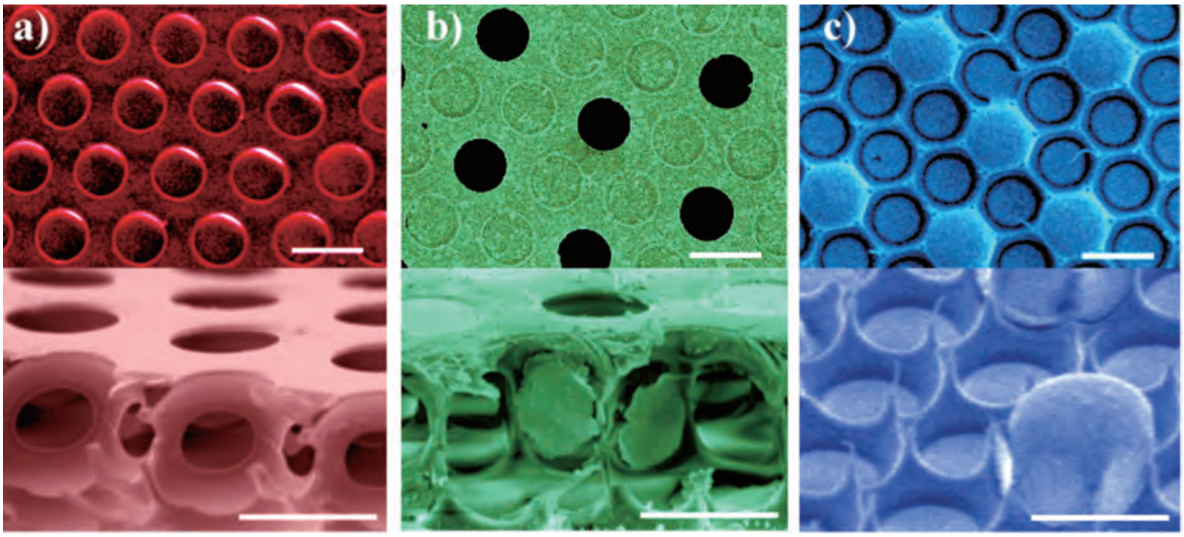
Volume 7

WPI-AIMR NEWS

October 30, 2009



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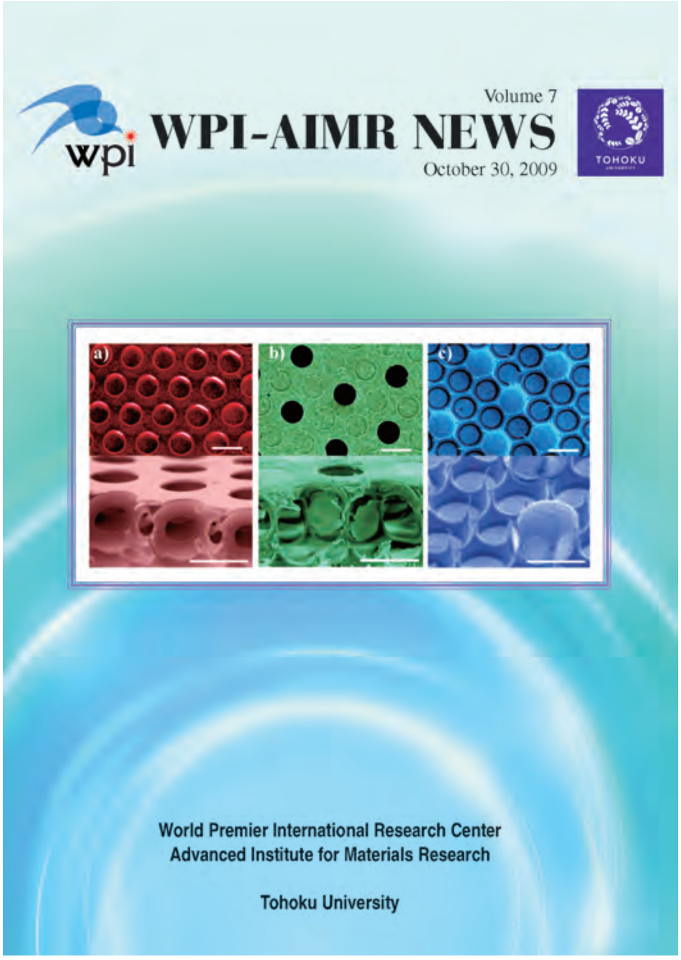

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Cover: SEM images showing top and tilt views of (a) the honeycomb film, (b) the plated honeycomb film, and (c) the hybrid dome-spike film, respectively (Scale bar: 10µm) by M. Shimomura, Professor of WPI-AIMR

The honeycomb film consists hexagonally-arranged micro porous allay prepared by self-organization of water droplet templates. The plated film is composed of metal layer covering many pores and metal pot-like structures under several pores. The hybrid dome-spike film is prepared by peeling off the top layer of the plated honeycomb film, and composed of hydrophilic metal micro-domes and hydrophobic polymer narrow spikes.

表紙: (a) ハニカム膜、(b)めっきされたハニカム膜、(c) ドーム - スパイクハイブリッド膜の走査型電子顕微鏡写真（スケールバー：10µm）(WPI-AIMR 下村政嗣教授 提供)

ハニカム膜は水滴をテンプレートとした自己組織化によって作られる六角形に配列されたマイクロポーラス構造をもつ。めっきされたハニカム膜は多数の孔を覆っている金属層といくつかの孔の下にある金属の壷状構造で構成されている。ドーム - スパイクハイブリッド膜はめっきされたハニカム膜の上面剥離によって得られ、親水性の金属ドーム構造と疎水性の高分子微細棘構造をもっている。

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Workshop, Fusion Research, and Others.

Yoshinori Yamamoto
Director, WPI-AIMR, Tohoku University

I would like to mention major events regarding WPI-AIMR, which occurred for the last three months (August-October). During August 25–28, the international WPI-INPG workshop on bulk metallic glasses was held at the Maison du Tourism in Grenoble, France. The workshop was organized by Professor Alain Reza Yavari at the Institute Polytechnique Grenoble (INPG), and significant numbers of researchers attended at the workshop from all over the world. Some details of the workshop are reported by Professor Hiroshi Komatsu in this NEWS. I thank Professor Yavari and committee members for organizing this successful meeting.

As mentioned in the preface of the last volume of WPI NEWS (volume 6), it was advised by the WPI program committee to further pursue fusion research among four thrusts. Accordingly, we encouraged all the researchers of AIMR to submit proposals on fusion research in April, and we received good numbers of applications from both young researchers and PIs. After reviewing those proposals and interviewing applicants, we selected 13 excellent proposals to which appropriate amounts of research grants were given. In the middle of October, we received the progress reports of those fusion researches. It seems to me that several very exciting fusion researches are currently undertaken, while some research groups need more effort. As a whole, I believe that we have made a good start. I sincerely hope that fruitful results will be obtained through the fusion researches in due course.

We have just started "tea time" of AIMR at the main lobby of WPI building. Every Friday, from around 5 pm right after the new joint WPI-seminar, the AIMR office kindly prepare coffee, tea, and a simple snack, and the researchers of WPI together with people the participants into the seminar get together at the lobby. This fun get-together provides a great opportunity for making friends among different laboratories and different thrusts, for strengthening the relation between researchers and staff, and for facilitating new fusion research. At present, mainly researchers at the Katahira campus attend this meeting, but I believe that researchers at the Aobayama campus will be able to attend at the time when the new WPI building will be completed around February, 2011.

I also welcome Mr. Wataru Iwamoto (Specially Appointed Professor of AIMR) as a new administrative director as of October 1, succeeding Professor Toshio Sakurai, who moved to the university headquarters as a special advisor to the President. I believe the new administrative system works very well similarly as before. If you have any requests and questions on administrative issues, please do not hesitate to let our staffs know.

It is a pleasure for me to deliver WPI-AIMR NEWS volume 7 to you.

Interviews

Interview with Professor Terunobu MIYAZAKI, Principal Investigator, WPI-AIMR

"Unlocking the Secrets of Tunnel Magnetoresistance"

---Materials are the Key---

On March 16, 2009, Professor Terunobu Miyazaki was awarded the Oliver E. Buckley Condensed Matter Prize at The March meeting of the American Physical Society (see WPI-AIMR News 5, p57).

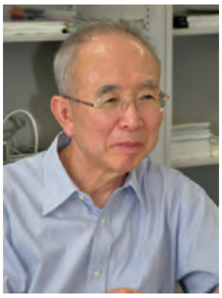
In 1994, Prof. Miyazaki discovered a tunnel magnetoresistance (TMR) effect with a value of 18% at room temperature, by far the largest room-temperature TMR effect reported to that point. This ground-breaking discovery triggered a boom in TMR research at companies and research institutions around the world (for more information, see "Research Prospect," WPI-AIMR News 6, pp.117-127).

On March 30, 2009, Prof. Miyazaki was also awarded the Outstanding Achievement Award of the Japan Society of Applied Physics. I visited Prof. Miyazaki in his office to learn the story behind the pioneering research whose impact has been felt around the world.

Prof. Miyazaki (M): I began my studies at the Department of Applied Physics at Tohoku University's School of Engineering in the year the department was established. I studied under Prof. Minoru Takahashi, a protégé of the world-famous metallurgy pioneer Prof. Hakaru Masumoto. Working under Prof. Takahashi, I learned how to grow a variety of crystals for use in the magnetism research they were carrying out at the Research Institute for Iron, Steel and Other Materials (now the Institute for Materials Research (IMR)). Mr. Tomi Sugai taught me how to grow single crystals, and from Dr. Tanji I learned how to determine the crystallographic orientation by the light figure method and how to cut out a crystal specimen. We had lots of fun learning and making things in those days.

Prof. Komatsu (K): Interesting. The Applied Physics department had just started up at that time, and didn't really have much in the way of equipment or knowledge, so you learned how to grow crystals from the IMR and made it possible to do this in Applied Physics.

M: At the time, we made crystals from steel, nickel, cobalt, bismuth and other materials, and we still have some of them. When I entered graduate school, only two graduate students could be assigned to each lab. There were four students wanting to work in Prof. Takahashi's lab, and I ended up going to Prof. Iwasaki's lab in the Research Institute of Electrical Communication, where I studied magnetic recording. Although I say "studied," I really couldn't get very excited about the recording and playback mechanism, so I concentrated on making magnetic recording media by electroplating. In the 1960s Andrew Bobeck of Bell Labs came up with his magnetic bubble memory. The basics of perpendicular magnetic recording came after that, I believe. For my doctoral studies I returned to the Takahashi lab. There I was able to make use of my earlier undergraduate work with single crystal formation and crystal cutting, as I formed cobalt and nickel thin-films on a copper single crystal by plating and studied the magnetic properties. Cobalt and nickel in equilibrium state have h.c.p. and f.c.c. structures, respectively, but under certain conditions I was able to make f.c.c. cobalt and h.c.p. nickel. I investigated their magnetocrystalline anisotropy and published the results in academic journals. In a sense this was research on artificial lattices. Looking back now, having gone to study in a different laboratory turned out to be a plus in many ways.



K: What led you into your present work?

M: Around 1985, someone who had graduated before me and was then working in a company stopped by our research lab. He said they were having difficulty with some research project at the company and asked if we can help, offering to pay us a small research fund for our work. At that time his company had started research on using the magnetoresistance effect of permalloy thin-films made of nickel-iron alloy in magnetic recording heads. His program involved permalloy magnetic anisotropy. Our lab needed the money, so we took his offer. This was the motivation for starting research on anisotropic magnetoresistance (AMR) effect. I had no idea at the time how greatly this would influence my research direction several years later.

Then in 1988, a GMR (giant magnetoresistance) effect using an iron and chrome artificial lattice was discovered by Albert Fert and Peter Grünberg (awarded 2007 Physics Nobel Prizes), exciting magnetic thin-film researchers around the world.

I was also inspired by this development to begin research of the GMR effect. To take the lead in this research, you had to have equipment capable of producing good artificial lattice thin-films and be the first to obtain great data. After all, the artificial lattice involved in the initial GMR effect discovery consisted of alternating layers of iron and chrome thin-films just a few nanometers thick, the product of high-precision

nanotechnology.

K: What kind of equipment did you have at the time?

M: Lacking in money, we recycled an old vacuum evaporation system discarded by the company. Under the circumstances it was no easy feat creating a lattice with precisely controlled thicknesses. So even while we conducted research into the GMR effect we also began research on the TMR (tunnel magnetoresistance) effect. Since we had gone from AMR effect to GMR, it was a natural step to proceed also in the direction of TMR.

K: How did you know about the TMR effect?

M: In my earlier studies of magnetoresistance effect, I first came across the TMR phenomenon (though the name itself was not yet used) in a paper by Sadamichi Maekawa, then visiting scientist at the IBM Thomas J. Watson Research Center in Yorktown Heights, published in a Japanese journal on *Kotai Butsuri* in March 1980. The paper referred to a 1975 doctoral thesis by M. Julliere for the University of Rennes in France. In that thesis, Julliere reported that when magnetic tunnel junctions are manufactured as Fe/Ge-O/Co-junctions, the rate of change in magnetoresistance by a magnetic field (MR ratio) was 14% at a Liquid He temperature of 4.2K. This was however not of practical use because of the low temperature of 4.2K.

I asked a senior student in our lab to study TMR as a research theme. I instructed him to fabricate on a glass substrate an MR structure consisting of an aluminum oxide element in between cobalt and permalloy layers. The student soon achieved an MR ratio of 1% at room temperature, and later raised this to 2 or 3%. He continued to pursue his research with great enthusiasm during his master's course, but left my group to work for a company after graduation with M.S. Another Ph.D. student followed up on the same research theme, trying out many different electrode materials and aluminum oxide layer fabrication methods.

Then it happened. On one Saturday afternoon in June 1994, the student came to me with some great news. "The recorder pen went practically off the charts!" he told me excitedly. Using an iron-aluminum oxide junction, he had achieved a previously unthinkable MR ratio of 18% at room temperature. This was the highest world record at the time.

With the proper aluminum oxide layer thickness, a TMR device can achieve a large MR ratio. It was very difficult, however, to fabricate thin-film layers with uniform thickness using our old recycled vacuum evaporation equipment. The student had tried to fabricate a layer around 2 nanometers thick, but in fact there must have been unevenness at the interfacial surface. In places the film was just thick enough not to have holes, resulting in areas where a tunneling current was able to flow. It was really a lucky success.

K: So in 1994, an unprecedented MR ratio of 18% was achieved in your lab. Where did you publish this result?

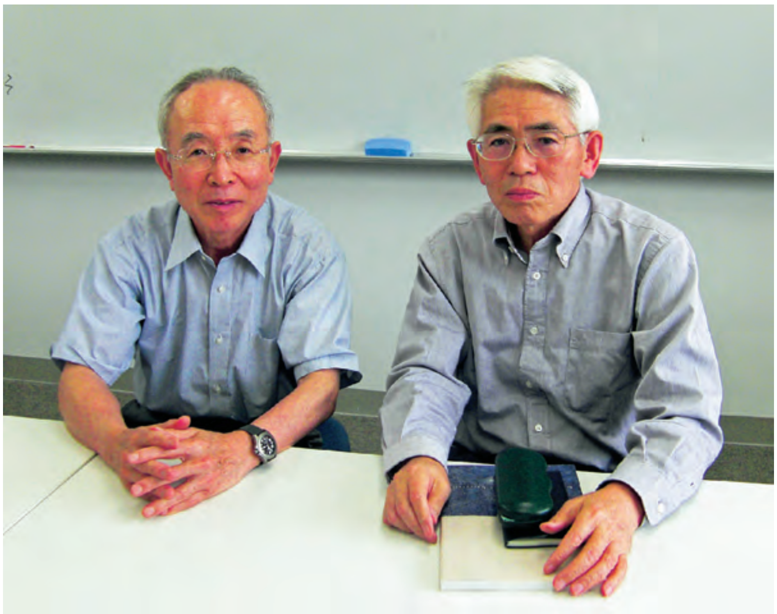
M: At first, we submitted it to *Physical Review Letters*, but it was held up in the review process. So we published it to the Journal of Magnetism and Magnetic Materials in 1995.

Before that, at a rump session of a November 1994 symposium in Japan on Spin-Dependent Phenomena in Multi-Layer Systems, I presented our achieving an MR ratio of 18% at room temperature. Since the symposium was attended by researchers from the U.S. and Europe, it's quite possible that our results became known around the world soon. Indeed in February 1995 I was invited to a Spin Polarized Electron Transport workshop in the U.S., and I discussed our results in detail in response to various questions. Looking back now, that may not have been such a good idea. Around that time, they apparently were thinking about starting up a government-funded project on MRAM (Magnetoresistive Random Access Memory) by means of TMR. The journal (PRL) that had held my July 1994 paper for review published a TMR paper by an MIT group in April 1995. But my paper for the Journal of Magnetism and Magnetic Materials appeared in March 1995, one month earlier.

Today even Japan has a government-backed MRAM project; but in the beginning no one, myself included, imagined that TMR might be applied to memory technology. I now realize that the ability to see further down the road makes all the difference. I didn't even know how to write a patent application back then.

K: What are your thoughts about revolutionary breakthroughs?

M: A breakthrough discovery requires thinking outside the usual framework. A good example is Prof. Sagawa's invention of powerful magnets at the IMR. The research world is full of people looking for materials with outstanding magnetic properties. Nearly all these studies were focused on amorphous magnetic materials and on soft magnetic properties. At a time when the experts in this field were looking only at soft magnets, Sagawa succeeded by turning his attention to hard magnets. Interdisciplinary fusion is important, and I believe nearly all major research achievements are the result of fusion. The method for creating artificial lattices proposed by Prof. Esaki when he was at IBM went from a dream to reality. Along with it, MBE (molecular beam epitaxy) and various other technical advances resulted in the establishment of ultra-thin-film fabrication technology. Its contribution to science is immeasurably great. I'm sure TMR research, too, will advance further through multifaceted cooperation.



K: As one last question, what kind of advice do you regularly give your students?

M: "Materials are the key." I believe materials are still important today. The development of materials such as the ferrite invented by Takeshi Takei, who studied chemistry at Tohoku University, and the steel magnet invented by Kotaro Honda at IMR, led to products that have continued to be useful throughout the world for many years. Cooperation by specialists in different fields will be sure to lead to additional breakthroughs in the creation of new materials.

Lately I have been recommending to my students two books relating to our forerunners. One is *Honda Kotaro Den* (The biography of Kotaro Honda) by Teijiro Ishikawa (Nikkan Kogyo Shinbun and the other is Yogoro Kato's *Sozo no Genten* (The Origins of Creativity) (Kyoritsu Shuppan).

Prof. Honda liked to say that "Now is the most important time." When he later became the president of Tokyo Science University, he reportedly put these words on the front bumper of his car.

K: Thank you for sharing so many interesting things with us today.

Interviewer: Prof. H. Komatsu
in Prof. Miyazaki's office, WPI Annex Bldg, June 3rd, 2009

WPI-AIMR PI 宮崎照宣教授にきく
（Interview with Professor Terunobu MIYAZAKI－Japanese version）

トンネル磁気抵抗効果発見の経緯

---材料が鍵---

宮崎照宣先生は2009年3月16日米国物理学会で「バックレイ固体物理学賞」を受賞されました（WPI-AIMR News Vol.5 57ページ参照）。

先生は1994年に、室温で18%もの変化を示すトンネル磁気抵抗効果を世界に先駆けて発見しました。この発見を契機に世界の多数の企業や研究機関でトンネル磁気抵抗素子の研究が盛大に行われています（詳細はWPI-AIMR News Vol.6のResearch Prospect）。

また、2009年3月30日に「第9回応用物理学会業績賞」を受賞されました。そこで、宮崎先生の教授室に伺って、世界にインパクトを与えた研究のいきさつをお聞きしました。

宮崎：私は東北大学工学部応用物理学科の一期生です。増本量先生のお弟子さんの高橋実先生の指導を受けました。先生の指示に従って、金研で研究用にいろいろな結晶を作製することを教わりました。菅井富さんには単結晶の作製を、丹治さんには光像法による結晶方位の決定と結晶面の切りだしなどを習いました。「ものづくり」は楽しかったですね。

小松：そうでしたか。工学部の応物がスタートしたばかりで道具やノウハウもなく、結晶作りを金研で教わって、応用物理で作製できるようになさったのですね。

宮崎：当時、鉄、ニッケル、コバルトおよびビスマスなどの結晶を作りました。今でもそれらの結晶の一部を持っています。大学院に入りましたが、各研究室に院生が2名の定員でした。高橋研には4人の希望者がいて、私は結局通研の岩崎研に行きました。そこで磁気記録の勉強をしました。勉強といっても記録、再生のメカニズムにはあまり興味がわかず、磁気記録媒体を電気めっき法で作製していました。1960年代にベル研究所でAndrew Bobeckがバブル磁気メモリーを出し、垂直磁気記録の基礎が生れたのはその後だったと思います。博士課程は再び応物の高橋研へもどりました。そこでは学部の時に習った単結晶作製と結晶の切り出しが役に立ち、銅単結晶上にコバルトとニッケル薄膜をめっき法で作製し、磁性を調べました。コバルトとニッケルは平衡状態ではそれぞれh.c.p.とf.c.c.構造ですが、ある条件ではf.c.c.のコバルトとh.c.p.のニッケルが作製できました。これらの結晶磁気異方性を調べ、学位論文として纏めました。ある意味で人工格子の研究だったわけです。今にして思うと、違う研究室へ行って勉強したことは後にいろいろとプラスになりました。

小松：現在のお仕事に入ったきっかけは何でしたか？

宮崎：1985年ころ、企業に居た先輩のTさんが研究室に見えて、「今会社で困っている研

究を手伝えば、少しぐらい研究費が出せますよ」と提案がありました。当時、企業ではニッケル・鉄合金のパーマロイ薄膜の磁気抵抗効果を磁気記録の磁気ヘッドに使う研究が始まっていました。T さんの依頼はパーマロイの磁気異方性にかかわる問題で、多少古めかしい話でしたが、研究室は赤字だったので、お金欲しさにこれを引き受けました。こんな動機で異方性磁気抵抗効果（Anisotropic magnetoresistance effect、AMR 効果）の研究を始めました。そのことが、数年後に私の研究方向に大きく影響してくるとは思ってもいませんでした。

その後、1988 年には鉄とクロムの人工格子で GMR (Giant magnetoresistance、巨大磁気抵抗) 効果が発表され、世界中の磁性薄膜研究者をあっと言わせました。

それに刺激を受け、私も GMR 効果の研究を始めましたが、この研究は、良い人工格子薄膜を作製できる装置を有する研究者が、早くデータを出せて研究をリードできます。なにしろ、最初の GMR 効果が発見された人工格子は、厚さが数ナノメートルの鉄とクロムの薄膜を交互に積み重ねた、精密なナノテクノロジーの産物です。

小松：先生はその時どのような装置をお持ちでしたか？

宮崎：お金がないので、企業で廃棄された真空蒸着装置を再使用しました。そんな状況では精密に厚さを制御した超格子を作るのは容易ではありません。そこで GMR 効果の研究を進める一方で、TMR (Tunnel magnetoresistance、トンネル磁気抵抗) 効果の研究も始めました。AMR 効果から GMR と研究してきたので、TMR もという方向に自然に傾いて行きました。

小松：TMR 効果は何から知りましたか？

宮崎：それまで、磁気抵抗効果の勉強をしてきたなかで、「固体物理」（1980 年 3 月）に当時、IBM のヨークタウンハイツの研究所にいた、前川さんが書かれた解説で、最初の TMR の現象を知っていました（但し、当時は TMR と言う言葉は用いられていませんでした）。それはフランスのレンヌ大学の博士論文です。M. Julliere が、酸化ゲルマニウムを鉄の薄膜ではさんでトンネル接合をつくり、4.2K（マイナス 268.8℃）で、磁場により電気抵抗（磁気抵抗比、MR 比ともいう）が 14%変化する報告を 1975 年に出していました。しかし 4.2K という低温では実用になりません。

研究室に来た 4 年生の研修テーマとしてこの TMR の研究課題を与えました。酸化アルミをコバルトとパーマロイではさんだ素子をガラス基板上に作るよう学生に指示しました。この学生は、すぐに室温で MR 比 1%、さらに 2～3%ほどの値を得ました。彼は修士課程でも非常に熱心に研究を続けましが就職してしまいました。そのテーマは二人目の博士コースの学生に引き継がれました。この学生は電極の材料、酸化アルミの作製方法を色々と変えていたようです。

1994 年 6 月の土曜日の午後のことです。「レコーダーのペンが振り切れた、大変です」と学生が私を呼びに来ました。なんと、それまでの記録とはケタ違いの室温で 18%という MR 比が鉄/酸化アルミ/鉄の接合で得られたのです。これは当時、世界最高の値でした。

TMR 素子の酸化アルミ層の厚さが適切だと、大きな MR 比が得られます。しかし、企業からもらってきた古い真空蒸着装置で、厚さ均一の薄膜作りは大変でした。厚さ 2 ナノメートルほどの薄膜にするつもりでしたが、実際は界面が凸凹だったに違いありません。部分的に穴があかない程度に薄く、うまくトンネル電流が流れる部分があったのでしょう。本当に、ラッキーな成功でした。

小松：1994 年の実験結果で画期的に大きい 18％の MR 比を得たとのことですが、それをどこに発表されましたか。

宮崎：結果を最初に投稿した雑誌（Physical Review Letters）のレフェリーに保留にされたので、別の雑誌（J. Magnetism and Magnetic Materials, 1995）に投稿し直しました。

なお、1994 年 11 月に日本国内であった Spin-Dependent Phenomena in Multi-Layer Systems シンポジウムのランプセッションで、私が室温で MR 比 18％を実現した話をしました。そこには欧米の研究者も招かれていました。この機会に我々の結果は海外にも知れたかもしれません。1995 年 2 月に米国で開かれた Spin Polarized Electron Transport ワークショップに招かれ、いろいろ質問され、説明しました。今にして思えばこれがまずかった。彼らはその頃すでに TMR による MRAM（Magnetoresistive Random Access Memory）の国家プロジェクトを立ち上げるつもりだったようです。1994 年 7 月に私が投稿し、レフェリー保留になった雑誌（PRL）に、MIT のグループの TMR の論文が 1995 年 4 月に載りました。しかし、私の J. Magnetism and Magnetic Materials 記載の論文の方が 1 ヶ月早かったのです。

小松：それは大変悔しいことですね。よく、レフェリーのところに長くとどめておかれているうちに、類似の研究が先に発表されたという話があります。

宮崎：今でこそ、日本でも MRAM は国のプロジェクトですが、私を含めて、TMR のメモリーへの応用は、最初は国内で誰一人思いつきませんでした。先を見通す目利きができるか否かが明暗を分けたと反省しています。私はパテントの書き方も知りませんでした。

小松：画期的なブレイクスルーについて先生のお考えを聞かせて下さい。

宮崎：それは枠から外れた発想が大切だと思います。例えば、金研にいた佐川さんの強力磁石の発明です。世の中には磁性材料の優秀な研究者はいっぱいいます。そのほとんどがアモルファスの研究ではソフトな磁性材料を念頭に研究していました。その分野のオーソリティーがソフトマグネットばかりに注目しているときに、佐川さんは逆のハードマグネットに目を付けたのが成功につながったと思っています。フュージョン（Fusion）は重要であり、大きな研究成果はそのほとんどがフュージョンではないでしょうか。IBM にいた時、江崎さんが提唱した人工格子の作り方は、夢から現実になっています。それとともに MBE（分子ビームエピタキシー）など、いろいろな技術発展があって超薄膜作製法が確立されました。その科学への貢献ははかりしれません。TMR の研究もこれから多面的な協力によって更に発展すると思います。

小松：話は変わりますが、先生が学生に日頃よくかける言葉は何でしょう。

宮崎：「材料が鍵だ」です。今も材料が大切と思っています。東北大化学出身の武井武先生

のフェライト、東北大金研の本多先生のマグネットなど、末永く世界的に役立っているものは材料の開発によっています。異なる専門家同士の協力により、新材料で必ずブレイクスルーができると信じています。

身近な先人に関する読みもので私は学生に石川悌次郎『本多光太郎伝』、日刊工学新聞社と加藤与五郎『創造の原点』、共立出版の二冊を推薦しています。

本多先生の「今が大切」は名言ですね。本多先生が後に東京理科大学の学長になられたとき、車の前に「今が大切」を付けてあったそうですね。

小松：今日は面白いお話をいろいろしていただきありがとうございました。

2009年6月3日 WPIアネックス棟　宮崎教授室にて

ひろし
小松　啓

Interview with Professor Hans-Joachim FREUND, Director, Department of Chemical Physics, Fritz-Haber-Institut, Max-Planck-Gesellschaft

“Try to be ethical, critical and honest”

---Describe what you see, but don’t overdo it---

Prof. Freund (F): I was born in 1951 and grew up in a medium sized city, on the outskirts of Solingen. Solingen is the city that is well known for cutlery and knives. My grandparents and my parents were in this industry. They had a very small company to produce nail nippers which were mainly exported to East Asia.

Prof. Komatsu (K): Henckels, the name is famous.

F: Henckels logo, that’s the Zwilling, the twins. It is still a relatively small company, but it was one of the bigger ones in Solingen. Henckels is a famous one. My parents’ company was two orders of magnitude smaller.

I grew up there and went to school. My father came back from war very late, only just before Christmas, 1949. My parents got married, although they were engaged already before the war.

My father had been in Russia for five years as a prisoner of war. He came back in 1949. It is sort of an important point for me because he could not finish his education before the war. He was pushing me to make sure that I get a good education. I very early started to get interested in two things, in natural sciences and in arts, because my mother was a sculpturer. We were an interesting household. We had this industrial environment that sort of brought the money into the household. For my mother however money was not important, she was interested in art. I had a very nice childhood and I went to school and did my abitur in 1969. They changed the school system during my time in the gymnasium. We used to have our marks given at the end of the school year in April. That did not fit to the yearly turnover. They shifted it to the summer; which meant that one of my school years was contracted to half a year. I finished my high school a year early which was good. So I started my studies in Cologne University, but it also meant that my physical examination for the military service came later. I had to interrupt my studies for 18 months.

K: Compulsory?

F: Yes. It used to be compulsory. Only if you have a medical reason, could you be excused.

K: Even now this is compulsory?

F: Yes, but not really. If you don’t want to serve in the military, then you can serve a social year. I was in the air force. Obviously I am shortsighted, I cannot be a pilot. I was a technical person in telecommunication services. I was in the search and rescue (SAR) unit. But the good thing was that our service was two weeks in a row and then you had one week free. Since I was stationed near Cologne, I could go for that week and continue my studies, which led to the fact that I basically did not lose much time during the military service. I studied physics and chemistry. After my first examination, which we now call the bachelors, but at the time in Germany it was called “Vordiplom.” So it is the pre-exam before you go to the diploma. I dropped chemistry.

K: Why?

F: Because I felt that some of the chemistry professors did not understand what they were teaching. So, I continued physics and then I wanted to work for a relatively famous person who was in Cologne in physics at the time, Professor Herbert Walther. He is a laser physicist and he went from Cologne to Munich to be the founding father of the famous Max Planck Institute for Quantum Optics. Herbert Walther left when I wanted to do my diploma work. So I had to look for someone else to mentor my diploma thesis. In physics, in Cologne, there was superconductivity, heavy fermions, very good theory, but not really solid state physics experiments that I was interested in. I changed over to chemistry because a young professor (Georg Hohlneicher) at the time came to chemistry from Munich and we had one of the first photoelectron spectrometer in Germany in 1973. I designed electron optics and studied charging effects in insulating solids

I finally defended my diploma thesis in chemistry. It was very nice. The chemists helped me to contract the time. Usually you need about 2.5 years and I did this in one year. They gave me extra lab courses that I could do over the weekend. Then I continued to do my thesis in the same group in 1978 on photoelectron spectroscopy of adsorbates in comparison with carbonyl compounds including some theory. Photoelectron spectroscopy was a new technique at the time. I finished my thesis and then I went to the United States, to the University of Pennsylvania as a postdoctoral fellow in Ward Plummer’s group, a very good group at the time and one of the few in surface physics. Bob Schrieffer and Alan Heeger were on the faculty. We had wonderful lunch seminars, it was a very stimulating atmosphere. I learned to work with synchrotron radiation on adsorbate systems. I returned to Cologne and got my habilitation in 1983.

In the same year I was offered a professorship at Erlangen-Nurnberg, which is in the south of Germany. It’s about 150 km north of Munich. After four years there, I went to

the University of Bochum, where I held a chair. In Germany every time you move up in the hierarchy, you have to change place. I spent about 9 years at Bochum and from Bochum I came to Berlin.

K: Somebody called you here.

F: Yes, I just got a telephone call from Matthias Scheffler who was managing director at the time. The way the Max Planck society appoints scientific members is a relatively involved procedure. The institute makes a proposal on a particular candidate to one sections of the Max Planck Society. Our society has three sections: chemical physics engineering, biomedical, and humanities. The section then assigns a committee in which the institute is not represented. They evaluate the candidate and either provide a recommendation to the president or not, in which case the institute has to come up with a new proposal. The Max Planck Society follows the so called Harnack principle to build a department around a person. Harnack was the first President (he was the most influential protestant theologist at the time) of the Kaiser Wilhelm Society (the predecessor of the Max Planck Society) who convinced the emperor to found a new activity to bring science forward. Germany was behind in science at the time and the "German Oxford" in Dahlem was meant to change this.

So I got the offer to join the Fritz Haber Institute in 1995 and I finally started to build up the group in 1996. I have been very happy here since then and though I had a couple of offers to leave I decided to stay.

K: I understand.

F: Once you are here, you are going to stay longer.

K: Very interesting. How is your family?

F: I am married. With my first wife, I had three children. She unfortunately passed away five years ago. She had a brain tumor. This was a very difficult time. I married again less than two years ago. My wife brought her son into the family, so I am dealing with four children now. I am very happy that I have a chance to have a family again because my children from my first marriage are grown up. They are out of the house, twin boys (22) studying economics and my daughter (27) who is a physiotherapist.

K: In Germany?

F: She is now living in Tuttlingen in Southern Germany and she is practicing there.

K: So you have a very happy family now.

F: I have a happy family. Yes.

K: What is the next request?

F: Motivation to science. Well motivation to science. When I was 12 years old, I started to run a laboratory at home, a typical chemistry laboratory. I was spending all my pocket money on trying to get the glassware, distillation and cooling apparatus' and I still own a small Kipps apparatus. A Kipps apparatus is a relatively complicated glass apparatus which allows you to prepare gases.

K: Kipps apparatus. You made it yourself?

F: No, no. That was too complicated. I think it cost 50 marks, which was a lot of money. I had to work my entire vacation for that. I bought a Kipps apparatus so I could prepare gases and do experiments.

K: So this automatically came up? Somebody suggested?

F: No I got interested. My father gave me two books from a guy by the name of Schenzinger (who also became known as a controversial writer during the national socialists regime) one was called "Atom" and the other was called "Anilin." Also, I had a very good biology teacher. I got very interested in biochemistry. I did paper chromatography at home trying to sequence casein from milk.

K: Just looking at the books and reading.

F: Doing experiments and reading more about it, I finally realized that biochemists in general at the time were not really very interested in atomic structure, except the DNA structure which was known. They are interested in big structures. My biology teacher gave me the book that Pauling wrote on the chemical bond. I started to learn about the peptide bond and that got me very interested and so that's basically how my interest in physics developed.

K: You read his general chemistry, Pauling's book or…

F: Yes, "The Chemical Bond"

K: I see. It is quite progressed then for a young high school boy.

F: I never had real difficulties with mathematics. When I was a high school student, I started to read about the foundations of quantum mechanics. In fact, about the history

more than about the mathematics. But knowing the history helps you a lot to appreciate how things hang together and that was very interesting for me. Until the last minute before I entered University, I could not decide whether I would do physics or chemistry. I decided to do chemistry and physics, both. And now we are back at the beginning when I talked about dropping chemistry.

K: There is no big barrier between chemistry and physics. Originally you were interested in atomic structure and the most elementary particles.

F: Not really in elementary particles in the sense of high-energy physics, rather in elementary ideas in chemistry, based on atomic structure.

K: Atomic structure, not even the action, the catalytic action.

F: The reason why catalysis I got interested in was that I noticed that photoelectron spectroscopy was a surface sensitive technique, which was only appreciated by a few groups at the time.

K: Really.

F: It was only in the very early 70s that I think the first paper came out from Wyn Roberts and his postdoc Dick Brundle who was a Turner student. David Turner one of the promoters of photoelectron spectroscopy, who was left out when the Nobel prize was given for photoelectron spectroscopy.

Of course, Gerhard Ertl had done his initial studies in the late 60s on the structure of oxygen on copper via LEED (Low energy electron diffraction). So I had the feeling that this black art of catalysis is getting some scientific basis and that got me interested. I think simply the time was right. For my thesis I did not work in a group interested in catalysis. As mentioned above, during my postdoc time at the University of Pennsylvania I worked in a group that was in surface physics. My thesis advisor was a spectroscopist. He was doing optical spectroscopy in solution mainly. Also photoelectron spectroscopy, but he was more interested in gases than in solids. So only slowly I moved into the field. Then after my habilitation in Erlangen, I started to have my own students. The students I worked with during my habilitation were formally associated with your mentor and not with you.

K: So from spectroscopy, you went to the real entity, not a spectrum, but the real atomic structure.

F: Spectroscopy is a tool to get information on atomic structure. Since Herzberg, we use spectroscopy to get information on atomic structure and I would say 80 % to 90 % of what we know about structure is due to spectroscopy or some kind of combination of spectroscopy and diffraction.

K: You mean Herzberg in Canada?

F: Herzberg who lived in Canada. He was born in Germany. He had a very thick German accent when you heard him speaks. I have had the pleasure of attending the Lindau meetings of the Nobel Prize winners in physics and chemistry and I remember Herzberg was attending.

K: Does it depend on the way he was born in Germany?

F: I guess it has to do with the fact that people learn to speak English only at a later age. I spend my post doc time in United States for two years.

K: That's why you speak fluently.

F: I don't have such a strong accent, as people tell me.

K: You have very good ears to discriminate different sounds. You like languages as well.

F: I now regret that I did not learn French well enough. I had four years of French in School and I spent a sabbatical in a CNRS laboratory in southern France, in Luminy.

Coming back to my thesis, I told you already a little bit about that. I was in Cologne and it was working on photoelectron spectroscopy and I continued as a postdoc but now including the application of synchrotron radiation. We started to look at phenomena that were new for many, namely electron correlation phenomena in the photoelectron spectra of adsorbates. Since you are not a physicist nor a chemist, I try to explain to you what correlation means in this context: An atom is built out of a nucleus and electrons. You can think of the electrons just as a gedanken experiment, as moving independently. You can think of it as such, but you immediately realize that it cannot be right, because electrons carry a charge, and the charge on one electron will influence the other electrons, which also carry a charge, so that there will be repulsion between the electrons. Quantum mechanics tell you that there is not only a repulsion but also exchange and this finally holds nucleus and electrons together. The electronic motion is not independent, but it is correlated.

If one electron changes its path, the other electrons adopt to the change so their paths are correlated. If you have materials where this effect is particularly strong, you will find effects in the spectroscopy that are due to this strong correlation of electrons. Often times you can explain the spectra by looking at the electrons as if they were moving independently or rather, if you want to be a little more precise, to move in an average field. You look at it as if all the other electrons create an average field in which this electron moves. It does not depend on the explicit positions of the electrons. In some cases, this is not a good description. There are materials where this plays a very important role. This has consequences for example in photoelectron spectra.

When Kai Siegbahn promoted photoelectron spectroscopy as an analytical tool, he knew about those effects but he would have said that they play a minor role. He was using the following arguments: if you have a carbon atom in a hydrocarbon, or a carbon atom in methanol, the carbon photoelectron signals, after ionizing the inner carbon electrons are different because the carbon atoms are in different chemical environments and experience a chemical shift. One carbon is bound to an oxygen and to hydrogen in the case of methanol. The carbon is only bound by hydrogen and other carbon atoms in hydrocarbons. Therefore if you have carbon atoms in different chemical environments in one molecule you will have separate peaks in the photoelectron spectrum due to the chemically shifted ionization potential. Now if you have these highly correlated materials, you can be fooled.

K: If it is highly correlated, you can differentiate.

F: You can have several peaks that are not due to a different type of chemical species but arise from only one chemical species because in the ionization process different states of the same species can be populated due to electron correlation. It took quite a while to figure out what was going on, and there were many questionable interpretations of spectra before this was understood. I was interested in this topic.

K: Only one master doing two things.

F: Exactly. We thought that this is very exciting and found that this effect is particularly strong on surfaces.

K: Enhanced in the surfaces.

F: Yes. Enhanced in certain systems with particular chemical bonding. It depends on the systems.

K: So you can tell the different situations in the surface. Comparing these signals, you can tell the difference of the surface. Then you start to have a probe.

F: If you understand your probe you can learn a lot about the system.

K: It is exciting.

F: So when I came back from the United States, I had to build up my own group. We got interested in more chemical problems such as carbon dioxide activation. That was in 1983-84. It is becoming increasingly interesting again today.

We identified a special intermediate. There are certain metals where carbon dioxide dissociates. Carbon dioxide is very inert. It is not very reactive. Often times, carbon dioxide is used as an inert gas, even, in chemistry. That’s why it us so hard to get rid of it once it is formed. We noticed that on some surfaces, CO_2 can be split spontaneously.

K: So such surface can be used as a catalyst.

F: To catalyze the carbon-oxygen bond cleavage.

What happens is the transfer of an electron from the surface to the molecule, as a consequence of which the molecule bends. CO_2 in the gas phase is a straight molecule. Carbon in the middle, two oxygens, one left, one right. If an electron is transferred, it bends. Quantum mechanics tells you it has to bend. Once it is bent, one of the oxygen carbon bonds gets weaker. If this happens on the surface, you create a precursor to dissociation which eventually falls apart into CO and Oxygen. If then other molecules are around there may be reaction and effectively incorporation of the CO_2 into other molecules that may be used further.

K: Very useful too.

F: But it turns out that you have to have certain energetics for the electron to be transferable and that's what we investigated at that time.

K: Still investigation is going on.

F: No, not in my group at present. Our findings were published in a review in Surface Science Report (Elsevier). Other groups use this information now.

K: So are you clear how do you excite electrons?

F: This is reaction in the ground state. No excitation. Now people are starting to do this with light. Because it is easier to transfer the electrons with photons or electrochemically. We had chosen a surface where the electron transfer happened without using light or electric power. Our systems worked by chemical means.

The transfer of electrons is, of course, dominated by two factors. The ionization potential of the surface. How much energy does it cost to take an electron out and how much energy do you gain when you put it on to the molecule. You can estimate what kind of surface do you have to take in order to make that process work. We came up with a surface, we tried it and it worked.

K: It is dependent on material of the surface and also the structure of the surface. Also if it is crystal, it depends on the crystallographic orientation.

F: If it was a surface with (110) crystallographic orientation, we would call it an open surface where the atoms are not close packed. The crucial factor is the ionization potential, the work function.

K: The work function.

F: The work function determines how much energy it costs to take an electron out of the surface. That's the leading term. Then you can put it on to the CO_2 and the electron is bound by something like 500 millivolts. Then the molecule bends and if you are lucky, it split. That's the process.

This was done while I was an associate professor in Erlangen. It was my main work there. When I moved to Bochum in 1987, we started to do the things that we are still trying to perfect. We started to create model systems for heterogeneous catalysts. We started to try to study oxide surfaces and those few people studying oxides at the time were using single crystal oxides, titanium dioxide and so forth, taking sort of the single crystals that they got. Now the problem is when you take oxide single crystals, often times they are insulators. In surface science, however, many of our tools involve charged particles, electrons, ions as information carriers. When you work with insulators, you have the so-called charging problem, something I worked on in my diploma thesis.

If you have an insulator and you take an electron out, the positive charge is not compensated, it stays there. When you try to measure the binding energy of electrons and you have an insulator, the spectrum gives you the wrong values because of the charges and so the measured chemical shift that we addressed above would be incorrect, and you would not know how to correct it. So we tried to circumvent this problem and we came up with the idea to grow very well ordered thin films on metal substrates using the rules of epitaxial growth where the lattice parameters of the metal and the oxide determine the structural quality of the film, and then these thin films will simply not charge.

K: They are not conductive.

F: They are in a way not conductive because they do have a band gap, but when you do these surface science experiments, say in photoelectron spectroscopy, you create secondary electrons and the secondary electrons will compensate because a metal creates many more secondary electrons than a dielectric. So, in a way these films behave as if they were conductive. So we can perform scanning tunneling microscopy and secondary electron microscopy, all these microscopies we can do on these thin films. We can also make sure that the thin films behave as if they were thick. The chemistry depends on the thickness. You can mimic the bulk when you make the film thick enough and study the chemistry that you find on the single crystal. If you make it very thin, an ultra thin, then you can have new phenomena. It is this field that we are still working in. The problem is these films have to be prepared in a very well ordered way. It takes a long time to design a reliable recipe. It’s tricky.

K: One layer, two layers.

F: Yes, this is the advantage of this technique. It opens up the possibility to study model systems for catalysis, where nano-particles are deposited onto the oxide film and you may count the number of layer you are working on. And you may investigate how molecules from the gas phase react with these nano-particles or clusters or directly interact with the oxide-cluster interface. It also allows you to choose ultra-thin oxide films and start to design systems with special properties because the nano-particle on top of the film interacts with the interface below the oxide films used in the preparation.

Metal nano-particles may have different shape, for example they could be facetted or not. You could have a small metal single crystal. They expose surfaces with varying crystallographic orientation. I can show you STM pictures if you want to. You can see that they are facetted in some cases if they are big enough. If they are small, they also have particular shapes, but then every atom counts, you could have for example an Au_{12} or an Au_{18} cluster.

K: Just like berries.

F: We can look at the electronic structure of these systems in detail using STM or all kinds of different techniques.

K: And also AFM as well?

F: We have built up an AFM facility in recent years, yes.

K: Unless AFM is used, you cannot really "see" the true surface. STM is only showing the Fermi surface. If there are vacancies then they would give some picture, which is not the real shape.

F: To have AFM available is very useful, but both AFM and STM give you comparable structures. But AFM can also be used on insulators directly while for STM you will have to use conductors in the above sense, because you need conductivity as we discussed. We are performing AFM in the laboratory with very good atomic resolution and at low temperature and get very comparable information with AFM and with STM. If you are interested, we can have a little tour maybe later so you can look at the laboratory.

K: I'm very interested in it. Originally I studied the crystal growth.

F: So one of the people here was Iwan Stranski. He was at the Fritz Haber Institute. He was also rector of the Technical University here in Berlin.

K: I met him long-long time ago in France. He attended the 3rd International Conference on Crystal Growth (ICCG-Ⅲ, 1971).

F: He came from Bulgaria.

K: Very famous. Original starting point of theory of crystal growth is based on Kossel-Stranski model.

F: Exactly. This is very much behind our ability to grow high quality thin films. A certain work force is needed to achieve your goals in this area. Our group is now relatively big. We are close to 70 people counting everybody. About 22 to 23 Ph.D. students. 8 group leaders. The different groups use and develop different techniques, but they are working on the same systems so there is some synergy.

K: Such as what sort of techniques?

F: We are using many techniques. STM, AFM, LEED, Auger electron spectroscopy, photoelectron spectroscopy infrared spectroscopy, EELS, TDS, TPR, photon STM, EPR, molecular beams, all kinds of stuff.

K: Quite extensive.

F: Yes, it's quite an extensive laboratory. Lots of ultrahigh vacuum machines (UHV), you can have a look later. But as I had the chance to see in Sendai at Prof. Sakurai's group in Tohoku University, there were also many machines.

K: But no comparison to your group?

F: Quite comparable to my group. There are places in the world where the density of UHV machines is higher. You just have to visit the Institute of the Academy of Sciences for Surface Science in Beijing with which we collaborate

K: I didn't know that. Who is the boss of that?

F: Oh, there are several people. I mean the person that we have particularly good contact with, who is also sending students from time to time is a Professor Hongjun Gao. But we also have three Japanese collaborators in the group.

K: Watanabe-san?

F: Watanabe-san is here still but he is leaving. He is going to the Oakridge National Laboratory. And then we have Dr. Hiroko Ariga from Iwasawa-sensei's group. Yasuhiro Iwasawa, who used to be at the University of Tokyo. He is going to be the next president of the Japanese Chemical Society, I understand, or he is already. Also one of his students, he left the University of Tokyo to do a Master already here in Berlin. He is very motivated, learns German and he is studying here. He is doing his master and then goes on perhaps to perform Ph.D work here.

K: So good old tradition between Japan and Germany.

F: Yes. We always had strong exchange with Japan. Right at the time the institute was founded by Fritz Haber, one of his assistants was Setsuru Tamaru, father of Kenzi Tamaru, a very important person in catalysis in Japan. Also in the field of electron microscopy we had strong ties because Ernst Ruska was here. Ernst Ruska, the inventor of the electron microscope. He won the Nobel Prize in Physics in 1986. I'll show you later where some of the instruments were located when we go across campus. By the way I live in the same house Ernst Ruska lived in. This is a tradition in this institute.

K: Now?

F: Yes.

K: Actually about Professor Ruska, Dr. Heinrich Rohrer was really happy because they got Nobel Prize together.

F: Ernst Ruska won one-half and Gerd Binning and Heinrich Rohrer won the other half I believe.

K: Heinrich Rohrer was saying that without Ruska it is shame to get Nobel Prize for STM.

F: Yes, but it took a long time. I mean he got the Nobel Prize when he was 84, so very late. Two years later he passed away.

K: This of course is very important.

F: Yes, it's very important. That's why it is so important to keep a good health (Laugh!).

K: What are your principles of research or belief in science?

F: There are principles. First of all, you have to be ethical. I mean it is not so important to only sell your science. It is important that you do the experiments as good as you can. Nowadays when you look at what people try to do, they try to publish their papers in *Science* and *Nature* only because it looks good and not because it's very good science. I think it is more important to perform good science than to be a good seller. But on the other hand, it is necessary sometimes to sell. But the most important principle in science is to be honest and self critical and to be describing what you have really done.

K: This is very important. This is sort of philosophy to be honest and not to be influenced by rumors and always you see things exactly.

F: Try to describe what you see and do not overdo it but be honest. Also be honest in admitting that we are standing on our predecessor's shoulders. There are lots of people who have done a lot of important work before oneself. One has to give credit to people who have done work before you. You used their information to do your own research.

K: So even private communication must be recorded in the reference; not only the papers but even a private communication from someone's discussion.

F: That's right. That is not done at all. On the other hand, it is also important that society recognizes that science needs funding and freedom. We need reasonable support. Good science cannot be done without being self critical and not without money, at least our kind of science. It cannot be done without freedom as well. Freedom is very important, trust as well. A society has to guarantee the freedom of science. There are not only examples from academia but also from industry where science has been very successful. We think of Bell Laboratories for example. But if you look at the time when Bell Laboratories were successful in science, the research laboratories were operated like an academic environment only with better funding. This is how the big discoveries were made. I do appreciate our industrial managers but I'm not sure they have all the best ideas.

K: American system is very much practical things oriented.

F: That's right. It has advantages. You look at General Electric, Irving Langmuir was an industrial chemist. He did very fundamentally important things.

K: But on the other hand, Michael Faraday, he did not intend to be used in industry, just investigated from intellectual curiosity.

F: That's right.

K: Very good principles. I'm very happy to hear that.

F: I wanted to say something about funding. In Germany we have decent funding organizations based on those principles. The German research foundation is organized in a very interesting way. The learned societies and the academies propose a list of sort of national referees to be elected. The list of people is about three times bigger than the number of posts. Then every scientist in Germany, who has a Ph.D. longer than a certain period of time, has a vote. It's very democratic. This creates a set of national referees, several hundred to elect them.

And I have been doing this in the third term. I can tell you I never get a phone call from people complaining or trying to influence decisions, because you have the backing of the scientific community and people know sometime it is tough. You have to take tough decisions if you are elected. This is something I like about the system.

And so I was very pleased when I realized that the European Union is now trying to establish a new pan European system to fund basic, investigator driven research. The ERC is the European Research Council and its strategy is developed by a scientific council of which I happen to be a member. We are trying to establish a funding organization that operates on the same principles. The ERC gives away two kinds of funds: the starting grant and advanced grants. You can use a substantial amount of money very freely.

K: That fund comes from the government?

F: It comes from the European Union, in particular from the European Commission. Everyone around the world can apply. People from China or from Japan can apply if they are willing to work in Europe for five years.

K: Very few people know this system.

F: You have to find an institution that is willing to accommodate you and your project that is all you need. I'm happy that Europe is finally taking this direction. There is a website to find out http://erc.europa.eu/index.cfm.

So my only message to the next generation is "to be honest and to be critical." I have to tell you none of my kids is doing natural sciences.

My principle that I had when I was a young man was I only tried to do what I could do best. I was not trying to do something because maybe in the future I can make a lot of money. I did only things that I was interested in. Now, I know that it is very dangerous to convey that message to young people because some people may make it and other people may not make it. You have to be careful in sending that message.

However, we badly need science; most developed societies are knowledge based. It's also important for the young generation to realize that the system you live in has to provide the means that people are attracted to science. When I look at the situation in Germany the salary level for a scientist has been declining over the years, it never was at a level you can reach if you go to industry but it was decent. With the present policy society will drive people out of science because in the end, of course, what also counts is whether you can have a reasonable life. You don't want to necessarily have a life in luxury, but decent if you work hard.

And so all these attempts that I see in politics nowadays, for example in the German system to reduce the starting salary for young people, in the long run it's going to hurt our German society particularly badly because we have no natural resources. The only resource we have is brain. Same in Japan. We must make sure that society realizes that this resource is worth a good salary. I am afraid that some of the politicians don't realize that.

K: Most of them don't know.

F: I mean when I look at what happens now, you look at the financial crisis where these people who are making in one year more than even a top scientist can make in his life, then things get out of control. I mean you lose touch.

K: They are spoiling their own lives as well as others just by gathering money.

F: That's right. I think it's a very important message to the next generation and to politicians who have to care about the next generation that we provide the means that people feel an incentive in addition to their wish to do science that they know that if they make it, they may have a decent life.

K: Indeed. Maybe primary school and middle school education is very important.

F: That's also right. It is important that an educational system in a country has a certain permeability. In other words, people go through personal developments. Some people only realize when they are 19 that they are really good at this or that and could be useful to society. You have to be able to give them a chance to prove themselves. I may be wrong, but I've always had the impression that in the Japanese society it is so important which school you go to, the next one, the next one so that almost from the beginning you decide whether you are going to make it or not so that there is this lack of permeability. Isn't it? Is that true or do I have a wrong impression?

K: You are right.

F: And I think that maybe its better if that would be changed. You cannot judge a person applying for a prestigious fellowship or a professorship on the basis of her or his grades in high school. Only because it is so much harder to judge someone on a scientific achievements. It is so much easier to judge on formal grounds or on the basis of those bibliometric measures that people use. I don't think this is a good development.

K: That right. I have the same opinion as you, indeed. In Kyoto University, they traced the achievement in university and achievement in the society. There is no connection.

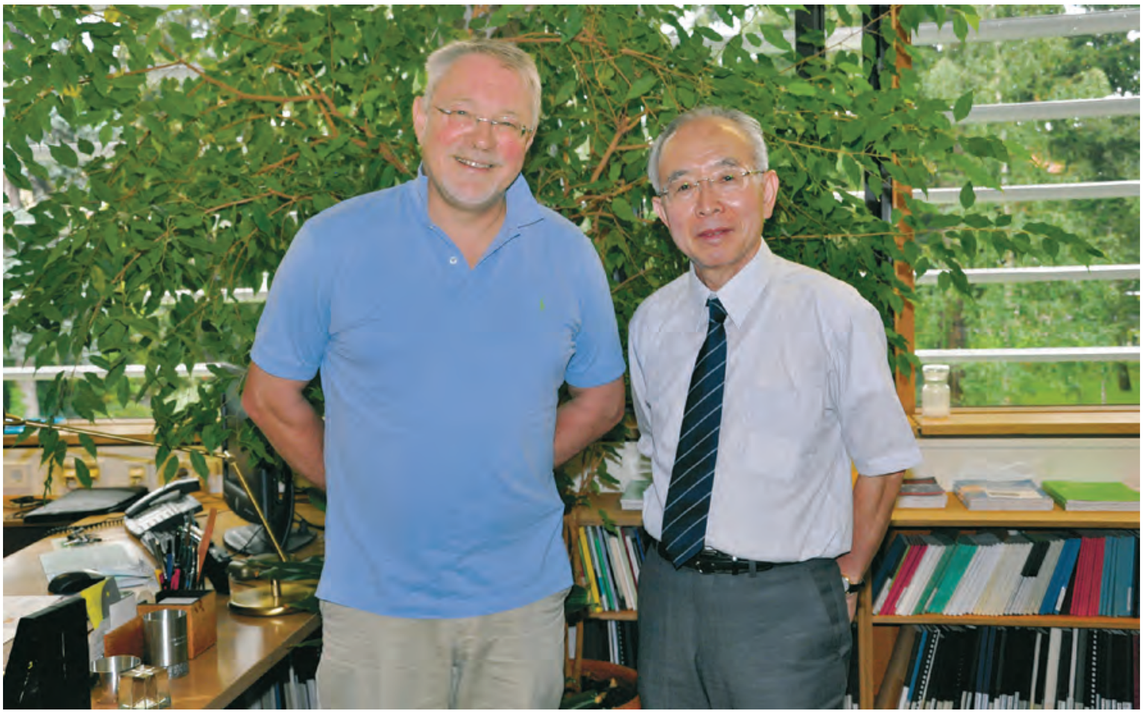
F: Right. You graduated from Kyoto University?

K: No. I graduated from Tokyo Kyoiku University. It's very old university in Tokyo. I studied mineralogy.

F: You said crystal growth. For us this is the key for growing films as I mentioned above. You have to know about that.

K: Actually mineralogical works, looking at the surface of minerals they found epitaxial relation. It is not proved yet by electron microscopy how atoms are matching in epitaxy. Dr. Bednorz also studied mineralogy

F: Now we are down to the hobbies. Years ago I was very much active in cycling. But since the period when my first wife passed away, I stopped somehow bicycling. I should pick it up again and maybe I will. But at that time I stopped. But I always like to do some sports, but I have to admit I have been rather lazy in the last years. But I



read a lot. I like reading, not just science, I read novels. I like crime stories somehow. There is a Swedish writer, Henning Mankell and I came to like him. He has very interesting stories. Well, I read them either in English or in German. Many of them are not very well translated in German. I am still interested in arts a bit. When they have an exhibition or something interesting here in Berlin, I would go. I still like that.

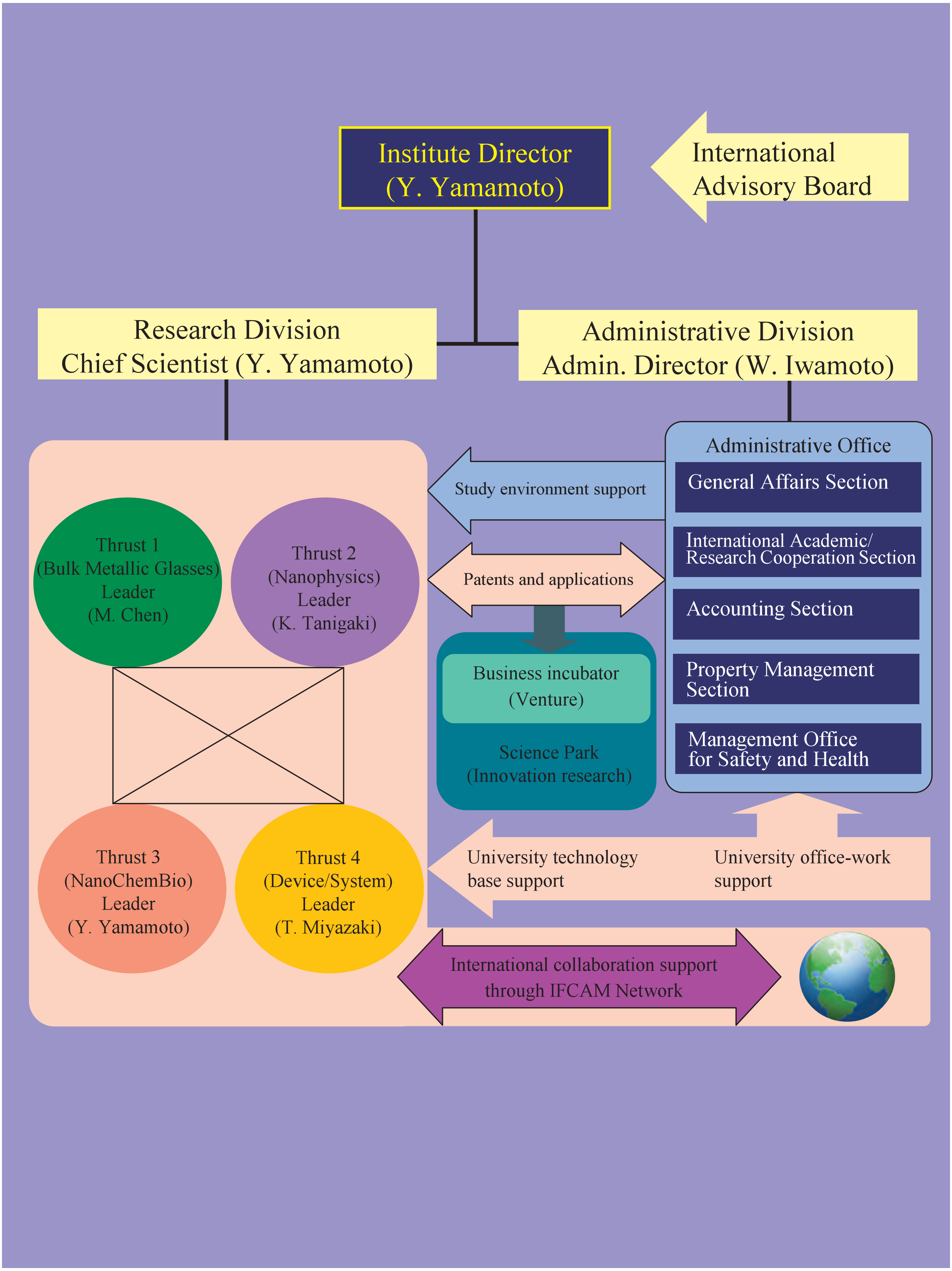
K: So we had a very nice time. I appreciate very much.

F: It was my pleasure.

K: Your philosophy and attitude toward science are most impressive.

Interviewer: Prof. H. Komatsu
at Prof. Freund's Office, August 21st, 2009

News Update


Institute Director
(Y. Yamamoto)
International
Advisory Board
Research Division
Chief Scientist (Y. Yamamoto)
Administrative Division
Admin. Director (W. Iwamoto)
Thrust 1
(Bulk Metallic Glasses)
Leader
(M. Chen)
Thrust 2
(Nanophysics)
Leader
(K. Tanigaki)
Thrust 3
(NanoChemBio)
Leader
(Y. Yamamoto)
Thrust 4
(Device/System)
Leader
(T. Miyazaki)
Study environment support
Patents and applications
Business incubator
(Venture)
Science Park
(Innovation research)
Administrative Office
General Affairs Section
International Academic/
Research Cooperation Section
Accounting Section
Property Management
Section
Management Office
for Safety and Health
University technology
base support
University office-work
support
International collaboration support
through IFCAM Network

Curriculum Vitae of Administrative Director

Wataru IWAMOTO

Specially Appointed Professor, Administrative Director
WPI Advanced Institute for Materials Research
Tohoku University

ACADEMIC:

1977 Bachelor in Law, The University of Tokyo
1980 Diplôme d'Etudes Approfondies (DEA) en science administrative, Université de Paris II

PROFESSIONAL EXPERIENCE:

1977-1979	Japanese Language Division, Agency for Cultural Affairs (Bunkacho)
1977-1981	Post-graduate Study in Université de Paris, France
1981-1983	Section Chief, Medical Education Division, Ministry of Education, Science and Culture (Monbusho)
1983-1984	Section Chief, Social education Division, Monbusho
1984-1986	Director of the Division for Cultural affairs, Shiga Prefecture
1986-1988	Deputy-Director, Planning Division, National Land Agency
1988-1990	Deputy Director, Policy Division, Monbusho
1990-1993	First Secretary in charge of Cultural Affairs, Embassy of Japan in France
1993-1996	Research coordinator, Research Institute Division, Monbusho
1996-1998	Director of the International Acadmic Affairs Divison, Monbusho
1998-2000	Director of the Technical Education Division, Monbusho
2000	Director of the Science Division, Monbusho
2001	Deputy Director-General, National Science Museum
2001-2006	Director of the Division of Secondary, Technical and Vocational Education, UNESCO
2006-2009	Director of the Division of Social Sciences, Policy and Research, UNESCO
2009-Present	Specially Appointed Professor, Administrative Director, WPI-AIMR, Tohoku University

PUBLICATION:

- "Accountability: Setting and meeting standards" in «The Conference Papers of the International conference on the Reform of Secondary Education» (Dec 2002, Muscat, Oman)
- "Les liens entre l'enseignement général et l'ETFP: fondement commun" in «Rapport de la Conférence internationale sur les défis et opportunités au niveau secondaire» (Dec 2003, CIEP, Paris, France)
- Preface to "Des quariers historiques pour tous" «Historical districts for all» (July 2008, UNESCO, Paris, France)

RECOGNITION:

✦ Ordre National du Mérite, Officier (1993, French government)

Interview with Mr. Wataru Iwamoto, Newly-Appointed Administrative Director

Prof. Komatsu (K): Mr. Iwamoto, did you join UNESCO from the Ministry of Education, Science and Culture?

Mr. Iwamoto (I): I started working for the Ministry of Education, Science and Culture in 1977 and, in 2001, applied for the post of a director within UNESCO. I heard that the number of applicants for the post was 200, but after passing the paper screening and interview, I was accepted and worked there for eight years. I applied for this UNESCO post after working as a government official in Japan for 24 years.

While in the Ministry, I was assigned to various jobs, as are all administrative officials. Posts related with academic research included Research Coordinator at the Research Institutes Division for two-and-a-half years, Director of the International Scientific Affairs Division, and Director of the Science Division for six months. During my last years at the Ministry, I was mostly involved in academic fields. I visited Tohoku University five or six times on business.

K: I see. You must have experienced a very different atmosphere at UNESCO compared with that of the Ministry of Education, Science and Culture?

I: In terms of my involvement in education, science and culture, there were really no major differences in my work. At UNESCO, I started with secondary, technical and vocational education and was then transferred to the Social and Human Science Sector where I engaged in matching social science and related policies. I also addressed sports-related issues, which is a somewhat different field from my other jobs. I was involved with the International Convention Against Doping in Sport, right from drafting to adoption. This convention has now been ratified by 127 countries, four years after its adoption. This was quite interesting work for me.

K: What made you apply for the UNESCO position?

I: While I was working at the International Scientific Affairs Division, I was thinking that Japan should be more involved in making an international contribution. One of the reasons why I applied to UNESCO was that I wanted to involve myself in addressing issues such as how to assist developing countries and how to improve levels of education around the world. Another reason is that the Japanese government needed to send an executive official to UNESCO where the staff are required to be fluent in both English and French, and I speak French because I had studied in France, and from 1990 to 1993 I served as first secretary at the Japanese Embassy there.

K: When did you study in France?

I: From1979 to 1981, I studied public administration at the Université de Paris II and earned a master's degree there.

K: That must have been a very enjoyable experience.

I: Yes, it was. Universities in Japan have changed a lot now but in those days when I was a university student, nothing else mattered but the results of the term-end examinations. In France, however, the time schedule of the course is not very hard, while more importance is placed on students' reports and presentations. So I studied very hard. It's a little exaggeration but for days at a time I would just go back and forth between my home, the university, and the library!

K: Didn't you have any time to enjoy yourself, then?

I: Nonetheless, I still frequently attended concerts. I also visited various museums. Not to mention the Louvre and Orsay, I also often visited the museums such as Gustave Moreau museum. When I was first secretary at the Embassy, some Japanese Diet members requested that they wanted to see the Louvre but they only had 15 minutes. To meet such a request, I went to the museum in advance to plan a short museum tour that included seeing the Mona Lisa and the Venus de Milo… that was very enjoyable!

K: I've also visited the museum a few times. Every time I see the Mona Lisa and the Venus de Milo, I feel I see something new. At UNESCO, were there many other Japanese staff members besides you?

I: UNESCO considers it desirable that the number of staff members from a country is proportional to the amount of contributions paid by the country. The contributions from Japan account for 22.5% of UNESCO's budget, the biggest contributor with the United States. There should, therefore, be 80 to 90 Japanese staff members, but at present there are 40, half of which are quite young, in their 30s. One of Japanese

executive officers is Director-General Koïchiro Matsuura (tenure: from November 1999 to November 2009). I was in a position next to him as Japanese, with nobody in between. So, in addition to my ordinary jobs, I listened to the worries and concerns of young staff members and sometimes offered them advice about their future.

K: Connecting the top and bottom is an important, but difficult role. Is Director-General Matsuura responsible for supervising the entire UNESCO?

I: Yes. He was elected Director-General 10 years ago on a recommendation by the entire Japanese government, in addition to his excellent qualifications. The tenure for one term was originally six years but, during his tenure, it was changed to four years. He is now in his second term, the tenth year as Director-General.

K: I'm afraid that what you have mentioned about Japanese people working at UN systems is not well known to us.

I: Dr. Sadako Ogata who served as United Nations High Commissioner for Refugees (UNHCR), is well known, but I'm afraid that very little is heard about all the other Japanese staff. The Japanese government contributes in terms of money but not in terms of personnel. And no matter how hard the Japanese staff work, it is not usually visible to people.

Among Japanese staff of UNESCO, in addition to those working at the Headquarters in Paris, there is one who serves as Director of the office in Kabul, Afghanistan, under very difficult circumstances, and another who is working diligently at the office in a small African country. I hope people will come to learn about such staff and that more people will apply for positions at UNESCO.

K: Japanese people are known for their seriousness in working toward objectives step by step, but are not so good at marketing themselves or demonstrating their performance.

I: I think so, too. I don't mean this in a bad way, but efforts should be made to have others appropriately evaluate what you have done.

K: In our educational system, we scarcely have any such opportunities.

I: As a symbolic example, when I was a child, I was told during meals to eat quietly and quickly and clear the plates from the table as soon as I was finished. But in other countries, they are raised to enjoy conversation with the family during mealtimes. This is a cultural difference. Japan is in a broad sense a rather homogeneous country. Having little experience of fighting other ethnic groups and then making friends with them again, we tend to think that we can understand each other without the use of verbal communication. If you behave in this way at UNESCO, people think that because you do not talk so much, they cannot understand you, and they may conclude that you do not think anything at all.

K: They only judge you from what appears on the surface…

I: Exactly. There were 30 staff members in the Division where I worked last at UNESCO. They were from 20 different countries and due to the cultural diversity, including how to express ourselves, it was impossible to understand each other without saying anything.

K: I agree with you completely. WPI encourages people to engage in free discussion during tea times but this is quite difficult to achieve. We recommend to exchange their business cards not just with other members of the same group but with at least three people in different groups and to talk with them. If you do not encourage them to do so, they tend to confine themselves to a small group.

I: That is true. When we have a reception and invite foreign guests, Japanese people tend to join together with those they are familiar with or with other Japanese participants. It is important to take advantage of such an opportunity to introduce yourself to those whom you have never met or talked with before. Then people will recognize and understand you: "I did not know him well but I found that he has some interesting ideas."

In terms of education, it may be important to provide English education from a younger age, but it is also important, in addition to the education of languages as a tool of communication, to encourage young people to establish and communicate their own ideas and to fit in with other people.

While I was studying in France, I took a summer course in French language. In the class, an American woman asked many questions. I once said to her, "Because you ask so many questions, the class isn't making much progress." In response, she said, "My family fled to the United States from Nazi Germany. In those days, nobody in Germany asked any questions, which resulted in such a disaster. Questioning is the cornerstone of democracy." I found that very interesting.

K: It would be a problem where there is an atmosphere that makes it difficult to ask questions.

I: It would also be unfortunate if nobody asked any questions or made any comments after a speech or lecture. There should be many questions and comments raised by audiences at good speeches and lectures. When I talked about my experience at UNESCO in Japan recently, there were no questions from the audience. I was truly worried for some time after whether my talk was interesting enough.

I think this is also true of scientific theories: the more counterevidence there is against your hypothesis, the closer the hypothesis will be to the truth. If you feel satisfied just with talking and listening, there will be no progress at all.

K: It is not rewarding if it stops there. Japanese education has long placed an emphasis on the interpretation of words and phrases. It is important to remember, word for word, exactly what your teacher said. If you express an opinion different from what has been taught, you will be blamed by your teacher.

I: The teacher's interpretation is everything there. I think it is important to further develop the teacher's interpretation or to deny it. Having doubts is what science should be about.

K: Maybe you can think in that way because you have experience of working overseas, particularly at UNESCO. If you had remained in Japan, perhaps you would have no doubts about the Japanese way.

I: While working at UNESCO, when I came back Japan for a vacation, I sometimes felt a little uncomfortable when talking and being with my old colleagues. For example, when we ordered something at a restaurant, they said, "Oh, I'll have the same…" Choosing the same as another person? I thought, "Well, this is strange."

K: In short, their individuality is not well established. People live according to the hierarchy of the group.

I: There is the atmosphere of each occasion and people sense that atmosphere around them. Japanese people tend to place an emphasis not on the individuals but on the relationship of the individuals. If you fail to read the atmosphere, people regard you as strange. If you remain within Japan, it would be fine only to respect your superiors and follow their opinions. But as globalization has progressed, whether we like it or not, it is no longer possible to avoid having contact with foreign people and products.

You should consciously train yourself from your childhood to establish your own individuality. But if you take too drastic measures, you will become conspicuously different from others, which may isolate you from the rest of Japanese society. This is what is most difficult. In Japan, the nail that sticks out will get a pounding, but when you are outside of Japan, you should be the nail that sticks out. It would be an ideal society where the nail that sticks out is recognized and those who have failed will be given a second chance in society.

K: I think such a basic concept has not yet been discussed by WPI. The other day, Dr. Matsuo, Director of Kyushu University California Office, who has been living in the United States for many years, talked about the "*takotsubo* (octopus trap) culture."

I think what you have mentioned is symbolized by the concept of the *takotsubo* culture.

I: This also applies to government authorities: a *takotsubo* called the "Ministry of Education, Culture, Sports, Science and Technology" and another *takotsubo* called the

"Ministry of Economy, Trade and Industry." They have their own ways of working and implementing policies within their *takotsubo*. Although at least they now interchange personnel among ministries little by little. This is one of the issues that need to be addressed.

K: Once you are stuck in such a trap, it is very difficult to escape from it, and, if you say something that should not be said in the trap, you will be isolated, which leads to a vicious circle. WPI needs to make it a rule that those who do not express their views and opinions will not receive a high evaluation. WPI researchers should be encouraged to present even a single hypothesis so as to vitalize the Institute.

I: The core aim of WPI is to integrate independently-established disciplines in the field of material science. If researchers in engineering disciplines conclude their discussion within the engineering field, there will be no fusion. Only when researchers from different disciplines discuss issues in an interdisciplinary manner will there be true fusion.

K: You are right. In that sense, it would be more convenient if the facilities were geographically proximate. The number of participants in "tea time" events from the Aobayama Campus has remained low and we are thinking we need to do something about this.

When I studied in England, I experienced "tea time" and I really enjoyed it. One of my colleagues once skipped tea time, saying that it is a waste of time. Then the professor's secretary called him and said, "You can skip other events but never skip tea time." So, it really is that important!

Professors whom I have interviewed in the past also said they enjoyed tea time very much, and that it gave them an opportunity to talk with other people in a relaxed atmosphere. They said that, when a prominent professor joined one of these occasions, they would listen to him attentively—even if they did not understand everything at that time, and that they studied even harder by being inspired by the professor. I hope to create a place where we not only teach the students but also provide them with opportunities to inspire each other and communicate positively with other researchers.

I: Tea time is one of those opportunities that enable people to interact with each other. We also need to put more efforts into increasing such opportunities where researchers from the four "thrusts" can interact with each other. I was informed that WPI organizes a large symposium once a year. In addition, WPI should organize more events to bring researchers working in different disciplines together.

K: While large-scale meetings are necessary, we also need additional opportunities for smaller groups of researchers to get together and partake in free discussions.

I: The English word "symposium" originated from the Greek word, as used in Plato's "*Symposion* (*syn* = together + *posis* = drink)," where people could freely discuss what they wanted, while relaxing on couches. Japanese custom allows us to enjoy conversation without any formal constraints at night while people are expected to behave with courtesy and without saying anything useless during the daytime. I think it desirable that we can talk about anything from informal to academic issues in the course of our daily activities.

K: Just for your information, the Japanese Association for Crystal Growth (JACG) has held two-night three-day "free-conversation meetings" for the last twenty years or so. A theme is selected for each meeting and participants are allowed to ask as many questions as possible regarding the presentation made by a researcher. Participants can interrupt the presentation at any time to ask questions. It is important for them to ask even silly questions one after another which the speaker finds difficult to answer. At the end of the meeting, the "Free-Conversation Award" is presented to the person who asked the most interesting question. Asking the speaker "Is that true?" is important, regardless of who is your superior and who is your subordinate. This also serves as a good opportunity for the speaker because such questions sometimes make him or her think about issues that they may not have considered before.

I: People may hesitate to ask questions because they think, "People will laugh at me if I ask such a question," or "My question may deviate from the issue the speaker is talking about."

When I was at UNESCO, I gave a lecture on anti-doping. One member of the audience said to me, "I now understand anti-doping issues among athletes, but how do we deal with the fact that children playing football use unauthorized drugs?" I was familiar with doping issues among adults but was not able to answer his question. Through this lecture, I learned from the audience that there was such a concern in the suburbs of Paris.

K: Most people who make irrelevant but in-depth questions are those outside the field. If they ask you three whys, you have to give up. At our free-conversation meetings, the speaker is not allowed to dodge even such questions. Because speakers are required to give serious answers to all questions, I believe that the free-conversation meetings have helped participants improve their knowledge and capabilities as researchers. You can make rapid progress through exchanging many opinions frankly and at a fast-paced tempo. It is important to understand how interaction with those in different disciplines exerts a positive influence and how we can establish a mechanism to facilitate such interaction.

I: I believe that what I am expected to do as Director of the Administration Department is not only to be engaged in administrative tasks but also to help establish such a mechanism. I will rely on researchers with regard to their research but I will be responsible for providing them with opportunities to promote interdisciplinary efforts.

K: Please visit each one of the groups frequently. Please discuss with them what is essential for integration and share your experiences at UNESCO, particularly about its atmosphere. I hope researchers will regard you as quite different from our former directors.

I: I have only exchanged business cards so far but am looking forward to visiting the professors at the earliest possible time to learn about the content of their research and also about the relationships between the different disciplines. In that way I can be better prepared for designing the appropriate mechanisms.

K: You may sometimes need to have an opportunity to discuss future plans only among PIs. Young researchers often participate in tea time but PIs seldom do. This is my impression but they seem to be stuck in an octopus trap. I hope they will come out of their trap. Prof. Yamamoto is strongly promoting integration. All staff members should have the same awareness, even if to a lesser degree.

I: I may sound presumptuous, but researchers should be well aware that this is really essential in undertaking their own research.

K: Gaining a Ph.D. is only like receiving an affirmation. The acquisition of a Ph.D. degree is not the end of anything, but the start of something new. It is important to start something new after earning the degree and be ready to absorb knowledge from all external resources.

I: That should be the start of “fusion” and “interdisciplinary studies” in its true sense.

K: Each person should be aware that he or she must start something new, something different from what they have been doing up to that point.

Many of the participants in tea time are theorists. Without knowledge about various experiments, theorists cannot develop their theories. They need a theme from an external source rather than an idea that comes up in their brain. Tea time is a good opportunity for them—not only in terms of academic development but also for making friends from around the world. Theorists are willing to take advantage of these opportunities.

I: When I worked at the Research Institutes Division, I was given an opportunity to speak regularly at meetings of the Japan-US Panel of High-Energy Physics, where researchers from Japan and the United Stated participated. I remember that researchers in theoretical physics took every opportunity to talk to as many people as possible—even during a short coffee break.

K: There was an article about Director Murayama of the Institute for Physics and Mathematics of the Universe (IPMU) with his picture in the Asahi Shinbun newspaper dated January 5, 2008. According to the article, he was going to organize a tea time where all members would be invited. One of the office staff said that when he visited Kashiwa to receive training the other day, he was surprised to find out that they have tea time every day. IPMU members are mainly engaged in theory development, which may makes it easier for them have tea time regularly. At Tohoku University, on the other hand, some groups are engaged in practical experiments, and, due to being fully occupied with their experiments, they have “no time for tea.” My hope is that, at least once a week, researchers at Aobayama Campus come to join us on Friday evenings. But I wish I could have tea time every day. In England, tea time twice a day is incorporated in their daily routine—just like three meals a day.

I: I recently talked with Dr. Kenzo Nakamura, Administrative Director of IPMU, and he also said that having tea time is wonderful. IPMU was built on a newly developed site in Kashiwa and all IPMU staff started together and got to know each other there. The operation of the institute seems to work very well, and we would like to follow suit.

K: Today we have talked about a wide variety of topics but I now realize that UNESCO and WPI have a lot in common. I’m certain that here you will be able to make use of all your experience.

I: Thank you. The staff of the Administration Department are all forward-looking and many are fluent in English. I trust my staff. My hope is to develop WPI by removing any barriers between the administrative and research departments.

I believe that the staff of the Administrative Department should be able to understand what research projects are ongoing at a certain level. In this context, efforts are required both from the Administrative staff and from the researchers. Researchers will be encouraged to build up a close cooperation with other researchers as well as with the Administrative staff. Our concerted efforts are required to achieve our goals.

I hope to combine approaches from Europe, where “individuality” is well-established, and Japan, where the emphasis is placed more on consensus in decision making. I believe that prominent researchers in the past in Japan also adopted this approach. While listening to others’ opinions, I will convey my thoughts and opinions to others. It would be ideal to combine the best of both worlds.

K: It will be very beneficial indeed if such an environment can be created. To fulfill this goal, you need a minimum amount of funds. You do not need huge amounts but sufficient to cover the required expenses. I hope you will be able to accomplish something interesting through trial and error without worrying about making mistakes.

I: We also consider that such expenses will be necessary. We are human beings and cannot predict the future. It is natural to make mistakes. We need to build a foundation for trial and error. In that sense, the conventional Japanese bureaucratic system is well designed and, under the system, superiors are responsible for any failure of their subordinates. I always encourage young people not to fear failure and to do what they want without hesitation. I aim to create an environment that will help them achieve our goals.

Interviewer: Prof. H. Komatsu
At the Office of Administration, October 2nd, 2009

新事務部門長　岩本先生にきく

小松： 岩本先生は文部省からユネスコへ行かれたのですか？

岩本：1977年に文部省に入りまして、2001年にユネスコで部長のポストを公募していましたので応募しました。200倍の倍率だったようですが書類選考、面接を通ってユネスコに入り、8年間いました。ですから日本の役人生活を24、5年過ごしてからユネスコにアプライしたことになります。

文部省にいた頃は事務官の常として、様々なところで働きました。学術研究との関連でいえば研究機関課で研究調整官を2年半ほど、それから国際学術課長、さらには学術課長を半年間務めました。最後は学術畑が長かったです。東北大学にも当時5、6回は出張でお邪魔したことがあります。

小松：そうですか。それでは文部省とユネスコでは全然違う雰囲気を味わったのではないのですか？

岩本：教育・科学・文化に関係するという意味で仕事自体はそう変わりません。ユネスコで始めにした仕事は中等教育、職業教育、技術教育というようなことでしたし、それから人文社会科学局に移り、社会科学と政策をマッチングさせる仕事をしました。変わったところではスポーツも私の所管で、「スポーツにおけるアンチドーピング条約(International Convention Against Doping in Sport)」という条約の草案作りから採択までに携わりました。この条約は、採択から4年たった現在では127カ国に批准されています。そうした仕事が面白かったです。

小松：ユネスコに応募された動機は何だったのですか？

岩本：国際学術課で働いていた頃から、日本はもっと国際貢献をすべきだと考えていました。実際に自分の身をもって開発途上国をどう助けるか、あるいは世界的な教育のレベルアップをどうするかという課題に携わってみたかったことが一つです。もう一つは日本政府としても幹部人材を送る必要がある中で、ユネスコの場合は英語とフランス語の両方を出来る必要があった。私はフランスに留学した経験もあり、また1990年から1993年までは日本大使館の一等書記官を務めましたので、一応フランス語はできました。

小松：フランスに留学されたのはいつ頃ですか？

岩本：1979年から1981年までパリ第2大学で行政学を学び、フランスの修士号を取りました。

小松：楽しい2年間だったでしょう。

岩本：そうですね。ただ、今は日本の大学もずいぶん変わってきましたが、私が大学生の頃は期末試験だけ頑張ればよかったようなところがありました。しかし、フランスでは授業時間の拘束は厳しくないがレポートや発表が重要視される。却って一生懸命に勉強をした覚えがあります。半分冗談ですが、当時は自宅と大学と図書館の往き来という生活がず

いぶん続きました。

小松：では遊ぶ時間はなかったですか。

岩本：とは言いながら、演奏会にはしょっちゅう行っていました。美術館回りもしました。ルーヴルやオルセーはもちろん、ギュスターヴ・モローなど象徴派の美術館に何度も足を運んで楽しみました。大使館時代には国会議員の先生方がいらっしゃると、ルーヴルを15分で見たいという要望があったりしましたので、予め下見をしてモナリザやミロのヴィーナスを見るつまみ食いコースを自分で開拓したことも面白かったです。

小松：私も何度か行ったことがありますが、モナリザやヴィーナスは何度見ても毎回新しいですね。ところで、ユネスコでは他にも大勢の日本人が働いていたのですか？

岩本：ユネスコでは国が出資した金額と働く職員の数とを比例させるのが望ましいとされています。日本の出資金額はユネスコの予算の22.5%を占め、加盟国の中ではアメリカとともに最大の拠出国です。本来は80人～90人が働いていてもおかしくないのですが、今現在はおよそ40人、その半分が30代の若い世代です。幹部人材では松浦晃一郎事務局長（任期：1999年11月～2009年11月）がいらっしゃいます。その下が部長の私で、その間の人材がいませんでしたので、通常業務の他に若手職員の悩みや将来の相談に乗ったりもしました。

小松：上と下とをつなぐ大変な役割ですね。松浦事務局長はユネスコ全体をまとめていらっしゃるのですか？

岩本：はい。これは松浦さんの自身の優れた資質に加え、日本政府全体で推して10年前に選ばれました。任期はもともと一期6年だったのですが、途中で一期4年に変更になりました。現在は二期目の4年目ですので、都合10年になります。

小松：案外、日本人がそうした仕事をしていることはあまり知られていませんね。

岩本：国連難民高等弁務官（UNHCR）として働いていた緒方貞子さんはよく知られていますが、そのほかは意外と知られていません。日本はお金を出しても、なかなか人は送らない。また、日本人は一生懸命働いていても、なかなか一般の人には見えてこないという側面があります。

ユネスコの邦人職員の中でもパリ本部だけではなく、アフガニスタンのカブール所長として大変な状況の中でも頑張っている人、アフリカの小さな国のオフィスで頑張っている人もいます。そういった方々の活躍をもっと皆さんが知って、アプライしてくれる日本人が増えるといいです。

小松：日本人は地道に、真面目にコツコツとやるのは得意ですが、売り出すことやパフォーマンスが本当に下手ですね。

岩本：そう思います。悪い意味ではなく、自分のやった分は正当に評価されるようにすべきです。

小松：われわれが育ってきた教育の中では、そういうチャンスがほとんどなかった。

岩本：象徴的なのが、私が子供の頃は、食事をするときには「静かにさっさと食べて片付

けなさい」と言われた。ところが海外では子供のころから家族の皆とおしゃべりをするのが当たり前の環境で育っています。そこはどうしても文化の差ですね。日本という国自体が大まかな意味で一民族国家ですので、他民族と喧嘩をして仲直りをする経験があまりなく、以心伝心で分かってもらおうとしてしまう。それをユネスコでやると、「何だあいつ、一言も言わないじゃないか。何を考えているのかわからない。結局何も考えてないんじゃないか」ということになってしまう。

小松：表面に表れた部分でしか判断してもらえませんからね。

岩本：その通りで、ユネスコの私の最後の部署では職員が30人おり、その国籍は20カ国にわたっていましたが、表現の仕方などの文化の違いから、やっぱりお互いに思っていることは言わないとわからない。

小松：全くその通りだと思います。WPIでもティータイムの時のフリーディスカッションを推奨していますが、なかなか難しいことです。同じグループの人ではなく、少なくとも3人と名刺交換をして違うグループの人と話す。そういったことを強制しないと、どうしても小さく固まってしまいます。

岩本：おっしゃる通りで、日本では、ともすると海外からのお客さんを交えてレセプションをやっても、どうしても知った者どうしや日本人どうしで固まってしまう。知らない人だからこそそういった機会に話して、知ってもらうことが大事です。そうしたことから「あいつは今まで知らなかったけれど面白いことを考えているじゃないか」と思ってもらえる。

教育に関しても、小さい頃からの英語教育も大事かもしれませんが、言葉というツールだけでなく、自分の考えをしっかり持って伝達し、積極的に他人に溶け込んでいくような姿勢を培うことも同じくらい大事だと思います。

私は留学中にフランス語の夏期講座に通っていたのですが、参加しているアメリカ人の女性が余りにもたくさん質問をする。ある時「あなたがそんなに質問をすると授業が全然進まないじゃないか」と言うと、「実は私の家族はドイツのナチの時にアメリカに逃げてきた。ナチの時は誰も質問しなかったからああなった。質問することこそ民主主義の基本だ」と面白いことを言っていました。

小松：質問ができないような雰囲気があることこそ大変です。

岩本：また、スピーチや講演の際に質問やコメントがないというのも困りものです。いいスピーチやいい講演というのは質問やコメントがどんどん来なくてはいけません。先日、ある所でユネスコでの体験談を話した際に質問を募ったら、全く質問がなかった。しまった、自分の話した中身が悪かったのか、としばらく悔やみました。

科学の理論でもそうだと思いますが、自分の仮説に対する反証がどんどんあってこそ真理に近づく。それがなくてただ「話した、聞いた」では全く進歩が生まれません。

小松：それでは話し甲斐がないですね。日本の教育では昔から訓古の学というのがある。先生に教えられたことを繰り返し一字一句覚えることが重要で、変な意見を言うと先生に「何だお前は」と言われてしまうわけです。

岩本：先生の言葉の解釈だけで終わってしまうのですね。そこから発展させたり、打ち消したりすることが重要なのですが。疑ってかかることがサイエンスでしょう。

小松：おそらくそれは岩本さんが海外、特にユネスコのような場に行ったからそう思うのでしょう。日本にずっといたらそれが当たり前になってしまいます。

岩本：ユネスコでの勤務中、休暇で日本に戻った時に昔の同僚と話すと、ちょっとした違和感もありました。例えば飲食店でオーダーをする際にも「僕も君と同じでいいよ」と言うのです。他人と同じでいいという世界には「あれっ？」と思いました。

小松：要するに「個」の確立がされていないわけです。集団のヒエラルキーに従って生きている。

岩本：場の空気があって、なんとなく皆が空気を読みながら生きていますね。また個の人と人ではなく、人と人との関係性を重視しがちです。空気が読めないと却って変に思われてしまう。日本社会だけで生活が済む頃は、目上を尊重して皆に意見を合わせていればよかったのですが、国際化が進んで否が応にも外国の人・モノとかかわる現在では、それでは済まなくなっています。

　子供の頃から意識をして「個」の確立をしていかないといけません。ただ、あまりドラスティックにやりすぎると、今度は日本社会の中で浮いてしまう恐れもあります。そこが難しいところです。日本では出る杭は打たれますが、外国では出る杭にならないといけない。出る杭は認めて、失敗しても社会全体でセカンドチャンスを与えられるようになることが理想です。

小松：WPI のディスカッションでもそういった基本的なところがまだ抜けているように思います。先日、長らくアメリカに滞在されている九州大学の米国オフィスの松尾先生が「タコツボ文化」の話をしてくださったのですが、その話に象徴されているように思います。

岩本：それは役所も同じです。「文部科学省」というタコツボ、「経済産業省」というタコツボの中で、仕事や政策の進め方にそれぞれのやり方があります。今でこそ人事交流を少し行っていますが、やはり何とかしていかなければいけないことの一つです。

小松：一度入ってしまうとなかなかそこから抜けられなくなってしまいますし、その中で変なことを言うと浮いてしまいますから、悪循環になっています。WPI でも黙っている奴は評価を下げるぞ、とした方がいいですね。一つの仮説でも思ったことはどんどん言って、もっと活気づけないといけない。

岩本：WPI では材料科学の中のそれぞれ確立した分野について、それらを融合していくことが柱になっています。ですから、例えばエンジニアリングの人がその分野の中だけの議論で終わっていたら融合もありえません。それぞれの分野の人が分野を越えてわいわい言って、そこで初めて融合になるわけです。

小松：そうですね。そういった意味でも地理的に一つの場所に集まっている方がいいのですが。ティータイムをやっても青葉山キャンパスからはなかなか参加者が増えないので、どうにかしなければいけないと思っているところです。

私もイギリスに留学していた時にティータイムを経験しましたが、本当によかったです。ある時私の同僚があんなの時間の無駄だとさぼっていたら、教授の秘書から電話がかかってきて「他のことは出なくてもいいからティータイムだけは出てこい」と言われていました。それだけ大事なんですね。

これまで私がインタビューした先生方も、リラックスした雰囲気の中で話せるティータイムはすごく良かったとおっしゃっていました。偉い先生が来て、話す内容はわからなくても、話の内容に刺激を受けて一生懸命勉強をしたそうです。ただ教えるのではなく、会うことによってお互いに刺激を与え合うようなポジティブな発信ができる場を何とか作りたいと思っています。

岩本：ティータイムもそうですが、いろいろな場を利用して4つのThrustの人が混じりあう場を何とかして増やさないといけません。WPIでは年に1回の大きなシンポジウムをやっているようですが、他にも異分野の研究者が集まる工夫が必要です。

小松：大きな集まりも必要ですが、小さなグループがいくつか集まって一つのテーマについてフリーディスカッションをするような場がほしいです。

岩本：シンポジウムの語源となっているプラトンの「饗宴」も、みんなで寝転がって言いたいことを言い合っていたわけですから。日本の場合、昼間は裃を正して何も言わず、夜になれば無礼講でくだらない話をする、という習慣がありますが、日常の中でもくだけた話から学問の話までできれば一番いいですね。

小松：ご参考までに、日本結晶成長学会では20数年にわたって毎年二泊三日で「放談会」という会を開いています。テーマを設定し、誰かのプレゼンテーションに対して徹底的に質問をする。いつ手を挙げて話を中断してもいいのです。先生が答えに詰まるような馬鹿な質問をどんどんすることが大事です。そして最後に一番面白い質問をした人に「放談賞」という賞を出しています。親分・子分なしでとにかく「本当ですか？」と聞くことが大事です。これは話す先生にとっても大切なことで、今まで考えてもみなかったことを考える契機になります。

岩本：「こんな質問をして笑われるんじゃないか」「この人が話したことから外れているんじゃないか」とついつい口ごもってしまうのですね。

ユネスコにいた時、私がアンチドーピングについて講演をした際に、聴衆から「スポーツ選手のことはわかった。じゃあ、今子供たちがサッカーをやる時にですら薬を飲んでいることについてどうするか？」と聞かれた。私は大人のドーピングについては詳しかったのですが、そんなことは知りませんでした。パリ近郊あたりではこうしたことが問題になっていると逆に教わりました。

小松：突っ込んだ馬鹿な質問をするのは自分の専門分野ではない「場違い」な人が多いですね。3つ「なぜ？」という質問をされるとたいていお手上げになります。これを放談会ではごまかさずにきちんと答える。これでずいぶんいい人材が育ちました。忌憚のない意見をテンポ良くたくさん交換できると進歩が速いです。違う分野の人との関わりがいかにポ

ジティブに働くか、その仕組みを作るにはどうすればいいかということですね。

岩本：事務部門長として私に求められていることは単に事務的に物事を進めることだけではなく、そういった仕掛けを作ることだと思っています。研究の中身は研究者の皆さんにお願いしますが、そういった研究を融合させるための場を考えていかなくてはいけない。

小松：それぞれのグループをどんどん訪ねて下さい。融合にはどういったことが必要か、ユネスコでの雰囲気などを積極的に話して、「今度の事務部門長は変わっているな」と言われるようになっていただきたい。

岩本：今のところはまだ名刺交換程度ですが、なるべく早い機会に先生方のところへ伺って研究内容や各分野の関係を勉強し、仕掛けを考えていきたいです。

小松：場合によってはPIだけが集まってお互いにどうするか話し合う機会があった方がいいかもしれません。ティータイムには若手は出てくるのですが、PIがほとんど出てきません。私の印象ではみんなタコツボに入ってしまっている感じがします。ぜひ自分たちのタコツボから出てきてほしいですね。山本先生も融合を強く奨励していますが、やはり小さくてもいいから全員がそうした意識を持たなくてはいけません。

岩本：口はばったい言い方ですが、自分の研究を進める上でもそれが絶対必要条件になるということを意識していかないといけませんね。

小松：Ph.D.は蕎麦屋でいえばのれん分けです。学位を取ったら終わりではなく、そこからがスタートです。取った後に新しいことを始めて、外から吸収することが大事です。

岩本：それが本当の「融合」「学際化」の始まりでしょうね。

小松：一人ひとりの中に、今までの延長線上ではなく新しいことをやらなければいけない、という意識があればいいんです。

ティータイムによく出てくるのは理論屋さんが多いです。理論屋さんはいろいろな実験を知らないと自分の理論を進化させられませんから。自分の頭の中で考えるのではなく、外からのテーマが必要なのです。ティータイムは学問だけでなく、インターナショナルな友人を作るいいチャンスです。理論屋の人たちは非常にこうした機会に積極的です。

岩本：私が研究機関課にいた頃、日米高エネルギー物理学会合という日米両国の研究者が集まって定期的に話す機会がありました。そう言われてみると、理論物理の先生方はコーヒーブレイクのちょっとした時間にでもたくさんの方と話をしていました。

小松：2008年1月5日の朝日新聞にIPMU（数物連携宇宙機構）の村山機構長の記事が写真入りで掲載されていて、全員参加のティータイムの時間を設けると書いてありました。先日、事務スタッフが柏に研修に行った際、やはり毎日ティータイムをやっていたと驚いていました。ただしIPMUは理論中心ですので、身が軽いのでしょう。東北大の場合は実験をやっているグループもありますので、実験をやっているとどうしても「ティータイムに行っている時間はない」となってしまう。ですから、最低でも週に1回、金曜日の夕方には青葉山からも降りてきて集まってほしいです。できたら毎日でもやりたいのですが。イギリスでは三度の食事と同じように、2回のティータイムも一日のリズムの中に組み込ま

れています。

岩本：私も最近IPMUの事務部門長の中村健蔵先生とお話をしたのですが、やはりティータイムは素晴らしいとおっしゃっていました。柏の場合は更地にできたところですから、全員がそこで知り合うところから始まっている。非常にうまくいっているようですね。当機構でも努力していきたいところです。

小松：今日はいろいろと話が飛びましたが、ユネスコとWPIには共通点が多くあることがわかりました。きっと今までの経験を生かしてくださることと期待しています。

岩本：ありがとうございます。事務部門の職員も前向きですし、英語ができるスタッフも揃っているようですので、信頼ができると思っています。事務部門・研究部門の垣根なくWPIを発展させていきたいと思っています。

事務部門のスタッフも研究内容の詳細はわからないにしても、ある程度どういうことなのかはわかるようにならないといけない。そういった意味で事務部門も努力をしなくてはいけないし、研究者の方も研究者同士や事務部門と交流を図っていただき、みんなが一つになって目標に向かっていく必要があります。

「個」が確立しているヨーロッパと、皆のコンセンサスを得て決めていく日本との両方のいいところを合わせていきたいです。日本の過去の優れた研究者もそうしてきたのでしょうから。人の意見を聞きながら、自分からも発信をする。両方のいい点がマッチングできればと思っています。

小松：そういった雰囲気ができればいいですね。そのためには最低限のお金がいると思います。贅沢なお金はいりませんが、経費としての当然のお金はいります。失敗を恐れず試行錯誤を繰り返して面白いことができればいいですね。

岩本：我々もそういったお金は必要経費として考えています。人間ですので将来のことは読めないわけですから、失敗して当たり前です。トライアンドエラーをする土壌を作っていかないといけない。そういった意味では、今までの日本の官僚システムはよくできていて、下の失敗は上が責任をとるようにできています。特に若い人は失敗を恐れず、自分の考えでのびのびとやっていってほしいです。私もそうした雰囲気を作っていけるようにします。

2009年10月2日　WPI事務部門長室にて
ひろし
小松　啓

“Atomic-scale heterogeneity of a multicomponent bulk metallic glass with excellent glass forming ability”

T. Fujita, K. Konno, W. Zhang, V. Kumar, M. Matsuura, A. Inoue,
T. Sakurai and M. W. Chen

Physical Review Letters 2009

Formation mechanisms of multicomponent bulk metallic glasses (BMGs) with very low critical cooling rates have been one of the most outstanding issues in solid-state physics and materials science. In general, the formation and stability of condensed matter are closely related to their atomic structure. Nevertheless, the structure of BMGs is poorly known and, as a result, the atomic origins of glass forming ability (GFA) of BMGs have not been well understood [1]. Traditionally, atomic size ratios of constituent elements have been suggested to be the most important factor governing glass forming ability (GFA), particularly in alloys only containing transition metals, and chemical effects arising from interatomic interactions have not been well assessed. In the recent ***PRL*** paper by Fujita, *et al.* [2], the atomic structure of a multicomponent $Cu_{45}Zr_{45}Ag_{10}$ bulk metallic glass was systematically investigated by state-of-the-art EXAFS experiments and *ab initio* molecular dynamics simulations. The excellent GFA of the ternary alloy in comparison with a binary $Cu_{50}Zr_{50}$ alloy is demonstrated to be associated with chemical short- and medium-range order through the formation of Zr-rich interpenetrating clusters centered by paired and stringed Ag atoms (**Figure 1**) and Cu-rich icosahedra. The atomic-scale heterogeneity caused by chemical short- and medium-range order is found to play a key role in stabilizing the liquid phase and in improving the GFA of the multicomponent alloy. This study uncovers the atomic origins of the excellent GFA of the multicomponent BMG and underscores the importance of chemical effect in the formation of amorphous structures in metal-metal based alloys.

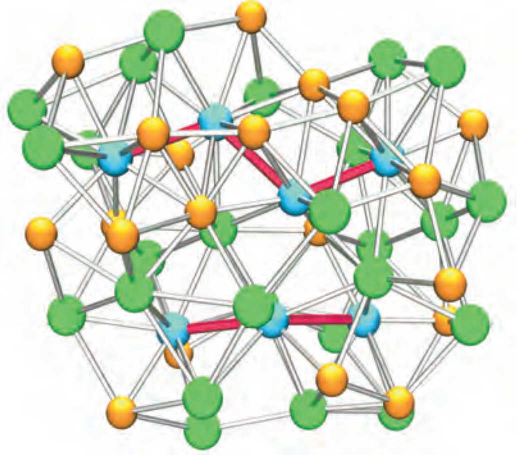


Figure 1 A large interpenetrating clusters centered by stringed Ag atoms. The red line denotes Ag-Ag connections, and the bronze, green, and light blue balls represent Cu, Zr, and Ag atoms, respectively.

Reference

[1] M. W. Chen, *Annual Review of Mater. Res.* **38**, 445 (2008).

[2] T. Fujita, *et al.*, *Phys. Rev. Lett.*, **103**, 075502 (2009).

The New WPI Joint Seminar Series

by M. Tsukada and T. Hashizume

The 6th Seminar July 15 (Wed.) 15:00~17:15

Dr. Koji S. Nakayama (WPI-AIMR):

"Nanostructures of Metallic Glass -Cutting Edge-"

Prof. Masatsugu Shimomura (WPI-AIMR):

"Hierarchically Structured Biomimetic Surfaces Prepared by Self-Organization"

The7th Seminar July 29 (Wed.) 14:00~17:15

Prof. Takeshi Egami (WPI-AIMR and Univ. Tennessee):

"Nature of the Glassy State and Democracy."

Prof. Tadafumi Adschiri (WPI-AIMR):

"Supercritical hydrothermal synthesis of hybrid nanoparticles for "Fusion Nano Materials""

Prof. Reo Kometani (The Univ. of Tokyo):

"The three-dimensional nano- and microstructure fabrications by focused-ion-beam chemical vapor deposition, and their applications"

The 8th Seminar Sept. 4 (Fri.) 15:00~17:35

Prof. Herbert Gleiter (Institute of Nanotechnology, Karlsruhe Research Center, WPI-AIMR Advisory Board member):

"Nanoscience and Nanotechnology: The Key to New Studies in Other Areas of Science and Technology"

The 9th Seminar Sept. 15 (Tue.) 14:30~18:00

Dr. Masayuki Nihei (Univ. of Tsukuba):

"Cyanide-bridged polynuclear metal clusters: The smallest units of bulk Prussian blue analogues"

The 10th Seminar Sept. 25 (Fri.) 15:00~17:00

Dr. K. Hono (WPI-MANA, NIMS):

"Advances in laser assisted atom probe"

Dr. K. Nakajima (WPI-AIMR):

"Rubber elasticity-from macro to nano, again to macro-"

Nanostructures of Metallic Glass

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WPI Advanced Institute for Materials Research

Keywords: metallic glass, nanowire, nanotube, mechanical property, amorphous

Bulk metallic glasses (BMG) have exciting potential for structural, chemical, and magnetic applications with the sizes ranging from micrometer to centimeter, but the fabrication and characterization down to nanoscale remains an important challenge. Progress has been hindered by the lack of bottom-up methodologies to produce amorphous nanostructures. Recently, Koji S. Nakayama (BMG group) and co-workers from WPI-AIMR, Tohoku University show the self-organized amorphous nanostructures including nanowire and nanotube (Fig. 1) that are formed on the fracture surfaces after conventional compression tests of BMGs [1]. The discovery of one dimensional nanostructures is important because the outstanding mechanical properties of BMGs are particularly attractive in nano-electromechanical system applications.

However, it is difficult to control their morphologies because these nanostructures were created by instantaneous fracture processes and the surface oxidation is not negligible. Nakayama and co-workers continue to investigate the controlled formation of individual metallic glassy nanowires based on superplastic deformation above the glass transition temperature and succeed to obtain mechanical properties from the Euler-Bernoulli equation [2]. These nanowires (Fig. 2) exhibit a high strength with the excellent flexibility where the elastic modulus is much smaller than that of the bulk owing to the hyper-excess free volume in the amorphous states.

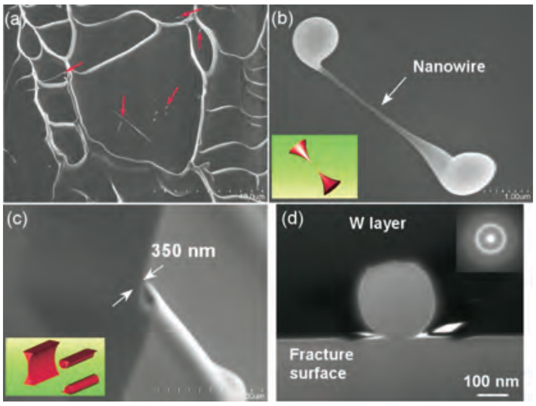
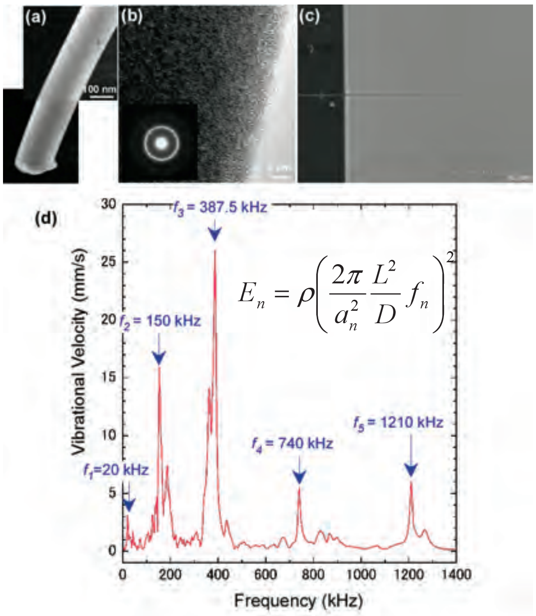


Fig. 1 Scanning electron microscopy (SEM) image of the fracture surface of Zr based BMG. (a) Vein pattern. (b) Nanowire. (c) Nanotube. (d) Transmission electron microscopy (TEM) image of a cross section of 250 nm diameter nanowire. Diffused electron diffraction pattern confirms the amorphous states in nanowire.



$$E_n = \rho\left(\frac{2\pi}{a_n^2}\frac{L^2}{D}f_n\right)^2$$

Fig. 2 (a)-(b) TEM images of the individual metallic glassy nanowire. (c) SEM image of cantilevered nanowire beam for vibration frequency measurements. (b) The result of resonant frequencies. E_n: Young's modulus, ρ: density, L: length, D: diameter, f_n: resonant frequency, a_n: constant.

The amorphous nanowire associated with the elongated length, excellent flexibility, handleability, and high strength is suitable for nanoscale tools in physical, chemical, electromechanical, biomedical, and materials science.

[1] K. S. Nakayama et al., *Nano Lett.* **8**, 516(2008).
[2] K. S. Nakayama et al., *Adv. Mater.* (in press).

Nature of the Glassy State and Democracy

Takeshi Egami
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Astronomy, Department of Materials Science and Engineering, University of Tennessee,
Knoxville, TN, and Oak Ridge National laboratory, Oak Ridge, TN, USA

Phil Anderson once famously wrote, "The deepest and most interesting unsolved problem in solid state theory is probably the theory of the nature of glass and the glass transition" [1]. As many of the fundamental questions in the theory of crystalline solids have already been basically answered and properties can even be predicted (materials by design), the glass theory could well be the ***last frontier*** in condensed matter physics. In liquids and glasses atoms are strongly correlated in space and time without periodicity, making it impossible to apply theories developed for crystalline solids. A model for such a state is a ***democratic society***, whereas crystals resemble a society under dictatorship. In a democratic society the element of irreducible representation is each individual. Thus the collective decision is made based upon the personal, or local, view of each individual. In my view the theory of liquids and glasses has to be equally democratic, ***bottom-up rather than top-down***. We created such a theory, the topological fluctuation theory, based upon the concept of atomic-level stresses [2]. The atomic-level stresses are directly related to the local topology of near neighbors of atoms. If all the nearest neighbor atoms are at the ideal distance from the atom at the center the stress at that atom is zero. A mismatch between the central atom and the site it is fitted creates the atomic level stress. Thus it measures the "happiness" of the atom. Just as is in our society the average of happiness is zero. The relevant order parameter is not the average (first moment) of the stress distribution, but is the width of distribution (second moment). Interestingly we discovered that the self-energies of the atomic-level stresses accurately follow the equipartition theorem in high-temperature liquids, suggesting that they are the quasi-particles of atomic dynamics [3]. We use these stress fluctuations as the basis for statistical mechanics of liquids and glasses to predict their behavior, including the glass transition [4], structural relaxation and mechanical deformation. In collaboration with the WPI team, the group of Prof. Mingwei Chen in particular, we are developing the general theory of metallic glasses based upon this concenpt.

[1] P. W. Anderson, *Science* **267**, 1615 (1995).
[2] T. Egami, K. Maeda, and V. Vitek, *Phil. Mag. A* **41**, 883 (1980).
[3] V. A. Levashov, R. S. Aga, J. R. Morris and T. Egami, *Phys. Rev. B,* **78,** 064205 (2008).
[4] T. Egami, S. J. Poon, Z. Zhang and V. Keppens, *Phys. Rev. B*, **76,** 024203 (2007).

The three-dimensional nano- and microstructure fabrications by focused-ion-beam chemical vapor deposition, and their applications

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Focused-ion-beam chemical-vapor-deposition (FIB-CVD) enables us to fabricate the arbitrary three-dimensional (3-D) nano- and microstructures at any local position.[1,2] In addition, various materials can be deposited by changing the gas source. Therefore, the developments of novel functional devices using FIB-CVD can be expected. Thus far, we have been researching on nanomanufacturing tool fabrications and bio-nanotool fabrications as electromechanical applications and biological applications of FIB-CVD, respectively.[2] In WPI Joint Seminar, the 3-D nano- and microstructure fabrications and their nanotool fabrication using FIB-CVD were reported.

Nanomanufacturing tool fabrications using FIB-CVD were carried out to achieve the handling nanomaterials and nanoparts in nanofactory. And, we have fabricated the nanomanipulator as a nanomanufacturing tool. Nanomanipulator is a very important tool to achieve the manipulation of the nanoparts in the nano- and micro-space. Nanomanipulator was made of diamond-like carbon (DLC). DLC deposited by FIB-CVD had Young's modulus and density of 190 GPa and 3.8 g/cm^3, respectively. DLC deposited by FIB-CVD had the higher density compared with it of the typical DLC. And the glass ring manipulation was demonstrated using a nanomanipulator. Furthermore, a glass capillary-based field electron emitter was fabricated to use as the nano-tool for the spot deposition. A electron emitter had the cathode and anode made of DLC. DLC deposited by FIB-CVD had a smaller work function (2.9 eV) than the work function (4.4 eV) of the commercial DLC deposited by ion-plating. This result indicated that DLC deposited by FIB-CVD was very useful material for field electron emitter fabrication. And, we confirmed that the glass capillary-based field electron emitter was driven by the threshold voltage of 180 V. This implied that the realization of a spot deposition tool using field emitter device could be expected. In addition to this, the inner vacuum of microcapsule fabricated by FIB-CVD was evaluated using a field emitter device (diode) to achieve a vacuum microdevice. A vacuum microdevice enables us to fabricate the high-sensitive sensing device. However, a miniaturization of the device structure was needed to incorporate it into nanoelectromechanial systems.

As a result, the vacuum in the microcapsule was maintained at atmospheric pressure. This indicates that the vacuum nano- and microdevices will be achieved using FIB-CVD. And, the results obtained in this experiment indicated that the FIB-CVD was a promising technique as a vacuum sealing technique to achieve the vacuum microdevices.

In biological applications of FIB-CVD, bio nanotool fabrications have been researched to achieve the single organelle operation and measurement. It is necessary to accurately manipulate and analyze single cells and organelles to better understand their biological phenomenon. And bio nanotools are very useful and important in clarifying unknown phenomenon. In this study, a several bio nanotools such as nanoinjector, cell cutter, capturing tool and so on were fabricated. As a bio nanotool fabrication, a glass capillary-based capturing tool fabrication was carried out to manipulate the single chloroplast in the cell. And, we succeeded in the single chloroplast manipulation from cell using a capturing tool. These indicate that the nanostructure fabrication using FIB-CVD is a useful technique as a research support tool fabrication technique on various basic research fields.

REFERENCES

[1] S. Matsui, *et al.*: J. Vac. Sci. Technol., B **18**, 3181 (2000).
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WPI-INPG Europe Workshop

Hiroshi Komatsu

In August 25-28, 2009, Professor Yavari organized the first Europe workshop for WPI-AIMR at the Maison du Tourism in Grenoble, France. The workshop was attended by 70-plus researchers from 20 countries.

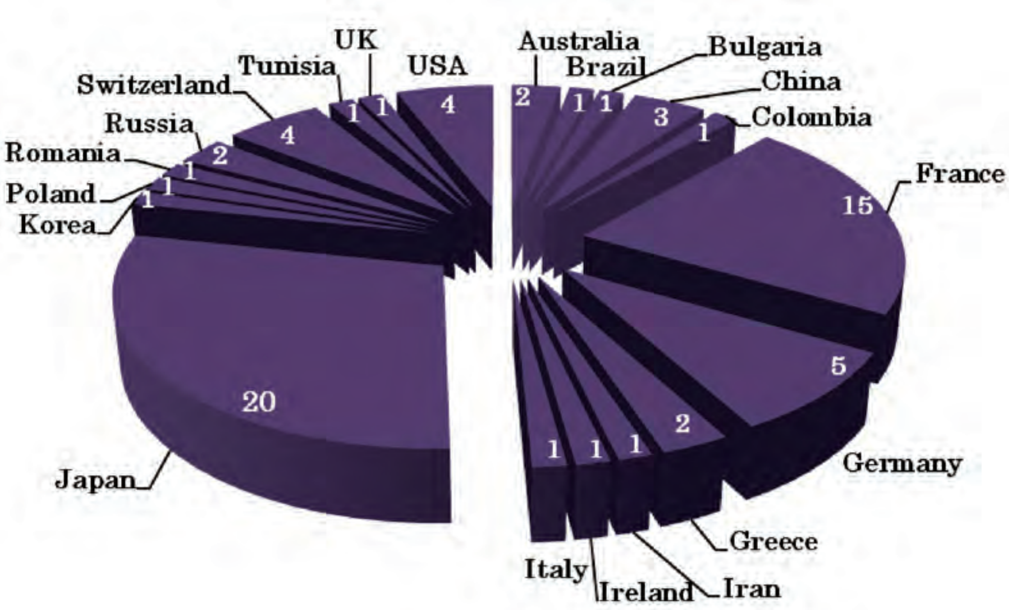
The topics of the 52 oral presentations and 13 posters varied from basic research to application with a focus on the fundamental properties of BMGs. Many researchers reported their attempts to unveil the origin of BMG's strengths compared to crystals. The central topic was the 'shear bands' that arise when a BMG is subject to plastic deformation. Individual presentations included the analysis of atomic bonding using synchrotron diffraction, observation of BMGs by scanning electron microscopy, and simulations of atomic bonding in BMGs. In particular, there were active discussions on cooperative phenomena, such as shear transformation zones and microscopic formation of shear bands in BMGs.

Understanding of the mechanical properties is the basis for all applications of BMGs, and elucidation of shear band phenomena is a key. In the past, the primary feature of single-crystal silicon for semiconductors was dislocation: for BMGs, it is shear bands. To enhance the degree of freedom for processing, it is desirable to enhance the temperature range of supercooling just before vitrification, that is, to freely control the glass-transition point. To this end, the number of elements forming high quality BMGs and the elemental ratio are important factors.

Researchers are making progress in discovering the compositions that form BMGs and unveiling the guiding principles. Starting from the eutectic phase diagram of three elements, and using the atomic radius and electro-negativity as guides, the participants consolidated their ideas by sharing their experiments results in the discussions.

At the end of the workshop, Yavari moderated comprehensive discussions by all the participants. Akihisa Inoue, president of Tohoku University, partook in the discussions and outlined the WPI-AIMR's objectives and organizational structure. Inoue reminded participants to be mindful of the critical evaluation of high-quality research results, interdisciplinary or 'fusion' research, and the application of research outcomes by the WPI-AIMR, while expressing his resolve to make WPI-AIMR more global and attract a greater number of promising young researchers.

A. L. Greer, Cambridge University pointed out that sustainability will be an important concept when proceeding with applications. He added that BMGs could be highly useful for maintaining the environment, for clean air and water and deveroping energy-saving technologies, in magnetic applications, and micro-device fablication.



The 2009 BMG workshop was attended by 70 participants from 20 countries.

Research Prospect

Atomic and Molecular Aspects of Solid/Liquid Interfaces

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1. Introduction

Of the phenomena which occur at the interface between a solid and a liquid, common examples include the deposition and corrosion of metals, the charging and discharging of storage batteries, the wet processing of semiconductor devices and crystal growth in liquid phases. Such processes, and many others of similar nature, involve electrochemical oxidation-reduction reactions that take place at solid-electrolyte interfaces.

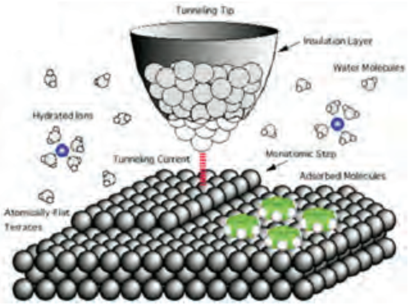

Figure 1. *In situ* STM

Since its invention by Binnig and Rohrer, scanning tunneling microscopy (STM) was immediately established as an invaluable and powerful surface analysis technique with atomic resolution in UHV. Belatedly, but assuredly, developments in STM operated at solid-liquid interfaces led to its valuation as arguably the premier technique for atomic-level surface structural investigations of chemical processes taking place at solid-liquid interfaces as shown in Figure 1. It has been demonstrated that *in situ* STM makes it possible to monitor, under reaction conditions, a wide variety of electrode processes such as the adsorption of inorganic and organic species, the reconstruction of electrode surfaces, the dissolution and deposition of metals and semiconductors. Several review articles on *in situ* STM and related techniques such as *in situ* atomic force microscopy (AFM) have been published [1-3]. The present paper describes the current topics of our researches.

2. Preparation of well-defined electrode surfaces.

As a fundamental basis for all *in situ* STM studies, electrode-electrolyte interfaces must be prepared reproducibly, and methods must be established to observe these interfaces accurately. A unique and very convenient way to expose well-defined clean Pt into aqueous solution was proposed by Clavilier in 1980, in which mechanically exposed single crystal Pt was annealed in an oxygen flame and quenched in pure water [1]. Although the cyclic voltammogram (CV) of a Pt(111) surface indicates that clean surfaces should be exposed into solutions using the so-called Clavilier method, a direct evidence to support the existence of well-defined surface in solution was demonstrated by us in 1990 using *in situ* STM. Figure 2(a) shows our first STM image of a flame-annealed Pt(111) in sulfuric acid solution. The height of each step is ca. 0.23 nm in accord with the monatomic step height of 0.238 nm on the Pt(111) surface. The monatomic steps observed on the surface are usually located on nearly parallel straight lines or form an angle of 60° as expected for the surface with threefold symmetry. Later it was demonstarted by us that the terrace was composed of Pt atoms forming a (1 x 1) structure as shown in Figure 2(b). On the upper and lower terraces, the Pt(111)-(1 x 1) structure was clearly discerned at potentials near the hydrogen evolution reaction.

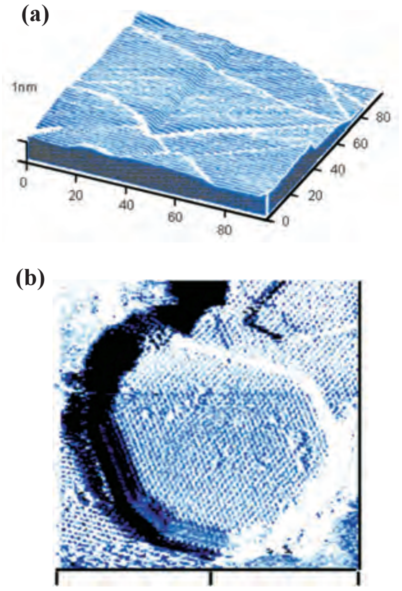

Figure 2. *In situ* STM images of the flame-annealed Pt(111) in solution.

The flame-annealing and quenching method can be applied to limited metals such as Pt, Au, Rh, Pd, and Ir and cannot be used for more industrially important less noble metals such as Ni, Co, Fe, and Cu, because they are heavily oxidized in the flame as well as in air. However, it was recently found that the anodic dissolution of various metals and semiconductors occur only at the step edge under carefully adjusted EC conditions, resulting in atomically flat terrace-step structures. Although the etching method has not yet been well recognized as a promising method for exposing well-defined surfaces of various metals, we recently found that the layer-by-layer dissolution occurs on various metals and semiconductors, such as Si, GaAs, and InP, resulting in the formation of atomically flat terrace-step structures.

It should be noted that these findings open up new fields to understand electrochemical reactions of various metals and semiconductors with atomic scales.

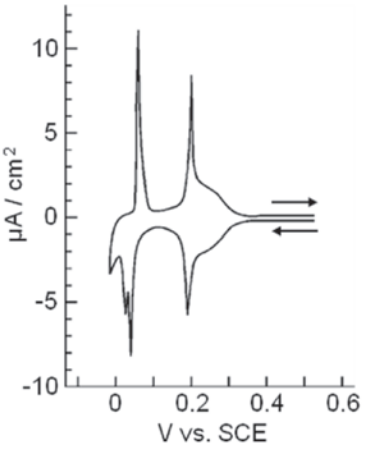

Figure 3. Cyclic voltammograms for a Au(111) electrode in 0.05 M H_2SO_4 +1 mM $CuSO_4$.

3. Underpotential deposition (UPD)

The UPD of a metal, M, on a different metal substrate, Ms, is expected to occur at potentials more positive than the reversible potential for the bulk deposition of M when an interaction between M and Ms is greater than that of Ms-Ms. The UPD process is important in EC reactions, such as metal deposition, as the initial step of a series of reactions and also because of electrocatalytic effects induced by adatoms formed by the process. Although a large number of UPD systems have been investigated by using conventional EC techniques, such as CV, to evaluate the thermodynamics and kinetics, the structural information of UPD layers can now be evaluated by in situ STM.

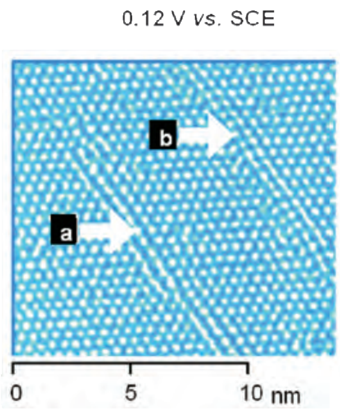

Figure 4. High-resolution STM image of a copper adlattice on Au(111).

Figure 3 shows a CV of an Au(111) electrode obtained in a pure 0.05 M H_2SO_4 solution in the presence of 1 mM $CuSO_4$. Two separated waves for the UPD of Cu are clearly observed in the potential region between 0.35 and 0 V *vs.* SCE before the beginning of the bulk deposition of Cu.

Figure 4 shows a high-resolution STM image obtained in a 0.05 M H_2SO_4 + 1 mM $CuSO_4$ solution. Although the wide terrace of the Au(111) surface was almost completely covered by the Cu adlayer with the ($\sqrt{3}$ x $\sqrt{3}$)R30° structure, several types of phase boundary can be seen in Figure 4. Although each spot was considered as a single Cu atom on Au(111), many in situ techniques such as pricise electrochemidcal method and *in situ* surface x-ray scattering technique (SXS) have been applied to understand the first Cu adlayer structure.

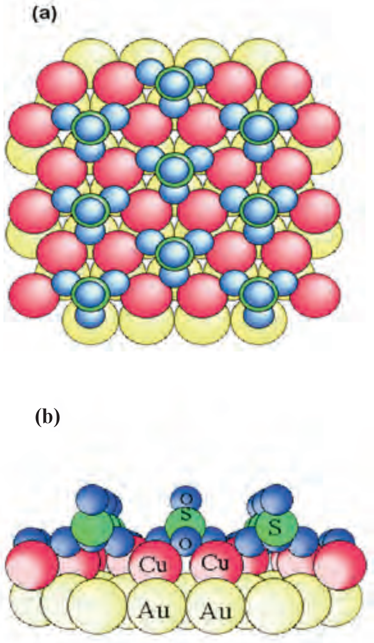

Figure 5. Top (a) and perspective view (b) of the coadsorbed Cu^{2+} and SO_4^{2-} adlayers on Au(111).

Note that Toney *et al.* examined the above system using an SXS technique following our STM results, and concluded that the Cu atoms form a honeycomb lattice and are adsorbed on threefold hollow sites with sulfate ions located at the honeycomb centers. Three oxygens of each sulfate ion bond to Cu atoms. According to all of the results obtained by different techniques, the most reliable model structure can be presented as shown in Figure 5, in which the top (a) and perspective (b) views are given. According to the model structure, the corrugation observed by *in situ* STM and AFM must be considered to be due to the coadsorbed sulfate ions, and not the Cu atoms.

4. Adsorption of organic molecules (Benzene)

Voluminous reports describe investigation of the adsorption of aromatics, such as benzene and its derivatives on Pt, Rh, Ni, Ir, Ru, and Pd in UHV, which were performed by Somorjai *et al.* using various surface sensitive techniques such as LEED, AES, and electron energy-loss spectroscopy (EELS). In UHV, the (3 x 3) superlattice of benzene and CO coadsorbed on Rh(111) revealed a well-ordered array of ring-like features associated with adsorbed benzene molecules.

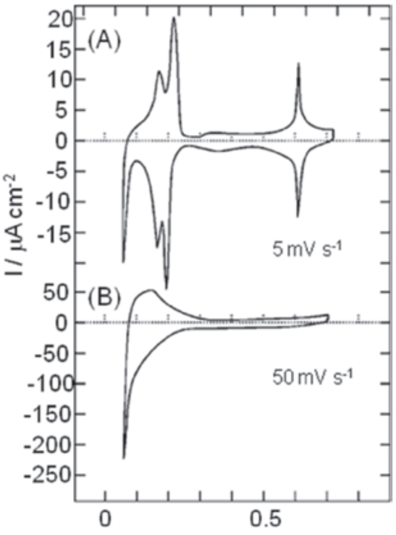

Figure 6. Cyclic voltammograms of Rh(111) without (A) and with (B) 1 mM benzene.

Nevertheless, we described, for the first time, the adlayer structures of benzene adsorbed on Rh(111) and Pt(111) in aqueous HF solutions. Figures 6(A and B) show cyclic voltammograms (CVs) of a Rh(111) electrode in the absence and presence of benzene in 0.01 M HF. In the absence of benzene, the CV obtained on the well-defined Rh(111) exhibited several highly reversible characteristic peaks. The CV indicated a featureless double-layer region between 0.3 and 0.7 V in the presence of benzene as shown in Figure 6(B), indicating that the surface of Rh(111) should be completely covered by benzene molecules.

Figure 7 shows an example of the STM images acquired at 0.45 V. It is evident that the atomically flat terraces are now covered by ordered benzene adlayers. The adsorbed benzene molecules appear to form a square adlattice in each domain. Details of the orientation of benzene in the adlayer are revealed by the higher resolution STM image. Based on the orientation of molecular rows and the

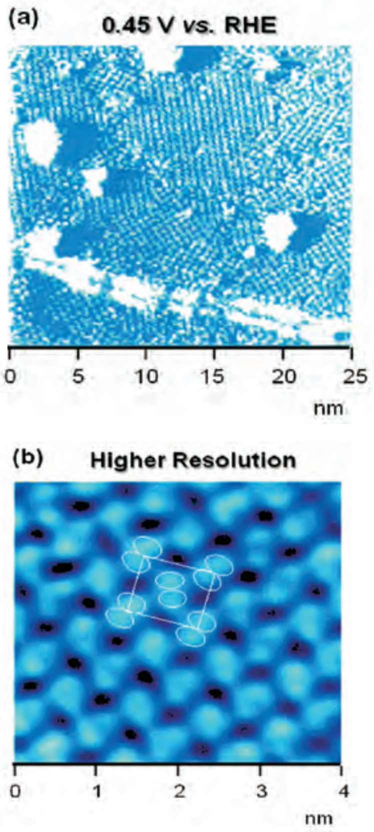

Figure 7. High-resolution STM images of the $c(2\sqrt{3} \times 3)rect$ benzene adlayer in HF.

intermolecular distances, we concluded that the benzene adlayer was composed of rectangular unit cells, namely $c(2\sqrt{3} \times 3)rect$ (θ=0.17), as shown in Figure 7.

Our successful observation of benzene molecule has initiated a large number of STM studies of ordered molecular adlayers at solid/liquid interfaces[4]. A more recent our paper demonstrates that even polymers form ordered structures at electrode surfaces [5].

5. Electrochemical dissolution processes of semiconductors

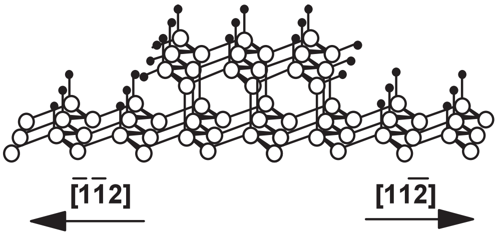

Figure 8. Side view of the Si(111) surface.

The preparation of clean and stable semiconductor surfaces is the first step in the manufacture of semiconductor devices. The drive towards nanometer-technology for ultra-large scale integrated circuits has focused special attention to wet chemical processes, since high-temperature-based procedures often lead to adverse effects that arise from new and difficult-to-control reaction channels; the pursuit of nanometer-scale technology has likewise necessitated the development of surface characterization methods that enable atomic-scale resolution.

In response to this need, *in situ* STM and AFM were adopted to semiconductor-etching studies. Our first *in situ* STM observation of the Si(111):H-(1 x 1) atomic structure in a non-corrosive solution (aqueous H_2SO_4) spurred investigation of the etching of Si(111) in corrosive solutions, such as aqueous NH_4F. We have demonstrated that *in situ* STM can be employed to monitor atomic scale features of the etching process. For example, we discovered that, in general, multiple H-terminated Si atoms at the kink and step sites were eroded more rapidly than the monohydride-capped atoms.

Figure 8 shows a ball-and-stick mode of a H-terminated Si(111) with $[11\bar{2}]$ and $[\bar{1}\bar{1}2]$ oriented steps. One of the most interesting features of a Si(111) surface is the existence of two structurally different steps where the Si atoms have monohydride and dihydride configurations. They can be exemplified by the steps in the $[11\bar{2}]$ and $[\bar{1}\bar{1}2]$ directions, respectively.

We focused our attention on evaluation of the reactivity difference between the microscopically different steps on Si(111). We were able to use *in situ* STM to locate some areas which contain both types of steps so that the reactivity of these steps can be simultaneously examined under identical conditions. As the initial surface feature of Si controlled the subsequent etching process, we first recorded an STM image at -1.1 V to show the initial surface morphology as shown in Figure 9(a), followed by stepping the electrode potential to a less negative value of -1.04 V to accelerate the erosion of Si. Figures 9(a and b) present the time-dependent etching process of Si(111) after acquiring the image of Figure 9(a). During the first 13 s etching of the Si from (a) to (b), the width of the upper portion of the terrace T marked by D decreased from 16 to 8 nm. The relatively faster erosion of the upper half of the $[\bar{1}\bar{1}2]$ dihydride step is thought to be due to the higher kink density within the zig-zag pattern step ledge. On the other hand, the monohydride step in the direction of $[11\bar{2}]$ seems to be unchanged from (a) to (b). Particularly, the steps within the circle marked C in Figure 9(b) remained still in both images, indicating that the ideal monohydride $[11\bar{2}]$ and $[\bar{2}11]$ step in the absence of kink sites is inactive in the present etching condition. The dihydride terminated steps continued to retract rapidly to dissolve the terrace T. The aforementioned results provide compelling evidence that the difference in the chemical reactivity of the monohydrogen-terminated and dihydrogen-capped Si surface atoms profoundly influences the Si-etching process. We have also previously investigated etching processes of GaAs and InP, and indicated that similar reactions should be also occured on these semiconductors. We are now extending investigations of the EC etching of Si single crystals with Prof. Ohmi.

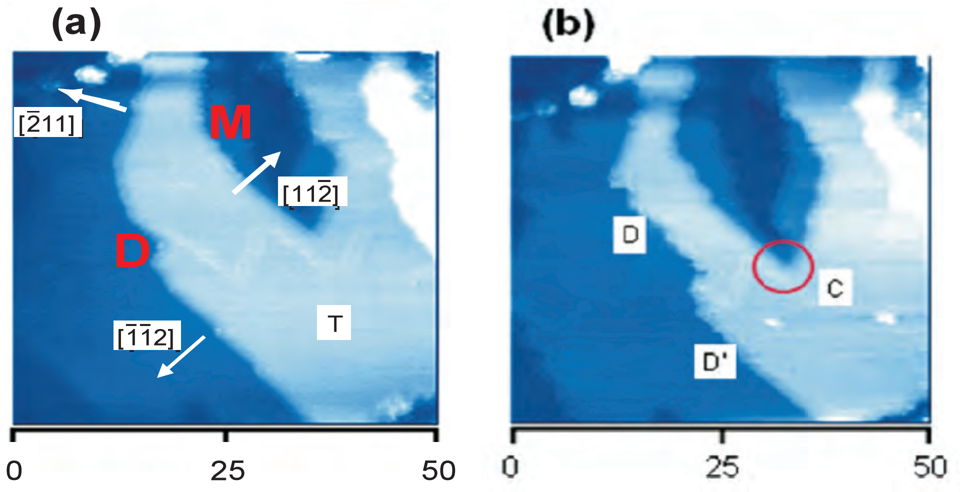

Figure 9. Successively recorded STM images for the etching process of Si(111) in NH_4F.
The images were acquired at the time interval of 12.8 s.

6. Crystal growth of perfect single crystals of organic semiconductors

Recently, single crystals of organic semiconductors such as pentacene and rubrene are attracting great interest as materials to be used for organic semiconductors for organic field effect transistors (OFETs), because single crystals are expected to possess a higher mobility than their polycrystalline counterparts. Intrinsic electronic properties of organic semiconductors cannot be evaluated by examining evaporated films, because of the presence of a large number of defects in the film. Most single crystals for OFETs have been prepared by the so-called physical vapor transport method. With these previous works in mind, we attempted to develop a chemical method for the preparation of well-defined single crystals of pentacene. We believed that chemical methods should be more suitable as a general technique for the preparation of nearly perfect single crystals of organic semiconductors for the application of OFETs [6].

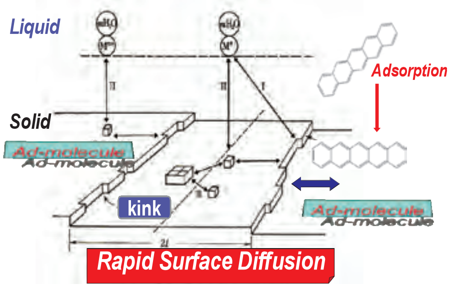

Figure 10. Schematical model of crystal growth at solid/liquid interfaces.

High-resolution FM-AFM images were obtained in the constant frequency shift mode using a frequency modulation (FM) detection method. Molecular-scale images were obtained with a commercial UHV-AFM instrument (JEOL JSPM-4610A) with an easy PLL plus (Nanosurf, Inc., Switzerland) in order to maintain a constant cantilever oscillation amplitude. It was surprising to us to find extraordinarily wide terraces extended over a few micrometers or even more as shown in Figure 11. The appearance of the wide terraces with no islands suggests strongly that the single crystals prepared from the solutions were nearly perfect with essentially no defects. Figure 12 shows the first molecular image acquired on the surface of a single crystal of pentacene on a flat terrace shown in Figure 11.

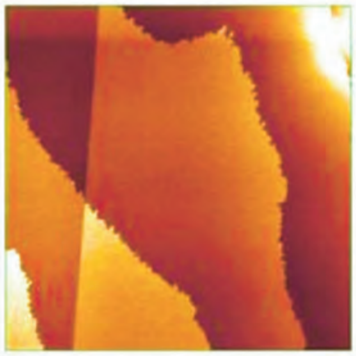

Figure 11. AFM image of pentacen single crystal. Scan area: 10 x 10μm.

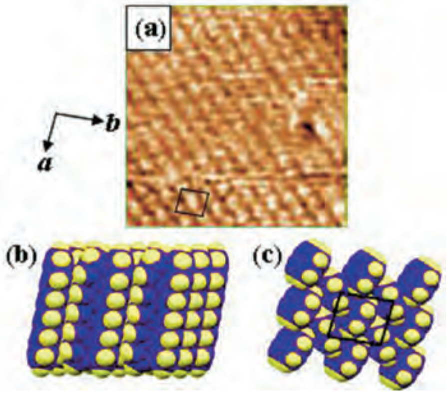

Figure 12. Molecular image(a) and crystal structures(b and c) of pentacene single crystal.

More recently, we have reported the molecular structure of rubrene single crystals [7]. Molecularly flat and extraordinarily wide terraces were extended over the width of more than a few micrometers with monomolecular steps. Molecular packing arrangements and internal structures were revealed by FM-AFM for the first time.

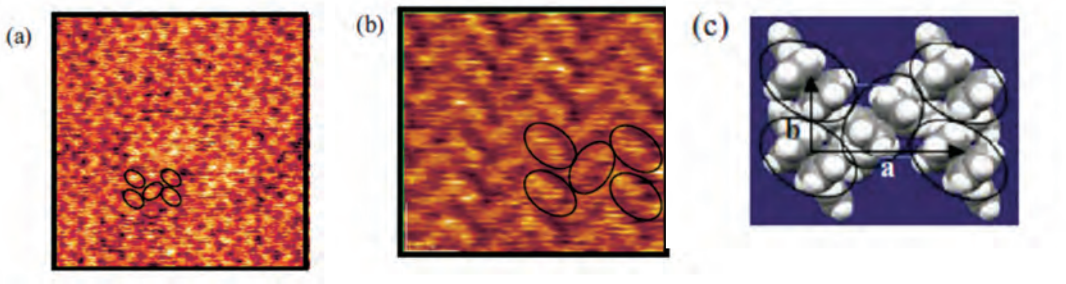

Figure 13. Molecular images(a and b) and crystal structure(c) of ruburene single crystal [7].

Although the crystal growth of organic and inorganic materials in solutions are not *pure* electrochemical reactions involving electron transfer reactions, the phenomena which occur at the interface between a solid and a liquid seems to be very similar to electrochemical reactions such as metal deposition. Preparation of perfect crystals of pentacene, rubrene, and other new compounds are extremely important for newly developing areas of electronic devices such as organic FET, EL and solar cells.

7. Conclusion

The methods for exposing well-defined surfaces in solution were first reviewed. The UPD of Cu on Au(111) in H_2SO_4 was discussed in depth. The adlayer structure of benzene on Rh(111) was also described in detail. The EC etching process of Si(111) was discussed in relation to the atomic structures of the step-edges. It is clearly demonstrated that in situ STM and related techniques allows us not only to determine interfacial structures but also to follow EC reactions. It is certain that *in situ* STM will continue to be the premier technique in the study of the relationship between the reactivity and the structure of electrode surfaces at an atomic scale.

Finally, it has been discussed that crystal growth in solutions should be more suitable as a general technique for the preparation of nearly perfect single crystals of organic semiconductors for the application of OFETs

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Hierarchically Structured Biomimetic Surfaces Prepared by Self-Organization

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1. Introduction

Biological surfaces of plants and insects have inspired functional biomimetic materials utilizing unique properties of liquid-solid interface as superhydrophobic coating, water droplet manipulation, and wettability control [1]. Lotus leaves possess superhydrophobic surfaces based on the bumpy microstructures [2]. Butterfly wings having oriented array of scales induce anisotropic water droplet moving [3]. Gecko's feet and rose petals show superhydrophobic surfaces with water droplet adhesion driven by large van der Waals forces of those hieralchically-structured surfaces [4]. Focusing on a large-size structured surface, submillimerter-scale patterned hydrophilic-hydrophobic surfaces of a desert beetle's back collect water droplets onto the hydrophilic domains through the hydrophobic patches [5]. As summarized in Fig.1, wettability, especially superhydrophobicity, of biomimetic surfaces is subjcted to relationship of a size of a surface structure and affinity to a water droplet.

Superhydrophobic surfaces which mimic lotus leaves, e.g. a fractal surface [6], a nanopin surface [7,8], etc. have been reported. These surfaces were prepared by crystal growth of organic or inorganic materials, lithography, and self-organization. Recently, superhydrophobic surfaces with strong adhesive force, mimicking gecko's feet or rose petals, are prepared by replica method, crystal growth, and dry etching [9,10]. Adhesion forces of these microstructured surfaces were attributed to a large accumulation of van der Waals force.

Our aim is to make a novel biomimetic surface with conflicting affinities of adhesion on hydrophilic micro-domains and repellent on a superhydrophobic micro-structured surface. It is expected that water droplet adhesion on the biomimetic superhydrophobic surface is controlled by density of the hydrophilic micro-domain and affinity to water droplets. In this report, we fabricate a novel biomimetic hybrid surface based on superhydrophobic structured polymer surfaces with metal micro domains as hydrophilic components. An adhesion force of the novel hybrid metal–polymer surface is driven by affinity between water and the hydrophilic metal domains. It is expected that water droplet adhesion is regulated by varying its affinity which is controlled by density of the hydrophilic metal component.

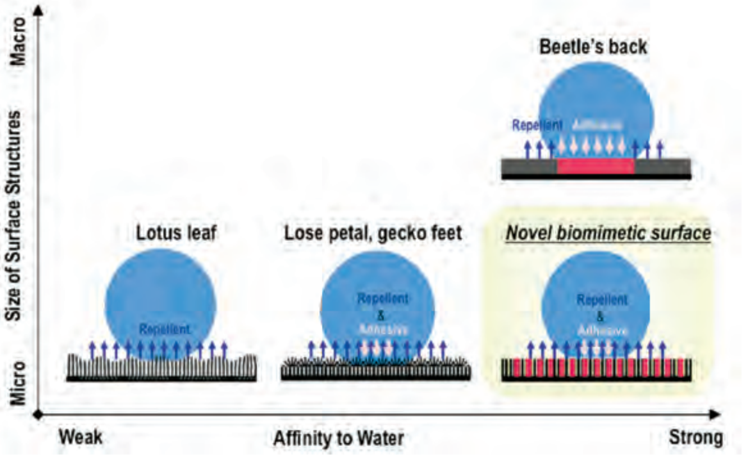


Fig. 1. Relation between water affinity and structure size of biomimetic surfaces.

2. Methods

The novel hybrid surfaces were prepared by nickel electroless plating of self-organized honeycomb-patterned polystyrene films prepared by breath figure phenomenon [11]. According to our previous report, the honeycomb-patterned polymer films were prepared by casting a chloroform solution of polystyrene containing small amount of amphiphilic surfactant polymer on a glass substrate under humid condition. The honeycomb film was soaked in a catalytic mixture solution containing poly (allylamine hydrochloride), and palladium(II) chloride at 25°C. The catalytic solution was gradually heated to 30°C, 45°C, and 60°C, respectively, and kept for 10 min under horizontal shaking at 10 rpm. The pre-treated honeycomb films were immersed in a nickel plating bath at 25°C containing nickel hypophosphite, boric acid, sodium acetate, and ammonium sulfate without any rinse and drying. Then the plating bath was heated to 70°C and kept for 2h with no stirring. After rinsing and drying, a nickel layer was covered on the honeycomb film. After electroless plating, metallic faces of the nickel-covered honeycomb films were adhered on an acryl substrate by an epoxy resin. After heating at 70°C for 2h, a lower half layer of the nickel-covered honeycomb film was peeled off from the acryl substrate.

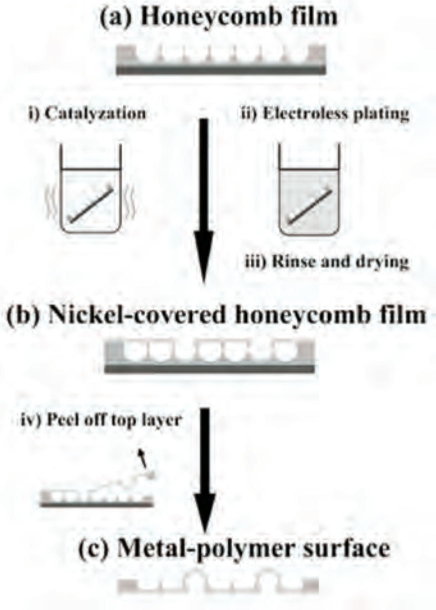


Fig. 2. Schematic experimantal preparation procedures of metal-honeycomb hybrid structures as biomimetic materials.

3. Results and Discussion

Figures 3 shows SEM images of the honeycomb-patterned polymer film, the nickel-plated honeycomb film, and the dome-spike hybrid surface after peeling of the metalized honeycomb film. The honeucomb-patterned film consists of hexagonally ordered array of microcavities having a center-to-center interval of about 10 μm and many narrow pillars that hold the top and bottom porous layers together (Figure 3a). After plating, some pores were covered by the nickel layer, but other pores were fully plated into their cavities, resulting in the formation of metal micro-pots (Figure 3b). The hybrid dome-spike surface was then formed by peeling; the surface consists of hexagonally ordered array of hydrophobic polystyrene spikes and hydrophilic nickel micro-domes (Figure 3c). Each metal dome was the base of a metal micro-pot in the fully plated cavity.

The wettability of the honeycomb film in the catalytic solution was a key factor of the metal pot formation. The contact angles of the catalytic solution on the honeycomb films at 25°C and 60°C were 118±5° and 96±3°, respectively. Wettability at 60°C is better than that at 25°C, because an interfacial energy between liquid and substrate becomes large with increasing liquid temperature. The density of the metal pots was controlled by the wettability of the catalytic solution, and the density of the metal domes could be regulated by the catalyzation conditions. At the low temperature of 25°C, no metal domes were formed in the polymer spike array. As shown in Figure 4, the dome density in the hybrid film increases linearly from 0% to 30% with increasing catalytic solution temperature. These results indicate that the dome density in the superhydrophobic hybrid dome− spike surface can be easily controlled by the catalytic solution temperature before electroless plating.

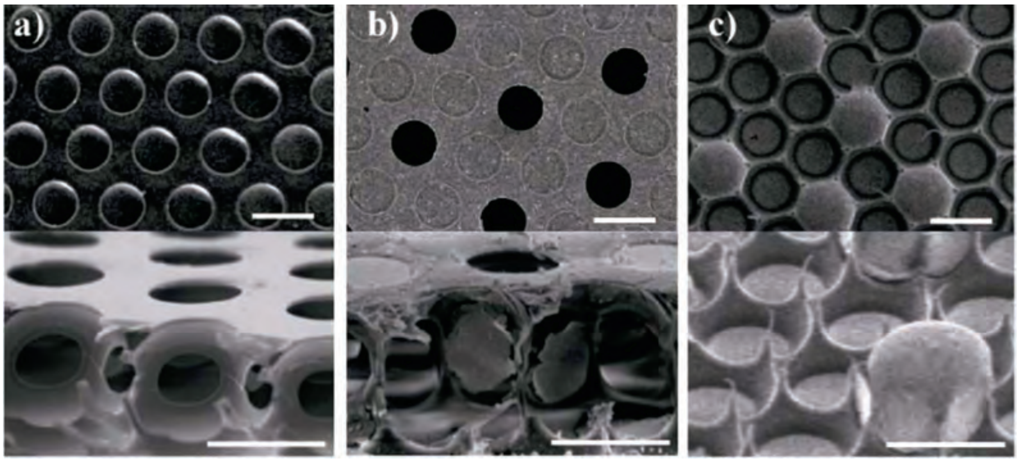


Fig. 3. SEM images showing top and side views of the honeycomb film, the plated honeycomb film, and the hybrid dome-spike film, respectively (Scale bar: 10 μ m).

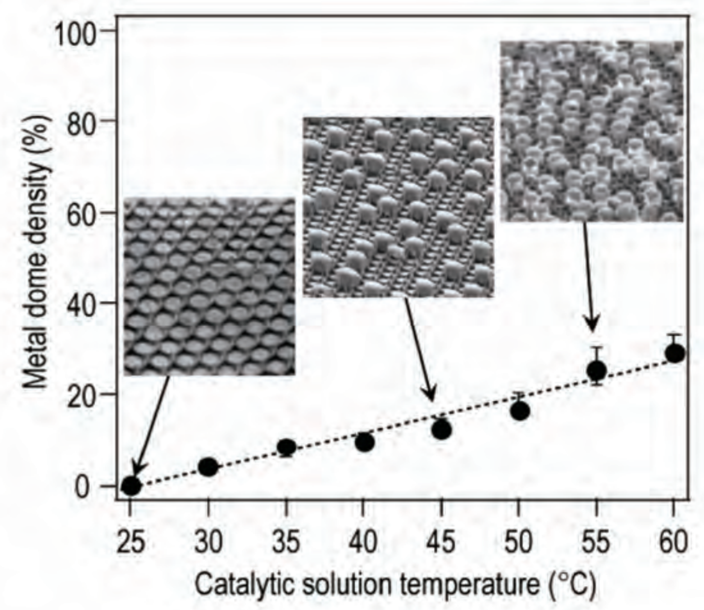


Fig. 4. Reaction temperature dependence of metal dome density of the metal-honeycomb hybrid structures.

Figure 5 shows plots of a contact angle (CA) and a sliding angle (SA) of 5.0 mg water droplet against the dome density of the hybrid surfaces. The CA and SA of the hybrid surface without domes were 160±2° and less than 5° respectively; these angles are almost the same as those of a superhydrophobic pincushion-structured honeycomb film without metal plating. Even though the dome density increased, the CA decreased slightly up to ca. 145°. This is described by Cassie's model of hydrophobicity, in which air cavities in the honeycomb film repel water and the wettability decreases with decreasing the air cavity because of formation of the metal domes. By contrast, the SA increased dramatically with increasing metal dome density with a high surface free energy. Water droplets on hybrid surfaces with dome densities of over 15% were strongly pinned and did not fall off even when the hybrid surface was inverted (inset of Figure 5). These results clearly demonstrate that the metal domes increase the adhesion of water droplets to the superhydrophobic surface and that the adhesion properties of hybrid dome– spike surfaces can be controlled by varying the metal dome density.

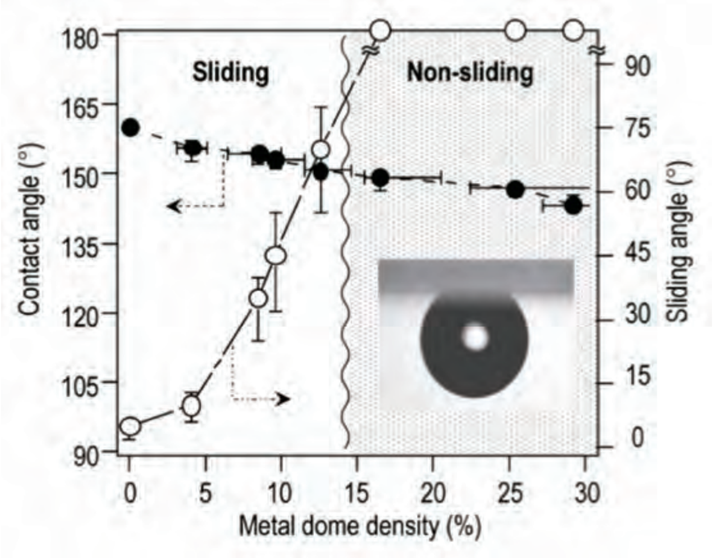
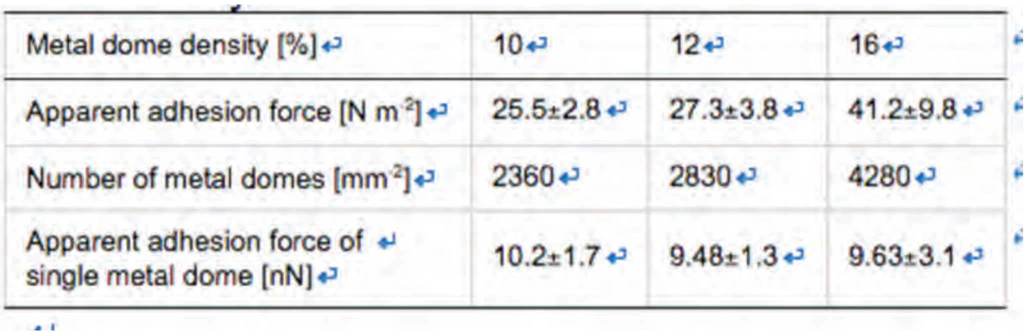


Fig. 5. Contact angles and sliding angles of water droplet on the hybrid dome-spike surfaces.

The dependence of the adhesion force on the dome density of the hybrid dome-spike surfaces is shown in Table 1. The apparent adhesion force per unit area was calculated from the 5.0mg water droplet and the apparent contact area as observed by an optical microscope. The apparent adhesion force of the hybrid films increased with the dome density.

Table 1. Apparent adhesion force of the hybrid dome-spike surfaces.



Metal dome density [%]	10	12	16
Apparent adhesion force [$\mathrm{N\ m^{-2}}$]	25.5±2.8	27.3±3.8	41.2±9.8
Number of metal domes [$\mathrm{mm^{-2}}$]	2360	2830	4280
Apparent adhesion force of single metal dome [nN]	10.2±1.7	9.48±1.3	9.63±3.1

The apparent adhesion force of a single metal dome was calculated by dividing the apparent adhesion force by the number of metal domes per unit area. The apparent adhesion force of a single metal dome was about 10 nN and independent of the metal dome density of the hybrid surfaces. This result indicates that in the case of the same mass of water droplets on the same hybrid surface, the adhesion force is strong with increasing apparent contact area.

Water droplet transfer was demonstrated by using the metal-honeycomb hybrid surfaces with deferent adhesion properties. Fig. 6 shows a schematic illustration of water droplet transfer. A 5-mg water droplet was placed on the film surface fabricated by using the catalytic mixture solution of 30°C (low adhesion). Then another film surface fabricated by using the catalytic mixture solution of 60°C (high adhesion) approached to the upper edge of the water droplet. With slow pulling of the high adhesion surface, the water droplet attached to the low adhesion surface was transferred to the upper surface. Then the water droplet captured by the high adhesion surface was moved to the third film fabricated by using the catalytic mixture solution at 45°C (middle adhesion). Gravity helped transport of the water droplet from the high adhesion surface to the middle adhesion surface.

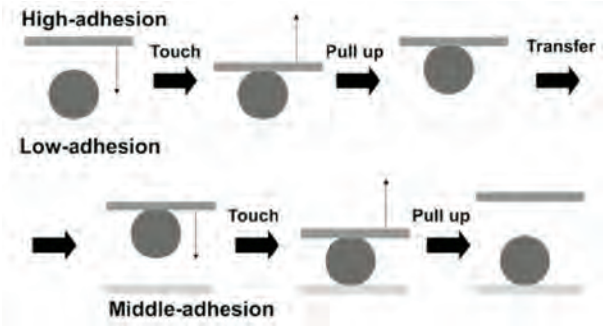


Fig. 6. Schematic illustration of a micro-droplet transfer by using the hybrid biomimetic surfaces of different adhesion force.

4. Conclusion

In conclusion, a biomimetic hybrid surface composed of metal-dome and polymer-spike superhydrophobic surfaces were prepared by electroless plating of self-organized honeycomb-patterned polymer films and simple peeling. The hybrid dome-spike surface is characterized by “affinity-driven adhesion” between water and hydrophilic metal domes, in contrast with the “van der Waals force-driven adhesion” of other high adhesive superhydrophobic surfaces. These results demonstrate that the surfaces can be used as novel digital-microfluidic-devices for manipulating micro droplets by controlled wettability. Further investigation of the wettability change of these hybrid metal–polymer surfaces is currently being conducted. Regulation of the adhesion property of the hydrophilic metal domains by applying external stimuli, such as heat [12], electric and magnetic fields, etc. is now under investigation.

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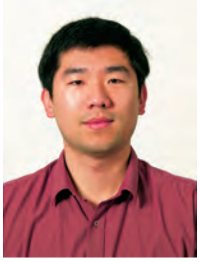

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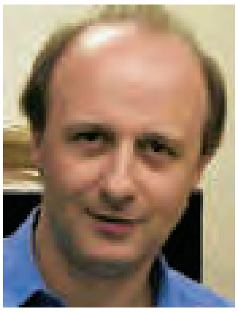
Synthesis new function materials such as high temperature superconductors and strongly correlated electron materials, explore their structure of physical properties. Studies on iron based superconductors.

Newly Appointed Adjunct Professors

Curriculum Vitae of Adjunct Professor

Eric BORGUET



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- ✦Visiting Fellow, Japan Society for the Promotion of Science (2007-2008)
- ✦ U.S. Young Observer to 2007 IUPAC General Assembly and Congress (2007)
- ✦ American Chemical Society, Philadelphia Section Award (2009)

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2001-2003	JSPS/Royal Society Special Postdoctoral Fellow
2003-2007	Panasonic/CREST Postdoctoral Fellow, Bionanoprocesss Laboratory, NAIST, Japan
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RECOGNITION:

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CURRENT RESEARCH:

Current research is a new field of “Semi-synthetic biology”, a form of bionanotechnology which concentrates on using modifying biological molecules (particularly proteins) so that they self assemble into useful 2D and 3D structures. Our ultimate aim is to produce highly complex structures which may be useful as components of electronics, smart drugs and “wet nanomachines”. Current Projects include:

- 2D arrays of ring proteins
- A self-assembled programmable protein nanotube
- Proteins as scaffolds for quantum wires
- Programmable, asymmetric protein arrays
- Blue skies research into super-complex multi-component, 3D, self-assembled bio-nano structures

WPI-IFCAM

WPI-IFCAM

International Frontier Center for Advanced Materials (IFCAM) was inaugurated in Institute for Materials Research (IMR), Tohoku University, in October 2001 to function, simply stated, as the world-first “materials science think-tank.” With wise steering by past directors, IFCAM has been performing well in its mission until now by 1) bringing in many world-renown researchers to IMR in the greater field of materials science/engineering, 2) enlightening / encouraging young scientists, post-doctoral fellows and graduate students by organizing and supporting workshops/summer schools, and 3) establishing and coordinating IFCAM branch offices around the world, including those in Cambridge University, Harvard University, Stanford University, and Institute of Physics, P.R. China.

We were also so fortunate to have had a government initial-equipment fund in 2002 to acquire several advanced tools, such as 3-dimention atom-probe tomography (3-D AP) and low energy electron microscope (LEEM). With untiring effort of able faculty members and their staff / graduate students, the LEEM program of IFCAM, for instance, has quickly become one of the most active and successful research centers in the world.

Realizing that IFCAM and newly established WPI-AIMR have essentially the same mission: namely, further promote international collaboration and cooperation in innovative research on advanced materials on a global bases, IFCAM was transferred from IMR to WPI-AIMR, effective of April 2008.

Briefly stated, WPI-IFCAM has following function and service.

1. Visiting Professorship
2. Workshops / summer schools

Ⅰ. Visiting Professorship

Qualified researchers who may be interested in IFCAM visiting professorship should first contact the WPI principal investigator(s) of the related research fields. Your contact PIs will initiate the further process to materialize the joint research.

(1) Tenure: For a period of minimum one month to a maximum of 3 months.

(2) Financial: The salary varies, depending on the qualifications, based on the Tohoku University regulations. Roughly speaking, “full professor” receives Y600,000 per month and “Associate Professor” receives Y500,000 per month.

Ⅱ. Workshops / summer schools

WPI-IFCAM will financially support the workshops and summer schools, if the scientific aims are along the WPI-AIMR missions. For more information, please contact WPI Administrative Office.

2009–2010 WPI-IFCAM VISITING SCHOLARS

	Candidate	Host	Position	Term							Term	Affiliation	Position	Graduated from	Diploma	Nationality	Age	Research Proposal
				From			～	Through										
1	**CHALLAPALLI, Suryanarayana**	A. Inoue	Visiting Professor	H21	**4**	13	～	H21	**7**	12	3m	University of Central Florida	Professor	Banaras Hindu University, India	Ph. D	USA	64	Synthesis, Processing, and Characterization of Nanomaterials and Bulk Metallic Glasses
2	**LEE, Seung-Hun**	K. Yamada	Visiting Professor	H21	**5**	28	～	H21	**7**	15	1m18d	University of Virginia	Professor	Johns Hopkins University, USA	Ph. D	South Korea	45	Novel quantum phenomena in complex transition metal oxides
3	**TEIZER, Winfried**	T. Adschiri	Visiting Associate Professor	H21	**6**	1	～	H21	**8**	31	3m	Texas A&M University	Associate Professor	University of Massachusetts, USA	Ph. D	Austria	38	Biophysical applications of magnetic nanoparticles
4	**JIA, Jinfeng**	M. Chen & T. Hashizume	Visiting Professor	H21	**7**	6	～	H21	**10**	5	3m	Tsinghua University	Professor	Peking University, P.R. China	Ph. D	P.R. China	43	Growth mechanism of Pb film by LEEM and LTSTM
5	**WANG, Weihua**	M. Chen & A. Inoue	Visiting Professor	H21	**8**	5	～	H21	**10**	30	2m26d	Institute of Physics, Chinese Academy of Sciences	Professor	Institute of Physics, Chinese Academy of Sciences, P.R.China	Ph. D	P.R. China	46	Understanding of deformation mechanism of bulk metallic glasses
6	**ORESHKIN, Andrei Ivanovich**	T. Hashizume	Visiting Professor	H21	**9**	4	～	H21	**12**	3	3m	Moscow State University	Senior Researcher	Moscow State University	Ph. D	Russia	42	
7	**CHEN, Ho Sou**	A. Inoue	Visiting Professor	H21	**10**	1	～	H21	**11**	30	2m	Bell Laboratories, Lucent Technologies	Adviser	Harvard University, USA	Ph. D	USA	76	Development of mechanical properties by fundamental approaches of fragility and relaxation control in metallic glasses.

WPI activity report of Prof. C. Suryanarayana
April 13th, 2009 - July 12th, 2009
Host: Professor Akihisa Inoue

Two objectives were achieved during this short period of three months at WPI-AIMR in Tohoku University. The first was investigating the role of impurities on the solidification behavior of bulk metallic glasses. Zr-based alloys are known to be very good glass formers. But, at the same time, Zr is a highly reactive metal and therefore it needs full protection from impurities getting into the melt before solidification. Therefore, it was decided to investigate the effect of using a low-purity Zr metal and compare its solidification behavior with that of a high-purity metal. It was very clearly shown that using an impure metal drastically reduces the glass forming ability of the alloy. In fact, rods as small as 3 mm in diameters were found to contain small amounts of crystalline phases. Another important observation made was that the solidification behavior when a low-purity Zr metal was used was very unusual and more than two different types of microstructural features started appearing simultaneously. These microstructural and mechanical properties were analyzed and a manuscript entitled "**Unusual solidification behavior of a Zr-Cu-Ni-Al bulk glassy alloy made from low-purity Zr**" was submitted to the international *Journal of Materials Research* for publication.

Another study started was to investigate the role of deep eutectics on the formation of metallic glasses. Even though deep eutectics are known to be good glass formers, there has been lot of discussion and disagreement in recent times about this aspect. Therefore, some new analyses have been made on eutectic systems and new experiments have been started. Work is going on this aspect and it will be continued by one of the researchers in WPI-AIMR.

WPI activity report of Prof. Seung-Hun Lee
May 29th, 2009 – July 16th, 2009
Host: Professor Kazuyoshi Yamada

My group has a very long-standing collaboration with Professor Kazu Yamada's group that goes back more than 10 years. The short-term visit program through the WPI has been very helpful in enhancing our collaborations. Furthermore, it has allowed me to start new collaborations with other groups at Tohoku University and also at other universities in Japan. Here is a short summary of my activities during my stay.

1. Collaborations with Prof. K. Yamada's laboratory. Our collaboration has focused on superconducting cuprates, the results of which can be seen in a couple of the most recent papers published over the past two years [1,2]. During this visit, a new project on a new Fe-based superconductor, Fe(Te,Se), has been initiated by associate professor, Masaki Fujita, at Yamada's lab, associate professor Taku Sato at ISSP, and myself. Among several Fe-based superconducting materials, $FeSe_xTe_{1-x}$ has the simplest crystal structure in which the layers consist of Fe-(Se,Te) tetrahedra. When $x = 0$, the system is non-superconducting and, upon cooling it undergoes a magnetic long-range order at $T_N = 70$ K with a characteristic incommensurate wave vector of $\mathbf{Q}_\mathrm{m}$ = (1/2+d, 0, 1/2). Recent neutron scattering studies reported that low energy spin fluctuations appear with a commensurate wave vector (1/2,1/2,L) in the superconducting phase with $x = 0.5$ and 0.4. The commensurate wave vector corresponds to Fermi surface nesting, indicating that magnetic fluctuations play an important role in the superconducting mechanism. Our motivation is to study how the magnetic correlations evolve as the system changes from insulating to superconducting, especially in the vicinity of the quantum critical point of $x = 0.15$. My postdoctoral fellow, Dr. Naoyuki Katayama, has grown single crystals of $FeSe_xTe_{1-x}$ with several different Se concentrations of $x = 0$, 0.1, 0.25, and 0.5. During this visit, Masaki and I have characterised the $x = 0.1$ and 0.25 crystals by performing SQUID measurements at the high magnetic field laboratory of Professor Nojiri in collaboration with Motoyoshi Yasui, a postdoctoral fellow. Our results show that the antiferromagnetic ordering is lowered to $T_N = 40$ K at $x = 0.1$, and it disappears at $x = 0.24$. We also planned to perform elastic neutron scattering at JRR-3 in JAEA on the $x = 0.1$ crystal under applied pressure to see if pressure can suppress the antiferromagnetic ordering. Unfortunately, however, the JRR-3 reactor was unexpectedly shutdown and our experiment was canceled. Instead, our experiment is going to be performed at the NIST Center for Neutron Research in late August.

2. Collaborations with Prof. H. Nojiri's laboratory. Our collaborations started a couple of years ago as a result of my previous visits to IMR. Over the last two years, two papers have been published from this collaboration: one paper on a frustrated magnet, $Cu_2(OD)_3Cl$, [3] and another paper on a quantum magnet $Ba_3Cr_2O_8$ [4]. For the latter, ESR measurements under an external magnetic field perpendicular to the crystallographic *c*-axis up to H = 30 Tesla were performed at Nojiri's lab, which provided important information regarding the effective spin Hamiltonian. During my current visit, in addition to the SQUID measurements on Fe(Te,Se) compounds mentioned above, ESR measurements on FeTe were performed. ESR measurements on $Ba_3Cr_2O_8$ with H parallel to the *c*-axis are planned and will be performed this summer.

3. Collaboration with Prof. S. Maekawa's group. One excellent opportunity that the WPI visiting scholarship provides is for the scholar to be in a research environment where many outstanding foreign researchers who visit through the WPI program as well as other programs available at the IMR can interact. This environment can lead to unexpected collaborations between the visitors. This happened to me this time. I have been working on a triangular system, Ag_2MnO_2. By chance, I met Prof. Tim Ziman from the ILL, a well-known theorist in the field of quantum and frustrated magnetism, who is visiting Prof. Maekawa's group. He provided valuable theoretical ideas that were very helpful in interpreting our neutron scattering data. This work has just been submitted [5].

4. Collaborations with people at other universities in Japan. During the period of my stay at WPI, I also had the opportunity to visit ISSP at the University of Tokyo. I presented a seminar on "Exotic states in quantum and frustrated magnets", and discussed with my collaborators, Profs. Y. Ueda, Z. Hiroi and T. J. Sato, about our projects, including our recent neutron diffraction data obtained from a powder sample of CeMnAsO.

I would like to thank Professor Kazu Yamada and the WPI for offering me such an excellent research opportunity. My family also had the opportunities to go to several beautiful places during the weekends, such as Matsushima, Oya-Kaigan beach, and Tokyo. It was a wonderful experience not only for science but also for learning Japanese culture, especially for my 5 year old daughter who greatly enjoyed new things.

References

[1] M. Fujita, M. Matsuda, S.-H. Lee, M. Nakagawa, K. Yamada, Phys. Rev. Lett. **101**, 107003 (2008).
[2] M. Kofu, S.-H. Lee, M. Fujita, H.-J. Kang, H. Eisaki, K. Yamada, Phys. Rev. Lett. **102**, 047001 (2009).
[3] J.-H. Kim, S. Ji, S.-H. Lee, B. Lake, T. Yildirim, H. Nojiri, K. Habicht, Y. Qiu, K. Kiefer, Phys. Rev. Lett. **101**, 107003 (2008).
[4] M. Kofu, H. Ueda, H. Nojiri, Y. Oshima, T. Zenmoto, K. Rule, S. Gerischer, B. Lake, C. Batista, Y. Ueda, S.-H. Lee, Phys. Rev. Lett. **102**, 177204 (2009).
[5] S. Ji, J.-H. Kim, Y. Qiu, M. Matsuda, H. Yoshida, Z. Hiroi, M. Green, T. Ziman, S.-H. Lee, submitted to Phys. Rev. Lett. (2009).

WPI Activity Report of Associate Professor W. Teizer
June 1st, 2009- August 31st, 2009
Host: Professor Tadafumi Adschiri

Two objectives were achieved during this short period of three months at WPI-AIMR at Tohoku University. The first was investigating the potential of fusion research for biophysical applications of magnetic nanoparticles. The primary goal of this project is the integration of magnetic nanoparticles, a speciality in Prof. Adschiri's group, with a motility system based on biomotor proteins that we have implemented at Texas A&M University. This would allow controllable motion of nanoparticles on surfaces, with a range of potential applications, e.g. nanosorting devices. In order to implement such a paradigm, one first has to control the surface interactions of the nanoparticles to a great degree of reproducibility. With this in mind, Dr. Hojo in Prof. Adschiri's group and myself have studies this summer the surface interactions of Ce-based nanocrystals on modified surfaces, where the modification has been varied and the subsequent annealing step is used to determine the strength of interaction. This system is complex, as particle surface interactions compete with particle-particle interaction and potentially particle solvent interactions if trapped solvent is present. While this study is not complete and we plan to continue a more detailed investigation, we have determined several important points: (1) there is no significant difference between rinsing the substrate after the film growth and a more gentle dipping procedure instead. This suggests that the dispersibility of the nanoparticles in the solvent is very high and interactions with the surface are comparably weak; (2) we did not observe any deterioration in film properties over a fairly wide range of annealing conditions, up to 450°C; (3) there is some indication, that annealing improves the ordering in the nanoparticle film, i.e. there are domains where hexagonal ordering is observable over domain sizes of ~50 particles.

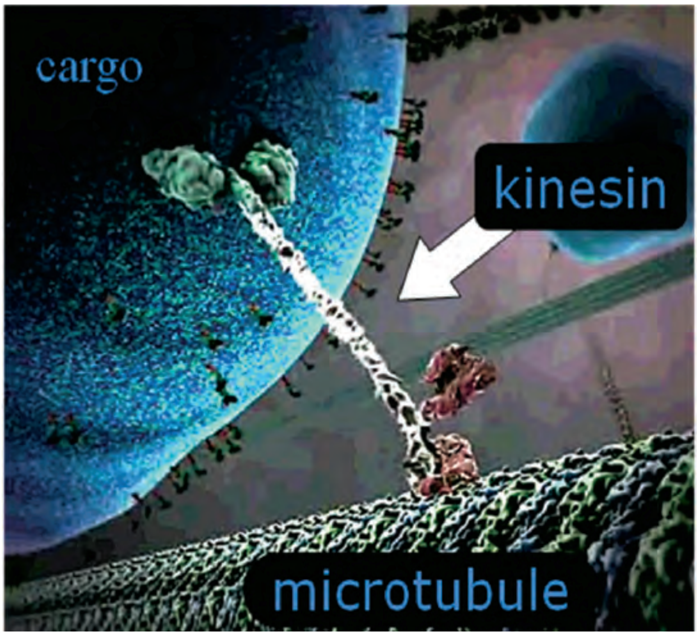


Figure 1: Artists view of the microtubule – kinesin – cargo system. We envision magnetic nanoparticles in the role of the cargo. Picture Source: Biovisions website, Harvard University.

This is in contrast to the unannealed film where at most 10 particles display short range order; (4) this raises the possibility of forming high-coverage, high-order nanoparticle films through the combination of wet processing and mild annealing.

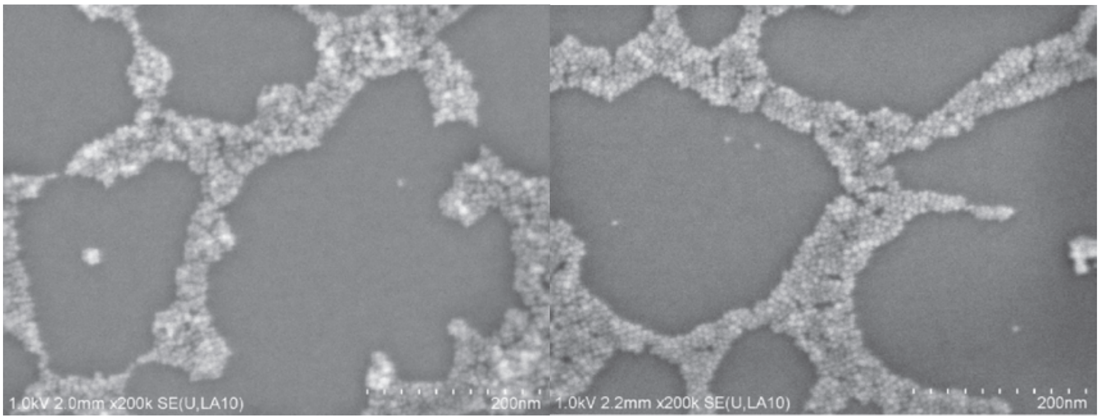


Figure 2: CeO2 nanocrystals adsorbed on hexyl terminated silicon surface after rinse. Left side is unannealed, right side is then annealed at 250°C. The local ordering in the annealed sample is significantly improved with some regions showing domains with hexagonal ordering over domain sizes of ~50 nanoscystals.

A second objective was the discovery of common interest and the development of further collaborations between the research groups at WPI-AIMR and Texas A&M University. Most interestingly along these lines are the following projects: (1) Prof. Hitosugi's low temperature Scanning Tunneling Microscope is capable of applying a controllable vector magnetic field (maximum: ~7T) during the tunneling operation. This system is therefore ideally suited to investigate the electronic properties of Single Molecule Magnets, novel molecules with large magnetic moments which can be controlled by the application of a precisely oriented magnetic field. At Texas A&M, we have succeeded in producing well controlled and characterized films of these fragile materials. Preliminary STM studies show a 2-dimensional lattice arrangement on an STM capable surface. Using these ordered films in a collaborative study with Prof. Hitosugi promises ground-breaking results in better understanding the electronic properties of individual Single Molecule Magnets. (2) Communication with Profs. Adschiri and Umetsu has shown a common interest in developing a protocol to create surfaces with selective chemical functionalization. The goal would be a massively parallel detector for thousands of chemical compounds, all integrated on one chip. By using artificial patterning techniques, biomolecular motility and biogenetically assisted surface modification we will explore the feasibility of such devices.

In order to proceed further along these projects, the basic conditions for Dr. Teizer joining WPI-AIMR as a foreign Junior Principal Investigator have been layed. It is expected, that this arrangement may soon be formally concluded.

WPI Activity Report of Professor Jinfeng Jia
July 6th, 2009- Oct. 5th, 2009
Host: Professor Mingwei Chen

During this short period of three months at WPI-AIMR in Tohoku University, two objectives were studied. As planned, the first one was investigation on the growth mechanism of Pb film by LEEM and low temperature STM. As we know that atomically flat Pb films can be obtained only by low temperature growth, the aim of our study is to find the reason why low temperature can induce the growth mode change and what determines the critical temperature above which flat film does not form. After careful experiments, we found that Pb atom motion across steps is suppressed at low temperature and the motion on the terrace makes Pb atoms form strips with uniform height. After a critical thickness, these strips becomes stable, and they connect each other to form a uniform film. At higher temperature, the Pb atom motion across steps is allowed, and Pb atoms form flat top island to minimize the surface energy and step energy. Therefore, the E-S (edge-to-step) barrier determines the critical temperature. If we can find a substrate with a high E-S barrier, or if we can increase the E-S barrier of Si(111) by step decoration, uniform Pb film can grown even at room temperature. Further experiments and theoretical calculation will be planned to confirm this result.

Recently, theory and experiments revealed that stoichiometric Bi_2Te_3 is a topological insulator with time-reversal-symmetry protected surface states that reside in its bulk insulating gap. The metallic surface states consist of a single Dirac cone at the Γ point and are predicted to exhibit a number of striking electromagnetic properties. Several months ago, our group in Tsinghua University succeeded in growing the first intrinsic topological insulator thin films of Bi_2Te_3 on Si(111) substrates by MBE. Since it's a very new and hot topic, we decided to study the growth dynamics of Bi_2Te_3 on Si(111) and graphene/SiC with LEEM after discussion with Prof. Chen. So, new parts using for the experiments were ordered and several K-cells were cleaned and tested. By now, they were already installed in the LEEM system and Bi_2Te_3 film growth is going on and will be continued by the researchers in WPI-AIMR.

On the other hand, two samples of Bi_2Te_3 films on Si(111) prepared at different conditions in Tsinghua were sent to Prof. Chen for TEM study. With the super TEM in WPI-AIMR, information on the defects, interfaces and charge carrier formation will be obtained and compared at different growth conditions. This study will help us grow high quality Bi_2Te_3 films with low carrier density.

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

(Chemists) **yoshi@mail.tains.tohoku.ac.jp**

(Physicists) **sakurai@imr.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
(Chemists) **yoshi@mail.tains.tohoku.ac.jp**
(Physicists) **sakurai@imr.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
(Chemists) **yoshi@mail.tains.tohoku.ac.jp**
(Physicists) **sakurai@imr.tohoku.ac.jp.**

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

Appendix

Prof. H. J. Freund

Prof. J. H. Perepezko

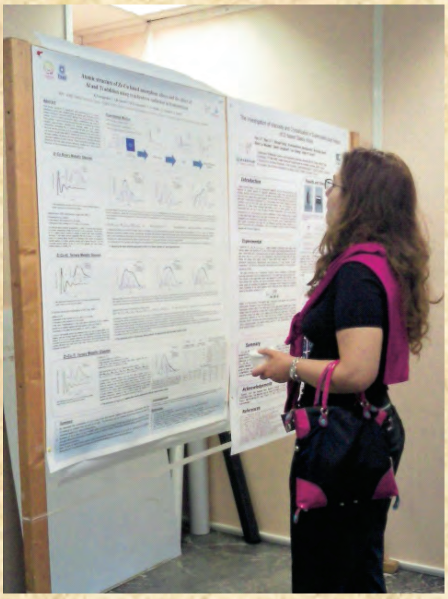
Prof. H. Gleiter

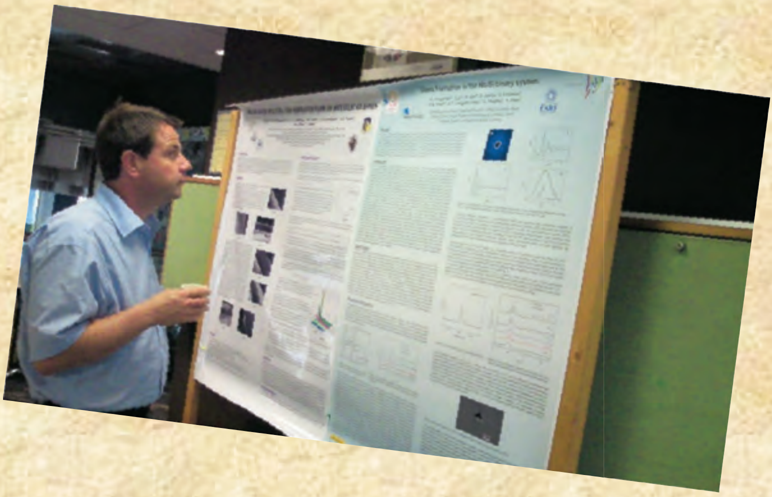
Workshop WPI-INPG Europe

Grenoble, France, August 26-28, 2009

WPI INPG-Europe Workshop
Grenoble, 25 - 28 August 2009


WPI-INPG-Europe Workshop
Grenoble, 25 - 28 August 2009









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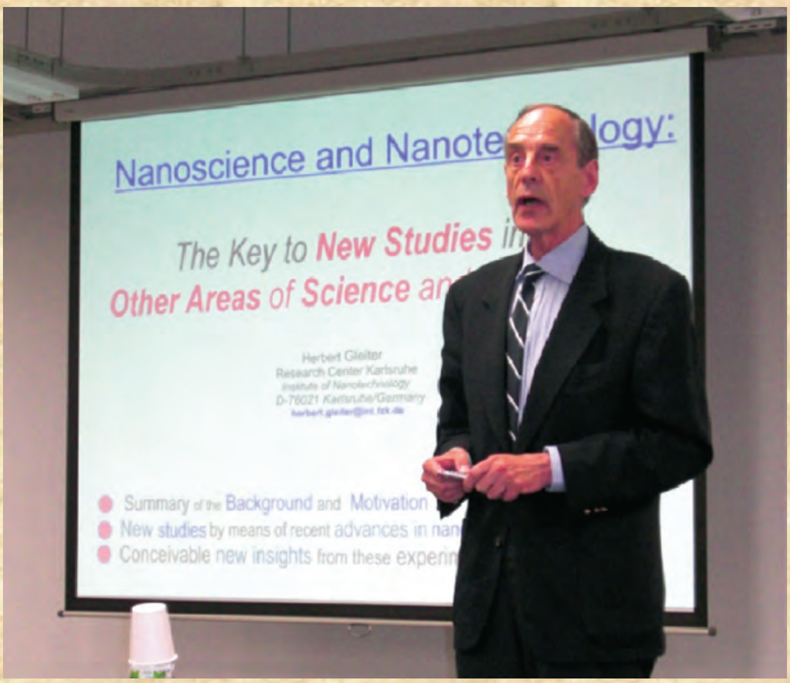
Nanoscience and Nanote logy:
The Key to New Studies in
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Summary of the Background and Motivation
New studies by means of recent advances in nan
Conceivable new insights from these experim

Dr. G. Bednorz's visit

October 8-9, 2009


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D. Hojo
K. Akiyama


Dr.Be z


D. Hojo


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T. Hitosugi
Y. Lin


Dr.Bednorz
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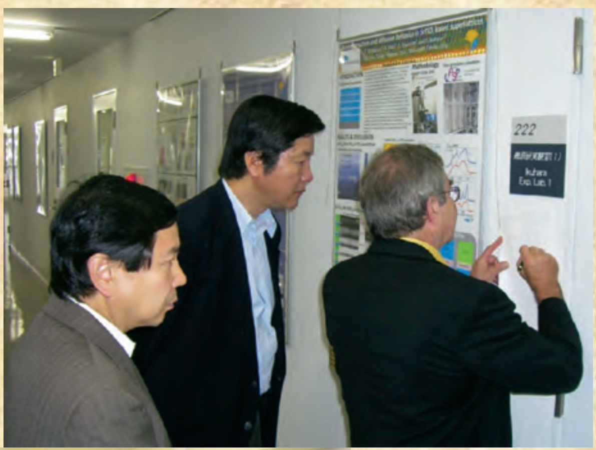
Nano Technology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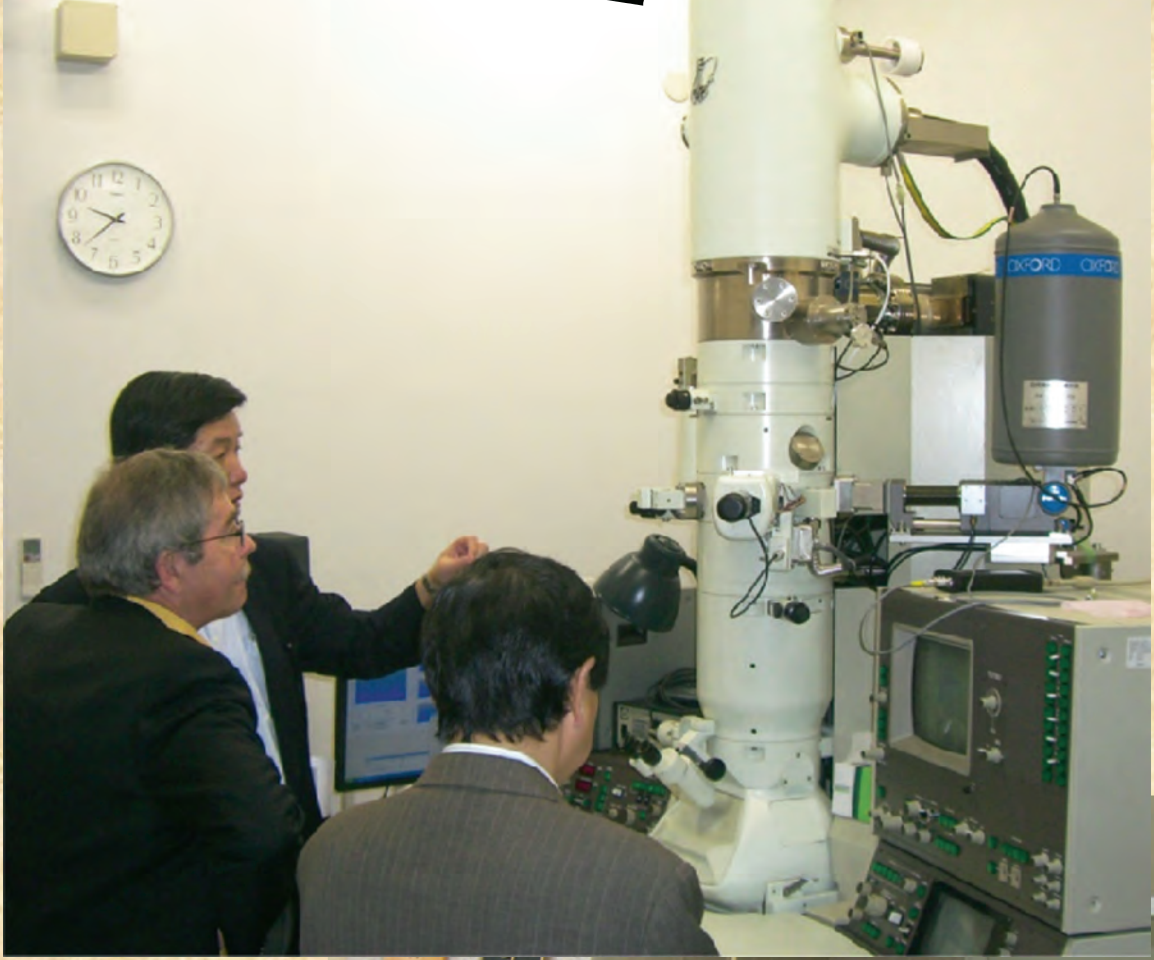
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