher's career. There is no way of recouping the time during which you cannot conduct any research. It is fatal for a researcher's career.

I: I understand.

H: This can only be overcome using your brains. It would mean that we may not be able to conduct any full-fledged research using the STM during the next six months or year, but we

have to do what we can ahead of time. All we can do is make changes to the research plan in a well-coordinated manner.

I: If you just sit and complain that things cannot be fixed or aftershocks do not end, you cannot move forward.

H: If you just sit and pray that the aftershocks will be over as soon as possible, it is not going to do any good. So you have to change the research plan. This is truly survival. At any rate, I think what is required of us is to produce output by using our brains.

Also, we suffered from a lot of psychological damage. After March 11, everyone was saying that we would pull things together somehow, and the new school year started on April 1, and we all thought we would make a new start, making preparations to resume our research. Then we were hit by an aftershock on April 7, and many things were destroyed again. If this is repeated, we are going to lose a lot of time....

I: It is a difficult situation from the perspective of maintaining motivation for research.

H: I think it would require less time and cost until recovery if we expected earthquakes to definitely occur and prepared for future earthquakes with thorough measures.

I also think that the earthquake posed a big question as to the modality of science. I had always used the words "safety" and "security" as synonyms, but I learned that they are quite different. I realized that the sense of "safety" is to understand in your head that your body will not be hurt and so on, and the sense of "security" is to understand in your heart that you can live a truly quiet and really peaceful life, I mean, a relief from the bottom of your heart. I think today's science had focused on the aspect of "safety."

I: You are referring to the announcements from governments such as, "the numbers are below the standard, so there is no problem," and things like that.

H: Yes. You do understand that it is okay in your head because it does not harm you when seen from a statistical perspective. This is "safety." But that alone is not sufficient. The absence of "security (a relief from the bottom of your heart)" leads to hoarding and harmful rumors. The important challenge for science to tackle is to consider what should be done to recover the sense of "security."

When an accident occurs, for example, if it takes a long time till you can feel you are "safe," it will be difficult to recover your sense of "security," but if you can recover a sense of "safety" quickly, you may be able to recover your sense of "security" promptly as well. It is not only how fast you can do it, but I think the role of science is to help people recover their sense of "security."

I: I agree. I believe that will then lead to social contribution.

H: Yes. I feel that Japan has the great ability of providing not only "safety" but also "security" to countries in trouble, and that by doing so Japan may be able to truly contribute to these countries. I do not know clearly what Japan should do, though. I strongly feel that we need to focus on the area of “security.” What are the materials that can help people recover their sense of security? There is a lot left for materials science to do.

I: It is important for Japan to learn lessons from these things and communicate to the people in other countries what we have learned.

H: It will be great if we can do that. I think Japan is good at these things; learning and creating new things based on what it has learned. I think that is the very thing that Japan ought to do.

I: I agree. This is important.

Research Environment Surrounding Young Researchers

I: From our point of view, you are a young researcher.

H: Thank you for calling me young (laugh).

I: You are Independent Investigator at the AIMR as well. As we head for the second phase, can you give advice to the people who are in the generation younger than you as to how they should move ahead with their efforts?

H: They are definitely all very motivated, so I have nothing more I can say to them. Rather, I feel it is more important to think about what we can do for them.

In that sense, one thing that is necessary is to establish a good research environment. This is also a challenge for the WPI. We receive a harsh evaluation every year, but we need to take a longer-term view of research. So a researcher needs to be properly evaluated based on his or her views or potential, even in cases where there has been no output yet. That way we can develop them as good human resources.

I: It is difficult, but that is the important point.

H: Currently, the researchers are often not evaluated based on such standards, but only based on their output such as the annual number of papers. I feel this approach is adversely demotivating them, which is not good. They are making their best efforts, so I think it is important that we view them from a long-term perspective.

At companies, it often happens that the mission of your division changes or the division becomes unnecessary because the policy of the entire company changes. Then people become preoccupied with these things the moment they happen, and they can no longer concentrate on their work. So unless it is decided in advance, from a long-term perspective, to which extent things are surely going to be completed, you cannot focus on your work. For example, suppose you are developing superior experimental equipment in the AIMR, if you feel you have to go to the next place soon, you cannot concentrate on your research.

I: Yes, I see your point.

H: So it is important that the management people have a strong will. If their policies are clear and solid, I think the research performance will naturally follow.
I: That is the difficult part. Nowadays we surely have accountability, with the amount of competitive funds on the increase. On the other hand, it is understandable if it is a span of five years or so, but we are asked the number of papers every single year. It may be acceptable if it is at the level of being reflected in the annual salary and so forth, but the situation is quite harsh if it is going to change the direction or the destiny of the organization.
H: Yes, it is an important point because it is also related to the morale of the researchers. I think the current situation is that if the policies at the management level are not stable, people at the research level are not able to engage in research comfortably.
I: This issue is also related to the government's science policy.
H: I think that is exactly the point. If the government's science policy is to foster the WPI, and there is a certain timeframe set from the beginning, of ten years for example, it is necessary to at least ensure the management of the research institute without discussing whether it should be continued or not. Of course, when a certain degree of policy change is necessary, it needs to be implemented. But when the positions of the researchers are not guaranteed, solid research cannot be conducted. I think this is a big issue.
I: That may be true.
H: So I think all of us need to discuss again what kind of research institute would produce results. We need to reconsider both the policy decision of the research institute and the improvement of the research environment as combined issues.
I: I think the mobility of human resources is also important on the other hand.
H: It is very important. But I think it is more wasteful than anything when even the superior human resources become unnecessarily nervous and cannot achieve good performance. This is a very important point.
I: After all, research institutes are supported by the human resources.
H: If talented human resources do not come to us, our program will not succeed, either.
I: Yes, you are right.
H: When questioned whether the AIMR has an environment that attracts talented human resources, we should not hesitate in our answer even for a moment. It is a question of whether we can tell talented people to "come work with us" with confidence. We need to improve the organization so we can say that. I think this is the challenge we are going to face in the second phase.
I: Yes. This is probably going to be a major topic of discussion.
H: Yes. There are a lot of good things about AIMR, but I think there is still a lot left to do in terms of how to support foreign researchers. I do not think there is sufficient structure to

incorporate the opinions of foreign researchers. So I think we may want to have regular opportunities to listen to the opinions of foreign researchers about their research environment.
I: I think our communication in English has improved significantly.
H: Yes, we have seen a lot of improvement in that area, but I am concerned about whether this place really provides positive opportunities for their career. In general, positive reports come to us easily, but negative reports are shut down to a management level, so we have to be particularly careful about that. I think we need to request the foreign researchers to provide us with negative reports.

In a company, the human resources department would communicate with the employees directly and listens to them to incorporate everyone's opinions. So we also need to have someone reliable in charge, and incorporate people's opinions without fail.
I: It is not that we are going to do that to evaluate people or anything, but rather to learn about the environment…
H: Yes, it is absolutely vital to ask about their research environment.
I: It is at least necessary to listen to them.
H: I think such a system should be established to provide active support to foreigners. If we can incorporate their opinions and create a good research environment, they feel happy about joining the AIMR, and they will tell other people, in the next institute they work, that they liked the AIMR
I: And they will speak to many people about us.
H: Yes. Without that, I do not think the brain circulation, which is the motto of the WPI program, will be realized. So the point is whether people can move to the next workplace, feeling happy that they spent time in the AIMR. In order to help people become happy here, of course it is important to make efforts by themselves, but I think how we approach them is also important. So it will be our challenge in the second phase to create such a system.
I: This is indeed a point we should think about as management.
H: I ask you to do so. I think it is one important point.

Everyone is motivated, so the issue is how to enhance their performance. I always believe that "the best of man is like water." It is not a *sake* brand (laugh). These are the words of Lao-tse, which mean that good things or successful events are like water. Water can freely change its shape and blend in with its surroundings, and benefits all things. Since the researchers are sufficiently motivated, if a good research environment is established, things will naturally run smoothly like water. Therefore, I think our role is to remove any obstacles that demotivate young researchers.
I: That is right. Thank you very much for sharing your opinion on a variety of issues today.

Interviewer: Administrative Director, W. Iwamoto

At Hitosugi Laboratory, WPI-AIMR Annex Building

May 17th, 2011

WPI-AIMR　一杉太郎准教授に聞く
(Interview with Associate Professor Taro HITOSUGI－Japanese version)

上善如水

科学との出会い

岩本：一杉先生は、確か神奈川県のお育ちで、高校も神奈川県の高校でしたね。

一杉：神奈川の県立高校です。その前に、父親が半導体のエンジニアだったものでアメリカに住んでいました。そこが最初に科学技術に接したところだったと思います。

岩本：アメリカにはお幾つぐらいのときいらしたのですか。

一杉：小学３年生から６年生までシリコンバレーにいました。アップルコンピューターの本社がある街です。小学３年生でいきなり現地校に入れられ、英語もわからないし友達もいないし１週間ぐらい泣いていました(笑)。

岩本：それは当然ですね。

一杉：でも、一週間経ったらもうなじんでいました。小学校３年生ぐらいだと言葉は要らないですからね。ボール遊びとかしていれば友達が自然にできます。それで、すぐにアメリカナイズされまして。

岩本：そうですね。お父様が半導体のエンジニアだったということは、小さいころから半導体とかには親しんでいた訳ですか。

一杉：ええ、少なくとも頭の中に入っていましたね。その点は父の影響があると思います。

岩本：小学校を終えて日本に戻ってこられたのですね。

一杉：そうです。そして１９８６年末、私が高校生のとき、超伝導フィーバーが起きました。新聞で毎日、超伝導のことが報道されているのを見て、わからないなりに科学っておもしろいなと思いました。これが私にとって運命の分かれ道の一つだったと思います。

岩本：ああ、なるほど。

一杉：その時に感じた“科学っておもしろいな”という印象が後々に効いてくるのですね。そのときは頭の中に擦り込まれただけで、まだ進路を決めるまでには至らなかったのですが。
それまで何十年も超伝導転移温度、すなわち超伝導になる温度はそれほど向上しませんでした。しかし、IBMチューリッヒ研のベドノルツ先生とミュラー先生の発見によって、超伝導転移温度が一気に液体窒素温度(77 K)を超えるという、物理の上で大パラダイムシフトがあったわけです。そして、多くの研究者がそれまでの研究を止めて、超伝導研究に飛び込んでいったのです。

岩本：そういう時期ですね。

一杉：はい。例えばアメリカの学会では、普通は朝９時ぐらいから夕方６時、７時ぐらいまで議論しているのですけれども、当時は朝の６時までです。一晩中セッションをやっていたと聞きます。それだけ、みんなが興奮して高温超伝導の発表を聞きたがっていた時だったのですね。

岩本：驚きますね。

一杉：今、我々が抱えている課題の多くが解決できると言ってもいいほどの、薔薇(ばら)色の実用化が考えられていました。例えば、電気エネルギーは、電力を日本で生産して日本で消費しますよね。しかし、超伝導技術が確立すれば、例えばサハラ砂漠で太陽光発電して、それをロスなく日本まで送電するとか、エネルギー問題がいろいろ解決できるのです。したがって、私の研究の最終目標は室温で超伝導を起こすことなのです。

岩本：なるほど。そうすると、高校時代は完全に自分は理科系に行こうということを決められた訳ですね。

一杉：はい。ただ、研究者になろうとは思っていなかったのですけれども。

岩本：その後、東京大学に進まれて、学部では工業化学を学んだ訳ですね。

一杉：そうです。工業化学科です。しかし、学部の４年間は全く勉強しませんでした。

岩本：何をやられていましたか。

一杉：ラグビーばかりでした。ずっとラグビーをやっていて、先生に、“君は５本の指に入るほど工学部で成績が悪い”と言われながら、何とか卒業しました。

岩本：今からは想像できませんね。

一杉：４年間一生懸命打ち込んだ、ということが非常に重要だと今は思います。そしてその後、大学院に入ってから勉強にきっちりと切りかえました。

岩本：学部時代はラグビーに専念ですね。

一杉：エンジョイしました。

岩本：東大のラグビー部は当時強かったのですか。

一杉：そのときは結構強かったです。当時は、命を懸けてやるみたいな感じでした。

岩本：そういうガッツが今生きているわけですね。

一杉：そうですね。その心意気というのは今も生きていますね、本当に。

企業と大学、そして研究者になろうと決断するまで

岩本：Nature誌４６６号でも紹介されましたが、先生は、博士課程修了後、初めは民間企業に行かれたとのことですが。

一杉：そうです。

岩本：それで、民間企業から大学に転身された訳ですが、まず、大学院で博士号をとられて、そのまま大学に残るという道もあったのに、民間企業を選択されたのはどうしてですか。

一杉：そのときは、自分の成果が本当に人の目に見えて役立つ姿というのを見てみたかったのです。自分が手がけた技術で皆の暮らしが良くなり、エンジョイしてもらえるというところまでやりたかったのです。企業ならそういうことができると思いました。

岩本：それでソニーに入られる。

一杉：はい、そうです。

岩本：ソニーでは主にどんなお仕事されていたのですか。

一杉：最初、光ディスクの開発です。当時、僕らはブルーレイディスクの先の技術を狙って新

技術の開発をやっていました。そこで、１０年後ぐらいの市場がどうなっているか考えるわけです。そして、それに合わせた商品開発、技術開発をしなければならない。僕らは光ディスク開発だから、DVDの将来を思い描く。そうしたら、将来は高速インターネットも家に普及してくるし、半導体メモリーも非常に高密度になる、そうするとDVDのような光ディスクの活躍の場はなくなるだろうという結論に達して、僕らの開発は中止しました。

岩本：へえ、そういうものですか。

一杉：結局、世の中の流れは今そのとおりになっています。デジタル配信が増えてきて、CD-ROMはパソコンに搭載されなくなっています。また、ハードディスクはどんどん半導体メモリーに置き換わっています。今はDVDの先のブルーレイ技術があるけど、そのブルーレイの先は、最適なアプリケーションが余り思いつかない。すなわち光ディスク技術は廃れていく技術になるということです。

岩本：そうすると、もちろん研究は研究で進められるけれども、企業は、そういった市場の動向の１０年後、２０年後を見据えてという世界だったわけですね。

一杉：はい、そうです。

岩本：ソニーに４年ぐらい在籍されましたかね……

一杉：ええ、４年半です。

岩本：それでまた大学のほうに戻られた訳ですね。

一杉：その前に僕の人生を特徴づける一つのイベントがありました。僕らはモノづくりの専門家ですね。どういう技術を組み合わせてどういう技術開発をやればモノづくりが実現すると考えることはとても得意です。しかし、もう一つの面として、技術を商品として、作った後にどうやって皆に届けるかという点を見ないと、技術が本当にこの先どうなっていくのだろうと見渡せないと思ったわけです。その思いは今も生きています。そこで、自分の作った技術や商品を、どう世の中に広げるかということを実際に経験したいと思いました。ソニーはとてもおもしろい会社で、ドクターを持っている人でも商品企画とかマーケティングとかセールスに移れるのです。

岩本：わかります。

一杉：先程、光ディスク開発プロジェクトが中止になったと言いました。生来、やりたいことがあるならどんどん突っ込んでやろうという性格なので、実際にやったことがないマーケティングやセールスをやりたいといって、世界中にソニーの商品、僕の場合は小さいバイオ(VAIO)、今のiPhoneのようなものを世界にセールスしました。“これがソニーの新商品だ、ソニーの戦略はこうだ！”と、自らプレス発表でプレゼンを行い、雑誌や新聞のインタビューで発言するなど、販売促進をやっていました。

そのような仕事をやりつつ、自分が一生かけてする仕事とは何か、ということをずっと考えていました。それで３０歳の時に、僕が一生かけて何をやるのかということがようやくわかったのです。一生懸命、研究をやろうと。研究から販売の最前線までの広いレンジを見渡したおかげで、自分がどこのポジションにいるのが一番楽しいのか、初めてわかったのです。それで研究に戻ろう、研究を一生の仕事にしようと決めました。もちろん、この決断には、高校生の時に

“科学っておもしろいな”と擦り込まれたことが大きな影響を及ぼしていると思います。

岩本：ああ、なるほど。ワイドレンジのことをやってこられた上での決断ですね。

一杉： もう一つ重要なことがあります。先程言いましたように、ソニーにいた時に、今で言うiPhoneのような製品をまさに僕らが作っていたのですが、今のiPhoneみたいにはブレイクできませんでした。非常に悔しく感じ、なぜだろうと考えました。結論としては、こうやってはいけないというような思い込みがあって、それで自分を縛っていたのですね。だから今は、自分になるべく制約を設けないようにと常に思っています。

岩本：その時の頭の中にあった制約っていうのは、何だったのですか。

一杉：音楽を聴くことを例にしましょう。ソニーは音楽会社を持っているので、著作権に敏感です。しかし、iPhone成功のきっかけとなったMP3技術というのは著作権問題を無視しているのですね。僕らは、音楽会社を持っているから、MP3技術なんか採用してはいけないという思い込みが出てくる。そうすると、おのずと使い勝手が悪くなる。そういう制約は一例です。今は、自分自身に制約を絶対に作らないようにと、自分に言いきかせています。何かに成功すると、かならず足が縛られて次の成功が遠のくのです。

岩本：大学の研究というのは、本来そういう制約はないですね。

一杉：本当ですね。会社に比べたら断然制約が少ないですよ。だから僕は心からエンジョイしています。大学での研究は楽しいですね。僕はいつも学生に言っているのですが、興味があることがあったら飛び込んでみて、悔いのない人生を送れるように、一生かけて取り組める仕事を探すといいよと。あれも興味あるな、やりたいなと思っていてもそこへ飛び込めず、今の仕事に何か不満を持ちながら嫌々やっている人が、かなり多いと思います。そうならないように、というメッセージです。

岩本：いろいろなことに関心を持って、その中から自分が探し出すということですね。

一杉：はい、自分が一生かけてやることを見つけられれば、それが一番幸せだと思います。

岩本：そうですね。その後、東大の研究者になられて、それで、AIMRが発足して２か月ぐらいでジョインされたわけですね。

一杉：２００７年１２月です。僕は確か最初に学外から常勤研究者として雇用されたと聞いています。その年１１月に開催された開所式にも来ました。

研究の特色

岩本：今、AIMRでやられている研究内容を、一言で説明してくださいますか。

一杉：包括すると、固体がどんな性質を持っているのかを調べ、その特徴を活かして応用に結びつけようというものです。簡単に言うと、電気製品、例えば携帯電話の小型化・高性能化や、パソコンの高速化・低消費電力化するための材料研究です。

岩本：そこで、物質を極めてミクロなレベルで測定したり、その性質を調べたりということが重要なのですね。

一杉：そうです。

岩本：先生の研究の主なツールというのは、走査トンネル顕微鏡(STM)ということになるわけですね。最近、岩波講座の「物理の世界」というシリーズで、橋詰先生と一緒に「走査トンネル顕微鏡技術」というご本を書かれましたが。

一杉：はい。

岩本：私も先生に勧められて第１章を読ませていただきました。ローラー先生とかビニッヒ先生とか出てくる。波の性質を使って表面を観察するのですよね。

一杉：原子の並びや原子そのものを見るのですね。原子は、１０のマイナス１０乗メートルという、とにかく小さいですから、人間が見ても、万物が粒でできていると思わない。例えば水だって滑らかに見えるけどあれも粒の集まりですね。その１個ずつの粒を見ることができるというすごい技術が1980年代前半に生まれました。それも物理や化学の分野で大ブレイクすることになった訳です。

岩本：そうですね。それがまさに、ローラー先生たちの大きな功績だったわけですよね。

今、このAIMRの中にある顕微鏡というのが、STMですね。

一杉：そうです。１階の装置がSTMです。世界でも誇れるような良い実験装置を作ったので、それで研究をどんどん進めようというところです。

岩本：はい、わかります。

一杉：原子とか分子からモノが構成されているので、まずそれを理解し、さらにその集合体を理解しようという流れです。今、階層構造についてよくAIMRで議論していますね。原子、分子がくっついたものがクラスターになって、それを一つの集団として見る。それがまたくっついたものをひと固まりとして考えましょうと。そういう階層構造にブレイクダウンして材料科学を再構築しようという流れです。

岩本：そして最後には、バルク状の物までいくのですね。

一杉：はい。現実にはどこかのレベルで機能が出始めるのですけれど、その機能の源はどこなのだろうと考え、さらに数学的な視点を導入して、もっといろいろな材料に展開して新材料科学を打ち立てようということを議論しています。

岩本：先生が今、取り組まれていることは、非常に基礎的な研究なのですね。ところで、AIMRで今後のアウトプットの方向としてグリーンマテリアルと言っていますが、それへの貢献というのは、具体的にどういうことになりますか。

一杉：僕らが手掛けているいくつかのプロジェクトのうちの一つがリチウムイオン電池開発です。これには相当力を入れてやっています。

岩本：これは具体的にはどういう研究ですか。

一杉：最近、走行距離が公称２００ kmである電気自動車が売り出されました。しかし、エアコンをつけたり渋滞にはまったりしたら実際の走行距離は１００ km程度に減るでしょう、１００ kmでは仙台から東京へも行けない。だから、５００から６００ km走行できるようにするためには、電池の容量を増す技術が重要になる。さらに、瞬間的に充電するというのが重要なことです。充電するのに何時間もかかったら大変なので、すぐに充電できるようにしなくてはいけない。

そういうことを実現するための技術です。これは材料が鍵を握っています。

岩本：なるほど、そういうのが重要なのですね。

一杉：二つ目が、透明導電体研究です。これは、発光ダイオード、太陽電池や液晶ディスプレイに使われており、これを革新的に良くすれば、低消費電力ながらもっと明るい照明が実現するし、太陽光発電の効率ももっと上がる。そうすると、グリーンマテリアルにどんどんつながっていく。そして、希少な金属を使わないという流れが重要です。新聞紙上をレアメタルという言葉が賑わしているように、地球上に埋蔵量が少ない元素を使い切ってしまい、産業が成り立たなくなる恐れがあります。たとえば、今のままではインジウムが枯渇すると、液晶ディスプレイ産業が廃れてしまいます。そこで、インジウムを使わない透明電導体というのが重要になります。そのような背景から、文部科学省は元素戦略、経済産業省は希少金属代替というプロジェクトを推進しています。透明導電体研究はその一環です。

岩本：なるほど。わかりました。そういう意味では、グリーンマテリアルに大きく貢献していくわけですね。

一杉：はい。僕らの研究は３本の柱から成り立っています。

岩本：STMによる酸化物の理解とリチウムイオン電池、そして、透明導電体、これが３本柱ということですね。

一杉：そうです。この３本柱はすべて酸化物です。酸化物をきっちりと原子から理解して世の中に役立てるというプロジェクトを行っているのです。

岩本：これはすばらしい。

AIMRの特色として融合研究があります。先生も「文部科学時報」の昨年の５月号でその重要性を力説されていますけれども、具体的にはどんなグループと融合研究を進めていますか。

一杉：僕らは、タイツァー研や阿尻研のように化学の人たちと組んでやることが多いですね。

岩本：具体的にはどのような研究ですか。

一杉：例えば、阿尻研の北条さんたちとやっているのは、阿尻グループの得意な液体を使って小さなナノ粒子を作り出す技術と、僕らの得意な真空成膜技術を組み合わせて、新しい物質を作ろうともくろんでいます。今、阿尻研では１０ナノメートル以下の四角いナノ粒子を作ることができ、これに機能を持たせようとしています。そこで、例えばAという物質のナノ粒子に、Bという物質をくっつけて、A・Bというダンベル状の新物質を作り、新機能を持つ物質を作ろうとしています。

岩本：まさにそれはフュージョンになるわけですね。

一杉：１、２年で成果を求められると大変なのですけれども、そういう取り組みをやって徐々に進展してきています。

岩本：AIMRは、そういう融合研究をしていくには恵まれた環境にあると思いますか。

一杉：各研究室が垣根を取り払う努力をしているので、非常にやりやすい環境だとは思いますね。もう一つは、東北大の片平地区の人々が、横のつながりを大きく重視するところがいいですね。要するに、知らない研究室でも人と知り合う機会が多いです。

岩本：東北大は割とそういうところがありますか。

一杉：多いですね。前任の東大よりは断然多いと感じます。ここはいろいろな人と知り合うことができる風土だと思いますね。東大と東北大、両方経験した人は、東北大のほうが横のつながりが生まれて非常によいと言います。AIMRだけに限らず、金研や多元研とも交流があります。一番町の飲み屋が触媒かも(笑)。

岩本：特に片平はそうですか。

一杉：片平はいいですね。非常にフレンドリーで。いろいろな知り合いが増えるし、共同研究が、まずは装置の貸し借りというところから入って、だんだん広げていけます。研究には人脈が非常に重要ですから。

岩本：特にAIMRの中でも、准教授や講師レベルの方々のいろいろな話し合いというかディスカッションは盛んですよね。

一杉：そうですね。非常に盛んですね。僕ら、特にこの建物(AIMRアネックス棟)の人々はみんなここに新しく来た人々で、最初から結束意識があるのでいろいろやりとりは多いです。

震災からの教訓——安全と安心

岩本：走査トンネル顕微鏡のお話がありましたが、３月１１日の震災では、あの顕微鏡はどうだったのですか。

一杉：あの顕微鏡自体は、思ったほど被害はなかったです。最初大変だなと思いましたけど、よくよく精密に調べてみるとダメージはほとんどなかったのです。

それには二つ理由があったと考えています。一つ目は１階だったことが良かった。そして、もう一つには、そもそも振動を嫌う装置なので、振動を絶縁するためにいろんな装置が組み込んであるわけです。具体的にはアクティブダンピングという装置で、道路に車が通ったりしたときに常に伝わる振動を打ち消すよう動作をする除振装置が入っています。だから、ガツンと来た揺れを打ち消してくれて、一番ひどい揺れをうまく避けられたのではないかなと思っています。除振台上で１．５トンの走査型トンネル顕微鏡が5 cmほどシフトしましたが、ダメージは最小限になったというのが実際のところですね。

岩本：それは良かった。

一杉：そう、本当に良かったと思います。だから、被害は思ったより少なかったです。5階はひどかったですが。

岩本：そうすると、１階のSTMは実際に今使えるわけですね。

一杉：そうです。しかし、ここで重要なことがあります。この走査型トンネル顕微鏡というのは、先ほど言いましたように地面の揺れが大敵なのですね。余震が今も続いているので、そうすると実験ができないのです。ですから、装置が直りましたと言っても、それで僕らの戦いは終わりじゃない。要するに、余震が終わらないと僕らはずっと実験ができない。だから時間が非常に重要ですね。

岩本：そこですよね。

一杉：そこが非常につらいところ。５階の実験室では、耐震固定していたボンベが倒れたり、いろいろな実験装置、計測装置が落下して、現在修理中です。ただ、お金で解決できるところというのはまだ何とかなります。問題は時間です。復旧のために膨大な時間がとられている。

岩本：その間に世界中でいろいろな研究が進んでいるわけですからね。

一杉：そうです。それが研究者のキャリアに大変響いてくるから、そこが今回の震災被害の最も重要なポイントだと思います。研究ができない時間というのは取り戻せない。それは研究者のキャリアにとって本当に致命的です。

岩本：分かります。

一杉：これは頭を使って乗り切るしかありません。この半年、あるいは１年間ぐらいはSTMを用いた本格研究はできないかもしれないけれども、今できることを先取りしてやっておくということでしょう。研究計画を上手に組みかえるしかないですね

岩本：ただ座していても直らない、余震が終わらないと言っていても、進まないですものね。

一杉：座して“早く余震が終わらないかな”と祈っているだけではダメです。だから、研究計画を組みかえる。もう本当にサバイバルですよね。とにかく、頭を使ってアウトプットを出していくというのが僕らに求められているところだと思います。

さらに、精神的なダメージも大きくて。３月１１日の後に何とか立て直そうというふうにみんな言っていて、４月１日に新年度となって「よし、心機一転だ」と思って研究再開に向けて準備していたのに、４月７日に余震が襲いました。そのときにまたいろいろなものが壊れました。それが繰り返されていたら、時間がどんどんロスするから……

岩本：研究のモチベーションから言っても厳しいですね。

一杉：だから、絶対に地震が来ると思って備え、万全な対策を整えたほうが、結局復旧までの時間も短いし費用も少ないと思います。

それと、今回、科学のあり方が大きく問われたと思います。これまで、安全・安心というのは、僕は、同義語として使っていたのですけれども、それは随分違うということがわかりました。「安全」というのは、自分の身は怪我しないとかそういうのを頭で理解することで、「安心」というのは、心から理解する、心から落ち着いて本当に平穏に暮らすということだと思いました。今の科学は、「安全」に対してはフォーカスしていたと思うのですね。

岩本：数値的にも基準値を下回っていますとかですよね。

一杉：そうです。確かに統計的に見て、自分に害はないから大丈夫と頭で理解します。これは「安全」です。だけど、それだけでいいかというと、そうではない。結局、「安心」が無いので、買いだめや風評被害があったりする。「安心」を取り戻すにはどういうことをすればいいのだろうというのが、科学が取り組むべきポイントですね。

だから、例えばある事故が起きたときに、「安全」と思うまでに長い時間かかったら「安心」というのはなかなか取り戻せないけれども、「安全」をすぐに取り戻せれば「安心」もすぐに取り戻せるかもしれない。時間の早さだけはありませんが、「安心」を取り戻すということが、科学の役割ではないかなと思います。

岩本：そうですね。それがまた、社会貢献につながるということでしょうね。

一杉：はい。地震などの災害で困っている国に「安全」だけでなくて「安心」をも提供することが日本の大きな力で、それができれば日本が本当に貢献できるのではないかなと今回思いました。ただ、何をするかというのは、明確にはまだ見えてないのですけれども。「安心」というところにフォーカスしなければいけないなと強く思いますね。心の安心を取り戻すための"材料"とは何か。材料科学のやるべきことは多いです。

岩本：むしろ、日本だからこそそういうところから学び取って、外国の人たちにもこういう教訓を得たというのを伝えていくことが重要ですね。

一杉：それができれば最高です。日本はそういうのは得意だと思います。学んで、それに対応して作り上げるって。だから、日本がまさにそれをやるべきだと思います。

岩本：そうですね。これは重要なことです。

若手研究者の研究環境

岩本：先生の場合は、我々から見ますと若手研究者ということになるのですが。

一杉：ありがとうございます。若手で(笑)。

岩本：AIMRでもインディペンデント・インヴェスティゲーターでおられます。これから我々も第２期に向かっていくわけですけれども、一杉先生よりも若い世代の人たちというのは、どういうふうに頑張っていかなくてはいけないというようなアドバイスをいただけますか。

一杉：まず、みんなやる気があるのは確実ですから、もう彼らに言うことはない。むしろ僕らが今、彼らのために何ができるかということの方がもっと重要な気がしています。

その面でいうと、まず一つは、いい研究環境を整えるということです。ＷＰＩの課題でもあるのですけれども、毎年厳しい評価にさらされています。だけど、研究はそんな１年ごとの評価ではなくて、もっと長い目で見ないとだめですね。だから、アウトプットはまだ出てないけど、その人の考え方や将来性というのを見て、本当はそこできっちり評価しなくてはいけないところですよね。それで、良い人材に育てていく。

岩本：難しいけれど、そこが重要ですね。

一杉：今はそのような評価基準ではなくて、年間の論文数といったアウトプットでしか見てないところがある。それは、逆に彼らのやる気を削いでいるような気がして、そこは良くないなと感じますね。彼らも一生懸命やっているので、僕らも長い目で見てあげるというのが重要と思います。

会社では、自分の部署のミッションが変わるとか、会社全体の方針が変わるからその部署は要らなくなるとか、そういうことが頻繁に起こります。すると、その瞬間にみんなそういうことに気をとられて、自分の仕事に手がつかなくなってしまう。だから、長期的に視野に立って、ここまではきっちりとやるっていう決めごとがないと、専念できないですよね。例えば、優れた実験装置をAIMRに作って良い研究をしようと思っても、すぐに次に出ていかなくてはいけないと思ったら身が入らないですよね。

岩本：そこですね。

一杉：だから、マネージメントの方々にしっかりして頂く必要があります。上の方針が明快できっちりしていれば、研究のパフォーマンスは自ずと出てくると思います。

岩本：そこは難しいですよね。今は、競争的資金の額はどんどん増えてきていて説明責任というものが確かにある。一方、５年とかそういうスパンならまだしも、毎年、毎年、論文数はと問われます。それも年俸に反映とかそういうレベルではあっても良いのかもしれないけれども、それが組織の方向とか運命を変えるようでは厳しいですよね。

一杉：はい、研究者の士気に関わるので重要な点です。上層部の方針が落ち着いていないと、なかなか下も落ち着いて取り組めないというのが現状だと思いますね。

岩本：この点は、国の科学政策にも関わって来ますよね。

一杉：そこだと思いますね。国の科学政策でWPIというものを育てるのならば、ある程度の年限、最初から１０年と決めていたら、研究所の存続を論じるなんてことは無く、運営を最低限、確保しなければならないと思います。もちろん、ある程度方針の修正が必要な場合は、それをやったほうがいいと思います。しかし、研究者のポジションが保証されないと、骨太の研究ができないですよね。これは大きな課題だと思います。

岩本：それはそうかもしれない。

一杉：だから、成果の出る研究所とはどのような研究所なのかということを、皆でもう１回議論しなければならないと思います。研究所の方針決定と研究環境改善をセットでもう一度考える必要があると思いますね。

岩本：もちろん人材の流動性とか、それはそれで大事だと思いますが。

一杉：それはとても重要です。だけど、優れた人材までが変な不安に駆られてパフォーマンスが出ないというのが一番もったいないことだと思います。そこが非常に重要な点です。

岩本：結局、人によって支えられているわけですからね。

一杉：優れた人材が来ないと、このプログラムもうまくいかないですからね。

岩本：そう。おっしゃるとおりです。

一杉：AIMRが優秀な人材を惹きつける環境かと問われたときに、どうなんだろう？と一瞬たりとも躊躇させてはならないのです。自信を持って、いい人に“こちらにおいでよ”と言えるかっていうところですね。そう言えるように組織を改善しなければなりません。ここは第２期の課題だと思います。

岩本：そうですね。そこは多分大きな議論になるところですね。

一杉：ええ。あと、AIMRのいいところはいっぱいありますけれども、外国人研究者をどうサポートするかというところは、まだまだやることがあると思いますね。外国人研究者の意見を吸い取る仕組みが今あまりないと思います。ですから、外国人研究者の研究環境について、定期的に聞く機会があってもいいと思うのです。

岩本：英語によるコミュニケーションは飛躍的によくなってきましたけれども。

一杉：そこは大分いいと思いますが、本当にここがキャリアのプラスになっているかっていう

ところが気になります。良い報告はいつも来るのだけど、悪いほうの報告は来ないから特に注意しなくてはいけないですよね。その悪い報告というのを、外国人研究者に僕らのほうから求めていかなくてはいけないと思います。

会社であれば人事部がダイレクトに本人とやりとりして、それでその人の意見を聞いて、どんな意見をみんな持っているかっていうのを吸い上げていきます。だからしっかりとした人がそういう担当でいて、きっちりと吸い上げないといけない。

岩本：別にその人を評価するとか何とかっていうのではなくて、むしろ環境を知るという意味で……

一杉：そうです、研究環境はどうですかという視点から聞くのは絶対重要です。

岩本：少なくとも話を聞いてあげるようなことは必要でしょうね。

一杉：そういうシステムを持って、外国人を積極的にサポートしていかなくてはいけないと思いますね。彼らの思うところを酌み取ってあげて良い環境で仕事をしてもらい、ハッピーで次の研究機関に移れば、AIMRは良かったよって言ってくれるでしょう。

岩本：そして、多くの人に広めていただけますものね。

一杉：そうです。それがないとWPIプログラムの標榜する頭脳循環が実現しないと思うのですね。だから、AIMRにいてハッピーだったと思いながら次の職場へ移れるかどうかっていうところがポイントなのです。ハッピーな状態をここで実現するためには、その人が頑張るだけでなくて、僕らがどうアプローチするかというのが重要だと思います。だから、そういう仕組みも作るというのも、第２期の課題だと思いますね。

岩本：これは確かにマネージメントとしても考えなくてはいけないところですね。

一杉：ぜひお願いします。そこが一つ重要なポイントだと思います。

皆やる気はあるから、それいかに成果に結びつけるのか。僕はいつも「上善如水(じょうぜんみずのごとし)」と思っています。お酒の銘柄ではないですよ(笑)。「上善如水」とは、良いことやうまく行くことというのは水のようなものだ、という老子の言葉です。水は自在に形をかえて周囲と調和し、万物に利を与えます。やる気は十分ですから、研究環境さえ整えば水のように自然とさらさらといく。だから、成果が出ることを妨げる要因を取り除くこと、それが僕らの仕事だと思います。

岩本：そうですね。今日は多岐にわたるお話をいただきどうもありがとうございました。

２０１１年5月１7日
WPI-AIMRアネックス棟　一杉研究室にて
岩本　渉

News Update

Site Visit by International Working Group of the WPI Program

Program Director Toshio Kuroki and the International Working Group of the WPI Program led by the Program Officer in charge of AIMR, Yoshihito Osada, made a site visit to AIMR on August 10 through 11, 2011. The site visit has been held once a year since FY2007 for the purpose of assessing the state of our project implementation through discussions with AIMR members and a site observation. This year, the exercise has high importance as the objective of the visit is especially to ascertain the progress made since the WPI's founding in 2007, in view of an interim evaluation.

On the first day, Director Yamamoto gave an overall briefing on the AIMR's progress, the group leaders presented the research of each of their groups, and young researchers made poster presentations. Following these sessions, overall discussion was conducted between visitors and AIMR members. On the second day, the Center Director gave a briefing on the new AIMR main building and facilities, and the visitors went around them. Finally, a post-site-visit discussion was conducted between visitors and AIMR members. Very fruitful discussions with the visitors were held throughout the sessions. The International Working Group will report their views to the WPI Program Committee which will make a final evaluation of the performance of WPI Centers.

International Working Group Members:
Yoshihito Osada, Program Officer, Special Advisor at RIKEN
Samuel M. Allen, Professor at Massachusetts Institute of Technology, USA
Hideo Hosono, Professor at Tokyo Institute of Technology
Colin Humphreys, Professor at University of Cambridge, UK
Yasuhiko Shirota, Professor at Fukui University of Technology
Samuel I. Stupp, Professor at Northwestern University, USA
Tomohiko Yamaguchi, Deputy Director at Nanosystem Research Institute,
National Institute of Advanced Industrial Science and Technology
Toyonobu Yoshida, Professor at the University of Tokyo

WPI-AIMR – Cambridge Symposium

Susumu Ikeda

The WPI-AIMR – Cambridge Symposium was held on June 14, Tuesday, 2011 at Pfizer Meeting Room in the Department of Materials Science & Metallurgy, University of Cambridge. So far, our collaboration has been carried out mainly in bulk metallic glasses (BMG). The purpose of this symposium was to extend the collaboration to other discipline, such as chemistry, physics, and device/system construction in order to enlarge the scope of collaboration with University of Cambridge, one of the satellites of AIMR. In this symposium, theoretical groups covering chemistry and physics, chemists, biochemists, surface scientists and optoelectronic physicists got together and prospect of our comprehensive and interdisciplinary collaboration was confirmed.
The delegates from two institutions are as follows.

Cambridge: Prof. Lindsay Greer, Prof. Michiel Sprik, Prof. Daan Frenkel,
Prof. Neil Greenham, Dr. Erwin Reisner, Prof. Paul Midgley, Dr. Caterina Ducati
WPI-AIMR: Prof. Yoshinori Yamamoto, Prof. Kazuto Akagi, Dr. Ikutaro Hamada,
Prof. Masaru Tsukada, Prof. Tadafumi Adschiri, Prof. Taro Hitosugi, Prof. Katsumi Tanigaki,
Prof. Motoko Kotani, Prof. Susumu Ikeda

The symposium was started with the opening remarks by Prof. Lindsay Greer and Prof. Yoshinori Yamamoto. Prof. Greer kindly welcomed us and expressed his deep concern about the situation of Sendai after the disaster. Prof. Yamamoto replied to this comment and appreciated the thoughtfulness and hospitality of Prof. Greer and delegates from University of Cambridge. Recent research interest and results were presented as follows and meaningful discussion was made for our future cooperation.

Atomistic Studies on Solid-Liquid Interfaces

Dr. Ikutaro Hamada showed his results of first-principles calculations of the electrochemical reactions, which are relevant to the hydrogen fuel cell reaction. Dynamical process of the chemical reaction $H^+ + e^- \leftrightarrow 1/2H_2$ at the water/Pt(111) electrode interface, via Heyrovsky and Tafel steps, were studied using the blue-moon ensemble molecular dynamics simulation, and microscopic mechanism of the reaction was discussed.

Prof. Kazuto Akagi presented the first-principle calculation of the structure and dynamics of water at the solid/liquid interfaces. He emphasized that analysis of the higher-order information such as size distribution and life-time of ring structures in the hydrogen bond network can provide important clues to understand various properties of the interfacial region including chemical reactivity.

Theoretical Studies in Physics and Chemistry

Prof. Masaru Tsukada introduced current activity of his group to establish the theory of molecular nanostructures. He also emphasized the importance of their SPM simulators which his group has developed pioneeringly. In order to investigate the nanostructures by collaboration between experimental and theoretical researchers, such simulators are very useful for discussing the phenomena observed by SPMs.

Prof. Michiel Sprik presented the recent results using a combination of density functional theory based molecular dynamics (DFTMD). He showed the computed result of the TiO_2/H_2O interface and compared the calculated conduction- and valence-band edges with the experimental data. The main purpose of this calculation was to study the oxidative

dehydrogenation of a water molecule absorbed on the TiO_2 surface. He suggested that using the solvation free energy of H^+ as energy reference led to good computational result of the conduction-band edge while not good in the estimation of the valence-band edge. He concluded that the activation by the surface is largely due, not to a reduction of the ionization energy, but the increase of the acidity of the water molecule.

Prof. Daan Frenkel described his current study on the numerical exploration of routes to design novel, self-assembling structures and materials; simulation of equilibrium and nonequilibrium properties of soft materials. He introduced novel Monte Carlo techniques to predict the thermodynamic stability of complex structures such as DNA-coated colloids. He also mentioned their exploration of novel dynamical simulation techniques to predict the process of structure formation from a meta-stable parent phase.

Hybrid Material

Dr. Erwin Reisner showed the catalytic activity of enzymes. He described [NiFeSe]-Hydrogenase from *Desulfomicrobium baculatum* (Db) attaced to dye-sensitised TiO_2 produces H_2 with high efficiency. Hydrogenases are microbial enzymes that catalyze the selective and reversible interconversion of H_2. He also described that TiO_2 nanoparticles (NPs) modified with a photosensitizer and the CO_2-reducing enzyme CODH I from the anaerobic microbe *Carboxydothermus hydrogenoformans* (*Ch*) provide an extraordinary catalyst for CO_2 photoreduction ($CO_2 \rightarrow CO$).

Prof. Tadafumi Adschiri talked about his material synthesis technique using supercritical water and focused his talk on the results of CeO_2, the catalytic oxide widely used for cleaning automobile emission. He first introduced the previous data of CeO_2 nanocrystals investigation and showed the latest challenge to obtain the most active crystal surfaces for improving the catalytic activity. They succeeded in obtaining such nanocrystals exposing the most reactive (100) surfaces by attachment the organic molecules to the surfaces, hindering growth in that direction. He also commented on possibility of collaborative study with Dr. Reisner's group.

Electron Microscopy and Optoelectronics

Prof. Taro Hitosugi introduced the strategy of his research group. In particular, he focused on the oxide thin films and showed some recent results of the high quality oxide thin films such as $LaAlO_3$ grown on $SrTiO_3$ by pulsed laser deposition (PLD) technique and STM investigation of the surface. One of their goals is to obtain novel electronic properties by making atomically ordered oxide films and/or atomically controlled oxide-oxide interface structures with homo- and hetero-epitaxy.

Prof. Katsumi Tanigaki talked about recent advancement of light-emitting organic field-effect transistors (LE-OFETs). He described that their goal was to realize electrically-driven organic laser using LE-OFETs and for this purpose he encouraged the fusion research with Prof. Yamamoto's group to obtain new organic semiconductors with high mobility and high luminescence efficiency. He emphasized that the molecular design appropriate for LE-OFETs has gradually been clarified.

Prof. Paul Midgley presented the vivid 3D images of the nano-structured materials obtained by the tomography technique using transmission electron microscopy (TEM). In the same way as X-ray computed tomography (CT), many projection (transmission) images are acquired with sample rotation and reconstruction computation is carried out to obtain the 3D data set. So far, their Electron Microscopy Group succeeded in 3D imaging of many kinds of materials, including a result obtained in collaboration with Prof. Adschiri. He also mentioned the use of electron energy loss spectroscopy (EELS) technique for imaging.

Dr. Caterina Ducati showed some instances of 3D imaging with the TEM tomography, for example, the observation of Grätzel Cell. She also presented her recent challenge, imaging the photo active sites in materials by irradiating the specimen in the TEM equipment using the light introduced through an optical fiber from outside light source to the specimen side.

After each presentation we had an animated discussion. For example, some challenges which should be attempted in our collaboration were proposed. The symposium made an important step for our further collaboration and provided many suggestions for our joint research. The success in this symposium largely due to the careful arrangements by Prof. Greer and we would like to thank his great hospitality.

WPI-AIMR Opens its New Building

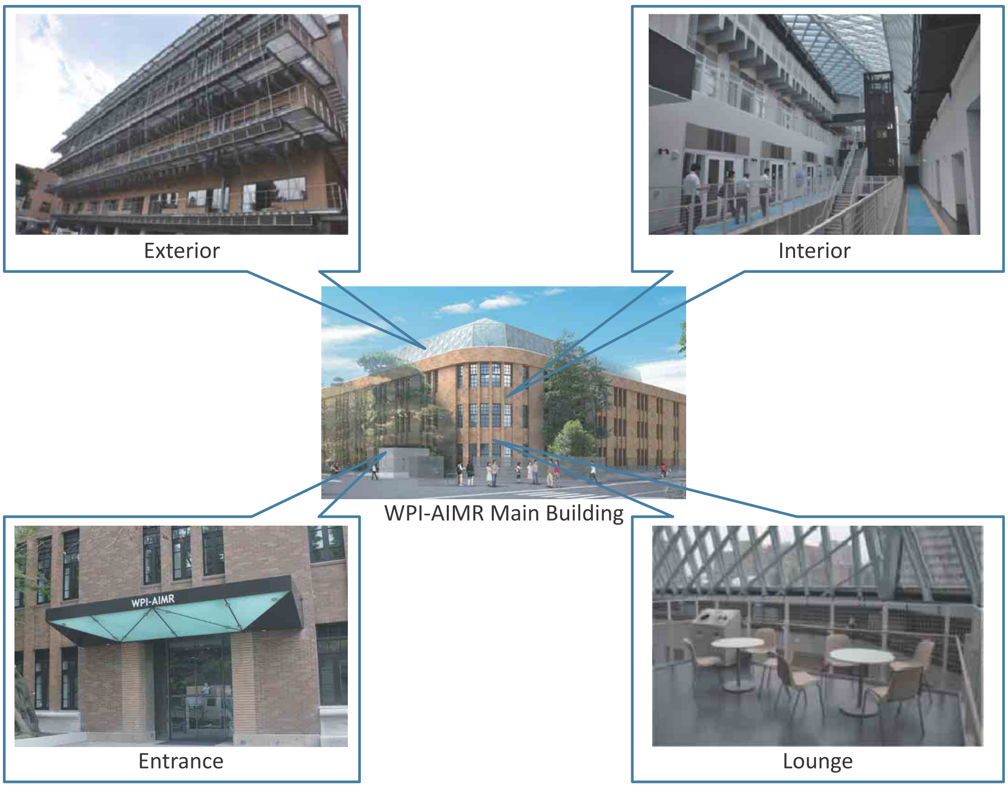
The WPI-AIMR main building was completed at Katahira campus, Tohoku University at the end of July, 2011. The construction was made possible with the help of the governmental supplemental budget of 2009 in the amount of 2 billion yen.

The design of the new building is characterized by the concept of harmony with the existing traditional building dating from the 1920s and the provision of an atrium which provides sunlight.

With the new building, the research environment of WPI-AIMR has been drastically changed. It enables 10 PIs and their staff who used to work in different campuses to get together and accordingly, all AIMR members can work at Katahira Campus. This will satisfy the conditions for further promotion of fusion research. The Combination Room and Lounge will enhance face-to-face communications between researchers. The Multi-purpose Hall will serve as a space for researchers' discussions, outreach events like science cafés and exhibits.

The Joint Seminar will be organized in the spacious seminar room and regular tea time will be held on the first floor under a shiny roof. With the Directorate, Administrative Office and library being located in the new building, it will play the role as the center of AIMR activities.

The new building, together with the International Guest House to be completed next year will become a landmark of Tohoku University as a World-leading University.



Iron-based Superconductors: Borrowing from Graphene

Seigo Souma

The paper “Observation of Dirac Cone Electronic Dispersion in $BaFe_2As_2$” was published in Europhysics Letters (EPL) has been selected for one of the EPL Most Cited Articles for last 25 years (1986-2011).
The outcome was also featured on Physics Today on April 25.
The following paragraphs give a detailed description of the title.

The discovery of iron-based superconductors in 2008 reenergized the field of superconductivity research, all the more so because the electronic properties of these new compounds have proved to be complex and full of surprises. Few, however, would have expected that these superconductors would display features similar to those of another material that has recently attracted the excitement of scientists — graphene.

A team of researchers led by Takashi Takahashi of the WPI-AIMR had been studying the iron-based compound $BaFe_2As_2$ in order to gain new insights into its magnetic properties, particularly with respect to the ‘spin-density wave’ (SDW) order previously reported for this material. The team discovered that the compound has a Dirac cone-like electronic band structure[1] — the same feature that gives graphene its exceptional properties.

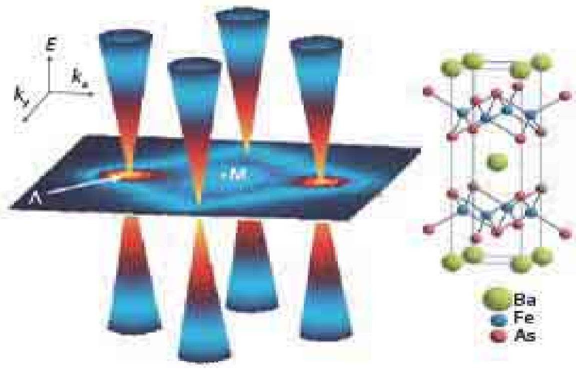


Fig. 1: Schematic illustration of the Dirac cones in $BaFe_2As_2$ and the bright points (Λ) in momentum–energy (k–E) space. The atomic structure of the compound is shown on the right.

$BaFe_2As_2$ is the parent compound of one member of the iron-based superconductor family. It is widely accepted that superconductivity in these iron-based compounds, as in the cuprate superconductors, is present in the parent compound but suppressed by another property, usually magnetism. The parent compound is induced into its superconducting state by adding impurity atoms and cooling it to extremely low temperature.

The researchers examined the parent compound $BaFe_2As_2$ using a technique known as angle-resolved photoemission spectroscopy, which revealed two bright points of photon emission in momentum space below the SDW temperature (Fig. 1). Focusing on these points and studying emission as a function of energy and momentum, the team then discovered the Dirac cone — a band structure that describes how electrons behave like massless relativistic particles at certain points in momentum space.

The similarity with graphene is not complete, however. While the Dirac cone of graphene is symmetric with respect to momentum, that for $BaFe_2As_2$ is distinctly asymmetric and displays small pocket-like features and nodes, features that present intriguing targets for future research.

The team's results have broad implications for many of the actively studied topics in solid-state physics. Aside from graphene, Dirac cones have also been observed in 'topological insulators', a class of materials that are at once both insulating in the bulk and metallic at the edges. "Whoever would have thought that iron-based superconductors, one of the hottest materials in materials science, would exhibit low-energy physics similar to graphene?" says Pierre Richard, one of the lead researchers involved in the discovery. "With our findings, people will have to think more carefully on the connection between all of these materials, which could lead to the development of new functional materials with exotic properties."

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Physics Today:
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“Fabrication of Li-intercalated bilayer graphene”

K. Sugawara[1], K. Kanetani[2], T. Sato[2], and T. Takahashi[1,2]

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[2] Department of Physics, Tohoku University

Intercalation of atoms or molecules into layered materials causes various interesting changes in the electrical and chemical properties. Graphite intercalation compounds (GICs) have a high potential for technological applications like chemical catalysis and storage of intercalants [1]. Lithium (Li) intercalated graphite (Li-GIC) has been widely used as an anode material in the rechargeable battery [2]. However, it is unclear whether the intercalation of Li atoms is possible in the thinnest limit, namely in bilayer graphene. Fabrication of Li-intercalated bilayer graphene is very important for developing a new nano-scale ion battery with a high charge/discharge rate [3].

We have succeeded in fabricating Li-intercalated bilayer graphene for the first time and studied the electronic structure with angle-resolved photoemission spectroscopy (ARPES) [4]. We have tried to fabricate Li-intercalated bilayer graphene by depositing Li atoms with a SAES getter on a graphene sheet grown on a SiC surface. Figure 1 shows a comparison of Fermi surface (FS) determined by ARPES between pristine and Li-deposited bilayer graphene. Pristine bilayer graphene shows a single FS at the K point in the Brillouin zone, while Li-deposited bilayer graphene exhibits two different types of FSs in the same momentum region; a closed triangular-shaped FS (S1 FS) and a relatively larger open-type FS (S2 FS). There are additional FSs (S3 and S4) around the G point, which are produced by the band-folding of S2 and S1 FSs, respectively, due to the $\sqrt{3}\times\sqrt{3}R30°$ superstructure of ordered Li ions as observed by the LEED measurement. These experimental results unambiguously indicate that deposited Li atoms are certainly intercalated in the bilayer graphene sheet with a well-ordered manner as in bulk GIC (Fig 1 (c)). The present experimental result opens a promising pathway for developing a new

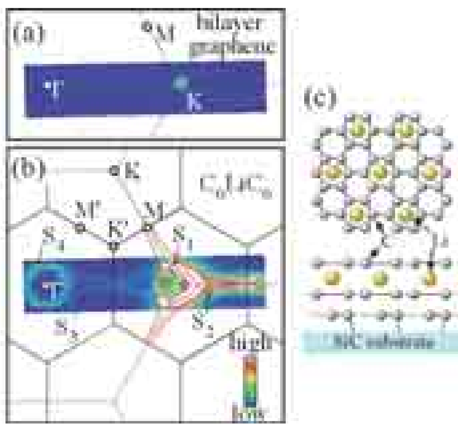

Figure 1 Fermi surface of (a) pristine and (b) Li-intercalated bilayer graphene determined by ARPES. (c) Crystal structure of Li intercalated bilayer graphene.

nano-scale ion battery with a higher charge/discharge rate and a reduced volume change.

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“Direct Measurement of the Out-of-Plane Spin Texture in the Dirac Cone Surface State of a Topological Insulator”

S. Souma[1], K. Kosaka[2], T. Sato[2], M. Komatsu[2], A. Takayama[2], T. Takahashi[1,2], M. Kriener[3], Kouji Segawa[3], and Yoichi Ando[3]

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[2]Department of Physics, Tohoku University
[3] Institute of Scientific and Industrial Research, Osaka University

The topological insulators (TIs) materialize a new state of quantum matter where an unusual gapless metallic state appears at the edge or the surface of a band insulator due to a topological principle. The surface state of three-dimensional TIs is characterized by a Dirac-cone dispersion which has been shown to have a helical spin structure where the spin vector points parallel to the surface and perpendicular to the momentum **k**, as shown in Fig. 1 [1, 2]. Because of this helicity in the spin direction and the protection by the time-reversal symmetry, the Dirac fermions in the TIs are immune to the backward scattering [1] and are not very sensitive to non-magnetic impurities or disorder. This peculiar situation provides a platform for novel topological phenomena such as the emergence of Majorana fermions in the proximity-induced superconducting state, and indeed many theoretical models or experimental results were developed or interpreted relying essentially on this simple helical spin structure [1, 2]. However, it is unclear at the moment to what extent such a simple spin texture is adequate. In fact, recent theoretical studies predicted that when the FS of the surface Dirac state is hexagonally deformed, the spin structure starts to obtain a finite out-of-plane component [3-5]. It was also predicted [3,5] that such a component can be as large as the in-plane counterpart in Bi_2Te_3 which shows the strongest hexagonal FS warping among known TIs.

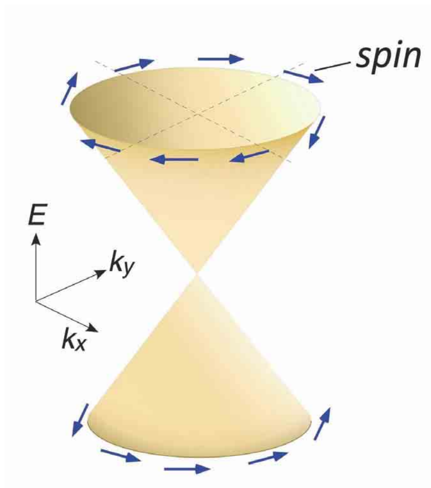

Figure 1. Schematic picture of the Dirac cone surface state with a simple hellical spin texture.

We have performed spin- and angle-resolved photoemission spectroscopy of Bi_2Te_3 and present the first direct evidence for the existence of the out-of-plane spin component on the surface state of a topological insulator [6], by using ultrahigh-resolution spin- and angle-resolved photoemission spectroscopy [7]. We found that the magnitude of the out-of-plane spin polarization on a hexagonally deformed Fermi surface (FS) of Bi_2Te_3 reaches maximally 25% of the in-plane counterpart while such a sizable out-of-plane spin component does not exist in the more circular FS of $TlBiSe_2$, indicating that the hexagonal deformation of the FS is responsible for the deviation from the ideal helical spin texture. The observed out-of-plane polarization is much smaller than that expected from existing theory, suggesting that an additional ingredient is necessary for correctly understanding the surface spin polarization in Bi_2Te_3.

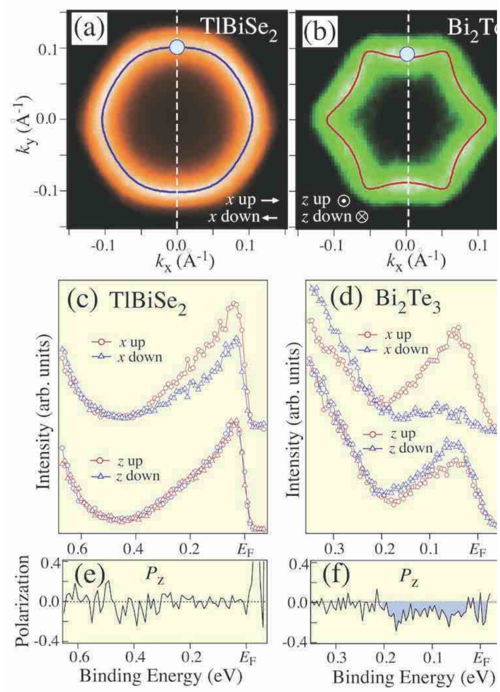

Figure 2. (a),(b) Comparison of the FS between $TlBiSe_2$ and Bi_2Te_3. (c),(d) Spin-resolved ARPES spectra measured at the point shown in (a) and (b) respectively. (e),(f) Corresponding E_B dependences of spin polarization Pz.

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“Voltage induces superconductivity: new era of searching for matters”

Masashi Kawasaki

WPI Advanced Institute for Materials Research, Tohoku University & School of Engineering Univ. Tokyo

Discovery of new superconductors is one of the most influential events in materials science. This has been accomplished by experiments based on empirical knowledge or alchemy; mixing some elements to produce new materials phases. Soon after the Onnes’s discovery of superconductivity 100 years ago, people had mixed metallic elements to synthesize new inter-metallic compounds in the first generation (See Fig. 1). When new discoveries had stopped (Nb_3Ge, critical temperature (T_c) of 23K), people shifted the strategy to mixing some dopant elements into insulating materials to make them conducting (second generation). The significant breakthrough in this approach was the discovery of high critical temperature (T_c) cuprates (T_c < 135K). Instead of these dopants, one could use a concept of field effect transistor (FET), where charge carriers are electrostatically injected into insulating (semiconducting) compounds. Collaborating with Prof. Y. Iwasa, we have developed a new way of accumulating charge carriers with a density two orders of magnitude greater than ever accomplished in conventional FET. This is the electric double layer (EDL) transistor. This EDL concept was revealed 130 years ago by Helmholtz and is now used as super-capacitor in modern electric vehicles. Figure 2 shows a schematic of EDL transistors where insulating crystal is in contact with an ionic liquid that behaves as electrolyte. With applying a few volts to the gate, one can accumulate up to $10^{15}cm^{-2}$ charge carriers; note that it is greater than the surface atomic density of $6x10^{14}$ cm^{-2}. This accumulation induced superconductivity in $SrTiO_3$ and ZrClN, which were known to be superconducting also by chemical doping[1,2]. Now, we discover $KTaO_3$ can be superconducting by electron doping, which has been impossible because of the lack in miscibility of any dopant element[3]. This discovery is a clear indication that we are entering the third generation of finding new superconductors that may give us even higher T_c.

1) K. Ueno, et al. Nature Mater. **7**, 855 (2008).
2) J. T. Ye, et al. Nature Mater. **9**, 125 (2010).
3) K. Ueno, et al. Nature Nanotech. **6**, 408 (2011).

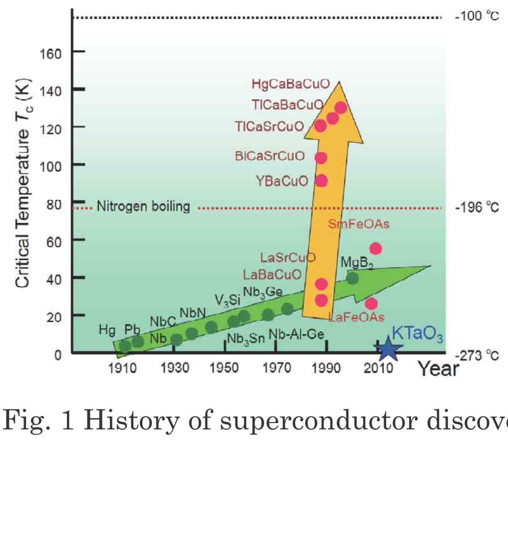


Fig. 1 History of superconductor discoveries.

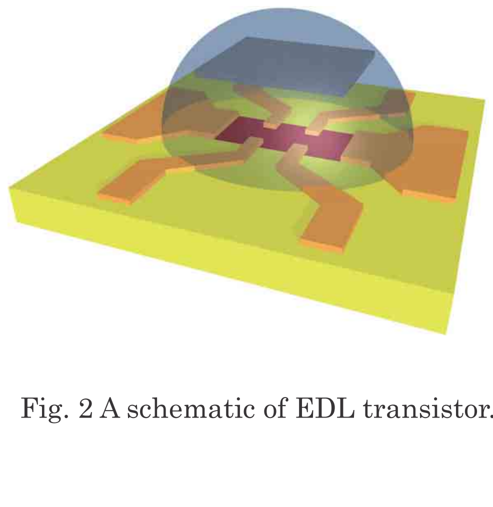


Fig. 2 A schematic of EDL transistor.

“Voltage induces magnetism: new era of magnetic devices”

Masashi Kawasaki

WPI Advanced Institute for Materials Research, Tohoku University & School of Engineering Univ. Tokyo

When you heat a matter, the temperature goes up. Similarly, applying a magnetic field induces magnetization and an electric field generates charge accumulation in a capacitor. Imagine, if there is cross term of these input-output relations. If you can control magnetism by electric field, you will be able to make useful magnetic devices with ultra-low power consumption that can replace existing memories and logic circuits in computers and smart-phones. There is an interesting materials system to accomplish this hard task, called ferromagnetic semiconductors. If you mix magnetic impurities in a semiconductor AND inject charge carriers, magnetic moment of impurities are aligned by exchange coupling with charge carriers. We made a significant advance 10 years ago[1)] by finding a room temperature ferromagnetism in an oxide semiconductor TiO_2 doped with a few % of CoO. The magnetism can be turned on and off by changing the oxygen deficiency that defines electron density in this semiconductor. The interaction between spin-aligned Co ions and electrons was confirmed by so-called anomalous Hall effect; electrons cannot run straight even in zero-magnetic field because of ferromagnetic magnetization[2)]. This also implies that the electron spin is also aligned. We now demonstrate that the ferromagnetism can be switched on and off by the control of charge carrier density in a field effect transistor geometry[3)]. Figure 1 (a) shows a transmission electron microscope image of our $(TiCo)O_2$ films taken by Prof. Ikuhara of WPI-AIMR that clearly indicates Co and Ti ions are homogeneously mixed. By accumulating emulous amount of charge carriers in an electric double layer transistor with $(TiCo)O_2$ as a channel, one can switch on and off the ferromagnetism even at room temperature. Fig. 2 shows the switching behaviors represented by the emergence of magnetic hysteresis in anomalous Hall effect. We hope this new finding will trigger further development in applications for post-silicon technology.

1) Y. Matsumoto, et al., Science **291**, 854 (2001)
2) H. Toyosaki, et. Al., Nature Mater. **3**, 221 (2004)
3) Y. Yamada et. Al., Science **332**, 1065 (2011)

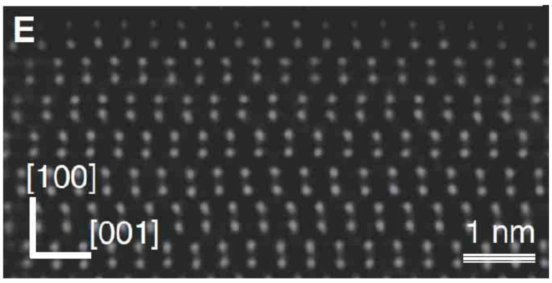


Fig. 1 Scanning transmission electron microscope image of a $(TiCo)O_2$ film.

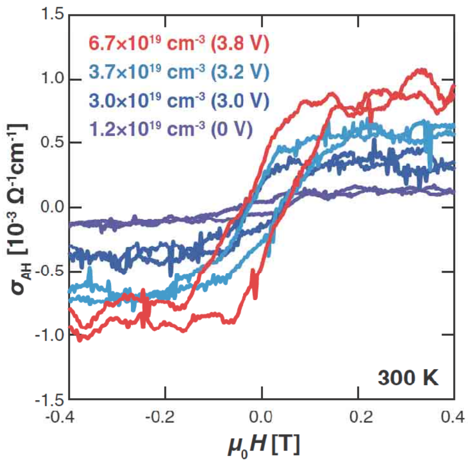


Fig. 2 Emergence of magnetic hysteresis in anomalous Hall effect by a voltage application.

“Gradient biomaterials for soft-to-hard interface tissue engineering”

A. Seidi[1], M. Ramalingam[1,2], I. Elloumi-Hannachi[3], S. Ostrovidov[1],
A. Khademhosseini[1,4,5]

[1]WPI-Advanced Institute for Materials Research, Tohoku University, Sendai, Japan
[2] National Institute of Health and Medical Research U977, Université de Strasbourg, Strasbourg, France
[3] Petit Institute for Bioengineering and Biosciences, Georgia Institute of Technology, Atlanta, USA
[4] Center for Biomedical Engineering, Department of Medicine, Brigham and Women’s Hospital, Harvard Medical School, Cambridge, USA
[5]Harvard-MIT Division of Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, USA

This paper was published in “Acta Biomaterialia, Volume 7, Issue 4, Pages 1441-1451, 2011” as the top downloaded paper so far this year.

Interface Tissue Engineering (ITE) is an emerging field that aims to regenerate functional tissues to repair or to replace damaged zones between different tissue types. Examples of tissue interfaces in the human body include ligament-to-bone, tendon-to-bone, and cartilage-to-bone. These tissue interfaces exhibit anisotropic structural properties, which gradually vary from one tissue to another. Conventional tissue engineering using isotropic scaffolds in monophasic or composites biomaterials do not match the needs required by interfacial tissue reconstruction and thus has limitations to re-create the structural organization seen at the junction of different tissue types. To support the growth of heterogeneous cell populations that reside at the tissue interfaces, anisotropic biomaterials are therefore essential and this anisotropy can be obtained by the use of compositionally and/or structurally graded biomaterials [1].

In this recent paper [2], we reviewed current developments in the fabrication and the uses of gradient biomaterials for ITE applications. In particular, we emphasize on microengineered gradient hydrogels and nanoengineered gradient fibers due to their ability to mimic some important properties of the native extracellular matrix (ECM). Indeed, hydrogels exhibit hydration and viscoelastic properties close to the native ECM. Their chemical and physical properties are tunable making them potentially suitable for producing tailored 3D microenvironments for cells. Hydrogels with gradients in physical properties like stiffness or porosity and hydrogels with gradients in chemical cues due to the incorporation of immobilized or soluble factors have been notably used for high throughput screening, cell migration studies, axonal guidance and cell differentiation. Also, electrospun fibers have a large surface to volume ratio, high porosity and good mechanical properties which are favorable for interaction with cells and tissue engineering applications. Technical approaches to generate gradient nanofibers have been mostly based on surface modification of the ejected fibers post-electrospinning. Both, gradient hydrogels and gradient nanofibers, as their combination, offer very promising perspectives for ITE due to their design flexibilities and functional properties, which could match the complex environment seen at the tissue interface and could promote the required heterotypic cell interactions.

References

[1] M. Singh, B. Tech, C. Berkland, M. Detamore, Tissue Engineering B, 14, 4, 341-366,(2008).

[2] A. Seidi, M. Ramalingam, I. Elloumi-Hannachi, S. Ostrovidov, A. Khademhosseini, Acta Biomaterialia, **7**, 4, 1441-1451, (2011).

[3] S. Sant, M. J. Hancock, J.P. Donnelly, D. Iyer, A. Khademhosseini, The Canadian Journal of Chemical Engineering 88, 6, 899-911, (2010).

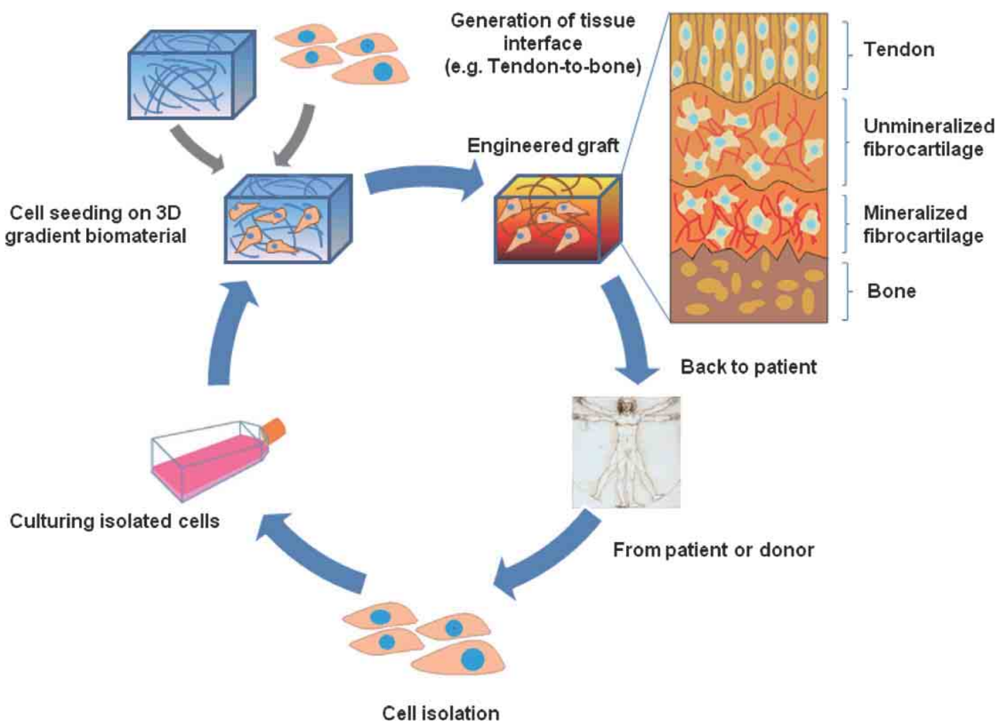


Fig. 1 Illustration of the concept of Interface Tissue Engineering.

FY2011 List of Major Governmental Research Funds
(As of August 1, 2011)

A. Grant-in-Aid for Scientific Research (KAKENHI)

(Unit: thousand yen)

Categories	Representative's Name		Budget Distribution (*1)
Scientific Research on Priority Areas	TANIGAKI, Katsumi (PI)		15,100
	TANIGAKI, Katsumi (PI)		13,300
	ASAO, Naoki		2,100
	HITOSUGI, Taro		800
	Subtotal	4	31,300
Scientific Research on Innovative Areas	KURIHARA, Kazue (PI)		14,690
	ASAO, Naoki		3,510
	HAMADA, Ikutaro		1,950
	Subtotal	3	20,150
Scientific Research (S)	ESASHI, Masayoshi (PI)		4,810
	ADSCHIRI, Tadafumi (PI)		33,280
	YAMAGUCHI, Masahiko (PI)		36,400
	TAKAHASHI, Takashi (PI)		72,410
	Subtotal	4	146,900
Scientific Research (A)	KOTANI, Motoko (PI)		9,620
	TSUKADA, Masaru (PI)		9,880
	MIYAZAKI, Terunobu (PI)		6,240
	YAMADA, Kazuyoshi (PI)		11,570
	MATSUE, Tomokazu (PI)		13,910
	IKUHARA, Yuichi (PI)		14,820
	YAMAMOTO, Yoshinori (PI)		15,860
	Subtotal	7	81,900
Scientific Research (B)	NISHI, Toshio (PI)		650
	Subtotal	1	650
Scientific Research (C)	ASAO, Naoki		1,170
	TAKEUCHI, Akira		1,430
	SHIMOMURA, Masatsugu (PI)		910
	NAKAJIMA, Ken		2,210
	SAITO, Mitsuhiro		2,990
	Subtotal	5	8,710
Challenging Exploratory Research	KOTANI, Motoko (PI)		1,300
	ISHII, Daisuke		2,080
	NAKAYAMA, Koji		2,730
	ADSCHIRI, Tadafumi (PI)		2,080
	Subtotal	4	8,190
Young Scientists (A)	ISHII, Daisuke		3,510
	HITOSUGI, Taro		17,940
	HOJO, Daisuke		22,880
	Subtotal	3	44,330
Young Scientists (B)	LIU, Hongwen		650
	YOSHIDA, Shinya		1,560
	MCKENNA, Keith Patrick		1,040
	XU, Limei		1,170
	JIN, Tienan		2,340
	FUJINAMI, So		650
	OHSAWA, Takeo		650
	HIRATA, Akihiko		1,300
	WANG, Zhongchang		1,560
	LIU, Yanhui		1,560
	TANABE, Yoichi		3,510
	JI, Sungdae		1,430
	TSUKIMOTO, Susumu		2,470
	Subtotal	13	19,890
Subtotal		44	362,020

B. Other Grant-in-Aid

(Unit: thousand yen)

Representative's Name	Distributing Organization	Project Title	Budget Distribution (*1)
ESASHI, Masayoshi (PI)	Japan Society for the Promotion of Science (JSPS)	Funding Program for World-Leading Innovative R&D on Science and Technology	679,000
	Subtotal	1	679,000

C. Research funds consigned from government directly

(Unit: thousand yen)

Representative's Name	Distributing Organization	Project Title	Budget Distribution (*1)
ADSCHIRI, Tadafumi (PI)	Japan Science and Technology Agency (JST)	Core Research Evolutional Science and Technology (CREST)	14,950
TSUKADA, Masaru (PI)	Japan Science and Technology Agency (JST)	Core Research Evolutional Science and Technology (CREST)	7,800
KURIHARA, Kazue (PI)	Japan Science and Technology Agency (JST)	Core Research Evolutional Science and Technology (CREST)	71,760
SHIMOMURA, Masatsugu (PI)	Japan Science and Technology Agency (JST)	Core Research Evolutional Science and Technology (CREST)	19,500
KOTANI, Motoko (PI)	Japan Science and Technology Agency (JST)	Core Research Evolutional Science and Technology (CREST)	37,713
YAMADA, Kazuyoshi (PI)	Ministry of Education, Culture, Sports, Science and Technology (MEXT)	Elementary Strategic Project	9,555
ESASHI, Masayoshi (PI)	Japan Science and Technology Agency (JST)	Strategic International Cooperative Program	4,620
ADSCHIRI, Tadafumi (PI)	New Energy and Industrial Technology Development Organization (NEDO)	Technical Development of Ultra-hybrid Materials (Technological Development of Contradictory Functional Materials by nano-scale Structure Control)	197,157
HITOSUGI, Taro	Japan Science and Technology Agency (JST)	Precusory Research for Embryonic Science and Technology (PRESTO)	22,880
NAKAYAMA, Koji	Japan Science and Technology Agency (JST)	Research Seeds Quest Program	5,200
FUJITA, Takeshi	Japan Science and Technology Agency (JST)	Research Seeds Quest Program	5,850
IWAYA, Katsuya	Japan Science and Technology Agency (JST)	Research Seeds Quest Program	5,200
SATO, Toyoto	Japan Science and Technology Agency (JST)	Research Seeds Quest Program	2,950
HITOSUGI, Taro	New Energy and Industrial Technology Development Organization (NEDO)	Grant for Industrial Technology Research (Financial support to young researchers)	9,750
	Subtotal	14	414,885

D. Research funds reconsigned through the private enterprise/university

(Unit: thousand yen)

Representative's Name	Distributing Organization	Redistributing Organization	Budget Distribution (*1)
NISHI, Toshio (PI)	New Energy and Industrial Technology Development Organization (NEDO)	Bridgestone Corporation	13,908
SHIMOMURA, Masatsugu (PI)	New Energy and Industrial Technology Development Organization (NEDO)	Fujifilm Corporation, Japan Tissue Engineering Co., Ltd. (J-TEC)	9,300
TSUKADA, Masaru (PI)	Japan Science and Technology Agency (JST)	Advanced Algorithm and Systems Co., Ltd.	3,120
TSUKADA, Masaru (PI)	Ministry of Education, Culture, Sports, Science and Technology (MEXT)	University of Tokyo	7,000
TANIGAKI, Katsumi (PI)	Misitry of Economy, Trade and Industry (METI)	Kuramoto Co., Ltd.	2,394
HITOSUGI, Taro	Japan Society for the Promotion of Science (JSPS)	University of Tokyo	30,193
	Subtotal	6	65,915

	Total	65	1,521,820

*1:Budget includes indirect expenses.

WPI-AIMR Outreach Activity Report

The outreach activity of WPI-AIMR has been promoted while the restoration of the research environment affected by the big earthquake continues to be undertaken. The outreach team held the following three events in June and July.

"The Academic Consortium of Sendai – Satellite Campus" (June 11)

WPI-AIMR participated in the satellite campus project of the Academic Consortium of Sendai and Outreach Manager, S. Ikeda gave a lecture entitled "Introduction to materials science – from rocks to state-of-the-art materials" on June 11, 2011 at Ichiban-cho Lobby of the Tohoku Institute of Technology, Aoba-ku, Sendai.

"The City of Academia 'Sendai-Miyagi' Science Day 2011" (July 10)

WPI-AIMR opened a booth at the "City of Academia 'Sendai-Miyagi' Science Day 2011" held at Kawauchi North Campus in Tohoku University on July 10, 2011. About 100 participants (elementary, junior and senior high school students, and their parents) enjoyed investigating the properties of light and materials using polarizing plates. For the first time, Director Y. Yamamoto gave out the "WPI-AIMR Award" to another exhibitor for their wonderful event showcasing genuine plasma which could be touched.

"Tohoku University Open Campus 2011" (July 27-28)

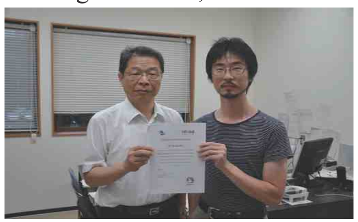
The Tohoku University Open Campus was held on July 27 and 28, 2011 and WPI-AIMR opened a booth in the Physics A Building, Aobayama Campus. About 200 participants (mainly high school students) visited the booth and learned about the experiment investigating the properties of materials and were given an introduction to WPI-AIMR using posters and magazines.

In the latter half of this fiscal year, we are planning to organize the first public exhibition at WPI-AIMR main building at the Katahira Festival 2011 (October 8-9), the WPI Joint Symposium in Fukuoka (November 12), and the Science and Technology Festa in Kyoto (December 17-18).

Award Information

Name	Position	Thrust	Name of Award	Awarding Organization	Date of Award
Daisuke Ishii*	Assistant Prof.	Device/System	SSSJ Young-Researcher Lecture Award 2010	The Surface Science Society of Japan	February
Kazunori Ueno	Assistant Prof.	Materials Physics	Tokin Foundation for Advancement of Science and Technology 22th Research Encouragement Award	NEC Tokin Corporation	March
Tomokazu Matsue	PI	Device/System	The Chemical Society of Japan Award for Creative Work	The Chemical Society of Japan	March
Tomokazu Matsue	PI	Device/System	Best Paper Award	The Electrochemical Society of Japan	March
Ali Khademhosseini	Junior PI	Device/System	Young Investigator Award	Society for Biomaterials	April
Mingwei Chen	PI	BMG	The 2011 Distinguished Award	The 8th International Workshop on Intermetallic and Advanced Materials, China	May
Esashi Group		Device/System	Outstanding Paper Award	Transducers	June
Ali Khademhosseini	Junior PI	Device/System	2011 Y.C. Fung Young Investigator Award	American Society for Mechanical Engineers (ASME)	June
Alain Reza Yavari	PI	BMG	Award for Scientific Excellence	French National Center for Scientific Research (CNRS)	July
Ali Khademhosseini	Junior PI	Device/System	Early Career Award in Nanotechnology	IEEE Advancing Technology for Humanity	August

* Assistant Prof. Ishii also received “The 4th WPI-AIMR Award” on July 20.
WPI-AIMR Award is given to the young researchers working at WPI-AIMR in Sendai when they won the prize from research organizations, academic societies, academic journals, or administrative organizations, and Institute Director evaluates their work is worth awarding.



Dr. Ishii

The Fourth Series of WPI-AIMR Joint Seminars FY2011

The topics of the Fourth WPI-AIMR Seminar Series of Fiscal Year 2011 are "Cooperation between Materials Science and Mathematical Science" and composed of two parts, i.e., (1) "Mathematical (Math-Mate) lecture + discussions", and (2) "Materials science presentation + discussion" meetings. The first half of the seminar is assigned to lecture/presentation, and the latter half to questions/ (panel) discussions. Initial several Seminars should be introductory to form a common understanding among WPI staffs on the aim/problems of the collaboration with mathematics.

As for the part (2), the speakers are chosen from younger/senior researchers mainly from WPI-AIMR and they provide topics concerning on the following questions;

[1] How does he/she expect the cooperation with mathematics or mathematical science?

[2] What does he/she expect from the concept of "Functon（see below）" for creating a novel research strategy of materials science?

[3] How can his/her research topics be seen from the view point of Functon?

Proposals of a presentation at the Seminar providing any opinions and related topics by research members at WPI-AIMR will be most welcome. But Committee members of Seminars may ask research members to give a talk at one of the Seminars at any occasion.

Please remind that the participation to this Seminar Series is mandatory.

＊＊＊ about Functon ＊＊＊

Definition of the concept of "Functon" itself is the important theme which will be discussed through this seminar series. Here is a starting point for you to think of it by yourself.

What is Functon（"機能子" in Japanese and Chinese）?

Functon is a constituent element of materials showing a certain definite function or property, and every material is composed of one or many kinds of assembled functons. The size of functons ranges over from the size of atom/molecule to macroscopic size. Functons often take spatial or temporal nesting structures, i.e., the structures like matryoshka (Russian doll); higher rank functon is formed as an assembly of lower rank functons.

Why Functon?

Functon is a central concept introduced at WPI-AIMR to create a novel research strategy of materials science. Namely we consider materials science can be performed without going back to atom/molecule, but by introducing the concept of minimum function unit, i.e., functons. Working on functons, materials science can be effectively executed with a help of mathematical science. So far existing materials science remained the science of matter where properties of matter is solved in turn from the lower to higher rank, i.e., from atom/molecule level to macroscopic level, which therefore treats ordinary (non-inverse) problems in terms of mathematics. However, a true materials science should treat an inverse problem to finding out necessary functons to create novel materials with desired function. Mathematical science should play important role for that cooperating with materials science.

Functons as a target of mathematical sciences

Mathematical science, of which important tool is the concept of functon helping a bridge with the materials science, is needed for solving the difficult inverse problem. It should solve how to combine complicated multilayer functon systems for the inverse problem. Furthermore the mathematical science is also expected to help developing materials as sensitive but robust, and those with multi-functions responding environment change. Mathematics is also necessary for the control of rare events, and for device processes utilizing pattern formation and so on. These can be also achieved with the help of the concept of functons.

Establishing the concept of Functon

Elucidation of easy processes forming higher rank functons from the lower rank functons, even from those of atoms/molecules level, and forming functons in artificial materials, which are related with non-equilibrium open systems, phase transition and nucleation core, interface processes, and self-organization, have been major topics of individual materials science so far. However, to create a guiding principle of innovative materials science, it is essentially important to explore and establish a general concept of “Functon”, and with its bolster, establishing a strategy of a novel materials design by solving the inverse problem.

Report on the 1st Seminar

Nobuaki Aoki

June 24, 2011

"A Role of Mathematics in a New Context
– Seek for Possible Collaborations with Materials Science"
Prof. Motoko Kotani

"Algorithms for Segment Packing and Generalized Kakeya's Problem"
Prof. Takeshi Tokuyama (GSIS, Tohoku University)

Panel Discussion

The main topic of the 4th WPI-AIMR Joint Seminar Series is "Cooperation between Materials Science and Mathematical Science", and having the knowledge on the relationship between mathematics and materials science is the first step for establishing the cooperation. In the 1st seminar, we had two mathematical lectures and held panel discussion as a starting point of our scientific exploration.

For the first math lecture, Prof. Kotani presented change in the historical role of mathematics. She pointed out problems the human society encounter have become more and more complicated and larger in data-size in the late 1980s, and complexity beyond the efficiency zone of the existing tools encourages mathematics to acknowledge a new position to handle them. Earlier applications by European Science Foundation were also introduced and examples of successful collaboration with materials science were reported.

In the second lecture, Prof. Tokuyama illustrated a suggestive instance of solving a problem with the help of accumulation of mathematics over the past hundred years. The problem was to determine the smallest area from given line segments. It was solved in the context of computer science, but finding optimal geometric structures should be an important theme also in material science. He mentioned that such a solving methodology may bridge mathematics and computational material science.

The panel discussion was also held. In order to promote the cooperation with mathematics, we started comprehensive consideration on the materials science as the combination of element of functions. Following the introductory talk by Dr. Akagi, several examples of "functional unit (electric circuit, structure of document, concentration blob in polymer, *etc.*)" were given by the organizing committee, which include a suggestive clue to find a non-material functional unit in materials science.

Report on the 2nd Seminar

Ryo Nouchi

July 8, 2011

"“Functon” in Adschiri Group's Research, Fusion of Ideas in WPI, Analogy & Math”
Prof. Tadafumi Adschiri

“What Is Functon, Why Functon and What Can Be Functon”
Prof. Katsumi Tanigaki

Panel Discussion

In this seminar, two Math-Mate talks were given by Prof. Adschiri and Prof. Tanigaki, which were followed by open discussions entitled “What can be *Functon* (2)” and “*Functon* as a Bridge between Materials Science and Mathematics”. In succession to the 1st seminar, the efforts were made to help materials scientists think of the possible collaboration with mathematics.

In the first lecture, Prof. Adschiri emphasized needs for high heat conductive materials to make an efficient recovery system of exhaust heat from automobiles. To obtain materials possessing this function, Adschiri group has developed super hybrid materials such as surface-modified nanoparticles, which can be a basic functional element of this function. He also introduced the research results in WPI-AIMR, which unveiled similarities between different materials. This kind of analogy between different materials can be found further in other materials with the help of mathematics.

In the second lecture, Prof. Tanigaki mentioned three inventions that have most contributed to science and technology: namely, lasers, transistors, and integrated circuits. Next, he introduced main research subjects in Tanigaki group, *i.e.*, light-emitting organic transistors, Dirac-cone states in Fe-based superconductors, and cage-like thermoelectric materials. He also discussed possible basic functional elements for these three subjects. Finally, he encouraged us to make researches for energy harvesting without using pseudoscience like Feynman's ratchet.

Following the two Math-Mate talks, we had open discussions, which were led by Dr. Akagi. At first, Dr. Ikeda made an introductory talk about the role/importance of mathematics to establish a new scientific principle in materials science. After that, in succession to the previous seminar, we discussed about re-examination of functional materials as a combination of basic functional elements in order to make effective collaborations with mathematics.

Research Prospect

Development of Novel Methods of Surface Forces Measurement for Nano-Materials Science

Kazue Kurihara

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1. Introduction

One of important challenges in advanced materials science is bridging a gap between materials nano-science and real materials, that is, designing real materials in nano-scale precision like biological systems. In order to achieve this goal, it is essential to elucidate and regulate molecular and surface interactions. Self-assembly is essential at all scales in biology, which demonstrates an ideal model for designing materials at the atomic and/or molecular level of precision.

Surface forces measurement and atomic force microscopy (AFM) have made it possible to directly measure molecular and surface interactions in liquids as a function of the surface separation with high sensitivity. Naturally, they have become powerful tools for studying the origins of forces operating between molecules and/or surfaces of interest [1, 2]. They also offer a unique, novel surface characterization method, which "monitors surface properties changing from the surface to the bulk (depth profiles)" and provides new insights into surface phenomena [3]. This method is direct and simple. It is difficult to obtain a similar depth profile by other methods; X-ray and neutron scattering measurements can provide similar information but require extensive instrumentation and appropriate analytical models.

Our research concerns "elucidation of molecular and surface interactions as well as surface properties of nano-materials", and "development of novel functionalized molecular architectures". For this purpose, we use the surface forces measurement as a major tool. Molecular architectures are self-organized polymolecular systems where molecular interactions play important roles. They exhibit specific and unique functions that could not be afforded by single molecules. Molecular architecture chemistry beyond molecules is not only gaining a central position in chemistry but becoming an important interdisciplinary field of science [4]. Recently, the concept has extended to architectures of nano-scopic objects such as nano-particles and nano-rods [5]. Investigation of molecular architectures by surface forces measurement is important from the following points of view.

(1) It is essential to elucidate intermolecular and surface interactions involved in self-organization, of which significance is not limited to material science but extends to the ingenuity of biological systems.
(2) The importance of surface characterization in molecular architecture chemistry and engineering is obvious since solid surfaces are becoming essential building blocks for constructing molecular architectures as demonstrated in self-assembled monolayer formation and alternate layer-by-layer adsorption [6], and assembles of nano-particls [5]. Surface-induced structuring of liquids is also well-known [7, 8], which bears implications for micro- and nano-technologies (i.e., liquid crystal displays and micromachines). Because surface forces are sensitive to change in surface force characteristics, force measurement could point out intriguing phenomena. For example, we found novel molecular architecture (alcohol macroclusters) at solid –liquid interfaces [9, 10].
(3) Two-dimensionally organized molecular architectures can be used to simplify the complexities of three-dimensional solutions and allow the surface forces measurement. By employing this approach, we can study complex systems such as polypeptides and polyelectrolytes in solutions [11], and specific interactions of proteins [12].

Earlier studies of surface forces measurement were mainly concerned with surface interactions determining the colloidal stability including surfactant assemblies [1, 2]. It has been demonstrated, however, that a “force-distance” curve can provide much richer information on surface molecules; thus it should be utilized for studying a wider range of phenomena [13]. Practically, the preparations of well-defined surfaces, mostly modified by two-dimensional organized molecules, and the characterization of the surfaces by complementary techniques are keys to this approach. A similar concept is “force spectroscopy” [14], coined to address force as a new parameter for monitoring the properties of materials. A major interest in force spectroscopy is the single molecular measurement generally employing an atomic force microscope [15]. On the other hand, the forces measurement of two-dimensionally organized molecules has advantages complementary to those of single molecule force spectroscopy. It can monitor many molecules at the same time and thus is better suited for studying long-range weaker forces. The measurement should bear a close relevance to real systems that consist of many molecules, because interactions between multiple molecules and/or macroscopic surfaces in solvents may exhibit characteristics different from those between single molecules. The surface forces measurement possesses its own virtue.

In spite of its obvious importance, the surface forces measurement remained a relatively specific tool in the field of colloid and interface science. A major drawback of surface forces measurement employing surface forces apparatus (SFA) is restriction of samples: it is applicable only for transparent substrates and liquids because it uses FECO fringes for the distance determination [1]. We have recently developed a novel SFA, a twin-path SFA (Figure 1), which is a practically only SFA for opaque samples [16].

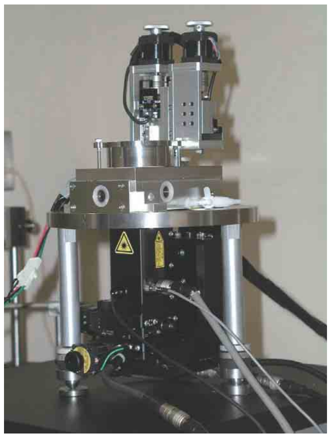

Figure 1. Photograph of a major part of the twin-path SFA.

Another instrumentation we have involved is the shear force measurements. Taking an advantage from an ability of the surface forces apparatus to regulate the surface separation with a high resolution, various shear measurements have been developed to study confined liquids. This paper describes the resonance shear measurements (RSM) which we have also recently developed [17]. Using this measurement, it is possible to perform measurement for nano-rheology and nano-tribology.

2. Experimental Section

2.1 Twin-path Surface Forces Apparatus (Twin-path SFA)

A schematic diagram of the twin-path SFA is shown in Figure 2. The top surface is fixed to the stainless steel chamber and the bottom surface is mounted on a double-cantilever spring supported by a shaft connected to the surface drive system. The distance between surfaces was mechanically controlled by the drive system composed of a pulse motor (Oriental Motor Co., Ltd.) in combination with the differential spring. The displacement of the bottom surface was measured using the twin-path distance measurement unit.

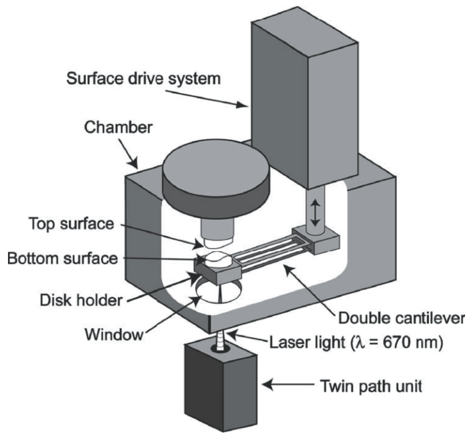

Figure 2. Schematic diagram of the twin path SFA. Laser light (λ = 670 nm) goes through the window at the bottom of chamber and is reflected by the back of the disk holder. The reflected light is monitored by the twin path unit. The surface distance is controlled by a surface drive system.

The mica surfaces glued on silica lenses were mounted in the SFA chamber, and the distance between them was measured by FECO (Fronges of Equal Chromatic Order) using the common procedure [1]. The lower surface was driven by a certain number of counts and the change in the distance was determined. The displacement/pulse thus determined was 0.0050 ± 0.0002 nm in the working range of 4 μm.

The detail description of the twin path unit is shown in Figure 3. The collimated light beam emitted from a laser diode (λ = 670 nm) (Applied Techno Corp.), was split into several orders of interferometric light by a diffraction grating. The +1st order diffracted light was entered to the SFA chamber from the bottom window and reflected by the mirror of the lower sample holder, while the –1st order diffracted light is reflected by the fixed mirrors in the twin path unit. These reflected lights are recombined with each other on the four diffraction gratings attached to the four-sectored photo diode (Hamamatsu Photonics K. K.). The different intensities of the interference pattern with the phase shift of 0, 90, 180, 270 degrees were detected by the four-sectored photo diode (Figure 4). The phase difference between the ± 1st order lights is calculated using the following équation[18],

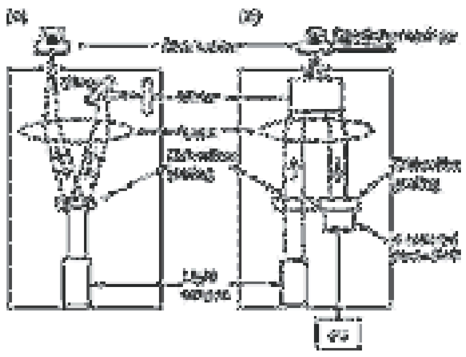

Figure 3. Schematic figures of the twin path distance measurement unit ((a) front view and (b) side view). The +1st and –1st order beams are reflected by the bottom of the disk holder and that by the fixed mirrors, respectively and are recombined on the diffraction grating. The recombined beam is detected by the 4-sectored photo diode and analyzed by the PC.

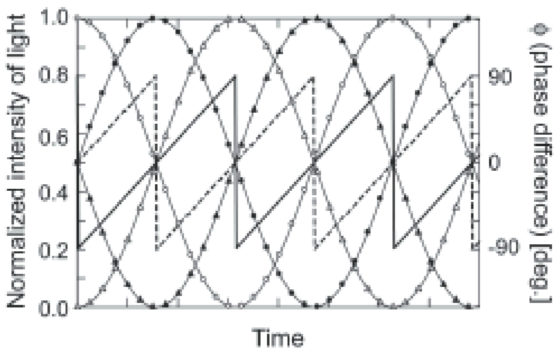

Figure 4. Schematic figure of the changes in the intensities of laser light (CH1, solid circles; CH2, open circles; CH3, solid triangles; CH4, open triangles) and obtained phase differences shown as jagged curves (ϕ_1 , solid line; ϕ_2 , broken line) on approach.

$$\phi_1 = \arctan\{(I_4 - I_2)/(I_1 - I_3)\} \qquad (1)$$

where ϕ_1 is the phase difference (degree) and I_1, I_2, I_3, and I_4 are the intensities of the light recorded by Channel 1 (CH1), 2 (CH2), 3 (CH3), and 4 (CH4) of the four-sectored photo diode, respectively. This phase difference shows the jagged curve with the change in the surface displacement as shown in Figure 3. The surface displacement, D (nm), can be obtained from the équation [18],

$$D = \frac{1}{2}\frac{\phi_1}{360} \times \lambda \qquad (2)$$

where λ is the wavelength of laser light (λ = 670 nm).

The resolution of the surface displacement would be low at the steep gradient parts of ϕ_1 as shown in Figure 3. To avoid this problem, we calculate simultaneously the phase difference, ϕ_2, by equation (3),

$$\phi_2 = \arctan\{(I_3 - I_1)/(I_4 - I_2)\} \qquad (3)$$

to replace ϕ_1 in equation (2), when the ϕ_1 is in steep gradient parts.

2.2 Resonance Shear Measurement (RSM)

A photograph and a schematic drawing of the device for resonance shear measurement are shown in Figure 5. The droplet of a liquid was confined between upper and lower solid (typically mica or silica) surfaces. The upper surface was laterally oscillated with various frequencies by applying the sinusoidal voltage (U_{in} and $-U_{in}$) to the two opposite electrodes of the four-sectored piezo tube. The movement of the upper surface is monitored by the capacitance probe, and the output voltage (U_{out}) was plotted as the amplitude ratio of U_{out} /U_{in} as a function of frequency. This is the shear resonance curve, which shows the maximum amplitude at a characteristic (resonance) frequency. When the upper and lower surfaces are in a large separation, the height of this resonance peak is sensitive to

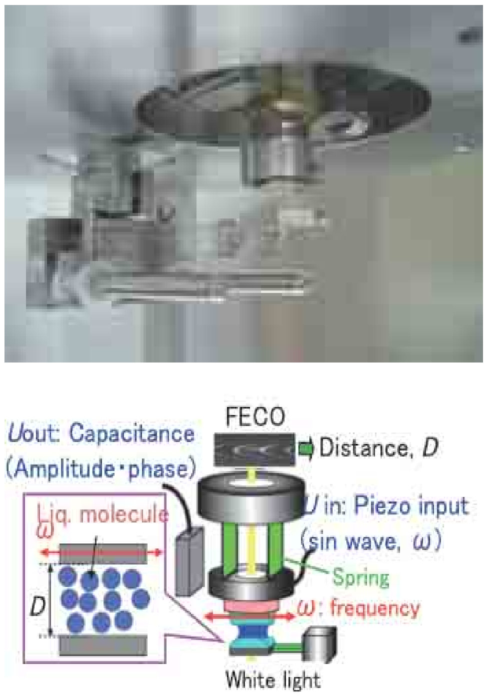

Figure 5. The device for resonance shear measurement : a photograph (top) and a schematic drawing (bottom).

the viscosity of confined liquid and decreases with decreasing the surface separation. When the surfaces come closer, the resonance frequency usually shifts to a higher frequency due to the coupling of the upper and lower surfaces mediated by confined liquid (due to the contribution of the spring of the lower unit).

3. Results and discussion

3.1 Linearity and Resolution of Distance Determination by Twin-path SFA

We first examined the linearity in the displacement measurement by the twin path unit for large displacement range. The movement of a mirror fixed at the end of the surface drive unit was measured by both of a capacitance probe (ST-0535A, IWATSU Electric Co., Ltd.) and the twin path unit. The surface drive unit was operated by a pulsed motor with a differential spring (see Figure 2). The displacement measured by the twin path unit and by the capacitance probe well agreed with the calculated value using the data (0.008 nm/pulse by FECO for this drive system). The deviations between the measured and the calculated values were ca. 2% for twin-path method and 4% for capacitance probe over the 5 μm, respectively. The measurements by the twin path unit showed higher accuracy and linearity than the capacitance probe used in this study.

In order to examine the resolution of displacement measurement by the twin path method, the stepwise motion of mirror was given by the pulse motor was monitored. The mirror surface was moved by 1 nm (pulse counts, 200; velocity, 400 counts/s) every 5 seconds interval and the total displacement was measured every second. Figure 6 plots the data at every second together with the calculated value based on the given pulses. The measured data agreed well with the estimated value, and the resolution of a current set-up is 0.2 nm, which is close to the resolution by FECO (0.1 nm).

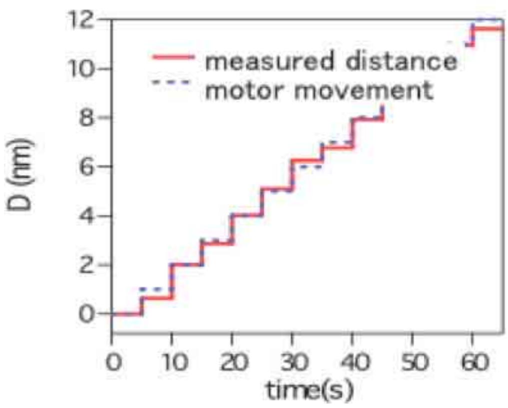

Figure 6. The displacements in air measured by the twin path method (solid line) compared with the calculated value from the pulse number of motor (dotted line).

3.2 Double Layer Force between Mica Surfaces Measured by Twin-path SFA

In order to demonstrate the reliability of the apparatus, we performed typical measurements. The surface forces between mica surfaces in aqueous KBr (MERCK, suprapur) (0.1 mM, 1.0 mM and 10.0 mM) were measured by injecting the KBr solution into the chamber. These surface force profiles are plotted in Figure 7. The decay lengths of 32 ± 3 nm, 11 ± 1 nm, 4 ± 1 nm for 0.1 mM, 1.0 mM and 10.0 mM, respectively, were well agreement with the theoretical Debye lengths (30.4 nm, 9.6 nm, 3.0 nm) [1]. The broken lines indicated the theoretical fits to DLVO forces of the constant surface potential (0.1 mM, 90 mV; 1.0 mM, 90 mV; 10.0 mM, 50 mV) and constant surface charge (0.1 mM, 0.02 charge/nm^2; 1.0 mM, 0.06 charge/nm^2; 10.0 mM, 0.08 charge/nm^2) conditions. The pull-off force was detected only in 0.1 mM KBr solution as 2.6 ± 1.6 mN/m. These results are well agreement with previous results measured by the conventional SFA[1,2].

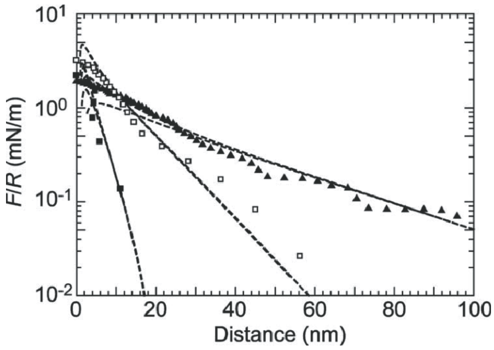

Figure 7. Surface forces between mica surfaces in aqueous KBr solution. The solid triangles, open squares, and solid squares are the profiles of 0.1 mM, 1.0 mM and 10.0 mM KBr solutions. The broken lines denote the theoretical DLVO curves at constant surface potential and constant surface charge conditions.

3.3 Aqueous NaCl Solution Confined between Mica Surfaces Measured by RSM.

The dynamics of confined water thinner than a few nanometers were in controversial in previous studies [19, 20]. Our study employing RSM provided a

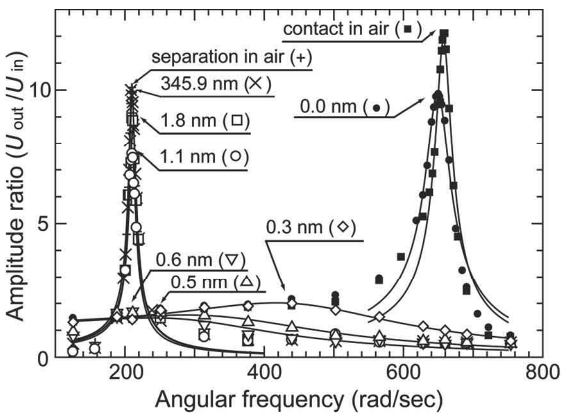

Figure 8. Resonance curves for NaCl solution (7 mM) confined between mica surfaces at seven distances: 345.9 nm, 1.8 ± 0.3 nm (load = 0.14 mN), 1.1 ± 0.3 nm (0.24 mN), 0.6 ± 0.3 nm (0.55 mN), 0.5 ± 0.2 nm (1.33 mN), 0.3 ± 0.2 nm (2.15 mN), 0.0 ± 0.3 nm. The reference states of the separation and mica-mica contact in air are shown together. The arrows denote the peak position of the resonance curve at the surface distances. The solid lines denote the fitting curves to our mechanical model.

comprehensive picture for this complicated situation[21]. The viscoelasticity of the thin film of aqueous NaCl solution confined between mica surfaces was measured by shear resonance apparatus. The observed shear resonance curves (Figure 8) at separations less than ca. 2 nm indicated that the solution exhibits the high lubrication effects under some loads. The distances were measured using FECO. The effective viscosity (0:1–10 Pa s) obtained for the separations less than 1 nm from a mechanical model was 2 – 4 orders of magnitude larger than the bulk value.

3.4 Ionic LIquids Confined between Silica Surfaces Measured by RSM.

Recently, we applied RSM for ionic liquids. Two types of imidazolium-based ionic liquid (IL), 1-butyl-3-methylimidazolium bis(trifluoromethanesulfonyl)amide ($[C_4mim][NTf_2]$) and 1-butyl-3-methylimidazolium tetrafluoro borate ($[C_4mim][BF_4]$), confined between silica surfaces were investigated by RSM together with surface force measurement [22]. The surface force profiles in the ILs showed oscillatory solvation forces below the characteristic surface separations: 10.0 nm for $[C_4mim][NTf_2]$ and 6.9 nm for $[C_4mim][BF_4]$. The more pronounced solvation force found in $[C_4mim][NTf_2]$ suggests that the crystalline property of the IL contributes to the stronger layering of the Ils adjacent to the surface. The resonance shear measurement (Figure 9) and the physical model analysis revealed that the viscosities of the confined Ils were 1−3 orders of magnitude higher than that of the

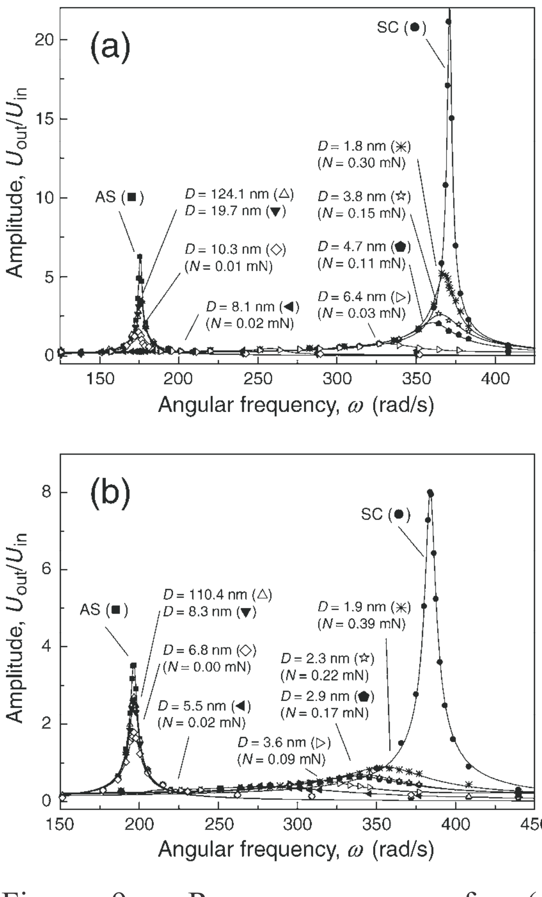

Figure 9. Resonance curves for (a) $[C_4mim][NTf_2]$ and (b) $[C_4mim][BF_4]$ confined between silica surfaces at various separation distances under applied load *N*. Reference curves for separated in air (AS) and connected by silica-silica contact (SC) are also shown. Solid lines denote the best fitting curves on the basis of a physical model [23].

bulk IL. This study also focused on the correlation between the resonance shear behaviour and the lubrication property of the Ils, and the suspension rheology in the Ils. An understanding of the solid-IL interface and of Ils confined in nanospace will facilitate the further development of novel applications employing Ils.

4. Conclusion

This paper reviews a new surface forces apparatus (twin-path SFA) and resonance shear measurement, both we have developed recently. With the twin-path SFA, it is possible to use metals, ceramics and other opaque samples for substrates. They are not only interesting materials but provide opportunities for broader applications of the forces measurement: for example, we have constructed electrochemical SFA using gold as electrodes [24]. The twin-path SFA is compact compared with the conventional SFA using FECO, and easily operated by a computer. Combining with a spectroscope, spectroscopic SFA for fluorescence lifetime measurement was developed [25].

The properties of confined liquids are different from those of the bulk due to the confinement effect and the interaction of liquid molecules with the surfaces. They attract increasing attention because of recent progress in the preparation of many porous materials including nanotubes and the nano-fabrication processes such as nanoprinting [25]. Shear measurement based on SFA can offer a useful tool for studying confined liquids. Especially, the resonance method is relatively easy to operate, and applicable for both nano-rheology and –tribpology. Resonance responses are sensitive to changes in properties of confined liquids, so it is possible to monitor changes in viscosity, traction and triblogical properties, and even stick-slip phenomena, which are often correlated with structural and/or packing properties of liquids. We expect these measurements will be more widely used in material science.

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Bioelectrochemical Imaging with Micro/Nanoelectrode Systems

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1. Introduction

Recently, the development of multipoint measurements and imaging of biomaterials has received a great deal of attention due to the strong demand for rapid, comprehensive, and high-throughput analyses. These techniques allow simultaneous detection and quantification of multiple analytes. A variety of array-based biosensing systems have been developed so far. Most of them are based on fluorescence detection or imaging because fluorescence measurements typically have high sensitivity and a variety of tools for performing the measurements is commercially available. However, fluorescence detection has some disadvantages, such as undesired fluctuations due to quenching or emission from non-target materials, shielding by turbid solution, and the need to label non-fluorescent species, which may cause toxic side effects during analyses. As an alternative method, electrochemical detection or imaging has also been applied for detailed analysis of biomaterials. Array-based electrochemical devices have also been used for multipoint measurements. The electrochemical signal can be processed by conventional electronics in a very cheap and fast manner. Furthermore, miniaturized electrochemical transducers can easily be integrated in a microsystem by employing conventional microfabrication technologies. In the past decade, various types of amperometric microelectrode arrays for multipoint measurements and bioimaging have been designed and applied to chemical and biological analyses. These electrochemical array devices have substantial advantages, including rapid response time and qualitative and quantitative detection. Scanning electrochemical microscopy (SECM) is also a popular electrochemical imaging system [2]. SECM uses a micro/nanoelectrode as a scanning probe and provides sample surface electrochemical property under physiological conditions without physical contact. Because of unique properties SECM has been applied localized electrochemical measurements.

In this article, we will describe the recent progresses of electrochemical measurements and bioimaging with integrated micro/nanoelectrde devices. Bioimaging with scanning electrochemical microroscopy (SECM) with a micro/nanoelectrode probe will also be reported.

2. Adderable measurement with micro/nanoelectrode devices

Among the various electrochemical arrays, the development of an individually addressable device for multipoint measurements and bioimaging has been recognized as a key issue to cope with increasing demands for a versatile, reliable and easy-to-use analytical system, especially for comprehensive screening purposes. However, it is difficult to collect electrochemical responses at many individual measurement points using a conventional electrochemical device, because sufficient space for the bond pads is not available on the chip border. To solve this problem, we have proposed a novel method to realize individually addressable electrochemical measurement using a device consisting of two sets of microelectrode arrays.

In the device, column and row electrodes were orthogonally arranged on two different glass substrates in order to assemble an addressable microelectrode device for the purpose of comprehensive electrochemical detection [3]. An amperometric signal was separately detected at the individual crossing points of the column and row electrodes on the basis of redox cycling of localized electroactive species occurring between the electrodes. The addressable microelectrode device was simple and could be easily assembled; however, it comprised as many as 10 × 10 addressable detection points on a single chip. The basic electrochemical performance of the device was investigated by using the ferricyanide/ferrocyanide redox couple. Electrochemical responses at 100 individual points could be collected within 22 s. The present device was successfully used for imaging the spots of alkaline phosphatase on the array substrate. The results indicate that the device can be applied to comprehensive and high-throughput detection and imaging of biochemical species.

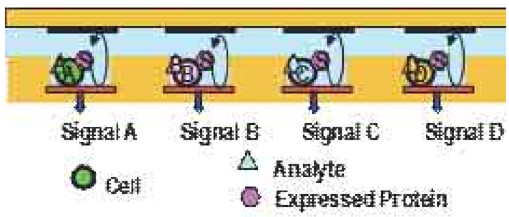

Fig. 1. Principle an addressable microelectrode / microwell array for comprehensive electrochemical analysis.

A microwell array was further incorporated into the addressable device to conduct high-throughput screening of bioparticles and genetically engineered cells accommodated in the wells [4]. We demonstrate the rapid electrochemical detection of the reporter protein—secreted alkaline phosphatase (SEAP)—from a single genetically engineered HeLa cell (HeLa-pSEAP) using the addressable microelectrode/microwell array device. Figure 1 shows the operation principle of detection of the reporter protein with the addressable device. The HeLa-pSEAP cells that secrete ALP were randomly seeded in the microwells and the amplified current was detected. The reduction current for the microwell with a single HeLa-pSEAP cell increased with time, while no meaningful response was detected for the empty wells. These results indicate that SEAP secreted from the cell catalyzes the hydrolysis of PAPP to produce PAP, which is accumulated in the well.

Figure 2 shows an image of the reduction current of each microwell after 20 min of incubation time. The responses in the empty microwell is 0.754 ± 0.996 pA while in cell occupied microwell is 16.3 ± 5.49 pA. Figure 2(c) shows histogram of the current responses distribution from the cells, unlike the case for ALP beads, each single HeLa-pSEAP cell showed a different current response, approximately 20 % of the cells show responses similar to those observed for wild-type cells. These variations in the response are due to the different expression levels of ALP from individual cells and the size variations of single cells. The average amount of PAP generated from the catalytic reaction of a single HeLa-pSEAP cell was calculated from the current responses and found to be 3.6 × 10–17 mol for an incubation time of 20 min. These results demonstrate that the present device can be used for highly sensitive and high-throughput screening to detect the protein expression activity of genetically engineered cells at the single-cell level. Since the ALP has been widely used as a labeling enzyme and reporter protein, the present device can be used for the screening of a

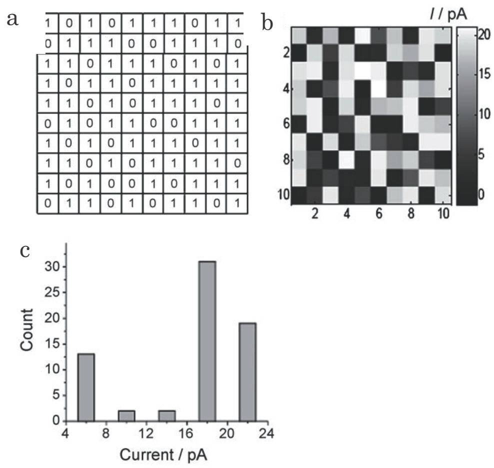

Fig. 2. a) Scheme of cells in the microwells. The number represents the number of cells in each well. b) Imaging of the current responses at 10x10 microwells. This image was taken 20 min after the injection of PAPP. c) Histogram of the current response distribution of the cells.

comprehensive analysis of DNA, proteins, and cells [5].

3. Bioimaging with micro/nanoelectrode devices

Although the device described above is very useful for high-throughput electrochemical detection, careful assembly of the device is required to align two different glass substrates with the row or column electrodes at exact locations upon each measurement, which is time-consuming and results in low reproducibility. Furthermore, there is no open space on the device for handling samples such as cells, because the sensor areas are surrounded by glass substrates with electrodes. In this study, we have developed a new device to solve these problems. The general architecture, outlined in Fig. 3, provides a means for creating a new detection system that enables electrochemical detection based on local redox cycling and 1024 addressable sensor points incorporated into a small area (40 mm^2) for the comprehensive imaging of electrochemical species [6]. Interdigitated array (IDA) electrodes were incorporated onto glass substrates to arrange a single IDA at each sensor point of the device. IDA electrodes have two interdigitated comb-type arrays, each of which consists of planar and parallel metal fingers.9 When the potential of each comb-type electrode is appropriately controlled, a species oxidized at an electrode finger can be reduced back at the neighboring fingers, resulting in redox cycling for amplification of the electrochemical signal. In this study, one comb-type electrodes of the IDA connected to a column electrode and the other to a row electrode.

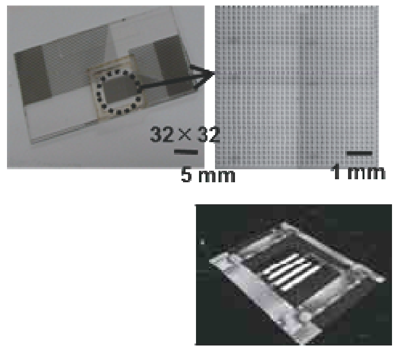

Fig. 3. Images of the 32 × 32 crossing points and the sensor point.

The device was applied for bioelectrochemical imaging of ALP aggregates. The image followed the position of the ALP aggregate in the solution and the intensity was dependent on the ALP activity of the aggregate (Fig. 4).

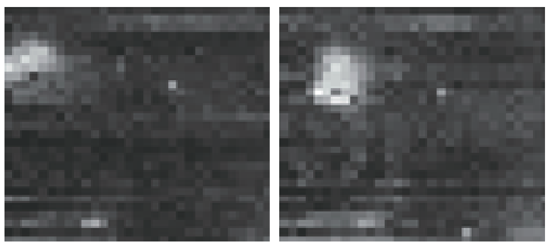

Fig. 4. Electrochemical imaging of ALP. The electrochemical response was acquired after adding the ALP/BSA aggregate (approximately 1-mm diameter) (right image).

Enzymes, such as ALP, were successfully detected using the device; therefore, this device could be used as a comprehensive, high-throughput lab-on-a-chip tool for applications such as enzyme-linked immunosorbent assay (ELISA), reporter gene assay for monitoring gene expressions, DNA analysis, and cell culture array. Although an application of electrochemical potentials to electrodes may be a critical issue for adhesive cells and spheroids, it is unnecessary to bound cells on the electrodes of the device since the device has microwells that can trap cells or spheroids on the sensors for cell assays.

4. Bioimaging with SECM

SECM has been applied for evaluating the enzyme and cellular activity estimating cell membrane permeability and detecting electroactive metabolic chemicals with short life spans. Membrane protein has also been detected with SECM. Miniaturization of the probe electrode is important for improving the temporal and spatial resolution. In addition, a fine distance regulation system is required to approach the probe electrode against live cell surfaces.

Significant efforts have been made to bring the electrode proximate with sample surface. Nevertheless, it was difficult to apply the system to the measurement of soft samples because the force interaction was usually very unstable to serve as a feedback signal. Shear force feedback regulation has also been used for control of the probe electrode sample distance [7]. We reported the simultaneous imaging of the topography and electrochemical signals of single living cells using shear force distance regulation of a ring type nanoelectrode probe. However, preventing probe-cell contact was still difficult because the solution viscosity interfered with the shear force detection. We adopted the feedback regulation used in scanning ion conductance microscopy (SICM) which uses a nanopipette as a scanning probe. SICM is based on the phenomenon that the ion flow through a sharp fluid filled nanopipette is partially occluded when the nanopipette approaches the surface of a sample. Living cell surface topography and dynamic measurements have been performed. Topographical information of the live cell surface can be used to improve the resolution of other analytical tools [8].

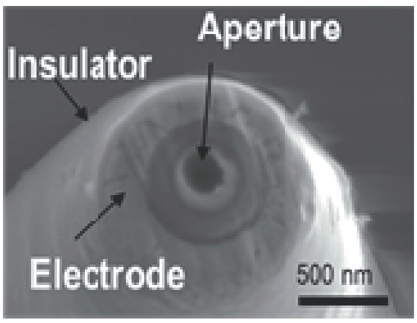

Fig. 5. SEM micrographs of the SECM/SICM probe.

We demonstrate a hybrid syst
and SICM with ion current feedb
of non-contact topography and
nanopipette/nanoring electrode
electrochemical measurement on
pipette had an aperture radius of
ring electrode were 330 and 55
probe was performed with scanr
and approach curve measurement
of topography and electrochem
(HRP) and glucose oxidase (GC
cardiac myocytes). The measu
enzyme spots on uneven surfa
acquired high resolution topog
electrochemical signals (Fig. 6).
evaluation of the permeability of

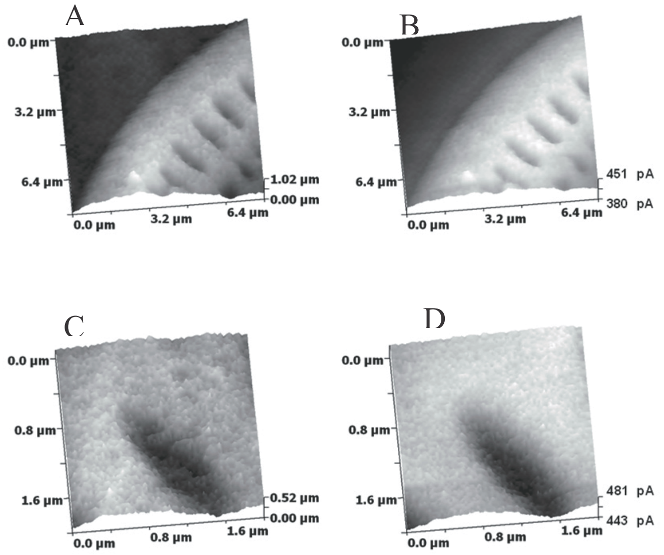

Fig. 6. Topographic (A,C) and electrochemical images (B,D) of a GOD immobilized substrate. Upper and lower images were captured with 8 μm × 8 μm and 2 μm × 2 μm, respectively. The probe-sample distances were held at 100 nm.

Summary

Bioelectrochemical sensing systems with micro/nanoelectrodes has been applied to localized characterization of biomaterials. The results so far obtained clearly indicate that electrochemical measurements afford indispensable information particularly on electron and ion-transfer at various biomolecules-related interfaces. Also, incorporation of modern micro/nanofabrication technologies into electrochemical devices will lead unique bioelectronics devices which ensure the realization of safe and secure society.

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- Optimization of MnGa based MTJs

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- Development of functional composite materials based on nanoporous metals

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 2011 to March 2012

B. Junior Researchers and Students <Visiting Scientists>

	Name	Host	Position	Term From			～	Term Through			Affiliation	Position	Nationality	Age	Research Topic
1	**FRÖMEL, Jörg**	Esashi (Gessner)*	Visiting Scientist	2011	5	11	～	2011	11	30	Fraunhofer ENAS , Germany	Depty Department Manager	Germany	34	Application of metakllic glass structures into silicon MEMS ˜ using low temperature solid liquid interdiffusion based on gallium and indium to fabricate packaged devices

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

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.

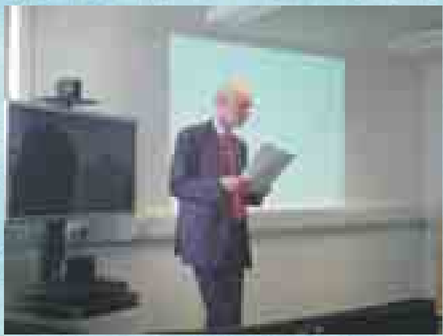
3) deadline

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

WPI-AIMR – Cambridge Symposium

Introductions and Welcome



Prof. Lindsay Greer

Prof. Yoshinori Yamamoto

Atomistic Studies on Solid-Liquid Interfaces

Dr. Ikutaro Hamada

Prof. Kazuto Akagi

Theoretical Studies in Physics and Chemistry

Prof. Masaru Tsukada

Prof. Michiel Sprik

Prof. Daan Frenkel

Discussion and Tea Break

Discussion and Tea Break

Hybrid Material

Dr. Erwin Reisner

Prof. Tadafumi Adschiri

Electron Microscopy and Optoelectronics

Prof. Taro Hitosugi

Prof. Katsumi Tanigaki

Prof. Paul Midgley

Dr. Caterina Ducati

The City of Academia
"Sendai-Miyagi" Science Day 2011

The City of Academia
“Sendai-Miyagi” Science Day 2011

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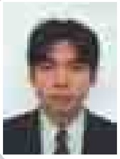

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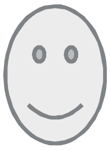

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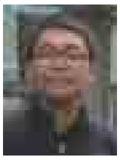

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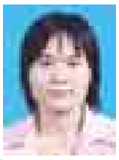

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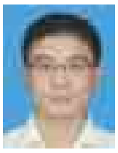

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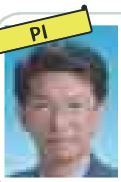

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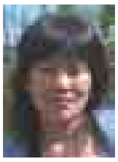

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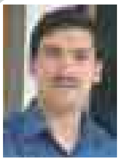

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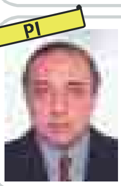

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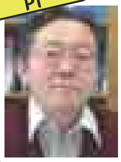

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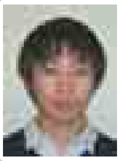

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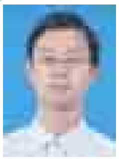

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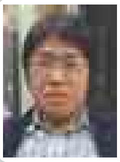

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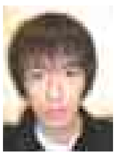

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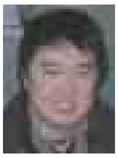

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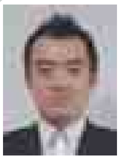

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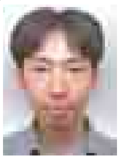

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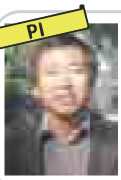

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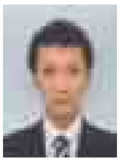

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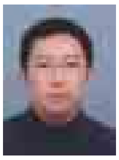

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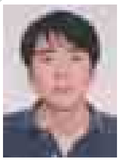

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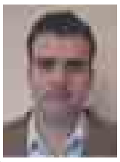

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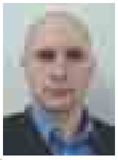

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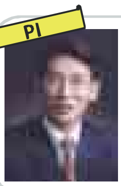

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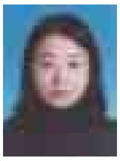

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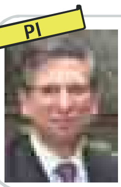

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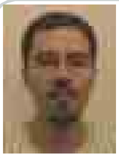

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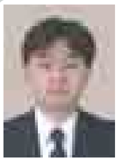

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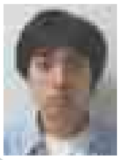

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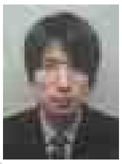

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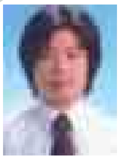

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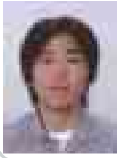

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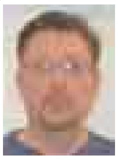

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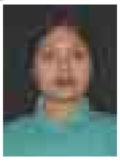

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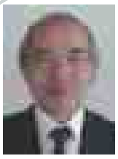

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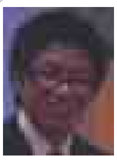

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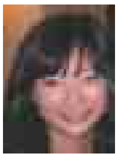

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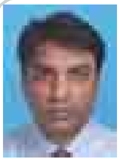

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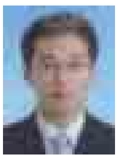

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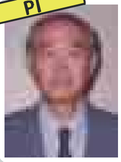

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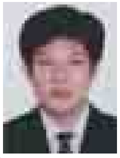

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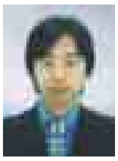

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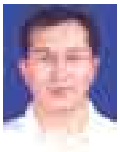

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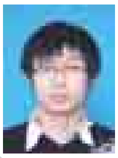

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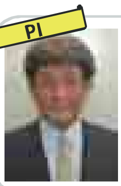

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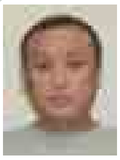

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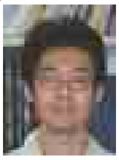

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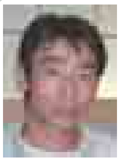

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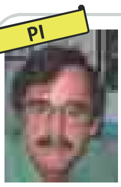

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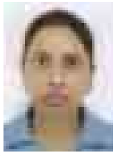

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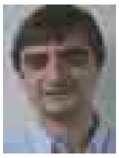

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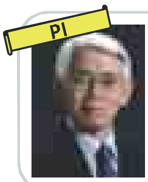

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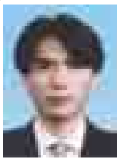

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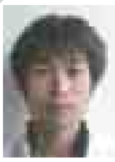

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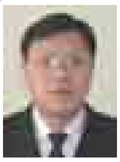

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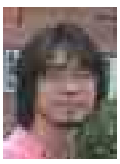

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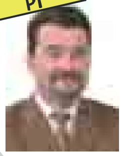

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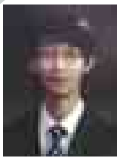

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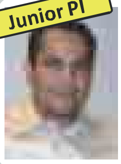

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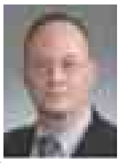

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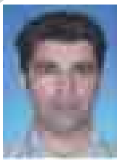

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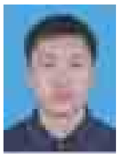

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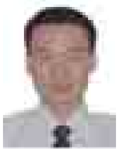

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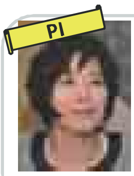

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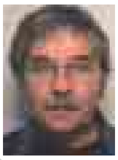

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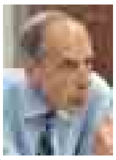

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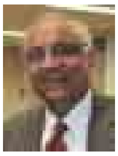

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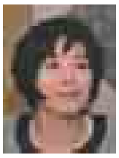

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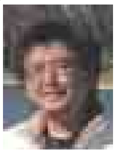

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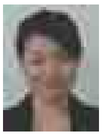

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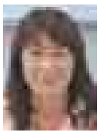

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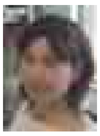

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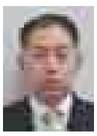

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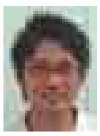

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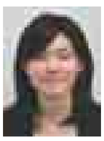

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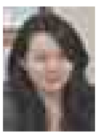

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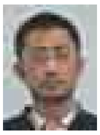

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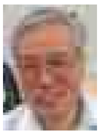

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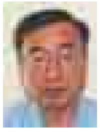

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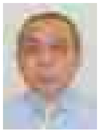

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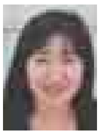

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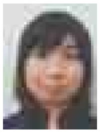

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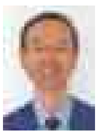

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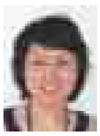

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