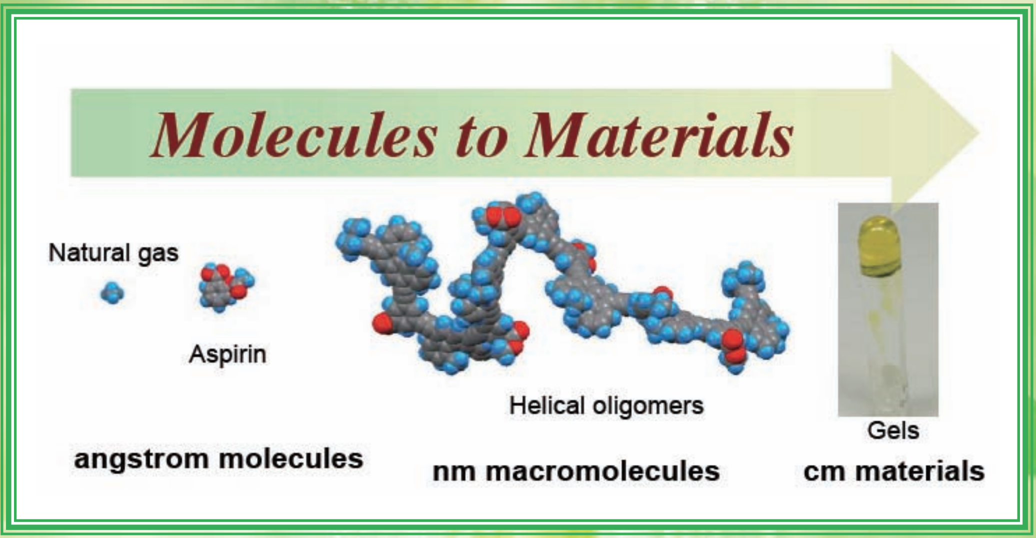
Volume 11

WPI-AIMR NEWS

December 24, 2010



World Premier International Research Center
Advanced Institute for Materials Research

Tohoku University

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Cover: This is a bottom-up approach in material sciences from small molecules of angstrom sizes. Small molecules are built up to macromolecules of nanometer sizes, and then integrated to centimeter-sized materials. (Masahiko Yamaguchi, WPI-AIMR)

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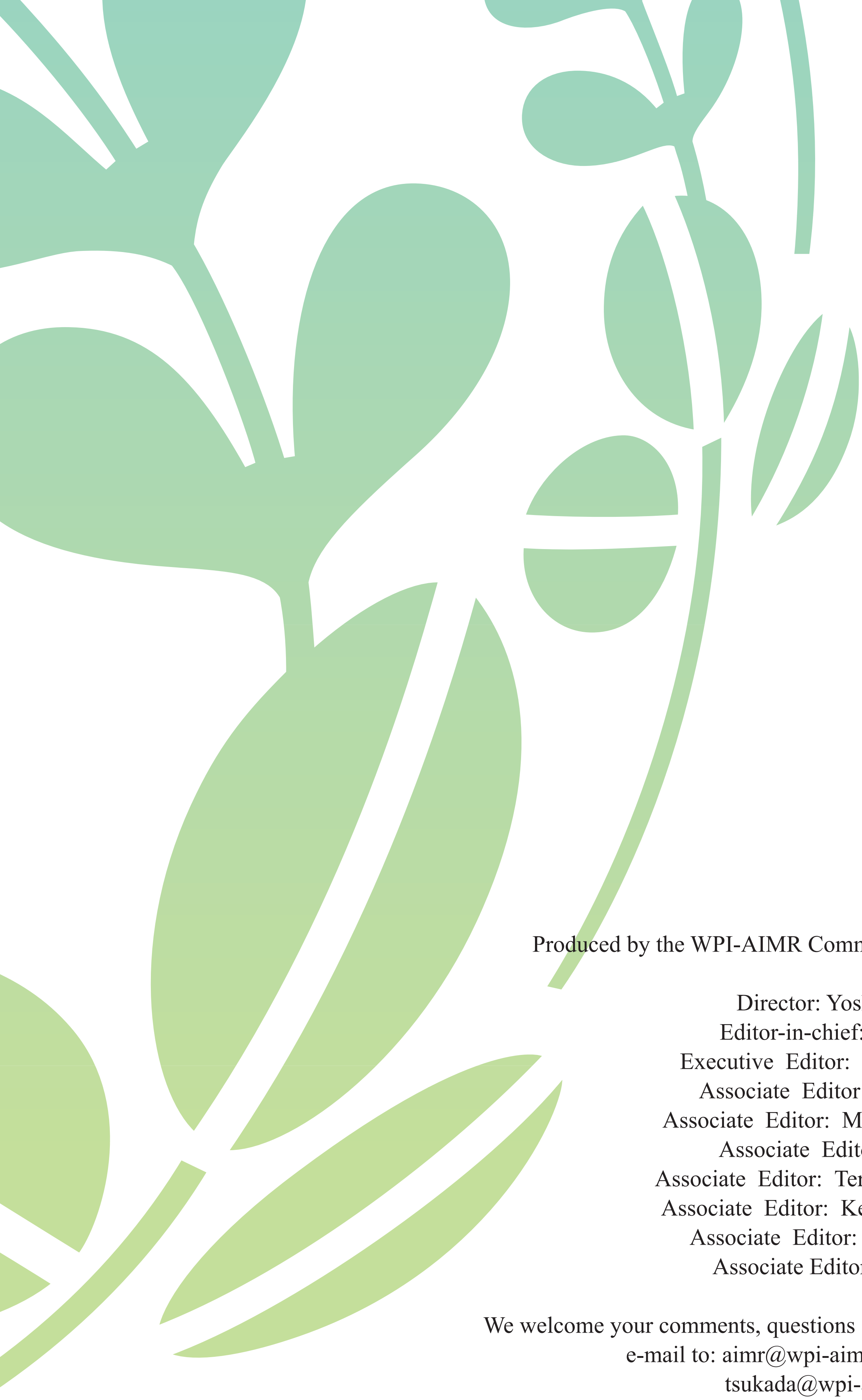

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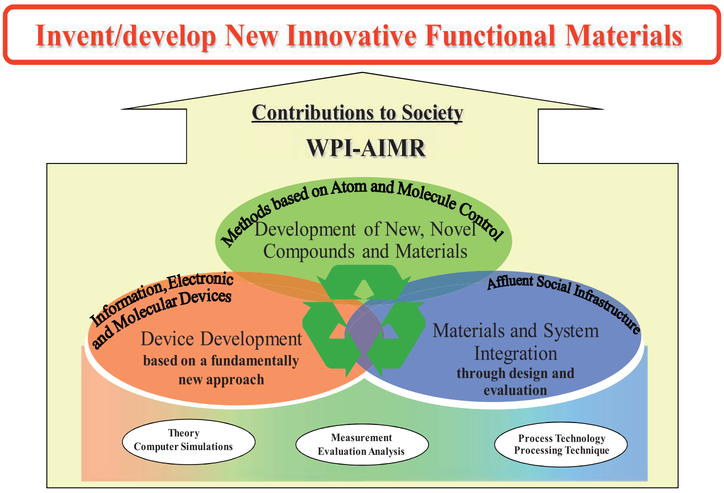
Green Materials

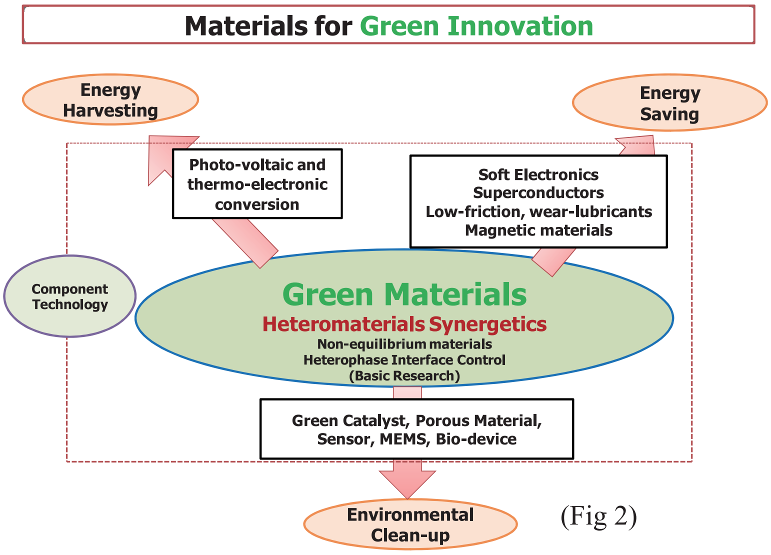
Yoshinori Yamamoto
Director, WPI-AIMR, Tohoku University

When we submitted an application to the WPI program in the spring of 2007, we proposed the objectives of AIMR as shown below (Fig. 1); the main objective is to (1) create new substances and materials with innovative functions by new methods of atom and molecular control, (2) construct devices based upon new fundamentals, and (3) promote applied research projects on materials and system architecture in order to produce outcomes for society. The program committee and site-visit team pointed out in the 2010 report that it is time to set a long-term strategy to firmly establish AIMR as a standard bearer of a new material science, and it is very important to define more clearly the mission of the institute.



(Fig. 1)

I have defined a more concrete and clear-cut vision of WPI-AIMR (Fig 2). We develop and explore the materials for green innovation; that is to say, "Green Materials" is a key word for WPI-AIMR. Innovative technologies for energy harvesting, energy saving, and environmental clean-up are explored as the outcome of the research. As for energy harvesting, new materials for photo-voltaic and thermo-electronic conversion are being sought. As for energy saving, for example, cutting-edge materials for soft electronics, superconductors, low-friction low-wear lubricants, and



(Fig 2)

low-energy consumption logic and memory circuits based on magnetic materials are searched for. As for environmental clean-up, innovative green catalysts, porous materials, sensors, MEMS and bio-devices are being sought. Innovative development of these component technologies must contribute to green innovation.

The basis of these component technologies lies in the research and development of Green Materials, which possess functional properties for fulfilling the objectives of those endeavors. The theme of “Green Innovation” extends over many divergences and contains complicated matter, and we have to face this problem by comprehensive and synthetic use of component technologies. It is no more attainable to solve such a complicated problem and to develop innovative component technologies by the use of a single previously existing material. It is necessary to investigate and explore heteromaterials by combining more than two different materials and to bring out innovative functional properties through synergetics of such heteromaterials.

I would like to give two examples of heteromaterials synergetics. Metallic glasses are hard materials and polymers are soft materials. They are seemingly different materials, that is to say, they are different statically. However, both of them are non-equilibrium materials dynamically. This property makes it easy to fabricate composite materials between metallic glasses and polymers, which may be useful as a low wear rubber. Another example is concerning a palladium catalyst for cross-coupling, which is the subject of the 2010 Nobel Prize. Cross-coupling was accomplished using a single material (Pd catalyst). However, a serious problem is that the coupling products are contaminated often by Pd and it is not easy to completely separate the Pd from the final product; this was especially problematic when this process was applied in pharmaceutical industries. A nanoporous palladium catalyst, which contains Pd-Ni-P heteromaterials, has the potential to solve this problem and it is clear that heterophase/interface control is very important to bring out these innovative characteristics.

Three years and a few months have passed since WPI-AIMR was launched, and it has become clear that Heteromaterials Synergetics is key for basic research of Green Materials. Further, it is becoming clear that it is essential to control the heterophase/interface of heteromaterials in order to fully utilize synergetics. By pursuing and deepening this basic research, I believe that we will be able to establish a research center for Green Materials that is recognized worldwide in the next six years.

I would like to thank you in advance for your understanding of the vision as outlined above.

Interviews

Interview with Professor Mingwei CHEN, Principal Investigator, WPI-AIMR

“Never Give Up”

Professor Chen (C): I was born and grew up in the eastern part of China, a city called Sūzhōu.

Professor Komatsu (K): And how do you write in Chinese character?

C: This is recorded in the “Three country (Three Kingdom Saga)”, *Sangoku Shi* in Japanese. It’s a very famous city in the book.

K: In Japanese, we pronounce this as *Joshu*.

C: Chinese call it Sūzhōu.

K: How far is it from your home to sea coast?

C: I think it is about 50 km or 60 km.

K: Very near compared to the size of the country.

C: Yes, it takes about 1 hour or 2 hours to get to the beach. This is a very old city in Chinese history. Actually the first emperor we called *Dongyu*. He set 9 states in China. One is Sūzhōu. This is also an important city in Chinese history since a lot of important battles that changed Chinese history are related to this city.

K: I see, even the modern *Joshu* is also a busy town?

C: Yes, it is. We have about 2 million or 3 million populations. We always call this city as the door of south part of China and the lock of the north part of China.

K: Historically very important city. Also climate should be nice.

C: It is pretty similar to Sendai.

K: You were born and spent your childhood there.

C: Yes. People like my age, around 40 to 45, are a pretty lucky generation in China since we didn’t need to pay for tuition and boarding when we passed the national exams and enrolled into colleges. At that time, the Chinese government covered almost everything.

K: Wonderful.

C: These days a lot of kids from poor families do not have chances to go to colleges because of the expensive tuitions in China. We frequently heard some sad stories that a smart student passed the national exams and accepted by a top university, but his/her parents could not afford to support him.

K: It is very expensive to attend college.

C: For a lot of families in China, it is. But at my time the Chinese Government covered everything.

K: How long the good time lasted?

C: I think it stopped in the middle of the 1990s.

K: About 15 years. Good time, I see.

C: But at that time very few students can pass the national exams. If you can pass the exams, regardless you come from a poor family or a rich family, Chinese government sponsors your education. I had a lucky time to get my education from college to graduate school. So, I have to say I owe the Chinese Government that gave me all my education for free.

K: Your generation has grown up now.

C: Yes.

K: Core persons.

C: These days you can see a lot of famous Chinese are at the age between 40 and 50.

K: Do you have some good memory of your school time, high school or middle school? No difficult time, everything always happy?

C: From primary school, most of my teachers liked me. They all said I was a smart student. But I was not always the best student. It is a little bit different, you know. I never ranked number 1 in my classes. If 50 students are in the class, I could rank the top 2 or 3. If 100 students in the class, I also could rank the top 2 to 5, but I do not remember I ranked the number 1 in my classes from primary to graduate schools.

K: And how did you select your specialty or major?

C: Well, actually that's another story. In China, when you apply for the college, you have to select your major first. At high school, I liked pure science very much. My physics, chemistry and mathematics were very good, and my Chinese writing was also very good too.

K: Chinese writing?

C: Writing essay.

K: Essay, sort of composition.

C: My teachers always read my essays in the class. When I was selecting the major, I had difficult time because personally I liked to be either a writer or a scientist. But my parents wanted me to major in engineering. They simply worried about my future. They said "If you do an engineering major, you can find a job easily when you graduate."

K: But if it is a pure scientific part, it is difficult to find a job.

C: Yes. That's my parents' concern. But I didn't like engineering too much. When my father's good friend came to visit us, my father asked me to talk to him. He was a senior mechanical engineer. He told me "Even you like science, you can also do something in engineering. The best major is physical metallurgy because it includes both engineering part and science part, and requires strong background in both physics and chemistry."

K: Practical theory.

C: That is the reason why I selected the physical metallurgy as my major. Now my research is a little bit far from engineering side and more close to the basic science.

K: Very interesting. Then for your Ph.D. work, what sort of subject did you choose?

C: Transmission electron microscopy (TEM).

K: That microscope was produced in China?

C: No, in Japan.

K: JEOL or Hitachi?

C: Hitachi. My first TEM was Hitachi's machine.

K: How much was accelerating voltage?

C: 200Kev.

K: 200Kev, quite popular.

C: That's a conventional TEM. You can do bright field imaging; dark field imaging and selected area electron diffraction.

K: And how was the resolution of the microscope at that time?

C: I don't remember exactly but it was about 0.3 nm.

K: What sort of material did you handle with this?

C: Intermetallic compounds. Actually, the intermetallic research started from IMR by Prof. Izumi in 1979. He is the first to find boron doping can improve the ductility of brittle Ni_3Al.

K: That was the knowledge you had at that time.

C: Intermetallics research was a very hot topic in 1980 and 1990s, just like today's bulk metallic glasses. I used electron microscopy to characterize the microstructure, deformation behavior and defects of intermetallics.

K: So you really enjoyed your Ph.D. work by yourself.

C: I had a very good time. My two major researches related to the metallic materials, intermetallics and now bulk metallic glass (BMG), both started from IMR.

K: I see. And is it already understood why boron changes the property of the material ductility?

C: Now people have pretty good sense on this issue. The boron addition leads to stronger grain boundaries.

K: Oh I see, the boundary becomes stronger by boron doping. And is it practically used now?

C: Some intermetallic alloys like TiAl have been used in the aircraft engines.

K: So that work was quite useful then.

C: Yes.

K: It is very interesting. So intermetallics were a sort of a hot subject all over China then.

C: In the 1990s, it was the hottest topic in the metallic materials field not only in China, but also in the United States and Japan. I think, all around the world, just like today's bulk metallic glasses.

K: You spent good time for continuing these new topics.

C: I came to IMR in 1997 and started the research on crystallization of metallic glasses using atom probe and TEM. At that time, bulk metallic glasses just became hot.

K: Very lucky in a sense.

C: I worked in Sakurai lab for 2 years. I have done two important works which are still very valuable in today's metallic glass research. I am the first person who used electron microscopy to find the quasicrystal phase in annealed metallic glasses. People always thought about the correlation between metallic glasses and quasicrystals, simply because icosahedron is the most stable structure in metal liquids and metallic glasses are just the frozen metal liquids.

K: After annealing, you found that the…

C: The quasicrystals.

K: And this is a kind of *Junkessho*. It was proved in a way.

C: Using the electron microscope, we can see the beautiful 5-fold pattern.

K: This was published in…

C: Applied Physics Letters in 1999. This is still one of the important papers in the metallic glass community.

K: Very interesting. Because I am a layman of this field, this sort of story is very interesting to me and very instructive.

C: We also used atom probe to prove impurity elements, like oxygen, can dramatically affect the stability and formation of the metallic glasses.

K: Because light element is not easy to detect…

C: You have to use atom probe. This is still a pretty important topic in today's metallic glass research. People are still trying to understand how the impurity elements affect the metallic glass formation.

K: Carbon and oxygen. Not hydrogen?

C: Hydrogen, we cannot detect actually by atom probe, it's too light.

K: And did you find something proved?

C: We proved oxygen induces the crystallization and leads to the loss of glass stability.

K: Stability of metallic glass will reduce, so easy to be….

C: Crystallized during cooling from liquid state.

K: That means…

C: You cannot get a large metallic glass sample at a low cooling rate.

K: Capability of glass forming is reduced.

C: It reduces because of crystallization.

K: So little impurity may act as nucleation centre of crystals, yes?

C: Exactly right.

K: But to make bulk metallic glasses available for the industry, you need to make metallic glasses as large as possible. How did you do that?

C: My work suggests that purer elements are better for glass formation.

K: I see. It's quite reasonable because nucleation centre is taken off.

C: I stayed in Japan for 2 years, and then I moved to the United States. That's in 1999.

K: In 1999, you went to the United States. What part?

C: I got a NRC Fellowship from the United States National Research Council. This fellowship sponsors foreigners to work in the research labs managed by the Federal Government.

K: And how many years did you stay?

C: With this fellowship, I worked for one year in the United States Naval Materials Research Center in Monterey, California. It's a very beautiful city. My apartment was nearby the beach and we can see the ocean from the windows.

K: And did you meet nice Professors there?

C: Yes, I met a nice professor, Prof. Indranath Dutta. Now he is a professor in Washington State University. In 2000, I moved to Johns Hopkins University where a new high-resolution transmission electron microscope, Philips CM300, was just installed.

K: This is also a lucky chance.

C: The new TEM. I was really interested to do the high-solution TEM study at that time. You cannot do anything without a good machine. So when I saw that the TEM, I felt very exciting.

K: Accelerating voltage was how much?

C: It's 300Kev. The point-to-point resolution is about 0.19nm.

K: So, how long did you stay there?

C: Almost four years. I left there for Japan in November of 2003.

K: Then you came back to Japan?

C: Yes, to IMR as a Professor. At Hopkins, I also had an enjoyable time and met a number of intelligent and knowledgeable young scientists and gifted students. At Hopkins, I authored and coauthored about 20 papers, including two papers in *Science* and one in *Nature*. The average citation per paper is about 50. I also broadened my research fields from traditional physical metallurgy to ceramics and nano-scicence.

K: So you expanded your field in ceramics as well?

C: Yes. The electron microscope is just a research tool. You can do everything. My ceramics research started from the collaboration with Dr. Jim McCauley who is a famous scientist in ceramic field.

K: What sort of material?

C: Boron carbide.

K: Boron carbide, a very hard material.

C: Yes, B_4C.

K: B_4C. And what did you find?

C: We found the shock loading induced local amorphization in the super-hard material. This material is very hard along with light weight and has been used as the armor ceramic. About 30 years ago, people found that this material is good for low-pressure impact, but not good enough for high pressures. At a pressure of about 20 GPa, this material dramatically loses the shear strength and becomes very soft. People didn’t know why. Using high resolution electron microscopy, we found that the loss of shear strength is associated with pressure-induced local amorphization.

K: Amorphization takes place.

C: That makes this material lose the strength.

K: I see, very interesting.

C: Yes, this paper was published in *Science* in 2003. Because we have a good electron microscope, I also started the study on the deformation behavior of nanocrystalline metals. It’s well known that materials become stronger and stronger when grains become smaller and smaller,.

K: The diameter becomes smaller.

C: And the strength gets up.

K: Irrespective of materials?

C: Yes, all the ductile metals show this behavior. This is called the Hall-Petch relationship.

K: This is the famous equation.

C: It tells us an important way to improve material strength and we always try to get small grains. At that time, people wondered whether there are new mechanical phenomena when the grain size is small enough, say down to the real nano-regime. For an example, can the Hall-Petch relationship be held when the grain sizes fall into the nanometer scale.

K: To what extent can we go?

C: Yes, that's an open question. There were a lot of discussions about this kind of issues. For the fundamental research, people were looking for new phenomena that were induced by the nanosize effect.

K: What sort of properties did you measure?

C: Hardness, yield strength and fracture strength.

K: And how do they measure hardness?

C: There are a lot of ways; you can use the indenter you can use…

K: Can you indent such a small…?

C: Well, you don't need to measure individual grains. It's still a bulk sample but inside grains are small.

K: I see. Just like Vickers?

C: Yes. Actually, we can also measure the mechanical properties by tension and compression testing.

K: Because I thought it might be very difficult to measure the mechanical properties when this grain size is very small.

C: For the individual grains, it is difficult. Since we still work with bulk samples, they just like conventional materials.

K: Okay, this is the average.

C: Yes. The bulk samples are comprised of nanograins.

K: So that means that the grain boundary must be counted?

C: Yes, actually the nanosize effect mainly comes from the grain boundaries. For example, the Hall-Petch relationship originates from the interaction between dislocations and grain boundaries.

K: When the material becomes very small it's…

C: When the grain size becomes small…

K: Then it's not easy to hold dislocations.

C: That's the point. The theoretical grain size is just about 2 nm for most materials. Below this, dislocations cannot be held in individual grains. But experimental observations tell us the critical grain size is about 10-20 nm, much larger than the theoretical one.

K: Not 2 nm.

C: We find actually something happened at a grain size of about 10-20 nm.

K: The experiment you found out that…

C: There is a transition in deformation behavior when grain sizes are down to about 10-20 nm. Using pure aluminum, unusual staking faults and deformation twins can be observed in nanocrystalline samples. In general, aluminum has high stacking-fault energy and thus stacking faults and twins are not supposed to operated as textbooks tell us.

K: Pure aluminum.

C: Yes. When the grain size is down to to about 10 nm, the deformation of aluminum is no longer carried out by normal dislocations, but by twins and stacking faults. This is a true nanosize effect.

K: I see. So aluminum behaves as a pure FCC with low stacking fault energy when it becomes a small crystal…

C: This paper was also published in *Science* in 2003 and it gets a high citation, around 300 times, up to today.

K: One thing I was worrying about is that aluminum is very sensitive to oxygen, very easily oxidized so not easy to really eliminate oxygen effect.

C: Yes, but this was observed in bulk samples and thick films.

K: The sample preparation is very critical.

C: Very important. They can be prepared by heavy plastic deformation at low temperatures and by PVD.

K: I see. Very interesting. So this is really coming already in the past exciting findings, you know. So I would like to have your papers related to exciting findings. And your principles in research. This is a kind of motto or your confidence or your belief about research…

C: Big topic.

K: Anyway, don’t take it very serious. When you come to something difficult to overcome, how do you think? When you meet with a failure, how can you recover?

C: I always talk to my friends, my students, “First we have to work hard and work smart. I learned this from Prof. Sakurai. But, the most important thing to do great work is to do something you really love to do. When you find the thing you love to do, then never give up.”

K: Never give up. Very good.

C: That’s important personality, I think, for a good scientist. When you love it from your deep heart, you should not give up. You need to keep trying, and keep thinking.

K: Very good.

C: For good researchers, I believe they all love what they are doing.

K: Love?

C: Yes, love. If you want to do something great, it starts from love.

K: So the intellectual curiosity kind of, scientific curiosity.

C: I think if you see the history, the great achievements all started from love, and of course, scientific curiosity.

K: Okay, very good, very good. So this can be also a message to the next generation or the younger generation.

C: Actually, you know the founder of the Apple Inc, Steven Jobs.

K: Steven Jobs, who raised Apple Company.

C: Yes. I have heard his speech many years ago. I forgot where but I remember one sentence he said, "All great work started from love."

K: Oh I see, love to what?

C: Love to do what you are doing. If you can find a thing you really love to do, just do it.

K: Not brain, but from heart.

C: From your deep heart.

K: Okay, sure. And have you got any hobbies? Working is your hobby; scientific research is your hobby.

C: That is a part. I like reading. I like listening music.

K: What sort of books do you read?

C: I like the topic on history. I read a lot of these books, partly because China has a long history.

K: Yes sure, several thousand.

C: I also like music.

K: What kind of music?

C: I like classical music.

K: What is your favorite composer?

C: I do not have a very specific composer. I like most of the famous ones in the classical music.

K: Such as Beethoven, Mozart.

C: Yes. I really enjoy listening the classical music.

K: Violin, piano. Yes, piano is also a very nice instrument. The best instrument is maybe piano.

C: I really like the sound of piano. But, when I was young, China was so poor and my parents could not afford to buy a piano. I did not have any chance to learn the piano. When I came to the United States, I encouraged my son to learn piano.

K: So is he still continuing to play piano?

C: Yes, now he likes piano very much.

K: How many children have you?

C: I only have one son.

K: How old is he?

C: He is now 18. This summer he just got into college.

K: And majoring?

C: Life science.

K: Life science. Oh, this is also a very top field.

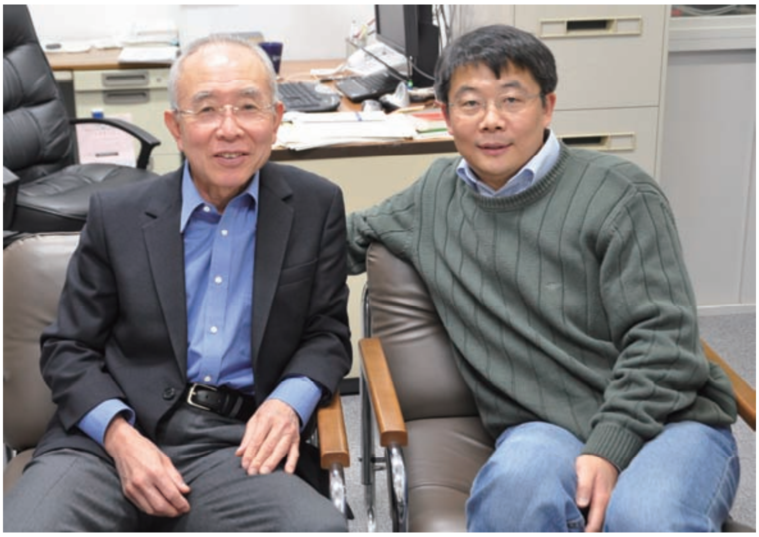
C: Yes, I think understanding ourselves may be the most important research in the next 20 years or even 50 years.

K: 100% I agree. That is why I studied 10 years protein crystallization even in IMR.

C: I see. That's exciting.

K: Yes, indeed. Okay, thank you very much for very nice talk and interesting stories.

C: Okay. Thank you.



Interviewer: H. Komatsu

in Prof. Chen's office in the WPI-AIMR Integration Laboratory Bldg,

December 16th, 2009

Interview with Professor Kazuo NAKAJIMA, Graduate School of Energy Science, Kyoto University (Former Director of IMR, Tohoku University)

"Multi-dimensional Intellectual Curiosity and Persistence Are the Source of Breakthrough"

Professor Nakajima (N): I am originally from Kyoto and earned my doctorate in Kyoto. Since there were so many excellent doctors working in the laboratory of Professor Yotaro Murakami, there was no room for me to stay there and I got a job at a company. There were not many openings since the economic situation was very bad when I graduated from university.

Professor Komatsu (K): So you are a dyed-in-the-wool Kyotoite. What year was it?

N: I think it was in 1975.

K: I see. Where did you go in elementary school?

N: The school faced the botanical garden across the Kamo River.

K: You were born and brought up around there.

N: Yes, I used to play around the Kamo River. I liked sports in my childhood and used to play baseball on the bank of the river. The water was clean with a lot of fish to catch and I enjoyed swimming there. When I was in elementary school, I liked reading books. When I was in the fifth grade, a school library was built. The first book I read was *Two Years' Vacation*.

K: The book by Jules Verne. That is an interesting one.

N: The book made me like reading novels.

K: You encountered a good book.

N: Around that time science books were not readily available but my parents bought me a big science book with various topics including biology and astronomy.

K: So was your father related to the field?

N: He was in a technical position. I read the book again and again and came to like science. Since I read science books earnestly, he told me that I should be a scholar in the future and I myself agreed with him.

However, I decided to work for a company since I could not remain in the laboratory. In spite of the bad economic condition, Fujitsu Laboratories welcomed me and I got a job there based on the recommendation of my professors. I was working on the four-element phase diagram of compound semiconductors in the doctorate course, so for five years after I joined the company I could leverage what I had studied for my work.

I was so lucky that I was able to experience the moment when the business was growing with the development of long-wavelength semiconductor lasers and light-sensitive elements at the burgeoning phase of optical communication.

K: I agree. You experienced a good time.

N: I was not sure what the four-element phase diagram was useful for, but as I joined Fujitsu I could utilize it there. I was very lucky in that way.

However, I could only work as a researcher to the fullest for the first five years since I became a manager early. I also worked on experiments as much as possible on my own as a manager since I wanted to come back to the university some day. The main responsibility that I had was leading my people. I left the company when I was around 52 years old, but I was still working as a researcher at that time.

K: How many people did you manage?

N: I managed about 15 people when I was a section chief.

K: That's a lot.

N: Yes. More people to manage means more work to be done. When I became a director, I managed about 30 people.

K: That's tough.

N: Yes, so I was very happy to be able to come to the Institute for Materials Research.

K: Good for you. You also talked about that at the last class you gave the other day.

N: You can choose what you study at your discretion in university but you cannot do that in a company. That is a big difference.

You also can acquire research funds by yourself and take overseas trips freely when you are in university, which you cannot do in a company. However, when I joined the company, even the employees who just joined the company could take business-class flights.

K: You had a nice environment.

N: That was a little fringe benefit. I could only take an overseas trip every 2-3 years. When you work for a university, you can go overseas every month. That is really wonderful.

When I was working as a director, I spent a large amount of time on overseas trips. As I resigned as a director, I suddenly got more time for myself and I was really impressed by that. The Institute for Materials Research is like heaven for me.

K: We need to take note that this environment leads to freedom in ideas and research flexibility, enabling the expansion of individual free ideas.

N: In comparison to the company environment, freedom in ideas for research is reserved in university. So I suppose university teachers are doing what they want to do to the fullest. Research is useful either in application or in basic research. Those researchers working on basic research should provide some results on the basics and those who are working on application should make the results useful for the society. I aimed at application. The reason why I moved from the company to the laboratory was that I wanted to study energy materials. My objective was clear that I wanted to study solar batteries.

I also became responsible for the Science Department, which required the study of basic elements. I specialized in crystal growth and there are many opportunities to study basic elements here. I worked on silicon, but no other people had worked on silicon crystal growth from melting based on in situ observation. I could observe what was happening, of which no one could dispute the validity. I discovered various basic phenomena that were actually taking place. This basic research had a great impact on application. You need to understand the crystal growth mechanism to come up with the real technology.

K: I see. I understand your goals.

N: I think I am lucky to be able to experience both corporate culture and university culture. Management, which I used to work on in a company, makes some sense in a university setting.

K: I suppose so.

N: Management means making your own decision at the end of the day. I could also leverage my company experiences for doing something based on commitments.

K: I see. Did your approaches and attitude change a lot as you joined the company in comparison with your middle school and high school days?

N: I had never thought about commercialization or commitment until I joined the company.

K: You only had intellectual curiosity.

N: If I had more books around me in my childhood, I would have been indulged in them. I had more intellectual curiosity than others. I really loved science.

K: The book which your father said was interesting and gave you included all the topics of natural science.

N: Yes, it covered electricity, earth science, biology, astronomy, and all other areas. I was really excited about natural science. It was superbly written to make the stories really interesting.

K: What was the name of the publisher?

N: I don’t remember it. A book has a great influence on your life. The first book given to me captured my interest and made me feel I was cut out for science.

K: Did you join any clubs related to science in middle school and high school?

N: I was not very active in club activities. By the way, do you know what a slide rule is?

K: Yes.

N: I was very good at handling it.

K: I see. We used to have slide rules made by Henmi. They were made of bamboo.

N: Right. We were given problems and competed to solve them as fast as possible.

K: It was like a competition of abacus calculation.

N: Yes. I remember I was ranked second in a competition held by the City of Kyoto when I was in middle school. I only missed one problem.

K: Did you join any club in high school?

N: My high school was co-ed and thought to be strict in education around that time. At school festivals, I enjoyed participating in folk dances and various events.

K: I see. It could be very different from the current high school life. Students do not have that much fun since they are given more work to do.

N: Everybody studied properly but there was an atmosphere to enjoy life.

K: Could you name some impressive books you read when you were in high school or university?

N: When I was in High School, I read *Jean Christophe*, *Les Thibaults*, and *War and Peace*.

K: You read a lot of classic literature.

N: I read a lot of those kinds of books.

K: Did that liberal arts background have an influence on you when you joined the company? Did it change how you interacted with people or how you made decisions?

N: I think so. I tried not to cause friction with other people. I tried to be nice to all the people.

K: You did not like disputes.

N: At least up until I joined the company, I did not like disputes. As I joined the company and became a manager, I could not just be nice to people. The life of my team members hinged on me. It is the manager who evaluates the people in the team. You need to be strict and rigid. You also need to be logical enough to be able to clearly explain what you have decided. That is where you need commitment.

K: I think I understand what you mean. Before you became a researcher, how did you choose the dissertation theme for your Ph. D., your key to becoming a researcher?

N: I was majoring in metals as a researcher but I picked up semiconductors for my research area. I thought they would open up a new world. There were so few researches in semiconductors in the metallurgy major. And I selected the four-element phase diagram for my doctorate dissertation.

K: Did you choose it by yourself?

N: I was studying phase diagrams in the laboratory with Professor Murakami. I was mainly involved in the study of precipitates in aluminum. Classes by Professor Murakami focused on how to read phase diagrams and how to analyze precipitates in alloys, so I was familiar in the topic. Professor Osamura suggested that I work on four elements.

I needed to select the number of elements myself. At that time even the three-element phase diagram of compound semiconductors was not yet worked on and what was available then was only the AlGaAs three-element phase diagram created by Dr. Panish of Bell Laboratories.

Professor Iwao Hayashi, who was at Bell Labs, was studying double-hetero-structure lasers based on AlGaAs semiconductors. A few years ago a Russian named Alferov became a Nobel laureate and he worked on AlGaAs lasers. I think it was professor Hayashi who improved its efficiency.

When I was in the doctor course, the three-element phase diagram not based on AlGaAs drew almost no attention. However, I thought someone would do the same thing if I had started with the study of the three-element phase diagram and picked up the four-element phase diagram in my doctorate dissertation. The four-element phase diagram involved complicated calculation and I did not how to decipher results based on experiments. It required three-dimensional analysis. I had to work on it based on a trial and error process at the beginning.

K: You needed to assemble pseudo binaries.

N: Since I worked on the four-element phase diagram, I could have been more trained intellectually. I found out that it included many phenomena related to the four-element phase diagram. At first I discovered that the four-element phase diagram of compound semiconductors had miscibility gap areas where solid solutions were not formed. A few years later miscibility gap areas for the four-element phase diagram became a hot topic and many research results were published. The topic drew a lot of attention since no miscibility gap was detected for the initially-studied AlGaAs semiconductors. This basic research I had worked on based on the four-element crystal helped me in my work immediately after I joined the company.

K: It was a perfect preparation to join Fujitsu.

N: If I had not worked on the four-element phase diagram when I was a student, I could have needed more time to produce the InGaAsP four-element crystal after I joined the company. Many researchers in the company specialized in electronics. So even researchers who specialized in materials needed to understand what was being discussed about lasers and light-sensitive elements at a minimum.

K: You just mentioned that Dr. Parnish was working with Professor Hayashi.

N: That's right.

K: When Professor Hayashi came back to Japan, the late Professor Masaharu Aoki and Professor Sugano of the University of Tokyo suggested we go meet him since we had also succeeded in room-temperature laser transmission.

N:The double-hetero-structure lasers were incredible. Up until that time, the efficiency was quite low, but the carrier was contained inside the active layers and the structure became the foundation for semiconductor lasers.

It was Dr. Panish who produced double-hetero-structure AlGaAs semiconductor lasers based on the liquid phase epitaxial growth method and he used the sliding boat method.

K: And it was Dr. Shigeyuki Kimura who assisted him. He later became the director of the National Institute for Research in Inorganic Materials. He was hired while he was doing postdoctoral research and worked on creating phase diagrams day in and day out based on the same experiments. He said he would never do that again.

N: Liquid phase epitaxial growth requires an accurate phase diagram. It is the growth from liquid-solid equilibrium proximity.

K: So you had been working on something Fujitsu needed. Fujitsu was so lucky to hire you.

N: Yes, that was a win-win situation. If Fujitsu had been unsuccessful in quickly developing the four-element crystal based on InGaAsP, it could not have made a head start in optical communication.

When I joined Fujitsu, the company did not know how to make InGaAsP crystal. In those days, NEC, NTT, and Bell Labs were also working on it but no company was successful in creating the phase diagram based on InGaAsP. So I wrote a book on the InGaAsP four-element semiconductors with researchers from Bell Labs.

K: I can see that. Basic research cannot be used for application immediately but contributes to advancement after some time.

N: After all, studying the basics is critical.

K: It gives you the impetus to move forward.

N: If you do not have the basis, you cannot deal with different situations.

K: That’s right. If you just seek for the immediate commercialization of technology and focus on the accountability towards tax payers, research capabilities will be impaired. That sort of foundation enables ecological solar batteries. If you just focus on one specific area, your ideas will be narrowed down even if you go to research in university.

N: I agree. When I came to the Institute for Materials Research, I did not think about working on silicon. I wanted to work on solar batteries but compound semiconductors looked more interesting. Since the university had limited facilities in comparison with the company, I felt scared about using arsenic and phosphorus. I did not want my students to handle them and decided to pick up silicon.

K: You have got a point there. In university you need to think, about risks and costs will increase as the equipment you use get more sophisticated. As a result, you need to focus on something you want to work on with as little cost as possible.

N: I did not think silicon would be a leading area at the onset. I currently believe it is a leading area, though. You need to adapt your strategy based on changing situations. The study of silicon multicrystal solar batteries is one of the areas where we can leverage crystal growth to the fullest. You can apply bias to light-emitting elements for optical communication, so they emit light with carrier injection even if they have defects and lower luminescent efficiency.

Solar batteries do not have any bias applied to them externally, so the carrier dies with crystal faults. What is required is almost fault-free, perfect crystal. Creating perfect crystal is the name of the game for crystal growth. Solar batteries are never-ending issues for researchers working on crystal growth. What I am working on is something far from perfect. This is a theme I can work on forever. As the quality is improved, so is efficiency. It is as simple as that. This is a good theme for a crystal growth specialist to work on.

I have come across two good themes as a crystal growth specialist. First, I was able to experience the burgeoning phase of light-emitting and light-sensitive elements for optical communication based on the creation of the InGaAsP four-element phase diagram. Second was the silicon I selected in order to work on solar batteries. Semiconductor devices did not usually use silicon multicrystal bulks but solar batteries were the only exception. You used to put silicon melt in the cubicle so that silicon multicrystal for solar batteries was concreted naturally with almost no concept of crystal growth applied to it.

As we brought the concept of crystal growth to it, controlled the structure of silicon multicrystal, aligned crystal grain orientation, enlarged crystal grain size, and changed grain boundary characters, it came closer to the quality of single crystal. So far there has been hardly anyone who tried to control the structure of silicon multicrystal bulks, but multicrystal has become more sensible as we have discovered the method to utilize dendrite crystal by chance and studied how to control the structure. Then the efficiency of solar batteries has been improved with more people paying attention to it.

It was so lucky for a crystal growth specialist to encounter the theme of silicon crystal for solar batteries.

K: The success of this sort requires the combination of intellectual curiosity and social situation changes or the availability of certain materials. With a good combination, a new technology comes out.

N: As I study silicon more, I find more interesting aspects to it. I observe silicon crystallization in situ, control freely the crystal structure of ingot, and deform silicon crystal three-dimensionally at my discretion. It is an interesting material with more aspects to discover. I have just begun to notice how interesting it is.

K: I see. How are you going to work on it going forward?

N: I am going to work on donation-based research, i.e. silicon crystal science for solar batteries, at the Energy Science Laboratory of Kyoto University.

K: You have a clear-cut plan. How are you going to staff the operation?

N: At the initial stage, two assistant professors will help me. I think it is important for them to work on donation-based research while still young so that they can experience the significance and methodology of social contribution. The staff here requires management sense. Donation-based research should be maintained based on the responsibility of each individual.

K: I see. It is challenging. Those two assistance professors will help you with experiments. They need to show consistent results in consideration of next steps.

N: You are right. In particular, commercialization requires you to present the crystal wafers you produce in the laboratory to corporations, let them evaluate them based on their own process, and show good characteristics. You need to produce commercial-sized wafers you can place on corporate assembly lines and show equal or better characteristics. Through the process of improving the quality of ingot, you will come up with various techniques and excellent technologies which cannot be found in companies.

K: You need to be creative.

N: Yes. I am trying to design brand-new devices to be utilized across the world. As

you go through hardships, you come across good results. You need to work your way out in order to accomplish something good.

K: You said it right. Could you specify what you can call your exciting findings?

N: In the area of solar batteries, as we precisely controlled the degree of supercooling, we succeeded in making dendrite crystal run through the bottom of the cubicle at the initial stage of growth, leading to the discovery that we could use it to control the structure of silicon multicrystal ingot. In the high-temperature pressure processing method, we found out we could deform silicon crystal three-dimensionally at our own discretion so we could use it for the X-ray spot light-gathering lens. In the area of optical communication, device specialists showed more results than crystal growth specialists.

K: It cannot be helped. Just like in soccer, those who have scored the goals get the biggest attention but defense players have to support the whole operation all the time.

N: It happens all the time as you work on basic research. However, in the area of optical communication, a Nobel prize was awarded last year to the person who incrementally improved the purity of optical fibers.

K: You are talking about Dr. Kao.

N: Yes. He was the first Nobel laureate in optical communication. It was so reassuring for us to be able to think that working on technology could lead to a Nobel Prize.

K: The recent Nobel Prizes have focused on technology as the area for their evaluation. LSI research also received a Nobel Prize.

N: Those people who have created devices and shown good characteristics do not know that phase diagram is the basis for the production of crystal. Since I thought I should not continue to support the technology behind the scenes, I decided to show the best device characteristics in the world. In the research of silicon multicrystal, I was able to deliver conversion efficiency of 18.2%, a leading number for device characteristics.

K: What was the efficiency ratio until then?

N: 15 to 16% for solar batteries based on multicrystal.

K: It went that far.

N: The average cell efficiency for silicon multicrystal solar batteries would be 15 to 16%. If we enlarge the crystal production device of this laboratory, I expect that we can come up with 18% on a constant basis. We need to carefully work on the challenges of purity and crystal faults in order to attain 18%. To attain 20%, we need to come close to the quality of single crystal.

We are proposing the floating cast growth method where we float silicon crystal in silicon melt and make it grow as the technique to realize the quality of single crystal based on the cast growth method in a cost effective manner. This is the next theme we will work on. Another discovery we came up with is the high-temperature pressure processing of silicon. In many fields, more attention is given to the flexibility of silicon, which can be deformed in any manner. Possible examples of the application include X-ray spot light-gathering lenses, crystal lenses for neutrons, and X-ray lenses for space telescopes. We discovered this technology when we came across mistakes while working on crystal growth.

K: What is the mechanism like?

N: We leverage the plastic deformation of silicon crystal just below the melting point. As we deform silicon crystal, it goes through elastic deformation. As we further deform it, it usually gets cracked and destroyed, but we have found out that it does not go through work hardening just below the melting point and is deformed in any manner based on plastic deformation.

K: So you lower temperature and enable the flexibility of transposition.

N: We shift transposition and find conditions where superfluous transposition is avoided.

K: Does that create an offset between plus and minus effects? Is it more likely to take place as the temperature goes up? Will the plus edge and minus edge combine and disappear?

N: We have not yet verified that far.

K: One side is tension and the other is compression, so they could offset each other and lose their effects. That mechanism must be in place. So as you adjust annealing temperature and time, you may be able to come up with more possibilities.

N: No one has ever done deformation tests at a high temperature just below the melting point, so more discoveries will come out of this. We have actually found out deformation behaviors are greatly influenced by plain orientations.

K: That’s interesting.

N: As I discussed this discovery at the applied physics meeting in March, industries we did not at all expect showed great interest in this technology. For example, those in the area of laser nuclear fusion observe the reaction of nuclear fusion based on the measurement of feeble X-rays and use X-ray spot light-gathering crystal lenses for that purpose.

However, they can only use the crystal lenses deformed based on elasticity limit and have difficulty due to impaired accuracy. Many researchers will be tempted to use the crystal lenses based on this technology.

K: That sounds interesting. It is what you call serendipity. As you miss your target, you find out it is actually useful.

N: That’s right. I was so surprised to find out it could be so flexible.

K: I see. That is very interesting. Could you give some advice to young people?

N: First of all, it would be better to determine what you want to do. I myself have been working on research based on a strong conviction to work on solar batteries, so I have never been daunted by various problems. You also need to make a lot of mistakes. Mistakes are there for you to overcome and they give you new discoveries as you find something interesting there. And what is most important is your own intellectual curiosity.

K: I agree. Did your intellectual curiosity change when you were in the company and when you were in university?

N: I think there is some difference.

K: You are not framed into a mold.

N: Even those working for companies could be doing what they like. However, those people who are involved in the development of important products within companies are less likely to satisfy their intellectual curiosity since they cannot do what they like.

K: Unless you cannot satisfy your intellectual curiosity, you cannot boost your morale. In most cases, you are not motivated. As I hear about success stories of Bell Labs and others, I somehow sense the atmosphere raising intellectual curiosity.

N: Bell Labs used to be like that.

K: Yes, I think so. Big companies like Fujitsu and Toshiba have some room for it but smaller companies need to work on their impending issues.

N: They need to keep their head above the water. It was great that Fujitsu let me work on the phase diagram.

K: I think so. Working on the phase diagram was so wild and very unlike a commercial company.

N: Fujitsu was commendable in that sense. They had that sort of discretion.

K: Many people now could be questioning the validity of the phase diagram and think it is just a waste of money and time.

N: Fujitsu did not keep the information closed and let us disclose the data. Some companies try to keep the data unpublished since it is considered as privileged information.

K: As you keep your information open, you get more information.

N: Universities can keep their information open. Those companies who let us disclose information are very generous and motivate researchers. Many good researches have come out based on that reason.

K: And it led to the development of people.

N: Many people who learned their skills in those days went to research at universities.

K: In the long run, those laboratories that do not develop the capabilities of staff members are failures. Laboratories creating capable staff are great laboratories in the end.

N: That’s right. We used to have the energy to do something big although we did not know how to do it. We were so full of energy.

K: So we need to remind young people of intellectual curiosity.

N: You need to satisfy your intellectual curiosity. You need to have your objectives. That is the starting point.

K: In the liberal arts education for the Materials Science Department of Cambridge University, professors are required to lecture not on their specialty but areas outside their specialty based on their analysis and observation. It is college professors themselves who keep their intellectual curiosity.

N: That’s wonderful. It is a little bit off the topic, but when I captured data for commercialization, I used to obtain vast ranges of partly meaningless data for the sole purpose of writing a paper. But that made a difference later. Materials specialists should capture data to the broadest possible degree even if it seems to be a waste.

K: I heard a nice story. The predecessors of the Institute for Materials Research placed dots based on experiment data that were in turn connected into lines. Materials specialists at Tohoku University should not just work based on their brain but take as many dots as possible through experiments.

Torahiko Terada once said that intelligent folks could not accomplish something meaningful since they thought they knew the results before they came out, and that faithful and consistent efforts would lead to new discoveries.

N: I think it is the essence of materials specialists.

K: You cannot achieve good results as far as you are thinking with your brain. Could you talk about your hobby in the end?

N: When I became the director, I started playing golf.

K: I see. That is your recent hobby.

N: I like playing golf. I also like history and read a lot of history books.

K: As you get satisfied with reading books, you may want to go here and there. I enjoyed talking with you today and covering various topics in great detail. Thank you for your time.

N: Thank you for bearing with my chitchat today.

Interviewer: H. Komatsu
At Nakajima Lab, IMR Bldg. I,
March 24th, 2010

京都大学エネルギー科学研究科中嶋一雄教授
(東北大学金属材料研究所前所長)に聞く
(Interview with Professor Kazuo NAKAJIMA-Japanese version)

多面的な知的好奇心と粘りがブレイクスルーの源

中嶋：私はもともと京都の出身で、京都の大学でドクターを取りました。その後、村上陽太郎先生の研究室には優秀なドクターが沢山おられましたので、研究室に残してもらえる余地はなく、就職しました。私が大学出たころは非常に不況だったので就職先も少なかった。

小松：生粋の京都っ子ですね。１９００何年ごろですか。

中嶋：１９７５年かな。

小松：なるほど。小学校はどの辺で。

中嶋：鴨川を挟んで植物園の反対側です。

小松：あの辺の生まれであの辺で育った。

中嶋：ええ。鴨川が遊び場です。子供のころはスポーツが好きだったので、鴨川で野球をよくやりました。昔はきれいで魚もとれたし、そこで泳いでいました。小学校のときは本を読むのが好きだったんですよ。5年生の頃小学校の図書館ができて、最初に読んだ本は「十五少年漂流記」でした。

小松：はい、ジュール・ベルヌの。おもしろいですよね、あれ。

中嶋：あれ読んですごく小説好きになりましたね。

小松：いい本に出会いましたね。

中嶋：それから、そのころ理科の本ってなかなか手に入らなかったんですけれども、親がこんな大きな理科の本を買ってくれまして、そこには生物から宇宙からいろんなことが入っていて…。

小松：では、お父さんはそちらの関係の人だったのですか。

中嶋：技術屋です。その本を隅から隅まで何回も読んで、理科が好きになりました。理科の本を熱心に読んでいるから、おまえは学者になるのが一番いいと単純に言われて、子供の頃からそういうものかと思っていました。しかし、研究室には残れなかったので、就職することにしました。この時期は不況にも関わらず富士通研究所からお誘いがあり、先生の勧めもあって富士通研究所に就職させて頂きました。博士課程では化合物半導体の 4 元系の状態図の研究をしていましたので、会社に入って５年間は、大学でやったことがそのまま活きました。しかも光通信の黎明期に当たり、長波長の半導体レーザや受光素子の開発でこれからビジネスが大きくなるというその瞬間にいたというのは、大変ラッキーだったと思います。

小松：そうですね。時代背景。

中嶋：四元系状態図は何の役に立つのかなと思ったけれども、富士通研究所に誘われて、そこで一番役に立った。そのことは非常に幸運だったと思います。しかしマネージャーになるのが早かったので、研究は最初の５年間ぐらいしか自分で思い切りできなかった。だけど大学に戻りたいという気持ちをずっと持っていましたので、マネージャーになっても自分でできる限りの実験はしていた。メインの仕事は部下を指導してやっていたのです。会社を退職する時は５２歳ぐらいでしたが、まだ現役で研究していたんですよ。

小松：部下というのは何人ぐらいの。

中嶋：室長のときは１５名ぐらいですね。

小松：結構ですね。

中嶋：はい、部下が多いと仕事も増えますし大変です。部長になると３０名くらいですね。

小松：結構大変ですね。

中嶋：はい。そういう意味で、運よく金属材料研究所へ来ることができて、本当に楽しい思いをさせて頂きました。

小松：よかったですね。この間の最終講義でもそう言っておられたけれども。

中嶋：大学ではテーマを自由に選べますね。会社ではまずテーマは自由に選べないのです。これは大きな違いですね。それから大学では研究費を獲得できますね、自分で。それから、もう一つ海外出張に自由に行けますね。会社ではそうはいきません。でも会社に入ったころは、新入社員でもビジネスクラスで行けたんですよ。

小松：ぜいたくなものですね。

中嶋：そこだけはちょっとぜいたくでした。海外出張はせいぜい二、三年に１回くらいしか行けませんでしたね。大学では毎月行こうと思ったら行けるわけですね、極端に言えば。これは非常に天国だと思いますね。所長の時は多くの時間をそのために使っていました。所長をやめるといきなり時間が空いてきまして、教授ってこんなに自由時間がたくさんあるのかと今更ながら感心しました。金研は天国みたいなところです。

小松：しかしそれが自由な発想とか、研究の柔軟性とかに結構はね返り、個人の自由な発想に繋がっている。

中嶋：会社から見たら研究の発想は自由にできます。だから、教員は思い切り自分のやりたいことをやっていると思います。研究は応用で役に立つか基礎で役に立つか、どちらかです。基礎をやった人は何か基礎での業績を残さないといけないし、応用であったら社会に還元されないといけない。僕は応用を目指していました。会社から金研に移った一番大きな理由は、エネルギー材料の研究をやりたかったからです。太陽電池をやりたいと、目標ははっきりしていました。理学の兼担になりましたが、理学は基礎をやっていないと納得されないところです。結晶成長が専門ですが、ここには基礎がいっぱいあります。シリコンの研究に特化しましたが、シリコンの融液成長を「その場観察」で実際に観察した人はいままでいませんでした。実際に起こっていることを観察できるので、これにはだれも

文句をつけられない。多くの実際に起っている基礎的な現象をいろいろ発見しました。これらの基礎研究は応用に非常に役に立ちました。やはり結晶成長メカニズムを理解して技術をつくった方が、本物の技術ができると思います。

小松：なるほど。よくわかりますね。

中嶋：企業の文化と大学の文化、二つを経験しておくというのは、ある意味では良かったと思います。会社でやっていたマネージメントが大学でもそれなりに役に立つんですね。

小松：そうでしょうね。

中嶋：マネージメントは最終的には自分の腹を決めることだと思っています。覚悟してやる、そういうようなところにも企業の経験は生きていたと思います。

小松：なるほど。そういうものに対する処置の仕方とか考え方というのは、中学・高校時代に比べるとかなり変わりましたか。企業というものに入って。

中嶋：企業に入るまでは、実用化とか、覚悟とか、そんなことを考えたこともなかったです。

小松：知的興味ですよね。

中嶋：子供の頃、もっとたくさん本があったら、読みあさっていたと思いますね。知的好奇心だけは人一倍ありました。兎に角ものすごく理科が好きだった。

小松：お父さんがこれはおもしろいよとくれた本に、自然科学の全部が入っていた。

中嶋：ええ、電気、地学、生物、宇宙など全部入っていましたね。自然科学ってこんなに面白いものかと。上手におもしろく書いてありましたね。

小松：それはどこの出版社でした。

中嶋：もう覚えていませんが。本って怖いですね。最初に与えられた本というのは大きいですね。それでおもしろいなと思ったら、おれは理科に向くと思っちゃう。

小松：それで、中学・高校ではそういう何とか部というようなことでやっておられた？

中嶋：余り部活動はしなかったんですけれども、そうそう、計算尺ってご存じですかね。

小松：はい。

中嶋：計算尺が非常に得意でした。

小松：そうですか。何かヘンミの計算尺というのがありましたね。竹製のね。

中嶋：ええ。問題を与えられて、計算の競争やるわけですね。

小松：なるほど。そろばんの競争みたいなものですね。

中嶋：ええ。覚えているのは、中学で京都市の大会で２番になったんですよ。１個だけ間違ったんですね。

小松：それで、高校に行って何かクラブに入ってやったんですか。

中嶋：高校は共学で、受験校だとその当時言われていたけれど。学園祭になるとフォークダンスをしたり、いろんな催しがたくさんあって楽しかったです。

小松：なるほど。今の高校生活とかなり違っているでしょうね。今はそんな余裕がないというか、もうちょっと勉強ですよね。

中嶋：勉強はみんなやっていたけれども、もうちょっと楽しむという雰囲気がありましたね。

小松：そのころ高校から大学にかけて読んだ本で、印象に残っている本というのはどんなものがありますか。

中嶋：高校のとき、「ジャン・クリストフ」、「チボー家の人々」とか、「戦争と平和」も読みました。

小松：結構大作を読んでいますね。

中嶋：そういうのをたくさん読みましたね。

小松：そういういわゆる一般教養的なバックグラウンドが企業に行ってもどこか生きていたでしょうか。人と対したときや、腹のくくり方などに。

中嶋：そうですね。あまり人とは摩擦を起こさないようにしていたんですね。八方美人的だったかもしれません。

小松：争いごとを好まないという。

中嶋：少なくとも就職するまでは争いを好まないような性格だったと思いますね。会社に入って、マネージャーになってからですかね。八方美人では絶対おさまらないです。部下の生活がかかっているわけですからね。彼らの評価をするのもマネージャーですからね。厳しく冷徹にやっていくわけですね。自分の決めたことには、しっかりと説明できるだけの理論武装が必要です。そこでだんだん覚悟がいるようになってきます。

小松：なるほど。わかるような気がしますね。

研究者になる前に、パスポートみたいな Ph. D. といいますか、ドクター論文みたいなものはどういうふうにして選んで、どうなされたのか。

中嶋：専攻ではほとんど金属の研究者だったけど、半導体を選びました。新しい世界が拡がると思ったんですね。冶金学専攻なので半導体の研究者は極めて少なかった。ドクターのテーマとして四元系化合物半導体の状態図というのを選びました。

小松：それは自分で？

中嶋：村上先生の研究室では、当時は状態図の研究をしていました。アルミニウム中の折出物の研究などが主流でした。村上先生の授業は、状態図の読み方とか合金の析出物といった内容だったので、非常に馴染みはありました。四元系をやったらどうかと、長村先生に提案して頂いたのだと思います。どういう系を研究するかは自分で選ばなければならなかった。当時は化合物半導体の三元系状態図もほとんどまだ研究されていなく、Bell 研究所の Panish がつくった AlGaAs 三元系状態図があったくらいです。Bell 研究所におられた林巌雄先生が AlGaAs 半導体でダブルヘテロ構造のレーザーを研究されていました。何年か前にアルフェロフというロシアの人がノーベル賞を受賞していますが、あれは AlGaAs のレーザーに関する研究です。その効率をよくしたのが林先生だと思います。僕のドクターの時には、この AlGaAs 系以外の三元系はまだほとんど関心がもたれていませんでした。しかし、三元系状態図の研究から始めるとすぐにだれかが追いついてくると思い、

ドクター論文では四元系にしようと。四元系状態図ってやはり計算も難しいし、どうやって実験的に決定したらいいかも分からなかった。それに四元系では立体になります。はじめは試行錯誤でした。

小松：シュード・バイナリーの組み立てで。

中嶋：四元系をやったおかげで頭が訓練されたかもしれません。四元系に特有のいろんな現象が出てくることがわかりました。化合物半導体の四元系状態図には、固溶体をつくらないようなミッシビリティギャップ領域が現れることを最初に実験的に見つけました。それから何年かして四元系のミッシビリティギャップが一時大きな話題になり、いろいろな研究が発表されました。半導体では最初に研究された AlGaAs にはミッシビリティギャップはありませんから興味をひいたのですね。この四元系結晶に関して学んだ基礎的な研究が、会社に入ってもすぐに役立ちました。

小松：まさに富士通の準備していたみたいですね。

中嶋：学生のときに四元系半導体を勉強していなかったら、会社に入って InGaAsP 四元系結晶をつくれと言われても、時間がかかったかもしれません。会社では多くの研究者が電気屋さんでした。そのため材料屋といえども、最低限にはレーザーや受光素子に関して彼らが言っていることを理解できないと話にならない。

小松：先ほどの Panish と林さんは一緒にやっていたんですよね。

中嶋：ええ、そうです。

小松：それで、僕らも室温発信レーザーできたというので、林さんが日本に帰ってきたときに、亡くなった東大の青木昌治先生や菅野先生のかけ声で、みんな林さんの話を聞こうというので、行ったことあります。

中嶋：ダブルヘテロ構造のレーザはすごかったですね。それまでは効率が悪かったけれども、活性層の両側にキャリアを閉じこめましてね。この構造が半導体レーザの基本になりました。ダブルヘテロ構造の AlGaAs 半導体レーザを液相エピタキシャル成長法でつくったのが Panish で、スライディングボート法を用いていました。

小松：それを手伝ったのが後に無機材研の所長になった木村茂行さんなんですよ。ちょうどペンシステイトのポスドクから雇われていって、毎日毎日同じ実験で相図作りをやって、僕はもう一生あんな仕事はやりたくないと言っていましたね。

中嶋：液相エピタキシャル成長には精密な状態図が不可欠です。まさに固液平衡近傍からの成長ですからね。

小松：だから、まさにそういう富士通の必要なものをずっと前から準備していた。雇った方は得したというか。

中嶋：そうですね、お互いに得をしたんですね。InGaAsP の四元系結晶がすぐに成長できなかったら、富士通が光通信で先行するのが遅れたでしょうね。私が入社した当時は、富士通では InGaAsP 結晶の作り方が解からなかった。当時は、NEC、NTT、Bell 研究所でも研究をしていましたけれども、InGaAsP の状態図をつくった人はいませんでした。だか

ら Bell 研究所の人と一緒に InGaAsP 四元系半導体の本を書いたりできました。

小松：そうでしょう。基礎というのはすぐには役に立たないけれども、ワン・ゼネレーションおいて、役立ってくるんですね。

中嶋：やはり基礎をきちんとやっていくことが一番重要ですね。

小松：底力になっているのですね。

中嶋：底が浅いと、ちょっと状況が変わったら対応できませんね。

小松：そうですよね。だから、今のタックスペイヤーにちゃんと説明しろなんて言って、すぐにこれやったらこんな金になりますみたいなことばかりみんな言ったら、やはり体力は落ちていきますよね。そういう基礎があるからエコロジー太陽電池だって生きてくる。一つのことだけやっていたら、多分大学に行っても発想は狭いところに固定されると思う。

中嶋：そうですね。金研に来たときには最初からシリコンとは思っていなかったんですよ。太陽電池やりたいけれども、化合物半導体だと思ったんです。けれども大学では企業と比べて施設が貧弱なので、ヒ素とかリンとかやると怖いと思いました。とても学生にヒ素やリンなどやらせられないからシリコンにしようと思って。

小松：まさにそうですね。大学へ来ると、危険性のことと、それから装置が複雑になるとお金がかかるので、できるだけ自分の知りたいことをできるだけ安い手づくりでできるようなものに発想を変えざるを得ないですよね。

中嶋：だから最初からシリコンが伸びると思ったわけではないんですよ。今ではそう信じていますが。そこは柔軟に状況によって変わっていかないといけない。シリコン多結晶太陽電池の研究は、結晶成長が最も生かせる分野の一つです。光通信用の発光素子にはバイアスをかけられますから、欠陥があって発光効率が少し悪くてもキャリアを注入していけば光るんですね。太陽電池は外部からバイアスをかけないから、結晶欠陥があったらキャリアは死んでしまいます。そこで要求されるのは、できるだけ欠陥の少ない、要するにパーフェクトなクリスタルですね。パーフェクト・クリスタルをつくるというのはまさに結晶成長のテーマですね。結晶成長屋から見たら太陽電池というのは無限に続くテーマで、エンドレスなんですよ。今僕がやっているのはパーフェクトのはるかに下ですからね。これは永久に研究できるテーマですね。品質が上がれば、それだけちゃんと効率が上がってくるから、非常にわかりやすい。結晶成長屋さんとしてはこれは運のいいテーマだったなと。

　結晶成長屋として二回運の良いテーマに会っています。１回目は InGaAsP 四元系状態図の作成から、光通信用の発光・受光素子の研究開発の黎明期に遭遇できたこと。もう一つは、太陽電池をやりたい気持ちから選んだシリコンです。半導体素子には通常シリコン多結晶バルクは使いませんが、唯一太陽電池に使われていました。当初太陽電池用のシリコン多結晶はるつぼの中にシリコン融液を入れて、そのまま凝固しており、ほとんど結晶成長の概念が入っていなかった。ここに結晶成長の概念を持ち込んで、シリコン多結晶の組織制御をして、結晶粒方位をそろえ、結晶粒サイズを大きくし、粒界性格を変えていく

と、だんだん単結晶の品質に近づいてきたんですよ。つまり、今までシリコン多結晶バルクの組織を制御しようという人はほとんどいなかったけれど、デンドライト結晶を利用するというその手法を偶然見つけて、組織制御性の研究をやっていると、多結晶がだんだんわけのわかるものになってきた。すると太陽電池の効率が上がってきて、人が注目してくれた。結晶成長屋が太陽電池用シリコン結晶のテーマに行き当たったのは非常にラッキーだったんですね。

小松：そういう成功の裏には知的興味プラスそういう社会のバックグラウンドの変化といいますか、材料の流れとの絡み合いですね。うまくマッチングすればぱっと花開く。

中嶋：シリコンの研究は深めていけばどんどんおもしろいことがあります。シリコンの結晶化を「その場観察」で見たり、インゴットの結晶組織を自在に制御したり、あるいはシリコン結晶を３次元的に自在の形状に曲げてみたり、まだまだ解らないことがいっぱいあるおもしろい材料だと思います。やっとシリコンのおもしろさに気づいたところです。

小松：なるほど。この後どういうようにされますか？

中嶋：京都大学エネルギー科学研究科で、寄附講座（太陽電池シリコン結晶科学）を担当することになります。

小松：はっきりしていますね。スタッフはどうするんですか。

中嶋：当初は２人の助教がいます。社会還元の意義と手法を体験するためには、寄附講座を若いときに経験するのも大事だと思いますね。ここのスタッフは経営者のセンスがいります。寄附講座は自分の責任でやらねばなりません。

小松：そうか。厳しいですね。しかし、ここの助教２人が来て働き手になって実験を手伝ってくれる。彼らも次のことがあるから、やはりきっちりやらないといけないという。

中嶋：きっちりやらないといけません。特に実用化というのは、研究室で作製した結晶ウェハーを企業に提供して企業のプロセスで評価してもらい、良い特性を出さないといけない。企業のラインに流せる実用サイズのウェハーを作製して同等以上の特性を出さないといけないんです。しかし、インゴットを高品質化する過程で、企業ではわからないようないろいろなノウハウが出たり、優れた技術が考案されることになります。

小松：発想の転換がいるわけですね。

中嶋：そうですね。いま全く新しい発想の装置を設計して世の中に使ってもらおうと思っています。苦労するといいことがあるわけで、いいことを生むための応用問題だと思って解けばいいと思います。

小松：そのとおりです。ところで、エキサイティングファインディングスというのを特に具体的に挙げるとすれば何でしょうか？

中嶋：太陽電池では、過冷却度を精密制御すると、成長初期にデンドライト結晶をルツボ底面に沿って走らせることができ、これが Si 多結晶インゴットの組織制御に活用できることを見出したこと。高温加圧加工法では、シリコン結晶を３次元的に自在の形状に変形させることを見出し、これが X 線の点集光用結晶レンズに使えることがわかったことでしょ

うか。光通信では、結晶成長屋よりもデバイス屋が目立ちましたね。

小松：それはそうですね。サッカーと同じですよ。ゴールへキックした人が何か一番目立ちます。だけれども、実際にはバックがずっと持っていかなければいけないんですね。

中嶋：確かに基礎研究をやっているとそうなんですね。しかし、光通信でもファイバーの純度をだんだんよくして、去年それでノーベル賞受賞者がでましたね。

小松：カオさんとかいう人ですね。

中嶋：ええ。光通信で初めてもらった人なんですね。テクノロジーをやっていてももらえるんだなと思えて、いいですね。

小松：特に最近のノーベル賞はテクノロジーが評価の対象になっていますね。LSI なんかでもノーベル賞になったりして。

中嶋：デバイスをつくって特性出した人は、状態図が結晶作製の基礎になっていることはわからない。縁の下の力持ちの研究だけをいつまでもやるわけにはいかないと思い、自分で世界一のデバイス特性を出そうと思ったんです。シリコン多結晶の研究では、一応特性的には世界のトップレベルの１８．２%の変換効率を出しました。

小松：それまでの効率はどのくらいですか？

中嶋：多結晶で使われている太陽電池は１５から１６%です。

小松：そこまでいっていましたか。

中嶋：シリコン多結晶太陽電池の平均的なセル効率は１５～１６%ですね。当研究室の結晶作製装置を大きくすれば、１８%はコンスタントに出ると期待しています。１８%の世界になると、純度と結晶欠陥の課題をかなり考えてやらないと出ない。２０%の世界になると、単結晶の品質に近くならないといけません。キャスト成長法の低コストで単結晶の品質を実現できる技術として、シリコン結晶をシリコン融液中で浮かして成長させる浮遊キャスト成長法を提案しています。これが次に研究するテーマです。さらにもう一つの発見は、シリコンの高温加圧加工の考案です。シリコンがどんな形にでも曲がることは、多くの分野で注目されています。例えば、X 線の点集光結晶レンズ、X 線分光用結晶レンズ、中性子用結晶レンズ、宇宙望遠鏡用 X 線レンズなどです。この技術は結晶成長をやっていて失敗した時に見出したものです。

小松：メカニズムはどういうことなんですか。

中嶋：シリコン結晶の融点直下における塑性変形を利用しています。シリコン結晶を変形させていくと弾性変形します、さらに変形させると通常はクラックが入って破壊しますが、融点直下では加工硬化されずに、塑性変形の領域に入り自在の形状に加工されることを見出しました。

小松：温度を上げて転位を動けるようにしてやるのですね。

中嶋：動けるようにし、しかもできるだけ余分な転位が入らない条件を見つける。

小松：すると、プラス、マイナスの打消しあいなんかも起こるんですかね。温度が上がっていくと起こりやすくなるんですかね。エッジでもプラス、マイナスのエッジが一緒にな

って消えていくというか。

中嶋：そこまでまだ見ていませんのでどうですかね。

小松：片方はテンション、片方はコンプレッションですから、そういうのがちょっとでもかかったらさっとお互いに打消しあいしてどんどん減っていくと。そのメカニズムは絶対あるはずですね。だから、場合によってはアニーリングの温度を、適当に時間とか温度を変えることで、もっとまだいろんなことができるかもしれないですね。

中嶋：融点直下の高温で変形試験をした人はまだいませんので、これからいろいろのことがわかると思います。実際に面方位により変形挙動が大きく変わることを見出しています。

小松：それはおもしろいですね。

中嶋：３月の応用物理学会で話をしましたが、まったく予想もしなかった分野の方から大きな関心が寄せられました。例えば、レーザ核融合の分野では、核融合反応を微弱なX線を測定して観察していますが、ここではX線の点集光結晶レンズが使われています。しかし弾性限で変形した結晶レンズしか手に入りませんので、精度が悪く苦労されている。ここにこの技術を用いた結晶レンズが使えると、多くの研究者が使用するだろうとのことでした。

小松：それはおもしろそうですね。いわゆるセレンディピティーというやつですね。ねらっていて失敗したと思ったら、実はそれが使えるという。

中嶋：そうですね。こんなに自在に曲がるとは、びっくりしました。

小松：なるほど。これはおもしろい話です。それで若い人にアドバイスをどうぞ。

中嶋：まず自分がやりたいことをはっきりさせる方がいいかもしれないですね。僕は太陽電池をやりたいという強い意志のもとで研究しているので、いろんな問題が起こってもめげなかったんです。それからいっぱい失敗をする。失敗というのは乗り越えるためにあるのであって、そこにおもしろいものを見つけることによってまた新たな発見ができると思いますね。やはり一番大きなものは、自分の知的好奇心でしょうね。

小松：そうですね。その知的好奇心は、企業にいる場合と大学にいる場合で違ってきますか。

中嶋：違うと思います。

小松：要するに、おっかぶせの枠の中へはめ込まれないんですよね。

中嶋：企業にいても好きなことやっている人はいると思います。しかし企業の中でも重要な製品開発に携わっている人は、好きなことができないから、どうしても知的好奇心が満しにくい。

小松：知的好奇心を満たさないとモラルも上がらないですね。たいてい、意気が上がらない。

しかし、Bell 研究所なんかの成功の話聞くと、結構そういう知的好奇心を盛り立てるみたいなところがありますね。

中嶋：かつてのBell研究所はそんな感じだったようです。

小松：そうですね。企業も富士通とか東芝とか大きいところはそういう自由があるけれども、小さくなればなるほど、もう目先の問題をやらざるを得ないですね。

中嶋：そうですね、会社つぶれちゃいますからね。まだ富士通はそれでもあんな状態図をつくらせてくれましたから。

小松：そうですよ。状態図からやろうだなんて、その発想自身がもう企業の発想じゃないですよね。

中嶋：富士通もそういう意味ではりっぱでした。そういった自由度があったんですね。

小松：そんなの、何の役に立つんだよ、金も時間ももったいない。早くやれって。

中嶋：情報を囲い込まないで、ああいうデータを発表させてくれたんですよ。企業によってはあれはノウハウだから発表はだめというところがあるはずですよね。

小松：オープンにすれば、またいろんなインフォメーションが来るんでしょう。

中嶋：大学はオープンにできますからね。企業でオープンにさせてくれるところはすごく寛容なところですね。そこではやはり研究者としてもやりがいあります。その当時、だからみんないい研究したと思いますね。

小松：そこから結構人が育ったんじゃないですか。

中嶋：そこから大学に出ていきました。そのころ育った人が多いと思いますね。

小松：結局人が育たないような研究所というのは、長い目で見たら失敗だと思います。人が育つ研究所というのはやはりすごい研究所だと、最終的には。

中嶋：そうですね。まだ何もわからんけれども、おれたちがやってやろうという雰囲気があったのですね。そういう時はものすごくエネルギーがあったと思いますね。

小松：だから、若い人に残す言葉としては、知的好奇心を。

中嶋：知的好奇心を満たすようにしてやるということですね。目標を持って、まずはそこが原点だと思いますね。

小松：ケンブリッジ大学材料科学の一般教養で、教授は自分の専門を学生に話すのではなくて、専門外のことを自分の目でつかんできて講義をするというのが大事な仕事になっているんだそうです。まさに知的好奇心を教授自身がいつまでも持っているわけですね。

中嶋：すばらしいですね。ところでこれはちょっと余談ですけれども、実用化のためにデータをとる時、論文を書くことだけから考えれば、ある意味実に無駄な広い範囲のデータを取ってきました。しかしこれはあとで生きてきました。やはり材料屋さんというのは無駄だと思っても、できるだけ広い範囲のデータをきちっと取るということが大事だと思いますね。

小松：金研の大々先輩たちは、実験したデータでドットを打って、そのドットで線にしたという話を聞きました。東北大の材料というのは頭じゃないく実験でドットをどんどんとれと。寺田寅彦も頭のいいやつは大した研究できない。やる前からわかった気になってしまう。自然に忠実にきっちりやっていくと、いろんな新しいことが見つかるんだと。

中嶋：それが材料屋だと思いますね。

小松：できないですね。頭で考えてやっていたのでは。最後に趣味としては、特に何か。

中嶋：所長になってからゴルフを始めたんですよ。

小松：なるほど。それが最近の趣味。

中嶋：ゴルフは好きですね。また歴史が好きなので、しょっちゅう読んでいます。

小松：それで一応満足したら、今度はいろいろなところに行ってみたいなと。今日はゆっくりいろんなお話を伺えて、楽しかったです。ありがとうございました。

中嶋：どうもとりとめのない話でしたが、ありがとうございました。

２０１０年3月２４日
金属材料研究所　中嶋教授室にて
小松　啓（ひろし）

Interview with Professor Tomokazu MATSUE, Principal Investigator, WPI-AIMR

"Making the Most of a Turning Point"

Administrative Director Iwamoto (I): Professor Matsue, you have been a great help for WPI-AIMR as an adjunct professor, and as of November 1, you are officially assigned to AIMR as a Principal Investigator (PI).

Welcome on board.

Professor Tomokazu Matsue (M): Thank you very much.

I: Is it correct to pronounce your name as "Matsue"?

M: Yes. It's a rather unusual name.

I: I am terribly sorry but I had been pronouncing your name as Professor "Suenaga", judging by the combination of the Chinese characters. Is this pronunciation related to your birth place?

M: Yes. I am from Tonami in Toyama Prefecture. For some reasons there are about 20 families whose name is pronounced as "Matsue", which is written in the Chinese characters that can be pronounced as "Suenaga". I think if I trace the roots, I can probably find some reasons. I have never tried to find out, but I suppose there was an origin that gradually expanded, and then remained only in that particular place.

I: So, were you born in Tonami in Toyama Prefecture?

M: Yes, I was.

I: Did you live there until you finished high school?

M: Yes. I went to a high school there.

I: After high school, you went to the Faculty of Pharmaceutical Sciences of Tohoku University, is it right?

M: Yes, that's right.

I: As a child, were you interested in science and such subjects?

M: Yes, I liked science. I was so young that I did not understand the details, though. Japan was developing significantly in those days and that made me very interested in technology. I wanted to be an engineer since I was at primary school.

I: Since your primary school days.

M: Yes.

I: Excuse me, but may I ask which year were you born in?

M: I was born in 1954.

I: Oh, same as me. We were born in the same year, but some people grew up to love science and some didn't…. When we were children, the high economic growth period started and there was certainly great interest in science and technology.

M: There was Tokyo Olympics, and then Osaka Expo'70 was held when I was at high school. It was the time when Japan was very vibrant.

I: Indeed. A lot of new products came into our lives.

M: When I saw new electronic goods, I was very curious to see what was inside. I used to disassemble a lot of things.

I: The products of those days were not black-boxed like the modern ones…

M: Yes, they were rather simple, weren't they?

I: They make you want to disassemble. I can understand that feeling very well. Then, although you had been living in Toyama Prefecture, you decided to come to Tohoku University. What made you do that?

M: If you were living in Toyama Prefecture and wanted to go to a university, there was a choice of three regions: Kansai, Kanto or Tohoku. People around me had a very good impression about the School of Engineering of Tohoku University. It seemed to have advanced technologies and conduct substantial researches. I went to the Faculty of Pharmaceutical Sciences. Engineering or pharmaceutical science was a difficult choice for me, but at that time I could not decide which one to choose. Since I was born in Toyama, medicine was always around me. So, medicine seemed to have a lower barrier for me, or I was more familiar with medicine. There was also a lot of information related to medicine around me. I did not especially want to study medicine, but when I thought about studying engineering or pharmaceutical sciences to become an engineer, the latter sounded more familiar to me.

I: That's interesting. In fact, Toyama is more famous for its medicine than any other prefecture.

M: There are a lot of small pharmaceutical makers in Toyama.

I: So, there is a tradition of medicine and it was a natural choice for you.

M: Yes. Medicine is very close to the people in Toyama.

I: I see. After the Faculty of Pharmaceutical Sciences you went to the Graduate School of Pharmaceutical Sciences and received a doctor's degree at Tohoku University. What was your main research subject?

M: Actually, although I studied medicine, or rather, pharmaceutical sciences at the Faculty of Pharmaceutical Sciences, I was not sure if it was the right choice. I was more interested in physics and chemistry since I was a child. You can choose such fields in the Faculty of Pharmaceutical Sciences too, but most study involves memorizing the names of medicine. I was not very interested in this kind of study. When I was in my fourth year and had to choose a laboratory, a new professor came from the Faculty of Engineering, The University of Tokyo. It was a very rare case to come to the Faculty of Pharmaceutical Sciences from the Faculty of Engineering, and I thought I might be able to try something different as it was a new laboratory, so I decided to join the laboratory. I started experiments in the laboratory and found research very interesting. I was not particularly interested in academic study in my undergraduate years, though.

I: You were more interested in doing experiments than memorizing the names of substances and medicine.

M: Yes, it was more interesting to create something using my hands, gather data and analyze it. Since my professor was from an engineering background, I learned a sense of engineering from him.

I was studying organic electrochemistry, which is to create organic substances by using electricity. It is a field of organic chemistry.

I: Could you give me an example of organic electrochemistry?

M: For example, put various chemical compounds into water, and then electrify the water. The electricity will cause chemical reactions and that will produce a new compound. Normally, a reagent is used to cause chemical reactions, but instead electricity is used in organic electrochemistry.

I: Was it a new trend at that time?

M: Yes. It was a new trend in those days. It was the early form of green chemistry, which is very popular now. Since electricity is used to cause reactions instead of a reagent, it is a very clean method.

I: I see. Reagent could produce something harmful that cannot be poured down the drain.

M: Yes, indeed. It was considered to be a cleaner chemical reaction because of the use of electricity, and it was a brand new research field at that time.

I: I see. Now I understand. In your case, although you studied at the Faculty of Pharmaceutical Sciences and the Graduate School of Pharmaceutical Sciences as you mentioned earlier, you were taking various approaches including engineering or a scientific approach.

M: Something like that.

I: I learned from your CV that you had been in the School of Engineering and also in the Environmental Studies until recently. I have an impression that you are very well-rounded.

M: It looks like I am moving about.

I: Your current research field is mainly bio devices, isn't it?

M: Yes.

I: What kind of research in bio devices do you do specifically?

M: The easiest example is development of devices to measure the level of sugar in blood. Diabetic patients have to measure the level of sugar in their blood by themselves, and there is a small device for that job: it has a needle to prick your body to get your blood out then measures the sugar level from the blood. My research involves from groundwork to development of such devices. An easy example would be a device to measure bioactive substances.

I: I was in hospital before and I often heard a nurse asking the patient in the next bed, "Have you measured your blood-sugar level?" over the partition curtain. I was wondering what was going on, and also wondering if the patient had to inject by himself. Now I know there is a device for that purpose.

How does it work?

M: Blood contains sugar. There are enzymes on the surface of a sensor, and they will react to sugar. When a reaction occurs, an electron will be produced. Then the electron will be measured as a current. It is a system to capture the reaction of enzymes as a current.

I: It is a clever use of electricity. Is it called "bio" because it uses enzymes?

M: Yes. Because it uses enzymes and also because the target is a bioactive substance.

I: I see. In addition, I often hear a term "self-organization". Is this also closely related to your research?

M: Yes, it is. For example, biological materials should be placed on an inorganic substrate such as silicon or glass in order to cause a reaction, but the substrate and biological materials such as an enzyme or protein will not react very well if the materials are not placed on the substrate properly. For this reason, it is very important how biological materials are placed or arranged on a substrate: this is where a technique called self-organization is used.

I: Interesting. What will be self-organized in this case?

M: If a bioactive substance such as protein is placed on a substrate, it will arrange itself thanks to the interactive effect of the substrate and bioactive substance. It will stick by itself.

I: Oh, I see.

M: This is called self-organization.

I: Because it does not require human intervention.

M: Yes. Actually, the surface of substrates needs various works so that the enzymes can be arranged in the way they can function well. The enzymes cannot be just placed on a substrate. Some work needs to be done to the surface of substrates to help enzymes stick to them properly.

I: And this is also a part of materials chemistry.

M: Yes.

I: Tohoku University includes the Institute for Materials Research and has an established tradition in hard materials; however, it is said that WPI-AIMR should place more focus on soft materials. In that case, bio-devices will become more important in relation to soft materials. Where do you think Tohoku University stands in the bio device field in Japan or in the world?

M: Tohoku University has strength in the materials and electronics field. It is also very strong in MEMS technology. I think creating bio devices by integrating these fields is something Tohoku University is very good at, and it is the field where Tohoku University can leverage its own strength.

I: Is this the reason why you think research on bio devices should be promoted as an output in which materials, electronics and MEMS fields are integrated?

M: Yes, that is my understanding. I would like to leverage and blend the strengths of Tohoku University to create something new.

I: I agree. It is an important point. In fact, when WPI-AIMR started three years ago, as we mentioned at the beginning, it was our profession to integrate various fields into new material science - from atom and molecule to bio devices. Ideally, I hope we can leverage our strength effectively and as a result we can not only make one plus one two but also three or even ten.

Talking about WPI-AIMR, you will meet various hard working researchers in Bio Device laboratory such as Dr. Ali Khademhosseini and Dr. Wu Hongkai. We are looking forward to seeing your collaboration with them.

M: Since I was in engineering for a long time, I tend to think that once I started the basis I should carry on to the exit. But recently I am more likely to think that I would rather work with companies at the exit phase in order to bring out my invention to the world, and I am trying various things for that. So, I want to produce something useful for the public from my research. This is my motive.

I: Another question - we talked about diabetic patients earlier. Are bio devices also

related to drugs?

M: Yes. Pharmaceutical makers are working very hard to develop drugs, and they have to test how effective the drugs they produced are for living bodies. There are several steps for the test: the first step is cell-level testing, and the next step is animal testing. Recently it is not easy to carry out animal testing, as it is discouraged and should be kept to the minimum. Instead, cell level testing should be employed. There are requirements for methods – very efficient methods - to check the effectiveness of the drugs at the cell level, since there are various types of cells and so many different kinds of drugs. For example, if cells are integrated into a chip and then a drug is added, it is possible to test the reaction all at once. The pharmaceutical industry and drug makers are requesting such devices.

I: So, you can see the result all at once?

M: Yes, you can see it all at the same time. This is called "high-throughput" in English.

I: So, bio devices will be more and more necessary for this purpose.

M: Yes. I think it will be used a lot more frequently in the bio field in the future.

I: I see. Then, it is a field with a lot of potential.

M: However, there are still a lot of black boxes in the bio field. There are many unknown factors. Experts in bio science are trying to analyze such black boxes, and it is important how effectively you can incorporate the cutting-edge information of bio science. We do not work in bio-science itself, but we are good at creating devices and developing measurement methods. The most important task is to incorporate the cutting edge information into our field.

I: Even though there is no biologist in WPI, I think it is important how we can apply what biologists have found or learned for materials.

M: Yes, indeed.

I: Going back to what we talked about earlier, a lot of researches in different fields are working together. It is so called "fusion research". We provide opportunities for that: for example, we hold "Joint Seminar" about twice a month while holding "Tea Time" every week. I know you have worked with people in various fields previously, but I would be grateful if you could take part here, too.

M: Of course. It is impossible to do everything by myself, and it is quicker to ask opinions of the experts in their fields when I have something I don't understand.

I: Yes, indeed. From this point of view, it is important to cooperate with other people – although it is also important to become an expert in a certain field.

I heard that you have been working for Japan Society for the Promotion of Science (JSPS) as a program officer until recently. What was included in your job?

M: I was in charge of building a system for Grants-in Aid for Scientific Research and checking whether the system is working correctly, as well as making sure that assessment for the grants is carried out properly.

I: So, it was more about how you can use the grants effectively for the academic researches rather than the actual contents of research.

M: Yes.

I: Are you interested in the management side of research too?

M: I'd rather say that I was doing it out of necessity. However, I could get a lot of information through that work. From this point of view, it was very useful.

I: I agree. We are also trying to work out the way to obtain the Grants-in Aid for Scientific Research as much as we can.

By the way, changing the subject from your research, what is the motto or slogan of your laboratory? You have a lot of young staff including graduate students.

M: Just try anything that looks interesting. Don't think about it too much from the beginning, but use your hands and try anything that looks interesting – this is the motto of my laboratory. I am encouraging the staff to move their hands instead of saying they can't do this or they can't do that before they even try.

I: Does it mean that some young staff tends to think theory comes first?

M: Yes, indeed. Some of them assume "this will not work" or "it will probably not be like that" from the beginning, but you never know until you actually do it, don't you?

I: Yes, it is important to just do it without making all sorts of excuses.

M: Yes, it is really important.

I: It is only through these experiences that you can open up and widen your capacity. So, the young researchers under your supervision in your laboratory are working with this spirit.

M: Yes.

I: It must be a great pleasure. In other words, you are encouraging the autonomy of the young researchers.

M: Yes.

I: Recently I often hear that young researchers are not willing to go abroad. There are many reasons for this, but what is your opinion?

M: I think it is recommended to go abroad - not just staying in Japan - to increase opportunity to learn different ways of thinking. I am also trying to send especially the students of the doctoral program to academic conferences abroad so that they can widen their view. One of my staff who has the doctor's degree is abroad now. Whenever my staffs have been abroad, they come back with a very different view or opinions and look more grown up.

I: I see. Although the research itself is universal, different countries have different approaches to research, don't they?

M: Yes.

I: I once studied public administration in France. Their teaching method and the way to develop theories were very different. That was a big shock to me, and I learned a lot from it.

M: I see.

I: In addition, when it comes to basic research, Europe and America has a very strong tradition.

M: Yes, I think so too.

I: From this point of view, as you mentioned, when young researchers attend workshops abroad and meet foreign researchers, it can be expected that they become motivated and develop themselves even further.

M: Indeed.

I: In WPI we recruit excellent researchers in Japan and from abroad, but I personally think that we also have to send out talented Japanese young researchers abroad.

M: I see.

I: Talking about the relation with foreign countries, you have studied in America, haven't you?

M: I studied at University of Wisconsin in America.

I: Yes, University of Wisconsin. Which school did you go to?

M: I studied with Professor Dennis Evans, who specializes in Chemistry.

I: He is well known in this field, I guess.

M: Yes. He is very famous in the field, very smart and intelligent. However, his research was very different from my research for the doctorial course in the Faculty of Pharmaceutical Sciences. As I mentioned earlier, I was studying organic chemistry, such as producing organic synthesis by using electricity, but in America the research was more about theory. Theory of electron transfer. When I was studying in Japan, I used to shake a flask to create something, but in America theory was more important and I used to spend all day in a computer room doing calculation. I am very grateful that he invited me despite the fact that I was in a totally different field. I studied electrochemistry and the theory of electron transfer really hard there, and it is still very useful for me.

I: So, was it the field you never studied in Japan before you went to America?

M: I was doing a more manual, unsophisticated method in Japan, but it was very different over there. In Japan, I had never used a computer for my research at that time.

I: When was it?

M: I received the doctor's degree in 1981. At that time there were hardly any computers. Although it was possible to do calculation in the large scale computing center, I never went there to do calculation.

I: Nobody did except computer specialist at that time.

M: However, once I was in America, I was in a computer room all day: I would make a program and calculate, then make another program and calculate… I did some experiments, but it was more for the purpose of comparing the experiment and the theory. It was very different research.

I: It sounds great. Two main pillars of experiment and theory – it will not always be possible to do both equally well, as we are not all Da Vinci after all, however, it must have been a great experience for your research activity after you came back.

M: Yes, it has been really useful. After I came back to Japan, I immediately started using simulation. I was probably one of the earliest who introduced simulation for electrode reaction.

I: By the way, talking about your private life, what is your hobby?

M: I used to like playing sports and played volleyball when I was young. I also played baseball and went skiing. But recently I mostly watch sports. When I have a spare time I go out by car with my wife to have a nice meal nearby. That is my hobby these days.

I: It is the best way to relax. I rarely have a chance to do exercise or play sports, and I guess you are also busy with your work…

M: I cannot be bothered to play sports recently.

I: By the way, you are involved in a lot of academic societies, and you are the Chairman of Tohoku Regional Branch of the Electrochemical Society of Japan (ECSJ). It is a rather large organization.

M: Yes, it is. It is the main academic society for batteries including solar batteries that is very popular now. It also does research and development of car batteries, fuel batteries and solar batteries. It is very active and large.

I: I see. So, what does the Tohoku Branch do? Do they coordinate organizations such as universities including Tohoku University and companies in six prefectures in Tohoku?

M: Yes.

I: It sounds interesting.

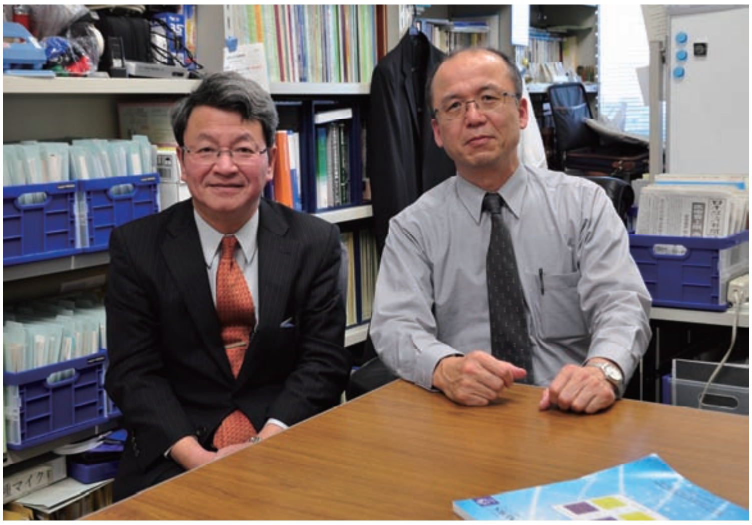
M: Toyota built a new plant in Sendai recently, and there is also a battery company jointly owned by Toyota and Panasonic. So, now the wind is favorable for us.

I: Indeed. Lastly, could you tell me your ambition – what do you want to do in WPI?

M: I think it is important to make the most of a turning point. It is very rare that you stay in one place for a long period these days. University staffs are on fixed term employment. It was my big turning point to move from Pharmaceutical Sciences to Engineering, so was moving from Engineering to Environmental Studies. I think this time will also be a good turning point. I would like to think that my transfer to WPI is an opportunity to develop and progress my research further, and I would like to make the most of it. So, I am thinking of doing something new in WPI, based on my current research.

I: I know you already know some professors in WPI, including Center Director Yamamoto, but there are also a lot of talented researchers in the fields that you had little contact with before. I would like to make an effort to provide opportunities to interact with each other. Also, if you can recommend foreign researchers for us to take on, even for a short period, I would like to actively work to make it happen.

Thank you very much for talking to me



Interviewer: Administrative Director, W. Iwamoto

At Matsue Lab,

Engineering Laboratory Complex Building

November 9th, 2010

WPI-AIMR PI　末永智一教授に聞く
(Interview with Professor Tomokazu MATSUE－Japanese version)

転機を活かす

岩本：末永先生には以前から連携教授としてWPI-AIMRはお世話になっていましたが、この11月１日からはPIということで正式にAIMRに所属していただくことになりました。よろしくお願いいたします。

末永：こちらこそ、よろしくお願いします。

岩本：先生の姓は「まつえ」先生ということでよろしいのですね。

末永：そうです。ちょっと名前が変わっています。

岩本：私、大変失礼なのですけれども、漢字の組合せからずっと「すえなが」先生とお読みしていました。この読み方は、ご出身と関係があるのですか。

末永：ええ。私の出身が富山県の砺波というところなのですが、どういうわけかそこには、20軒ぐらいですかね、「末永」と書いて「まつえ」と呼ぶ家があるんです。ルーツをたどれば恐らく何かあると思います．調べたことはないですけれども、何か元があって、それから少しずつ増えていって、そこだけにあるようになったのではないですかね。

岩本：では、お生まれはその富山県の砺波で。

末永：はい、そうです。

岩本：高校までですか。

末永：そうです。高校までそこです。

岩本：それから東北大学の薬学部に進まれたわけですね。

末永：そうですね。はい。

岩本：お小さいころから理科とかそういうのが好きだったんですか。

末永：理科は好きでしたね。小さいころだから細かいことはよく分からなかったですけれども、あのころ日本がすごく発展するような時期だったので、技術というのは非常におもしろいなと思って、小学校のころから将来は技術者になりたいなと思っていたのです。

岩本：小学校のころからそう思っていた。

末永：はい。

岩本：先生、失礼ですけれども、お生まれになったのは何年ですか。

末永：昭和２９年です。

岩本：ああ、私と同じです。同じ生まれ年でも、こうやって理科が嫌いになった人間と好きになった方がいるのですね。我々の小さいころは確かに高度経済成長が始まって、科

学技術に大きな関心が集まりました。

末永：オリンピックがあって、そして万博もちょうど高校生のころあって、日本がすごく元気があったころですよね。

岩本：ええ。我々の家庭の中にもいろいろ新しい物が入ってきたりということで。

末永：電気製品なんか入ってきて、その中がどういうふうになっているのかなというのが非常に興味がありました。いろいろな物を分解したりしていました。

岩本：また、今のとは違ってブラックボックス化していないから……

末永：割とシンプルでしたよね。

岩本：分解してみたくなる。それはよくわかります。

それで、富山県にずっとお住まいで、東北大学に来られたきっかけは何ですか。

末永：富山県から大学に行くとなると、関西、関東と東北があったのです。私の周りの人たちは東北大学の工学部はすごくいいというようなイメージがありました．高い技術があり、しっかりとした研究をしているというイメージがありました。薬学に進んだのは、当時、工学、薬学、ちょっと分野が違うのですけれどもね、どっちかなと迷っていました．富山ですから薬というのが身近にありました。だから、薬にはそんなにバリアがないというか、親しみがあったのですね。周りに薬に関わる情報もありましたし。私自身は特にやりたいと思ったわけではないのですが、技術者として工学、薬学、どこかそのあたりに行こうと思ったとき、薬学の方が少しなじみがあったというところですね。

岩本：ああ、おもしろいですね。確かに、他の県に比べれば富山というと、薬が有名ですね。

末永：富山には小さな製薬メーカーが結構いっぱいあるんです。

岩本：やはり伝統的にそういう風土があって、極めて自然なことだったんですね。

末永：そうですね。薬というのは割と我々にとっては身近ですね。

岩本：はい、わかります。

そして、薬学部から薬学研究科、それで博士号を東北大学で取られたわけですが、主にどんなことを研究されていたのですか。

末永：実は、薬学部に入って薬というか薬学の勉強をしたのですが、どうも薬の方がしっくりこなかったのです。やっぱり昔から物理とか化学とかそういうのが好きで。薬学部でもそういうふうな分野はあるのですが、薬の名前を覚えるとか暗記ものが多いのです。どうもそういうのが合わなくて。４年生になって研究室を選ぶときに、ちょうど東大の工学部から新しく先生が来られました．工学部から薬学部に来られたというのは非常に珍しいケースで、新しい研究室でもあるということで、ちょっと変わったことができるかなと思って、そこに入ったのです。そこで実験をし出して、研究というのはおもしろいなと思いました。学部時代の勉強というのはそれほど興味がなかったのですが。

岩本：物質の名前を覚えたり薬の名前を覚えたりというよりは、そういう実験に興味をもたれたのですね。

末永：自分で手を動かして物をつくったり、それでデータが出て、それを解析したりというのがおもしろかったです。先生が工学系の先生だったので、そういう意味では工学的なセンスを学びました。

　やっていたのは、要は電気を使って有機物をつくるという有機電気化学という領域なんですけれども、有機化学の一分野です。

岩本：有機電気化学というのは、例えばどういうものと言ったらよいでしょうか。

末永：例えば、水の中にいろいろな化合物を入れて、そこに電気を流す。電気を流すとそこで化学反応が起きますけれども、それで新しい物をつくり出す。普通だったら電気を流さないで試薬を入れて反応させるのですが、そうではなくて電気で反応させる、そういうふうな研究です。

岩本：それは、そのころとしては新しい流れだったのですか。

末永：そうですね。あのころとしては新しい流れでした。今はやりのグリーンケミストリーのはしりですね。変な試薬を使わないで電気で反応を起こしますから、非常にクリーンなんです。

岩本：ああ、試薬を使うと、そこら辺にも流せないようなものができてしまったりしますよね。

末永：そう、そう。電気を使うので割とクリーンな反応だということで、当時、始まったばかりの新しい研究分野でした。

岩本：そうでございますか。はい、わかりました。

　先生の場合には、先ほど来、薬学部、薬学研究科と申しましたけれども、先生もおっしゃったとおり、工学的あるいは化学的、そういった多様な関心からアプローチしていったということですね。

末永：そういう感じですね。

岩本：というのは、先生のCVを見せていただきまして、工学研究科にもいらっしゃいましたし、最近までは環境科学ということで、極めてオールラウンドという印象を持ちました。

末永：なんか、あっちこっち動いているという感じですね。

岩本：今おやりになっている研究の内容は、一言で言えばバイオデバイスということになりますね。

末永：そうです。

岩本：バイオデバイスについて、具体的にはどんなことを研究されているのですか。

末永：一番わかりやすい例が、血液中の糖分をはかるような装置の開発です。糖尿病の

患者さんは自分の血液中の糖分を測ることをやらなければいけないんですけれども、小さな器械で、ちょっと針を刺して出てくる血液で自分の血液中の糖分をはかるような装置が出ているんです。そういうふうな装置の基礎から開発まで研究しています。生体成分をはかるような装置がわかりやすい例ですかね。

岩本：私も以前入院していたときに隣に糖尿病の患者さんがいて、看護師さんにいつも「血糖値測りましたか」と言われているのが、仕切りカーテン越しに聞こえて「あれ、何やっているんだろうな、この人。自分で注射打っているのかな」と思っていましたが、そういう装置があるわけですね。

それは、どういう仕組みで測るわけですか。

末永：血液中に糖分があります。センサーの表面に酵素が乗っかっているのですけれども、糖分があると酵素と反応するのです。反応すると、そこで電子が出てくるんです。その電子を電流として測る。酵素の反応を電流としてとらえるような仕組みになっています。

岩本：ここに電気をうまく使ってということで。そうすると、酵素とかがあるという意味でバイオと言うわけですか。

末永：そうです。酵素を使いますし、対象が生体成分ですから。

岩本：なるほど。あと、これもよく聞く言葉ですが、自己組織化と言う用語があります。これもやはり先生のご研究とは非常に関係があるのですか。

末永：関係あります。例えば、シリコンやガラスの無機物質の基盤の上に、バイオの材料を乗せてうまく反応させるようにするのですが、基盤と生体物質、例えば酵素やたんぱく質を基盤の上にうまく乗せないと反応しないのです。ですから、基盤にバイオ材料を並べるというか乗せるというか、そういう技術というのが非常に重要で、そこには自己組織化というテクニックを使います。

岩本：ほう。先生、ここでは何が自己組織化するのですか。

末永：例えばたんぱく質とかそういう生体成分を基盤の上に置くと、基盤と生体成分の相互作用の力で、自分で並ぶのです。自分でくっつく。

岩本：ああ、わかりました。

末永：そういうのを自己組織化と言っています。

岩本：つまり、人が手を加えなくともということですね。

末永：そうですね。実際には基盤の表面にもいろいろな細工が要りますけれども。酵素をうまく機能するように並べるには。ただ単にぱっと置くというわけではなくて、基盤表面にいろいろな細工をして、その上に酵素がうまくくっつくように細工する。

岩本：そういうのも材料化学と言うわけですね。

末永：そうです。

岩本：東北大学は金属材料研究所があって、ハードマテリアルというのが確固として伝

統があるわけですけれども、WPI-AIMRについては、ソフトマテリアルというのにもっと力を入れなければならないのではないか言われています。そうすると、バイオデバイスというのも、まさにそういったソフトマテリアルとの関係で重要なのですね。バイオデバイスの分野は、日本あるいは世界の中で東北大学というのはどうなのでしょうか。

末永：東北大学は材料，そしてエレクトロニクスが強いですね。あと、MEMSといったのも非常に強いですね。そういう分野をうまく取り入れてバイオデバイスをつくるというのは、これは東北大だからこそできるというか、東北大の強みを出せる分野だと思います。

岩本：そういう意味では、材料であり、エレクトロニクスであり、MEMSであり、そういったものを融合したアウトプットとしてバイオデバイス研究というのが推進されるというわけですね。

末永：はい、私はそういうふうにとらえています。東北大で強いところをうまく生かして、それをうまくミックスして何か新しいものができればなというふうに思っています。

岩本：そうですね。それは重要なポイントですね。確かに、本機構も３年前に発足したときには、冒頭申しましたように、いろいろな分野が融合して新しい材料科学を、原子・分子からデバイスまでということで標榜しているわけです。結局、そういう我々が既に持っていた強み、それをうまく、１足す１が２でなくて３にも１０にもなるような感じになれば良いと思っています。

WPI-AIMRで言いますと、バイオデバイスでは、これから先生もいろいろ会われると思いますが、アリ・カデムホッセイニ先生や、ウー・ホンカイ先生も一生懸命頑張っています。そういう意味では、先生にもそういった人たちとのコラボレーションというか、それを期待しているわけですけれども。

末永：私はもともと工学にずっといましたので、基礎をやったらやっぱり出口まで自分でやりたいというのがありまして、今はどちらかというと出口の部分を企業と一緒にやって、自分で考えたものを世の中に出したいなと思っていろいろやっているところなんです。ですから、私自身はやっぱり皆さんの役に立つようなものをつくりたい、自分の研究の中から、そう思って今やっています。

岩本：もう一つ、さっき糖尿病の人の例が出ましたけれども、よくバイオデバイスというと医薬品とも関係してくるんですか。

末永：そうです。医薬品の開発を製薬メーカーで一生懸命やっていますけれども、作った薬がどの程度生体に効くかというのを調べなければいけないですよね。幾つかステップがあるのですが、最初の段階は細胞レベルで調べる。次に動物に持っていく。今は動物実験がしづらいというか、それをなるべく止め細胞レベルでやりましょうということになっているんです。細胞レベルで薬の効き方を見たい、それも、いろいろな細胞がありますし薬の種類もいっぱいありますから、非常に効率良く見たいという要望があります。例えば

チップ状に細胞を集積化すると、それに薬を加えたときの応答を一度に調べることができます。そういうデバイスを、製薬業界や薬の開発をしている人たちは欲しいと言っています。

岩本：すると一遍にぱっとわかる。

末永：一遍にわかります。英語でハイスループット、と言いますけれども。

岩本：そういうのにもバイオデバイスというのはだんだん必要になってくるわけですね。

末永：そうです。これからはバイオ分野でかなり使われるようになると思います。

岩本：わかりました。そうすると、極めて将来性の高い領域なのですね。

末永：ただ、バイオの領域というのは、ブラックボックスがまだ多いんですよね、分かっていないことがたくさんあります。バイオサイエンスをやっている人たちはそういうブラックボックスを一生懸命解明しようとしていますけれども、バイオサイエンスの最先端の情報をいかにうまく取り入れていくかが重要です。我々はバイオサイエンスそのものをやることはできないけど、デバイス作製とか計測法の開発とかは得意です。最先端の情報を我々の分野にいかにうまく取り入れていくというのが重要な課題です。

岩本：WPIの場合でも、バイオロジストがいるわけではないのですが、そういう方の発見したり得たものを我々がどう材料に生かしていくか、そこが大事だと思います。

末永：そうですね。

岩本：先ほどの話に戻りますけれども、いろいろな分野の研究者が共同研究している。融合研究と言うのですかね。私どもとしては、その場所として例えば「ジョイントセミナー」というのを月に２回ぐらいやる一方、「ティータイム」というのを毎週実施しています。先生もいろいろな分野の方との共同研究というのは、従来もやってこられたわけですが、今後もよろしくお願いします。

末永：ええ。やっぱり自分でいろいろなことはできないですから、わからないことはその道の専門家に聞いて、いろいろな意見を伺った方が早いですね。

岩本：そうですね。そういう意味では、もちろん一つの分野を深めるというのはそれはそれで大事なんでしょうけれども、ほかの人といろいろやっていくということは大事です。

先生は、最近までたしか日本学術振興会のプログラムオフィサーをやっていらっしゃいましたね。これは、どんなお仕事でしたか。

末永：科研費のシステムを作ったり、科研費の制度がうまく動いているかどうか、あるいは科研費の審査がちゃんとなされているかどうかということをチェックするような立場にいました。

岩本：それは、研究の中身というよりも科研費をどれだけ実効的に学術研究の向上に役立てるかということですね。

末永：そうです。

岩本：先生は、そういった意味で、研究のマネジメントといったことにも関心がおありというか。

末永：役割でしようがなくやっていたというのはありますけれども。でも、あれはいろいろな情報が入ってきますから、そういう意味では非常に役に立ちました。

岩本：そうなんです。我々も、科研費を何とか多く取れないかとか、いろいろ考えているんですけれども。

　ちょっと研究の話と外れますけれども、先生、大学院生あるいはいろいろな若いスタッフがいっぱいいらっしゃいますが、研究室のモットーといいますかスローガンというか、それはどういったことですか。

末永：とにかくおもしろそうなことは試してみようと。最初から余りいろいろなことを考えないで、とにかく手を動かして、おもしろそうなことをやってみましょう、というのがうちの研究室のモットーです。これはできない、あれはできないと最初から言わないで、とにかく手を動かしてやらせようと。

岩本：ということは、ともすると若くして入ってきた人たちの中には頭でっかちで……

末永：そう、そう。最初から「これはうまくいかない」とか「そんなふうには多分いかないだろう」というふうに思い込んでいる人もいるんですけれども、実際やってみないとわからないですよね。

岩本：ごちゃごちゃ言う前に、まずやってみるというのが大事ですね。

末永：本当にそれは重要です。

岩本：そういったことを通じて初めてまた新しい自分のキャパシティーが広がっていく。そういう意味では、今先生の指導されている若手研究者というのは、そういったタイプでやっていく人たちということですね。

末永：そうです。

岩本：それは楽しみなことですね。言い換えれば、先生も若手研究者の自主性をエンカレッジしたいということですね。

末永：そうです。

岩本：最近、若手研究者が余り海外に出たがらないと言いますけれども、原因はいろいろあるのでしょうけれども、どうお考えですか。

末永：日本に閉じこもっていないで外に出て、いろいろな人の考え方というか、そういうのを見る機会をふやした方がいいと思います。私もなるべく、特にドクターコースの学生は、海外の学会などに行かせるようにして、なるべく視野を広くしてほしいというふうには考えています。今、私の研究室でドクターを取った者で海外に行っているのがいますけれども、やっぱり海外へ行くとかなり見方が変わってきますから、一皮むけてくるのが多いですよね。

岩本：そうですね。もちろん研究自体はユニバーサルなものなのでしょうけれども、国によって研究に対する接し方みたいなものが違うのではないですか。

末永：そうです。

岩本：私も昔、行政学を学びにフランスへ留学したことがありました。全然教え方は違うし、理論の展開の仕方から何から違うし。そういうのは大きなショックだし、いい勉強になりますね。

末永：そうですね。

岩本：それと、基礎研究は、やはり欧米はその点、かなり強い伝統みたいなものがありますね。

末永：伝統はやはりありますね。

岩本：そういう意味では、先生がおっしゃったように、若い人が研究集会等に出て行って向こうの人たちと知り合う、そういうことから始まって、どんどん一皮も二皮もむけていくというのは期待できるのでしょうね。

末永：そうですね。

岩本：WPIの場合は、内外からすぐれた研究者を集めている訳ですけれども、逆に日本人の優秀な若い者を出していく、そういうことも考えなければと個人的には思っています。

末永：なるほどね。

岩本：海外との関係で言えば、先生はアメリカに留学されましたね。

末永：私はアメリカに留学していました。ウィスコンシン大学。

岩本：ウィスコンシン大学でしたね。ここではどういう関係の研究科でしたか。

末永：化学のデニス・エバンス先生というところに行っていました。

岩本：この方は高名な方……。

末永：はい。その分野では非常に有名な，非常にスマートで、頭のいい先生でした。ただ、私が薬学の博士課程でやっていた研究とは全然違う研究で、私は先ほど言いましたように有機化学、電気を流して有機合成をするということをやっていたのですが、アメリカはどちらかというと理論なんです。電子移動の理論。日本にいたときはフラスコを振って物をつくるということをやっていたんですけれども、向こうに行ったら理論で、コンピュータルームに閉じこもって計算するというような毎日でした。全然分野が違うのによく僕なんかに来てもいいよと言ってくれたと思って。ただ、あそこで電気化学、電子移動の理論をみっちり勉強しまして、それは今でもすごく役に立っています。

岩本：では、渡米されるまでは日本では余りおやりになっていなかった分野ということですか。

末永：日本では、泥臭いようなことをやっていたのですが、全然違う。日本では、研究でコンピュータなんかを使ったことがなかったんですよ。

岩本：それはいつ頃ですか。

末永：ドクターを取ったのは８１年です。そのころはコンピュータなんてほとんどなかったですから。大型計算機センターで計算はできましたけれども、そこに行って計算するということは全くありませんでした。

岩本：まずないでしょうね。

末永：ところが、向こうに行ったらコンピュータルームに閉じこもって、一生懸命プログラムつくって計算して、またプログラムつくって計算して。実験もありましたけれども、実験と理論を対比させるというか。全然違った研究でした。

岩本：すごいですね。そういう実験と理論の二本柱というのは、人間、皆がダ・ビンチではないですから、両方すべてが得意というわけにはいかないでしょうけれども、ただそういうことも経験されたというのは、その後の自分の研究活動にとって大きなものでしたね。

末永：本当に役に立ちました。日本に帰って来て、早速シミュレーションを取り入れて、多分、日本でも非常に早く電極反応のシミュレーションをやったと思います。

岩本：先生、プライベートな話ですけれども、ご趣味は。

末永：昔は運動するのが好きで、若いころは、バレーボールをやっていました。それから，野球をやったりスキーやったり。でも，最近は観るばかりですね。ちょっと時間ができたときには女房と一緒にドライブに行って、何かその辺でおいしいものを食べてくるというのが最近の趣味ですかね。

岩本：それは一番いいリラックス法ですね。私もなかなか運動とかスポーツというのはできませんが、先生もお仕事の方もお忙しくなってくるし……

末永：自分でもおっくうになっちゃいましたね、最近。

岩本：ところで、先生はいろいろな学会に関わっていると思いますが、確か日本電気化学会の東北支部長でいらっしゃいますね。電気化学会というのは、かなり大きな学会ですね。

末永：大きいですね。今はやりの太陽電池も含めた電池を扱うメインの学会ですから。自動車用のバッテリーとか、燃料電池、太陽電池などの研究開発をメインにやっている学会で、非常に大きくアクティブですね。

岩本：なるほど。では、東北支部と言いますと、東北大学はもちろん、東北６県といいますか、ここの大学、あるいは企業もあるのかもしれません、そういったところの取りまとめをされているということで。

末永：はい。

岩本：なかなかおもしろいですね。

末永：仙台に今度トヨタが来ましたし、トヨタとパナソニックと共同の電池会社も来ま

した。だから、今非常にある意味では追い風になっています。

岩本：そうですね。

　最後にWPIに入って、こういうふうにやっていきたいといった抱負を聞かせて下さい。

末永：私自身は、転機をうまく活かすというのが重要だと思っています。一つのところにずっといるというのは、今は恐らくないですよね。大学のスタッフも任期制が導入されていますし。私も薬学から工学に移ったのは非常に大きな転機で、工学から環境に移ったのも一つの転機。今回も非常にそういう意味では良い転機になると思っています。その転機をうまく活かして研究をさらに進展させるというか展開を図るというか、そういうふうな機会として今回WPIに移ったことをとらえようと思っています。ですから、WPIでは、今やっている研究をベースに少し新しいこともやってみようかなと思っています。

岩本：もちろんWPIには以前からご存知の先生方が、山本機構長を初め何人もいらっしゃるんでしょうけれども、また別の今まで余り接触のなかった分野のすぐれた研究者の方もいらっしゃいますし、また我々もそういった交流の場をつくったりということでお手伝いしていきたいと思います。また、外国の研究者等で、こういった人は短期でも受け入れた方がいいという話があれば、また積極的に実現していきたいと思います。

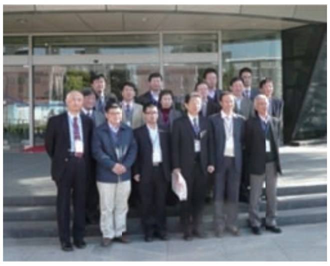
　本日は貴重なお話し、どうもありがとうございました。

２０１０年１１月９日
東北大学工学系総合研究棟　末永研究室にて
岩本　渉

News Update

WPI-AIMR-ICCAS Joint Symposium in Beijing, China

Ken Nakajima

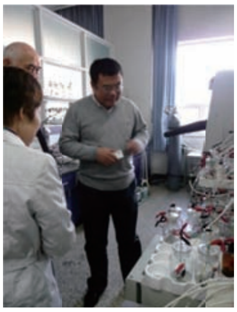


WPI-AIMR hosted WPI-AIMR-ICCAS Joint Symposium at Institute of Chemistry, Chinese Academy of Science (ICCAS), in Beijing, China on October 29, 2010. The symposium, attended by 13 researchers from 2 countries, Japan and China, and about 25 Chinese students, was a great success thanks to effort by Li-Jun Wan, Director of ICCAS and CAS Academician, who concurrently holds the position of Principal Investigator (PI) at the WPI-AIMR.

ICCAS was founded in 1956 as a multi-disciplinary research institute dedicated to the basic research in broad fields of chemical sciences. As the third phase of the Knowledge Innovation Project of the CAS, ICCAS focuses its research on the following 4 areas: frontiers of molecular and nano sciences, organic polymer materials, chemical biology, as well as energy and green chemistry. Those have perfect match of WPI-AIMR scope. ICCAS currently has 9 CAS Academician, 3 State Key Laboratories, and 7 CAS Key Laboratories.

The symposium began with Wan's opening remark, followed by the introduction of WPI-AIMR by Yoshinori Yamamoto, Director of WPI-AIMR with anticipating a future strong cooperation between two institutes. There were 4 speakers from Japan (Yamamoto, Kurihara, Nakajima from Soft Materials Group and Tanigaki from Materials Physics Group). They talked about nano-structured materials catalyst, resonance shear measurement for nano-tribology and nano-rheology, nano-palpation technique, thermoelectricity and superconductivity, respectively. Hongkai Wu from Hong Kong University of Science and Technology, who is concurrently holds the position of Junior PI at the WPI-AIMR, also attended and gave his talk on polydimethylsiloxane microfluidics. Qi-Kun Xue, CAS Academician, from Tsinghua University, who is also concurrently holds the position of PI at the WPI-AIMR, joined the symposium with the introduction of his excellent research on single molecular spin probing. Those talks definitely fascinated Chinese attendees.

CAS researchers' concern seemed strongly related biochemistry: bio-inspired chiral primary amine catalyst, conjugated polyelectrolyte for biosensing and bioimaging, biofunctionalized biocompatible polymers. They are very young professors still in the early thirties. They had experiences on studies overseas (USA, Germany, Japan) and came back to ICCAS. This implies the current trend and future prospect of ICCAS. Two guest speakers from the Chinese University of Hong Kong and Tsinghua University mentioned gold nanocrystals for biosensing and organic porous structure again for biosensing, respectively. The latter can be also used for the fabrication of pure single-layer graphene. It was no doubt that those talks gave good impression to Japanese attendees and that the future agreement of cooperation between two institutes would be quite beneficial. This was evident by stimulating discussion during the symposium and the lab tour of ICCAS held beforehand. Chemistry fusion among researches came true.

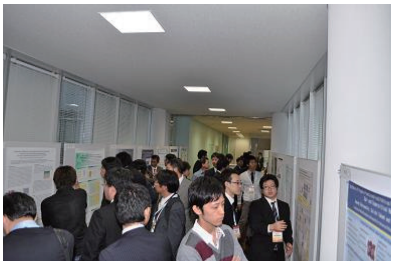


The 1st International Symposium on Super-hybrid Materials (ISSM-1)

Tadafumi Adschiri

WPI-AIMR hosted an international symposium on super-hybrid materials (SHMs) at the Laboratories for Advanced Materials Research (building No.1), Tohoku University in Sendai, Japan from September 30 to October 2, 2010. The symposium, attended by 109 researchers from 11 countries, was a great success thanks to the support of New Energy and Industrial Technology Development Organization (NEDO).

The purpose of this symposium is to provide a forum for exchange cross-fertilization of ideas of a variety of fields, i.e., ‘hybridization of ideas,’ coincident with that of “Fusion Research” of WPI-AIMR, expecting a widespread development of science and technology of SHMs. The topics of the 12 oral presentations and 20 posters varied from basic research to application with a focus on the all aspects of inorganic/organic nano - hybrid materials based on nanoparticle technologies. The topics also include current results of NEDO Project "Super Hybrid Materials". Out of these 12 oral presentations, 6 were presented by WPI-AIMR researchers: Self-assembly in a block terpolymer (Adjunct Prof. H. Jinnai), hydrothermal synthesis and wastewater treatment in SCW (Visiting Prof. Y.-W. Lee), control of nanoparticle and surface structure (Assist. Prof. T. Trevethan), functional nanoparticle structures by solvothermal processing (Assoc. Prof. D. Ehrentraut), nano-tribology and nanorheology (Prof. K. Kurihara), and finally polymer nanotechnology (Prof. T. Nishi). Successful achievement of the incompatible multi-functional properties of SHMs in the NEDO Project was also reported by Prof. T. Adschiri (WPI-AIMR), the organizer of the symposium and a leader of the project. By tuning the affinity of NPs and polymers, the polymer film that has high/low refractive index (1.6/1.4) and high trasparency (90%) could be achieved and heat conductivity as high as 35 W/mk could be achieved, and the samples were demonstrated. Besides oral presentations, 20 posters were presented by young researchers and students.



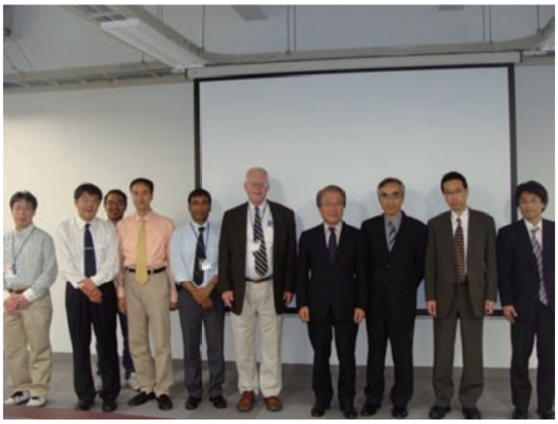
Green materials and green process, key aspects in WPI-AIMR fusion research, were stressed as main topics, leading to trigger of good discussions throughout the symposium. In consistent with the expectations in the opening remarks by Yoshinori Yamamoto, Institute Director of WPI-AIMR, ‘hybridization of ideas’ and fusion of a variety of research fields was successfully achieved in this symposium. It is expected that the outcome of the symposium will help future development of both WPI-AIMR & SHMs for the society in view of environment, energy, and safety.

International Workshop on High Performance Ceramics for Sustainable Life

Takeshi Fujita

On October 5th, 2010, WPI-AIMR hosted an international workshop on High Performance Ceramics and Composites at the WPI Integration Building in Tohoku University, Japan. The workshop, attended by 35 researchers, was a great success.

The topics of the oral presentations varied from basic research to applications of high performance ceramics and composites. A transparent ceramic material, aluminum oxynitride (AlON) was introduced by Dr. McCauley, past chair of American Ceramic Society. The unique optical properties combining with the excellent mechanical properties make this material as a promising candidate for laser appliations. Multifunctional ceramic nanocomposites and their industrial applications were introduced by Prof. Niihara, the President of Japan Ceramic Society and the President of Nagaoka University of Technology. A ceramic nanocomposite developed by his group has been commercialized as pressure sensing in robots, AIBO®. Prof. Goto from Institute for Materials Research, Tohoku University (IMR) presented the recent progress of laser CVD for ceramic film growth. Dr. J. P. Singh from Argonne National Lab highlighted the superior heat resistance of ceramic thermal barrier coatings (TBCs). With thickness less than 0.5 mm, TBCs can be operated in the most demanding high-temperature environments of aircraft and industrial gas-turbine engines. Boron-based icosahedral cluster solids were introduced by Prof. Kimura at The University of Tokyo, showing unexplored solid-state physics. Ceramics are known to be brittle for a long time. For example, Japanese experienced, when a rice bowl is dropped on a floor, the bowl is broken to pieces. But, under extreme loading conditions, such as high pressures and high loading rates, the brittle ceramics can be deformed like ductile metals as introduced by Prof. Mingwei Chen, the organizer of the workshop and the PI of WPI-AIMR. In the workshop, several young scientists from WPI-AIMR and IMR were invited to give short presentations to introduce their recent achievements in ceramic research. The extensive discussion in the workshop leads to the conclusion that ceramics have



been playing the important role as the key materials for our sustainable life.

The 6th Fraunhofer Symposium in SENDAI

Yu-Ching Lin

In the framework of cooperation agreement between the City of Sendai and Fraunhofer-Gesellschaft, European largest organization for applied research, which exists since 2005, "The 6th Fraunhofer Symposium in Sendai" was held in Dec. 7th in Sendai, Japan. The symposium proceeded successfully with good presentations and talks about their research and activities from totally 19 people from 2 countries; Japan and Germany, and with participation of over 120 scientists, engineers and managers from many companies, institutes, universities and Fraunhofer.

The symposium began with opening remarks by Emiko Okuyama, who is Mayor of Sendai, followed by the welcome address by Professor Masayoshi Esashi, Principal Investigator (PI) at the WPI-AIMR. For the introduction of WPI-AIMR, Professor Yoshinori Yamamoto, Director of WPI-AIMR gave the speech to the audience with anticipating a future strong cooperation between two institutes (WPI-AIMR and Fraunhofer-Gesellschaft). Key point of his talk was the strong focus of his institute to develop and apply new materials for a green society and create international visible, outstanding research results. There were also talks from WPI-AIMR side by Professor Thomas Gessner (foreign PI), Assistant Professor Yu-Ching Lin and WPI visiting scientist, Jörg Frömel. Professor Gessner gave talks about business units and core competences of Fraunhofer ENAS. And Assistant Professor Lin gave an introduction about the world class frontier research in the field of innovative material MEMS of Gessner group within WPI-AIMR and also stressed out the remarkable international cooperative research. And Mr. Frömel talked about the latest results of research in the field of semiconductor wafer bonding for wafer level packaging of MEMS. In Assistant Professor Lin’s talk, many outstanding results of research at the WPI-AIMR about AuSi eutectic wafer bonding, metallic glass film fabrication, BMG molding, micro-mirror fabrication using BMG material and nanoporous gold for semiconductor bonding technology have been

described to the audience. That these novel and innovative results could only be reached by the international cooperation and through fusion research across different fields was an important point of her speech. Not only pictures and graphs of research results but also the successfully developed prototypes of MEMS mirror made from metallic glass have been impressively shown to the participants of the symposium by Dr. JaeWung Lee, a member of the Gessner group of WPI-AIMR. This clearly demonstrated that the research is not only aimed at academic results, but also towards a visible impact for society. The demonstration of the micro-mirror devices gave great impression to the mayor of Sendai and all audience about the success of the research at WPI-AIMR. There was no doubt that outstanding research greatly benefited from collaboration between WPI-AIMR and the German Fraunhofer and that the future cooperation between the two institutes will create great synergy for both of them.

Advances in ZnO based heterostructures

Masashi Kawasaki
WPI Advanced Research Institute for Materials, Tohoku University

ZnO is an oxide semiconductor with a band gap of 3.3 eV, enabling ultraviolet light emission upon radiative recombination. Intense research was triggered by our demonstration of highly efficient laser action at room temperature caused by an exciton recombination process [1]. It took us 8 years before we succeeded in making *p*-type ZnO to accomplish light emitting diodes (LED) composed of *pn*-junction [2, 3]. However, the color of the light was not ultraviolet but blue as shown in Fig. 1 (a) due to the recombination taking place in *p*-type ZnO with full of defects. In order to prevent this, one needs to realize *p*-type (MgZn)O that have wider band gap than ZnO. We spent sometime to make (MgZn)O of much better quality and found that the interface can be very sharp. When ZnO/(MgZn)O heterointerface was formed, two-dimensional electron gas (2DEG) is spontaneously generated due to the discontinuity in electric polarization of piezoelectric compounds. Actually, the mobility of 2DEG could be very large, over 5,000 $cm^2V^{-1}s^{-1}$ and exhibited integer quantum Hall effect at low temperatures as shown in Fig. 1 (b) [4]. This breakthrough was highlighted as a milestone in oxide electronics [5-7].

One of the prerequisites for making *p*-type (MgZn)O is to make the host compound as intrinsic as possible before the incorporation of an acceptor (N). In case of ZnO, pulsed laser deposition enabled this because there can be very pure ZnO single crystalline target. However, (MgZn)O target has to be prepared through conventional ceramics processes, yielding in a dirty one with impurities of Si and Al known as donors over 100 ppm. Therefore, we switched to molecular beam epitaxy (MBE) to accomplish this prerequisite. Soon after this, the mobility of 2DEG in MBE-made heterostructurs exceeded 10,000 $cm^2V^{-1}s^{-1}$. Actually, mobility was the only measure that can detect the difference in quality of our films because the quality of the films is so excellent that any other tool cannot distinguish them due to its instrumental limitation. Thus prepared films doped with N turned into *p*-type and *p*-(MgZn)O/*n*-ZnO heterojuntion could be used for ultraviolet LED. Figure 2 (a) shows the appearance of LEDs with *p*-ZnO/*n*-ZnO and *p*-(MgZn)O/*n*-ZnO structures that was coated with a green phosphor to visualize the light. Preventing the electron injection into *p*-type layer by the use of *p*-(MgZn)O, we could tune the emission at the wavelength where it should be [8]. That means, many existing high quantum efficiency prospers will be excited so that cheap true-white LED will become possible.

Our continuing efforts of improving the mobility brought us to an entirely different stage of basic research from the interest in LEDs. When the value exceeds 100,000 $cm^2V^{-1}s^{-1}$, we start to see fractional quantum Hall effect as shown in Fig. 2 (b) that can be seen only in extremely clean semiconductors such as GaAs, SiGe, and graphen [9, 10]. Since the effective mass of electrons in ZnO is rather heavy, the strength of electron-electron interaction (r_S) is more pronounced. Therefore, we will be able to reach a regime that any other material cannot reach, where r_S is very large with keeping reasonably long scattering time (τ_{tr}). Here, new quantum phenomena are expected to exist.

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[10] “News and Views” D. G. Schlom and L. N. Pheiffer, *Nature Mater.* **9**, 881 (2010)

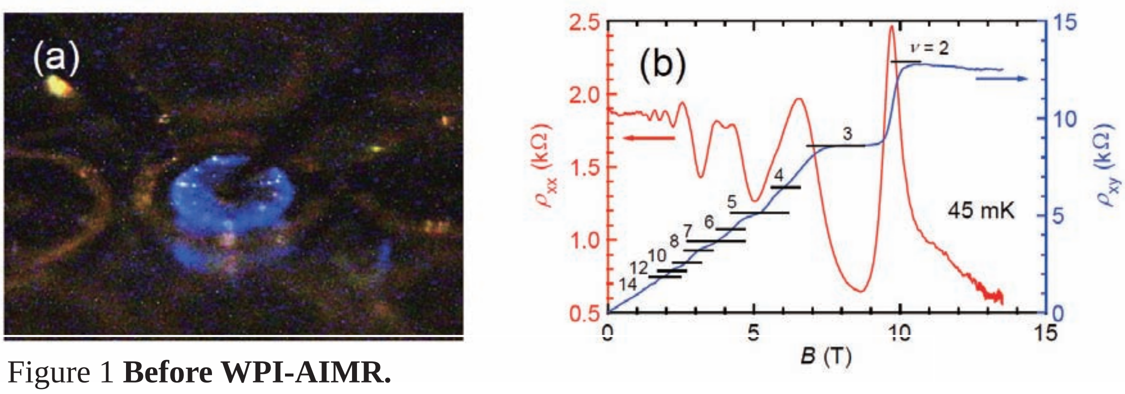

Figure 1 **Before WPI-AIMR.**

Appearance of blue ZnO LED (a) and integer quantum Hall effect (b).

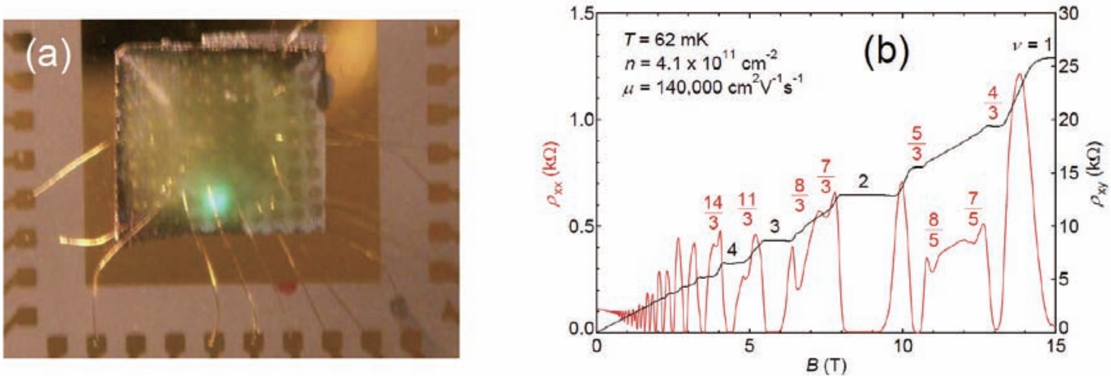

Figure 2 **After WPI-AIMR.**

Ultraviolet LED with a green phosphor (a) and fractional quantum Hall effect.

“Ultrahigh-resolution spin-resolved photoemission spectrometer with a mini Mott detector”

S. Souma[1], A. Takayama[2], K. Sugawara[1], T. Sato[2], and T. Takahashi[1,2]

[1] WPI Advanced Institute for Materials Research, Tohoku University
[2] Department of Physics, Tohoku University

Spin-resolved angle-resolved photoemission spectroscopy (spin-resolved ARPES) is one of most advanced experimental techniques which enables the complete determination of all three quantum parameters of electrons, namely, energy (*E*), momentum (*k*), and spin, and thereby would serve as a powerful method to investigate the exotic quantum properties originating in the spin state of electrons [1]. Many efforts have been made to develop a spin-resolved ARPES spectrometer based on various methods such as the Mott scattering [2], the diffuse scattering [3], and the very-low-energy electron diffraction [4]. However, spin-resolved ARPES involves an inherent difficulty in achieving a high energy resolution because the efficiency of detecting the spin polarization is typically three orders-of-magnitude lower than that of non-spin-

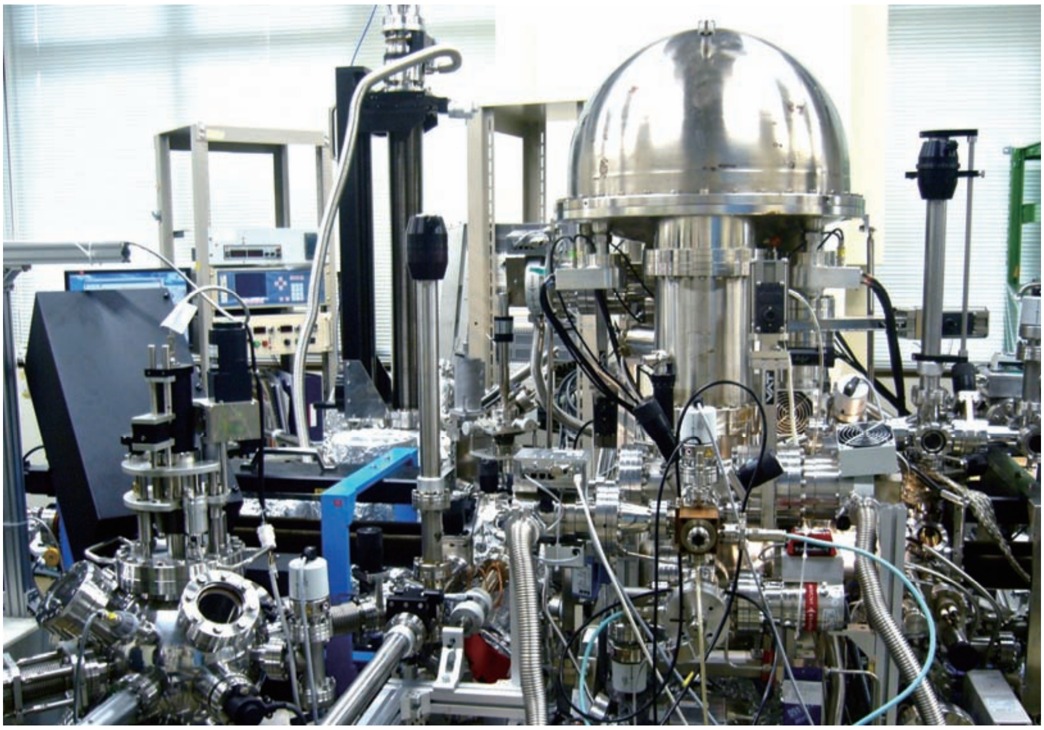

Figure 1 Ultrahigh-resolution spin-resolved photoemission spectrometer constructed at WPI-AIMR, Tohoku University

resolved measurement. Actually, the typical energy resolution of spin-resolved photoemission spectrometers has been about 100 meV, insufficient for investigating various novel materials where the spin of electrons plays an essential role in realizing the exotic physical properties.

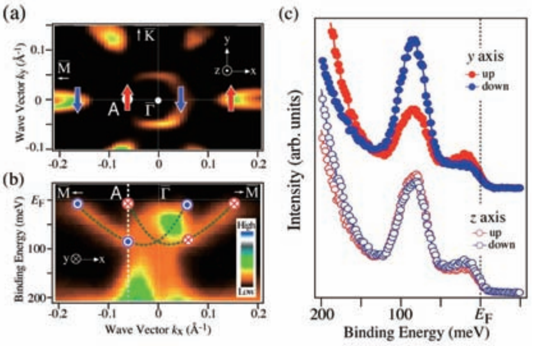

Figure 2 (a) Fermi surface and (b) band dispersion of surface states of Bi(111). Arrows indicate the spin direction at specific *k* points. (c) Spin-resolved ARPES spectra of Bi(111) surface polarized along *y* (top) and *z* (bottom) axes.

We have developed an ultrahigh-resolution spin-resolved photoemission spectrometer (Fig. 1), which enables the direct observation of the spin-resolved electronic states with the world-best energy resolution (8 meV) [5]. To show the high performance of the spectrometer, we show in Fig. 2 the experimental data obtained for Bi(111) surface. Spin-resolved ARPES spectra in Fig. 2(c) show that the energy bands at the Fermi level and 80 meV are spin-polarized (up and down, respectively) along the surface plane (*y*-axis), but unpolarized along the direction normal to the surface (*z*-axis), in good agreement with the theoretical prediction on the surface-Rashba effect.

The newly developed spin-resolved ARPES spectrometer would contribute to our better understanding of various novel phenomena caused by electron spins, such as the giant magnetoresistance and the quantum spin Hall effect, leading to the significant development of spintronics devices that have attracted much attention as next-generation, high-speed and low power-consumption electronic devices.

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“Direct Evidence for the Dirac-Cone Topological Surface States in the Ternary Chalcogenide $TlBiSe_2$”

T. Sato[1], K. Segawa[2], H. Guo[1], K. Sugawara[3], S. Souma[3],
T. Takahashi[1,3] and Y. Ando[2]

[1] Department of Physics, Tohoku University
[2] Institute of Scientific and Industrial Research, Osaka University
[3] WPI Advanced Institute for Materials Research, Tohoku University

Topological insulators are recently attracting significant attentions since they materialize a new state of matter where the bulk excitation gap generated by the spin-orbit coupling (SOC) leads to the appearance of unusual metallic states at the edge or surface due to a topological principle. Such a surface state emerges within the bulk band gap and exhibits a gapless electronic band dispersion protected by the time reversal symmetry [1]. This novel surface state has been an subject of intensive investigations because of not only its fundamental novelty but also its high potential for spintronics devices and fault-tolerant quantum computations. The topological 2D surface state has been observed in group-V alloy $Bi_{1-x}Sb_x$, which becomes a narrow-gap semiconductor for $0.07 < x < 0.22$, [2] as well as in tetradymite semiconductors Bi_2Se_3 and Bi_2Te_3 [3].

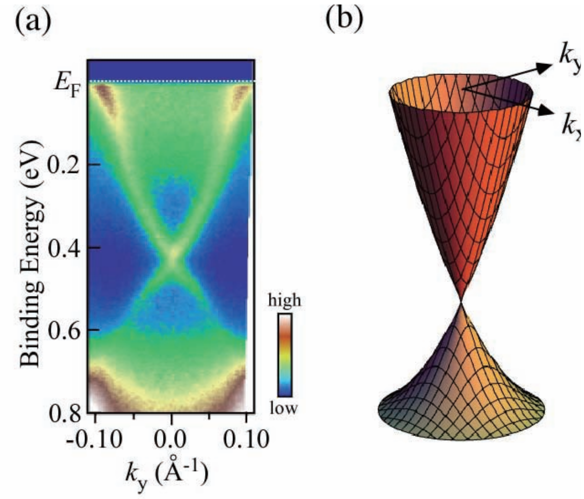

Figure 1 (a) ARPES intensity of $TlBiSe_2$ around the Γ point plotted as a function of k_y and binding energy. (b) 2D band dispersion of the topologically protected ‘Dirac-cone’ determined by ARPES.

We have performed high-resolution angle-resolved photoemission spectroscopy (ARPES) on $TlBiSe_2$, a member of ternary chalcogenides which have been theoretically proposed as a candidate for a new class of three-dimensional topological insulators [4]. By utlizing the unique capability of ARPES to resolve the electron momentum, we have determined the energy band dispersions of bulk and surface electronic states over the entire Brillouin zone. Figure 1 shows a direct evidence for the non-trivial surface metallic state showing a ‘X’-shaped energy dispersion within the bulk band gap. The present result unambiguously establishes that $TlBiSe_2$ is a strong topological insulator with a single Dirac cone at the Brillouin-zone center. The observed bulk band gap of 0.35 eV is the largest among known topological insulators, showing $TlBiSe_2$ being the most promising material for studying room-temperature topological phenomena.

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Dimensionality-Driven Insulator-Metal Transition in A-Site Excess Non-stoichiometric Perovskites

Z. Wang[1], M. Okude[2], M. Saito[1], S. Tsukimoto[1], A. Ohtomo[2], M. Tsukada[1],
M. Kawasaki[1,2], and Y. Ikuhara[1,3,4]

[1] WPI Advanced Institute for Materials Research, Tohoku University
[2]Institute for Materials Research, Tohoku University
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This paper was published in the “Nature Communications 1, 106 (2010)”.

For decades, how an insulator is transformed into a metal by manipulating either the Fermi level or the electronic states has been one of the central themes in condensed matter physics, whatever it is a band or Mott insulator [1]. In general, this tuning is achieved via either chemical doping to introduce charge carriers, or external stimuli to lower the ratio of Coulomb repulsion to bandwidth. Definitely, none have supported a seemly counter-intuitive strategy: the application of an insulating layer to induce an insulator-metal transition because neither the well pinned Fermi level in the insulator is shifted nor the gaps are eliminated.

In a recent paper [2], we combines experimental studies of atomic structure characterization and quantum Hall measurement with the high-precision density functional theory calculations to demonstrate an unexpected and unprecedented transition from electrically insulating states to metallic states in an A-site excess nonstoichiometric perovskite oxide, $La_{0.5}Sr_{n+1-0.5}Ti_nO_{3n+1}$ [3], which is triggered by an intrinsically insulating $SrTiO_3$ layer at an atomic scale. The transition is accompanied by electron localization due to a complex interplay of electrons and phonons, and is unusual as the majority of electrons in the conducting phase are confined within an atomic layer forming a two dimensional electron gas (2DEG) as shown in Fig. 1. This observation is a significant step toward the revolution of our view on the role played by insulating layers on inducing insulator-to-metal transition, and this finding presents an important stage in the development of next-generation transparent and environment friendly superconductor and thermoelectric devices.

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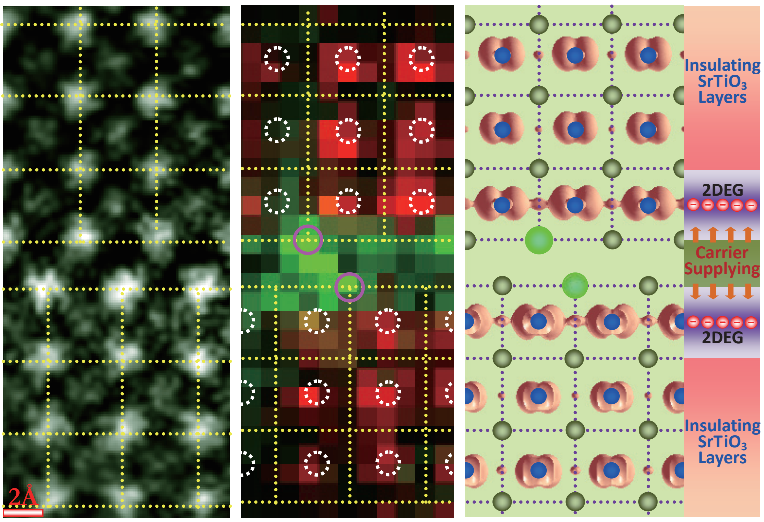


Fig. 1 Left: Scanning transmission electron microscopy (STEM) image of the oxide with electrically metallic state. Brightest spots represent Sr and darker ones Ti. Middle: Element mapping showing the substitution of Sr by La (red). The carriers in the insulator are supplied on Ti (white) by La. Right: Distribution of carriers indicating formation of 2DEG.

FY2010 List of Major Governmental Research Funds
(As of November 1, 2010)

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

(Unit: thousand yen)

Categories	Representative's Name		Budget Distribution
Specially Promoted Research	OHMI, Tadahiro (PI)		194,090
	Subtotal	1	48,100
Scientific Research on Priority Areas	TANIGAKI, Katsumi (PI)		25,900
	TANIGAKI, Katsumi (PI)		9,200
	LOUZGUINE, Dmitri Valentinovich (PI)		9,300
	ASAO, Naoki		2,100
	HITOSUGI, Taro		1,600
	Subtotal	5	48,100
Scientific Research on Innovative Areas	KURIHARA, Kazue (PI)		12,350
	ASAO, Naoki		3,510
	MAKINO, Takayuki		3,900
	Subtotal	3	19,760
Scientific Research (S)	ESASHI, Masayoshi (PI)		13,390
	ADSCHIRI, Tadafumi (PI)		41,340
	YAMAGUCHI, Masahiko (PI)		36,400
	Subtotal	3	91,130
Scientific Research (A)	KURIHARA, Kazue (PI)		9,230
	ITAYA, Kingo (PI)		3,770
	TSUKADA, Masaru (PI)		9,750
	MIYAZAKI, Terunobu (PI)		6,760
	YAMADA, Kazuyoshi (PI)		18,720
	IKUHARA, Yuichi (PI)		24,440
	MATSUE, Tomokazu (PI)		20,800
	Subtotal	7	93,470
Scientific Research (B)	YAMAMOTO, Yoshinori (PI)		5,590
	NISHI, Toshio (PI)		780
	Subtotal	2	6,370
Scientific Research (C)	SHIMOMURA, Masatsugu (PI)		1,820
	ASAO, Naoki		1,820
	TAKEUCHI, Akira		1,690
	NAKAJIMA, Ken		1,950
	Subtotal	4	7,280
Challenging Exploratory Research	YAMADA, Kazuyoshi (PI)		900
	ADSCHIRI, Tadafumi (PI)		1,500
	Subtotal	2	2,400
Young Scientists (A)	SHIRAKI, Susumu		7,020
	SOUMA, Seigo		4,160
	UENO, Kazunori		6,110
	ISHII, Daisuke		11,180
	Subtotal	4	28,470
Young Scientists (B)	MUROYAMA, Masanori		1,950
	HAMADA, Ikutaro		1,950
	LIU, Hongwen		1,040
	HOJO, Daisuke		1,690
	YOSHIDA, Shinya		2,600
	MCKENNA, Keith Patrick		1,300
	XU, Limei		1,040
	OHSAWA, Takeo		3,900
	HIRATA, Akihiko		2,860
	FUJINAMI, So		3,250
	WANG, Zhongchang		2,470
	GU, Lin		2,210
	Subtotal	12	26,260
Research Activity Start-up	SUGAWARA, Katsuaki		1,287
	Subtotal	1	1,287
Subtotal		44	518,617

*1 Budget includes indirect expenses.

B. Research funds consigned from government directly

(Unit: thousand yen)

Representative's Name	Distributing Organization	Project Name	Budget Distribution
TSUKADA, Masaru (PI)	Japan Science and Technology Agency (JST)	Core Research for Evolutional Science and Technology (CREST)	10,790
KAWASAKI, Masashi (PI)	Japan Science and Technology Agency (JST)	Core Research for Evolutional Science and Technology (CREST)	51,211
TAKAHASHI, Takashi (PI)	Japan Science and Technology Agency (JST)	Core Research for Evolutional Science and Technology (CREST)	33,800
ADSCHIRI, Tadafumi (PI)	Japan Science and Technology Agency (JST)	Core Research for Evolutional Science and Technology (CREST)	11,700
KURIHARA, Kazue (PI)	Japan Science and Technology Agency (JST)	Core Research for Evolutional Science and Technology (CREST)	80,600
SHIMOMURA, Masatsugu (PI)	Japan Science and Technology Agency (JST)	Core Research for Evolutional Science and Technology (CREST)	24,570
YAMADA, Kazuyoshi (PI)	Ministry of Education, Culture, Sports, Science and Technology (MEXT)	Elementary Strategic Project	9,620
FUKUDA, Tsuguo	New Energy and Undustrial Technology Development Organization (NEDO)	Strategic Development of Energy Conservation Technology	99,999
ESASHI, Masayoshi (PI)	Japan Science and Technology Agency (JST)	Strategic International Cooperative Program	3,960
ADSCHIRI, Tadafumi (PI)	New Energy and Industrial Technology Development Organization (NEDO)	Development of Technology for High-efficiency Convension of Biomass and Other Energy	9,999
MIYAZAKI, Terunobu (PI)	New Energy and Industrial Technology Development Organization (NEDO)	Spintronics Nonvolatile Devices Project	26,998
ITAYA, Kingo (PI)	New Energy and Industrial Technology Development Organization (NEDO)	Research and Development of Nanodevices for Practical Utilization of Nanotechnology	9,998
HITOSUGI, Taro	New Energy and Industrial Technology Development Organization (NEDO)	Grant for Industrial Technology Research (Financial support to young researchers)	8,060
MIZUKAMI, Shigemi	New Energy and Industrial Technology Development Organization (NEDO)	Grant for Industrial Technology Research (Financial support to young researchers)	9,932
Subtotal		14	391,237

C. Research funds reconsigned through the private enterpise

(Unit: thousand yen)

Representative's Name	Distributing Organization	Redistributing Organization	Budget Distribution
NISHI, Toshio (PI)	New Energy and Industrial Technology Development Organization (NEDO)	Bridgestone Corporation	4,900
ITAYA, Kingo (PI)	New Energy and Industrial Technology Development Organization (NEDO)	Research Institute of Biomolecule Metrology Co., Ltd. (RIBM)	7,350
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.	2,808
TANIGAKI, Katsumi (PI)	Ministry of Economy, Trade and Industry (METI)	Kuramoto Co., Ltd.	1,009
Subtotal		5	25,367

Total		63	935,221

*1 Budget includes indirect expenses.

Science Agora 2010

AIMR held a workshop entitled “Discussions on future strategies in science and technology in Japan” in conjunction with other WPI research centers and the Japan Society for the Promotion of Science (JSPS) at “Science Agora” in Tokyo on November 20, 2010.

Science Agora - the Greek word “Agora” means “place of assembly” or “meeting” - is an open assembly organized since 2006, where participants (scientists, researchers, citizens) enjoy, discuss, and share what science brings to us. The purpose of “Science Agora” was to win a better tomorrow. Everyone should take one more step forward, willing to be more informed of, and collectively consider what science brings to us and the relationship between science and ourselves.

As a researcher who moved from industry back to academia, Dr. T. Hitosugi, Associate Professor at AIMR, explained the attractiveness of research at the university to the audience at the workshop. Three other speakers including a researcher at IFReC of Osaka University stressed the importance of the innovation that WPI has been working towards, and gave them an idea of what is needed and how it should be carried out.

All the participants who filled the conference room listened attentively to the lectures, and also asked several questions concerning the role of science in society, innovation, research, and so on.

The participation of WPI-AIMR strongly reflects its efforts for the promotion of the public’s understanding of science through various events.

Award Information

Name	Position	Thrust	Name of Award	Awarding Organization	Date of Award
Zhongchang Wang*	Assistant Prof.	Materials Physics	The Young Scientist Award, XIII International Conference on Intergranular and Interphase Bounderies in Materials (iib 2010)	iib 2010	June 28
Tadafumi Adschiri	PI	Soft Materials	National Commendation for Invention (the 21st century Invention Incentive Award)	Japan Institute of Invention and Innovation	July 30
Ryo Nouchi*	Assistant Prof.	Materials Physics	The 28th JSAP Incentive Award for Excellent Presentation	The Japan Society of Applied Physics	Sep 14
Abhishek Lahiri	Research Associate	Soft Materials	Best Poster Prize	The Tohoku Branch, The Chemical Society of Japan	Sep 26
Takanari Togashi	Researcher	Soft Materials	Best Poster Prize	The Tohoku Branch, The Chemical Society of Japan	Sep 26
Ali Khademhosseini	Junior PI	Device/System	the 2011 Young Investigator Award	Society For Biomaterials (SFB).	Nov 1

＊ Assistant Prof. Wang and Assistant Prof. Nouchi also received “The 2nd WPI-AIMR Award” on November 8.

WPI-AIMR Award is given to the researchers working in WPI-AIMR at Sendai excluding PIs immediately when they won the prize from foreign and domestic research organizations, academic societies, academic journals, or administrative organizations, and Institute Director evaluates their work is worth awarding.

Dr. Wang

Dr. Nouchi

The Third Series of WPI-AIMR Joint Seminars FY2010

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

Lineup of the third series of WPI-AIMR Joint Seminars (8th to 12th)

8th Seminar, Aug. 20, 2010

Itaya Group Organizer: R. Wen, A. Lahiri, Moderator: N. Asao

S. Kobayashi "Introduction/Overview"

R. Wen "In situ Electrochemical Scanning Tunneling Microscopy"

A. Teramoto "Atomically Flat Silicon Surface and Silicon/Insulator Interface Formation Technologies for (100) Surface Orientation Introducing High Performance MOSFETs"

T. Matsukawa "Single Crystal Growth of Organic Semiconductors for FET"

T. Ikeshoji "Angstrom and Pico Second Electrochemistry-first Principles sSimulations"

9th Seminar, Sep. 3, 2010

Kawasaki Group Organizer: T. Makino, Moderator: R. Nouchi

T. Makino "Overview and “Optical Properties of Low-dimensional Oxide Structure"

H. Hiraga "Growth and Optical Properties of CuMO2 (M = Sc, Cr, Mn, Fe, Co) Delafossite Thin Films"

K. Ueno "Electric Field Induced Superconductivity in Oxides"

10th Seminar, Oct. 1, 2010

Yamamoto Group Organizer: N. Asao, Moderator: Q. Zhang

N. Asao "Nanoporous Metals as New Nanostructured Materials Catalysts for Molecular Transformations"

T. Jin "Copper Nanoporous Catalysis in Organic Transformations: Heterogeneous Catalytic [3+2]Cycloaddition of Terminal Alkynes and Azides"

T. Minato "Mechanism Elucidation of Chemical Reaction on Nanoporous Gold Catalysts by Fusion of Organic Synthetic Chemistry & Surface Science"

M. Uzzaman "Molecular Design of Novel π-Electronic Systems for Organic Electronics"

S. Ikeda "Light-emitting Organic Transistors Using Newly Synthesized Compounds: Toward Electrically-driven Organic Lasers"

11th Seminar, Oct. 15, 2010

Nishi-Nakajima Group   Organizer: K. Nakajima, Moderator: Z. An

K. Nakajima "Overview of “AFM for Soft Materials” "

D. Wang "Compositional and Structural Mapping of Polymer Surfaces by AFM Force Measurement"

H. Liu "Study on the Polymer/BMG Composites as Biomaterials"

S. Fujinami "Expansion of Force Measurement to Viscoelasticity Analysis"

12th Seminar, Dec. 3, 2010

Takahashi Group   Organizer: S. Souma, Moderator: D. Hojo

S. Souma "Overview of “High-resolution Angle-resolved Photoemission Spectroscopy”"

K. Nakayama (in place of Pierre Richard) "Novel High-Tempereture Superconductors: Fe-pnictide"

K. Sugawara "Single-layer and Double-layer Graphite"

S. Souma "Spin-resolved Photoemission: Surface Rashba Systems"

The 8th Seminar (Itaya Group)
Solid/Liquid Interfaces with Atomic Scale

Organizer: R. Wen and A. Lahiri (Interface PhysChem Lab., Soft Materials)

All the electrochemical phenomena take place at the electrode/electrolyte interface and therefore it becomes important to evaluate the interfacial reaction both at atomic as well as in macro scale. Over the last 25 years significant contribution in observing the interfacial phenomena at atomic scale has been achieved using electrochemical scanning tunneling microscope (EC-STM) [1], electrochemical atomic force microscopy (EC-AFM) and UHV-STM techniques which has led to significant technological breakthroughs in electronics and semiconductor industries. To observe the interfacial phenomena at macro scale, an optical microscopy technique namely, Laser confocal microscopy with differential interference contrast microscopy (LCM-DIM) has been recently developed in our lab. The new technique has already shown results related to gold dissolution in acidic medium over areas of 70 μm^2 with single atomic layer resolution [2].

Electrochemistry on semiconducting materials is not only challenging but also important for all the electronic industries. It has been established that ultraflat silicon improves the mobility of electron within the surface which enhances the CMOS performance. As the dimensions of silicon surface for CMOS application is in micrometer range, LCM-DIM is a perfect tool to characterize the surface quickly. Similarly, organic semiconductor material, 5,6,11,12-Tetraphenyltetracene (rubrene) single crystal was also evaluated using LCM-DIM technique which showed ultraflat surface over large area and the potential device being researched will have better performance. Further exploitation of the new optical microscopy technique in electrochemistry is being researched.

Finally, simulation in electrochemical systems is important to understand the interfacial process in more detail [3]. As most electrochemical phenomena initiates within few nanoseconds, it is essential to model the process at the same magnitude. It was shown that it is possible to observe the electrified interface both by experiments and simulations.

References

[1] K. Itaya, Prog. Surf. Sci. **58**, 121, 1998.

[2] R. Wen, A. Lahiri, M. Azhagurajan, S. Kobayashi, and K. Itaya, J. Am.Chem. Soc. **132**, 13657, 2010.

[3] M. Otani, I. Hamada, O. Sugino, Y. Marikawa, Y. Okamoto, and T. Ikeshoji, Phys. Chem. Chem. Phys. **10**, 3609, 2008.

The 9th Seminar (Kawasaki Group)
Growth and Properties of Low-dimensional Oxide Structures

Organizer: T Makino (Interface PhysChem Lab., Materials Physics)

On September 3 (Fri.), 2010, in WPI Seminar Room, 5th floor, Integration Lab. Bldg., approximately 50 delegates participated in the 9th Seminar. This event, moderated by Ryo Nouchi (Tanigaki Group, Electronic Materials Lab), organized by Takayuki Makino (Kawasaki Group, Interface PhysChem Lab), brought them to examine how fusion research can be performed based on the research activities of Kawasaki Group.

This joint seminar illustrated that many possibilities are available for the future fusion research based on the oxide thin films that have been extensively investigated in this group This joint seminar was composed of the following three talks.

Dr. Takayuki Makino gave a talk about the optical properties of low-dimensional oxide structures the developments in the field of oxide epitaxial growth have been spectacular. He discussed the experimental aspect of the optical properties of ZnO heterostructures and Cu-delafossite thin films the optical nonlinearity of dense excitonic systems was also described to determine the interaction process between excitons by means of the femtosecond pump-probe spectroscopy

Afterwards, Dr. Hiroki Hiraga gave a talk about growth and optical properties of CuMO$_2$ (M = Sc, Cr, Mn, Fe, Co) delafossite thin films The results have been focused by targeting Cu-based delafossite compounds These CuMO$_2$ (M: trivalent metal ion) attracts much attention because of unveiled potentials He reported the epitaxial growth and the optical properties of CuMO$_2$ (M = Sc, Cr, Mn, Fe, Co) thin films and its optical properties of excitons

Finally, Dr. Kazunori Ueno presented electric-field induced superconductivity in oxides He has developed of a completely new method to induce superconducting states in insulators with an electric double layer transistor (EDLT) device He presented results on electric-field induced superconductivity on $SrTiO_3$ and $KTaO_3$ At 0.4 K, channel resistance showed a sharp drop to zero, which is the first observation of field induced superconductivity on $SrTiO_3$ An EDLT device with $KTaO_3$ single crystal was also developed Attainable sheet charge density of $KTaO_3$ turned out to be much higher than the limit by the chemical doping, which led to the successful observation of superconductivity at 45 mK.

The 10th Seminar (Yamamoto-Asao Group)

Molecular Synthesis with Nanostructured Materials Catalysts and Development of New Organo-electronics

Organizer: N. Asao (Organosoft and Hybrid Materials Lab., Soft Materials)

Molecular synthesis is a powerful tool for creating new functionalized materials from simple molecules. The research activities in our lab are based on the following two concepts, "Molecular synthesis with materials" and "Molecular synthesis for materils".

1. Nanoporous metals have attractive materials properties for a wide range of applications in catalysis, sensing, and bio-detection due to their high specific surface area, and excellent thermal and electrical conductivity. Recently, we have found that a nanoporous gold (Np-Au) with the range of pore sizes between 20-40 nm exhibited a remarkable catalytic activity in the oxidation of organic silanes with water [1]. The reaction proceeded smoothly at room temperature to give a wide variety of organic silanols, which are useful building blocks for silicon-based polymeric materials as well as nucleophilic coupling partners in organic synthesis. It is well known that gold can be activated as a catalyst by depositing small particles on suitable oxide supports. But they have tendency to agglomerate to lose the catalytic activity. In contrast, the nanoporous gold catalyst is robust and it can be reused repeatedly without any significant loss of activity. Further studies to elucidate the reaction mechanism from the surface scientific approaches are in progress.

2. Organic semiconductors have attracted wide interest due to their flexibility, low energy consumption, low production costs, as well as large area electronics applications. Particularly, ambipolar characteristic is a unique property generally unavailable in inorganic semiconductors, which enables the simultaneous injection of electrons and holes into an organic crystal and leads to light emission. Based on this background, ambipolar charge injection in light emitting organic field effect transistors (LE-OFETs) has extensively been studied as one of the promising candidates to realize an organic laser. We are working together with Tanigaki group as a fusion research for development of new LE-OFETs by designing and synthesizing new π-conjugated organic semiconductor materials.

References

[1] N. Asao, Y. Ishikawa, N. Hatakeyama, Menggenbateer, Y. Yamamoto, M. Chen, W. Zhang and A. Inoue, Angew. Chem. Int. Ed. in press.

The 11th Seminar (Nishi-Nakajima Group)
Nano-palpation Techniques for Soft and Hard Materials

Organizer: K. Nakajima (Organosoft and Hybrid Materials Lab., Soft Materials)

In this seminar, main focus was placed on the recent activity in Nishi-Nakajima laboratory. In their laboratory, one of the most well-known nanotechnology tools, atomic force microscope (AFM), is not merely a tool to observe the surface topography of the sample, but a method to measure mechanical properties on nanometer scale. By this unique feature, they have a lot of collaboration projects with companies, which include very important issues like CO_2 reduction by fuel-efficient tire and the contribution to oil mining technology by Carbon nanotube-reinforced elastomers. Prof. Nakajima mentioned that oil crash would be delayed quite a lot with this technique.

Dr. Wang reported the way to reconstruct “true” surface topography and to develop a universal and quantitative mechanical characterization method for polymeric materials at nanoscale, by AFM nanomechanical mapping. The technique has been successfully used for characterizing the structure and mechanical properties of triblock copolymer, poly (styrene-b-ethylene-co-butylene-b-styrene) triblock copolymer (SEBS) and nylon 6/polyolefin elastomer polymer blends. He also showed the possible application of the technique to bio-related and bulk metallic glass (BMG) materials.

Dr. Liu treated biodegradable polymers such as poly (lactic acid) (PLA), poly(ε-caprolactone) (PCL), poly (butylene succinate) (PBS) as biomaterials for the applications in tissue engineering. However, relatively poor mechanical property and difficulty in controlling the degradation speed hinders their application. Here comes the blending such polymers and BMGs. In his talk he discussed the main ideas and difficulties and appeal for possible fusion research.

Dr. Fujinami employed nanomechanical properties mapping method to measure natural rubber (NR)/isoprene-co-isobutene rubber (IIR) blend. The deviation from elastic contact model was also mapped into a two-dimensional image, which clarified differences of viscoelasticity of NR/IIR. Mapping the deviation from elastic contact model can be a convenient technique to visualize the viscoelastic distribution. He also measured relaxed stress using AFM. This technique can also be of great use to evaluate nanoscale viscoelastic properties.

The 12th Seminar (Takahashi Group)
High-reolution ARPES on Novel Functional Materials

Organizer: S. Souma
(Advanced Spectroscopy for Materials Physics Lab., Materials Physics)

We gave a brief introduction of angle-resolved photoemission spectroscopy (ARPES), and presented three major researches of Takahahsi group in advanced spectroscopy for material physics laboratory. Summaries of each topics are follows;

(1) Novel high-tempareture superconductors: Fe-pnictide

Recent discovery of T_c = 26 K superconductivity in an iron-based compound electroshocked the material science community which is now racing once more for the highest possible T_c. We presented recent ARPES results obtained on the so-called 122 class of materials over a wide of doping. We found the evolution of the multi-band Fermi surface and the superconducting gap, and revealed the importance of magnetic interband scattering between hole and electron Femi surfaces for emergence of high-*T*c superconductivity.

(2) Single-layer and double-layer graphite

Single-layer graphite (graphene) have attracted a considerable attention because of the anomalous properties such as the semimetal-insulator transition and the superconductivity induced by intercalation. We introduced the growth of single-layer and double-layer graphene on SiC(0001) substrate and our recent high-resolution ARPES studies on them to elucidate the origin of anomalous physical properties. Upon increasing layer number, the energy gap between π and π^* bands is gradually decreased and at the same time the Dirac point approaches E_F. Substrate effect from the SiC and the buffer layer is suggested for the origin of opening gap in Dirac-cone band.

(3) Spin-resolved photoemission: surface Rashba systems

We have developed an ultrahigh-resolution spin-resolved photoemission spectrometer which enables the direct observation of the spin-resolved electronic states with the world-best energy resolution (8 meV). The performance of the spectrometer has been demonstrated by Rasha effect on Bi(111) and Sb (111) surface electronic state. Spin-resolved ARPES would contribute to our better understanding of various novel phenomena caused by electron spins, such as the giant magnetoresistance and the quantum spin Hall effect, leading to the significant development of spintronics devices that have attracted much attention as next-generation, high-speed and low power-consumption electronic devices.

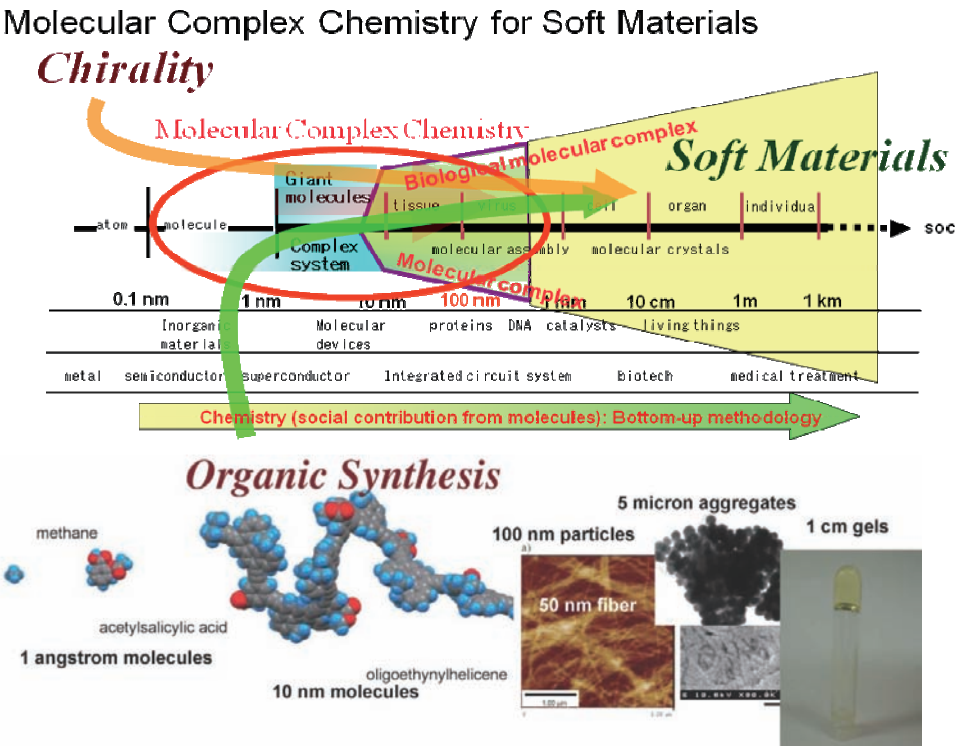
Helicene-containing Built-up Macromolecules for Soft Materials

Masahiko Yamaguchi

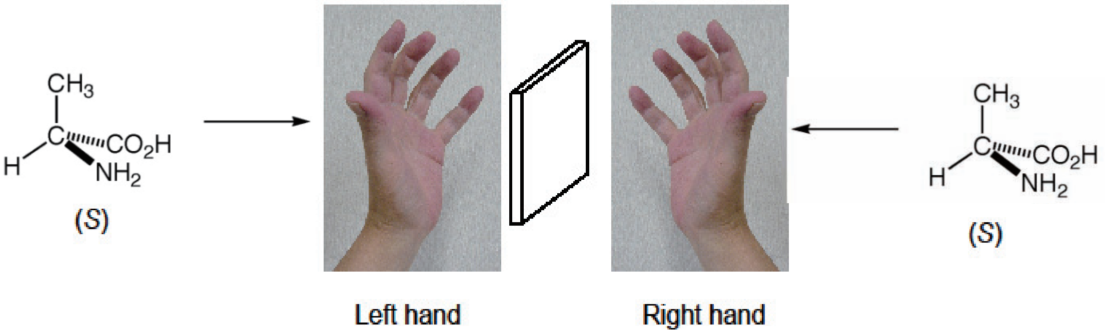
WPI Advanced Institute for Materials Research, Tohoku University
Department of Organic Chemistry, Graduate School of Pharmaceutical Sciences,
Tohoku University

1. Bottom-up Approach towards Soft Materials from Organic Synthesis

Our approach in material sciences is based on organic synthesis. Organic synthesis treats small molecules of angstrom size in a precise manner. We applied this methodology to the development of micro- to centimeter-sized materials. A variety of approaches to constructing ordered and heterogeneous structures with novel functions are conceivable. New science and technology, which we call "Molecular Complex Chemistry," will emerge from the bottom-up study of soft materials.



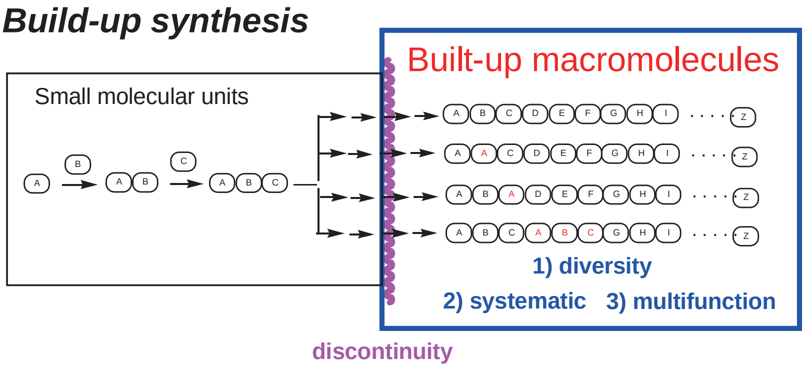
Another characteristic aspect of our study is the consideration of chirality. Chirality is an important molecular phenomenon, and synthetic chemists know how different molecules with mirror-image structures may be: Living things are built from one of the enantiomeric amino acids. Chirality is important also in our life as exemplified by right hands and left hands. However, it is not known how right hands and left hands are formed from single (*S*)-amino acids. This is an interesting subject in “Molecular Complex Chemistry”. Among chiral structures, we are particularly interested in helical structures, which have right-handed helices and left-handed helices.



2. Built-up Macromolecules

Macromolecules have molecular weights ranging from several thousand to several million Daltons; they are constructed by connecting small molecular units with covalent bonds. Such molecules are important in biological systems and materials, and exhibit properties quite different from those of small molecules. Depending on their origin and/or application, they are called biological macromolecules (biopolymers) or synthetic macromolecules (synthetic polymers). Proteins, DNA, and cellulose are typical examples of the former; polyethylene, polyaniline, and polymethacrylates, of the latter. Although these two types of macromolecule possess the common feature of high molecular weight, their structures and functions differ substantially. On one hand, synthetic macromolecules are generally constructed by the repetition of a single small molecular unit and are mixtures of compounds with regard to the number of units in the macromolecule. Their properties therefore emerge as an average of these molecules. On the other hand, biological macromolecules are composed of several types of small molecular unit, and their combination and order are very important for their structure and function as exemplified by DNA. A biological macromolecule is synthesized in a biological system by a programmed build-up method, and functions as a single compound with a definite structure.

Organic synthesis is a chemical method of constructing organic compounds with molecular weights generally below one thousand daltons. It is carried out using consecutive chemical reactions and purification procedures, and treats a pure compound with a definite structure for analysis and use. We considered it interesting to synthesize macromolecules by the build-up method using organic synthesis techniques. This method has some similarity to the preparation of biological macromolecules. However, it was expected that the extension of the methodology using a variety of natural and unnatural small molecular units would result in various properties of macromolecules that would be different from those of conventional biological and synthetic macromolecules. This new type of macromolecule is referred to in this article as a built-up macromolecule.[1,2,3]

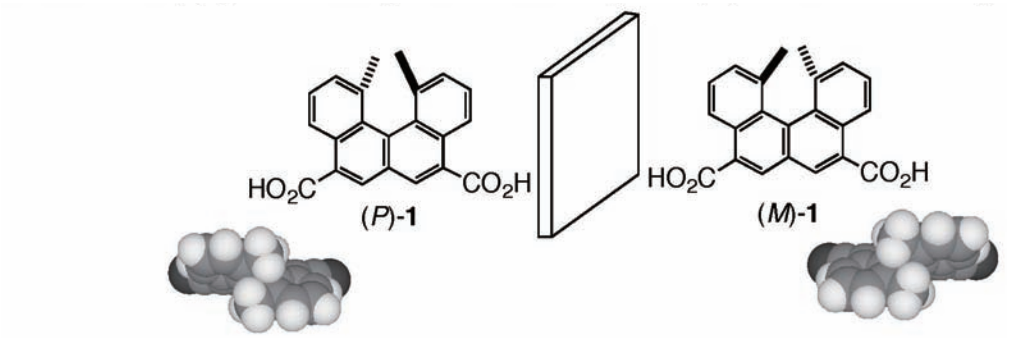


The synthesis of built-up macromolecules by connecting each unit in a stepwise manner has several advantages in terms of understanding and controlling the structures and properties of macromolecules: 1) It provides pure compounds that can be precisely analyzed and used; 2) it provides an opportunity to compare macromolecules of various sizes; 3) it provides an opportunity to compare a series of closely related derivatives in a systematic manner by changing the structure of small molecular units; 4) in some cases, the structure and properties exhibit discontinuities at a specific molecular weight, which is noted during the stepwise synthesis. The principle that governs the discontinuity is not yet well understand. It was expected that the study of related discontinuous systems would lead to the understanding of built-up macromolecule chemistry and to the development of novel useful substances.

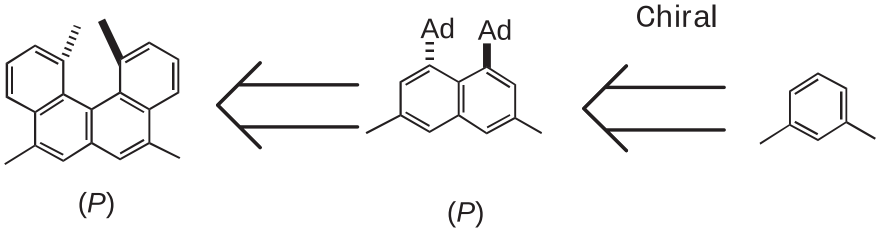
From the synthesis point of view, it is interesting to determine whether the existing synthesis methods used for small molecules could be applied to the synthesis of built-up macromolecules that have a very small reactive site in a large-volume molecule. The built-up macromolecules can assume many complex conformations, which further complicate the reactivity. It was expected that the study of built-up molecules would provide an opportunity to develop highly effective synthetic methods, which could have an impact on conventional organic synthesis of small molecules.

3. Helicenes

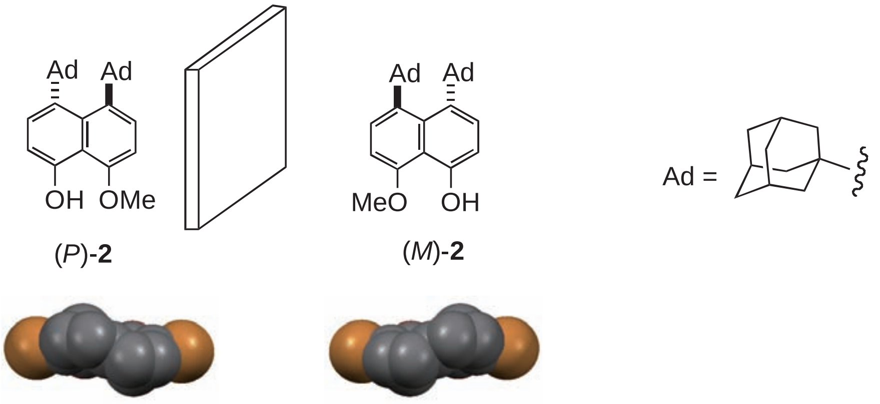
Helicenes are a group of *ortho*-condensed polycyclic aromatic compounds possessing nonplanar helical π-electron systems. Because of the severe steric repulsions between the terminal groups, the aromatic compounds form strained structures and therefore exhibit chirality with either right- or left-handed helicity. Although a variety of derivatives have been prepared since their discovery in the 1950s, their properties have not been well investigated. Ten years ago, we began a project to explore the chemistry of a helicene, 1,12-dimethylbenzo[*c*]phenanthrene, which is one of the configurationally stable helicenes with the fewest benzene rings. We developed a method of preparing optically pure dicarboxylic acid **1** in multigram quantities,[4] synthesized various derivatives containing the helicene, and examined their properties. In terms of nomenclature, (*P*) indicates right-handed helicity and (*M*) left-handed helicity.



During this study, the use of the helicene as the small molecular unit to construct the chiral built-up macromolecules was considered interesting. Our approach is to regard the helicene as a chiral equivalent of *m*-phenylene. Because many organic compounds exhibiting important functions have that partial structure, the substitution of the achiral aromatic moiety with 1,12-dimethylbenzo[*c*]phenanthrene can change the structure of the original achiral compounds to chiral without markedly changing the original structure. In addition, such manipulation provides a diversity of structurally related compounds as derivatives of the original single achiral compounds: two enantiomers, racemic compounds, and partially optically pure compounds. It should also be noted that, if the original compound possesses *n* parts of the *m*-phenylene moieties, this manipulation provides 2^n diastereomers.



Recently, we have added a new helicene, 1,8-di(1-adamantyl)naphthalenes **2**.[5] This bicyclic helicene does not racemize at room temperature.



On the basis of the development of multigram synthesis for optically pure helicenes, studies of chiral aromatic compounds have been conducted. Various helicene derivatives were synthesized, and shown to exhibit interesting chiral properties. Notable concepts established in helical chirality are as follows.

1) Right/right and left/left rule: In the noncovalent bond interactions of helicenes, (*P*)-compounds form a more stable complex with (*P*)-compounds than with (*M*)-isomers.

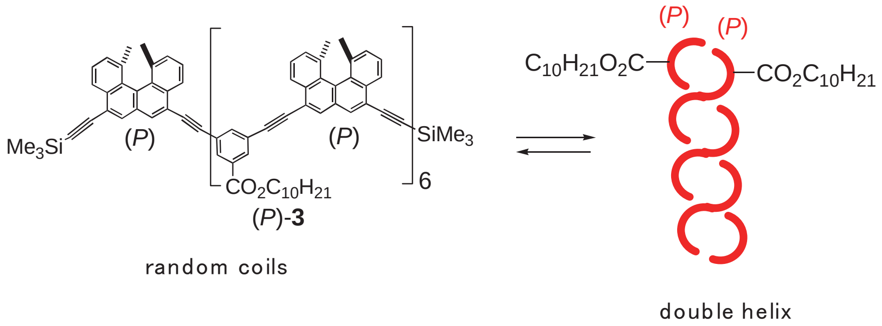
2) Right-handed helical (*P*)-helicenes exhibit higher affinity with natural compounds such as nuclei acids and sugars than (*M*)-helicenes.

3) Helicenes can be used as chiral reagents in molecular recognition, folding/unfolding, catalysis, aggregation/deaggregation, and other processes, exhibiting different properties from central chiral molecules.

The study of small molecular helicenes may be extended to built-up macromolecules. Such macromolecules form layer structures, controlled bimolecular, and higher aggregate structures by the interactions of their helical π-electron systems. For example, various double-helix forming molecules have been obtained. Gel formation and nanoparticle aggregation by the self-assembly of the built-up macromolecules have been examined. This is an example of organic synthesis used to integrate the formation of substances of various sizes from small molecules to soft materials.

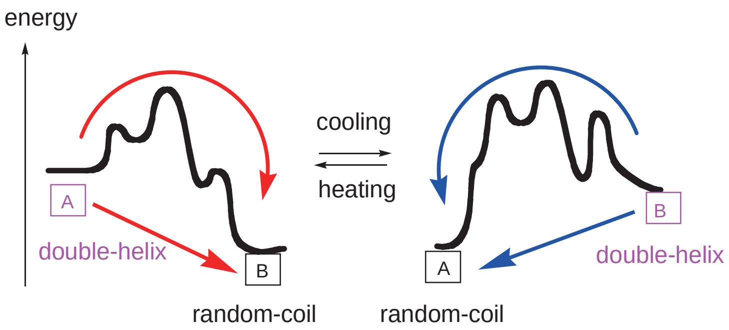
4. Double-helix Forming Ethynylhelicene Oligomers

Examples of built-up macromolecules containing helicene are ethynylhelicene oligomers, which are obtained by connecting the helicene and *m*-phenylene with a carbon-carbon triple bond.[6] The higher ethynylhelicene oligomers formed double-helixes in solution, and reversibly changed structure from a double-helix to a random-coil.[7] The process is affected by their structure as well as by conditions such as temperature, concentration, and solvent.



The structural change is relatively slow, the half-lives being on the order of seconds to days, and kinetic studies as well as equilibrium studies could be conducted in detail. Kinetic studies using CD reveal an extremely large solvent effect in substituted benzenes. The unfolding of (*P*)-**3** in trifluoromethylbenzene (5x10^{-6} M) is extremely slow with a rate constant at 25°C of $k < 10^{-6}$ min^{-1}. In contrast, when the compound is dissolved in iodobenzene, unfolding is complete within 1 min. Varying the benzene substituent of the solvents changes the rate constant *k* over 7 orders of magnitude. The value of log *k* exhibited good correlation with absolute hardness.[6] The rate constant *k* decreases in soft solvents, which suggests the soft nature of the nonplanar π–π interactions of helicenes. The HSAB principle is related to π–π interactions.

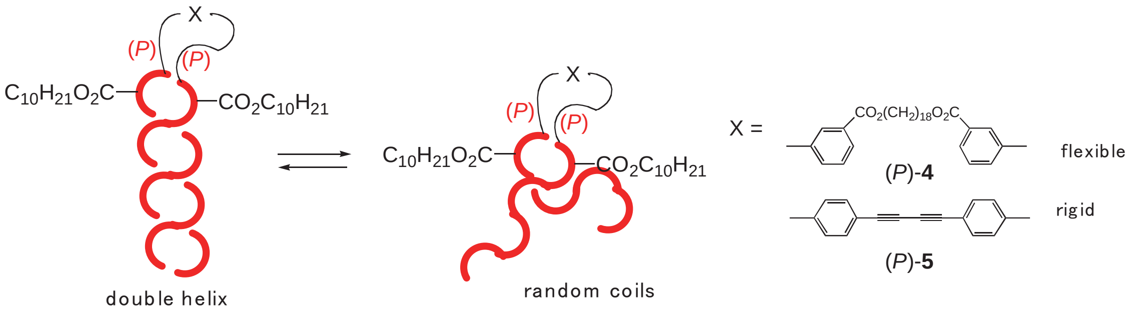
Under appropriate conditions, (*P*)-**3** reversibly changes its structure from double-helix dimer and random-coil monomers and back on heating and cooling. By heating and cooling, the relative thermodynamic stability reverts between double-helix **A** and random-coil **B**, which indicates large entropy changes ΔS characterizing the equilibrium. In addition, the kinetic aspects of this process are substantial, as noted above. To control the reversible process in a precise manner, both thermodynamic and kinetic properties need to be understood. This synthetic switching system of a built-up macromolecule behaves like DNA.



5. Various Double-helix Forming Derivatives of Ethynylhelicene Oligomers

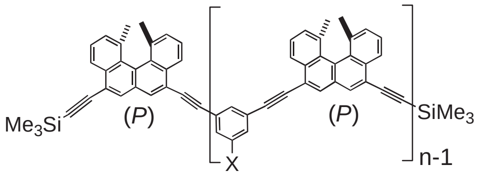
Various double-helix-forming compounds are suggested by the structure-activity relationship analysis of **3**. The derivatives **4** and **5** possessing two oligo(ethynylhelicene) moieties were synthesized,[8] and linked by a flexible hexadecamethylene linker (3.0 nm) and a rigid butadiyne linker (1.2 nm), respectively. Both **4** and **5** form intramolecular double-helices, and undergo thermal and reversible transition between a helix and a random-coil. The folding processes of **4** and **5** to form the double-helix structure are quite different from those of **3**: 1) The folding of **4** and **5** is accelerated at lower temperatures and characterized by an apparent negative activation energy, which can be explained by the presence of an exothermic pre-equilibrium in the rate-determining step; 2) the folding rates of **4** and **5** are concentration-dependent despite the apparent intramolecular reaction, which may be attributed to self-catalysis. The results reveal that, although **4** and **5** form similar intramolecular double-helix structures analogous to that of **3**, the process of the double-helix-to-random-coil transition is quite different.

When **4** and **5** are compared, the unfolding rate of **5** is lower than that of **4**; the reaction of **5** requires a larger activation energy than that of **4**. The transition structure is destabilized by the rigid linker of **5**, and the helix and random-coil states of **5** can be separated by gel permeation chromatography (GPC). The linker structure markedly affects the aggregation of built-up macromolecules.



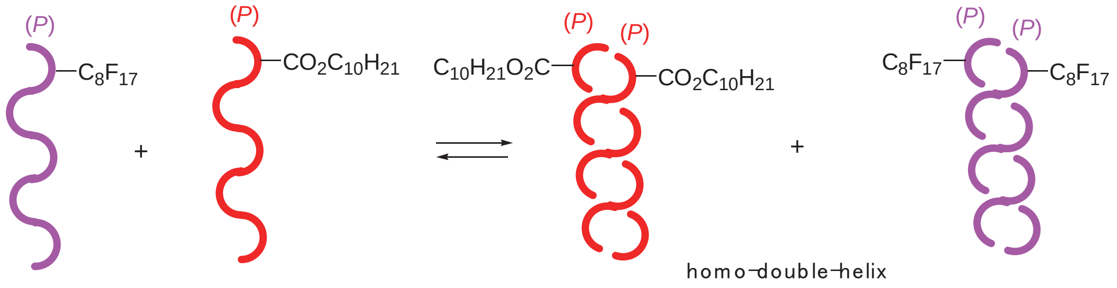
Derivatives of ethynylhelicene oligomers with different side chains were synthesized.[9] They also form double-helices in solution, although their stability differs considerably. The following order is obtained for the stability depending on the side chain structure: C_8F_{17} > $CO_2C_{10}H_{21}$ > alternating $CO_2C_{10}H_{21}/C_8F_{17}$ ~ $SC_{10}H_{21}$. It appears that derivatives with the hard *m*-phenylene moiety form more stable dimeric aggregates than those with soft moieties.

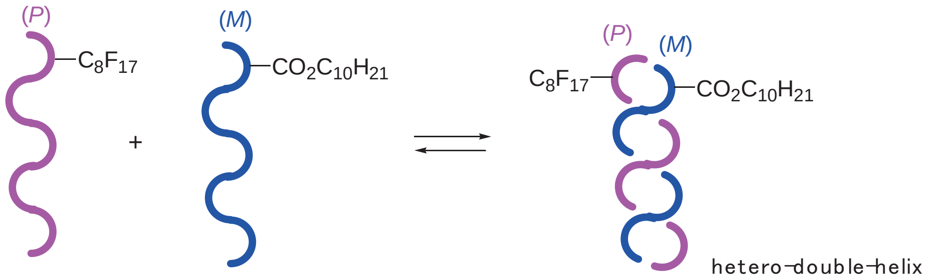
Oligoethynylhelicenes



$X = CO_2C_{10}H_{21}$ n = 1,2,3,4,5,6,7,8,9
$X = CO_2C_{10}H_{21}/C_8F_{17}$ n = 1,2,3,4,5,6,7,8,9
$X = C_8F_{17}$ n = 1,2,3,4,5
$X = SC_{10}H_{21}$ n = 1,2,3,4,5,6,7,8,9,10

Using various enthynylhelicene oligomers with different side chains and stereoisomers, hetero-double-helix formation was examined.[9] When a (*P*)-oligomer with the $CO_2C_{10}H_{21}$ side chain is mixed with a (*P*)-oligomer with the C_8F_{17} side chain, each compound forms a homo-double-helix, which indicates that homoaggregation is much stronger than hetero-aggregation. In contrast, a mixture of a (*P*)-oligomer with the $CO_2C_{10}H_{21}$ side chain and a (*M*)-oligomer with the C_8F_{17} side chain forms a hetero-double-helix. In this case, the hetero-double-helix is much more stable than the homo-double-helix. That enantiomeric ethynylhelicene oligomers with different side chains forms heteroaggregates stronger than homoaggregates is a general phenomenon.

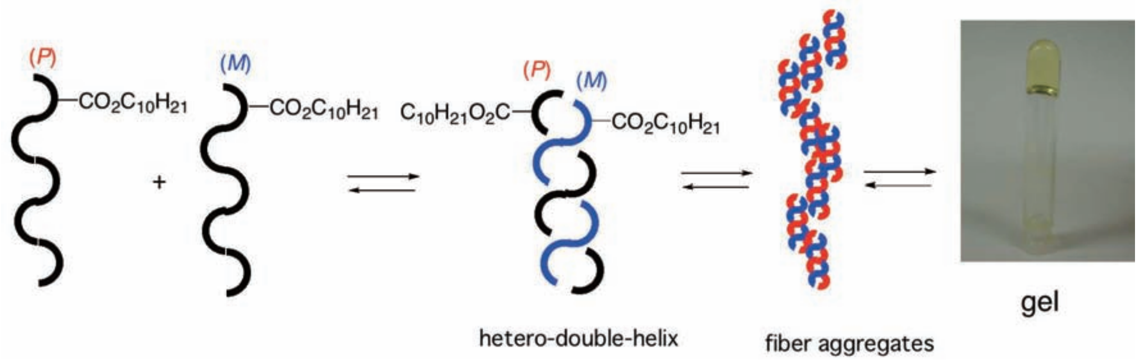




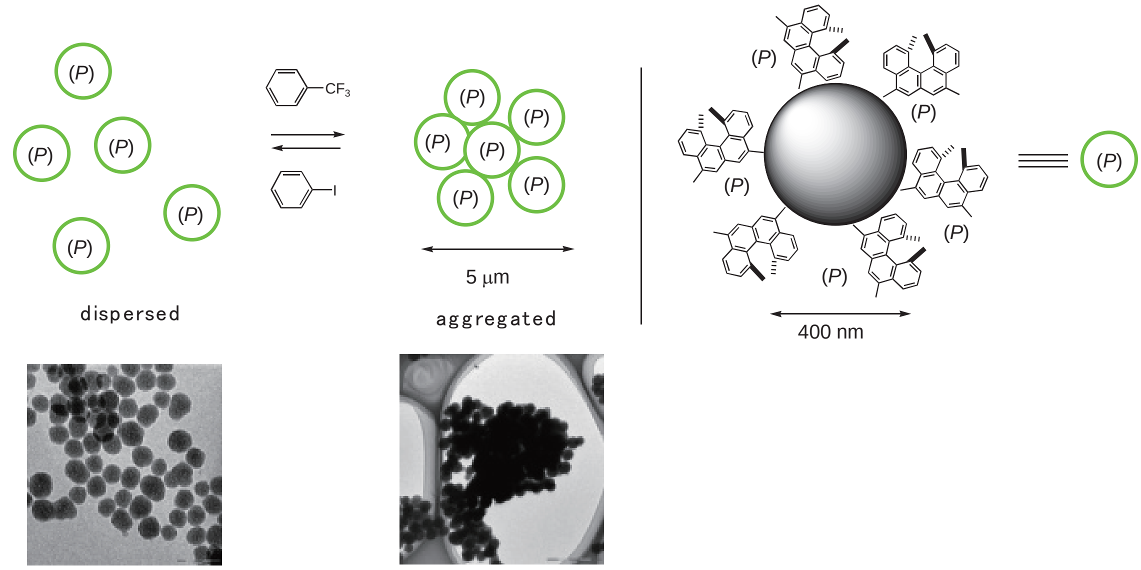
Various double-helix forming compounds with different properties now have become available as a result of the study of ethynylhelicene oligomers.[10]

6. Higher Order Structures Formed by Self-assembly of Built-up Macromolecules

Built-up macromolecules can be used to construct higher-order molecular assemblies from micrometer size to centimeter size. When enantiomeric (*P*)- and (*M*)-oligomers with the $CO_2C_{10}H_{21}$ side chain are mixed in toluene, a gel is formed.[11] Each compound by itself does not form a gel, and this system is a novel two-component-gel. It is thought that the initially formed hetero-double-helix aggregates forming fibrous structures, in which the solvent is incorporated.



We consider nanoparticles of controlled size as macromolecules, which can be manipulated by the methods of organic synthesis. The aggregation and deaggregation of nanoparticles could be controlled by noncovalent bonding interactions of helicene.[12] Silica nanoparticles 200 and 400 nm in sizes were grafted TO the (*P*)-helicene. Such chiral nanoparticles aggregate to a size of 5 μm in hard aromatic solvents and disperse in soft aromatic solvents. The soft/hard phenomenon is related to the previous observations in the unfolding of double-helical ethynylhelicene oligomers, and suggests strong π–π interactions between helicenes.



Several built-up macromolecules containing helicenes have been synthesized by stepwise methods, and they exhibit interesting structures and properties. Starting from the chemical synthesis of small molecular helicenes of angstrom size, the method of built-up macromolecules integrates the substances into nanometer-sized and even larger molecular systems of micro- to milimeter sizes. It is expected that the methodology of “Molecular Complex Chemistry” can be used to explore new scientific fields for application to soft materials.

Acknowledgements

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Microfabrication Technology for Cell and Tissue Engineering

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1. Introduction

The development of new cell culture techniques and materials remains of great importance in biomedical applications, notably for tissue engineering. Since in the body cells are exposed to a controlled microenvironment that is regulated by micron scale architectural features and signaling cues, the ability to recreate such features by using microfabrication techniques is of benefit for generating tissues for transplantation [1]. One approach to do this is by using microfluidic technologies. Microfluidics techniques can be used to control the flow of liquids or gases in small volumes (microliter to nanoliter). Microfluidic devices were initially fabricated in silicon and glass materials by using photolithography and etching techniques adapted from microelectronics industry in the 1970s [2,3]. In the 1990s, soft lithography was introduced by Whitesides and colleagues to build microfabricated systems, including microfluidic channels, in a more simplified manner. Soft lithography is a set of techniques which uses elastomeric materials to generate microscale patterns by using approaches such as replica molding, microcontact printing, micromolding in capillaries, and microtransfer molding, to replicate 2D or 3D patterns [4]. A central component of these techniques is the use of polydimethyl siloxane (PDMS) or other elastomeric polymers. PDMS is an elastomer with interesting properties for biological applications because it is biocompatible, transparent and permeable to gases such as oxygen. PDMS has been widely used to fabricate microfluidic channels and networks[5]. A key feature of PDMS is that it can be bonded to other PDMS and glass surfaces to build sealed microfluidic channels. Given their ability to control fluid flow profiles, microfluidic devices have become of interest in various biological applications. For example, microfluidic based chips, also known as biochips, have emerged in the marketplace in various formats with applications in biological assays such as DNA sequencing [6], polymerase chain reaction (PCR) [7,8], electrophoresis [9], DNA separation [10], protein analysis [11], immunoassay [12], cell counting [13,14], and cell culture [15].

An interesting property of fluid flow in microscale channels is that they can flow laminarly [16]. This behavior can be quantified by the ratio between the inertial and viscous forces, which is known by the dimensionless Reynolds number (Re). Reynolds number is defined by the equation: $Re = \rho VD/\mu$ in which ρ is the fluid density, V the fluid velocity, D the hydraulic diameter of the channel and μ the fluid viscosity. At low Reynolds numbers (below 2000), viscous forces are dominant resulting in a laminar flow that is characterized by a smooth flow and a low level of mixing in the fluid. At high Reynolds numbers, inertial forces are dominant and the flow is turbulent with vortices and eddies.

The ability of microfluidic channels to control the level of mixing in fluids can be used to generate stable concentration gradients. Such gradients can be used to recreate concentration gradients of chemical cues or material properties properties that are found during tissue formation for cellular and tissue engineering. In our laboratory, we are using microfluidic systems to generate gradients for use in various biological applications using two distinct approaches. In one strategy, gradients are generated perpendicularly to the flow direction while in the other approach gradient are generated parallel to the flow direction. The first system allows for precise spatial control of a dynamic gradient, while the second system allows the formation of long-range gradients.

2. Experimental details

The master mold for fabricating the microfluidic channels is generated by patterning a photoresist (SU-8) under UV irradiation on a Silicon wafer. To build PDMS microstructures, the PDMS prepolymers (Dow Corning Corporation, USA) was mixed with curing reagent at a 10:1 mass ratio and poured on the master mold. After degassing, the PDMS was cured in an oven at 70ºC. The microstructured PDMS layer was then peeled off from the master and holes were drilled at the outlet and the inlet of the channel. After oxygen plasma treatment the PDMS layer was bonded permanently on a glass slide and tubes were fixed at the inlet and outlet. This replica molding technique was used for the fabrication of both gradient generator systems.

3. Results and discussion

3.1 Generating gradients perpendicular to flow direction

By building microchannel network of branching and recombining channels, it is possible to generate spatial and temporal concentration gradients perpendicularly to the direction of flow [17]. These microfluidic systems use the laminar property of the flow, for which there is only lateral mixing by diffusion. To investigate the effects of biological gradients on cell and tissue cultures, we fabricate such microfluidic systems to generate concentration gradients of various growth factors and chemokines that influence cell behavior. The microfluidic gradient generator that we fabricate for these experiments is comprised of two portions. The first part of the gradient generator contains a tree shape serpentine microchannel, whereas the other part is a chamber for cell cultures. The schematic of the microfluidic device pattern is shown in Figure 1A. The microfluidic device is 4 cm in length, 1 cm in width and 180 µm in height. The tree shaped serpentine channels repeatedly mix and separate different streams allowing them to mix by diffusion. At the end of the network, all streams combine in a broad channel linked to the cell culture chamber and the gradient is generated perpendicularly to the flow. By using this design, we and others have generated stable concentration gradients under flowing conditions (see Figure 1B). We are currently using this device to generate poly(ethylene glycol) (PEG)-based hydrogels with embedded gradients of adhesive peptides (e.g. RGDS) and signaling molecules (e.g. BMP2) for bone tissue engineering applications. The efficiency of the device will be evaluated for the cellular response of bone progenitor cells to this concentration gradient through cell attachment, cell density, cell morphology and proliferation. This study would pave the way to understand how bone cells respond to the molecular gradients during their development and at bone-cartilage interfaces. It is expected that the outcome of this research help bypass the problems of soft to hard tissue interfaces, for which cellular complexity and organization of interface tissues remain a challenge during the tissue regeneration.

3.2 System generating gradient parallel to flow direction

Another method being used in our lab to generate a gradient in a microfluidic channel involves introducing two different fluid components to the inlet and outlet of a straight channel, respectively [18,19]. This approach can be used to generate gradients along the channel and parallel to the flow direction. In this system, the concentration gradient of the target molecule is created through pumping the solutions in forward and backward directions in the channel. This method has proven to be suitable for generating centimeter-long gradients of biomolecules and cells, and to be useful in maintaining a wide concentration range of those molecules in the channel. We used this method to develop a high-throughput screening system for rapid and accurate drug screening. The microfluidic channel (Figures 2 and 3 A) used to generate a gradient parallel to the flow direction is 50 mm in length, 2 mm in width, 100 μm in height size. The method to generate this concentration gradient is illustrated in Figure 2. Initially, the channel was filled with deionized water and a 2 μL drop of a solution containing the molecule of interest (in this case dyes such as trypan blue or rhodamine) was dropped onto the inlet and entered the channel automatically due to the passive pump flow. Forward flow was further continued by addition of drops until the dyes approached the outlet. A backward flow from the outlet side to the inlet side of the channel was then induced due to evaporation resulting in the formation of a dynamic concentration gradient along the channel. The gradient was immobilized by closing the inlet and outlet apertures with two pieces of flat PDMS pieces. A centimeter-long gradient of trypan blue dye was formed along the channel (see Figure 3B). Using the same method, a gradient of rhodamine solution was generated in the channel. Further quantification of the fluorescence intensity profile of rhodamine indicates the formation of an exponentially decreasing concentration profile along the gradient (Figure 3C-D).

An aim of this research project is to establish a fast, inexpensive, and efficient platform, as an alternative to animal models, for drug discovery and drug screening for the treatment of Parkinson”s disease (PD). PD is a degenerative disorder of the central nervous system that impairs patient’s motor skills, speech and other functions. Although causes for PD are not known, genetic disorders and neurotoxins have been involved in the risk of this disease. Oxidopamine, also known as 6-hydroxydopamine, is a neurotoxin that enters the dopaminergic and noradrenergic neurons via the dopamine and noradrenaline transporters and causes an active process of neural apoptosis. This neurotoxin is used to generate animal models of PD to develop and test new drugs for the treatment of PD in humans. In our research project, we aim to build a neural microenvironment to detect and quantify the apoptosis of pheochromocytoma neural cell line PC12 by using an oxidopamine gradient system in a microfluidic channel. We anticipate that neurons will respond to the oxidopamine concentration gradient and that we could determine the effective concentration required to trigger neural apoptosis. In a next step, PEG-based hydrogels loaded with this effective oxidopamine concentration and with a growth factor neurotrophin-3 (a known counter-actor of oxidopamine) concentration gradient will be generated and used for PC12 culture under the same conditions. This study may reveal the optimal concentration of neurotoxin and anti-toxin required for neural apoptosis and neural viability respectively, along a graded hydrogel, in a single experiment. It is expected that the outcome of this research will aid in bypassing the problems of using animals to study the effect of drugs and toxins, which will minimize the cost, time, sample size requirements, ethical issues, and legal concerns associated with animal or human use in the process of drug screening.

4. Summary

We demonstrate that the designed microfluidic devices are capable of generating gradients of soluble factors perpendicular and parallel to the flow direction. The functionality of both devices has been checked, and the flows speed parameter to generate concentration gradients with different solutions has been evaluated and optimized. We are currently using these devices in biological applications, in particular to control cell behavior under fluidic environment.

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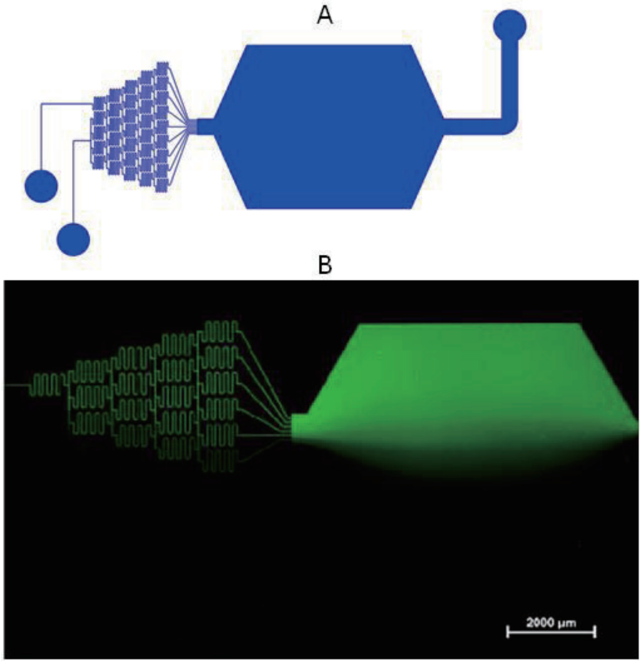

Fig. 1

A) Microfluidic tree-line design for generating concentration gradients. The microdevice is 4 cm long x 1 cm wide x 180 µm high. B) Fluorescence image of gradient generated with the device from Part A.

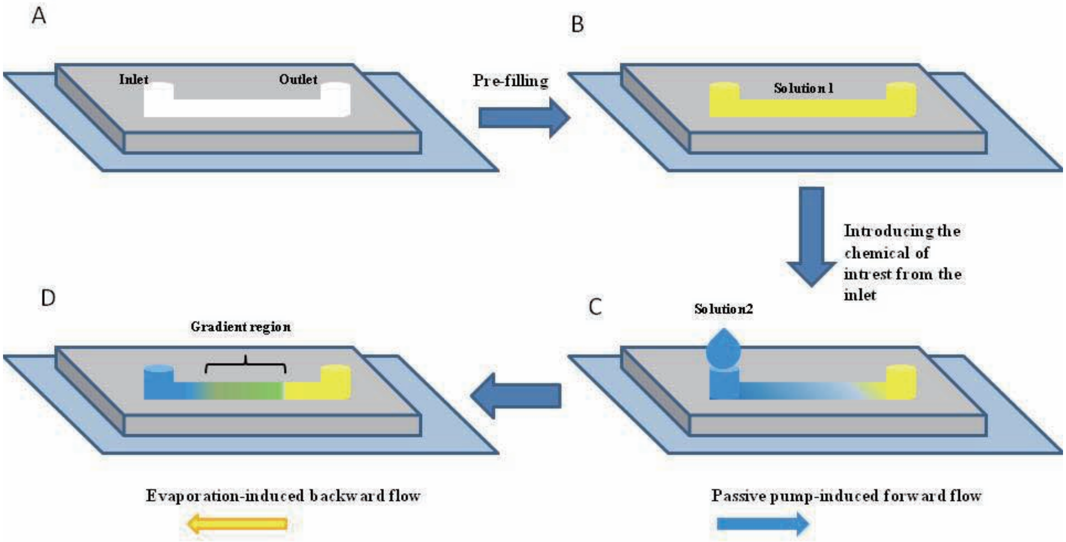

Fig. 2

Schematic of device to create gradients parallel to flow direction: A) Channel filled with water, B) Dye drops added to inlet, C) Diffusion into the channel, and D) Gradient generation during backward flow.

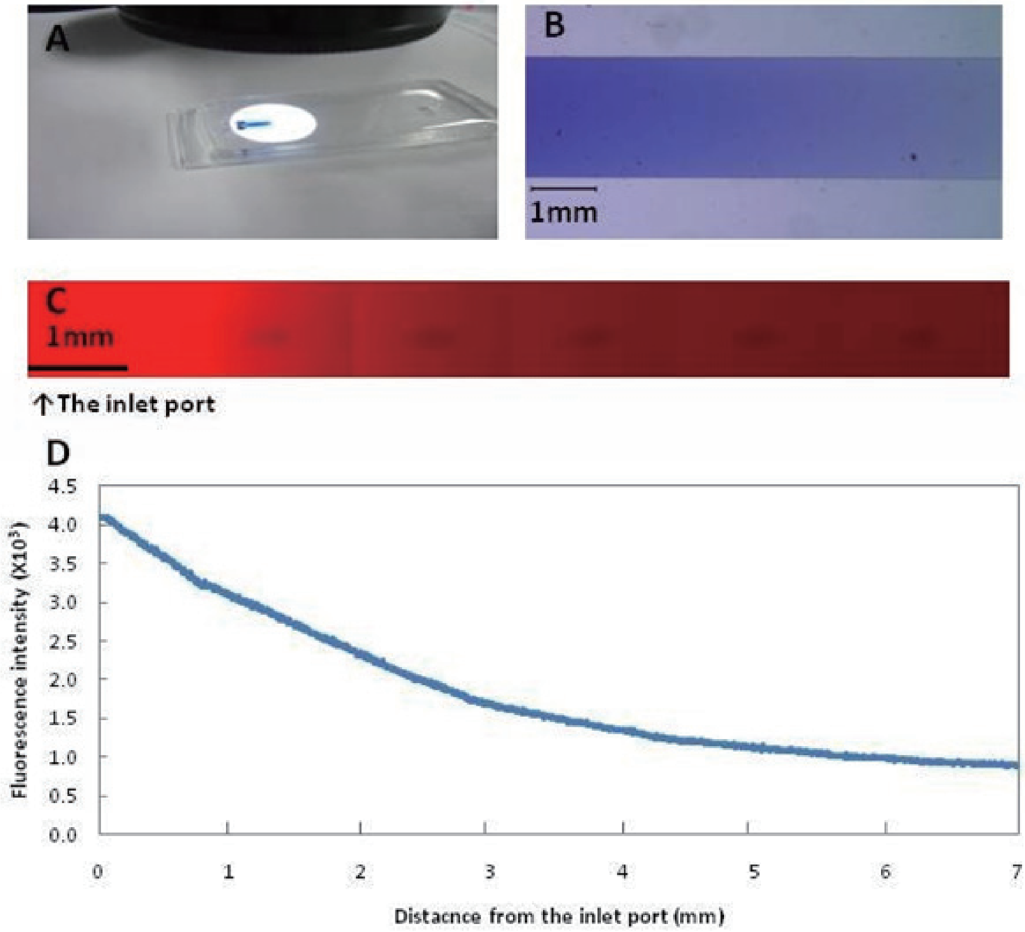

Fig. 3

Concentration gradients of trypan blue (A, B) and rhodamine (C, D) in a microfluidic channel that used a passive pump-induced forward flow and evaporation-induced backward flow to induce gradient formation.

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ACADEMIC:

2005 B.S. in Materials Science and Engineering, Fuzhou University, P. R. China
2010 Ph.D in Engineering, South China University of Technology, P. R. China

PROFESSIONAL EXPERIENCE:

2007-2009	Researcher, Nanyang Technological University, Singapore
2010-2010	Research Assistant, Hong Kong University of Science and Technology, P. R. China
2010-present	Research Associate, WPI Advance Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

Biomaterials for therapeutic cell delivery; drug/protein delivery for therapeutics; adjacent reproducible tissue sourced stem cells for engineered therapeutics; tissue-biomaterials integration

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Aurélien SIKORA

Research Associate
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ACADEMIC:

2003 B. Sc. (Hons) in Materials Science, Université de Pau, France
2005 M. Sc. (Hons) in Materials Science, Université Aix-Marseille II, France
2009 Ph.D in Materials Science, Université Jean Monnet (Saint-Étienne), France

PROFESSIONAL EXPERIENCE:

2009-2010	Post-doc, Institut Néel, Grenoble, France
2010-present	Research Associate, WPI Advance Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

Biomotor studies, thermal properties measurements

Curriculum Vitae

Boon TEO

Research Associate
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ACADEMIC:

2004 B.A.Sc. in Psychology and Chemistry, The University of Melbourne, Australia
2005 B.Sc. (Hons) in Chemistry, The University of Melbourne, Australia
2010 Ph.D in Chemistry, The University of Melbourne, Australia

PROFESSIONAL EXPERIENCE:

2010-2010 Research Assistant, The University of Melbourne, Australia
2010-present Research Associate, WPI Advance Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

Investigation of interaction forces of polymers using surface force apparatus

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Junqiang WANG

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ACADEMIC:

2005 B.S. in Physics, Northeast Normal University, P. R. China
2010 PhD. in Condensed Matter Physics, Institute of Physics, CAS, P. R. China

PROFESSIONAL EXPERIENCE:

2010-present Research Associate, WPI Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

Fabricating new metallic glasses (MGs) with novel properties
Studying the correlations between various properties and their underlying physical mechanisms for MGs

Curriculum Vitae

Vladislav ZADOROZHNYY

Research Associate
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ACADEMIC:

2004	M.S. in Materials Science, Orenburg State University, Russia
2008	Ph.D., National University of Science and Technology "MISIS" (MISIS), Russia

PROFESSIONAL EXPERIENCE:

2008-2009	Engineer, Moscow Institute of Steel and Alloys (Technological University) (MISA), Russia
2009-2010	Researcher, National University of Science and Technology "MISIS" (MISIS), Russia
2010-present	Research Associate, Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

Mechanical alloying process, Investigation of the phases and structural transformation during mechanical alloying process

Investigation of the phases and structural transformation in a Bulk Glassy Alloys, Mechanical behavior of the amorphous alloys

Newly Appointed Adjunct Professors

Kohzo ITO

PRIMARY AFFILIATION:

Professor
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ACADEMIC:

1981	B.E. in Appleid Physics, The University of Tokyo, Japan
1983	M.E. in Appleid Physics, The University of Tokyo, Japan
1986	Ph. D in Engineering, The University of Tokyo, Japan

PROFESSIONAL EXPERIENCE:

1986-1990	Researcher, Research Institute for Polymers and Textiles
1991-1994	Lecturer, The University of Tokyo
1994-2003	Associate Professor, The University of Tokyo
2003-present	Professor, The University of Tokyo

RECOGNITION:

✦The Award of the Society of Polymer Science, Japan (2006)

CURRENT RESEARCH:

Polymer, Supramolecular Science, Materials Science

Hideo OHNO

PRIMARY AFFILIATION:

Director
Center for Spintronics Integrated Systems, Tohoku University
Professor
Research Institute of Electrical Communication, Tohoku University
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ACADEMIC:

1977	B.S. in Electronic Engineering, The University of Tokyo, Japan
1979	M.S. in Electronic Engineering, The University of Tokyo, Japan
1982	Ph. D in Electronic Engineering, The University of Tokyo, Japan

PROFESSIONAL EXPERIENCE:

1982-1983	Lecturer, Department of Electrical Engineering, Hokkaido University
1983-1994	Associate Professor, Department of Electrical Engineering, Hokkaido University
1988-1990	Visiting Scientist, IBM T. J. Watson Research Center, New York, USA
1994-1995	Professor, Department of Electronic Engineering, Tohoku University
1995-present	Professor, Research Institute of Electrical Communication, Tohoku University
2002-2007	Project Leader, IT Program of Research Revolution 2002 (RR2002), Ministry of Education, Culture, Sports, Science and Technology (MEXT)
2002-2008	Research Director, Exploratory Research for Advanced Technology (ERATO), Japan Science and Technology Agency (JST)
2004-2010	Director, Laboratory for Nanoelectronics and Spintronics, Research Institute of Electrical Communication, Tohoku University
2007-2010	Project Leader, Research and Development for Next-Generation Information Technology, Ministry of Education, Culture, Sports, Science and Technology (MEXT)
2010-present	Director, Center for Spintronics Integrated System, Tohoku University

RECOGNITION:

✦IBM Japan Science Award (1998)
✦IUPAP Magnetism Prize (2003)
✦Fellow, Institute of Physics (2004)
✦Japan Academy Prize (2005)
✦Presidential Prize for Research Excellence (2005)
✦The 2005 Agilent Technologies Europhysics Prize (2005)
✦Honorary Professor, Institute of Semiconductors, Chinese Academy of Sciences (2006)
✦Distinguished Professor, Tohoku University (2007)
✦IEEE Magnetics Society, Distinguished Lecturer for 2009 (2008)

Murugan RAMALINGAM

PRIMARY AFFILIATION:

Associate Professor
INSERM (National Institute of Health and Medical Research)
Research Center at the University of Strasbourg,
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ACADEMIC:

1997	M.Phil in Nuclear Physics, University of Madras, India
2003	Ph.D in Biomaterials, University of Madras, India

PROFESSIONAL EXPERIENCE:

2002-2006	Postdoctoral Fellow, National University of Singapore, Singapore
2006-2008	SMF Fellow, National University of Singapore, Singapore
2006-2008	Research Associate, University of Central Florida, USA
2008-2010	NRC Fellow, National Institute of Standards & Technology (NIST), USA
2008-2010	NRC Fellow, National Institutes of Health (NIH), USA
2010-2010	Assistant Professor, Tohoku University
2010-present	Associate Professor, University of Strasbourg, France

RECOGNITION:

✦IPR Summer Fellowship, India (1994)
✦NSC Summer Fellowship, India (1995)
✦CSIR Fellowship, India (1997)
✦Young Scientist Award, The International Union of Crystallography (IUCr) (1998)
✦DBT Fellowship, India (2002)
✦SMF Fellowship, Singapore (2004)
✦Who's Who in Science and Engineering, Marquis Who's Who, USA (2005)
✦Fellow of Institute of Nanotechnology, UK (2005)
✦Who's Who in Medicine and Healthcare, Marquis Who's Who, USA (2006)
✦Bajpai Saha Best Paper Award, Society for Biomaterials and Artificial Organs, India (2007)
✦NRC Fellowship (National Academies), USA (2007)
✦Man of the Year 2009, American Biographical Institute, USA (2009)
✦International Peace Prize, The Consulate of the United Cultural Convention, USA (2009)
✦International Profiles of Accomplished Leadership Award, American Biographical Institute, USA (2009)

CURRENT RESEARCH:

・Multiphase BiomaterialsNanofibers, Microfluidics
・Stem Cell Engineering
・High-throughput Screening
・Tissue Engineering

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 to October, 2010

(You can read the listed researcher's report from next page)

A. Senior Researchers <Visiting Professors/Associate Professors>

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

B. Junior Researchers and Students <Visiting Scientists>

	Name	Host	Position	Term							Affiliation	Position	Nationality	Age	Research Topic
				From			~	Through							
1	**ALJERF, Moustafa**	Louzguine (Yavari)*	Visiting Scientist (PhD Student)	2010	1	14	~	2010	4	14	Institute National Polytechnique de Grenoble, France	PhD Student	Syria	34	Mechanical and magnetic properties of metallic glasses
2	**HAUBOLD, Marco**	Esashi (Gessner)*	Visiting Scientist (PhD Student)	2010	3	17	~	2010	4	5	Chemnitz University of Technology, Germany	PhD Student	Germany	26	・Grinding and polishing of lithium niobate substrate ・Deposition of gallium thin films(sputtering/vaporation)
3	**CAO, Fei-Fei**	Yamamoto (Wan)*	Visiting Scientist (PhD Student)	2010	6	15	~	2010	7	14	Institute of Chemistry, Chinese Academy of Sciences (ICCAS), P. R. China	PhD Student	P.R. China	26	Exploration on nanomaterials synthesis
4	**TEOBALDI, Gilberto**	Tsukada (Shluger)*	Visiting Scientist	2010	4 6	17 27	~	2010	4 7	30 6	University City College London, UK	Researcher	Italy	33	First-principles modelling of processes and STM/STS imaging at nanostructured surfaces
5	**WATKINS, Matthew**	Tsukada (Shluger)*	Visiting Scientist	2010	7	15	~	2010	8	5	London Centre for Nanotechnology, UK	Researcher	UK	33	Development of realistic tip models for simulating atomic force microscopy

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

GI^3 Activity Report of Associate Professor Nicolas GIOVAMBATTISTA
June 28th, 2010 - July 29th, 2010
Host: Professor Michio TOKUYAMA

The main goal of this visit was to extend our previous computer simulation work on *liquid* polyamorphism to study polyamorphism in the *glass* state. Using computer simulations of a non-trivial monoatomic model system, we were able to reproduce two of the main transformations that are known to occur in polyamorphic glasses, the crystal-to-glass transition (pressure-induced amorphization) and the glass-to-glass transition. These results are relevant since in computer simulations studies of monoatomic systems, crystallization is usually unavoidable, even for the short computer simulation time scales. Based on these findings, we wrote a manuscript that has just been submitted for publication to the Journal of Chemical Physics.

Two other studies have also been started, both based on our monoatomic model system. In one of these studies, we plan to explore the glass forming ability (GFA) of binary mixtures where one of the components corresponds to our monoatomic non-crystallizing model. This will allow us to study the effects of pressure, cooling rate, and relative size of the components in the mixture's GFA. The second project is meant to explore the effect of confinement in the GFA of our previously studied monoatomic model system and, in particular, how confinement affects its polyamorphism. We are actually working on these projects and expect to finish them in the next few months.

GI^3 Activity Report of Associate Professor Esmaiel JABBARI
July 16th, 2010 - August 15th, 2010
Host: Professor Ali KHADEMHOSSEINI

The purpose of the short one month visit was to investigate the effect of patterned osteogenic/cell adhesion peptides on a gel substrate on cell fate, and to expand the collaboration between the WPI-AIMR group in Tohoku University and Jabbari's research group at the University of South Carolina. We identified the following areas of collaboration between the WPI-AIMR research group with expertise in developing patterned/gradient substrates and that of Jabbari's group with expertise in synthesis of peptide-conjugated biomaterials: a) developing hydrogels with gradient/pattern in BMP-2 osteogenic peptide and RGD cell adhesion peptide for controlling cell differentiation and b) developing electrospun fiber-reinforced hydrogels with gradient in osteogenic and chondrogenic peptides for applications in regenerative medicine. Preliminary experiments were conducted to pattern the surface of poly(ethylene glycol) (PEG) hydrogels with RGD cell-adhesion peptide using micro-contact printing with PDMS stamps. A PEG hydrogel precursor solution was partially crosslinked on a glass substrate. Next, the hydrogel was brought in contact with an acrylated-RGD (Ac-RGD) coated PDMS stamp to produce a square pattern of Ac-RGD on the hydrogel. Then, the hydrogel was fully crosslinked to covalently attach the RGD peptide to the substrate. Osteoblasts were seeded on the patterned hydrogel and the attached cells were stained and imaged with a fluorescent microscope. Results demonstrated that additional characterization of the gel is required to prevent the diffusion of RGD pattern away from the stamped areas. Based on the preliminary results, the group at WPI-AIMR and jabbari's groups plan to submit a joint proposal to US National Science Foundation (NSF) and JSPS in response to the NSF-JSPS bilateral joint projects to provide financial support for the joint collaboration.

GI^3 Activity Report of Professor Youn-Woo LEE
July 20th, 2010 - October 19th, 2010
Host: Professor Tadafumi ADSCHIRI

In WPI, many fusion researches are now going on with Adschiri's Nano Hybrid Nano Particles (NPs) including transparent magnetic hybrid polymers, nano magnetic spring with his block-tripolymers and NPs, TiO_2-nano porous gold for catalysis, and chiral inorganic assembly with his chiral molecule and NPs. Although all the researchers in the above fields are intensively working on the fusion research, to provide NPs from Adschiri's group is a limiting step. To increase the man-power (number of technicians), to make some more set-ups, namely numbering-up, and to establish methodology to synthesize the NPs with larger amount in a short time, namely scale-up, are the critical issues. Prof. Tadafumi Adschiri invented supercritical hydrothermal method for nanoparticle synthesis around 20 years ago. One of the most important discoveries of this invention is continuous process which is completely new approach. Many researchers in the world began adopting this innovating method to synthesis nano materials. However, this process needs to improve to increase its production capacity without losing particle quality. This can be solved to optimize mixing point design in which both the rapid heat transfer (rapid and effective fluid heating from room temperature to around 673 K within a second) to ensure the generation of the nano particles with narrow PDS and the enough space to ensure preventing from plugging should be provided. To untangle the knot of contradictory phenomena, we have desperately sought better solution. Since I have experienced to design a commercial plant in Korea, I have a know-how solve the problem, which involve the optimization technology between the super-rapid mixing of supercritical water and precursor which can be achieved by micro channel and the spacious mixing point not to plug but still to provide the rapid and effective turbulent heat and mass transfer. This method was commercialized for the first time in 2004 in Korea for CeO_2 particles production (30t/year), and scaled-up recently (200 ton/year) by Hanwha Chemicals, Co., under my supervision. By end of this year, a new plant with a capacity of 600 ton/yr will be constructed for the production of Li ion battery materials for GM electric cars, for which his contribution is significant. I also contributed a lot for the development of 10,000 t/year combined process of waste water treatment and catalyst recycling. These experiences will apply a new process in which I now am serving as a leader of a national project of the biomass conversion to bio-based polymer. In this project, sufficient scientific/technical knowledge of the scale-up for the large scale supercritical reaction process is needed. Recently, Prof. Adschiri group has developed a novel process to prepare the Super Hybrid Materials which need to continuous feeding of the quite large amount of modifiers into the reactor. Even though this technology is a bit more complicated than the previous hydrothermal synthesis without modifiers, almost the same principle is applied to scale-up the process. Prof. Adschiri and I continue to discuss, debate, ruminate on the issue of scaling-up the supercritical reaction process during my visiting professor at WPI-AIMR. Now Prof. Adschiri and I thought one idea to prepare paper filler which is modified by organic compounds. We are going to apply the new idea to our plan. Increasing ash inorganic content of the paper is one of the most effective methods for saving raw materials and improving optical properties and better print quality. However, the increase of filler loading using conventional fillers is limited due to severe loss in strength properties, affecting product quality. This is attributed to the fact that the filler is not compatible with cellulosic fibers. Therefore, if we provide filler which is covered by organic modifier, we can make the paper with high content inorganic filler. I already demonstrated to produce $CaCO_3$ particle in supercritical water without modifiers. Next step is to choose proper modifier to produce nano particles that are hybrids between organics and inorganics.

Another study started to investigate extraction organic solvents from nano hybrid particles. Even though hydrothermal synthesis of hybrid nano particles are known to be green process, there still are some cases to need a large amount solvent to collect and disperse particles. In order to make dry super hybrid particles, vaporization process is the current technology, however, it leads to agglomeration of the particles even though the particles are covered by organic modifiers. One alternative process is the extraction process in which supercritical CO_2 is used as an extraction solvent. Since supercritical CO_2 has a high solvency power to organic solvent compared to super hybrid particle, one can remove selectively the organic solvent from the particle surface after collecting the particles at the filter. Another alternative process is the precipitation process in which supercritical or liquid CO_2 is used as an antisolvent to precipitate the super hybrid particles. In this case, one can extract organic solvent from aerosol by supercritical or liquid CO_2 effectively to take away solvent power. My graduate student, Mr. Youn from Seoul National University has been working in the field of supercritical CO_2 process, constructed an apparatus and new experiments have been started. The research is going on this aspect and it will be continued by middle of February, 2011 at WPI-AIMR.

In summary, Prof. Adshiri and I are challenging to scale up the supercritical water synthesis process, which can produce super hybrid particle, especially in the design of the mixing point to increase the production capacity and in the collection of fre flowing drying nano particles without agglomeration.

GI^3 Activity Report of Professor Ze ZHANG

August 18th, 2010 - September 17th, 2010

Host: Professor Mingwei CHEN

Study on three important scientific issues were carried out during this a month long visiting at CHEN's Lab. of WPI-AIMR in Tohoku University.

The first was a continuing investigation on the relationship between the microstructure and transport property of the phase transition random memory (PCRAM) in an alloy system of Si-Sb-Te newly found in China. This alloy shows an extremely high quality of I-V curve during the reversible phase transition from the amorphous to crystalline phases, together with the writing-erasing cycling life, and other key parameters concerned. All of that are the key engineering target physical properties for future important PCRAM application. Our previous experimental results obtained from China shows that there is an obvious existence of phase separation during the amorphous-crystalline transition. We found, for the first time, that Si remained as amorphous state during the whole transition history of the alloy, whilst there is a crystalline Sb_2Te_3 phase formed during the crystallization process and it became amorphous again under certain heat or laser treatments. All of these experimental results imply that the thermal-electrical semiconductor and/or the topological insulator of Sb_2Te_3 plays a major role for the phase transition and the corresponding I-V property with sharp difference of 2-4 orders of magnitudes. The amorphous Si behaves like a matrix while the Sb_2Te_3 acts as nano-particles embedded inside of the matrix. The theoretical analysis of the transportation mechanism of this wonderful alloy was carried out here by collaboration with Prof. Chen's assistance Dr. Guan based on our thorough discussions together with Prof. Chen. He made a systematic calculation of the density of state (DOS) from both amorphous and crystalline of Sb_2Te_3. The theoretical results shown that the crystalline phase of Sb_2Te_3 is with much high DOS near the Fermi energy therefore more conductive compare with its original amorphous state, which is agree well with the experimental observations. This will be very important for the future application of the new system of PRAM and it provides also a deeper understanding of the science issue from the key engineering requests.

Another work concerns with the advanced mechanical property of a new generation of super-alloy. Owing to the fact that few degrees of temperature increasing in the strength of this alloy at high temperature shall bring tremendous benefits for energy saving and low CO_2 emission for thermal power generation, this alloy has long been a strategic structural material. The sample we studied here in WPI were brought from

China and detailed structure analysis was carried out by collaboration with Prof. CHEN's another assistance Dr. Hirada. By employing the advance microscopy power of the double corrector electron microscope, we could figure out the alloy elemental distribution within this alloy before and after high temperature creep at high loading of tensile test. Some experimental results concerning the advanced mechanical property have been observed, for the first time, and that is close to publication from our joint research carried out during my visit.

The third work just beginning and it related with a study on an unusual large elasticity result from an ultra thin film of nanocrystalline Ni. The key scientific issue is the grain size confinement produced local strain build up under an in-situ tensile test. In-situ electron microscopy observation at atomic scale has been carried out in China and the theoretical calculation was down here in WPI by Dr. Guan. Some tentative results have been obtained and it will be continued by the following up task that might be down by Prof. CHEN's team members in WPI-AIMR.

The helpful discussions with the director of NIMS, Prof. Sukekatsu Ushioda and the director of super alloy group of NIMS, shall be very much acknowledged.

GI^3 Activity Report of Dr. Moustafa ALJERF
January 14th, 2010 - April 14th, 2010
Host: Professor Dmitri LOUZGUINE (Professor Alain Reza YAVARI)

The main objective was achieved during this short period of three months at WPI-AIMR in Tohoku University: to further investigate the role of glassy particles reinforcement on mechanical properties of metallic matrix composite. The conception of this new category of metallic matrix composites is based on the fact that metallic glass particles become soft above their glass transition temperature T_g so they can act as a soft binder and porosity remover. After compaction to full density and cooling to below T_g and down to room temperature, the same glassy particles become the hard reinforcing phase.

In collaboration with WPI-AIMR, we developed a novel aluminum alloy matrix composite reinforced by Fe-based glassy particles. Fine powder of the matrix phase (commercial alloy Al6061) and of the reinforcing phase (glassy $[(Fe_{½}Co_{½})_{75}B_{20}Si_5]_{96}Nb_4$) were produced by mechanical milling. Sintering temperature of the mixed powder was chosen within the supercooled liquid region of the glass slightly above the glass transition temperature T_g and close to the solidus temperature of the aluminum alloy. By examining the microstructure of the new composite, no pores in the matrix or in areas adjacent to the metallic glass reinforcement particles of any size are visible. This indicates successful consolidation of the composite to full density without any undesirable effects. The composite shows considerable increase in yield strength (550 MPa) relative to the matrix alloy (250 MPa) while keeping noticeable plasticity (~14%) prior to fracture.

The high strength and low mass density of these new composites imply that they possess very high specific strength and can be used as replacement for some structural, functional or machine parts of heavier alloys such as stainless steels. This in turn leads to weight reduction and significant energy saving in the transportation sector. Strong and light composites are therefore green materials focused on technologies reducing CO_2 emissions and the improved efficiency of car and aerospace structures and will contribute to reduction of emission of gases and the consumption of carbon based fuel, harmful for the atmosphere (greenhouse effect), as well as in the release of harmful ingredients thus benefitting the overall environment.

This work is to be added to the previous collaboration with WPI on the same subject which gave two publications in 2009-2010 [1, 2] and a new manuscript entitled

“**Aluminum and magnesium metal matrix composite reinforced by three different metallic glasses**” is to be submitted to Scripta Materialia for publication.

[1] Dudina, D.V., et al., A magnesium alloy matrix composite reinforced with metallic glass. Composites Science and Technology, 2009. 69(15-16): p. 2734-2736.

[2] Dudina, D.V., et al., Cu-based metallic glass particle additions to significantly improve overall compressive properties of an Al alloy. Composites Part A: Applied Science and Manufacturing, 2010. 41(10): p. 1551-1557.

GI^3 Activity Report of Marco HAUBOLD
March 17th, 2010 - April 5th, 2010
Host: Professor Masayoshi ESASHI (Professor Thomas GESSNER)

The main objective of the short period research stay at WPI-AIMR in Tohoku University was the accomplishment of basic experiments for a laser assisted bonding process of substrates, used in MEMS fabrication. The main advantages of affecting just a very small region with the laser radiation and the locally limited raise of temperature therefore, are unique opportunities in means of applicable materials for MEMS production and structure design. Basing on silicon-glass direct bonding, tests have been performed in order to evaluate an adequate process window (e.g. wave length, output power, focus depth, repetition rate). After a training period at common laser tools by the laboratory's staff, several test runs were performed with pre-bonded samples with altered parameter sets, aiming on the enhancement of the mechanical stability. The achieved bond was subsequently characterized by pull testing and scanning electron microscopy (SEM), providing a good comparison for the different experiments. The results showed almost no increase of bonding strength for low energy levels, whereas significant changes could be induced at the touching interfaces at certain high output powers, resulting in a partly high bonding strength. Samples treated by these settings got destroyed during the characterization, proving the potential of bonding technique without an additional intermediate layer. The tests provide a basis of further investigations.

In addition to the experimental intention, the trip was used to participate in the WPI workshop form March 25th to March 27th. The author therefore used the opportunity to present his results of a former research project at WPI-AIMR **"Bonding Investigations of oxidized Silicon Substrates with Metal-based Intermediate Layers"** during the poster session.

A last purpose of the research trip describes the extension of the scientific exchange between the Fraunhofer Research Institution ENAS and the WPI-AIMR in Tohoku University. Therefore it is envisaged to join a project of the European Community in order to strengthen the collaboration and expand the joint high level research.

GI^3 Activity Report of Dr. Fei Fei CAO
June 15th, 2010 - July 14th, 2010
Host: Professor Yoshinori YAMAMOTO

Two objectives were achieved during this short period of one month at WPI-AIMR in Tohoku University. The first was studying the basic experimental operations and analytical methods in organic synthesis. During the one month period, I was systematically trained to master basic synthetic methods such as extraction, filtration and basic characterization methods such as ^1H NMR, ^{13}C NMR, IR, UV-Vis and so on. The main work I carried out was the synthesis of dithieno[3,2-*b*:2’,3’- *d*]thiophene (DTT), which followed the reference *Organic Syntheses, Vol. 83, p. 209-216 (2006); Coll. Vol. 11, p. 843-849 (2009).* In recent years, much interest has been focused on DTT as a unit in semiconducting organic materials. In particular, the dimer α,α'-bis(dithieno[3,2-*b*:2’,3’-*d*]thiophene) and its derivatives have been used as high mobility semiconductors in field-effect transistors, with field-effect mobility of up to 0.05 $cm^2\ V^{-1}\ s^{-1}$ being recorded. This synthesis may be carried out on the scale of over 30 g, although the lithiation step is limited on a laboratory scale due to the difficulty in cooling largescale glassware. I successfully repeated this whole experiment and obtained final as-expected products. I also mastered these organic operations and gained knowledge about organic synthesis as well as solar cells from Professor Yoshinori Yamamoto in his laboratory.

Another study was preparing CNT-TiO_2 nanocomposite and investigating its application in solar cells. In China, I have successfully prepared various TiO_2-based nanocomposites such as CNT-TiO_2, Cu-TiO_2 and TiO_2-C, and investigated their electrochemical performances as anode materials in lithium ion batteries (LIBs). In my research, I found that coaxial cable morphology provides a clever solution to the ionic-electronic wiring problem in LIBs. Since TiO_2 was also a promising material for solar cells, I collaborated with post-doctoral Akhtar to prepare CNT-TiO_2 coaxial nanocable during the one-month period. This work is still going on and it will be continued by post-doctoral Akhtar in WPI-AIMR.

GI^3 Activity Report of Dr. Matthew WATKINS
July 15th, 2010 - August 5th, 2010
Host: Professor Masaru TSUKADA (Professor Alexander SHLUGER)

Following arrival in the afternoon of Monday 28th of June, on Tuesday 29th of June I gave an introductory seminar on part of my research to the Theory Laboratory of the Materials Physics Group. The seminar was focused on 'DFT-based approaches for the simulation of the geometry, chemical reactivity and STS/STM imaging of Titania (TiO_2) surfaces".

The seminar was followed by a presentation by Assistant Professor I. Hamada on his recent results on a Strontium Titatanate surface [$SrTiO_3$(001-√13x) √13]. The session was concluded by discussion with Prof. M. Tsukada, Ass. Prof. K. Akagi, and Assistant Professor I. Hamada on possible applications of the methods presented in my talk to the Strontium Titanate line at WPI-AIMR. Afterwards, I started collaborating with Assistant Professor I. Hamada on the activation of both the VASP and bSKAN programs at WPI-AIMR.

On the 29th-30th of June, together with Assistant Professor I. Hamada, we considered the details of the input format for both the VASP and bSKAN codes. This activity was carried out on the basis of targeted examples which I provided to Assistant Professor I. Hamada.

On July the 1st, the discussion with Assistant Professor I. Hamada concentrated on the execution and output files of both the VASP and bSKAN program with assisted preparation of files relative to the study of the considered Strontium Titanate surface for both the VASP and bSKAN programs.

It is my intention to conclude the presentation of the bSKAN program capabilities to Assistant Professor I. Hamada on Friday 2nd.

Finally, arrangements are currently being made with Prof. M. Tsukada to discuss possible overlap between the WPI-AIMR line on carbon-cages and a Van der Waals corrected – Density Functional Theory method which was developed for my Osaka-based project in collaboration with Prof. A. Shluger and Prof. K. Tanimura.

GI^{3}Activity Report of Dr. Gilberto TEOBALDI
April 17th, 2010 - April 30th, 2010
June 27th, 2010 - July 6th, 2010
Host: Professor Masaru TSUKADA (Professor Alexander SHLUGER)

Following my previous visit in February 2010 I am continuing to discuss methods to develop atomic force microscope tip models with Dr Akagi and Prof Tsukada of the theory laboratory at the WPI-AIMR. Realistic atomic-force microscope tip-models are vital to carry out (semi)quantitative simulations to aid understanding of experimental images. The models derived from the oxidation of silicon will be of interest in other areas as well. We have discussed the tip models that I have generated since my previous visit to the WPI-AIMR in February and how the work could be prepared for publication. Possible deficiencies in the current models due to their low density and how to generate better starting structures were discussed. We decided that clean silicon tips, constructed using software developed in Prof Tsukada's group, will be used as initial models and look into the literature on wet silicon oxidation to help refine our model. Looking ahead, the current methods I have used, density functional theory based molecular dynamics simulations, are too costly for a fully systematic study of silicon oxidation. To overcome this, I am working to implement a reactive molecular forcefield model to allow us to examine the oxidation of these silicon tips when exposed to ambient or solution environments. I will also visit the laboratory of Dr. Fukuma of Kanazawa University to expand our collaboration on imaging mechanisms of non-contact atomic force microscopy in solution. We will discuss in detail the experimental tip preparation procedures that have been used. Of particular interest are information on the thickness of the oxide layer formed on the silicon cantilever, which will suggest appropriate starting structures to consider in our simulations.

A meeting with Prof Louzguine and Dr Caron of the advanced functional materials group at the WPI-AIMR has been organised to discuss their experimental results using atomic force microscopy to measure friction properties of metallic-glasses. We will consider the role played by surface oxidation of the metallic-glasses in ambient condition and how this may lead to surprising frictional properties. Discussions will concern the conditions that the glasses have been exposed to and tip preparation procedures. We will consider how atomistic simulations could be used to aid understanding their results.

On 29th July I will attend the first “nano-interface” meeting at the WPI, organised by Dr Nakajima of the Organosoft and Hybrid Materials Laboratory at the WPI-AIMR. The topic of “hydration and water phase behavior in hydrophobic/hydrophilic nano-scale confinement” presented by visiting scientist Prof. Nicolas Giovambattista will be of direct relevance to work on understanding water and surface structure using the atomic force microscope. The meeting will present an excellent opportunity to establish further links to the WPI-AIMR.

Announcement

The 2011 WPI-AIMR Annual Workshop

The 2011 WPI-AIMR Annual Workshop will be held on February 21 through 24 in Sendai. On February 22-24, the workshop will be composed of plenary sessions and parallel sessions, inviting world class researchers.

Date :	Monday, February 21 - Thursday, February 24, 2011
Location :	Sendai International Center (sessions) & Sendai Kokusai Hotel (reception, lodging)

In the process of realizing three major goals of AIMR; (1) Invent and develop new functionally innovative Green Materials, (2) Establish a new system adequate as a World Premier Research Center, and (3) Strengthen international cooperation and construct a world visible center, we have been organizing WPI-AIMR Annual Workshop; the 2009 Annual Workshop was held in March, 2009 at Miyagi-Zao Royal Hotel and the 2010 Annual Workshop was held in March, 2010 at Sendai Excel Hotel Tokyu and Sendai International Center. Following them, we are announcing the 2011 WPI-AIMR Annual Workshop which will be held on February 21, Monday, through 24, Thursday, 2011 at Sendai Kokusai Hotel and Sendai International Center.

The scientific scope of our workshop is “Cutting-edge Functional Materials for Green Innovation”. In the morning of February 22, special session is planned inviting Dr. J. Georg Bednorz, 1987 Nobel Prize in Physics Laureate, Dr. Peter Grünberg, 2007 Nobel Prize in Physics Laureate, and Dr. Sumio Iijima of Meijo University, also Adjunct Professor of WPI-AIMR, a recipient of the Japanese Order of Culture in 2009.

Plenary sessions and parallel sessions will be organized with presentations by world premier researchers of the fields of AIMR research (thrusts), which are Bulk Metallic Glasses, Materials Physics, Soft Materials and Devices/Systems Construction. For encouraging younger researchers and further discussing the fusion researches, we also have a poster session.

We would appreciate very much if you would join the Workshop.

To participate in this Workshop, please resister on the following website.

http://www.wpi-aimr.tohoku.ac.jp/workshop/

Tentative Schedule

February 21 (Monday): Sendai Kokusai Hotel
17:00 – 19:00 Welcome Reception

February 22 (Tuesday): Sendai International Center
09:00 – 09:10 Opening session
09:10 – 11:00 Special session
11:10 – 12:40 Morning plenary session
12:40 – 14:20 Poster session
14:20 – 16:20 Afternoon plenary session
16:30 – 18:00 Parallel session

February 23 (Wednesday): Sendai International Center
09:00 – 10:30 Morning plenary session
10:40 – 12:10 Parallel session
13:10 – 14:40 Parallel session
14:50 – 16:50 Afternoon plenary session
18:00 – 20:00 Banquet at Sendai Kokusai Hotel

February 24 (Thursday): Sendai International Center
09:00 – 12:10 Morning plenary session (10:30 – 10:40: Break time)
12:10 – 12:20 Closing remarks

Tentative list of Invited speakers (As of Dec. 10)

Johannes Georg Bednorz, *1987 Nobel Prize in Physics Laureate*
Jason A. Burdick, *University of Pennsylvania*
Fariba Dehghani, *University of Sydney*
Rafal E. Dunin-Borkowski, *Technical University of Denmark in Lyngby*
Thomas Gessner, *Chemnitz University of Technology*
Alan Lindsay Greer, *University of Cambridge*
Peter Andreas Grünberg, *2007 Nobel Prize in Physics Laureate*
Zhong-Ze Gu, *Su Zhou Southeast University*
Ryan C. Hayward, *University of Massachusetts Amherst*
Kevin J. Hemker, *Johns Hopkins University*
Sumio Iijima, *Meijo University*
Lei Jiang, *Institute of Chemistry, Chinese Academy of Sciences*
John H. Perepezko, *University of Wisconsin - Madison*
Itamar Procaccia, *Weizmann Institute of Science*
Pierre Richard, *Institute of Physics, Chinese Academy of Science*
Konrad Samwer, *Georg-August-Universität Göttingen*
Ashwin A. Seshia, *University of Cambridge*
Takao Someya, *University of Tokyo*
C. Suryanarayana, *University of Central Florida*
Li-jun Wan, *Institute of Chemistry, Chinese Academy of Sciences*
Andrzej Wieckowski, *University of Illinois*
Fred Wudl, *University of California, Santa Barbara*
Alain Reza Yavari, *Grenoble Institute of Technology*
Deqing Zhang, *Institute of Chemistry, Chinese Academy of Sciences*
Ze Zhang, *Zhejiang University*

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.

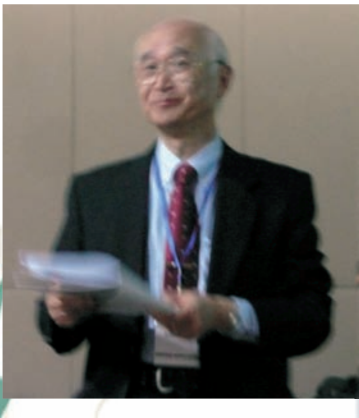
3) deadline

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

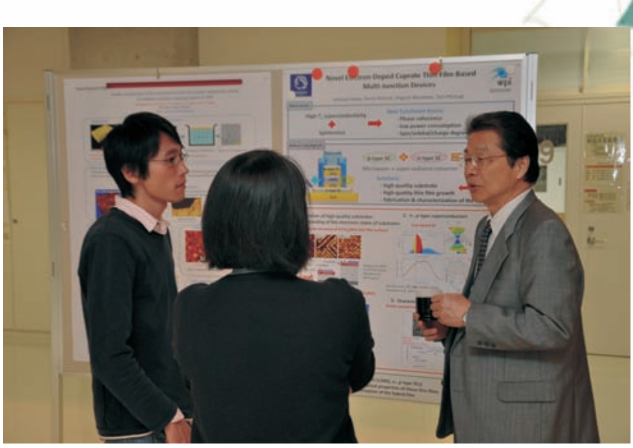
WPI-AIMR-ICCAS Joint Symposium in Beijing, China

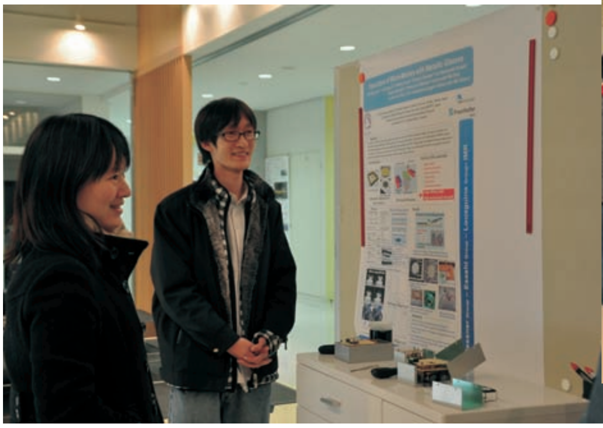
October 29,2010



Friday Tea Time in new shape

-Fusion Research Presentation-





The 6th Fraunhofer Symposium in SENDAI

December 7, 2010

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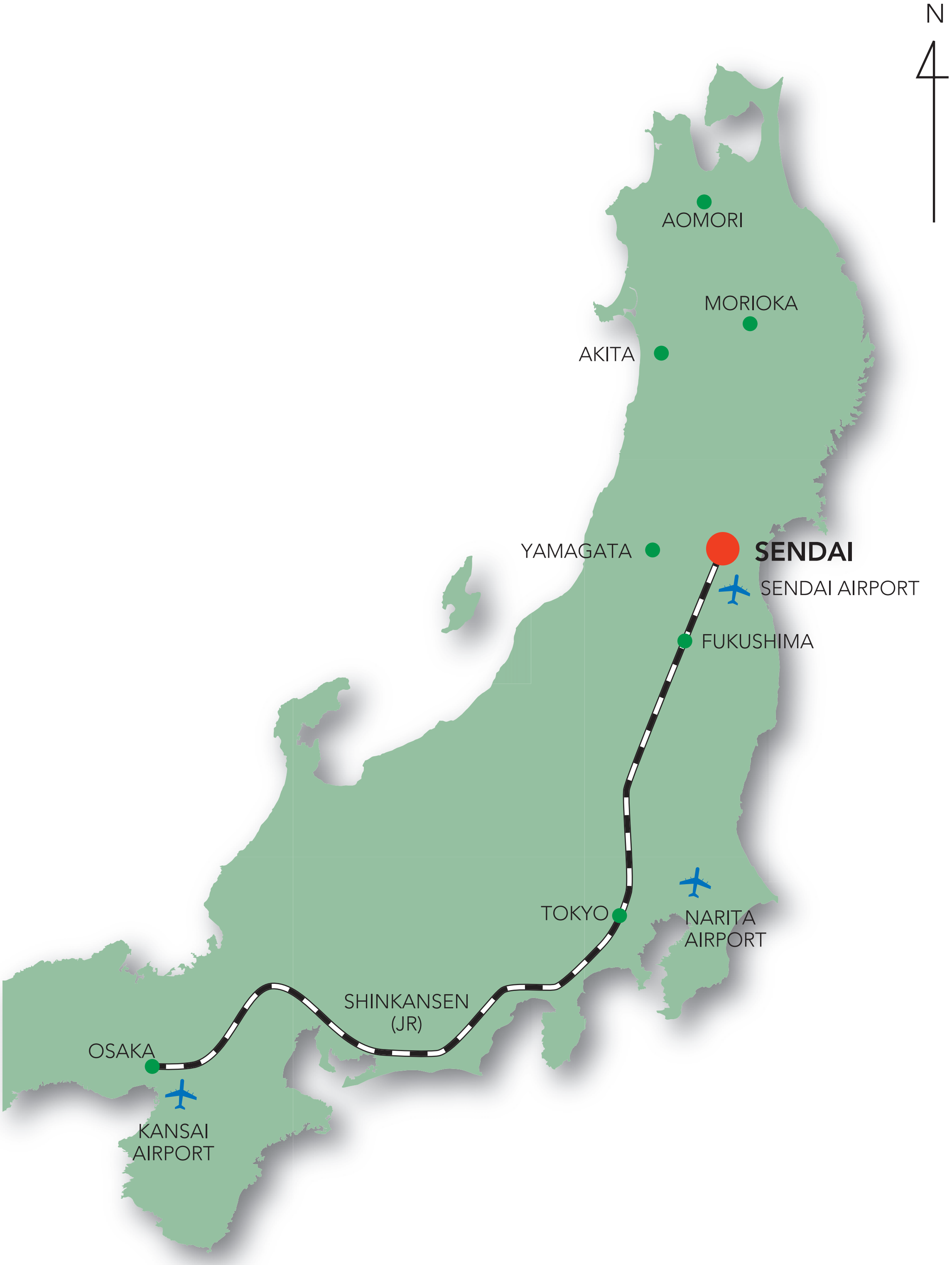

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