Volume 9

WPI-AIMR NEWS

April 1, 2010

World Premier International Research Center
Advanced Institute for Materials Research

Tohoku University

Cover: Interference optical micrograph of a symmetric diblock copolymer thin film on a silicon substrate where the colors result from a surface terracing due to an orientation of the copolymer domains parallel to the substrate. (Thomas P. Russell, WPI-AIMR and Polymer Science and Engineering Department, University of Massachusetts)

Volume 9

WPI-AIMR NEWS

April 1, 2010

World Premier International Research Center
Advanced Institute for Materials Research

Tohoku University

Produced by the WPI-AIMR Communication Office

Director: Yoshinori Yamamoto
Editor-in-chief: Toshio Sakurai
Executive Editor: Wataru Iwamoto
Associate Editor, writer: Hiroshi Komatsu
Associate Editor: Masaru Tsukada
Associate Editor: Hiroshi Oikawa
Associate Editor: Sayaka Unoura

We welcome your comments, questions and involvement.
e-mail to: wpi-office@bureau.tohoku.ac.jp, or
sakurai@imr.tohoku.ac.jp

Contents

New Start of AIMR in FY 2010; Changes and Future Vision

Yoshinori Yamamoto
Institute Director

Two years and six months have passed since the WPI-AIMR was launched on October 1, 2007. At the beginning, we went this way and that, and struggled to carry forward the mission of the AIMR smoothly and to make the organization in a better shape. The MEXT committee for the WPI program advised us to improve many points in the FY2008 follow-up report. We did our best to follow the advices, and now I believe that the structure of the organization is approaching to a most desirable shape, while we continuously pursue further improvement.

On February 4-5, there was a site-visit of the MEXT working group for WPI-AIMR program, chaired by Professor Yoshihisa Osada. The working group interviewed many PIs and young researchers to discuss their research progress, research environments, and other pertinent issues. I appreciate the PIs/researchers of AIMR for attending it and the working group for spending two days and encouraging us in order to make our organization better. They gave us valuable advices. One of the important suggestions is “it is time to set a long-term strategy to establish AIMR firmly as a global excellence bearer of an advanced material science.” I agree with this opinion, and we have to make the mission statement/road map clearer.

Accordingly, I have just started to reconsider (1) the mission statement of AIMR, and to draw up (2) a road map to accomplish the mission. The outline of our mission is shown in the next page as frequently told from the beginning of WPI program. What kinds of innovative materials should we intend to develop and study? We should explore innovative materials which play an important role to solve the problems facing mankind, such as energy, environment, health and safety problems. This is shown in the chart in the next page, mission details (1); We have to spell out the final goal and materials science (sections 1) and 2)), and I hope this will be completed in a next few weeks; Handling matters and fundamental substances (Sections 3) and 4)) are fixed as shown in the next page.

AIMR, Mission Statement

Outline

(1) Establish the World Premier Research Center for Materials; Invent/develop New *Innovative Functional Materials*

(2) *Reform* the Japanese Traditional Research System and Management System; Establish a System Suited to a World Premier Research Center

(3) Strengthen International Cooperation and Construct a *"World Visible Center"* through Tie-up Research with Networks and Satellites

1

Mission Details, (1) *Innovative Materials*

Innovative materials, which play important role to solve the problems facing mankind, such as energy, environment, health, and safety.

1) Device/systems through innovative materials; expected final goal
xxxxxxxxxx

2) Materials science; World top equipments for innovation, Only one technique and substances, Widely usable theories and concepts;

xxxxxxxxx

3) Handling matters; Metallic glasses, Metallic oxides, Polymers, Gels, π-Electron systems,

4) Fundamental substances; Metals, Metal derivatives, Organic substances

2

The mission details (2) and (3) are shown below, and those two missions are approaching to a desirable shape.

Mission Details (2), *Reform the traditional system*

- Evaluation/Promotion based on performance and future potential
- Fair merit system instead of the traditional equalitarianism
- Global search/securing of gifted young talents
- Encouragement/support to independent "blue-sky" research and fusion research
- Flexible staff and research space allocation, based on achievements and potential
- Start-up funds for invited researchers, as needed

3

Mission Details (3), *World visible center*

- Attract materials researchers from all over the world through outstanding research achievements and world-top research facilities/equipments/environment
- Act as platform for interactions of researchers where young bright foreign brains come and go
- Establish overseas network and global cooperation

Satellites at Univ. of Cambridge (BMG) and at CAS, Institute of Chem.(soft materials)

Foreign PIs; *Harvard*, Wisconsin, UCLA, Johns Hopkins, UMass, *Texas A & M*, Cambridge, UCL, Grenoble, Chemnitz, CAS- Beijing, Tsinghua, *Hong Kong S & T*

(PIs from the underlined universities have labs at AIMR)

4

The road map for the AIMR is shown below, but of course we need a road map of research project of each PI and researcher. I hope this will be completed soon.

Road Map of AIMR

2007, 10; Starting point; 30 PIs, and 139members in total-

2010, 4; The structure and organization at Phase I of AIMR project are almost complete; 32 PIs, and 176 members in total

2011, 4; The main building of AIMR will be completed.

2011.9-10; Interim Evaluation

2012, 4; Phase II project starts. All the PIs, researchers, and the director are reevaluated, and some of them are changed if needed. The research theme focuses on development of innovative materials mentioned in the mission statement.

2017, 3; Ten years pass, and really useful innovative materials/methodology/concept must be established .

2017, 4; Phase III; Either a new university organization, based on AIMR, is launched, or the WPI project continues for the next five years.

5

Besides the above issues, I would like to note that the 2010 WPI-AIMR annual workshop was held in March 25-27 successfully. I appreciate very much all the participants and members of program and organizing committees for their strong support and cooperation to make the workshop successful and enjoyable.

Most importantly, I would like to announce and welcome that Professor Kazue Kurihara joined us as a PI on April 1. She belongs to Interface PhysChem Laboratory of Soft Materials Thrust, and her group will explore the research field of surface forces to develop this technique as a unique tool in material science. Their researches concern interactions between biological molecules, polyelectrolytes, confined liquids, as well as novel instrumentation.

Please note that the names of two Thrusts has changed on 1st April; NanoPhysics becomes Materials Physics, and NanoChemBio becomes Soft Materials.

Spring has come, we all have made a fresh start of FY 2010, and I hope this FY will be very fruitful, too, for all of us.

Interviews

Interview with Professor Peter A. Grünberg, 2007 Physics Nobel Laureate

"Intellectual curiosity as well as looking at the application"

Professor Komatsu (K): First, we'd like to know your personal history, such as your family, childhood, your education, and the university life you have experienced. I've heard that you were born in Pilsen.

Professor Grünberg (G): Right.

K: Then at that time it was occupied by Germany, but originally Czechoslovakia.

G: It was in a way mixed already for many centuries. For example, the name of the famous founder of the Škoda factory, Škoda, sounds Czech. But he was German.

K: I see, and when you were born, it was already Germany or still Czechoslovakia?

G: I tried to find my citizenship when I was small. What kind of citizenship I had when I was born is for me an open question. I never found a document answering the question in this way or in other way. I think my parents were at that time German. For my mother, there is no problem. She was born in a purely German area not far from where my father had worked. They met and married and I was born. I have a 2 years older sister than I.

But then my father is in fact a Russian immigrant. My father came from the Baltics – his father and his family came from the Baltics. They were the Baltic Germans. They spoke half German, half Lithuanian, and we still have documents at home where my grandfather graduated from a Lithuanian school.

Now, one can ask, how did the Germans come into that area? That was a process which went over centuries in fact, it was due to the Hansa Trade Company, and along with the Hansa, many Germans came into the Baltics and settled there and my ancestors obviously the same. They were in the Baltics and as Germans and spoke there own Baltic German dialect. So this way they came into the Baltics, but many of them came also into Russia, changed over to Russia because Russia was militarily also very important. And my father became an officer in the Russian army, officer under the Czar. So, my father was there serving for the Russian Czar.

K: King or Czar.

G: Yeah, Czar it's the Russian most – like the Emperor. And my father was in his army and served for him. Then came the October Revolution and there was a lot of fighting between the army of the Czar and the Red Army, the Bolsheviks.

And then of course, the Bolsheviks won the war and my grandfather meanwhile had died. But the rest, which was my grandmother and her two children, who were my father and my uncle, had to escape and flee because they were on the Czar's side – because he was in the Czar army, so clearly they were on the Czar's side and they would have been killed if they had not gone as soon as possible, left that part of the world. They did so and had a boat ride across the Black Sea, for example, very adventurous and then came to Czechoslovakia to live.

And my father started his engineering study at that time, so he became an engineer working on locomotives or trains.

K: Constructing locomotives?

G: Yes, he made some inventions for the brake system, I heard.

K: So you have traced your history back in your eyes, quite complicated.

G: Yes, sure. Okay, then he was working for the Škoda factory constructing locomotives. There was an interruption because for a year we went to the western part of Germany to Kassel, where there was also a very famous company with locomotives and that was the company Henschel. So for a year, he worked for Henschel, but then moved back to Pilsen, Czechoslovakia. He went back to Škoda and that was maybe not a very good decision because then the war was almost over. My father in the meanwhile had German citizenship because it was occupied by Germans and we started as German; his ancestors were German, although they were Baltics, but in fact German. He took the German citizenship, but then the war was over, and my mother and my father were taken to the camp close to Pilsen and in fact all Germans were collected.

Now, the Czech side was in power and they had the Russians behind them, although I think the first-time it was the Americans who backed up the Czechs. But anyway, they were taken to a camp, and my father never came back from that camp, I don't know what really happened, but they got all a bad treatment.

K: How old was he then?

G: Yes, as a young officer he must have been at least 20 – I think he was born close to the turn of the 19th to 20th century. So then he was around 50 at that point.

K: I see. Originally, he was born in Germany?

G: No, Nizhny Novgorod, Russia. So, he was in fact a born Russian and he had also of his previous citizenship because he served for the Czar. So then he never came back from that camp.

K: I see, but you remained with your mother?

G: Right.

K: Not in the camp?

G: No, my mother came from that area around Pilsen, somewhere in the countryside near Pilsen, and my grandfather was a cobbler I think, cobbler works mostly with the saws. He worked with wood and made furniture…
K: Furniture, I see. Your grandfather was making furniture.
G: Yes.
K: So you have a good memory of your grandfather?
G: Yes, because there was so much happened.
K: And also grandmother too?
G: Yes.
K: Yes, because you stayed with your mother and your sister together.
G: Right. Then we came to West Germany that was not Pilsen but now it was in the Czech territory, Czechs took that. Moved all Germans out.
K: I see and pushed to Bohemian area? [Showing a map] Bohemia is here. You were raised near this Czech area and Bohemia is here, yes.
G: Well, what city is that? [Pointing the map]
K: This is the Praha, Prague.
G: But we lived near Pilsen, famous for beer. And my grandfather was a furniture worker and they lived maybe 20 kilometers west of Pilsen. My father and my mother were separated in that camp anyway, but my mother managed to be delegated to fieldwork. The field's harvest and cut the straw and all kinds of things, cut grass, and so she was much better off than in the camp because she came to the village where she was born and where my grandfather lived with grandmother. So, she could join them again and live there. But officially, she was delegated to fieldwork.
K: I see. So the grandfather and mother are your mother's parents?
G: Yes.
K: So you have several memories of your childhood.
G: Yes. My aunt with whom we lived in the town close to Pilsen, she was Czech but most Czechs knew also German. My sister and I we also knew Czech. I was brought up at that time bilingual, Czech and German, I could speak both. But now I've forgotten practically all my Czech.
K: Is there a big difference between Germany, and Czech German, and Czechoslovakia linguistically very different?
G: No, I think one can say both nations, both people knew both languages. All Czechs essentially knew German. They were mostly bilingual, and most Germans who lived there knew also Czech.
K: I see. Historically, Czechoslovakia has a very higher standard of scientific

knowledge.

G: Yes, Prague has had universities very early. I think that the first German university was in Prague.

K: I see. You went to primary school in this area?

G: My first school education was given to me by my mother because I should have gone to school already in 1945, but due to the whole political situation I did not. So, my mother gave me some education. And in fact, when we came back later to West Germany, I didn't have to go to the lower class because her education was so effective. There was no problem with school.

K: So what she taught to you is reading and writing.

G: Yes.

K: Not science of course.

G: Not so much, mainly reading and writing.

K: Now, let's see, so your mother's education was perfect in that sense.

G: Yes, it was very intense and effective because I was her only pupil. My 2 years older sister, she went in fact to school there because at the time of her enrollment we had German occupation. So that was only after the war that my mother was my teacher, but before we were then expelled, moved out, put together in a big train, what was called *Densha*.

K: Oh, train.

G: Took a lot of Germans.

K: I see. And also your mother taught you mathematics?

G: Yeah, elementary mathematics, of course. So, this is enough for the primary school education. There wasn't a problem.

K: Very good. And after primary school, you went to middle school and high school in the same area?

G: No. I went to no school at all during that time when my mother took care of my education. And in 1946, we were moved out because now Czech said we have to solve this problem with the Germans now once and forever and the best way to do that move all Germans out and then we'll have it uniquely Czech, so they did that because now they were in power, so they could do that.

Now I sometimes go to the Bavarian Forest. It's that mountain land between Germany and Czechoslovakia and even there is a lot of interaction, and people also go on both sides again, speaking German and Czech, so there's no hostility now, except for a few people. There are always also from the other side, from the German side, those who have been repatriated, so to say still keep the old memory and sometimes they were

nasty together. We know some people and I see these guitars here and we traveled to that area and I'm interested in the folklore music in the Bavarian Forest and there's a lot of folklore going on and those Czechs and Germans perform this kind of music with a guitar. Very famous is the woodwind music from Bohemia.

K: Bohemia.

G: Yeah, Bohemian woodwind music, trumpet and clarinet; there is a lot of folklore music. So both participated there and have competitions together.

K: And did you play some musical instrument by yourself?

G: I started with violin, but I thought I'm not so talented for that, that's why I switched to something else that was the guitar. But I like that music very much, only that I didn't have the right instrument. I finally found the right instrument for me. This is the contra-guitar, it's called, which was very much used in the folklore music.

And now I found some friends here in Tokyo, I found some friends, who like to sing and we have some guitarists and then I'll play the…

K: Special type of guitar.

G: So we will have sometimes our performances, but I only started with that, I played all the time the usual guitar if the finance was there. This I bought in Tokyo, but now I'm playing this one…

[Guitar Playing]

K: That's folklore.

G: It's not right tuned in. So, they had to introduce some modifications. This is the old Austrian style guitar and I was lucky to find this in Vienna which has a very nice sound. But I have to learn how to play it. I started 3 months ago, and because it is called also a harp-guitar. This part is a harp, and this part you play with frets and strings. Apart from folklore you can play old German songs with wonderful chords from the Renaissance originally set for the lute. Sounds about like this. [Sings a song with playing his guitar] But as I said I am still learning.

K: Very interesting.

K: What sort of sound does it make, harp sound…?

G: It has these strings, which are very long and representing so the bass is very nice.

K: Yes. I see. Quite contrasting to guitar string.

G: What is folklore music, for example, I've played very much. [Playing with his harp-guitar]

K: Very low frequency. Very good. Very interesting. [Folklore played by Guitar]

G: As I said, I have to still practice it. Hopefully in half a year…

It is also interesting that the character of a chord is essentially contained in that bass

note and everybody can hear whether in accompanying a song I have picked the right or wrong bass note. Scholars of music theory still debate whether this is given by nature or education. Therefore I am very happy to have found in Tokyo a group of Japanese musicians around the soprano Keiko Hibi who perform both traditional Japanese and European folklore so we can compare.

K: And you used to play ordinary guitar when you were young.

G: Yes.

K: Old one.

G: Yes. Well, up to until about 3 months ago, then I started with this one. But it gives me the opportunity to play just this kind of folklore and other old music which I like. So, I specialize on this kind of music.

But from the technique I still have to learn it, whereas the other conventional guitar I played now for a long time, I'm still really better on this one.

[Guitar playing with humming]

K: [Clapping of hands] Very good.

G: Thank you.

K: You really enjoy it a lot.

G: Oh, yes.

K: So, after this you went to high school?

G: Right. Then we had been brought to the western part of Germany and into an area not far from Frankfurt, about 100 kilometers from Frankfurt.

And that's where we lived from then on. And I went to school there. The whole school time I spent there, which was the elementary school in a small village, then went on to the biggest town in that district and so I continued there which was near to the village where I had been before. So that was, as I said, about a 100 kilometers north of Frankfurt, this area, until I was 19 and then I started studying physics in Frankfurt.

K: You really started physics in Frankfurt?

G: Yes.

K: And what was your motivation to study physics? Why do you like physics or selected it?

G: Because I have the impression it gives me the best answers for my questions about nature and gives the best motivated or the best founded answers will attempt to explain what is around us. I had the feeling that I could get the most relevant and prominent answers from physics.

K: I see. That means before you preferred physics, you're interested in nature or natural things itself.

G: Yes, I was very fascinated about, for example, about stars and…

K: Cosmos.

G: Yes, and what is it called, astronomy. Astronomy fascinated me very much for a long time.

K: That means you could observe beautiful stars in the place where you were born, nice sky and…

G: Yes and that area of Germany was a very clean area at that time. And we could see the Milky Way – of course everybody knew Milky Way and you could see that very nicely, which one cannot see now anymore from the many parts of the world.

K: Because of air pollution.

G: Yeah, the air pollution. We saw it for the last when we were in Australia, on a conference in Australia about magnetism, which is also now at least 20 years ago There one still can see the Milky Way and…

K: Oh, I see because they had good air, not polluted.

G: I remember a joke, you see Sirius so well, you know the fixed star Sirius. It's the brightest star on the southern hemisphere, in the southern sky, very famous as the Southern Cross, for example very famous. But the Sirius is also very well seen and falls out of the usual star because from all stars on the sky, Sirius is the brightest. We were so surprised about the brightness of Sirius, when we went home from Australian Bushman's Show and then saw the brightest Sirius. And I am not sure if it was the satellite or is it really a star and we always said to them, "Are you serious?" [Hearty Laugh]

K: I see. So you are really interested in astronomy?

G: I was very much interested also as a child always looking at the star. We built ourselves a telescope to see these even better; we could see the Jupiter, Jupiter moons, so such things.

K: Have you seen the ring of the Saturn?

G: Yes, I think the rings of the Saturn, but now I cannot remember.

K: But you of course observed the surface of the Moon.

G: Yes, I've seen the volcanoes and the structure of the surface.

K: So that was your real root of scientific interest.

G: Yes. Scientific interest is the curiosity.

K: Yes, yes intellectual curiosity. Even now you're interested in origin of cosmos, or expanding or Big Bang.

G: Yes, of course. But although I studied that so much, my feeling is somehow the answers I could get, or basically when you don't expect to learn very much now because from the main questions, we simply don't know, for example what was before Big Bang, such questions I don't think we can know more, and it will not be possible also.

K: There are several theories.

G: I don't see. On the other hand, the first 3 minutes after the Big Bang and the development of Hadrones and all kinds of, I think this is not such a relevant answer to me – you can calculate everything, but who knows how it really works, so I don't pay attention too much to these theories, to these books, like the 'First Three Minutes.'

K: Yes and George Gamow.

G: I don't know if it is so relevant.

K: Okay. You studied physics and you got Ph.D., what part of physics…?

G: After my first semesters in Frankfurt and the pre-examination, I passed that in Frankfurt, I decided that I should continue in close by Darmstadt. I know it is 30 kilometers from Frankfurt and I went to continue there. And also I got very much interested in computers. So that was my new hobby now, fascinated computers, but you

can do as computers, how fast you can calculate, for example, I was pretty fascinated about the computers. So then I wanted to understand the computer better, what's going on in the computer.

I did that for a while but then I switched back into physics because now came the time that I should also look for thesis for diploma, and Ph.D. thesis maybe. Then I did my diploma thesis and my supervisor encouraged me to continue that field with the Ph.D. thesis and also working together with my supervisor from the master thesis. We do both, knowing the hazards and we do work for – this time at least, but I don't know if it is still now, but at this time we did master thesis then continued with the Ph.D. thesis as well.

K: On what subject did you do master thesis, related to computer or physics?

G: No, I switched and I went, as I said, back to physics. I thought I had enough seen now from the computer so now to see the principle how it works was enough. And I switched back to solid state research and magnetism. But more at that time crystallography, and crystal field analysis.

States in all kinds of crystals, I took for example, garnets. I put some dysprosium into the garnets enclosed into the special sites of the garnets crystal and produces spectra, which come from crystal field interaction, and then you can determine from that spectral data to do the crystal field parameters and Hamiltonian which is to evaluate as you can get then crystal field parameters which describe a crystal field around a rare-earth ion into that crystal. And then they have the dysprosium aluminum garnet, which you can determine the parameters which describe the crystal field around the rare-earth ion.

K: YAG and DyIG?

G: Yes, YAG and DyIG, essentially yes, but then the dysprosium would only with impurity. For example, YAG doped with some dysprosium will give you such spectra and a light spectrum because the rare-earth states are reasonably sharp and then you get fine spectrum lines and determine the crystal field states, it seems like these materials. Then it was learnt and I continued with this for my Ph.D. thesis. I started with the thesis, but I continued.

So for that period of my life I was really working very narrowly on that field, on crystals.

K: I see, crystal field theory.

G: Then later on, I switched to other topics, but for that master and Ph.D. thesis, it was crystal field.

K: When did you get interested into the magnetic part of the crystal?

G: It was rather late, after this period in Darmstadt; I went to Canada, Ottawa. Because there was somebody also who had been working on these crystal field phenomena before. So I joined his group and stayed there for 3 years and did a lot of research still on these rare-earth garnets and crystal field phenomena.

K: After finishing Ph.D. on garnet field separately, you went to Canada and continued this work in Canada.

G: Because the supervisor there had been working in that field too. I joined but meanwhile then I helped in a new experimental technique, which was Raman spectroscopy, and he had discovered this, in fact, to measure this effect to these crystal field garnets by means of Raman spectroscopy, which was called electronic Raman Effect. We exploited that and did various rare-earth garnets, but now with the technique of electronic Raman Effect. But slowly I switched also to other fields, like acoustic because in Raman spectroscopy we see lots of acoustic phenomena, also other phenomena. So, we switched slowly also now to other problems by applying Raman spectroscopy.

And at the end of this period, the ambition of many people in the field was to come in the light scattering spectra as close as possible to the elastic line to study phenomena with very small frequency shift from the elastic line. For some reason, it excited the ambition of the experimentalists. They wanted to see what is very near to the excited line. So I did that too and in this way I became familiar with Brillouin spectroscopy, which is similar to Raman spectroscopy, but the instrumentation is rather different. In Raman spectroscopy you have a grating monochromator; which is replaced by a Fabry Perot interferometer in Brillouin spectroscopy.

K: For purifying wavelengths to determine them sharply…?

G: Yes.

K: You used the Fabry-Perot interferometer.

G: Right, exactly. And we use it in the multimode operation. You have a mirror system guiding the light which you want to investigate a few times through the same apparatus, with kind of mirrors. But practically, our spectrometers with 5 or 3 passes for the light through the interferometer, you have mirrors which are of the order of 6 centimeters in diameter.

That was the technique which was pioneered by John Sandercock in Zürich and he is a good friend of mine, so I visited him very often and he showed me also his laboratory institute and the variants of his interferometer. I took all that from when he developed them and he is very good in that. But I used it and was able then to go into that field of layered magnetic structures, which was a very good application of this technique.

And we were able, by this, to investigate the interaction between magnetic layers across interlayers of doubled-layer structures. You can study all these coupling phenomena very nicely with Brillouin spectroscopy from the spin waves on these doubled-layer structures, so that we did, and finally we found interlayer exchange coupling using that method.

And then, 2 years later, we found then also the Giant Magnetoresistance Effect based on this knowledge how to identify antiferromagnetic coupling and use it for new phenomena to use this coupling phenomena in order to see the transition between the parallel orientation of magnetizations and antiparallel, in other words interlayer exchange coupling. You could see from this – also investigate in fact result of these different orientations on their electrical resistivity…

K: I see. At that time in France, Dr. Fert was also doing the same work?

G: He came from a completely different field. His history was transport resistivity phenomena, bulk samples, with magnetic impurities essentially. First on such samples, investigated the influence of dopant from the 3d series when he doped these atoms into other transition metals. And so he had a lot of experience with that because he had done that for years. Then when he heard of the interlayer exchange coupling, then he thought obviously, well this is the right method now to continue to get more information also on resistivity from the layer structure.

He asked me about that and he started that. Interlayer exchange coupling leading to antiparallel alignment provides a convenient way to study the effect of the alignment on the resistivity. With a sufficiently high external field you can remove it, so you can very conveniently switch between two different orders in the magnetization.

K: How strong is the magnetic field to be applied?

G: Conveniently between 0.1 and 1 Teslas, depends on the thickness of the ferromagnetic films.

K: I see. So you came to the finding of this Giant Magnetic Resistance Phenomena after you had worked on crystal field theory and analyzing optical spectra of Rare Earth garnets. –I'm not an expert of this – I can't combine.

G: These phenomena are rather separated. The garnet work is not very much linked. Also the garnet work was essentially by bulk properties but the thin film work of this coupling phenomena was in thin iron film layer structures of thin iron films.

K: Where did you get this thin iron film?

G: We built it up ourselves during the course of the years. I had a very good technician who designs, thinks, plans, organizes things very effectively and I was very fortunate to

have him, otherwise that would not be possible.

K: Where did you get this nice guy? In Germany?

G: In Germany, yes.

K: Darmstadt?

G: No, that was very later on when I was already in Jülich.

K: Jülich, I see. So you moved to Jülich after Canada?

G: After Canada, I came directly to Jülich. Supervisor was Professor Zinn.

K: Where this sort of work was very popular in Jülich.

G: Basically I was supposed to work on Europium chalcogenides. So I did but I had enough freedom to try also other topics like the Brillouin spectroscopy I mentioned before. After I had found for the first time Brillouin light scattering from a surface spinwave in Europium oxide I looked at the same phenomenon in other materials like thin Fe films and layered structures including nonmagnetic interlayers. It is important to find the right balance between continuity and trying out new things. Mostly I changed only one thing at a time: either the experimental method or the material for example but not both at the same time.

K: Any practical application or physical study, eventually aiming at the practical use?

G: Not for us really, only in a sense that we would prepare to give it as a license.

K: I see. How did you come to this image of applying magnetic field changing resistivity in terms of the spin?

G: My thoughts about why I expected that I started to do that experiment, there was somewhat different from Dr. A. Fert's interpretation. My expectation was founded on the fact that when you make thin films and reduce the thickness, then you get an increase in the resistivity which is stronger than linear. Furthermore we can assume that a structure of two magnetic films separated by a metallic film due to spin polarization for electrons moving perpendicular to the sample plane is less transparent for antialignment as compared to parallel alignment. Then for antialignment we would describe this by two resistors in parallel with increased resistivity of the individual thinner films and hence increased resistivity altogether.

By that time we had antiferromagnetc interlayer exchange coupling well under control and could make such samples reproducibely. As it seemed not to be so difficult we did the experiment and the first attempt was successful

K: So experimentally you have had confidence.

G: You never know but I thought always there must be the effect. You can only argue whether it is small also or big. It is the only question how big is it. Because only from the symmetry already you see there must be an effect.

K: I see. So this is your exciting finding.

G: 1988, but for me as an important finding was 1986 because it was the year of the antiferromagnetic coupling.

K: Antiferromagnetic coupling. Very interesting. So, eventually your mottos in research, if you say something to your students when they came to the deadlock, how do you advise him?

G: My motto, in fact, is curiosity. But I don't mind to be close to application, I like application also.

K: Both, intellectual curiosity as well as looking at the application, both.

G: On the other hand for the reality in your daily life you have to consider further aspects. I mentioned already the balance between continuity and novelty. For the work in the laboratory or before the computer, I believe very much in "quick and dirty" in the beginning but rapidly more reliable and professional if there is hope that something might work.

K: I see. So you are interested in fundamental phenomena as well as application and also you're interested in acoustics as well.

G: Yes.

K: If you have a message to younger generation or next-generation, what will you say about science or future?

G: I think it's different to expect from all this experience something which is straightforward and gives a unique answer. I would not dare to say because it can be so different, the writing you do you should, for example, I was in my institute, I felt very often like a revolutionary who is working against my supervisor. So I tried to avoid that because I think it's not good, it's also not fair, you have been hired for that work and under special conditions. So it's better to be constructive and convince him that you're doing good work. But then apart from this, I think it's also important to develop something own.

K: Both are necessary, your own and also supervisor's idea.

G: Yes. I say that likely freely sometimes and I will not encourage you to neglect what the supervisor says in your work…

K: You have to take first.

G: You might already put it on to your coffin also when you do that work on your own misfortune or – he might decide one day that he can't get along this with another guy and won't support you. So you have to satisfy him reasonably, but at the same time you also should not forget it's not bad to be a revolutionary. When you insist, you have to be sure also that you are thinking along the right line, for example. These are very

vaguely what I think.

K: I see. Finally how about your hobby? I understand your hobby is musical instrument.

G: Yeah, music. It used to be more sports, when I was young I did skiing.

K: Oh, skiing?

G: Yeah. But now I am 70 and skiing is not so anymore. It's also a bit too dangerous.

K: How about tennis or something like the sport?

G: I still do lot of things, I do table tennis and once in a while also tennis, maybe next summer it will be more, I hope.

K: How about swimming?

G: Not so much.

K: And how about reading novels or books?

G: Yes.

K: Story.

G: No, not stories, but popular science. From people who try to explain phenomena qualitatively, but not so much with the mathematics.

K: It's very important, I think. Image of the things is rather important than finding calculation. First image is essential.

G: Exactly yes, that's what I want to say.

K: Things are, always you visualize image.

G: We try to find such reasoning also wherever in the little children or in discussions as they give me a physical argument, give me a physical picture.

K: Yes, physical picture, not mathematical picture.

G: Then on that one can build up a real quantitative physical picture.

K: Well, almost one hour passed. Thank you very much for a nice talk.

G: Thank you, it was my pleasure.

K: And I really appreciate.

G: Rather interesting conversation here.

Interviewer: Prof. H. Komatsu

in Prof. Grünberg office in the IMR Bldg I, December 21st, 2009

Interview with Professor Kazuyoshi YAMADA, Principal Investigator, WPI-AIMR

Hold onto challenges in your subconscious

Prof. Yamada (Y): Today I thought I would like to show you News Letter of our Laboratory, *Shimamoyou (Stripes)*. This is already No. 10 issue. I started this News Letter to familiarize science to younger generations. I always try to select the best photograph for the cover.

Prof. Komatsu (K): I didn't aware of such nice newsletters.

Y: The first issue tells how we started this News Letters. A student laid out the Japanese characters "Shimamoyo" on the computer just for fun, but the hiragana was so well fitted to the News Letter that we have been using it for every issue.

I initially asked great professors to contribute feature articles, but their writing tends to be rather formal. Recently I've switched to asking people who can write somewhat more relaxed pieces.

K: How often do you publish it?

Y: At first, I intend to publish twice a year. Now, once a year, maybe once and a half. For the last issue's feature, I asked a guest researcher at the International Frontier Center for Advanced Materials, Dr. Seung-Hun Lee, to write a message for young scientists. Working with neutrons, we often conduct research in large facilities outside the university. So I asked Dr. Lee to write about how he came to be a "nomadic scientist" traveling the world and conducting experiments. I translated his story into Japanese. It turned out to be very popular.

K: The aims of *Shimamoyou* and WPI News are similar in that we both want to familiarize people with science.

Y: Yes, that's why I recently stopped asking contribution from renowned professors. For instance, the research assistant who stopped by to say hello a while ago used to be a corporate employee. He has an interesting career, so I've asked him to write about it.

I always ask contributors not to write too much about their research, so that young readers are interested in science.

K: For WPI News, too, we avoid getting into the details of the interviewees' research. We ask topics of general interest, like what led them to start their research activities and what attracted them to science.

Y: I grew up in Kyoto until high school. I had two choices for university, Hokkaido University or Tohoku University. In high school I read several books in *Blue Backs* series, and I made up my mind to either research on snowflakes started by Dr. Ukichiro Nakaya at Hokkaido University or research on magnets developed by Dr. Kotaro Honda at Tohoku University. I was more inclined to Hokkaido but, on the verge of taking the entrance exam, started having second thoughts. Eventually I decided on Tohoku University. I lived in Sendai for 32 years, then transferred from Physics at the Faculty of Science to Kyoto University's Institute for Chemical Research in 2000. I planned to retire there, so I never dreamed of coming back to the Institute for Materials Research (IMR) only five years later. It feels as if I was drawn by fate.

K: You went to elementary and junior high school in Kyoto – whereabouts?

Y: I lived in Uzumasa, near the filming studios but in a busier area with a shopping street.

I found out later that the famous conductor Yutaka Sado lived only 20 or 30 meters away, and that we had attended the same elementary school. Also, curiously, within a two-kilometer radius of my house, there were four people including myself who researched neutrons or superconductivity and became professors. One is Mikio Takano, a former director of Kyoto University's Institute for Chemical Research and now a principal investigator of its WPI program [Institute for Integrated Cell-Material Sciences, Kyoto University (iCeMS)]. He and I lived in the same school district. Another is Shuzo Kawarazaki, who was a professor at Osaka University. Our houses were back to back. And another is Kiyoichiro Motoya, currently a professor at the Tokyo University of Science. He was one year my senior in junior high and high school, and also went on to research neutrons.

K: The short supply of Japanese neutron scientists seems to come exclusively from your neighborhood.

Y: The curious thing is it's a lower middle class neighborhood, not the kind of place you would expect to produce scholars.

I attended Sagano Senior High School, near the current tourist spot. It was a good area, only a 15-minute walk to Arashiyama.

In my days Kyoto enforced the "small district system," meaning the high school you

attended depended purely on where you lived, and you had many different types of classmates. Looking back the past, this was a good thing. Not all the students were brilliant, so to speak, so we went on to pursue a variety of careers. It was a valuable experience for me to mix with many interesting people. The public high schools in Kyoto were neither extremely prestigious nor extremely low-level. Yet all of them sent 10 or 20 graduates to the University of Tokyo or Kyoto University each year.

K: I think you've just pinpointed one of the vulnerabilities of Japan's elite education system. When did you decide to pursue a career in science?

Y: I made the final decision when I chose my university, although I suppose I was always fond of science. I have a brother six years my elder, who used to come home and teach me what he had just learned in high school. He would explain how to prove the Pythagorean theorem, for instance. I didn't understand everything he said, but he inspired a vague interest in me.

K: Did your brother also become a scientist?

Y: He went into engineering. I was influenced by him a lot. Also monthly magazines for elementary students implanted me an interest for nature. I clearly remember sending a letter to one of the monthly magazines. I asked why snowflakes come in many different shapes but snow crystals always come in six-fold symmetry (hexagons). They never replied. Later I discovered that's a difficult question to answer even today.

I was a cheeky student in junior high and high school, a handful for my teachers. On top of the small district system, the governor of Kyoto, Torazo Ninagawa of the Communist Party, was a big advocate of equality. Individual schools had lost their reputation for producing university entrants, so parents who wanted their children to enter a good university sent them to a private school after regular school hours. I was opposed to the whole idea of ambitious second- or third-year junior high school students going to these private schools, and instead joined the track and field team. I didn't like kids who were studying all the time. I preferred mixing with outcast types.

K: What track and field events did you compete in?

Y: In junior high school I wasn't especially good at any one event, so I did multiple-event competitions like the triathlon (high jump, shot put, and 100-meter sprint). My mother died soon after I entered high school, and my father wanted me to help out at the small candy store we owned. So I took a break from track and field from around my junior year.

I started track and field again in university. This time, rather than running, I competed mainly in throwing events like the javelin, discus and hammer. Professor

Yuichiro Nishina at the IMR was a team advisor when I first joined. Hiromasa Ito, who later became director of the Research Institute of Electrical Communication (RIEC), was four years my senior and a long distance runner.

K: You had quite a wide circle of friends.

Why did you choose neutrons?

Y: I chose neutrons more or less by accident. I wanted to study magnets, and we did a game of rock-paper-scissors (*janken*) to decide which course to take in our fourth year. I got Professor Yoshikazu Ishikawa's course.

K: Professor Ishikawa died very young. So you started studying neutrons before he passed away?

Y: I run the third generation of the Ishikawa Lab. Professor Ishikawa came to Tohoku University in his early 40s, I believe. I joined his lab when he was about 45, and stayed for about ten years. He was full of vigor and liked mountain climbing and skiing, so his death came as a shock. This was when I had completed my doctorate and joined the Laboratory of Nuclear Science (LNS – Research Center for Electron Photon Science). I was one of the candidates of a long-term visitor for a US-Japan cooperative project, and was preparing for a short-term trip prior to long-term dispatch. Professor Ishikawa lost consciousness a couple of weeks before I was to depart. I wondered whether I should cancel the trip under the circumstances, but decided to go when I found out that Professor Endoh was named successor.

K: Where did you go on that trip?

Y: Brookhaven National Laboratory. I worked with the famed scientist Dr. Gen Shirane for the first time, which got me deeper into the world of neutrons.

K: I only know Dr. Shirane by name, but he is very famous.

Y: He certainly is. I would say more than half of Japan's leading neutron researchers today were influenced by Dr. Shirane. That's phenomenal.

I stayed a few months in Long Island. Then high-temperature superconductivity was discovered soon after I returned to Japan, so I was sent back for another year or so.

K: How did you like Brookhaven?

Y: I loved it. Everyone liked tennis; we played everyday. Dr. Shirane's motto was "play hard, study hard." So even though work kept us busy seven days a week, we also went all out to enjoy our precious time off.

K: I also like tennis; in fact, I played this morning. I understand Professor Endoh likes tennis, too. Do you invite each other to play often?

Y: Yes, he's one of the reasons I got started. It was right before the tennis boom in Japan. A while later, women carried their rackets to go to the office. I played a lot of tennis at Brookhaven. One time they arranged a doubles match on the day I landed.

K: They never gave you a chance to get jet-lagged! I find sports like tennis because I can continue playing at any age.

Y: I also appreciate the chance to meet people in different fields or lines of work. I didn't work as hard at my job as I did at building connections.

K: What did you do in your doctoral work?

Y: I completed my doctoral degree at the Ishikawa Lab. When Professor Ishikawa asked what I wanted to research, since I was interested in magnets, I said liquid magnets. I didn't even know if such a thing existed. Professor Ishikawa said it didn't exist yet – what did exist, and what I should research, was amorphous metal. At the time, no one at the Ishikawa Lab was researching amorphous metal.

During my master's course, the Masumoto Lab had started developing amorphous tape, so I asked them for samples some 1 mm wide that I could measure. It was decided that I would do joint research with the Masumoto Lab for my master's, and research neutrons in amorphous material for my doctoral work. The LNS was working on pulsed neutrons, and the Kenji Suzuki Group aggressively on liquid and amorphous metal.

At the time, we mixed transition metals with silicon and germanium from semiconductors, and measured the structure of the resulting metal for magnetism and conductivity. Because transition metals couldn't be mixed with ordinary crystals, we made the samples amorphous before conducting experiments. Kyoto University's Professor Hirohisa Endo was doing similar research, and I asked our Professor Endoh, at the Ishikawa Lab, to introduce me so I could use the evaporation system in Kyoto and make samples. I used to visit my family in Kyoto during summer vacation and the

New Year's break, but only spend a couple of days at home. The rest of the time I slept over at the Endo Lab at Kyoto University making samples.

K: You made the samples with an evaporation system, and not a sputtering system?

Y: It was an evaporation system. The tungsten wire used to break after several runs. The heater would shut down after injecting five or six small rods of the raw material, so I had to recreate a vacuum and restart the heater. I repeated this process numberless time. Making a ten-gram sample from several grams of neutrons sounds crazy. But that's what I did.

The strength at which neutrons scatter varies depending on the isotope. The same material composition shows a different pattern of scattering with and without an isotope. Appropriately processed, it is possible to analyze a substructure (partial structure). So I had Professor Ishikawa buy me nickel isotopes. It must have cost 400,000 yen a gram back then. Most of the money Professor Ishikawa spent on me was for isotope samples. It was a simple process of inserting the sample in a vacuum, melting it, and quenching. But my hands shook every time because if any air leaks in and oxidizes the sample, I would have wasted 400,000 yen for every gram I ruined.

K: Was it a large bell jar?

Y: It was a regular-sized diffusion-class bell jar. I would break down the hand-made sample and insert small pieces of it into the target, spin the wheels one by one by hand, cool the sample, melt it once every 15 minutes or so… Over and over again while lying on the bed at the Endo Lab.

K: You must have needed a lot of physical strength to keep up the work.

Y: Yes, and also mental strength. You had to be a natural for caring about the details.

K: A natural who performs those tasks humming a tune. So with neutrons, it takes a lot of stamina to first make samples.

Y: Professor Yao who was taking his master's course at the time and took over the Endo Lab at Kyoto University. He says each time before a student sets out on the tedious task of making samples, he tells about my hard working experiments.

K: Were you able to do something interesting with the samples?

Y: Using isotopes and creating structural details attracted some attention in the neutron research field, but it wasn't particularly sensational.

K: But certainly you felt your efforts were rewarded?

Y: It made me very happy when in my doctoral work I made neutron apparatuses and samples and conducted experiments and analyses at the LNS, and I discovered that I would ultimately produce the results that I did. I might have been happier if those results caused a wide sensation, but they didn't. What I did wasn't as hot a topic as

high-temperature superconductivity in those days.

K: Research is about the accumulation of unnoticed efforts. After you got your doctorate, where did you work?

Y: I became a post-doc at the High Energy Accelerator Research Organization (KEK) to attend a project for construction of a pulsed neutron source.

K: Did you live in Tsukuba?

Y: I was based at the Ishikawa Lab and traveled to the KEK. Around 5 p.m. a group of us including Professor Ishikawa and Professor Watanabe at the LNS went by car.

A few months later, I applied for an assistant post at the LNS. I was hired to do work half on pulsed neutrons, half on synchrotron radiation and atomic nuclei, for which they were preparing to launch a project.

K: A classmate of mine who studied radiochemistry at Kanazawa University sometimes worked with the LNS.

Y: Radiochemistry – he must have done radiation analyses. That's still in progress

K: You seem to have paced yourself in terms of work. What about marriage?

Y: I had a scholarship for my doctoral course, but it was stopped after April for the ten months or so that I was late getting the degree. I got married around that time, as I needed for my wife to support me.

I also did all kinds of part-time jobs. Private teacher, guest lecturer, restaurants, opening and closing curtains at a puppet theater, knocking down old houses… In the second grade of university I put down and away futon mattresses at an inn at Sakunami hot springs as a live-in worker. The job offered three meals a day. In the daytime I was free to use any vacant guestroom, so I took my textbooks and studied in perfect privacy. If I got tired, I relaxed in the hot springs. My boss in the inn asked us to collect leftover sake, so we drank every night until midnight. I lived like that for two or three weeks.

K: Wow. Based on your prolific experience, what advice would you give to younger people today?

Y: Younger people today probably aren't at leisure to follow my advice I could offer them. The staff members at my lab, for instance, are too busy. They're constantly pressed to produce results and being evaluated. When I first joined the LNS, there hadn't been a thesis in several years. If that happened today, I would be fired.

K: In our days, university didn't bring to mind the image of writing thesis after thesis and being evaluated.

Y: But now, even post-docs are too busy. I feel sorry for today's younger people. If I were asked how to change the situation, I'm not sure I would have an answer. But it's a big problem that students are being forced to do work that leads to a thesis, and they don't have room to research in depth the little things that interest them.

K: I once suggested a certain theme to a group of young students who came to my lab, and they asked whether they could write a thesis on it. I told them you've got to research it to find out whether you can write a thesis or not. If you knew from the beginning, there's no need for research. The American style of evaluation is a problem for the whole of Japan.

Y: It really is. The US is a competitive society, but Japan seems slightly different. What do you think is the difference?

K: The US has wider opportunities for employment.

Y: Yes, and maybe the US is also more inherently dynamical than Japan is. There's no resistance to changing jobs.

K: The Japanese see someone leaving as disloyal, unreliable. But the Americans see someone staying at one place forever as unmotivated.

Y: That's a substantial difference. Unlike the US, there is surprisingly little merit in transferring in Japan. The salary is different, too. When I moved back from Kyoto to Sendai, my urban area allowance was cut drastically. My retirement allowance is carried over as long as I transfer from one university to another, but it will be slashed the moment I transfer to a different organization. It will bring few benefits. The system needs straightening out.

The incorporation of national universities, and the fixed term system, was supposed to have been a mechanism for encouraging personnel to transfer. But I think it backfired and triggered localization. Not all universities adhere to the system, and some even work around it to keep competent personnel. That is, they started sorting out people into those they want to send away and those they want to keep. Young people are sensitive to this kind of manipulation. It's a difficult time for them to relax and concentrate on their research.

K: The WPI calls it "fusion," but in reality there is no space or capacity for working with people in different fields. It's a difficult issue. The social system overall is inflexible.

Even hiring people can't be done by top management alone; they have to hold a meeting. But all the ceremony is just a way to rub off the responsibility in case something goes wrong. When I was at the University of London, I thought their way of hiring post-docs was strict. They don't stand over you and tell you what to do.

Instead, when your contract is about to expire, the boss comes to you and says straight out, “You can go. Thank you. Good bye,” or shakes your hand and says, “You can stay.” The dryness was shocking. The researcher, too, says, “OK, thank you.” It was a tremendously competitive society. It boils down to results in the end. The Japanese are too humane to do that. They could be sued.

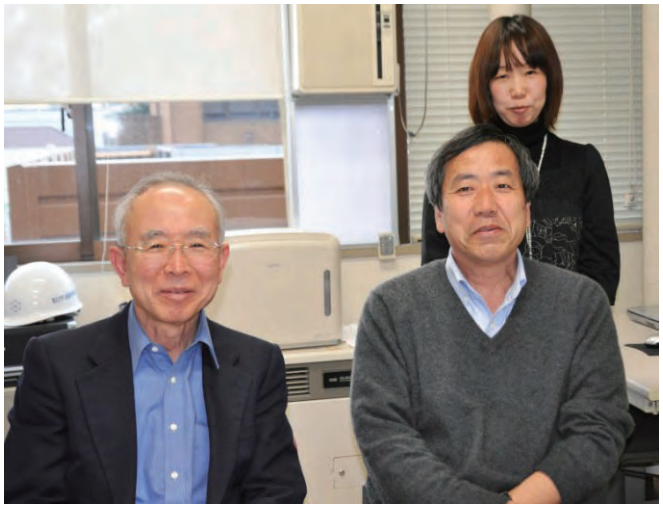
Y: I don’t think dryness is necessarily bad, but a follow-up mechanism has to be in place or the consequences could be disastrous. Even if one organization doesn’t renew the contract, if the researcher is motivated and has several other prospective employers, that’s a good system.

But the truth is, being let go in a year sounds negative. Most organizations don’t want to hire someone who was let go at all, and that frightens young people. Transferring on a regular basis would function if the society recognizes it as a normal thing, and creates a system of accepting mid-career personnel.

K: The ideal mood would be for everyone else to have experienced a job change, and you could play as many return matches as you want. Right now, however, if you go down once you can never get back up again. Active, healthy job changing is impossible unless the overall atmosphere of the society changes.

You’ve told me so many interesting stories today. My impression was that you’re a man of many interests. The story about “play hard, study hard” reminded me of Dr. Yoshio Nishina, Professor Yuichiro Nishina’s father and the former president of RIKEN. Dr. Sin-Itiro Tomonaga once told me that he went to RIKEN and asked for the president, and was surprised to be told to go to the tennis court. He said the most painful experience was Dr. Nishina telling him, “Do what you want.” Dr. Tomonaga was a diligent man, so he turned it over and over in his mind what he should study.

Y: I always think it’s a good idea to store challenges in the corner of your mind. Don’t obsess about a unique challenge all the time but let it pop up sometimes, store it away again, remember it again. And after a while, a solution will come to you. It seems that the younger people today are too pressed to be efficient. They’re not at leisure to do that.



Like tennis. Sometimes I play with people who practice every day. But they haven’t improved, rather they play worse than the last time.

I recently realized why. They play tennis so much that they're not giving themselves time to improve. I think you brush up on your tennis skills when you're not playing. Your mind or body remembers the challenges you're facing, and works them out for you in your subconscious. So you actually take a step toward improvement when you take a break from tennis or you're asleep.

This got me thinking about the ideal way to train for sports. If you train the wrong way, making mistakes becomes a habit. This defeats the original purpose of training. Ideally, training should fix your mistakes and improve your form. Whereas if you go out day after day and repeat the same mistakes, you acquire the wrong habits. It's much better to stop and do image training by looking at pictures of good players and studying their correct form. Players who never get better are merely keeping at it without stopping to reflect. They're forming habits of their own mistakes.

This goes for physics as well. Nothing good comes of merely researching day in and day out. If you're deadlocked, forget about it. But not forever. Keep it in the corner of your mind and let it pop up from time to time, look at it from a different angle. As with tennis, it's a question of why you're training (researching) in the first place.

K: With tennis, it's difficult to know what to fix without a coach. The racket has changed so much that you have to hold it at an entirely different angle from the wood racket I first used. A coach I know says hitting the ball has evolved into a more soft tennis-style. Even coaches' textbooks, which used to advise holding the racket at a level and pushing the ball forward, recently recommend facing forward and snapping with the wrist.

Y: Tennis is a curious sport in that sense. I'm also attracted to golf and plan to take it up once my body stops moving, but as long as my body moves I want to continue playing tennis – because it has both aspects, technical and mental. Mental pressure is essential in sports. Without it, you're deprived of half the fun. You could be leading a game 5 to 0 but the opponent could still catch up. It's happened to me many times. I've thought I've won a tournament, let my tension loose, and lost. It's never the tournaments you win that you remember; always the ones you lose.

K: I had a lot of fun talking to you today. You have so many sides to your character. I've learned that the accumulation of seemingly pointless work is key to keeping a researcher healthy. Authenticity is built on sundry knowledge. Thank you.

Interviewer: Prof. H. Komatsu

at Yamada Lab, IMR Bldg. 2, January 18th, 2010

WPI-AIMR PI　山田和芳教授にきく
(Interview with Professor Kazuyoshi YAMADA－Japanese version)

寝ても覚めても問題を離さない

山田：私が今日お見せしようと思っていたのは、うちの研究室で発行しているニュースレター「しまもよう」です。今回で第 10 号くらいになります。発行のきっかけは、若い世代にちょっとはサイエンスに familiar になってほしいということでした。表紙の写真が一番いいところで、なるべくきれいな写真を掲載するようにしています。
小松：知りませんでした。こんな立派なものがあるのですね。
山田：創刊号にはどうして発行することになったか理由が書かれています。題字の「しまもよう」は学生がパソコンで適当に書いたのですが、字のバランスがよかったので創刊号からずっとこれを使っています。
　創刊当初は大先生から特別寄稿をいただいていましたが、みなさん書かれることが少し堅いので最近はそれをやめて、もう少し柔らかく書いてくれる人にお願いしています。
小松：どのくらいのインターバルで発行しているのですか。
山田：始めは年に二回と頑張っていましたが、最近では年一回か一回半です。前回のこの記事は WPI-IFCAM の客員研究員として来た Dr. Lee, Seung-Hun に若い人へのメッセージとして書いてもらったものです。我々中性子の仕事は外の大型施設で研究することが多いので、世界中を実験しに渡り歩く「遊牧民」として、どのように彼が今の仕事をやるようになったのかを書いてくれたものを、私が適当に翻訳しました。これは非常に評判が良かったです。
小松：親しみを持ってもらうということで、まさしく WPI News の狙いと重なっていますね。
山田：最近では超大物よりもこういう人に書いてもらっています。先ほど挨拶に来た研究補佐員の方も元々は企業に勤めておられたのですが、非常に面白い経歴を持っていて、彼にも書いてもらいました。研究のことはあまり載せず、若い人たちにサイエンスに親しんでもらうようにしています。
小松：WPI News でも研究のことに細かくは触れず、一般の人が興味を持つような、どういったきっかけで研究を始めたのか、サイエンスに興味を持ったのかということを聞いています。
山田：私は高校までは京都で育ちました。大学は、さてどこに行こうかと考えた時に、北海道大学と東北大学の二つ候補がありました。当時から今のブルーバックスのような本をよく読んでいて、北海道大学に行くなら中谷宇吉郎先生の雪の研究、東北大学なら本多光太郎先生の磁石の研究のどちらかにしようと思っていました。北海道に行きたかったので

すが、受験をする間際になって青函連絡船に乗ることを迷い始めて、結局は東北大学にしました。その後 32 年間仙台に住み、2000 年に理学部の物理から京都大学の化学研究所に移りました。そこで定年を迎えるつもりだったので、移って 5 年後に金研に来るとは思いもしませんでした。何かの縁を感じますね。

小松：小、中学校の頃も京都だったのですね。京都のどの辺に通われましたか。

山田：京都の太秦です。撮影所にも近いのですが自宅があったのは商店街などがあってごちゃごちゃしたところです。

後でわかったのですが、有名な指揮者の佐渡裕さんは我が家から 2、30 メートルの所に住んでいて、同じ小学校を出ました。もう一つ面白いことに、我が家から半径 2 キロ以内に中性子や超伝導の研究をしていて、教授になった人が私を入れて 4 人もいます。一人は京大の化学研究所の所長になられ、今は京大の WPI の高野幹夫さんで、彼は私と同じ学区でした。自宅の裏には、河原崎修三さんという大阪大学の教授をされていた方も住んでいました。中学、高校の一年先輩には東京理科大学で教授をされている元屋清一郎先生がいますが、彼も中性子をやっています。

小松：日本の中性子屋さんはそんなに多くはいないのですが、その一帯に集中していますね。

山田：しかも、私の住んでいたあたりは下町で学者が出るような雰囲気ではないので非常に面白いですね。

高校は今では観光スポットになっている嵐山・嵯峨野の近くの嵯峨野高校です。嵐山までに行くのにも歩いて 15 分くらいで、とても環境のいいところでした。

小松：いいところですね。私は嵐山には新婚旅行で行きました。

山田：京都の高校は私の頃には小学区制で、住んでいる地域で行く高校が決まっていました。だからいろいろな生徒がいて、今考えるとそれがよかった。勉強ができる子だけではなかったので、卒業生の仕事の幅も非常に広いです。そこで面白い人とたくさん付き合ったことが私にとってはとても重要だったと思っています。超有名高はなかったけれど、ものすごく下の高校もなかった。公立高校はどの学校からも東大・京大に 10〜20 名くらいは入っていました。

小松：今のエリート教育の弱点の一つを聞いたように思いますね。それから、サイエンスに行こうと思ったのはいつごろですか。

山田：やはり大学を選んだ時です。その前からも好きなことは好きでした。六つ上の兄がいて、彼が高校時代に学校で習ってきたことをすぐに私に教えてくれた影響で興味はありました。例えばピタゴラスの定理の証明のやり方などを説明してくれて、わからないけれどなんとなく面白いと思いました。

小松：お兄さんは理科の方に行かれたのですか。

山田：兄は工学部へ行きました。そういった影響もあり、本をよく読んでいました。ブルーバックス、特に相対性理論から本多光太郎の磁性の話、雪の結晶についてなどいろいろ

です。

小学校時代には月刊誌に質問を投稿したことをいまだによく覚えています。雪にはいろいろな形があるのに、雪の結晶は全て六回対称（六角形）のような形をしているのはどうしてなのかと質問をしましたが、全く答えがなかった。後になって、いまだにそれは難しい質問だということが分かりました。

中学・高校時代は、生意気で先生の手に負えない人間でした。京都は小学区制で、しかも当時は共産党の蜷川虎三さんが府知事で皆平等にやるというので学校自身の進学校としての実力がなく、子供をいい学校に行かせたい家庭はみんな塾に行かせていました。中学校二、三年生にもなるといい大学に行きたい人は塾に行っていたのですが、私はむしろそういったことに反発して、陸上部に入ってクラブ活動ばかりしていました。勉強ばかりしている人はあまり好きじゃなかった。むしろちょっと外れたような人とばかり付き合っていました。

小松：陸上ではどんな競技をされていましたか。

山田：中学時代にはずば抜けてできる種目がなかったので、三種競技（走り高跳び、砲丸投げ、100 メートル）などの混成種目をやっていました。高校に入学してすぐに母が亡くなり、実家が駄菓子屋をしていたので、父に陸上をやめて手伝えと言われて高校二年生くらいで一度陸上をやめました。

大学に入ってからまた陸上を再開しました。大学では走るよりも投擲（とうてき）が主で、槍、円盤、ハンマーなどをやりました。入った当時は金研の仁科雄一郎先生が陸上部の顧問をされていました。それから通研の所長もされた伊藤弘昌さんが私の四つくらい先輩で、彼は長距離をやっていました。

小松：それでは付き合いが広いですね。

山田：最近では JST でプロジェクトの取りまとめをしている同級生から急に連絡が来たり、昨日も遠藤先生の古希のお祝いを遠刈田でしたのですが、同級生から話を聞いたりしていろいろなつながりもありますね。

小松：そうですね。そうして、だんだんサイエンスの方に進まれていったわけですが、ニュートロンを選んだのはどうしてですか。

山田：ニュートロンを選んだのは偶然にも等しいです。磁石に興味があって、大学四年の講座配属の時にジャンケンで石川義和先生の講座に入ったことがきっかけです。

小松：石川先生はずいぶん若くに亡くなりましたが、中性子を始められたのは石川先生が亡くなる前ですか。

山田：石川研ができてから私で三代目です。石川先生が東北大に来られたのは 40 代前半だと思いますが、先生が 45 歳くらいの時に私が石川研に入って、それから 10 年くらいいました。山登りやスキーが好きな元気な先生だったので、亡くなられた時はショックでした。ドクターが終わって核理研（原子核理学研究施設）に勤めていた頃、日米協力で長期派遣する人を探しているというので私が候補の一人になり、長期の前に短期で行く準備をして

いました。ところが出発の前に石川先生が倒れられたので、行っていいものなのかと非常に悩みました。結局は遠藤さんが後を継がれるというので行くことにしました。

小松：その時はどこへいらっしゃったのですか。

山田：ブルックヘブン国立研究所です。白根元先生という非常に有名な先生がいらっしゃいました。その時に初めて白根先生にお会いして、ニュートロンにもっと足を突っ込むことになりました。

小松：私は白根先生のお名前しか知りませんが、非常に有名な先生ですね。

山田：そうですね。今、日本でニュートロンの指導的な立場になっている人の半分以上は白根先生から大きな影響を受けているのではないでしょうか。すごいことだと思います。

ブルックヘブンに数カ月滞在し、帰ってきたら高温超伝導が発見されて、それでまた行けと言われて一年くらい行きました。

小松：ブルックヘブンの印象はどうですか。

山田：よかったですね。テニス大好き人間ばかりで、毎日のようにテニスをしていました。白根先生のモットーが「よく遊びよく学べ」でしたので、土日もなく仕事は忙しかったですが、遊ぶ時は徹底的に遊びました。

小松：私もテニスが好きで、今日もテニスをしてきました。遠藤さんもテニスが好きですので、よく誘われたのではないですか。

山田：そうですね。彼がテニスをやっていたこともテニスを始めた理由の一つです。あの頃はテニスがブームになる直前で、その後しばらくすると会社へ行くのにラケットを持っていった女性までいたような時代です。ブルックヘブンではかなりテニスをしました。私がブルックヘブンへ行くと、着いたその日にダブルスがアレンジされていることもありました。

小松：時差も関係なしですね（笑）。テニスのような道具を使うスポーツは年をとってもできるからいいですね。

山田：それと、分野や仕事が違う人と、テニスを通じて知り合えたことは本当にありがたかったですね。仕事はあまり真っ当にやっていなかったのですが、そういったことはよくやっていました。

小松：ドクターワークは何をされましたか。

山田：ドクターでは石川研でしたが、石川先生に何をやりたいか聞かれた時に、磁石に興味があったので液体の磁石をやりたいと言いました。そんなのものがあるかどうかは知らなかったのですが。石川先生にそんなものはないでしょうかと聞くと、今のところそんなものはないけれどもアモルファスだったらあるからアモルファスをやれと言われました。当時、石川研ではアモルファスをやっている人はいませんでした。

マスターの時は、増本研究室がアモルファスのテープを作ってやり始めた頃でした。そこで幅が 1mm 程度のものを分けてもらって、それを測ったりしました。マスターの仕事は増本先生のところと共同研究をして、ドクターではアモルファスをニュートロンでやろうと

いう話になりました。核理研で丁度パルスニュートロンがあり、鈴木謙爾グループが精力的に液体やアモルファスの仕事をやっておられたので、私は石川研としてその研究をしに行きました。

ただ当時のサンプルは半導体のシリコンやゲルマニウムの中に遷移金属を入れて、最終的にメタルになったものの磁性と伝導などを構造を測りながらやるというものでした。普通の結晶だと遷移金属が入らないので、アモルファスにして実験をしました。その頃、京都大学の遠藤裕久先生が近い系をやっておられて、石川研の遠藤先生の口利きで、そこの蒸着装置を使ってサンプルを作りました。私の実家は京都なので、夏休みや正月に京都に帰ると家には一日、二日いただけで、あとは遠藤研に泊まり込んでずっとサンプルを作っていました。

小松：それはスパッタ装置ではなくて蒸着装置で作っていたのですか。

山田：蒸着装置です。タングステン線のワイヤーが何回かやると切れてしまいます。小さく切った原料棒を五、六回ぽっと飛ばすとヒーターが切れてしまうので、また真空を破ってヒーターをつけ直して、という作業を延々と繰り返していました。ニュートロンで数グラムから 10 グラムのサンプルを作るのはもう気違いじみたことなので、それをずっとやっていましたね。

しかも中性子はアイソトープで散乱される強さが変わります。同じ物質の組成でもアイソトープを使ったものと使っていないもので散乱パターンが異なってきます。それを適当に処理すると、いわゆる部分構造が出せるので、石川先生にニッケルのアイソトープを買ってもらいました。当時は１グラム４０万円だったと思います。石川先生に出してもらった金額の大半はアイソトープです。ただ真空封入をし、溶かしてクエンチしてというプロセスで合金を作るのですが、１グラム４０万円の試料を使うと、空気を入れて酸化させて失敗してしまったらそれで終わりなので手が震えました。

小松：大きいベルジャーだったのですか？

山田：ごく普通のベルジャーでした。ディフュージョンクラスです。中に小さく砕いた手作りの試料を解体させてターゲットの中に入れ、手で回すようなものを一つ一つ回して、一度冷まして、１５分に一回くらい溶かして、というのを遠藤研の仮眠ベッドに横になりながら延々とやりました。

小松：相当な体力がないとできないですね。

山田：体力もそうですが、そういったことを気にするような性格だとできないですね。

小松：鼻歌交じりでできるような性格でないと。ではニュートロンの場合には試料作りにまず大変な体力がいるわけですね。

山田：当時マスターだった八尾君が遠藤研を引き継いで今でも京大にいるのですが、学生に面倒な試料を作らせようとする時には、まず私の話を出して「昔こんな人がいた…」と説明してから始めるそうです。

小松：それで、そのサンプルで面白いことができましたか。

山田：ニュートロンでアイソトープを本格的に使って、構造のディテールを出すことはその業界では割と、注目されたのですが、非常にセンセーショナルだという感じはしませんでした。

小松：山田先生ご自身では苦労が報われたという感じはあったでしょう。

山田：ドクターワークの時には、核理研で中性子の装置やサンプルを自分で作って実験・解析をし、最終的にこういう結果が出ることが見えてきた時には、非常にうれしかったです。世の中にとってそれが非常にセンショーナルな結果であればなおいいのかもしれませんが、当時の高温超伝導の分野ほどはそれ自体がトピックス的な話でもなかったので、そうでもありませんでした。

小松：研究と言うのはそういった目に見えないことの積み重ねですね。ドクターの後、職はどうされましたか。

山田：ドクターを取るのが１０ヶ月くらい遅れていたのですぐに職もなく、割とのんびりやりました。KEK（高エネルギー加速器研究機構）にパルス中性子の線源とか装置の建設の計画が走っていたので、KEK のポスドクになりました。

小松：では筑波にいらしたのですか。

山田：石川研にいて、KEK に出かけていくという形でした。石川先生や核理研の渡辺先生たちと午後５時くらいになったら車で行きました。

その何ヶ月か後に、核理研に助手のポストがあるというのでアプライしました。核理研ではパルス中性子の仕事が半分と、将来計画が立ち上がろうとしていた放射光、原子核の仕事が半分として雇われました。

小松：私の同級生で金沢大学の放射化学にいた人が、時々核理研にお世話になっていました。

山田：放射化学、放射分析ですね。そちらはまだ続いていますが、中性子関連は、KEK に新しいパルス中性子源ができると、そちらに主力が移りました。

小松：なかなか悠々とされていた感じがありますが、結婚はどうされましたか。

山田：ドクターの期間は奨学金が出ていたのですが、１０ヶ月くらい延びたので、４月以降は出なくなってしまった。そこからはしばらく女房の世話にならないといけなくて、それもあってその頃に結婚しました。

私も学生時代にはいろいろなアルバイトをしていました。今の学生よりもはるかにいろいろな仕事をしたと思います。家庭教師や非常勤講師、レストラン、人形劇の緞帳（どんちょう）の上げ下げ、家の解体工事など、様々な職種です。作並の旅館に三食付きの住み込みで布団の上げ下ろしもしました。昼間はどの部屋に行ってもいいというので教科書を持ち込んで悠々と勉強をして、疲れたら温泉に入って。宴会で余った酒を集める人がいて、毎日酒盛りでした。そういう生活を二、三週間しました。

小松：すごいですね。そういった経験をもとに今の若い人にアドバイスをするとしたらどんなことがありますか。

山田：アドバイスというよりは、今はそういったことができないですからね。例えば自分の研究室のスタッフを見ていても、忙しすぎます。各所から業績、評価を求められる。私が核理研に入った当初のことを考えると、論文も数年間出ていませんでしたし、今だったら首になっていただろうと思います。

小松：しかし昔は大学とはそういうものだというイメージがありましたね。ガツガツ論文を書いて評価されるなんてとんでもない、という。

山田：今の若い人は、ポスドクも含めて忙しすぎて本当に大変だと可哀そうに思います。どういう形でそれを変えられるかと聞かれればあまり自信はありませんが、追い立てられるように論文になる仕事をしなければいけないので、面白いことをさらに突っ込んで深くやっていく余裕がない。これはとても大きな問題だと思います。

小松：昔、研究室に若い連中が入ってきて、このテーマはどうだというと「先生、それで論文は書けますか」と言う。書けるか書けないか、わからないから研究するんだと言いました。始めからわかっていたら研究の必要はありません。このアメリカ方式の評価スタイルというのは日本全体の問題ですね。

山田：本当にそうですね。アメリカの人はそういった競争社会の中にいますが、今の日本の若い人ともちょっと違うように思います。あれは何が違うのでしょう。

小松：雇用の間口が広いのもあるのではないでしょうか。

山田：それもあるでしょうし、日本と比較して元々ダイナミカルなのではないかという気がします。職場を動くことに対しての抵抗が全くないです。

小松：日本の場合は、移っていく人間に対して尻が軽い、信用ならん、となってしまいますよね。向こうでは逆に同じところにずっといるとお前は何をやっているんだ、となる。

山田：そういうところが若干違いますね。逆に移ってプラスになることは、日本では意外と少ないです。給料に関してもそうです。京都からこちらに戻ってくる際には都市手当が大幅に減ってしまった。それから大学から大学に移れば退職金はキープされますが、大学から別の機構に行くと途端に退職金が減ってしまう。移ることのメリットがほとんどないですね。だからそういうところもきちんとする必要があります。

大学法人化の際に、任期制も含めて、人が動くべきであるという仕組みを作りましたが、全部が全部そうなってはいないし、逆に残したい人は何とかして残すという、局在化が起こってしまったように思います。外に出てもらう人と、残したい人を仕分け始めてしまった。若い人はそういったことを敏感に感じ取るので、のびのびとした研究がしづらい時代になってしまいました。

小松：WPI でもフュージョンと言っていますが、違う分野の人と一緒にやるにはゆとりも無いし、なかなか頭が働かない。難しい問題です。社会のシステム全体が堅いですね。

人を雇うにしても、トップの判断だけではなく、会議などを開かなくてはいけない。そうした儀式は何か問題が起きた時の責任分散ですね。ロンドン大学にいた時、ポスドクの雇い方で私が厳しいと思ったのは、常に「やれ、やれ」と言うのではなく、契約期限が近く

なったらボスが直接、「君はもういいよ、ありがとう。さようなら」もしくは「君は残れ」と握手する。こんなにドライにやるものかと驚きました。言われた方も「わかった、サンキュウ」と。すごい競争社会だと思いました。最後に結果を問うんです。そういうことは日本では「人情」などといって、とてもできないですね、訴えられたりすることもありますから。

山田：ドライにできるのであればやってもいいと思うのですが、フォローする仕組みができていない段階でそうしてしまうと、凄いことになってしまいます。辞めても、本人にやる気さえあれば、他の所で受け入れられる可能性がいくつかあるのであれば、私はそれでもいいと思うのですが。

今は「一年で辞めさせられた」という情報がものすごくネガティブに伝わります。そんなことがあった人間は自分のところでは採りたくないという姿勢のところばかりなので、若い人は皆それを恐れているわけです。世の中がそれをごく普通のことだと認めて、受け入れる体制ができれば機能すると思います。

小松：そんなことは誰でも経験することだと、何度でもリターンマッチをできるようなムードがあればいいと思います。今は一回ダウンしたらもう立ち上がれない。社会全体にそういう雰囲気がない限り、生き生きした交流はとてもできないですね。

今日は面白いお話をたくさん伺いましたが、これまでのお話をうかがっていると先生はいろいろな趣味がおありのようですね。よく遊びよく学べ、というお話を聞いて、仁科雄一郎先生のお父さんで、理化学研究所の所長をされていた仁科芳雄さんを思い出しました。朝永振一郎先生の話では、理研に行って所長はどこだと聞くと「テニスコートにいるらしいですよ」と言われてびっくりしたそうです。そして仁科さんから「お前、好きなことをやれ」と言われたことが一番つらかったそうで、朝永さんは真面目な人なので何をやったらいいのかと必死で考えたそうです。

山田：常に頭の隅っこに問題を抱え続けて、四六時中考えるのではなく、ある時にぱっと思い出し、仕舞っておく、また思い出す、ということを繰り返して、ある時にいいアイデアが出てくることがあります。効率を問われる今の若い人にはそれをやる余裕がなくなっている気がします。

それはテニスに通じているように最近思います。毎日かかさずテニスをされている方々と時々一緒にテニスをしてみると、全然上達していない、むしろ下手になっていることがあります。それがなぜなのかが最近分かりました。みなさんテニスをしすぎているから、上手になる暇がないのです。テニスは、やっていない時に上手になるものだと私は思います。自分の頭や体の中に何かがあれば、テニスをしていない時や寝ている時にそれが作用して、上手くなるのだと思います。

さらに、スポーツの練習というのは一体何なのかを最近考えました。下手な練習をするとミスが癖になってしまう。それでは本来の練習にはなっていないわけです。本当の練習とはミスをしないように直したり矯正したりすることですが、同じミスを繰り返しているか

らミスが癖になる。それならば一旦練習をやめて、上手な人のフォームや写真を見てイメージトレーニングをする方がましです。毎日考えずにやっている人は自分のミスを癖にしている。だからいつまで続けていても上手くならないのです。

物理も同じことです。何も考えずにがむしゃらにやっていても、いいものは出てきません。デッドロックに乗り上げたら一旦忘れる。ただし本当に忘れるのではなく、どこか頭の隅っこに入れておいて、事あるごとに出してきて別の視点から見てみる。テニスと同じで、何のための練習（思考）なのかということです。

小松：練習をするにも、コーチがいないとどこを直していいかわかりませんね。テニスは道具がずいぶん変わり、昔のウッドを使っていた頃の打ち方とは全然違います。コーチの話を聞いていると、コーチの教本もどんどん変わっていっているようで、軟庭的な打ち方になってきています。昔はラケットを水平にして押せと言っていたのが今は正面を向いて手首から打ち込む、という具合です。

山田：テニスはそういった意味で非常に面白いと思います。私はゴルフにも非常に興味がありまして、体が動かなくなってきたらゴルフがいいかなと思っていますが、体が動く間はやはりテニスがいいですね。やっぱりテクニカルな面とメンタルな面があるからです。スポーツではそれが絶対に必要で、メンタルなプレッシャーがかからないようなスポーツは面白くありません。５-０でリードをしていても逆転される場合もあります。私はその経験を何回もしています。大会などに出て、これは勝ったと思っていると気の緩みで一気に負けてしまう。勝った試合は全然覚えていませんが、そういう負けた試合は覚えています。

小松：今日は本当楽しいお話をさせていただきました。山田先生の幅の広さをつくづく感じました。一見無駄なことをたくさん積み重ねていかないと、どうしてもひ弱になってしまいます。雑学の上に本物が乗っていることを感じました。どうもありがとうございました。

２０１０年1月１８日

金属材料研究所２号館　山田研究室にて

小松　啓（ひろし）

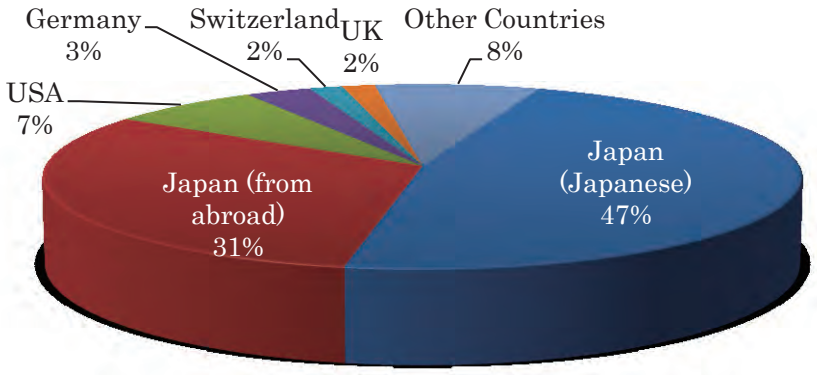
News Update

2010 WPI-AIMR Annual Workshop Report

The 2010 WPI-AIMR Annual Workshop was held from March 25, Thursday, to March 27, Saturday, 2010 at Sendai Excel Hotel Tokyu and Sendai International Center in Sendai. Main purposes of the workshop was to stimulate current and future fusion researches among WPI-AIMR researchers and between WPI-AIMR and world researchers, and to make major progress in realizing three major goals of WPI-AIMR, (1) invent and develop new and innovative functional materials, (2) establish a system adequate as a world Premier Research Center, (3) strengthen international cooperation and construct a world visible center. The Program Committee has set up the special sessions, plenary sessions, parallel sessions and a poster session. The Organizing Committee and all the members of Administrative Office contributed to run the workshop successfully.

The registered participants of the workshop counted to 192. Among 151 participants registered from Japan, about 60 researchers are those who are from abroad and working in Japan, at WPI-AIMR and other research institutions. Registration of 41 researchers are from abroad; 14 from USA, 6 from Germany, 3 from Switzerland and UK, 2 from China and Korea, and one each from Australia, Austria, Brazil, France, Greece, New Zealand, Singapore, Spain, Sweden, and Taiwan. As a whole, more than 50% participants are foreign researchers.

[Participants by origin country]



The total number of talks at the workshop was 130, which included 4 invited lectures in the special sessions, 15 invited talks in the plenary sessions, 32 invited talks in the parallel sessions, and 79 poster presentations.

In the plenary sessions, we had invited the world leading scientists on the most advanced sciences. In one of the special sessions, the Nobel Laureate Lecture was given by Dr. J. Georg Bednorz, 1987 Nobel Prize in Physics, Fellow, IBM Zurich Research Laboratory, and an International Advisory Board member. He talked on the selected and most advanced activities at the IBM Zurich Research Laboratory exploring the nanotechnology applications.

In another special session, we had a very happy event. The Acta Materialia Gold Medal of 2010 was awarded to Professor Akihisa Inoue, President of Tohoku University, for his outstanding achievements in the development of materials science including bulk metallic glasses. The presentation ceremony was held in the session after the special lecture on phase stability and properties of alloys and compounds by Professor Ted B. Massalski, Carnegie Mellon University, and Executive Secretary at Acta Materialia, Inc, who kindly came from USA for this special award presentation. Professor Inoue gave an award lecture on development and applications of bulk glassy and nonequilibrium crystalline alloys followed by a celebrating special lecture by Dr. Chikara Hayashi, ULVAC, Inc. on particles and microbes.

In the parallel sessions, we highlighted current and forthcoming fusion researches and sessions of (1) BMG and Nanophysics, (2) Nanophysics, Nonochemistry and Device/System, (3) NanoChemBio, (4) Younger researchers were arranged. For encouraging younger researchers and further discussing the Fusion Researches we also had a poster session.

On behalf of the Program Committee of the 2010 WPI-AIMR Annual Workshop, we would again like to express our warmest appreciation to all the participants of the workshop. We look forward to seeing you again at the 2011 WPI-AIMR Annual Workshop in February/March, 2011. For the complete program and the abstract booklet, please visit our workshop website:
http://www.wpi-aimr.tohoku.ac.jp/workshop/.

(by T. Hashizume, program chair)

Prof. Yamamoto's Interview in "ScienceWatch"

new hot papers - 2010

January 2010

PDF

Yoshinori Yamamoto talks with *ScienceWatch.com* and answers a few questions about this month's New Hot Paper in the field of Chemistry.

Article Title: Coinage metal-assisted synthesis of heterocycles
Authors: Patil, NT;**Yamamoto, Y**
Journal: CHEM REV, Volume: 108, Issue: 8, Page: 3395-3442, Year: AUG 2008
* Tohoku Univ, Grad Sch Sci, Dept Chem, Aoba Ku, Sendai, Miyagi 9808578, Japan.
* Tohoku Univ, Grad Sch Sci, Dept Chem, Aoba Ku, Sendai, Miyagi 9808578, Japan.

SW: Why do you think your paper is highly cited?

Heterocycle synthesis is extremely important to the pharmaceutical industry and also to the material sciences, in some parts, because most drugs contain heterocyclic structures. For example, rather old medicines such as penicillin and vitamins, and the more recently successful drug Viagra, contain heterocyclic structures. Accordingly, not only chemists in academia, but also those in industry are interested in new synthetic methods for heterocyclic compounds.

In addition to the importance of the compounds and structures themselves, "coinage metal-catalyzed (assisted) reactions" are a newer methodology in the field of synthetic chemistry. It had been believed that Au, Ag, (and Pt) are expensive metals and synthetic chemists have not been familiar with the reagents/catalysts derived from those noble metals.

However, entirely new molecular transformations have been discovered using those noble metals as catalysts. This is another reason why this article is a highly cited paper; not only practical industrial researchers, but also pure chemists in academia have had an interest in this paper and also in this research field.

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

Yes, as I mentioned above, entirely new molecular transformations have been discovered in this research field, which had previously not been possible through the use of previously known synthetic methodologies.

"...even catalytic reactions, after everything is done, have to be thrown away—especially in the case of homogeneous molecular catalysts. This is not a green process! "

SW: Would you summarize the significance of your paper in layman's terms?

Coinage metals (Au, Ag, and Cu) and other noble metals, such as Pt, attract particular interest from synthetic organic chemists, because those metals become useful catalysts for synthesizing the core structures of many important drugs.

Most drugs have heterocyclic structures and those structures can be synthesized readily and quickly by their coinage metals-catalyzed molecular transformations, i. e., carbocycles and heterocycles; cyclic compounds made by only carbon atoms (C) are called carbocycles. Cyclic compounds made by heteroatoms—such as N, O, and S—and carbon atoms are called heterocycles.

SW: How did you become involved in this research, and were there any particular problems encountered along the way?

For many years, I have been involved in the research of metal-catalyzed reactions, but at the beginning of my career, coinage metals (except Cu) and noble metals had never been included in the general materials of chemists, primarily because of their expense and the fact that almost no investigations using noble metals had been done in the past. However, about 10 years ago, one of my students used an Au complex in testing some reactions. I hadn't told him to use it and I was not even aware that he had used it.

Later on, I realized that this unexpected use of an Au complex induced a very interesting molecular transformation. This was the starting point for my entering this research field. The only problem, even at that time, was that people believed that coinage metals were too expensive to utilize in this process, but it is not true, as Pd and Rh are nowadays even more expensive.

SW: Where do you see your research leading in the future?

I regularly examine leading journals such as *Nature, Science,* and the more specialized *JACS/Angew. Chem.,* in order to be made aware of which direction the most timely and important investigations are headed. With my own strong background in the field, I can thereby direct and handle my research based on the latest findings.

SW: Do you foresee any social or political implications for your research?

This is an important task for scientists. Nowadays, social and political implications (or influence) of our own research is becoming increasingly important to us, and we have to adapt our thinking to this requirement. For my own research, catalytic reactions are quite important when compared to stoichiometric reactions, because of the waste problems and energy savings.

However, even catalytic reactions, after everything is done, have to be thrown away—especially in the case of homogeneous molecular catalysts. This is not a green process! Nowadays, to undertake a solution to the environmental problem, we will have to create a catalyst for a greener process. This will be my next research target.

Yoshinori Yamamoto, Ph.D.

Director, WPI-AIMR (Advanced Institute for Materials Research)

Professor, Department of Chemistry

Graduate School of Science

Tohoku University

Aobaku, Sendai, Tohoku, Japan

Web | Web

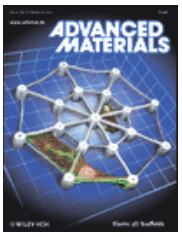
KEYWORDS: DIELS-ALDER REACTIONS; GOLD-CATALYZED CYCLIZATION; TRANSFER RADICAL CYCLIZATION; HIGHLY EFFICIENT SYNTHESIS; 1,3-DIPOLAR CYCLOADDITION REACTIONS; NONSTABILIZED AZOMETHINE YLIDES; C-C-BOND; GOLD(I)-CATALYZED INTRAMOLECULAR HYDROAMINATION; COPPER(I)-CATALYZED 3-COMPONENT REACTION; ENANTIOSELECTIVE 3+2 CYCLOADDITION.

PDF

back to top

2010 : January 2010 - New Hot Papers : Yoshinori Yamamoto on Synthetic Chemistry

Science Home | About Thomson Reuters | Site Search



Advanced Materials

Volume 22 Issue 8, Page NA

Published Online: 18 Feb 2010

Inside Front Cover

Metallic Glass Nanowires: Controlled Formation and Mechanical Characterization of Metallic Glassy Nanowires (Adv. Mater. 8/2010)

Koji S. Nakayama [1*], Yoshihiko Yokoyama [2], Takahito Ono [3], Ming Wei Chen [1], Kotone Akiyama [1], Toshio Sakurai [1], Akihisa Inoue [2]

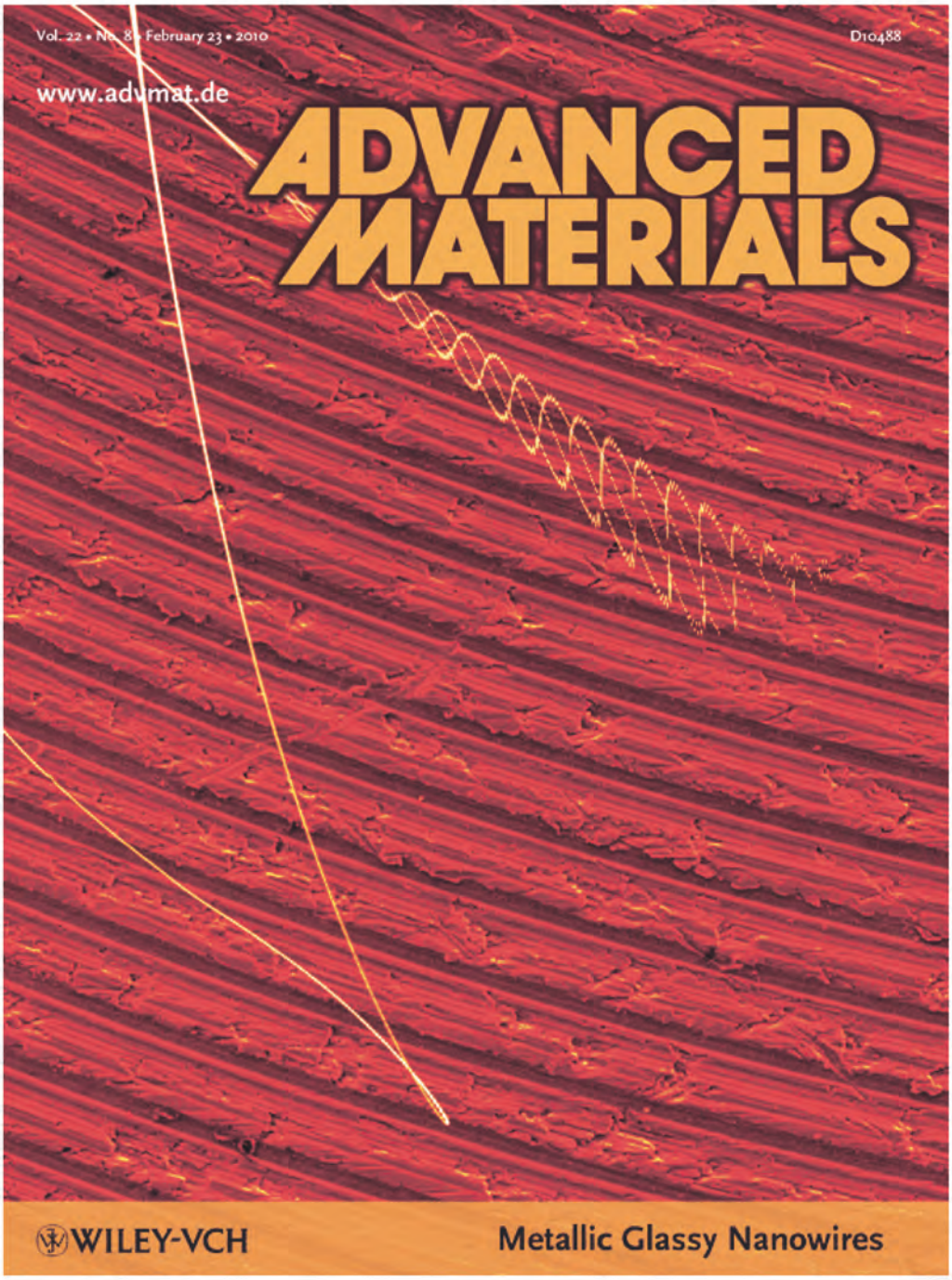
[1]WPI-Advanced Institute for Materials Research, Tohoku University Sendai, 980-8577 (Japan)
[2]Institute for Materials Research, Tohoku University Sendai, 980-8577 (Japan)
[3]Graduate School of Engineering, Tohoku University Sendai, 980-8579 (Japan)
email: Koji S. Nakayama (kojisn@wpi-aimr.tohoku.ac.jp)
[*]Correspondence to Koji S. Nakayama, WPI-Advanced Institute for Materials Research, Tohoku University Sendai, 980-8577 (Japan).

KEYWORDS

mechanical properties • metallic glass • nanowires

ABSTRACT

Owing to the absence of dislocation defects and grain boundaries, the amorphous structure of metallic glass possesses superior mechanical properties compared to its crystalline counterparts. Koji Nakayama and co-workers present on p. 872 a method that is capable of producing metallic glass nanowires. The image shows that the free end wire in the center oscillates like a sine-wave pattern implying extremely high elasticity. The authors have succeeded to measure these mechanical properties at the nanoscale.



DIGITAL OBJECT IDENTIFIER (DOI)

10.1002/adma.201090017 About DOI

Related Articles

- Find other articles like this in Wiley InterScience
- Find articles in Wiley InterScience written by any of the authors

Wiley InterScience is a member of CrossRef.

Request Reprint

Two researchers of WPI-AIMR won the Prizes of MEXT

Professor Tadafumi Adschiri and Associate Professor Taro Hitosugi of WPI-AIMR won the Prizes of the Minister of Education, Culture, Sports, Science and Technology Prize. The award ceremony was held on 13 April 2010.

Professor Adschiri was awarded "Prize for Science and Technology (Research Category)" by the Minister of Education, Culture, Sports, Science and Technology to his following outstanding research achievement. The award ceremony was held on 13 April 2010.

Achievement: "Study on New Materials Synthesis in Supercritical Hydrothermal Reactions"

Summary: There is a strong need in industries for organic and inorganic nano hybrid materials that show new functions. For the development of nano hybrid materials, molecular level of control for the interactions between organic and inorganic domains is a crucial issue. However, the affinity between the two materials is extremely low, and thus its control had been considered a difficult task.

In this research, Prof. Adschiri has succeeded in the hybridization of organic and inorganic materials in molecular level by using supercritical water, in which organic molecules and inorganic precursors (metal salt) forms a homogeneous phase. Furthermore, based on the knowledge of process engineering and thermodynamics of supercritical water, he invented a new process to synthesize hybrid nanoparticles continuously.

Based on the newly developed technology, various kinds of new nano hybrid materials that show compatible (trade-off) functions have been developed, and expected to be soon market-in.

The essential point of this study is on the success of molecular level of hybridization for organic molecules and inorganic nanoparticles, by using SCW. This new invention will lead to a new industrial technology platform, and pave a way to new areas of hybrid materials in a variety of applications including super hybrid materials, electro-magnets, optics, meta-materials, medical care etc.

Associate Professor Hitosugi was awarded "The Young Scientists' Prize" by the Minister of Education, Culture, Sports, Science and Technology to his following outstanding research achievement.

Achievement: "Development of TiO_2-based Transparent Conducting Oxide"

Summary: Transparent conducting oxide (TCO) is an electrical conductor with high transmittance in visible region. The development of TCOs has led to the evolution of a variety of optoelectronic devices, such as flat panel displays, touch panels, Si-based solar cells, and light emitting diodes. There remains, however, a strong demand for the development of new TCOs, for two major reasons, that is, for highly-efficient devices and for the replacement of Indium based TCO (ITO) which faces scarcity problem.

Dr. Hitosugi has developed a TiO_2-based transparent conductor, which is abundant in earth's crust and less toxicity. This TCO is the first TCO based on transition metal, and it shows many properties that is unique to TiO_2-based TCO.

These results should encourage the practical use of this material as transparent electrodes, and future applications should utilize its unique characteristics to enable new fields of application.

"Interface Atomic Structure and its Impact on Quantum Electron Transport in Electronics"

Z. Wang, S. Tsukimoto, M. Saito and Y. Ikuhara

Obtaining atomistic understanding of the impact of buried interface structures on electric properties, i.e. quantum electron transport, is a long-standing goal in material science and engineering. Generally, to achieve this objective, developing fundamental knowledge on how interfacial atoms bond at atomic-scale resolution is prerequisite for further studies on the effects of interfaces. This is extremely important for the next-generation electronics such as SiC wide-band-gap semiconductor devices [1], which need novel methods to substitute the trial-and-error designing fashion in addressing the critical contact (ohmic electrode) issues limiting its device performance and reliability. In a recent paper [2], the origin of this long-standing contact problem has been demonstrated to be capable of being understood and technologically manipulated at the atomic level. Using advanced scanning transmission electron microscopy, the recent improvement of ohmic contacts (Ti_3SiC_2) to SiC is attributed qualitatively to an epitaxial, coherent, and atomically ordered function interface. Quantitatively, atomistic first-principles calculations predict that this contact interface can trap an atomic monolayer of carbon (see **Fig. 1**) and hence enable lowered Schottky barrier and enhanced quantum electron transport [3]. The combined experimental atomic-scale observation and theoretical calculation provide insight into the complicated electronic and electric effects and physics of the buried interface, which would make a guideline for designing and processing the electronic devices.

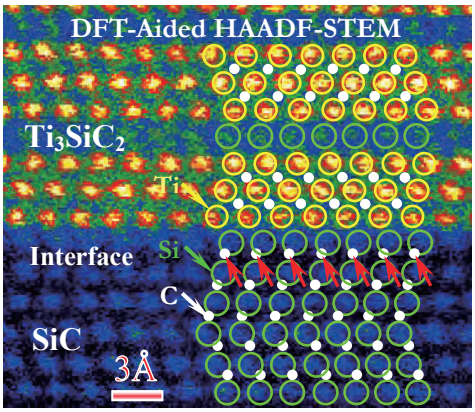


Figure 1. Scanning transmission electron microscopy image of an atomic carbon layer at an ohmic contact interface between Ti_3SiC_2 and SiC. Schematic of atomistic structure model simulated by first-principles is overlapped.

[1] Z. Wang, S. Tsukimoto, M. Saito, and Y. Ikuhara, *Phys. Rev. B* **79**, 045318 (2009).

[2] Z. Wang, M. Saito, S. Tsukimoto, and Y. Ikuhara, *Adv. Mater.* **21**, 4966 (2009).

[3] Z. Wang, *et al*., *Phys. Rev. B* **80**, 245303 (2009). [Editors' Suggestion]

Report of the Second Series WPI Joint Seminars

T. Hashizume and M. Tsukada

The WPI Joint Seminars are aimed to provide an excellent forum of communications of younger research staffs at WPI-AIMR, which makes possible the active exchange of ideas of different research fields to catalyze new fusion researches. The second series of the seminars, which started from April, 2009 and ended on January 2010, have been very successful to achieve this aim.

The lineup of the Seminars for the second series WPI Joint Seminars is given below. The organizers of this series were Professors Hashizume and Tsukada, and co-organizers are Dr. K. Akiyama, Dr. T. Hitosugi, Dr. S. Tsukimoto, Prof. D. Louzguine, Dr. A. Kuzume, Dr. S. Mizukami, Dr. K. Nakajima, Dr. T. Trevethan, Dr. P. Richard, Dr. K. Akagi.

From April 2010, the third stage of the WPI Joint Seminars will start. The aim of the third series of WPI Joint Seminars is to substantially enhance mutual scientific communications among research staffs in the Institute to promote further fusion researches. Most of the speakers should be chosen from younger research staffs in WPI-AIMR, and the Seminar should not be formed by only one way talks on the established research results, but debates, discussions and exchange of ideas should be the major part of the Seminar. The details will be given elsewhere.

Lineup of the Second Series of the WPI Joint Seminars

1st Seminar, 2009 Apr. 14 (Tue.) Y. Yamamoto (WPI-AIMR) How can we achieve our mission to WPI?

2nd Seminar, 2009 May 12 (Tue.) M. Yamaguchi (WPI-AIMR) Chemical Study on Helicene Derivatives Directed to the Development of Novel Chiral Materials H. Komatsu (WPI-AIMR) Let's make it a custom to discuss into the bottom of the problems

3rd Seminar, 2009 May 29 (Fri.) M. Esashi (WPI-AIMR) Advanced materials for MEMS T. Minato (IIARE) Atomic scale investigations at surface/interface by STM/AFM

4th Seminar, 2009 Jun. 17 (Wed.) K. Yamada (WPI-AIMR) A New Era of Neutron Science H. Morita (AIST) Meso-scale simulations of soft materials - Applications to the problems in nanorheology, 3DTEM, and lithography-

5th Seminar, 2009 Jun. 29 (Mon.) W. Teizer (Texas A&M University) Microtubule Patterning and Manipulation using Self-assembled Monolayers and Electrophoresis

6th Seminar, 2009 Jul. 15 (Wed.) K. S. Nakayama (WPI-AIMR) Nanostructures of Metallic Glass - Cutting Edge - M. Shimomura (WPI-AIMR) Hierarchically Structured Biomimetic Surfaces Prepared by Self-Organization

7th Seminar, 2009 Jul. 29 (Wed.) T. Egami (WPI-AIMR and Univ. Tennessee) Nature of the Glassy State and Democracy T. Adschiri (WPI-AIMR) Supercritical hydrothermal

synthesis of hybrid nanoparticles for "Fusion Nano Materials (WPI fusion research project) R. Kometani (Univ. Tokyo) The three-dimensional nano- and microstructure fabrications by focused-ion-beam chemical vapor deposition, and their applications

8th Seminar, 2009 Sept. 4 (Fri.) H. Gleiter (WPI and Institute of Nanotechnology, Karlsruhe Research Center, Germany) Nanoscience and Nanotechnology: The Key to New Studies in Other Areas of Science and Technology **Introduction of FUSION Researches -1-** M. Esashi (WPI-AIMR) MEMS bonding technology with metallic glass and nanostructured metals H. Liu (WPI-AIMR) Studies of plasmonic scanning tunneling microscope-luminescence from the unique nanoporous metals -To establish a photon mapping system in STM- D. Hojo (WPI-AIMR) Fusion of Wet and Dry processes to Explore New Materials and Functions P. Richard (WPI-AIMR) Novel Electron-Doped Cuprate Thin Film-Based Multi- Junction Devices

9th Seminar, 2009 Sept. 15 (Tue.) M. Nihei (Univ. of Tsukuba) Cyanide-bridged polynuclear metal clusters: The smallest units of bulk Prussian blue analogues **Introduction of FUSION Researches -2-** D. Pan (WPI-AIMR) Fabrication of micro mirrors with metallic glasses T. Hitosugi (WPI-AIMR) Exploration of Spin-Ion-tronics S. Souma (WPI-AIMR) Direct observation of electronic structure in novel bulk-metallic-glass systems M. Tsukada (WPI-AIMR) Formation of perovskite nano-oxides ribbons towards novel Devices Z. An (WPI-AIMR) Conductance investigation of nanomaterials by developing. A nano-lithography K. Tanigaki (WPI-AIMR) Application of graphene to polarized spin current transport layer in nano scale spin electronic device

10th Seminar, 2009 Sept. 25 (Fri.) K. Hono (WPI-MANA, NIMS) Advances in laser assisted atom probe K. Nakajima (WPI-AIMR) Rubber elasticity-from macro to nano, again to macro-

11th Seminar, 2009 Oct. 23 (Fri.) W. Wang, (Institute of Physics, CAS) Microalloying induced giant properties & GFA change in BMGs

12th Seminar, 2009 Oct. 30 (Fri.) T. Ando (Tokyo Inst. of Technology) Physics of graphene and its multilayers:From zero-mode anomalies to band-gap opening K. McKenna (UCL, WPI-AIMR) Electronic and optical properties of polycrystalline metal-oxide materials

13th Seminar, 2009 Nov. 6 (Fri.) A. Züttel (EMPA Materials Sciences and Technology) What We Learn from the Past to Master The Future with H_2 S. Orimo (IMR) Metal Borohydrides for Energy Applications

14th Seminar, 2009 Nov. 20 (Fri.) K. Iwaya (WPI-AIMR) Tutorial to Scanning Tunneling Microscopy (STM) T. Nishizaki (IMR) Low-temperature STM studies on superconductors T. Hitosugi (WPI-AIMR) Introduction to low temperature SPM at WPI-AIMR

15th Seminar, 2009 Dec. 18 (Fri.) A. Khademhosseini (Harvard Medical School) Microengineered hydrogels for stem cell bioengineering and tissue regeneration D. B. Weibel (University of Wisconsin-Madison) Transforming Microbiology Using Soft, Biocompatible Polymers

16th Seminar, 2010 Jan. 29 (Fri.) H. Shigekawa (Univ. Tsukuba) Imaging carrier dynamics in nanoscale potential landscapes by laser-combined STM

The Third Series WPI-AIMR Joint Seminars

M. Tsukada and D. Louzguine
Organization Committee of the WPI Joint Seminars

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

The length of each seminar, which should be held on Friday afternoon before the WPI Friday Tea Time, is two hours. Each seminar is assigned to a particular PI's research group, and the presentations are made by younger research staffs belonging to that group, followed by substantial discussions involving all the research staffs of WPI-AIMR.

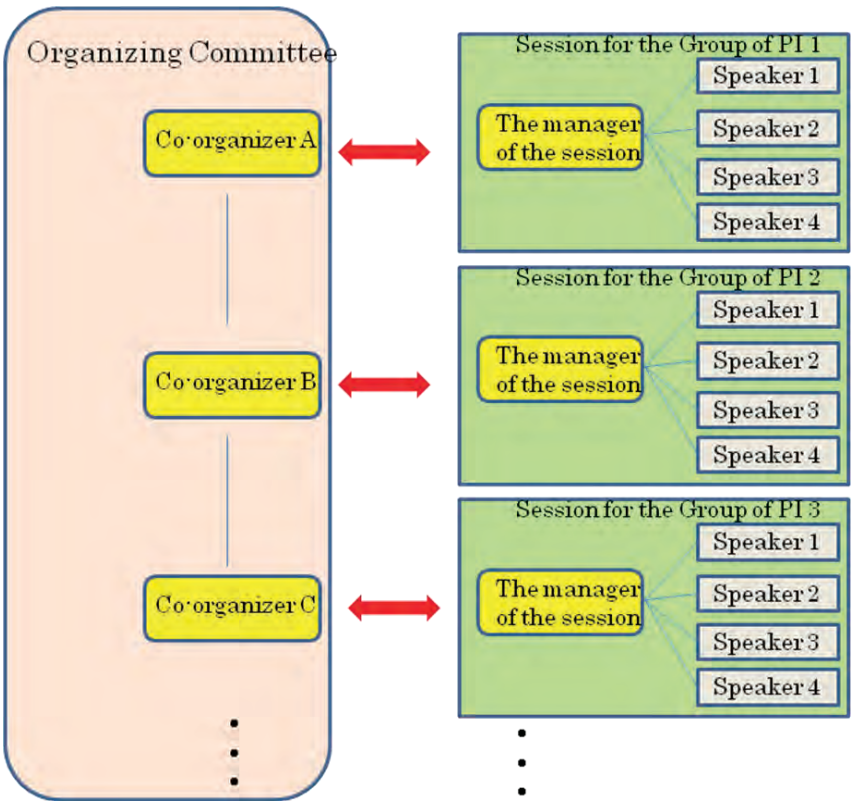


Fig.1 Organization of the third Series of WPI-AIMR Joint seminars

Each seminar is organized in cooperation between the manager in the group and the moderator outside the group. The moderators and managers may be chosen from the co-organizers of the WPI-AIMR Joint Seminars. They should put an effort to induce active discussions during the seminar and good communication among research staffs. The manager is a member of the PI's group of the session and in charge of the coordination of the presentations. A few speakers belonging to the PI's group present individual research topics, but the first speaker also gives a sketch of the general research activities of the group. The moderator chairing the session, who does not belong to the PI's Group, is chosen in turn from the co-organizers.

Presentation material should be prepared and distributed at least a week before the seminar. Before distribution, the material should be checked by the PI or a responsible supervisor of the research group to insure confidentiality. Seminars with the former WPI Joint Seminars style, i.e., 45min talk (followed by 15min discussion) by a single invited speaker from outside or inside WPI-AIMR, can also be held, although not as frequently as those of the new style described above.

List of sessions

5/14	M.Chen
5/21	T.Adschiri
6/4	M.Esashi
6/25	T.Hitosugi-Hashizume
7/9	Y.Ikuhara
7/23	D.Louzguine
8/20	K.Itaya
9/3	M.Kawasaki
to be announced	T.Miyazaki
10/1	Y.Yamamoto
10/15	T.Nishi
11/5	T.Ohmi
11/19	M.Shimomura
12/3	T.Takahashi
12/17	K.Tanigaki
1/14	M.Tokuyama
1/28	M.Tsukada
2/18	K.Yamada
3/4	M.Yamaguchi

Fig. 2 Tentative Schedule of the third Series WPI-AIMR Joint seminars

List of Co-organizers

T. Fujita (M.Chen G) ---D. Hojyo(Adschiri G)---

Y. Lin(Esashi G)--- T. Hitosugi(Hitosugi-Hashizume G)---

S. Tsukimoto(Ikuhara G)--- C. Qin(Louzguine G)---

A.Lahiri(Itaya G) ---T. Makino(Kawasaki G)---

S. Mizukami(Miyazaki G) ---N. Asao(Yamamoto G)---

Nakajima(Nishi G)---D. Ishii(Shimomura G) ---

P. Richard(Takahashi G)--- R. Nouchi(Tanigaki G)---

L. Xu(Tokuyama G)---K. Akagi(Tsukada G)---

T. Sato (Yamada G)---Y. Yasui(Yamaguchi G)

Fig.3 The present members of the co-organizers

The tentative schedule of the Seminars is shown in Fig.2. The list of the present co-organizers is shown in Fig.3.

Research Prospect

Thin Films of Block Copolymers: A Simple Route to Nanostructured Material

T.P.Russell
Polymer Science and Engineering Department
University of Massachusetts
Amherst, MA 01003 USA

The current demand of the semiconductor industry is to develop nanofabrication processes that can allow the production of nanoscopic features with reduced cost and greater functionality. In current semiconductor processes, "top-down" photolithographic procedures are well-established and highly optimized. However, with the rapid progress in system requirements, driven in part by Moore's law, the progress of conventional photolithographic techniques to sub-30 nm features is problematic due to the inherent limitation of optical diffraction and the wavelength light sources. Among several possible strategies, block copolymers (BCPs) have received considerable attention, due to the inherent processing advantages. For example, the self-assembly of BCPs can lead to arrays of nanoscopic spherical, cylindrical, and lamellar domains,, depending on the composition and chain architecture of the BCPs, and the size is limited by the size of the block copolymers themselves. Typical domain sizes range from ~ 5 -50 nm, and can be tuned by varying the molecular weight of the BCP. The underlying physics of BCPs in bulk and thin film are well-established and the mechanical properties of BCP thin films are comparable to those of conventional polymer photoresists. As a result, BCP lithography is compatible with current manufacturing conditions.

To achieve a viable process with potential in areas beyond microelectronics, significant effort has been devoted to understanding the behavior of BCP thin films. The initial scientific and technical issue was how to control the orientation and lateral ordering of microstructures in thin films. Although the phase behavior of BCPs in bulk is dictated by the Flory-Huggins segmental interaction parameter, χ and the volume fraction of blocks, boundary conditions, like preferential interactions of one block with the substrate, differences in the surface energies of the blocks, or incommensurability between the period of the BCP microdomains morphology and the film thickness, place additional constraints on the morphologies in thin films. In general, there are preferential interactions between the blocks and the interfaces (at the free surface and the substrate), resulting in an orientation of microdomains parallel to the surface. For symmetric AB-type BCPs, there are two situations – symmetric and antisymmetric wetting. With symmetric wetting, one block wets both the interfaces, while with asymmetric wetting, different blocks preferentially interact with one of the interfaces. For antisymmetric wetting, the film

thickness, t, is commensurate with the period of the BCP, L_o, when $t = (n+0.5)L_o$, while for symmetric wetting, $t = nL_o$. If the film thickness is incommensurate, i.e. does not satisfy these conditions, then discrete topographic features are observed on the surface, i.e. islands or holes, where the step height is L_o. This can be easily observed by optical reflection microscopy, as shown in Figure 1, where interferences colors are observed corresponding to different thicknesses. Such interference colors are seen in everyday life in oil slicks at gasoline stations where a rainbow of colors are observed as the thickness of the layer of oil on the surface varies. Of particular note with BCPs, the changes in the interference colors are sharp (to within the resolution of the optical microscope (~1 μm), which is consistent with the constraint that the film thickness at any point in the film must conform to the commensurability conditions imposed.

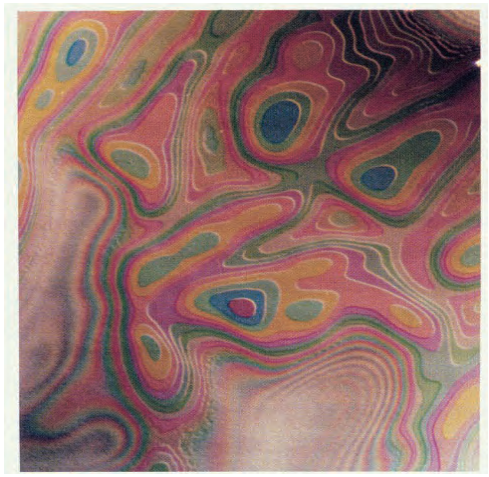


Figure 1 Interference optical micrograph of a BCP film showing discrete changes in the films thickness as evidenced by the discrete color changes.

The microdomains orient parallel to the substrate everywhere over the entire surface so, for a symmetric diblock copolymer, alternating layers of the polymers comprising the BCP fully coat the surface. Similar types of micrographs can be obtained for BCPs with cylindrical and spherical microdomain morphologies. For many applications phase selective chemistries can be performed placing tailored materials, like metal, semi-conductors or inorganics, at well-defined depths in the film in a periodic manner. While this oriented microdomain morphology can be quite useful for developing barrier resistant films, in the case of lamellar microdomains, or nanowire arrays oriented parallel to the surface with cylindrical microdomains, there is no control over the lateral ordering and, for many applications, an orientation of the microdomains normal to the surface is required. Controlling the orientation of the microdomains reduces to gaining control over the interfacial interactions and much research has been done in this arena.

2. Orientation

The orientation of the microdomain parallel to the substrate is the rule, not the exception. In general, one of the blocks of the BCP interacts preferentially with the substrate and/or has a lower surface energy which preferentially locates one block at the interface, forcing an orientation of the microdomains parallel to the surface. Orienting the microdomains normal to the surface on the other hand, requires overcoming these preferential interactions. When thin films of BCPs are thermally annealed above the glass transition temperature, the resulting

morphology is governed by preferential interactions at the surfaces. To overcome this preferential orientation, the usual approach is to control the polymer/substrate interaction by modifying the substrate using a random copolymer anchored to the substrate or by chemically modifying the sbstrate interface to balance interfacial interactions. In the case of the random copolymer, by adjusting the fraction of styrene and MMA in the a random copolymer of the two, denoted, PS-*r*-PMMA, interfacial interactions of both blocks a with the substrate can be balanced for one specific composition of the P(S-*r*-MMA).

Yet, balancing interfacial interactions alone is not sufficient to control the orientation. Under the condition where the interfacial interactions are balanced, both a perpendicular and parallel orientation of the microdomains can occur. The final trick to induce the orientation normal to the surface is to ensure that the film thickness is not commensurate with either the symmetric or asymmetric commensurability constraints. This is not difficult to realize, but there must be an addition force imposed to control the orientation. If commensurability constraints are satisfied and the interfacial interactions are truly balanced, then parallel and perpendicular orientations will occur with equal probability. Cutting microdomains in half does not introduce any additional contributions to the free energy. However, even if there is a slight degree of incommensurability, then the BCP chains would have to stretch or compress to maintain a parallel orientation. Since this causes a significant increase in the free energy, the BCP domains will orient normal to the surface.

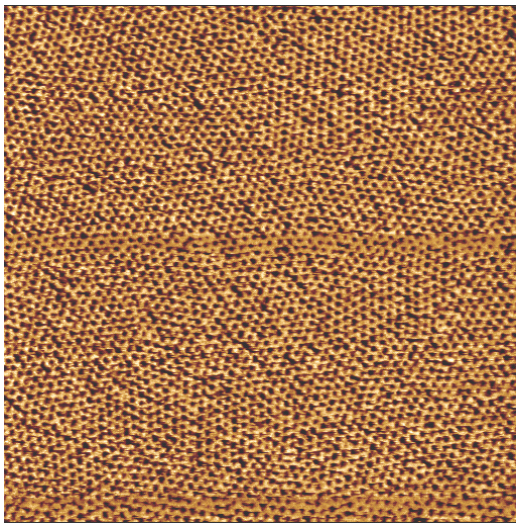


Figure 2 Nanoporous template generated from a thin film of an asymmetric PS-b-PMMA film.

If a thin film of PS-*b*-PMMA BCP is thermally annealed to produce the PMMA cylindrical microdomains oriented normal to the surface. After the thin film is exposed to UV radiation, the PMMA block is degraded and the PS matrix is crosslinked. Upon removing the decomposition products with acetic acid, a nanoporous crosslinked PS film is produced, as shown in Figure 2. These nanoporous templates derived from PS-*b*-PMMA have found wide applications in many fields, including microelectronics, and the fabrication conditions for this system have been optimized. In general, the annealing conditions can be understood by considering the relation between the polymer mobility and the molecular weight, $L_D \propto \frac{\sqrt{t}}{N} e^{-\frac{C}{T}}$, where L_D, t, N, C, and T represent the polymer diffusion length, the annealing time, the degree of polymerization, a material-dependent property of polymer, and

the temperature, respectively. Once well-ordered films of PS-*b*-PMMA were obtained, the nanoporous templates can be prepared by removing the PMMA block by deep UV irradiation (λ = 254 nm) under vacuum. A typical value necessary for degradation of PMMA homopolymer is 3.4 J/cm^2, and a dose of 25 J/cm^2 is usually used for PS-*b*-PMMA thin films.

The resulting pore size of the nanoporous templates can be simply tuned by varying the molecular weight of PS-*b*-PMMA BCPs. For cylindrical PS-*b*-PMMA, pore diameters in the porous films can be tuned from 14 to 50 nm by changing the molecular weight of the PS-*b*-PMMA BCP from 42,000 to 295,000 g/mol, in which the associated domain spacing (L_0) scales as $N^{-0.64}$. The limits of the accessible pore size should be understood in terms of the phase behavior of BCPs. The smaller pore size is limited by the degree of segregation, χN, as no phase separation is expected for lower limit of χN. On the other hand, the larger pore size is limited by the kinetics of ordering, which is significantly slower for BCPs with higher molecular weight. To overcome this inherent limitation, a more precise control of pore size could be achieved by either incorporating small amounts of homopolymer, either PS or PMMA, can be added to either increase the domain size or to increases the separation distance between the domains while keeping the domains size constant.

The success in gaining control over the orientation of the microdomains is reflected in IBM's announcement of "the first-ever application of a breakthrough self-assembling nanotechnology to conventional chip manufacturing", in which air gap insulators are fabricated using nanoporous templates derived from the self-assembly of poly(styrene-*b*-methyl methacrylate) (PS-*b*-PMMA) BCPs. Although it is the first example of an industrial application of BCP lithography, it certainly demonstrates the potential for use of BCPs.

While processing conditions for PS-*b*-PMMA based nanoporous templates have been optimized, one of the major variables to be improved is the surface modification by PS-*r*-PMMA random copolymers. The conventional approach of attaching a random copolymer to the substrate requires specific end-group functionalization and specific surface chemistries. By incorporating thermally crosslinkable groups into the PS-*r*-PMMA random copolymer, ultrathin crosslinked films can be coated onto the substrate surface, forming an insoluble layer where the composition of the random copolymer will dictate the surface interactions. Compared to the conventional method using 'random copolymer brushes', this process is much more effective and versatile, requiring only a few minutes to modify the surface and without relying on specific chemical reactions with the substrate surface.

Solvent Annealing Process

While the surface modification approaches have been primarily developed for PS-*b*-PMMA BCP systems (though the concepts developed should be generally applicable to other systems),

there have been a variety of other efforts to control the orientation of various BCP systems. The most convenient approach is solvent annealing, which, like thermal annealing, exploits the increased mobility in the BCP thin film. However unlike thermal annealing in which the films are heated above T_g, solvent annealing uses the solvent vapor, mostly derived from a saturated solvent atmosphere, to partially solubilize and, hence, plasticize the thin films and increase mobility. The solvent used is typically a good solvent for both blocks, and the annealing process can be done at ambient temperature. Under the saturated solvent vapor, the films are highly swollen and are driven into the disordered phase, as evidenced by *in situ* grazing incident small-angle x-ray scattering (GISAXS) measurements. In many cases, interesting film morphologies have been obtained via a rapid evaporation of the solvent from the thin film, i.e., the film is removed from the saturated solvent vapor and exposed to an ambient atmosphere. During solvent evaporation, it can be expected that the evaporation begins surface, and a gradient in solvent concentration will develop normal to the surface. As the solvent evaporates further, the top surface rapidly anneals, due to the presence of solvent, and coarsens into a highly, laterally ordered morhology. As the solvent evaporates and ordering front propagates into the film, templated by the surface morphology, resulting a highly ordered, highly oriented morphology in the thin fim. An example of the type of order that can be achieved is shown in Figure 3.

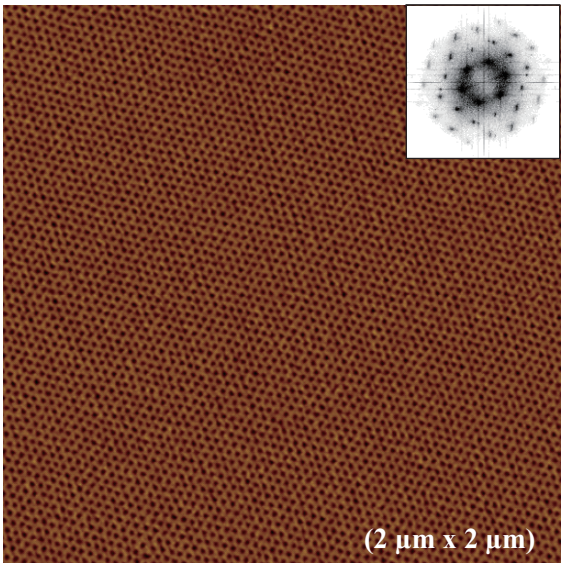


Figure 3 Scanning force micrograph of a solvent-annealed PS-b-PEO film with cylindrical microdomains oriented normal to the films surface where the diameter of the cylindrical domains is 13 nm with a period of 30.2 nm. This corresponds to 0.7 Teradots/in^2. The inset shows the Fourier transform of the micrograph.

The potential for obtaining well-defined nanopatterns with solvent annealing is perhaps best demonstrated with polyethylene oxide (PEO) based BCPs where the effect of humidity plays a significant role in defining the obtained nanostructure. Initial work by Russell and coworkers observed that a thin film of PS-*b*-PEO BCPs, having cylindrical microdomains of PEO, exhibits highly-ordered arrays of cylindrical domains that are oriented normal to the substrate with nearly defect-free arrays of microdomains being produced that span over several microns (5 × 5 µm). In comparison to PS-*b*-PMMA, where the typical grain size formed by thermal annealing is 200 – 300 nm, PS-*b*-PEO is much more advantageous for the nanofabrication of addressable media. However, the PEO block is not easily removable by simple etching process which limits the application of this process. To

impart degradability to this system, ABC triBCPs, PS-*b*-PMMA-*b*-PEO, were synthesized by living free-radical polymerization with the overall morphology being controlled to have cylindrical microdomains of PEO and PMMA blocks. The solvent annealing process was found to lead also to a high degree of lateral ordering, as with PS-*b*-PEO, and nanoporous structures were obtained by UV degradation of the PMMA middle block. For these systems, it was found that the microdomains were efficiently removed only when the PMMA blocks have a degree of polymerization high enough to form a distinct domain, namely a core/shell cylinder of PEO/PMMA domains in a PS matrix.

Solvent Reconstruction

While degrading the minor coponet using radiative or ion beam etching techinAnother approach to generate nanoporous films of diblock copolymers is to orient the microdomains normal to the film surface and to swell only the the minor component microdomains with a preferential solvent. A solvent-induced reconstruction of the film occurs where the minor component is drawn to the surface and, upon solvent removal, is trapped at the surface. Grazing incidence small angle x-ray scattering (GISAXS) and x-ray reflectivity studies have shown that the pores penetrated through the entire film and the lateral spacing of the pore was not affected by the solvent swelling. The process, schematically shown in Figure 4, was shown to be fully reversible, since neither block was degraded or removed to generate the pores. Heating above the glass transition temperature of the block copolymer resulted in a recovery of the initial film morphology i.e., nanoscopic cylindrical PMMA domains oriented normal to the surface. If the BCP film is heated to temperatures well in excess of T_g, then interfacial interactions will control the orientation of the microdomains. If, prior to heating, metal is evaporated at a glancing angle onto the surface of the reconstructed film, a porous metal film is obtained. If the metal film is thin enough, metal can be drawn into the film. In most pattern transfer approaches, a nanoporous polymer template has been used to transfer a pattern into underlying substrates using RIE and/or milling, while the control of spatial location of metal on polymer template can be used as etching

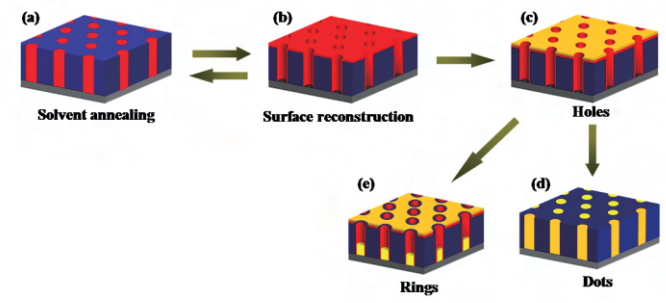


Figure 4 Schematic diagram of reconstructing a BCP thin film (a,b) follwed by a glancing angle metal evaporation © to produce a porous metal film. Subsequently the films is annealed rapidly to produce a template to transfer cylinders (e) or slowly to produce cyliners of metal in the BCP template (d).

masks for preparation of various kinds of nanostructured patterns. Consequently, this simple reconstruction process opens numerous possibilities for placing nanoscopic materials at well-defined lateral positions in a thin film.

Summary

While much research has focused on gaining a fundamental understanding of the ordering and orientation of BCP microdomains in thin film, we are at a stage where applications are beginning to emerge and where the integration of highly ordered BCP films with other disciplines is opening numerous avenues of research an enabling the fabrication of nanostructured materials. One such avenue is being pursued in the World Premier Institute, Advanced Institute of Materials Research where nanoparticles are being placed with the porous thin films formed with BCPs. In particular, if the nanoparticles are magnetic, then highly ordered arrays of magnetic nanoparticles can be produced where the lateral positioning of the nanoparticles can be controlled. In addition, the spacing between the nanoparticles can be manipulated to within a diameter f the nanoparticles. For magnetic storage media, such films are of particular relevance. In addition, this opens the opportunity to fundamentally understand the magnetic coupling between elements imbedded in a non-magnetic media.

Suggested Reading

- Hawker, C.J., Russell, T.P *MRS Bull.* 2005, *30*, 952.
- Fasolka, M.J., Mayes, A.M. *Ann. Rev. Mater. Res.* 2001, *31*, 323.
- Segalman, R.R., *Mater. Sci. Eng., R* 2005, *48*, 191.
- Anastasiadis, S. H.; Russell, T. P.; Satija, S. K.; Majkrzak, C. F. *Physical Review Letters* 1989, 62, (16), 1852-
- Anastasiadis, S. H.; Russell, T. P.; Satija, S. K.; Majkrzak, C. F. *Journal of Chemical Physics* 1990, 92, (9), 5677-91.
- Kellogg, G. J.; Walton, D. G.; Mayes, A. M.; Lambooy, P.; Russell, T. P.; Gallagher, P. D.; Satija, S. K. *Physical Review Letters* 1996, 76, (14), 2503-6.

Rotational Sublevels for Quantum Rotor of Ortho-Hydrogen Molecule Encapsulated in Isotropic Cage Structure

Jun Tang[a], Jingtao Xu[a], Yoshimitsu Kohama[b], Tooru Atake[b], Hiroshi Sawa[c], Yasujiro Murata[c], Koichi Komatsu[d], and Katsumi Tanigaki[a,b]

[a]WPI Research Center, Advanced Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan

[b]Department of Physics, Tohoku University, Sendai 980-8578, Japan

[c]Tokyo Institute of Technology, Yokohama, 226-8503 Japan

[d]Department of Applied Physics, Nagoya University, Nagoya, 464-8603, Japan

[e]Institute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan

[f]Fukui University of Technology, Fukui 910-8505, Japan

1. Introduction

Molecular hydrogen (H_2), the simplest system among all molecules, has been studied extensively to date [1–3], and its electronic spectra have been fundamental in establishing the fundamentals of quantum mechanics. An H_2 molecule is not expected to be completely localized at lattice sites even in the solid state at 0 K due to its large zero point motion, and therefore H_2 retains translational freedom as a quantum solid. The rotational motion of the H_2 molecule persists, and thus an H_2 crystal is also an orientational quantum solid. This unique free-rotor description can be expected in consequence of the nuclear spin isomers denoted by para-H_2 (J=0, 2, 4…) and ortho-H_2 (J = 1, 3, 5…), where J is the rotational quantum number. Because of wave-function symmetry requirements, the conversion between these spin isomers is quantum-mechanically forbidden, and, therefore, the energetically higher J=1 state leaves an angular momentum degree of

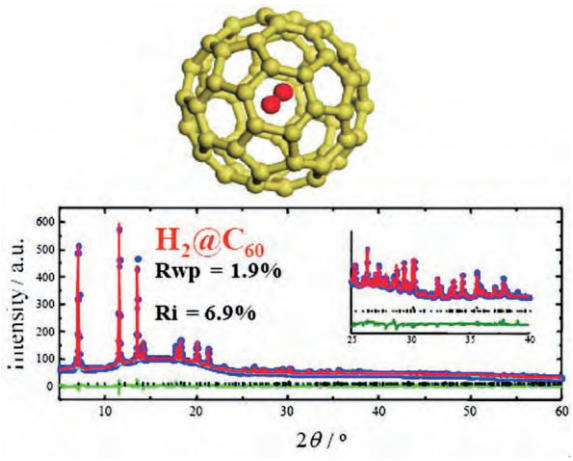


Fig.1 Graphical model of H_2-molecule enodhedral C_{60} (H_2@C_{60}) and Rietvel refinement of its promitive cubic crystal of X-ray diffraction data measureded in Spring-8.

freedom down to 0 K. As a result, the rotational motion in solid H_2 can be described as a nearly three-dimensional free rotor where the rotational motion is barely disturbed by the neighboring hydrogen molecules. However, the small interactions originating from the neighboring molecules have still been a central issue in researches of solid H_2 because these interactions can drastically modify the ortho-para conversion, crystal structure, and rotational and translational spectra.

An H_2-encapsulated molecule (H_2@C_{60}) displayed in Fig.1 has been only recently macroscopically synthesized by an organic reaction named as the "molecular surgery method" [4] and offers an unprecedented opportunity to study the rotational and translational states of the H_2 molecule. The molecular dynamics of endohedral H_2 have recently been studied by nuclear magnetic resonance [5] and inelastic neutron scattering measurements [6] by means of H_2@ATOCF (ATOCF: azacyclic-thiacyclic molecule, an open cage structure of C_{60}). The results, however, indicate that the endohedral H_2 in H_2@ATOCF shows limited 3D rotational freedom due to the low symmetry of open cage C_{60}. Although infrared spectroscopy was recently used to evaluate the rotational-vibrational coupling [7], this technique is not sensitive enough to detect the fine structure of the J=1 triply degenerate rotational sublevels [8,9], and cannot provide direct information about the intriguing rotational states.

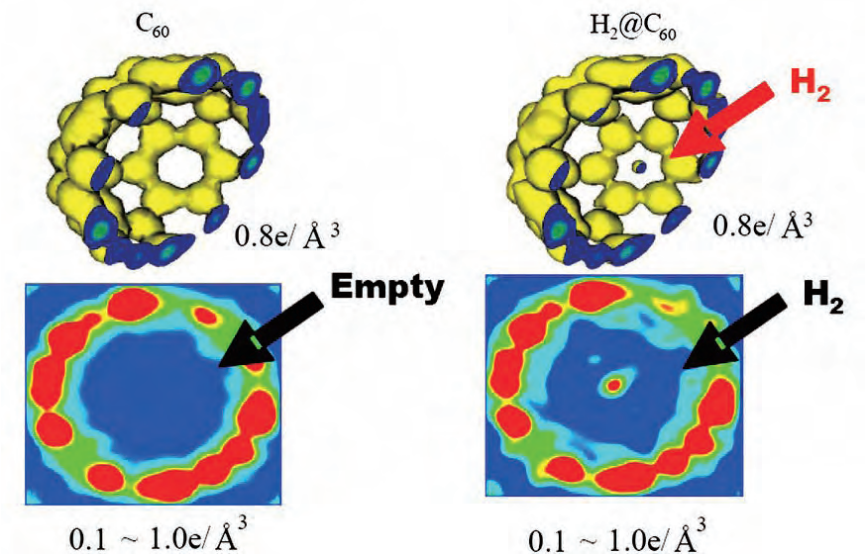


Fig.2 The electron density surface of H_2@C_{60}. The view (right side) shows that an endohedral H_2 molecule locates in the center of the cage.

Here, we discuss the first specific heat results of 99% pure H_2@C_{60} in a wide range of energy scale from room temperature down to 0.085 K. An anomaly observed at

T=0.6 K is unambiguously attributed to the almost degenerate quantized rotational level state. The observed small 0.1–0.2 meV energy splitting between states allows us to conclude that the encapsulated H_2 in the C_{60} cage can be regarded as an almost 3D free quantum rotor [10].

2. Structure of $H_2@C_{60}$ and experimental setup

2.1 Structure of $H_2@C_{60}$ molecule and its crystal

$H_2@C_{60}$ was synthesized by organic chemical reactions by opening and closing the C_{60} cage structure as described elsewhere [4]. Repeated column chromatography isolation was used to produce 99% pure $H_2@C_{60}$. In order to increase crystallinity of the $H_2@C_{60}$ powder, the samples were repeatedly dissolved in toluene and re-crystallized on a surface of a glass plate while keeping the plate temperature at 400 K. High resolution x-ray powder diffraction data were collected at different temperatures in the BL02B2 beam line (0.1 nm in wavelength) at SPring-8 as shown in Fig.1, followed by maximum entropy method (MEM)-Rietveld refinement to analyze the crystallographic structure of the samples. Both C_{60} and $H_2@C_{60}$ crystals adopt a primitive cubic Pa-3 symmetry having two orientational orderings at low temperatures [11]. On the basis of the intensity of the (200) peak, where the form factor of C_{60} and endohedral H_2 can cancel each other, it can be concluded that an H_2 molecule was encapsulated at the center inside the cage. The density maps illustrated in Fig. 2, obtained using MEM-Rietveld analyses for both C_{60} and $H_2@C_{60}$, show H_2 in the center of the C_{60} cage.

2.2 Experimental details

Specific heat measurements were made using a thermal relaxation time method with two calorimeters for different temperature regions. From 0.085 to 5 K, a homemade calorimeter in a $^3He/^4He$ dilution refrigerator was used. To obtain good thermal contact, the specimen was pressed between two plates of sapphire together with a small amount of Apiezon-N grease. The heat capacity of the sample was obtained by subtracting the contribution of the sapphire, Apiezon-N grease, and the sample cell from the total heat capacity. The heat capacity of the sapphire plates was extremely small, and the contribution was estimated by the Debye T^3 extrapolation from the data for sapphire reference standard material (NIST SRM 720). From 2 to 300 K, the specific heat was measured using a physical property measurement system (PPMS) from Quantum Design. The values of specific heat of $H_2@C_{60}$ obtained by the two calorimeters agree in the overlapping temperature region from 2 to 5 K.

3. Results and discussion

C_p data for $H_2@C_{60}$ and C_{60} (with the same treatment for comparison) are shown as a function of temperature in Fig.3. Two distinct anomalies were observed: one being around 260 K and the other around 0.6 K. The former transition (260 K) is the well known rotational disorder (high-T, space group Fm3m) to rotational order (low-T, space group Pa-3) phase transition of C_{60} [11,12]. In the high-temperature regime, the C_{60} rotational barrier is smaller than the thermal energy k_BT, and C_{60} freely rotates, whereas the intermolecular interactions of hexagon-hexagon and hexagon-pentagon fusion block the C_{60} rotation leading to its lower symmetry with two preferred orientations in the low-temperature regime [11]. The same rotational phase transition temperature for both $H_2@C_{60}$ and C_{60} implies that the rotational motion of the C_{60} cage is not affected by the endohedral H_2 molecule.

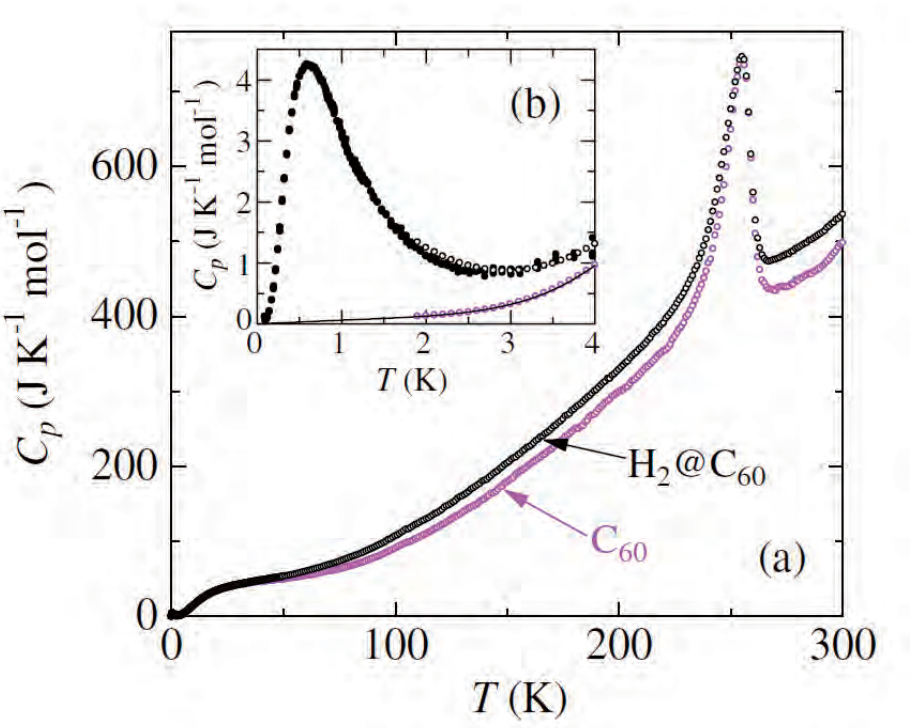


Fig.3 Specific heat capacity data of C_{60} and $H_2@C_{60}$ as a function of temperature: (a) Open circles are measured by a PPMS, and solid black circles are measured by a homemade calorimeter. The solid line was obtained by extrapolation.

In Fig. 3, it is possible to see that C_p for $H_2@C_{60}$ is larger than that for pure C_{60} over the entire temperature range. Given that the crystal structure of $H_2@C_{60}$ is the same as that of C_{60}, it is reasonable to assume that the contribution from the C_{60} cage to

the specific heat is identical for both compounds. Therefore, the difference in C_p (ΔC_p; excess specific heat obtained by subtracting the C_p of C_{60} from that of $H_2@C_{60}$) shown in Fig.4 is ascribed to endohedral H_2. Since H_2 is a diatomic molecule, there are 6 degrees of freedom: i.e., 3 translational (C_{trans}), 2 rotational (C_{rot}), and 1 intramolecular vibrational (C_{vib}) degrees of freedom. Considering that the H_2 intramolecular stretching vibration frequency of 4161 cm^{-1} [1] is too high to be excited below room temperature, the excess ΔCp likely originates from C_{trans} and C_{rot}, i.e., $\Delta C_p = C_{trans} + C_{rot}$.

The rotational specific heat C_{rot} is affected by the presence of ortho-para conversion. Indeed, in the presence of such conversion, C_{rot} is calculated as $C_{rot}=d/dT\{RT^2 d/dT[\ln(0.25Z_{para}+0.75Z_{ortho})]\}$ while, in the absence of the ortho-para conversion, C_{rot} is given by $C_{rot}=0.25d/dT\{RT^2 d/dT[\ln(Z_{para})]\} +0.75d/dT\{RT^2 d/dT[\ln(Z_{ortho})]\}$, where the participation functions Z_{para} and Z_{ortho} are $Z =\Sigma(2J + 1)\exp(-E_J/k_BT)$ and the rotational quantized energy levels are $E_J=B_JJ(J+1)$ [5]. If the ortho-para conversion occurs, the equilibrium specific heat (C_{rot}) must show a large anomaly around 50 K as shown in Fig.4 [13] according to the equation given earlier. In the present experiments, however, no such anomaly was observed, and therefore our results indicate that the ortho-para conversion is prohibited in $H_2@C_{60}$. Similar conclusions are reported in the open cage system H_2@ATOCF [5,6].

The translational motion of H_2 corresponds to the oscillation of the center of mass, bound by the spherical potential created by the C_{60} framework. Similar oscillation of endohedral intercalants has been observed in other systems, such as clathrates and filled skutterudites, where the translational specific heat originating from the endohedral atoms is described by anharmonic potentials [14,15]. In order to evaluate the translational energy of the endohedral H_2 molecule, we have also employed the Einstein model derived from the quantized energy levels of a harmonic oscillator, with an Einstein temperature Θ_E. This view is consistent with previous theoretical predictions [8,9] as well as the electron density map of H_2 described earlier. Applying these models with one fitting parameter Θ_E, we have calculated $C_{fit} = C_{trans} + C_{rot}$ in Fig.4. As seen in Fig.4, the curve fitted with Θ_E =260 K is in good agreement with the experimental data.

We note that the deviation observed above 200 K is due to the orientational phase transition of C_{60}, which strongly depends on the crystal quality. Our analysis shows that the endohedral hydrogen molecule in $H_2@C_{60}$ can be described as an almost isolated harmonic oscillator with quantized translational motion confined in the C_{60} framework and acts as a free rotor without ortho-para conversion. The translational energy can also be discussed by solving the Schrödinger equation for a single particle confined in an ideal three-dimensional spherical potential: $E_{trans}(n,\ell)= \beta^2_{n,\ell}\hbar^2/(2\mu r^2)$,

where r is the radius of the cavity, $\beta_{n,\ell}$ is the n^{th} root of the spherical Bessel function with the quantum numbers of n and ℓ, and μ is the reduced mass [5,6].

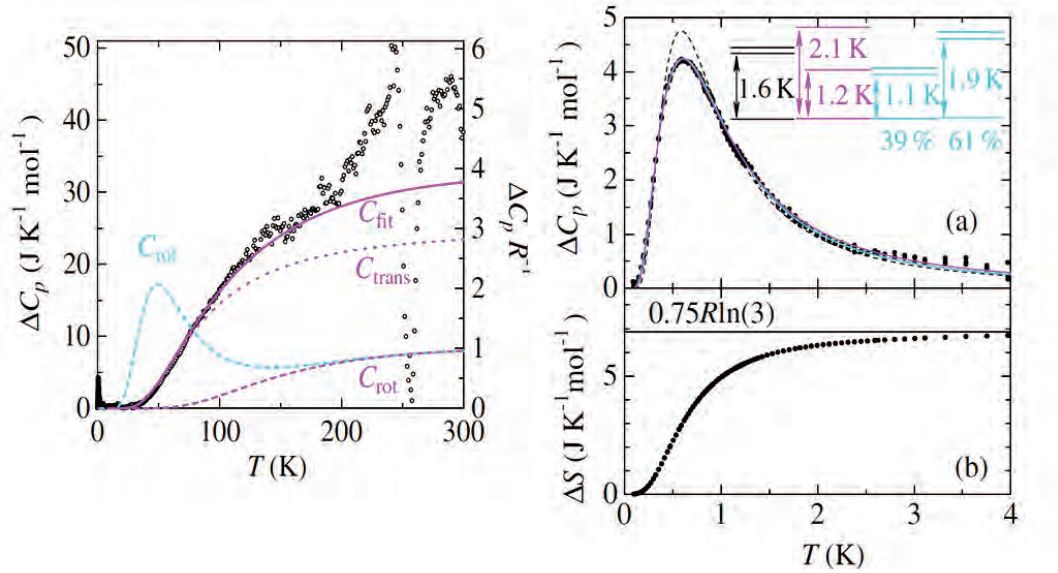


Fig.4 Excess specific heat ΔC_p (left figure) These data (black circles) were obtained by subtracting the C_p data of C_{60} from that of $H_2@C_{60}$. For the calculation below 2 K, C_p of C_{60} is estimated by extrapolation to 0 K from temperatures above 2 K [shown in Fig. 2(b)]. The magenta solid curve indicates the fitted specific heat C_{fit}, which is the summation of C_{trans} (magenta dotted curve) and C_{rot} (magenta dashed curve), while the dashed cyan curve is the rotational C_p of H_2 with the equilibrium ortho-para ratio. Excess specific heat ΔC_p and excess entropy ΔS below 4 K (right figure). (a) The black dashed, magenta, and cyan curves indicate the results of two-level, three-level, and dual two-level Schottky fits, respectively. (b) ΔS was calculated from ΔC_p.

The translational energy difference between the ground and the first excited translation levels can thus be estimated from $\triangle_{trans}=E_{trans}(1,1) - E_{trans}(1,0) = 10.32\hbar^2/(2\mu r^2)$ to be ~25 meV $\triangle_{trans}/k_B$ ~290 K) with r=0.65 nm estimated from the diameter of the fullerene (0.71 nm) and the van der Waals radii of H (0.12 nm) and C (0.17 nm) [5]. The Θ_E used to fit $\triangle C_p$ is fairly consistent with this translational energy and slightly larger than the translational energy of H_2 (~17:5 meV=200 K [Ref. [6]]) in anisotropic open cage fullerenes. Considering that the $\triangle_{trans}$ is reduced by the increase of r, this difference can originate from the larger diameter along the two long axes of the open cage fullerene (0.73–0.78 nm) as compared to the isotropic C_{60} fullerene.

In the low-temperature region, a Schottky-like anomaly is clearly evident in Figs. 3 and 4. The entropy associated to this anomaly was calculated to be 6.8 J K^{-1} mol^{-1} and displayed also in Fig. 4(b). Since the rotational excited levels in both ortho and para spin isomers are located a few hundred Kelvin above the ground state as discussed earlier [1,5,6], we take into consideration only the lowest rotational sublevels of the nuclear spin isomers (J=0 for para-H_2 and J=1 for ortho-H_2). The threefold degeneracy in the J=1 level can be lifted by the energy potential in the low-temperature Pa-3 phase [16,17], and such splitting is expected to produce a C_p anomaly as the one observed in our experiment. Indeed, the expected excess entropy due to the splitting of the J=1 level with 75% ortho-H_2 (0.75Rln3=6.85 JK^{-1} mol^{-1}) is quite close to the measured entropy. The ortho-H_2 fraction of 0.75, expected to hold in the entire temperature range [1,13], provides additional support for a forbidden ortho-para conversion in C_{60} cages. Additionally, we checked the sample dependence of the entropy and found it to be proportional to the H_2 content. This fact unambiguously supports the interpretation of the anomaly in terms of rotational sublevel splitting. We have then tentatively analyzed the rotational sublevel splitting $\triangle E_{rot}$ of the triply degenerate J=1 levels by employing a two-level Schottky model (one ground state and doubly degenerate excited states), which can be expected in the S_6 symmetry of a C_{60} molecule in the Pa-3 phase [16,17]. The best fit was achieved for $\triangle E_{rot}$ =0.14 meV (_E_{rot}/k_B=1.6 K) as shown in Fig. 4(a).

Because a small disagreement remained as seen in the dashed line of Fig. 4(a), this encouraged us to apply a three-level model. A much better fit was achieved for $\triangle E_{rot}$ =0.10 (_E_{rot}/k_B=1.2 K) and 0.18 meV ($\triangle E_{rot}/k_B$=2.1 K) as displayed in Fig. 4(a). The further splitting of the J=1 level suggests that the local symmetry is slightly lower than S_6 symmetry. In fact, in the case of anisotropic H_2@ATOCF, a clear three-level splitting was observed ($\triangle E_{rot}$=1.50 and 2.85 meV [6]). The magnitude of the splitting first elucidated in the present specific heat measurements shows rotational sublevel splitting much smaller than those of H_2 in the open caged fullerene [6] and of similar order to those of those observed in solid H_2 [1,18]. The large splitting of the rotational degeneracy observed in the open cage C_{60} is most likely caused by the anisotropic energy surface accommodating the H_2 molecule, and the rotational angular momentum of the ortho-H_2 is quenched. In contrast, the J=1 rotational sublevel splitting is rather small in the higher symmetry of C_{60}, which allows one to treat the rotational spectrum as that of a 3D free quantum rotor.

A similarly good fit can be obtained when two types of rotational sublevel splitting in the scheme of one ground and two excited levels are used at the same time. This situation might become possible when the two types of orientation of C_{60} below 90

K are taken into consideration [11], because these orientations can lead to two different crystal fields within the Pa-3 space group depending on the orientations of C_{60}. The best fit was achieved for $\triangle E_{rot}$= 0.095 meV($\triangle E_{rot}/k_B$=1.1 K) and 0.16 meV ($\triangle E_{rot}/k_B$=1.9 K) with fractions of 0.39 and 0.61. However, these values are far from the reported fractions of 0.165 and 0.835 [11]. An alternative possibility for explaining the small deviation from the simple two-level Schottky model is that another type of disorder induces a continuous distribution of crystal field effects. However, in our measurements, the shape of the low-temperature anomaly does not depend on the sample quality, which suggests that rotational sublevel distribution is not caused by such a disorder.

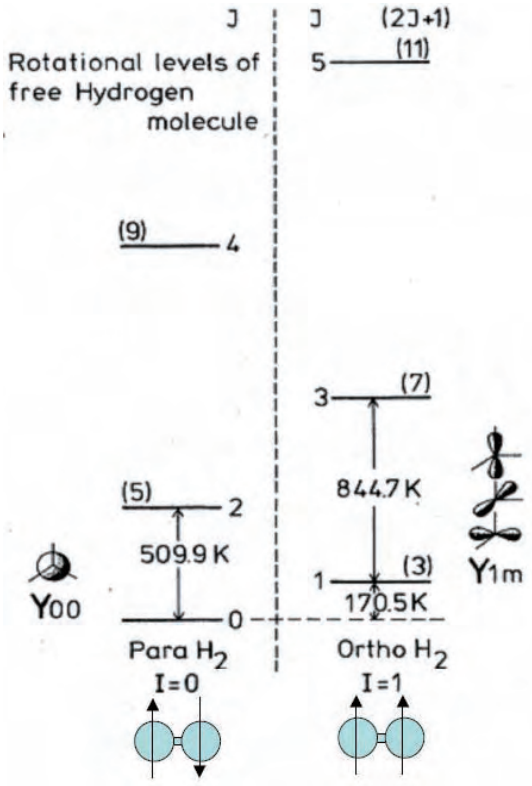


Fig. An typical energy level diagram of para and ortho H_2 molecules.

4. Summary

In summary, our low-temperature specific heat measurements provide the first experimental evidence for a small energy splitting of 0.1–0.2 meV in the J=1 state of the ortho-H_2 nuclear spin isomer. This tiny rotational sublevel splitting is likely due to C_{60} having slightly less local symmetry than S_6 in the low-temperature Pa-3 phase. Our detailed analysis of the excess specific heat in the intermediate energy scale suggests that the confined H_2 molecule can be described as a quantized oscillator in a cage. A single molecule or an atom endohedrally accommodated in C_{60} can be used as an ideal model compound for studying quantum dynamics, which cannot be realized in any conventional solid.

Acknowledgements

This work was supported by Grants-in-Aid (No. 18204030, No. 19014001, No. 18651075, and No. 18204032) and Scientific Research on Priority Areas (‘‘New

Materials Science Using Regulated Nano Spaces-Strategy in Ubiquitous Elements'') from the Ministry of Education, Culture, Sports, Science and Technology of Japan. Synchrotron radiation experiments were performed with the approval of the Japan Synchrotron Radiation Research Institute (JASRI) as a Nanotechnology Support Project. This work was partially supported by Grants-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (JSPS) (No. P07025 and No. 199728). The research was also partially supported by Tohoku University GCOE program. The authors thank Scott A. Baily and Marcelo Jaime for insightful discussions.

References

[1] I. F. Silvera, Rev. Mod. Phys. **52**, 393 (1980).

[2] P. Loubeyre, F. Occelli, and R. LeTouullec, Nature (London) **416**, 613 (2002).

[3] W. F. Mao et al., Science **297,** 2247 (2002).

[4] K. Komatsu, M. Murata, and Y. Murata, Science **307**, 238 (2005).

[5] M. Carravetta et al., J. Chem. Phys. **124**, 104507 (2006).

[6] A. J. Horsewill et al., Phys. Rev. Lett. **102**, 013001 (2009).

[7] S. Mamone et al., J. Chem. Phys. **130**, 081103 (2009).

[8] M. Xu, F. Sebastianelli, Z. Bacˇic´, R. Lawler, and N. J. Turro, J. Chem. Phys. **128**, 011101 (2008).

[9] M. Xu, F. Sebastianelli, Z. Bacˇic´, R. Lawler, and N. J. Turro, J. Chem. Phys. **129,** 064313 (2008).

[10] Y. Kohama, T. Rachi, J. Jing, Z. Li, J. Tang, R. Kumashiro, S. Izumisawa, H. Kawaji, T. Atake, H. Sawa, Y. Murata, K. Komatsu, and K. Tanigaki, Phys. Rev. Lett. **103**, 073001 (2009).

[11] W. I. F. David, R. M. Ibberson, T. J. S. Dennis, J. P. Hare, and K. Prassides, Europhys. Lett. **18**, 219 (1992).

[12] T. Atake et al., Physica (Amsterdam) 185C–189C, 427 (1991).

[13] E. S. R. Gopal, Specific Heats at Low Temperatures (Heywood Books, London, 1966).

[14] V. Keppends et al., Nature (London) **395**, 876 (1998).

[15] R. P. Hermann et al., Phys. Rev. Lett. **90**, 135505 (2003).

[16] S. A. FitzGerald et al., Phys. Rev. B **60**, 6439 (1999).

[17] In the Pa-3 phase, the local symmetry in the C_{60} cage is S_6, which is analogous to that of an interstitial site in a C_{60} lattice. In this case, the ortho-H_2 can show the splitting of the J=1 level [16].

[17] R. J. Roberts and J. G. Daunt, J. Low Temp. Phys. **6**, 97 (1972).

Newly Appointed Principal Investigator

Kazue KURIHARA

PRIMARY AFFILIATION:
Professor
WPI Advanced Institute for Materials Research
Tohoku University
2-1-1, Katahira, Aoba-ku
Sendai, 980-8577 Japan
E-mail: kurihara@tagen.tohoku.ac.jp
URL: http://www.tagen.tohoku.ac.jp/labo/kurihara/index.html

ACADEMIC:

1974 B.S. in Chemistry, Faculty of Science, Ochanomizu University, Japan
1976 M.S. in Chemistry, Faculty of Science, Ochanomizu University, Japan
1979 Ph.D. in Chemistry, Faculty of Engineering, The University of Tokyo, Japan

ACADEMIC DEGREE: Ph.D. in Chemistry, The University of Tokyo, 1979

PROFESSIONAL EXPERIENCE:

1979-1983	Research Associate, Institute of Industrial Science, The University of Tokyo, Japan
1981	Postdoctoral Fellow, Department of Chemistry, Texas A&M University, USA
1982-1984	Postdoctoral Fellow, Department of Chemistry, Clarkson University, USA
1984-1987	Research Associate, Research Institute for Production Development, Japan
1986-1987	Visiting Researcher, Institute for Surface Chemistry, Sweden
1987-1992	Group Leader, ERATO Kunitake Molecular Architecture Project, JRDC (Research Development Corporation of Japan)
1992-1997	Associate Professor, Department of Applied Physics, School of Engineering, Nagoya University, Japan
1997-2001	Professor, Institute for Chemical Reaction Science, Tohoku University
2001-2010	Professor, Institute of Multidisciplinary Research for Advanced Materials, Tohoku University

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

CURRENT RESEARCH:

- Surface Forces Measurement and Its Application to Materials Science
- Nanorheology and Nanotribology
- Characterization and Functionalization of Supramolecular Systems at the Solid-Liquid Interfaces

RECOGNITION:

- ✦ Award from the Society of Japanese Women Scientists (1997)
- ✦ The Award of the Chemical Society of Japan (2000)
- ✦ Member, Science Council of Japan (2005~)
- ✦ President-elect, International Association of Colloid and Interface Scientists (2009~)

WPI-AIMR
Newly Appointed Research Staff

Curriculum Vitae

Susumu SHIRAKI

Lecturer
E-mail: shiraki@wpi-aimr.tohoku.ac.jp

ACADEMIC:

1995 B.S. in Engineering, The University of Tokyo, Japan
1997 M.S. in Engineering, The University of Tokyo, Japan
2000 Dr. Eng., The University of Tokyo, Japan

PROFESSIONAL EXPERIENCE:

2000-2001	Research Associate (PD), Institute of Industrial Science, The University of Tokyo, Japan
2001-2004	Special Postdoctoral Researcher, The Institute of Physical and Chemical Research (RIKEN), Japan
2004-2007	Research Associate, Department of Applied Chemistry, Graduate School of Engineering, The University of Tokyo, Japan
2007-2010	Research Associate, Department of Advanced Materials Science, Graduate School of Frontier Sciences, The University of Tokyo, Japan
2010-present	Lecturer, WPI Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

- Solid State Physics, Surface Science, Surface Magnetism
- Studies on oxide thin films and magnetic nanostructures

Murugan RAMALINGAM

Assistant Professor
E-mail: murugan@wpi-aimr.tohoku.ac.jp

ACADEMIC:

1992 B.S. in Physics, University of Madras, India
1994 M.S. in Physics, Annamalai University, India
1996 M.Phil. in Nuclear Physics, University of Madras, India
2002 Ph.D in Physics-Biomaterials, Central Leather Research Institute (University of Madras), India

PROFESSIONAL EXPERIENCE:

1999–2002	CSIR-Senior Research Fellow, Central Leather Research Institute, India
2002–2004	Postdoctoral Research Fellow, National University of Singapore, Singapore
2004–2006	SMF Fellow, National University of Singapore, Singapore
2006–2008	Research Associate, University of Central Florida, USA
2008–2010	NRC Associate (U.S. National Academies), National Institute of Standards and Technology (NIST), Gaithersburg, USA
2008–2010	NRC Associate (U.S. National Academies), National Institute of Dental and Craniofacial Research (NIDCR), National Institutes of Health (NIH), Bethesda, USA
2010–present	Assistant Professor, WPI Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

- Multi-Phase Biomaterials
- Electrospinning
- 3D Scaffold Engineering
- Stem Cell Differentiation
- Cell Patterning
- Tissue engineering

Curriculum Vitae

Shane HARTON

Research Associate
E-mail: shane.harton@wpi-aimr.tohoku.ac.jp

ACADEMIC:

2001 B.S. Chemical Engineering, The Pennsylvania State University, USA
2006 Ph.D. in Materials Science and Engineering, North Carolina State University, USA

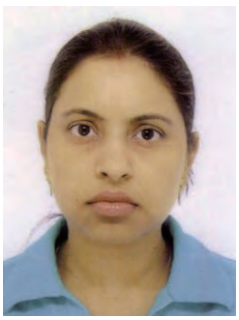
PROFESSIONAL EXPERIENCE:

2006-2008	Postdoctoral Research Scientist, Department of Chemical Engineering, Columbia University, New York, NY, USA
2008-2010	Postdoctoral Staff Researcher, Materials Research Department, Toyota Research Institute of North America, Toyota Technical Center, Ann Arbor, MI, USA
2010-present	Research Associate, WPI-Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

- Thermodynamics of polymer/polymer and polymer/inorganic interfaces, including thin films, nanocomposites, and coatings.
- Self-assembly and dispersion of nanoparticles within polymer matrices.
- Superhydrophobic polymer nanocomposite coatings.

Neelam KAUSHIK



Research Assiciate
TEL: +81-22-795-6936
E-mail: neelam@mems.mech.tohoku.ac.jp
URL: http://www.mems.mech.tohoku.ac.jp/index_e.html

ACADEMIC:

2001 B.Tech in Engineering, Himachal Pradesh University, India
2004 M. Tech in Engineering, Punjab Technical University, India
2010 Dr. Engineering, Tohoku University, Japan

PROFESSIONAL EXPERIENCE:

2004 Lecturer, JMIT, Kurukshetra University
2010 Research Associate, WPI-AIMR Tohoku University

CURRENT RESEARCH:

- Design and fabrication of MEMS devices using Metallic glass thin films.
- Metallic glass thin films and their application for patterned recording media.

Curriculum Vitae

Takahito KAWANO

Research Associate
E-mail: kawano@poly.tagen.tohoku.ac.jp

ACADEMIC:

2003 B.E. in Applied Chemistry, Nagasaki University, Japan
2005 M.E. in Applied Chemistry, Nagasaki University, Japan
2008 Ph.D. in Applied Chemistry, Kyushu University, Japan

PROFESSIONAL EXPERIENCE:

2008-2010 Postdoctoral Researcher, Institute for Materials Chemistry and Engineering, Kyushu University, Japan
2010-present Research Associate, WPI-Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

- Cellular mechanobiology: studies of biomechanics on regulation of cellular functions and migrations.
- Tissue engineering: development of biomimetic extracellular matrix and mehanobiomaterials

Takahide KUBOTA

Research Associate
E-mail: takahide@wpi-aimr.tohoku.ac.jp

ACADEMIC:

2005 B.S. in Engineering, Tohoku University
2007 M.S. in Engineering, Tohoku University
2010 Ph.D. in Engineering, Tohoku University

PROFESSIONAL EXPERIENCE:

2008-2010 JSPS Fellow, Graduate School of Engineering, Tohoku University
2010-present Research Associate, WPI-Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

- Spin-dependent transport in magnetic tunnel junctions and magnetic multi layers.
- Investigations of magnetic materials with high spin-polarization.

Curriculum Vitae

Abhishek LAHIRI

Research Associate
E-mail: a.lahiri@atom.che.tohoku.ac.jp

ACADEMIC:

2004 B.E. in Chemical Engineering, Ramaiah Institute of Technology, India
2008 Ph.D. in Material Science, University of Leeds, UK

PROFESSIONAL EXPERIENCE:

2008-2009	Postdoctoral Researcher, Department of Metallurgical and Materials Engineering, University of Alabama, USA
2009-present	Research Associate, WPI-Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

- Electrochemical dissolution and deposition of metals (Pd, Au, Ag, Cu etc)
- Characterization of the surface using in-situ scanning probe microscopy (SPM) and laser confocal microscopy with differential interference contrast microscopy (LCM-DIM).

Denis MARYENKO

Research Associate
E-mail: d.maryenko@imr.tohoku.ac.jp

ACADEMIC:

2003 Diploma in Physics, Ludwig-Maximilians-University Munich, Germany
2010 Dr. in Physics, Stuttgart University, Germany

PROFESSIONAL EXPERIENCE:

2002-2003	Visiting Researcher, Ginzton Laboratory, Stanford University, USA
2003-2010	Research Assistant, Max-Planck Institute for Solid State Research, Germany
2010-present	Research Associate, WPI-Advanced Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

- Oxide Materials
- Transport in low dimensional systems
- Magneto-photoluminescence

Curriculum Vitae

Daniel OLIVEIRA

Research Associate
E-mail: oliveira@wpi-aimr.tohoku.ac.jp

ACADEMIC:

2001 B.S. in Chemistry, University of Sao Paulo, Brazil
2005 M.S. in Chemistry, Marquette University, USA
2008 Ph.D. in Chemistry, Tohoku University, Japan

PROFESSIONAL EXPERIENCE:

2008-2010 Postdoctoral Fellow, Institute of Multidisciplinary Research for Advanced Materials, Tohoku University
2010-present Research Associate, WPI-Advanced Institute for Advanced Materials, Tohoku University

CURRENT RESEARCH:

- Bioconjugation of Nanoparticles
- Fabrication and Transport of Nanoparticles Using Microtubules and Kinesin

Azadeh SEIDI

Research Associate
E-mail: a.seidi@wpi-aimr.tohoku.ac.jp

ACADEMIC:

2001 B.E. in Chemical Engineering, University of Tehran, Iran
2003 M.E. in Biotechnology, Sharif University of Technology, Iran
2007 Dr. Eng. Tokyo Institute of Technology, Japan

PROFESSIONAL EXPERIENCE:

2008-2009 Postdoctoral Fellow, Institute for Genetic Medicine, Hokkaido University, Japan
2009-2010 Postdoctoral Fellow, Department of Microbiology, The University of Tokyo, Japan
2010-present Research Associate, WPI-Advanced Institute for Advanced Materials, Tohoku University

CURRENT RESEARCH:

I am interested in using novel microfabrication technologies and advanced materials to develop functionalized microfluidic chips capable of capturing, sorting and culturing cells. These chips can have potential applications in immediate point of care diagnosis of diseases and also more elaborate analysis like molecular profiling towards a better and personalized understanding of the disease pathophysiology.

Curriculum Vitae

Md. Akhtar UZZAMAN

Research Associate
E-mail: akhtar@m.tains.tohoku.ac.jp

ACADEMIC:

1996 B.S. (Bachelor of Science) in Applied Chemistry &Chemical Technology, University of Dhaka, Bangladesh
1998 M.S. (Master of Science) in Applied Chemistry & Chemical Technology, University of Dhaka, Bangladesh
2003 Ph.D., Institute for Molecular Science (IMS), Japan

PROFESSIONAL EXPERIENCE:

1998-2000 Research Assistance, Department of Applied Chemistry & Chemical Technology, University of Dhaka, Bangladesh
2003-2006 Postdoctoral Researcher of Venture Business Laboratory (VBL), Department of Electronic Chemistry, Tokyo Institute of Technology, Japan
2006-2007 Researcher, Department of Organic Synthesis Research Laboratory, Fujifilm Fine chemicals Co., Ltd., Japan
2007-2009 JSPS (Japan Society for the Promotion of Science) Postdoctoral Fellow, Dept. of Electronics and Applied Physics, Tokyo Institute of Technology, Japan
2009-2010 Assistant Professor, College of Engineering, King Saud University, Kingdom of Saudi Arabia
2010-present Research Associate, WPI Advance Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

Organic Semiconductor Device and Processes Research such as OFETs, Solar Cell, OLEDs, etc. Organic synthetic Chemistry and Organic Functional chemistry, Structural Organic Chemistry, Molecular Electronic, *Pi*-Electronic Chemical Compounds and Hetero Ring Chemical Compounds, Polymer-Clay Nanocomposite Materials, Supramolecular Wires and Cavity.

Xianmin ZHANG

Research Associate
E-mail: xmzhang@wpi-aimr.tohoku.ac.jp
URL: http://www.wpi-aimr.tohoku.ac.jp/miyazaki_labo/

ACADEMIC:

2003 B.S. in Physics, Ludong University, P.R.China
2008 Dr. in Condensed Mater Physics, Chinese Academy of Science, P.R.China

PROFESSIONAL EXPERIENCE:

2008 Assistant Professor, Department of Physics, Liaoning University, P.R.China
2008-2010 Postdoctoral Researcher, Institute for materials chemistry and engineering, Kyushu University, Japan
2010−present Research Associate, WPI Advance Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

- Creation of spin transistor with graphene
- Optical spin manipulation of nano-structured ferromagnetic metals and organic dye composite

Curriculum Vitae

Wataru ICHINOSE

Research Assistant
TEL: +81-22-795-6813
E-mail: a9yd1001@s.tohoku.ac.jp

ACADEMIC:

2007 B.S. in Pharmaceutical Sciences, Tohoku University, Japan
2009 M.S. in Pharmaceutical Sciences, Tohoku University, Japan
Present Ph.D candidate in Pharmaceutical Sciences, Tohoku University, Japan

CURRENT RESEARCH:

Acetylene oligomers containing helicene formed double-helix structure, while amide oligomers formed thermally stable helix-dimer. Then hybrid chiral macromolecules composed of acetylene- and amide helicene oligomers were synthesized. The hybrid compound could form various aggregates in respond to enviormental change.

Nobuhiko MITOMA

Research Assistant
TEL: +81-22-795-6468
E-mail: mitoma@sspns.phys.tohoku.ac.jp

ACADEMIC:

2008 B.S. in Engineering Science, Osaka University, Japan
2010 M.S. in Engineering Science, Osaka University, Japan
Present Ph.D candidate

CURRENT RESEARCH:

- Spin injection into a single layer graphene

Curriculum Vitae

Koji YAMAMOTO

Research Assistant
TEL: +81-22-795-6815
E-mail: B0YD1008@s.tohoku.ac.jp

ACADEMIC:

2008 B.S. in Pharmaceutical Sciences, Tohoku University, Japan
2010 M.S. in Pharmaceutical Sciences, Tohoku University, Japan
Present Ph.D candidate in Pharmaceutical Sciences, Tohoku University, Japan

CURRENT RESEARCH:

My current research is focused on the investigation of structure change of double-helix formed by the oligo(ethynylhelicene), which contains optically active helicene and *m*-phenylene. The differences in structure change of artificial double-helix in solution and on the solid surface is compared, and method to control their aggregation and deaggregation on solid surface will be developed.

Newly Appointed Adjunct Professors

Tomohiro HASHIZUME

PRIMARY AFFILIATION:

Chief Research Scientist
Advanced Research Laboratory, Hitachi, Ltd.
Tel: +81-49-296-6111
Fax: +81-49-296-6006
E-mail: tomihiro.hashizume.qb@hitachi.com

ACADEMIC:

1981	B. S. in Applied Physics, The University of Tokyo
1983	M. S. in Applied Physics, The University of Tokyo
1986	Ph. D. in Applied Physics, The University of Tokyo

PROFESSIONAL EXPERIENCE:

1986-1987	Postdoctoral Member of Technical Staff AT&T Bell Laboratories
1987-1989	Research Associate, The Institute for Solid State Physics, The University of Tokyo
1989-1994	Associate Professor, Institute for Materials Research, Tohoku University
1994-1996	Senior Contract Research Scientist, Advanced Research Laboratory, Hitachi, Ltd.
1996-2009	Senior Research Scientist, Advanced Research Laboratory, Hitachi, Ltd.
2009-present	Chief Research Scientist, Advanced Research Laboratory, Hitachi, Ltd.
2007-2010	Visiting Professor, WPI-AIMR, Tohoku University
2005-present	Liaison Professor, Department of Physics, Tokyo Institute of Technology

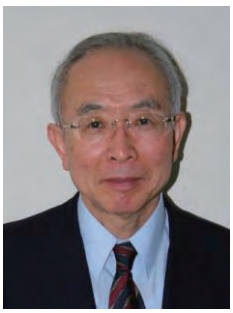
RECOGNITION:

- ✦Kumagaya Award for the Best Annual Vacuum Science Paper (1987)
- ✦Inoue Award for Young Scientists (1988)
- ✦Scientific Measurement Award (1992)
- ✦Metallic Materials Science Award (1992)
- ✦Harada Award for Young Scientists (1992)

CURRENT RESEARCH:

Interfaces of materials have been attracting great attention due to their appealing physical and industrial properties. In order to understand these fascinating interfaces in an atomic scale, we explore new interface physics at the organic/inorganic interfaces and oxide heterostructures, such as ferromagnetism, superconductivity, and charge transfer, by utilizing scanning probe microscopy (SPM), atom probe, and other advanced nanomeasurement techniques.

Hiroshi KOMATSU



PRIMARY AFFILIATION:

Emeritus Professor

WPI-AIMR, Tohoku University

2-1-1, Katahira, Aoba-ku,

Sendai, 980-8577 Japan

E-mail: hiroshi@wpi-aimr.tohoku.ac.jp

ACADEMIC:

1959 B.S. Department of Geology and Mineralogy, Tokyo University of Education

1961 M.S. Department of Geology and Mineralogy, Tokyo University of Education

1964 Ph.D. in Mineralogy, Tokyo University of Education

ROFESSIONAL EXPERIENCE:

1964-1966 British Council Scholar, Physics Department, Royal Holloway College, University of London

1966-1975 Research Officer, NIRIM (National Institute for Researches in Inorganic Materials)

1975-1998 Professor, IMR (Institute for Materials Research), Tohoku University

2000-2005 Professor, Iwate Prefectural University

2005-2008 Special Advisor to the President, Iwate Prefectural University

RECOGNITION:

✦Distinguished Paper Award of JACG (Japanese Association for Crystal Growth) 1990

✦President of JACG (1996-1998)

✦Honorary member of JACG 2006

Tomokazu MATSUE

PRIMARY AFFILIATION:

Professor and Vice-Dean
Graduate School of Environmental Studies
Tohoku University
6-6-11-605 Aramaki, Aoba, Sendai 980-8579, Japan
Tel/Fax: +81-22-795-7209
E-mail: matsue@bioinfo.che.tohoku.ac.jp

ACADEMIC:

1976 B.S. in Pharmaceutical Institute, Tohoku University
1981 Ph.D in Pharmaceutical Institute, Tohoku University

PROFESSIONAL EXPERIENCE:

1982-1984	Post-doctoral Fellow, Univ. of Wisconsin, USA.
1984-1986	Research Associate, Pharmaceutical Institute, Tohoku University
1986-1988	Research Associate, Faculty of Engineering, Tohoku University
1988-1999	Associate Professor, Faculty of Engineering, Tohoku University
1999-2003	Professor, Graduate School Engineering, Tohoku University
2003-present	Professor, Graduate School Environmental Studies, Tohoku University
2008-present	Vice-Dean, Graduate School Environmental Studies, Tohoku University
2000-2005	Advisor, Institute for Life Support Technology, Japan
2002-present	Editor, Electrochimica Acta (International Society of Electrochemistry)
2003	Invited Member, Council for Science and Technology Policy, The Cabinet Office of Japan
2003-2005	Chairman of Tohoku Regional Branch, The Surface Finishing Society of Japan
2004-present	Advisor, New Energy and Industrial Technology Development Organization (NEDO)
2005-present	Advisor, Japan Science and Technology Agency (JST)
2006-2008	Program Officer, Japan Society for the Promotion of Science (JSPS)
2006-2007	Director, The Electrochemical Society of Japan
2007-2008	Director, The Surface Finishing Society of Japan
2009-present	Chairman of the New Topics Committee, The International Society of Electrochemistry
2009-persent	Chairman of Tohoku Regional Branch: The Electrochemical Society of Japan

RECOGNITION:

- ✦ Award for Young Electrochemists. The Electrochemical Society of Japan (1986)
- ✦ Award for Creative Work. The Electrochemical Society of Japan (2002)
- ✦ Award for Technical Development. The Electrochemical Society of Japan (2006)

CURRENT RESEARCH:

- ・Biosensing Devices and Systems
- ・Bioelectronic Devices
- ・Characterization and Application of Cellular Functions
- ・Micromanipulation and Micropatterning with Biomaterials
- ・Intelligent Biosystems Using Micro/Nano Technologies

Matsuhiko NISHIZAWA

PRIMARY AFFILIATION:

Professor
Department of Bioengineering and Robotics
Tohoku University
6-6-01 Aramaki-Aoba, Sendai 980-8579, Japan
Tel/Fax: +81-22-795-7003
E-mail: Nishizawa@biomems.mech.tohoku.ac.jp

ACADEMIC:

1989 B.E. in Applied Chemistry, Tohoku University
1991 M.E. in Applied Chemistry, Tohoku University
1994 Dr. of Eng., Tohoku University

PROFESSIONAL EXPERIENCE:

1994-1995	Research Fellow, Japan Society for the Promotion of Science
1995-1997	Research Assistant, School of Engineering, Osaka University
1997-2002	Research Assistant, Department of Applied Chemistry, Tohoku University
2002-2003	Associate Professor, Department of Applied Chemistry, Tohoku University
2003-present	Professor, Department of Bioengineering and Robotics, Tohoku University
2008-present	Research Director, Core Research for Evolution Science & Technology (CREST), Japan Science and Technology Corporation (JST)

RECOGNITION:

- ✦ Best Paper Award, Electrochemical Society of Japan (1999)
- ✦ Young Investigator Award, Chemical Society of Japan (2002)
- ✦ Young Investigator Award, Electrochemical Society of Japan (2002)

CURRENT RESEARCH:

- ・MEMS for clinical and environmental applications
- ・Bio-interfacing materials for biochips and Implant devices
- ・Biolithography for manipulating proteins and cells
- ・Bionic battery and fuel cells

New GI^3 Laboratory

New GI^3 Laboratory

In order to strengthen international fusion/joint research and construct a world "visible center", we started "Global Intellectual Incubation 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

Announcement

Junior Faculty/Post-doctoral Positions

Tohoku University
WPI-AIMR

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

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

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

by email to
wpi-office@bureau.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,
by email to
wpi-office@bureau.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

wpi-office@bureau.tohoku.ac.jp

All files must be submitted electronically in pdf or Word format.

Appendix

The 2010 WPI-AIMR Annual Workshop
March 25-27, 2010


東北大
TOHOKU UNIVER


ZHU


東北大
TOHOKU UNIV


H. FECHT
東北


P. AJAYAN

Administration


Y. Yamamoto


W. Iwamoto

Research staff


T. Adschiri


K. Akagi


Z. An


M. Araidai


N. Asao


M. Atashfaraz


Q. Bao


A. Caron


L. Chen


M. Chen


N. Chen


Y. Cho


A. Chutia


D. Ehrentraut


M. Esashi


H. Fujii


S. Fujinami


T. Fujita


N. Fukui


K. Georgarakis


T. Gessner


A. Greer


L. Gu


P. Guan


I. Hamada


S. Harton


J. Hedin


K. Hemker


T. Higuchi


H. Hiraga


A. Hirata


T. Hitosugi


D. Hojo


K. Horigane


W. Ichinose


Y. Ikuhara


D. Ishii


K. Itaya


J. Iwasaki


K. Iwaya


T. Jin


N. Kaushik


T. Kawano


M. Kawasaki


A. Khademhosseini


K. Kimura


T. Kubota


K. Kurihara


M. Lagally


A. Lahiri


X. Lang


J. Lee


S. Li


Y. Lin


H. Liu


H. Liu


D. Louzguine


J. Lu


S. Madge


T. Makino


D. Maryenko


A. Masago


K. Mckenna


N. Mitoma

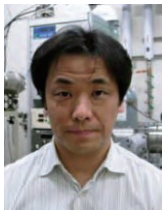

T. Miyazaki


S. Mizukami


A. Mukkannan

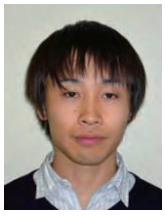

M. Muroyama


K. Nakajima


K. Nakayama


M. Nakazawa


T. Nishi


R. Nouchi


T. Ohmi


T. Ohsawa


D. Oliveira

C. Qin

M. Ramalingam

P. Richard

T. Russell

S. Sanchez

T. Sato

M. Saito

A. Seidi

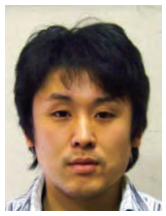

R. Shimizu


M. Shimomura


S. Shiraki


A. Shluger


S. Souma


K. Sugawara


T. Takahashi

A. Takeuchi


H. Tamura


Y. Tanabe


J. Tang


K. Tanigaki


W. Teizer


T. Togashi


M. Tokuyama


T. Trevethan


M. Tsukada


S. Tsukimoto


K. Ueno


A. Uzzaman


R. Varu


L. Wan


D. Wang


Z. Wang


P. Weiss


R. Wen


F. Wu


H. Wu


J. Xu


L. Xu


Q. Xue


K. Yamada


M. Yamaguchi


K. Yamamoto


Y. Yasui


A. Yavari


Y. Yokoyama


S. Yoshida


Q. Zhang


K. Zhao

X. Zhang

Supporting staff


Y. Chiba


N. Daigaku


E. Hagita


K. Hashimoto


H. Hirayama


S. Ikeda


K. Kamoshida


Y. Kobayashi


H. Naganuma


Y. Ohtomo


H. Oikawa


A. Okamoto


T. Okazaki

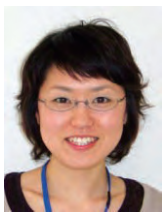

T. Ono


M. Onodera


A. Saito


I. Saito


H. Sato


A. Umezawa


S. Unoura


Y. Yanagawa


H. Yoshida


M. Yoshida


I. Zeniya

DIRECTORY

As of April 1, 2010

Name	Phone Number (+81-(0)22- _____)	E-mail Address
<Administration>		
1.YAMAMOTO, Yoshinori (Institute Director)	217-5130	yoshi@mail.tains.tohoku.ac.jp
2.IWAMOTO, Wataru (Administrative Director)	217-5965	iwamoto@wpi-aimr.tohoku.ac.jp
<Research Staff>		
<Adschiri Group>		
3.ADSCHIRI, Tadafumi (PI, Prof.)	217-5629	ajiri@tagen.tohoku.ac.jp
4.HOJO, Daisuke (Assist. Prof.)	217-5631	dhojo@tagen.tohoku.ac.jp
5.HARTON, Shane (Research Assoc.)	217-5630	shane.harton@wpi-aimr.tohoku.ac.jp
6.RANI, Varu (Research Assist.)	217-5630	chauhan@mail.tagen.tohoku.ac.jp
7.ATASHFARAZ, Mehrnoosh (Researcher)	217-5630	mehr@mail.tagen.tohoku.ac.jp
8. LU, Jinfeng (Researcher)	217-5630	lujf@mail.tagen.tohoku.ac.jp
9.TOGASHI, Takanari (Researcher)	217-5630	togashi@tagen.tohoku.ac.jp
<Chen Group>		
10.CHEN, Mingwei (PI, Prof.)	217-5992	mwchen@wpi-aimr.tohoku.ac.jp
11.FUJITA, Takeshi (Assist. Prof.)	217-5959	tfujita@wpi-aimr.tohoku.ac.jp
12.HIRATA, Akihiko (Assist. Prof.)	217-5959	hirata@wpi-aimr.tohoku.ac.jp
13.CHEN, Luyang (Research Assoc.)	217-5959	chenly@wpi-aimr.tohoku.ac.jp
14.GUAN, Pengfei (Research Assoc.)	217-5959	pf.guan@wpi-aimr.tohoku.ac.jp
15.LANG, Xingyou (Research Assoc.)	217-5959	xylang@wpi-aimr.tohoku.ac.jp
16.ZHAO, Kai (Research Assoc.)	217-5959	kzhao@wpi-aimr.tohoku.ac.jp
<Esashi Group>		
17.ESASHI, Masayoshi (PI, Prof.)	795-6934	esashi@mems.mech.tohoku.ac.jp
18.MUROYAMA, Masanori (Assist. Prof.)	795-6937	muroyama@mems.mech.tohoku.ac.jp
19.YOSHIDA, Shinya (Assist. Prof.)	795-6936	s-yoshida@mems.mech.tohoku.ac.jp
20.KAUSHIK, Neelam (Research Assoc.)	795-6936	neelam@mems.mech.tohoku.ac.jp
<Gessner Group>		
21.GESSNER, Thomas (PI)	+49-37-53124060	thomas.gessner@zfm.tu-chemnitz.de
22.LIN, Yu-Ching (Assist. Prof.)	795-6256	yclin@mems.mech.tohoku.ac.jp
23.LEE, Jae Wung (Research Assoc.)	795-6256	dlwodnd77@mems.mech.tohoku.ac.jp

Name	Phone Number (+81-(0)22- _____)	E-mail Address
<Greer Group>		
24.GREER, Alan Lindsay (PI)	+44-1223-334308	alg13@cam.ac.uk
25.MADGE, Shantanu V. (Research Assoc.)	217-5956	shantanu.madge@wpi-aimr.tohoku.ac.jp
< Hemker Group>		
26.HEMKER, Kevin (PI)	+1-410-5164489	hemker@jhu.edu
<Ikuhara Group>		
27.IKUHARA, Yuichi (PI)	+81-3-58417688	ikuhara@sigma.t.u-tokyo.ac.jp
28.TSUKIMOTO, Susumu (Lecturer)	217-5934	tsukimoto@wpi-aimr.tohoku.ac.jp
29.SAITO, Mitsuhiro (Assist. Prof.)	217-5933	saito@wpi-aimr.tohoku.ac.jp
30.GU, Lin (Research Assoc.)	217-5933	gu@wpi-aimr.tohoku.ac.jp
31.WANG, Zhongchang (Research Assoc.)	217-5933	zcwang@wpi-aimr.tohoku.ac.jp
<Itaya Group>		
32.ITAYA, Kingo (PI, Prof.)	795-5868	itaya@atom.che.tohoku.ac.jp
33.MUKKANNAN, Azhagurajan (Research Assist.)	795-5869	alagurajabs1@atom.che.tohoku.ac.jp
34.LAHIRI, Abhishek (Research Assoc.)	795-5869	a.lahiri@atom.che.tohoku.ac.jp
<Kawasaki Group>		
35.KAWASAKI, Masashi (PI, Prof.)	215-2085	kawasaki@imr.tohoku.ac.jp
36.MAKINO, Takayuki (Lecturer)	215-2088	tmakino@imr.tohoku.ac.jp
37.UENO, Kazunori (Assist. Prof.)	215-2088	uenok@imr.tohoku.ac.jp
38.HIRAGA, Hiroki (Research Assoc.)	215-2088	hiraga.hiroki@imr.tohoku.ac.jp
39.MARYENKO, Denis (Research Assoc.)	215-2088	d.maryenko@imr.tohoku.ac.jp
< Khademhosseini Group>		
40.KHADEMHOSSEINI, Ali (Junior PI)	+1-617-768-8395	alik@rics.bwh.harvard.edu
41.RAMALINGAM, Murugan (Assist. Prof.)	217-5997	murugan@wpi-aimr.tohoku.ac.jp
42.SEIDI, Azadeh (Research Assoc.)	217-6142	a.seidi@wpi-aimr.tohoku.ac.jp
<Kurihara Group>		
43.KURIHARA, Kazue (PI, Prof.)	217-5673	kurihara@tagen.tohoku.ac.jp
44.HEDIN, Jesper Niels (Researcher)	217-5675	jhedin@tagen.tohoku.ac.jp
<Lagally Group>		
45.LAGALLY, Max G. (PI)	+1-608-2632078	lagally@engr.wisc.edu

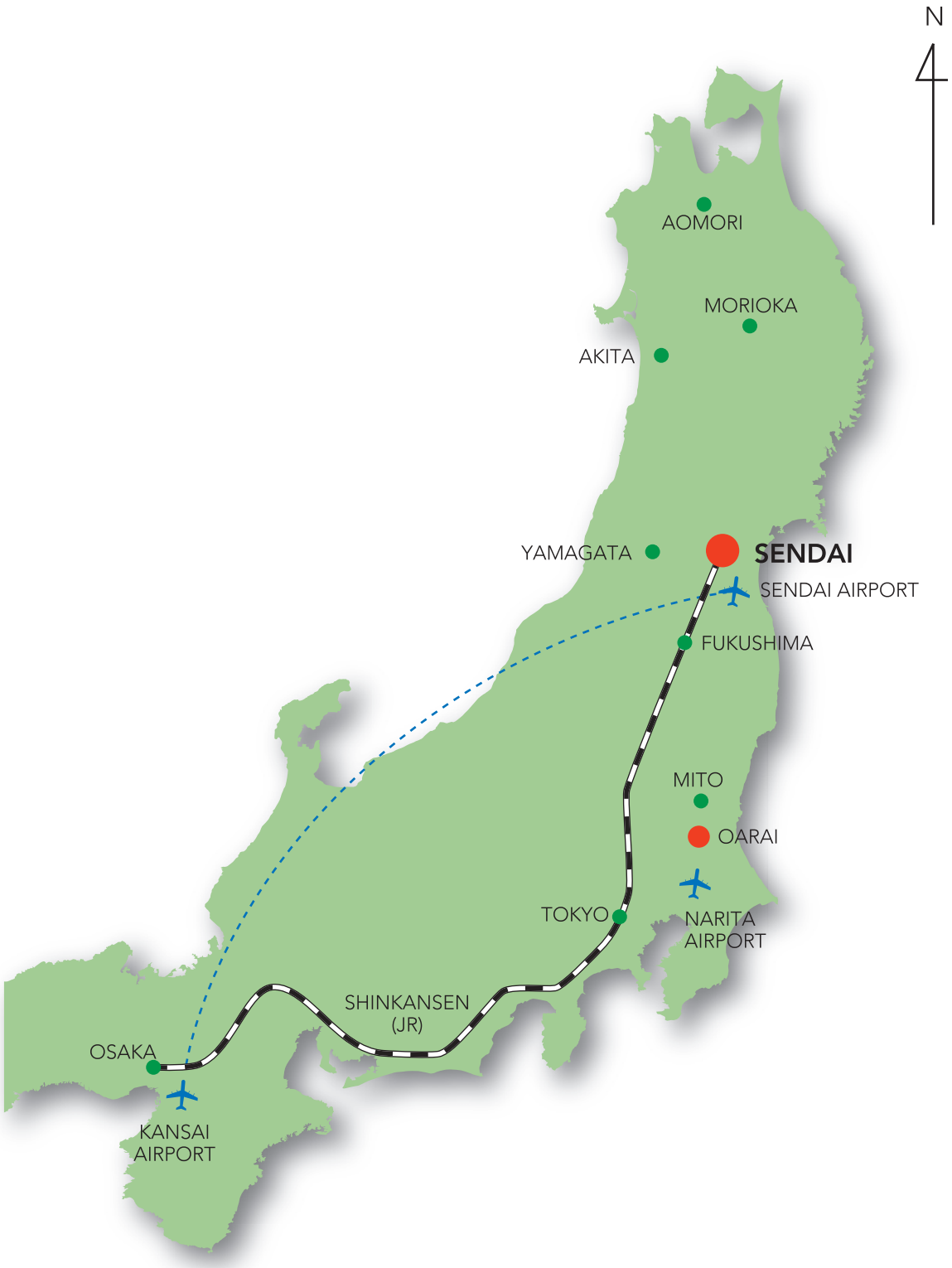
Name	Phone Number (+81-(0)22- _____)	E-mail Address
<Louzguine Group>		
46.LOUZGUINE, Dmitri V. (PI, Prof.)	217-5957	dml@wpi-aimr.tohoku.ac.jp
47.NAKAYAMA, Koji (Assoc. Prof.)	217-5950	kojisn@wpi-aimr.tohoku.ac.jp
48.TAKEUCHI, Akira (Assoc. Prof.)	217-5956	takeuchi@wpi-aimr.tohoku.ac.jp
49.YOKOYAMA, Yoshihiko [Assoc. Prof. (Concurrent)]	215-2199	yy@imr.tohoku.ac.jp
50.QIN, Chunling (Assist. Prof.)	217-5956	clqin@wpi-aimr.tohoku.ac.jp
51.ZHANG, Qingsheng (Assist. Prof.)	217-5956	qszhang@wpi-aimr.tohoku.ac.jp
52.CARON, Arnaud (Research Assoc.)	217-5956	a.caron@wpi-aimr.tohoku.ac.jp
53.CHEN, Na (Research Assoc.)	217-5956	chenn@wpi-aimr.tohoku.ac.jp
54.SANCHEZ, Sergio Gonzalez (Research Assoc.)	217-5956	sergiogs@wpi-aimr.tohoku.ac.jp
55.LI, Song (Researcher)	217-5956	lisong@wpi-aimr.tohoku.ac.jp
<Miyazaki Group>		
56.MIYAZAKI, Terunobu (PI, Prof.)	217-6000	miyazaki@wpi-aimr.tohoku.ac.jp
57.MIZUKAMI, Shigemi (Assist. Prof.)	217-6003	mizukami@wpi-aimr.tohoku.ac.jp
58.KUBOTA, Takahide (Research Assoc.)	217-6003	takahide@wpi-aimr.tohoku.ac.jp
59.ZHANG, Xianmin (Research Assoc.)	217-6003	xmzhang@wpi-aimr.tohoku.ac.jp
60.WU, Feng (Research Assoc.)	217-6004	fengwu@wpi-aimr.tohoku.ac.jp
<Nakazawa Group>		
61.NAKAZAWA, Masataka (Adjunct PI)	217-5522	nakazawa@riec.tohoku.ac.jp
<Nishi Group>		
62.NISHI, Toshio (PI, Prof.)	217-5926	nishi.toshio@wpi-aimr.tohoku.ac.jp
63.NAKAJIMA, Ken (Assoc. Prof.)	217-5927	knakaji@wpi-aimr.tohoku.ac.jp
64.FUJINAMI, So (Research Assoc.)	217-5928	fujinami@wpi-aimr.tohoku.ac.jp
65.LIU, Hao (Research Assoc.)	217-5928	liuhao@wpi-aimr.tohoku.ac.jp
66.WANG, Dong (Research Assoc.)	217-5928	wangdthu@wpi-aimr.tohoku.ac.jp
<Ohmi Group>		
67.OHMI, Tadahiro (PI, Prof.)	795-3952	ohmi@fff.niche.tohoku.ac.jp
<Russell Group>		
68.RUSSELL, Thomas (PI)	+1-413-5452680	russell@mail.pse.umass.edu

Name	Phone Number (+81-(0)22- _____)	E-mail Address
<Shimomura Group>		
69.SHIMOMURA, Masatsugu (PI, Prof.)	217-5329	shimo@tagen.tohoku.ac.jp
70.ISHII, Daisuke (Assist. Prof.)	217-5824	dishii@tagen.tohoku.ac.jp
71.HIGUCHI, Takeshi (Research Assoc.)	217-5825	higuchi@mail.tagen.tohoku.ac.jp
72.KAWANO, Takahito (Research Assoc.)	217-5825	kawano@poly.tagen.tohoku.ac.jp
73.IWASAKI, Junko (Tech. Staff)	+81-11-758-0056	iwasaki@poly.es.hokudai.ac.jp
74.KIMURA, Konomi (Tech. Staff)	+81-11-758-0056	kimura@poly.es.hokudai.ac.jp
<Shluger Group>		
75.SHLUGER, Alexander (PI)	217-5942/+44-(0)20 7679 1312	a.shluger@ucl.ac.uk
76.MCKENNA, Keith (Assist. Prof.)	217-5942	k.mckenna@wpi-aimr.tohoku.ac.jp
77.TREVETHAN, Thomas (Assist. Prof.)	217-5942	tomt@wpi-aimr.tohoku.ac.jp
<Takahashi Group>		
78.TAKAHASHI, Takashi (PI, Prof.)	795-6417	t.takahashi@arpes.phys.tohoku.ac.jp
79.RICHARD, Pierre (Assist. Prof.)	795-6477	p.richard@arpes.phys.tohoku.ac.jp
80.SOUMA, Seigo (Assist. Prof.)	795-6477	s.souma@arpes.phys.tohoku.ac.jp
81.SUGAWARA, Katsuaki (Research Assoc.)	795-6477	k.sugawara@arpes.phys.tohoku.ac.jp
<Tanigaki Group>		
82.TANIGAKI, Katsumi (PI, Prof.)	795-6469	tanigaki@sspns.phys.tohoku.ac.jp
83.NOUCHI, Ryo (Assist. Prof.)	795-6468	nouchi@sspns.phys.tohoku.ac.jp
84.TANG, Jung (Assist. Prof.)	795-6468	tangjun@sspns.phys.tohoku.ac.jp
85.TANABE, Yoichi (Research Assoc.)	795-6468	youichi@sspns.phys.tohoku.ac.jp
86.XU, Jing-Tao (Research Assoc.)	795-6468	jtxu@sspns.phys.tohoku.ac.jp
87.MITOMA, Nobuhiko (Research Assist.)	795-6468	mitoma@sspns.phys.tohoku.ac.jp
<Teizer Group>		
88.TEIZER, Winfried (Juior PI)	217-5979/+1-979-845-7730	teizer@physics.tamu.edu
89.OLIVEIRA, Daniel (Research Assoc.)	217-5979	oliveira@wpi-aimr.tohoku.ac.jp
<Tokuyama Group>		
90.TOKUYAMA, Michio (PI, Prof.)	217-5953	tokuyama@wpi-aimr.tohoku.ac.jp
91.XU, Limei (Assist. Prof.)	217-5954	limei.xu@wpi-aimr.tohoku.ac.jp
92.CHO, Young Seok (Research Assoc.)	217-5954	jho@wpi-aimr.tohoku.ac.jp
93.CHUTIA, Arunabhiram (Research Assoc.)	217-5954	arun@wpi-aimr.tohoku.ac.jp
94.FUJII, Hiroyuki (Research Assist.)	217-5954	fujii@athena22.wpi-aimr.tohoku.ac.jp

Name	Phone Number (+81-(0)22- _____)	E-mail Address
<Tsukada Group>		
95.TSUKADA, Masaru (PI, Prof.)	217-5937	tsukada@wpi-aimr.tohoku.ac.jp
96.AKAGI, Kazuto (Assoc. Prof.)	217-5940	akagi@wpi-aimr.tohoku.ac.jp
97.HAMADA, Ikutaro (Assist. Prof.)	217-5938	ikutaro@wpi-aimr.tohoku.ac.jp
98.TAMURA, Hiroyuki (Assist. Prof.)	217-5938	hiroyuki@wpi-aimr.tohoku.ac.jp
99.MASAGO, Akira (Research Assoc.)	217-5939	masago@wpi-aimr.tohoku.ac.jp
100.ARAIDAI, Masaaki (Visiting Scientist)	217-5939	araidai@wpi-aimr.tohoku.ac.jp
<Wan Group>		
101.WAN, Li-Jun (PI)	+86-62558934	wanlijun@iccas.ac.cn
102.WEN, Rui (Research Assoc.)	795-5869	ruiwen@atom.che.tohoku.ac.jp
<Weiss Group>		
103.WEISS, Paul S. (PI)	+1-310-267-5993	psw@cnsi.ucla.edu
<Wu Group>		
104.WU, Hongkai (Junior PI)		chhkwu@ust.hk.
<Xue Group>		
105.XUE, Qikun (PI)	+86-10-62795618	qkxue@mail.tsinghua.edu.cn
106.LIU, Hongwen (Assist. Prof.)	217-5948	liu@wpi-aimr.tohoku.ac.jp
<Yamada Group>		
107.YAMADA, Kazuyoshi (PI, Prof.)	215-2035	kyamada@imr.tohoku.ac.jp
108.SATO, Toyoto (Assist. Prof.)	215-2039	toyoto@imr.tohoku.ac.jp
109.HORIGANE, Kazumasa (Research Assoc.)	215-2039	khorigane@imr.tohoku.ac.jp
<Yamaguchi Group>		
110.YAMAGUCHI, Masahiko (PI, Prof.)	795-6812	yama@mail.pharm.tohoku.ac.jp
111.YASUI, Yoshizumi (Assist. Prof.)	795-3873	yasui@mail.pharm.tohoku.ac.jp
112.AN, Zengjian (Research Assoc.)	795-6815	zjan@mail.pharm.tohoku.ac.jp
113.ICHINOSE, Wataru (Research Assist.)	795-6813	a9yd1001@s.he.tohoku.ac.jp
114.YAMAMOTO, Koji (Research Assist.)	795-6815	b0yd1008@s.he.tohoku.ac.jp

Name	Phone Number (+81-(0)22- _____)	E-mail Address
<Yamamoto Group>		
YAMAMOTO, Yoshinori (Institute Director)	217-5130	yoshi@mail.tains.tohoku.ac.jp
115.ASAO, Naoki (Prof.)	795-3898	asao@m.tains.tohoku.ac.jp
116.JIN, Tienan [Assist. Prof. (Concurrent)]	795-3585	tjin@mail.tains.tohoku.ac.jp
117.UZZAMAN, MD. Akhtar (Research Assoc.)	795-6582	akhtar@m.tains.tohoku.ac.jp
<Yavari Group>		
118.YAVARI, Alain Reza (PI)	+33-(0) 4 76 82 65 16	yavari@minatec.inpg.fr
119.GEORGARAKIS, Konstantinos (Assist. Prof.)		georgara@minatec.inpg.fr
<Fukuda Group>		
120.FUKUDA, Tsuguo (Adjunct Prof.)	217-5983	ts-fukuda@wpi-aimr.tohoku.ac.jp
121.EHRENTRAUT, Dirk (Assoc. Prof.)	217-5983	ehrentraut@wpi-aimr.tohoku.ac.jp
122.BAO, Quanxi (Researcher)	217-5983	bao@mail.tagen.tohoku.ac.jp
< Hitosugi Group>		
123.HITOSUGI, Taro (Assoc. Prof.)	217-5944	hitosugi@wpi-aimr.tohoku.ac.jp
124.SHIRAKI, Susumu (Lecturer)	217-5948	shiraki@wpi-aimr.tohoku.ac.jp
125.IWAYA, Katsuya (Assist. Prof.)	217-5948	iwaya@wpi-aimr.tohoku.ac.jp
126.OHSAWA, Takeo (Assist. Prof.)	217-5948	ohsawa@wpi-aimr.tohoku.ac.jp
127.FUKUI, Nobuyuki (Research Assoc.)	217-5948	n-fukui@wpi-aimr.tohoku.ac.jp
128.SHIMIZU, Ryota (Research Assist.)	217-5948	shimizu@chem.s.u-tokyo.ac.jp

Name	Phone Number (+81-(0)22- _____)	E-mail Address
<Supporting Staff>		
129. HASHIMOTO, Keiichi (Deputy Administrative Director)	217-5980	k-hashi@wpi-aimr.tohoku.ac.jp
General Affairs Section	217-5922 or 5972	wpi-shomu@wpi-aimr.tohoku.ac.jp
130. NAGANUMA, Hiromi (Chief)		naganuma@bureau.tohoku.ac.jp
131. SAITO, Asuka		asuka-s@bureau.tohoku.ac.jp
132. OIKAWA, Hiroshi		hiroshi@bureau.tohoku.ac.jp
133. CHIBA, Yoko	217-5956	ykchiba@wpi-aimr.tohoku.ac.jp
134. ONODERA, Mariko		m.onodera@wpi-aimr.tohoku.ac.jp
135. UNOURA, Sayaka		unoura-0@wpi-aimr.tohoku.ac.jp
Accounting Section	217-5923 / FAX: 217-5129	wpi-keiri@wpi-aimr.tohoku.ac.jp
136. SATO, Hiroto (Chief)		hiroto-s@bureau.tohoku.ac.jp
137. OKAZAKI, Tomohiro		tokazaki@bureau.tohoku.ac.jp
138. ZENIYA, Ippei		zeniya@bureau.tohoku.ac.jp
139. KOBAYASHI, Yuki		y-kobayashi@bureau.tohoku.ac.jp
Property Management Section	217-5924 / FAX: 217-5129	wpi-yodo@wpi-aimr.tohoku.ac.jp
140. YOSHIDA, Masahiro (Chief)		masa-y@bureau.tohoku.ac.jp
141. HIRAYAMA, Hirotaka		h-hiraya@bureau.tohoku.ac.jp
142. YOSHIDA, Hajime		hyoshi@bureau.tohoku.ac.jp
143. ONO, Toshio		toshi-ono@bureau.tohoku.ac.jp
144. DAIGAKU, Noriko		daigaku@bureau.tohoku.ac.jp
145. OHTOMO, Yumi		yumi-o@bureau.tohoku.ac.jp
International Academic Affairs Section	217-5971 / FAX: 217-5129	wpi-kenkyo@wpi-aimr.tohoku.ac.jp
146. YANAGAWA, Yasukazu		yanagawa@bureau.tohoku.ac.jp
147. SAITO, Ikuo		s-ikuo@bureau.tohoku.ac.jp
148. HAGITA, Etsuko	217-5978	hagita@bureau.tohoku.ac.jp
149. OKAMOTO, Ayumi	217-5978	a-okamoto@bureau.tohoku.ac.jp
Safety and Health Management Office	217-5970	wpi-safety@wpi-aimr.tohoku.ac.jp
150. KAMOSHIDA, Kazuyoshi (Manager)		kamoshida@bureau.tohoku.ac.jp
151. UMEZAWA, Akiko		akiko_umezawa@bureau.tohoku.ac.jp
152. IKEDA, Susumu (Outreach Manager)	795-6468	sikeda@sspns.phys.tohoku.ac.jp



World Premier International Research Center
Advanced Institute for Materials Research
Tohoku University

2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
Phone : +81-22-217-5922
FAX : +81-22-217-5129
E-mail : wpi-office@bureau.tohoku.ac.jp
URL : http : //www.wpi-aimr.tohoku.ac.jp

World Premier International Research Center
Advanced Institute for Materials Research
Tohoku University

●

2-1-1 Katahira, Aoba-ku, Sendai 980-8577
Japan
Phone: +81-22-217-5922
FAX: +81-22-217-5129