AIMR

Advanced
Institute
for
Materials
Research

MAGAZINE

Vol.8

ISSUE | Vol.08 | August 2016

[A Series of Talks]
AIMR's Director Speaks with the World

Best Partner

A. Lindsay Greer

AIMR Principal Investigator
Head of the School of Physical Sciences, the University of Cambridge

[Series]

The Resurrected Lab Takashi Takahashi

On-site at AIMR

Math and I Yasuaki Hiraoka

[Feature Article]

A Passion for the Elements

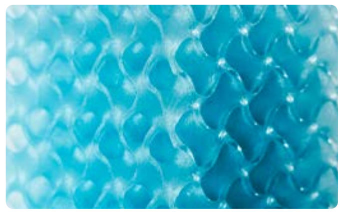
Foreword

It is our great pleasure to publish Volume 8 of AIMR Magazine. Fiscal year 2016 marked the 10th year since AIMR was established. We have renewed this magazine in order to effectively showcase the scientific excellence that AIMR has fostered over these past years until now. Our feature article is "A Passion for the Elements" but also appearing in this issue is a researcher who believes they can change the world for the better through research on hydrogen, a researcher who continues to conduct research with the goal of making the ideal battery, and yet another researcher who is pursuing electrochemical reactions at the nano level. There is a truly wide range of research fields in materials science, and researchers' approaches are very diverse. Here at AIMR Magazine we will continue to share with our readers about the "shape" of AIMR through the stories of its fascinating researchers as AIMR continues to be a hub of global brain circulation. We hope you enjoy this issue.

AIMR Director Motoko Kotani

Cover

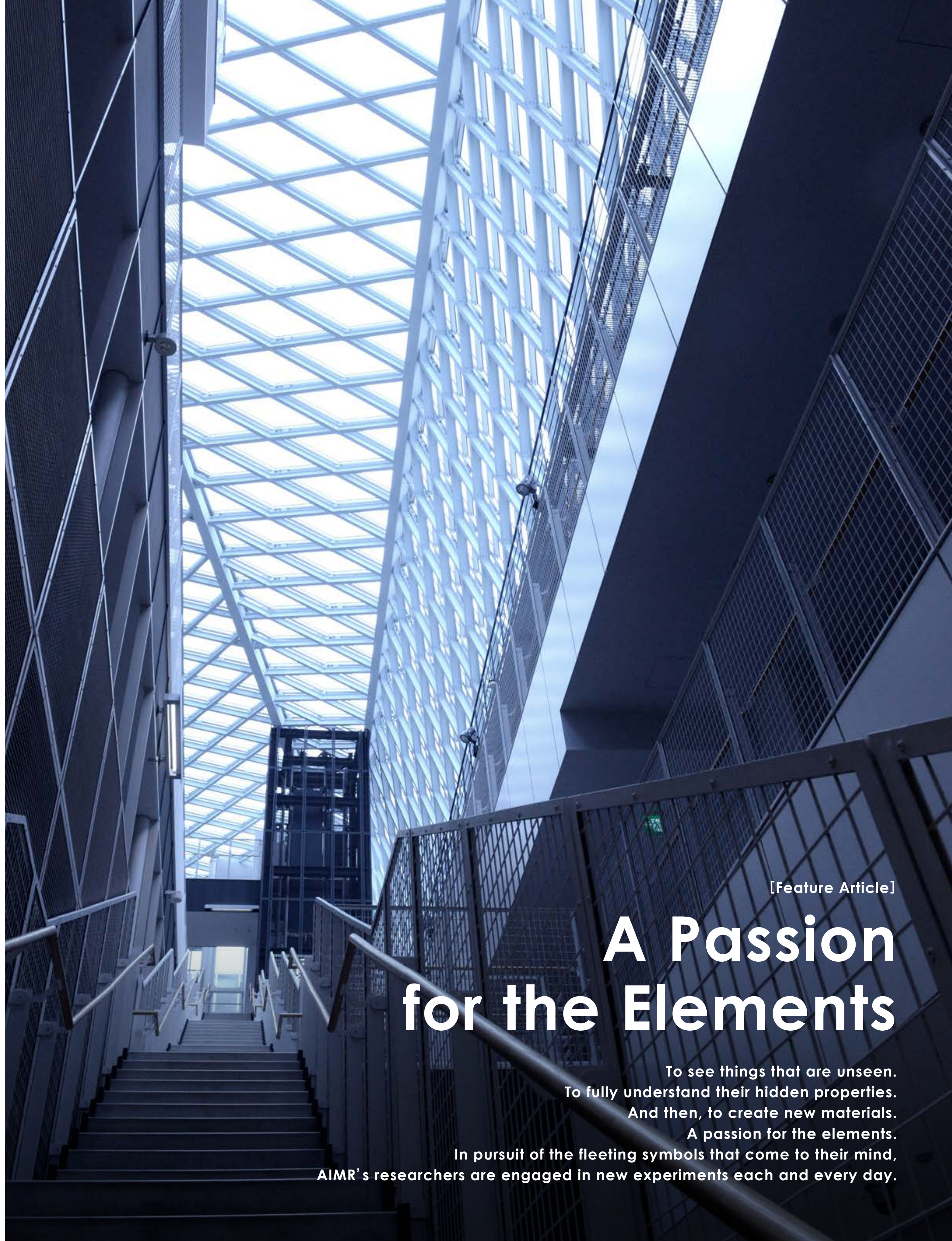
The picture on the cover is a model of a curved surface known as a "gyroid." The mean curvature throughout the structure is zero and takes on a shape similar to that of "a horse's saddle." Research regarding this curved surface is ongoing at AIMR as well, such as "Development of Novel Porous Materials Using Hints Gained from the Shape of a Gyroid" by Associate Professors Takeshi Fujita, Natsuhiko Yoshinaga and Ryotaro Kumashiro.



Contents

The Advanced Institute for Materials Research (AIMR) at Tohoku University

The Advanced Institute for Materials Research (AIMR) at Tohoku University seeks to promote collaboration between materials science and mathematics at the research institute level, which is the first such attempt in the world. AIMR is one of nine World Premier International Research Center Initiative (WPI) programs established with the support of the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), aimed at developing world-class research bases in Japan. After its establishment in 2007, AIMR has been active in conducting leading-edge research activities and creating new organizational systems in order to become a global center for materials science.



[Feature Article]

A Passion for the Elements

To see things that are unseen.
To fully understand their hidden properties.
And then, to create new materials.
A passion for the elements.
In pursuit of the fleeting symbols that come to their mind,
AIMR's researchers are engaged in new experiments each and every day.

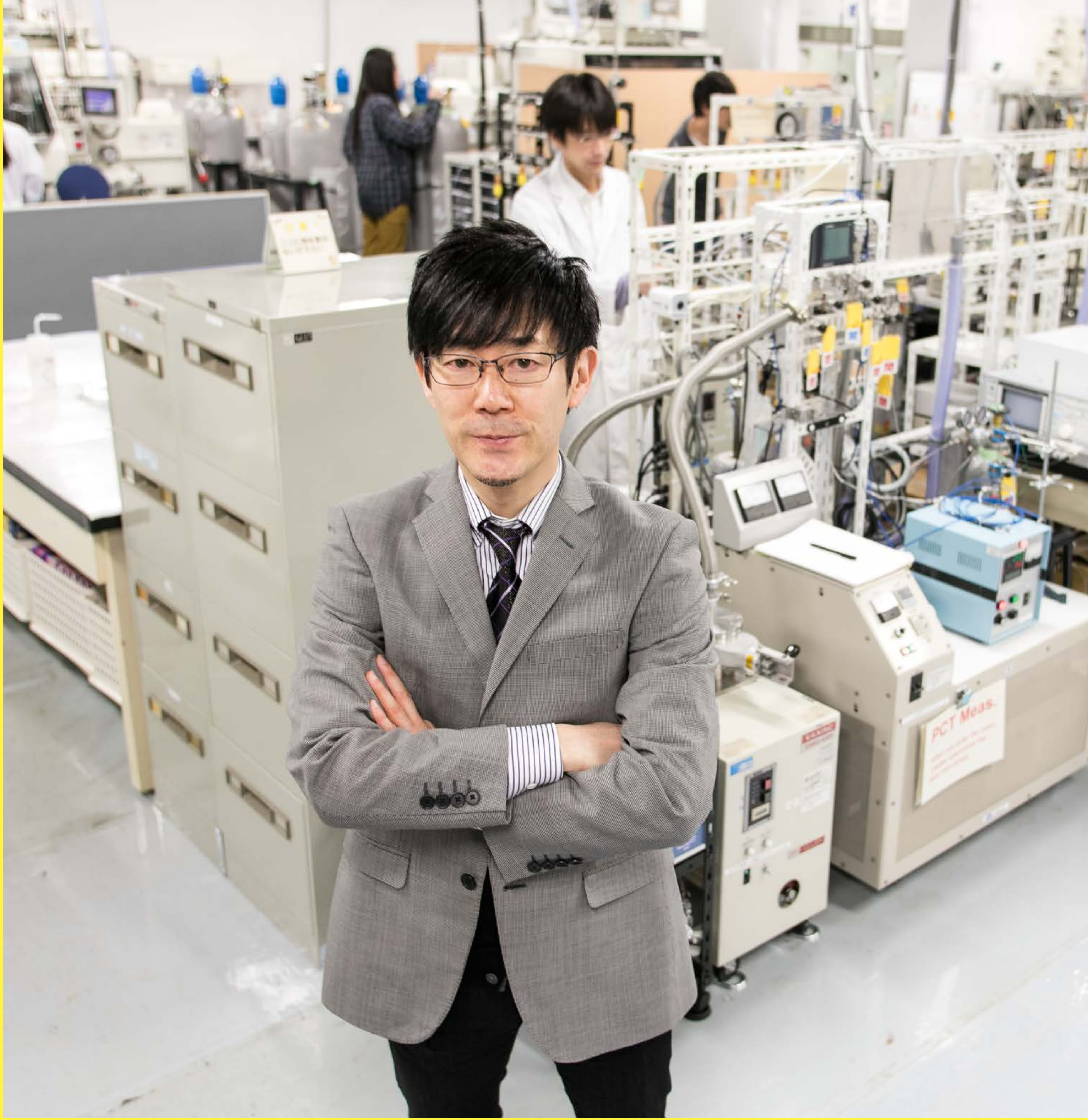


photo by Shunichi Atsumi

Let's Talk about "Hydrogen" for the Future

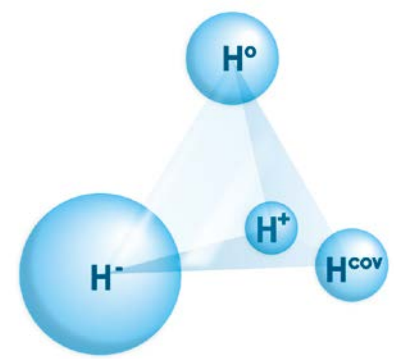
Shin-ichi Orimo
AIMR Principal Investigator

A new energy that is possible to completely transform society. At the moment, hydrogen energy seems to offer the most potential to do just that. The term “hydrogen society” is already being used as a “legitimate” term.

I’m fascinated by “hydrogen” and have conducted research on it for about 30 years. Its appeal and potential are unlimited. And I’m still interested in it. The certainty I have from new ideas and experiments, as well as the outlook for the future means that... to me, “hydrogen” is an infinite research subject that I want to pursue to the full extent that I can.

Hydrogen (H) lies at the upper left edge of the periodic table of elements, right? It’s the smallest and lightest element that has just one proton and one electron. Taking away the one electron from hydrogen turns it into H^+ with a single proton, and by adding an electron it becomes H^-. Actually, this hydrogen can move horizontally all the way across the periodic table and cause its location to be changed to the right edge, and by sharing an electron, it could be positioned in the very middle. In other words, it is a very flexible element that can change its position quite freely. It’s a transformative element with a high degree of binding freedom, as it binds flexibly by adjusting to the condition of another element. That is hydrogen. This flexible characteristic of hydrogen is the root of functionality for a variety of energy devices including fuel cells, nickel hydrogen batteries, and lithium ion batteries. Yet we can’t say that we’ve been able to draw out enough of this potential that hydrogen can offer under the current state of science. That’s why I want to apply the properties of hydrogen to materials science and draw out the “as of yet unseen performance in energy.”

In addition to being flexible, there is also an appeal to the “simplicity” in hydrogen. Hydrogen is hardly ever found existing independently on the earth. In most cases it binds with oxygen and exists as “wa-



“Hydrogen map” that illustrates the degree of freedom in the binding of hydrogen. Hydrogen can freely change shape by receiving and shedding electrons.

ter." Producing hydrogen from this water allows us to use energy. The fuel cell is a system that generates electricity/heat energies when it produces water with the hydrogen and oxygen in the form of a fuel cell. That's why water is ultimately produced. Hydrogen can again be produced from that water, leading to production once again of electricity/heat energy... so the "simple beauty of hydrogen" is seen here in that it can be both born from water and returned to water.

Originally hydrogen came to be used as a raw material for a variety of items. Without hydrogen we wouldn't be able to make things such as many petrochemical products and margarine. That hydrogen that is known as a raw material was used in fuel cells for the US Apollo project in the 60s. After that, hydrogen found use as a secondary energy in science and technology for consumer applications, and this became a national project in Japan as well throughout the 80s and 90s, which brings us to our current status.

However, at the present, there are very few researchers that are developing hydrogen's freedom of binding in actual material science. So I am trying to lead the way in proceeding with that approach.

In Pursuit of Research Surrounding Hydrogen

To give some specific examples of the research I am working on... well, you're familiar with the term "superconductivity," right? This is the condition where electrical resistance becomes zero. If this could be achieved, a significant amount of electricity could be transported to far-away locations and it would be very innovative. However, the reality now is that in order to produce a condition of superconductivity, it normally is necessary to have extremely low temperatures that are less than -140℃. Actually, it was theoretically predicted around 50 years ago that "with hydrogen, superconductivity could be achieved even without extremely low temperatures." Then last year, we finally saw how that might actually be achievable. When sulfur hydrides, which is when hydrogen and sulfur bind to each other, is highly pressurized to approximately 200 GPa, it enables superconductivity even at -70℃. That sort of paper was published in *Nature* magazine. The research I am working on is to see whether I could make hydride materials that could enable superconductivity even without ultra-high pressure.

This... (points to a white-colored powder). This is called a complex hydride and is said to be like salt. It's not actually salt, but it's close to salt. I've been continuing to conduct research on this complex hydride since when I first came to Tohoku University 14 years ago. Actually a lot of hydrogen is packed into just this small amount. If I was to warm this up a little, the hydrogen would soon dissipate away. So you can see why this is excellent for hydrogen storage functions. I conducted research on how to use this in a fuel cell, but in 2007 I discovered the phenomenon that "by changing the atomic structure of complex hydrides, one can make the lithium ions inside move at high speed (lithium super-ionic conductivity). Hydrogen can support the "location" when lithium ions move. When I discovered this, I thought "ah, I can also use this in lithium ion batteries, since moving lithium ions is the very principle of lithium ion batteries. In 2014, a Joint Research Division with Hitachi, Ltd. was established in AIMR in the hope of actually trying to apply this to batteries. This research unit was given the name "Next Generation Innovative Battery Laboratory" and together with Visiting Associate Professor Jun Kawaji we engaged in research on next generation lithium ion batteries that use complex hydrides. For a long while, we continued to try various research regarding hydrogen, and one outcome was the discovery of lithium super-ionic conductivity, and that led to talk of next generation lithium ion batteries. Looking back on this, all of these things that we tried were connected.

University, Corporate World, then Overseas

I was born and raised in Hiroshima. I encountered hydrogen at a lab I joined in my fourth year at Hiroshima University and I've been researching hydrogen continuously ever since.

Around the time when I had to choose my master's course, I started working with automobile manufacturer Mazda Motor Corporation for joint research on a "hydrogen rotary engine." Working together with company researchers I was able to look through an electron microscope and so I kind of thought "ah, it is because of this sort of fine structure that a lot of hydrogen can be absorbed." I can still recall the feeling of "I'm developing materials" that I felt at the time. The feeling of creating materials that had previously not existed. I think that feeling was the driving force that allowed me to commit and continue research on "hydrogen." At the time, the university (and probably the company as well) had a greater degree of freedom than now. This is because now I am evaluated by how I progress with research as part of a project, but at the time I was free to think of many different things and it was very stimulating.

I then joined Kobe Steel after I finished my master's course. Here I could be responsible for a research project and

produce some research outcomes from scratch in a short period of time. After that, I returned to Hiroshima University, where I was able to receive my doctorate in a reduced amount of time, and then took the chance to study abroad in Germany (as a Humboldt Fellow). Upon returning to Japan, I headed over to the Institute for Materials Research at Tohoku University. I've become a Principal Investigator at AIMR since 2013, which has taken me to my present situation. I really feel that I've had a tremendous variety of experiences as I started my career as a researcher from a regional university, then became a company researcher, left to research abroad, and am once again continuing academic research at Tohoku University. Despite the fact that I've come all this way just with research on hydrogen, my position at each different time has changed my perspective, and I've taken a different approach towards hydrogen. I'd like to think that is one of my strengths.

To Change the World with Hydrogen

In December of 2014, Toyota Motor Corporation announced their own fuel cell vehicle. Then, in 2015 (just last year), we saw the phrase "the first year of hydrogen" being used by the mass media in Japan, among other places. This is because Japan's industry, academia and government are collaborating on technological development for hydrogen use in preparation for the Tokyo Olympics that will be held in 2020. One example is Toshiba Corporation's Hydrogen-Based Autonomous Energy Supply System. This is system research on power generation that produces hydrogen from water using solar power, and sends that to fuel cells.

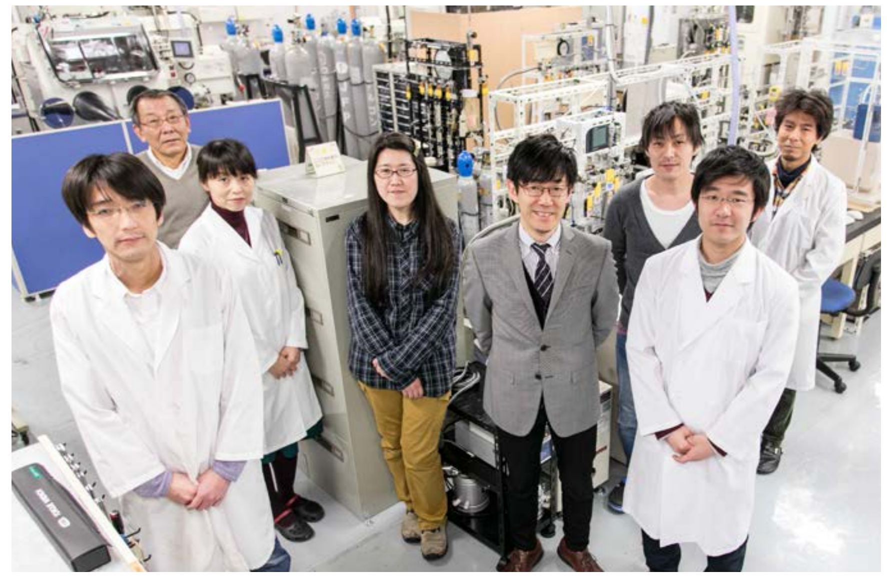
In research regarding hydrogen, the "connection with society" even in basic research goes very deep. Among my own research that I am working on such as "development of 'practical, lightweight hydrogen storage materials' using commonplace metals such as iron," I am researching the deep connection with society in particular. I greatly desire to continue that kind of research in the future.

As the future prospects for this research going forward, I want to proceed with "Integrated research that takes a broad view of materials science - physics - chemistry - biology, regarding hydrogen and hydrides." Lithium super-ionic conduction and superconductivity regarding "hydrogen" are still full of unexplained areas. I want to clarify those one by one. Especially now, "Hydrogen" is one very important theme for humanity. That is because the use of hydrogen could change the world significantly. Society is actually facing deep energy problems, from the problem of CO_2 emissions regulations to national border issues developing over contested resources. If "hydrogen energy that does not involve fossil fuels" can truly spread, we should be able to resolve most of those various kinds of problems.

That's especially why... I want to change the world with hydrogen.

By speaking to many people about "hydrogen" in the future, we should be able to see the shape of our future. That's how I see it.

[December 24, 2015. At Building 4 at the Institute for Materials Research, Tohoku University]



Publications and Awards

[Primary Publications]

1) "Complex hydrides for hydrogen storage", S. Orimo et al., *Chem. Rev*. 107, 4111 (2007).
2) "Lithium fast-ionic conduction in complex hydrides: Review and prospects", M. Matsuo and S. Orimo, *Adv. Energy Mater*. (Review Article) 1, 161 (2011).
3) "Complex hydrides for electrochemical energy storage", A. Unemoto et al., *Adv. Functional Mater*. (Feature Article) 103, 133903 (2014).
4) "True boundary for the formation of homoleptic transition-metal hydride complexes, S. Takagi et al., *Angew. Chem. Int. Ed*. 54, 5650 (2015).

[Principal Awards]

1) Intelligent Cosmos Encouragement Prize (2004)
2) The Japan Institute of Metals and Materials Murakami Young Researcher Award (2004)
3) The Japan Institute of Metals and Materials Technical Development Award (2008)
4) The Japan Institute of Metals and Materials Meritorious Award (2011)
5) Prize for Science and Technology of the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology (2012)
6) Science of Hydrogen & Energy Award (2015)

INTERVIEW

Being Fascinated by Batteries

Jun Kawaji

AIMR Hitachi Joint Research Division (Next Generation Innovative Battery Laboratory) Visiting Associate Professor / Hitachi, Ltd. Senior Principal Researcher

Normally we do not really think much about the device known as a "battery." They seem to have an existence like that of an inconspicuous stage hand, so to speak. But there is one researcher who has continued to be deeply interested in this "battery." Even now he is engaged in new experiments while still thinking about the "ultimate battery."

I would guess that most of you normally don't really think much about batteries, right? Normally a battery is just something to be "used." But actually, I'm always thinking about batteries. You could say that I am "a guy who is fascinated with batteries."

I am engaged in research on lithium ion battery materials. Lithium ion batteries are the kinds of batteries used in mobile phones and laptop computers. They are used in a wide variety of applications because a lot of electricity can be stored inside despite their light weight. Researchers are now trying to develop "large batteries" in order for those lithium ion batteries to be used in electric vehicles and in electricity storage from household photovoltaic power generation. If they can be made larger than that, much more energy can be stored and they can be used in applications like automobiles. But packing a large amount of energy can lead to overheating and the possibility of fire. You've likely seen articles in the news about accidents involving a sudden burst of fire from notebook PCs. That's why my overall goal at the moment is to "create a large battery that will not catch fire." In addition to that over-arching goal, now, I'm very focused on "a lithium ion battery that can be used in a high temperature environment." Current mobile phone batteries become unusable when the environment is more than 60℃ because the component materials inside the battery degrade. Up until now we have not discovered battery materials that will not degrade at high temperature, but by applying Prof. Orimo's (AIMR Principal Investigator Shin-ichi Orimo) research outcome of "high-speed lithium ion conductivity is possible if hydrides are used," we were able to produce "a lithium ion that has incorporated hydrides." A recent outcome of that research is that our test battery worked properly in an environment of 150℃. If this could be commercialized, then lithium ion batteries could be used in areas like the engine compartment of automobiles.

Fig. A Conventional LIB
(Organic electrolyte solution)

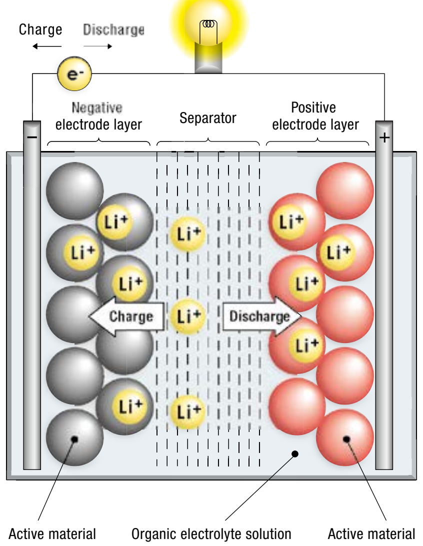


Fig. B All-solid-state LIB

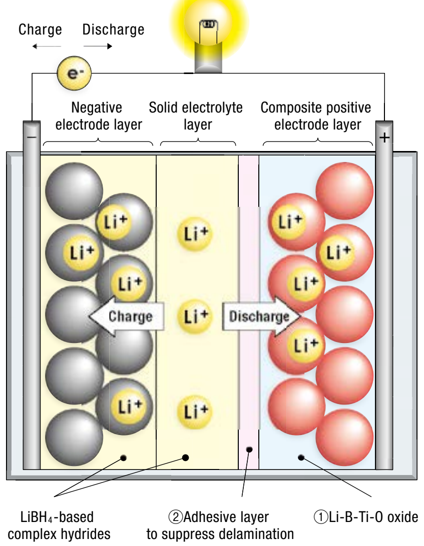
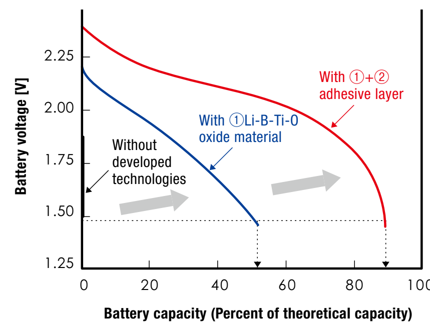


Fig. C Discharge curve at 150℃



Achieving a Solid-state Battery with Two Measures

The structure of a lithium ion battery is shown in this figure [Fig. A Conventional LIB]. Lithium is packed into the battery overall, and there is a cathode, anode, and separator. The battery is structured such that a current will flow when lithium ions that have been amassed in the anode move over to the cathode. During discharge, lithium ions are moving rapidly from the anode to the cathode. When the voltage inside the battery starts to drop, the battery is connected to a power outlet, which will now cause the lithium ions to move from the cathode to the anode. This is the charging process. The cathode, anode, and separator are impregnated in organic electrolyte, and the lithium ions are moving within that. This organic electrolyte easily catches on fire. And it also degrades at around 60℃. So from that we considered trying to make the organic electrolyte into a solid state so that the battery would be difficult to catch on fire and difficult to degrade. The official name was "high heat-resistant solid state lithium ion rechargeable battery." The horizontal axis on this graph [Fig. C Discharge curve at 150℃] represents the "amount of electricity extracted." This is the amount of electricity. Ideally this would be 100. The vertical axis is the "battery voltage." For this as well, the higher the number the better. The part at the beginning of the graph that says "no application" refers to the value when we had made the solid state battery but electricity did not flow whatsoever. By adding some measures to this, electricity started flowing as seen in the red line and blue line.

To explain what sort of measure we tried... the figure in [Fig. B All-solid-state LIB] is a structural diagram of the solid state battery, and this yellow colored area is the $LiBH_4$-type complex hydride. We had Dr. Unemoto (Prof. Orimo's Lab/Lecturer Atsushi Unemoto) and Dr. Yoshida (Hitachi Joint Research Division/Research Associate Koji Yoshida) make the solid electrolyte. It is used in the battery's overall materials. At first it was "no application" but by adding Li-B-Ti-O oxide to the cathode (composite cathode layer), we could get it to charge and discharge properly. If we don't add this oxide, it will be unstable in a high temperature environment even when it is in a solid state. However, the composite cathode layer and solid electrolyte layer (separator) would detach from each other when using this battery. That led us to start talking about "we have to put something like glue in here." Dr. Shohei Suzuki (AIMR Visiting Joint Researcher), a researcher from Hitachi who was stationed at AIMR, read the paper by the Orimo Laboratory closely, and was kind enough to think about an "adhesive layer" material for the part about the glue. He developed a substance by adding another element to $LiBH_4$ so that "it melts at high temperature but hardens and returns to its original shape when cooled," and after experimenting with it, we found that it stopped detaching. With the two measures of "the addition of Li-B-Ti-O oxide" and "development of an adhesive layer" we were able to achieve a solid state battery that worked in an environment of 150℃.

The solid state lithium ion battery is built and used in experiments inside a glove box so that it will not come in contact with air

Dreams of an Outstanding Assistant, "The Ultimate Battery"

What makes me happiest after coming to AIMR is being able to conduct win-win joint research with university laboratories. I have meetings once a week with the Orimo Laboratory, and I'm very happy that we can adjust each other's opinions and summarize them into one unified direction. Also, the fact that there are various researchers in AIMR with a breadth of experience is very attractive. I'm satisfied that "the solid-state battery worked" but, for example, I'd like Dr. Kumatani (AIMR Matsue Laboratory/Assistant Professor Akichika Kumatani) to evaluate my work at the nano level using nano-scanning electrochemical cell microscopy. He might be able to tell me that, "actually we found this kind of problem."

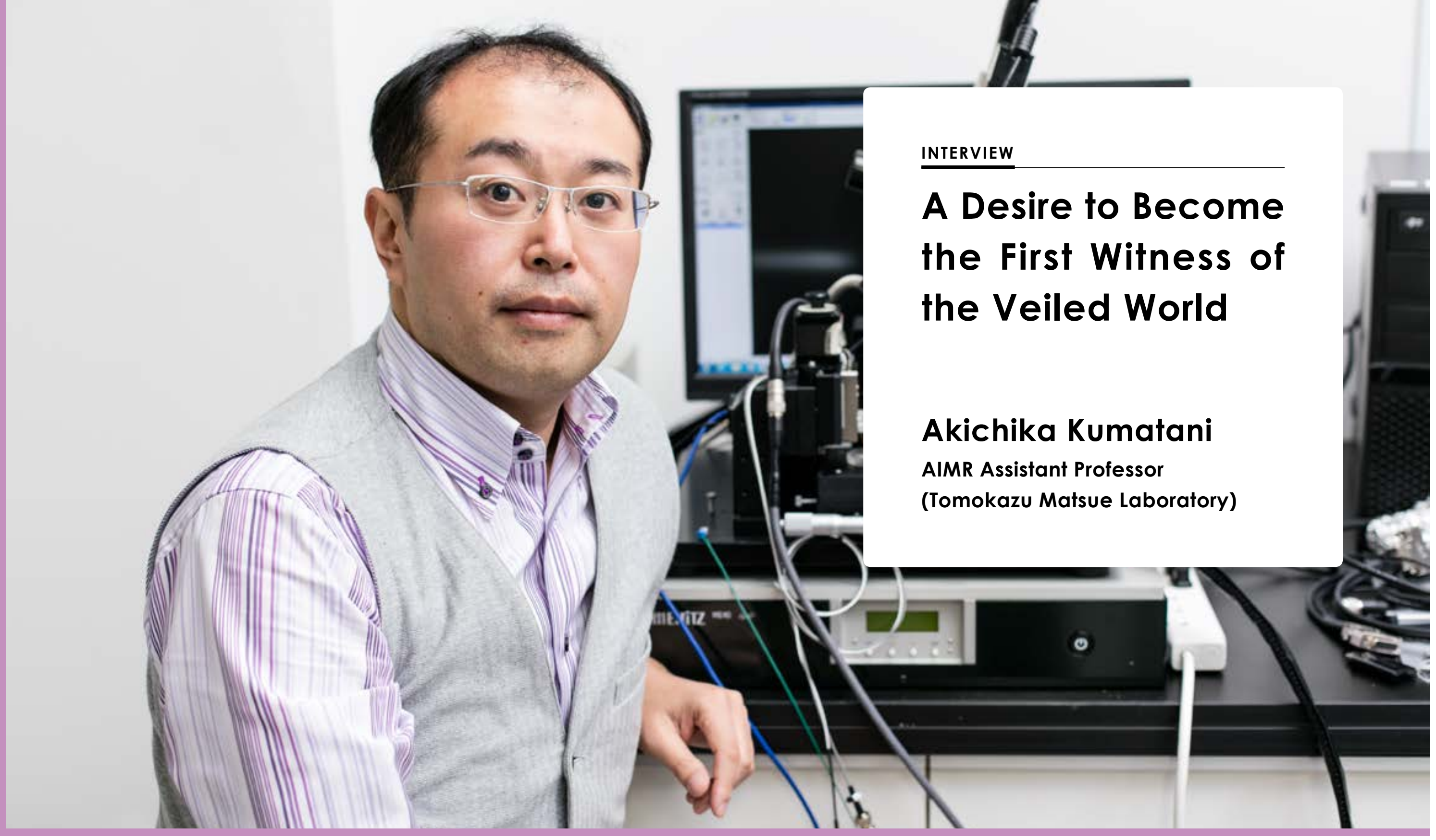
Batteries have kind of a sad existence, don't you think? It's taken for granted that they should supply electricity and be used for a long period of time. And if they start to take a long time to charge, then users start to complain (smiles). Even in such a case I want to consider a battery that is operating normally as an outstanding assistant. To me, the ultimate battery is "a battery that doesn't make you aware of its presence." As a "guy fascinated by batteries" I always end up thinking about that vision. Ah, by saying that, I'm sure people are now going to tell me "your whole life is about batteries," when I eventually leave AIMR and return to the corporate world. But, perhaps that is ok... I feel like I might have said too much in today's interview, and now I'm beginning to regret that (smiles).

[January 21, 2016. At the Next Generation Battery Laboratory in the AIMR Laboratory Building]

High Thermally Durable All-Solid-State Li Ion Battery

http://www.wpi-aimr.tohoku.ac.jp/en/news/press/2015/20151112_000592.html

photo by Shunichi Atsumi



INTERVIEW

A Desire to Become the First Witness of the Veiled World

Akichika Kumatani
AIMR Assistant Professor
(Tomokazu Matsue Laboratory)

From time immemorial, people have been in fear and awe of "Unseen Phenomena."
The sense is similar to a sense of longing.
People are stimulated by them, and charge headfirst to find out more about the "Veiled World."
Hence, researchers are steadily and stoically studying to become the first witnesses of the "Veiled World."

In our daily lives, we probably somehow think that we are "able to see what's around us." But if we could see at the nanometer scale (10^{-9} m), we would realize that not all phenomena can be seen. That's why I want to "visualize such phenomena for the first time." The reason why I've worked in AIMR as a researcher is in order to "be able to visualize things that couldn't before be seen."

The research that I am engaged in is "visualization of reactions using a microscope to discover veiled phenomena that we've never known before." Well, when I say a microscope, I'm not referring to the standard microscope that most may imagine, but rather a microscope that can allow us to see electrochemical phenomena on a nanometer (10^{-9} m) scale that is called "nano-scanning electrochemical cell microscopy (nanoSECCM)." In particular, I enjoy studying any interfaces using this microscope. Interface refers to the border between two substances with different properties, the part where one surface makes contact with another surface. One can see "how electron or ion transfers occur at the interface." Electron transfers have already been widely researched using well-known microscopes such as by scanning tunneling microscopy, but we still don't know very much at all about what is happening in regard to ion transfers. That's why I want to "visualize that directly," to see it before anyone else.

Here, I would like to introduce two examples of my current research. One is research in collaboration with Prof. Hitosugi (AIMR Junior Principal Investigator/ Tokyo Institute of Technology Professor) regarding "Investigation of ion transport at electrode materials in lithium ion batteries; in particular, visualization of ion transport at grain and grain boundaries in thin film electrodes with different crystal orientation." Thin film studies are ideal for investigating their intrinsic properties because this fabrication technique can define their structures. We can therefore quantify the defined structure by only using nanoSECCM. The second is collaborative work with Prof. Komaba (Tokyo University of Science) on "local electrochemical properties of binders inside practical battery electrodes." We investigate the importance of binders at the nanometer scale which was only possible from information obtained from our microscope.

Fig. 1 Scanning Probe Microscopy

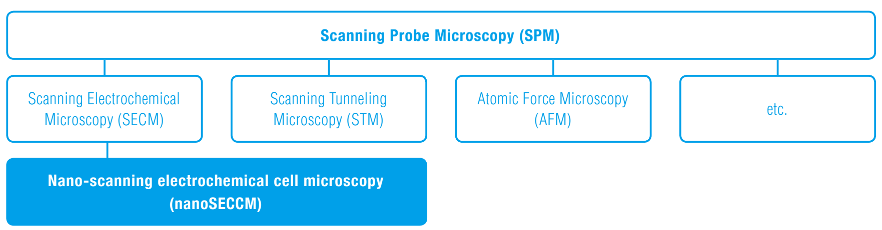
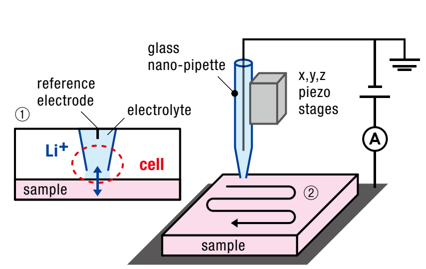


Fig. 2 A schematic of nanoSECCM



① Localized electrochemical analysis through a cell
② Visualization of lithium-ion (de)intercalation process and topography on the sample by scanning a nano-pipette

"Seeing" with World-Class Resolution

The nanoSECCM that I am using is a member of the "scanning probe microscopy (SPM)" family. SPM is a form microscopy in which a probe traces over the object to be investigated. One type of that SPM is a genre that is called "scanning electrochemical microscopy (SECM)" and "nanoSECCM" falls under this category. To explain using a schematic diagram of SPM families, it would look like this. [Fig. 1 Scanning Probe Microscopy] in that arrangement... we are using a pipette. By irradiating a laser on a glass capillary and pulling it, we created a pipette with a hole that is at about 50 nm in diameter. This pipette's size is the resolution of the microscope, and a 50 nm resolution is a world-class level. We fill the pipette with electrolyte solution with a reference electrode, and as it approaches the object, a "meniscus (cell)" is created before it adheres to the object. It's kind of like this [Fig. 2 A schematic of nanoSECCM]. If you look carefully at this meniscus structure, we can see that a "battery (cell)" has indeed been created with the electrolyte solution between the electrodes. The (de) insertion processes of lithium-ions occur through this microscopic cell. A mapping can also be taken by repeating that process for all of the measurement points (scanning), and an electrochemical image can be obtained. This is how we can directly visualize or "see" the ion transfer at the interface of a localized space. The unique point about nanoSECCM is that one can observe the area in which the electrochemical reaction occurs at the nano-scale. In other SECM, one can see the object that is soaked in solution, but with nanoSECCM, since you can see the electrochemical reaction inside the droplet, we can obtain local information directly. Since this microscope can verify any responses caused by electrochemical reaction, it could be used for observations of a wide variety of local phenomena. Currently, there are only a few units of nanoSECCM in the world. In particular, the only place in the world where one could imitate the lithium-ion transport that occurs in a normal practical battery and see this is at AIMR, and only by using this 1 unit.

The Encounters with Prof. Hitosugi and Prof. Takahashi

I did my master's degree at the King's College London (UK), and studied for my doctoral course at University College London. When I was in graduate school, my research topic was in the field of surface science related to nano-carbons, and after my doctoral degree, I joined to the lab of Dr. Tsukagoshi (Principal Investigator in National Institute for Materials Science, NIMS). At NIMS, I conducted research on "charge injection at the interface between organic semiconductors and metal electrodes." I was captivated with phenomena at the "interface" during this time. Then I joined the lab of AIMR's Prof. Hitosugi in 2011. In the Hitosugi Lab, my research involved "ion conduction in film electrodes for batteries and in the electrode/solid electrolyte interface," which is what I continue to study even now. In 2011 I hadn't yet encountered nanoSECCM, and struggled to take quantitative measurements of ions in the above research. At that time, I met Prof. Yasufumi Takahashi (then AIMR Assistant Professor, now Kanazawa University Associate Professor) at AIMR Symposium 2012. At the time, Taka was an expert on using SECM and their families to find the electrochemical reactions in "biology." We hit it off immediately at the poster session venue, and this led to talk of "let's work together to make use of the SECM technology utilized in biology to start a new SECM with a new concept, and apply this to materials research!" After that, I went to the laboratory of Prof. Tomokazu Matsue (AIMR Principal Investigator) of which Taka was a member. Based upon the guidance of Prof. Matsue, who is one of the world leaders in electrochemistry, I'm now engaged in research on nanoSECCM.

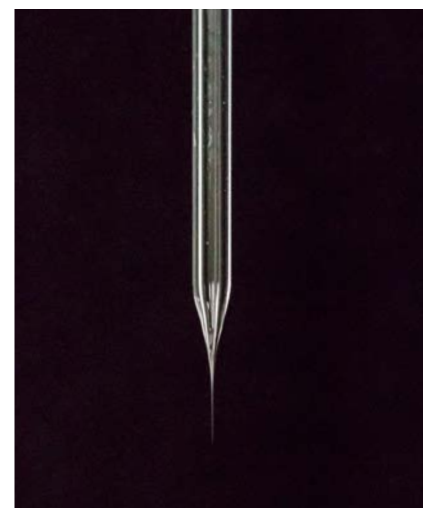
Working Together with Researchers in a Wide Range of Fields

Among SPM, nanoSECCM is still a technique that has really just been born. That's why I'd like researchers in various fields to know about the existence of and make use of nanoSECCM. In the future, I'd also like to investigate the local electrochemical responses of graphene and other such two-dimensional materials.

If I were to look back... the target of my interest changed from nano-carbons, to organic semiconductors, and then to lithium ion batteries, but I continued my research with the consistent feeling that "I want to be the first to witness the interface phenomena that are occurring at the nano level. I want to find a way to try and see things that I haven't been able to see yet." This is my fundamental desire. I'd really like to make use of this treasure that is nanoSECCM in the future as well and continue witnessing "things that no one has ever seen before" at the nano level.

[December 15, 2015. At the Matsue Laboratory in the AIMR Laboratory Building]

In-situ Study of Lithium-ion (De) intercalation by Using Interface Ion Conduction Microscope for Creation of High-performance LIBs
http://www.jst.go.jp/alca/en/kadai.html



The nanoSECCM's glass pipette. The diameter of the opening at the tip is approximately 50 nm.

photo by Shunichi Atsumi

[A Series of Talks]
AIMR's Director Speaks with the World

Best Partner

Establishment of overseas bases is an important measure so that AIMR can serve as a hub of global brain circulation. The Cambridge AJC is an ideal base.

A. Lindsay Greer × Motoko Kotani

photo by Miki Sato

PHASE 01

A. Lindsay Greer

AIMR Principal Investigator
Head of the School of Physical Sciences,
the University of Cambridge

Motoko Kotani

AIMR Director
Tohoku University

Greer More than 4 years have passed since AIMR and the University of Cambridge established the AIMR Joint Research Center at Cambridge (hereafter, "Cambridge AJC"), haven't they?

Kotani One of my first initiatives after becoming director of AIMR was to strengthen our international network. We selected three organizations out of our 15 partner organizations as core partners - the University of Cambridge, UC Santa Barbara, and the Institute of Chemistry, Chinese Academy of Sciences - and we have certainly established strong collaborative relationships. Then I proposed establishing Joint Research Centers at these three institutions to create a tangible network and to proceed with systematic joint research. Prof. Greer, I remember that you promptly told me "I'd like to give positive consideration to this." Then since AJC was established even at the University of Chicago, there are now 4 bases, but the Cambridge AJC was the first to be implemented. I get the impression that it is still continuing ideal development, and has become a model for AIMR Joint Research Centers. To promote effectively joint research with overseas research institutions, researchers who can act as a bridge need to be jointly appointed at both organizations, and it's important that each can work freely at both organizations. AIMR has created the Cambridge AJC as a place to achieve that and I think we are already seeing a high effect.

Greer The University of Cambridge has a school tradition of "valuing basic research," so the collaboration with AIMR, which aspires to be world class in basic science, is very familiar to us. I feel that we've been able to have a very high synergistic effect. In 2012 when the Cambridge AJC was established, researcher Dr. Jiri Orava (AIMR Research Associate), who belongs to the Cambridge AJC, and I achieved the outcome of "quantification of crystallization growth rate for chalcogenide liquid in operating temperature range."

Kotani Yes, that's right. I think the fact that researchers belong to both is very significant. Since we're aiming for systematic joint research, we first held a workshop with Cambridge and AIMR, and discussed in detail plans about joint research in this workshop, we selected the best from among several joint research proposals and started supporting them. Besides your research, Prof. Greer, on metallic glass with Prof. Dmitri Louzguine (AIMR Principal Investigator), Dr. Erwin Reisner (Principal Investigator in the University of Cambridge's Department of Chemistry), Dr. Katherine Orchard (AIMR Research Associate), Prof. Tadafumi Adschiri (AIMR Principal Investigator), Prof. Naoki Asao (then AIMR Professor, now Shinshu University Professor) have launched a research group as joint research. In terms of the connection between AIMR and the University of Cambridge, I think it's really significant to have the presence of two Cambridge AJC researchers, Dr. Orava and Dr. Orchard. Prof. Greer, from the time when you were young, you also spent time at Tohoku University several times, didn't you? I believe that strong connection is now living on in the Cambridge AJC.

Greer The first time I came to Tohoku University was in 1981, when I was a postdoctoral fellow. Unfortunately the train schedule from Tokyo to Sendai had been disrupted and not only was it hard to reach the city of trees, I also became sick and ended up spending three weeks in the hospital in Sendai. However, I really felt a strong attachment from this time to Tohoku University, Sendai, and Japan as well. Even on the research side, from this time, I proceeded with joint research on metallic glass little by little. The other day, in another interview with the media I was asked "Why did you choose AIMR as a partner?" to which I answered that "Cambridge seeks only 'best with best' collaborations, and that is what makes the AIMR such an obvious partner in materials science." This was a decision based on the "trust" towards joint research with Tohoku University that I've personally continued to experience over many years.

Kotani Yes, each of the AIMR researchers is individually well known throughout the world, but the Cambridge AJC was created to combine that individual ability into an organization. I'm pleased that by having the Cambridge AJC, new joint research will expand even further.

Greer Last year as well, we were able to announce both the research outcome with Dr. Orava regarding "phase change memory," and the research outcome with Prof. Louzguine and others regarding "rejuvenation of metallic glass." I really feel that the Cambridge AJC system is actively functioning now.

Kotani As the director of AIMR, I really have a lot of hope for the Cambridge AJC going forward as well. Well, it's almost time for the AMIS2016 (The AIMR International Symposium 2016) reception to start.

Greer Let's get going. I'm really looking forward to this year's AMIS2016 as well that starts tomorrow.

[February 21, 2016. At The Westin Sendai's 2nd Floor Foyer]

What is the Cambridge AJC ?

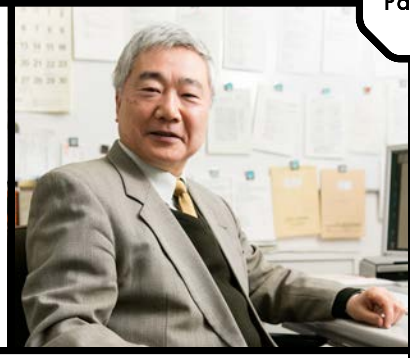
AIMR Joint Research Center at Cambridge (Cambridge AJC) is an overseas satellite that AIMR has established at the University of Cambridge in the U.K.. The Cambridge AJC was founded through an academic agreement that was concluded in 2012 between Tohoku University AIMR and the University of Cambridge Department of Materials Science & Metallurgy, Department of Chemistry, and Department of Mathematics, and AIMR Director Motoko Kotani and University of Cambridge Professor A. Lindsay Greer renewed the contract for the Cambridge AJC in November of 2015. They are focused on activities that seek developments in the non-equilibrium material field and soft material field, as well as mathematics, and two AIMR researchers are stationed there.

The Resurrected Lab

Part 1

A Late Night in the Lab that Made Me Reflect On the Joy of Research

Takashi Takahashi AIMR Principal Investigator



In this series, we introduce "an indelible scene in the lab" that had an impact on the particular researcher's life.

▶ The Day When I Added Just a Little Insight to My Experiment

A lab story that has stayed in my heart the most? Hmm... I would have to say that is probably a certain day in the lab when I was a graduate student. I can still recall this day vividly because that was a very important experience for me.

When I was a graduate student, I was a member of Prof. Yoshiya Harada's lab at the University of Tokyo Komaba campus. The lab I was in was crowded with experiment equipment, machines, workbenches and other equipment. Entering in from the doorway, I would have to weave my way past these items to get to the desk. Outside the window was a sports field, and I often watched the students playing soccer. I was the only graduate student in the Harada Laboratory then. There were times when I spent the night by myself in the lab working on experiments, and I also wrote papers in that room. When I had to sleep there because of experiments, etc., I would take out a folding bed that I kept in the corner of the room and spread it out in the middle of the lab. Around the time I was living that sort of graduate student lifestyle, that lab ended up determining my life as a researcher later on.

On that day, I was carrying on with my experiments as usual. This was an experiment using photoelectron spectroscopy. At the time (in the 1970s), photoelectron spectroscopy did not yet exist in the world as products. So I had the lab let me use primitive equipment that Prof. Harada had constructed himself by hand. The preparation for those experiments required more than a day. I would open a vacuum chamber and break it, put in deposits and then close it. Then I would bake that once. I would bake the equipment overall. In order to thoroughly process the deposition, I would make sure the substrate was clean and clean the filament. So in that way I would prepare from the day before, and on that day I started making the test samples from about 3 in the afternoon.

Just as I was making the test sample, I had a little inspiration. "I think I'll try to make these at low temperature." Amorphous selenium at room temperature still becomes amorphous, but my inspiration was that if it was at low temperature, the amorphous properties might be more prominent. So right away I cooled the temperature of the substrate to liquid nitrogen temperature: 77 Kelvin, which is about -196℃. No one had ever tried such a low temperature with this experiment in the past, so this was a new attempt.

In experiments for photoelectron spectroscopy, we direct light at the film created from the deposition and take measurements. A cable coming from the photoelectron spectroscopy is connected to a plotter that lies on a shelf, and the plotter would draw out a graph of the measurement results. Do you know what a plotter is? This is an output device that draws a chart or graph with a pen on paper when you input data. It takes approximately one hour for the plotter to draw out 1 spectrum. So you can see that it really took a long time from preparation until the measurement results could be confirmed, but I worked at that steadily by myself. But this wasn't boring to me. I was really excited when I was running the experiment. This is still the case for me even now.

Let's see, where did I leave off... ah, yes, so I cooled the substrate to 77 Kelvin, set it, and started the experiment. In order to be able to see the results, I sat in front of the shelf with the plotter and just stared at it. During this time, I was very earnest to see what kind of results would be produced.

The plotter made some noise and the graph started to be drawn on the paper. Two peaks were drawn on the graph of the results from that experiment. The first peak drawn was the same as always. I stared at the graph. Then, when I saw the point at which the second peak had started to be drawn, I thought to myself, "huh?"

▶ Getting Data that Nobody has Ever Seen Before

Normally, the first peak should be the larger one. However, in this graph the second peak was larger... At first I thought, "I must have performed the experiment improperly and didn't get the correct results." So I tried the experiment once again. It was already well into the night by this time.

I folded my arms, sat in front of the plotter, and carefully watched the results of the second time. And that's when I noticed... this time as well the second peak was drawn larger. As soon as I saw this I shouted a big, triumphant "Yes!"

This was definitely not a mistake. Clearly the second peak was stronger. Seeing these results for this experiment, I realized that I was probably the first person in all of Japan to see this. No, not just the first in Japan but the first in the world, the first in the universe even! Now I was looking at phenomena that nobody had ever seen before.

I was very excited that I had produced a new outcome through the combination of many other experiences. And I was incredibly overjoyed... that was the first time I had ever experienced something like that. Intense ecstasy. I was full of excitement. That day I watched the dawn break and the sun rise as I made my way home. I reflected on the joy I felt.

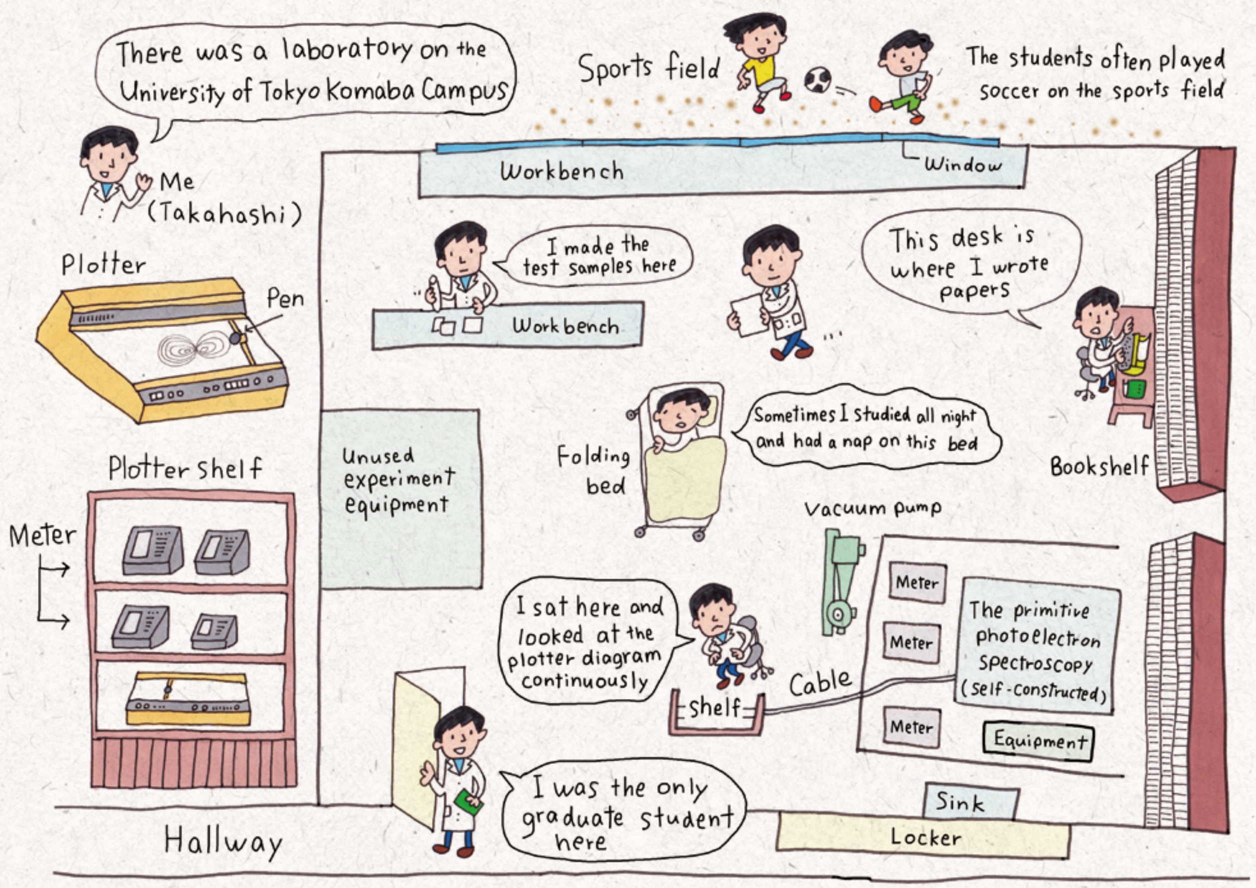
I later wrote about the outcomes of that day in my dissertation to obtain my doctoral degree. I even wrote my paper on the desk in that room. This is that paper, and you can see that the date reads 1980. It was published in the American Physical Society's academic journal "Physical Review B."

I often advise students to "take good care of the data you have collected" and "be happy if you've gotten data that is different from the usual data." These two pieces of advice stem from my thoughts that resulted from my experience from that day. Good data is data that differs from what is conventional. This is especially so because getting different data is what allows you to begin asking "why" and start working from there.

So why is it so important to treasure the data that you've gotten? Because the data that you've gathered is the "strongest." You can have confidence in the data that has been derived because you thoroughly witnessed the experiment from beginning to end using the test samples you've made and the equipment you've set up. It allows you to argue with confidence even when your data becomes controversial in conferences. This becomes "trust in oneself" combined with genuine experiment data that lies at the very opposite of data forgery.

If I think about it... the incident that happened to me in the lab that day was the starting point of my life as a researcher. I think the reason why I've been able to continue researching is especially because I had those thoughts that day. And I'm certain that I'm still going to recall what happened that day at every opportunity in the future as well.

[January 8, 2016. In the Physics Building on the Tohoku University Kita-Aobayama Campus]



On-site at AIMR

First Report

A Foreigner-Friendly AIMR

In this corner, our reporter acts as if this was an actual live report to tell our readers about the various characteristics that make AIMR such an outstanding organization.

IAC, Here to Help Foreign Researchers

The Best Staff to Provide the Best Service.

As of this past April, the International Affairs Center (IAC) was established in the Tohoku University Organization for Advanced Studies as a support office with the objective of "helping researchers that arrive from overseas start their lives in Japan." We asked these four IAC members to learn more about what it's like.

photo by Shunichi Atsumi

First can you tell us a little about "what is IAC"?

Oikawa IAC stands for the International Affairs Center. This was established this past April in order to provide livelihood support for foreign researchers. Actually, this supporting work has already become one important topic for AIMR, in which approximately half of the researchers are non-Japanese. The year before last, the AIMR office staff was divided into three groups to conduct a survey on the reality of foreigner support in famous universities in the West, including Harvard University, the University of Chicago, and the University of Copenhagen. What we found was that "all of these universities have a foreigner support department that was functioning very efficiently." We looked closely at each type of support and I remember being overwhelmed at how complete they were. After that, in July of last year, RCC (Research Reception Center) which is the predecessor of IAC, was established within AIMR, and began earnest consideration of multifaceted foreigner support. Then IAC's duties began as of this past April.

What are IAC's specific duties?

Oikawa First is "provision of lifestyle information." We distribute a newsletter concerning lifestyle information through a mailing list, provide information through an information exchange bulletin board, and publish a lifestyle information magazine. Next, another duty is "arrival support." This support for researchers who arrive from overseas includes opening bank accounts, assisting in procedures at government offices, helping them move into their lodging, and arranging rental services for home appliances.

In regards to foreigner support, what sort of problems did you usually experience before?

Oikawa Since we have an exchange student department at the university, there was support for foreign students, but in regard to support for foreign researchers, this kind of office didn't exist, and that role fell to the laboratory to which they arrived. People such as young researchers in laboratories provided support to researchers who arrived from overseas. However, in departments like AIMR, which have a large number of foreign researchers, this was a great impediment on research for laboratories that had to provide foreigner support at the office level. So creating an organization like IAC was indeed an urgent task.

What is your future outlook?

Oikawa Since there are many foreigners arriving from overseas in the new fiscal year, first we plan to gather everyone together for an orientation, and then provide fundamental lifestyle information to them there.

Well then, could each of you share some words of enthusiasm as an IAC member?

Tanno In my case, I was allowed to visit the University of Copenhagen's foreign researcher support office, called International Staff Mobility (ISM) on two occasions to observe their services. What I felt at the time was that "Recruitment is important, but retention that makes that researcher wants to continue working here for a long time is also important." As might be expected, we have to provide support that will help foreigners come to appreciate the environment to which they have arrived.

Unoura To have foreigners come to appreciate the environment, how we prepare "an environment in which they can be together with their family and enjoy a lifestyle with peace of mind" is really important. We want to provide total support that includes care for the families of foreign researchers that have just arrived.

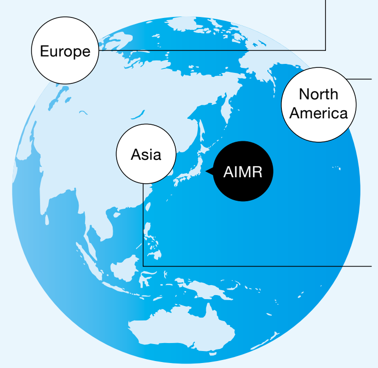
Honda First, we'd like to raise awareness by making and distributing flyers regarding IAC. After that, after providing various support services, we'd also like to receive feedback about "of all the services you received, which services were helpful?" It will be possible to think about the contents of new services depending on those answers.

Oikawa IAC's catch phrase is "The Best Staff to Provide the Best Service." As you can see from the enthusiasm of these three staff members, since I've already arranged the best staff, now we just have to put into practice the best service. Ultimately this is a case of "people support people," so I really want us to give our all to provide support to foreign researchers.

[April 4, 2016. At the International Affairs Center on the AIMR Main Building's 5th Floor]

AIMR's Overseas Partner Institutions / Satellites

AIMR has 15 overseas partner institutions as shown in the figure to the right. This enables researchers' interactive and vibrant academic exchange with each research institution in multiple fields including materials science, physics, chemistry and mathematics. In particular, overseas satellites known as "AIMR Joint Research Centers (AJC)" have been established at the four research institutions of the University of Cambridge, UC Santa Barbara, Institute of Chemistry, Chinese Academy of Sciences, and the University of Chicago. AIMR researchers are stationed within each AJC, and they serve to form a bridge between that research institution and AIMR.



University of Cambridge [satellite]
Grenoble Institute of Technology
Chemnitz University of Technology
University College London
Polish Academy of Sciences

UC Santa Barbara [satellite]
University of Chicago [satellite]
University of Wisconsin-Madison
The University of Massachusetts Amherst
UC Los Angeles
Texas A&M University
Harvard University

Institute of Chemistry, Chinese Academy of Sciences [satellite]
Tsinghua University
The Hong Kong University of Science and Technology

The AIMR International Symposium 2016 (AMIS2016) was held.

The AIMR International Symposium 2016 (AMIS2016) was held from February 22, 2016 for a period of 3 days at the Sendai International Center. At AMIS2016, in which 22 invited speakers gave presentations and 104 groups of posters were displayed, 235 researchers from 14 countries congregated to exchange various knowledge in a wide variety of fields including Materials Science, Physics, Chemistry, and Mathematics. This year's theme was "Harmonious Collaborations between Mathematics and Materials Science."

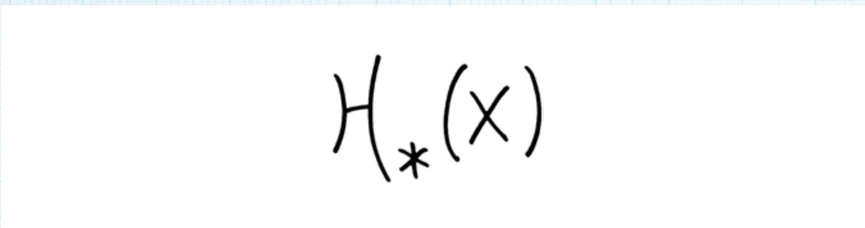
The expertise that AIMR has accumulated over these past 10 years is now flourishing significantly.

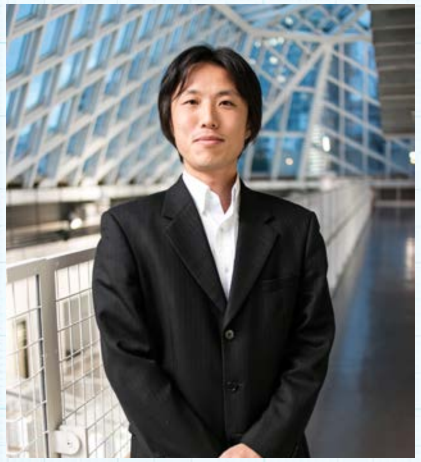
MATH AND I

Part 1

To Command This "Language" Skillfully

Yasuaki Hiraoka AIMR Principal Investigator





**Here different researchers share about their thoughts on math.
In this first part, an applied mathematician talks about his impression of math.**

What do you think math is? I'm sure there are many different viewpoints, but to me it is a "language," one uses to express phenomena and shapes. Of course I didn't feel this way right at the beginning, but now after these many years I am quite confident that this is so.

It is often said that "The book of nature is written in the language of mathematics." But as much as I think "it can describe anything" I don't think that I really understand all everything there is to know about math. It's only just in one specific area where I've been proceeding with research thinking that "math could probably describe something here." Now I am using a type of math known as topology in order to describe the various "shapes" that occur in materials science. This is because I think math is the language that best fits them.

My first involvement with applied mathematics was for telecommunications. After that when I was at Hiroshima University, I worked on characterizing the shape of proteins with math. During this time, my research theme was starting to approach materials, and was connected to the research I am now doing here at AIMR. At first I was interested in how to mathematically describe "movement," but partway through my doctoral course, the target of my interest changed to describing "shape," and I've gone in that direction since then.

What is the most important formula to me? Rather than a formula, I'm always using a symbol. The symbol of $H_*(X)$. In this $H_*(X)$, X is the shape of something. Anything can be put into X. An image would be ok, or scattered points would also be fine. Even abstract data would be alright. This is because I'll use these symbols to describe the shape.

Among mathematicians I think there are significantly more pure mathematicians that want to research something that has been concluded in the world of math. Since I am a researcher that has moved over to math from engineering, my basic stance is that there is some specific thing, and I'll think about math from that. In other words I am an applied mathematician. There are many pure mathematicians that pursue one theme over the course of many years, so it might not be a good thing in the math world for me to say that my research theme changed because of the object I was looking at (smile). But I'm that kind of mathematician.

Math training has been full of setbacks up until now. Generally mathematicians learn broadly about all the fields of math in their undergraduate years, and based on that they find the field that will become their own theme. But since my department was engineering, I don't have the experience of learning all the fields of math. Since I've only had concentrated training on the field of math that is related to my topic, there is a "gap" in my knowledge of mathematics. I'll admit that the fact that there is a gap can lead to a sense of frustration. But overseas there are many outstanding mathematicians who possess various intellectual backgrounds. So that's why the feeling of frustration diminishes when I shift my attention overseas, and I can feel reassured that I was able to gain good experience during my student days.

Now my future vision is to try and apply the tool of topology that I have to all kinds of fields in materials science. Then, I want to take the things that I have learned in that, put that feedback into math and create "new math." As for my more distant outlook? Well, I don't really have one (smiles). Would I be trying to show off too much if I said that I always want to be looking at the present? Looking at the present... I always feel that as a mathematician, I continually want to be useful to society.

[January 6, 2016. At Associate Professor Hiraoka's office in the AIMR Main Building]

AIMR Action Log

April 2015 - March 2016

Academic Agreement / Appointment	April 2015	Prof. Li-Jun Wan became the 9th President of University of Science and Technology of China.
	November 2015	AIMR signed an agreement to extend the term of the AIMR Joint Research Center (AJC) with the University of Cambridge.
	January 2016	Prof. Tomokazu Matsue was selected as the Vice President of the International Society of Electrochemistry (ISE).
Award	April 2015	Prof. Yuichi Ikuhara received the Japan Institute of Metals and Materials (JIM) Tanikawa-Harris Award.
	April 2015	Dr. Sota Sato won the Young Scientists' Prize of the Ministry of Education, Culture, Sports, Science and Technology (MEXT).
	May 2015	Dr. Yoshikazu Ito and Dr. Yasufumi Takahashi received the Chemical Society of Japan (CSJ) Presentation Award.
	May 2015	Dr. Yasufumi Takahashi obtained the Japan Society for the Promotion of Science (JSPS) Nanoprobe Technology Award.
	May 2015	Dr. Yu-Ching Lin won the Gold Prize of the Tanaka Kikinzoku Memorial Foundation's Research Grant.
	October 2015	Prof. Yuichi Ikuhara received the Robert B. Sosman Award.
	November 2015	Emeritus Prof. Yoshinori Yamamoto received the Order of the Sacred Treasure by the Government of Japan.
	December 2015	Prof. Masayoshi Esashi received the IEEE Jun-ichi Nishizawa Medal.
	January 2016	Prof. Hiroyuki Isobe received the Chemical Society of Japan (CSJ) Award for Creative Work.
	March 2016	Dr. Yoshikazu Ito won the Tokin Science and Technology Award.
Seminar & Symposium	April 2015 - January 2016	[The WPI-AIMR Joint Seminar] 1st (April 24): Prof. Takuji Takahashi (Institute of Industrial Science, The University of Tokyo) 2nd (May 22): Prof. Kazuaki Sawada (Toyohashi University of Technology) 3rd (June 19): Dr. Yoshimi Kubo (National Institute for Materials Science) 4th (July 31): Prof. Masahiro Yamashita (Graduate School of Science, Tohoku University) 5th (Oct 30): Dr. Hideki Hirayama (RIKEN Quantum Optodevice Laboratory) 6th (Nov 27): Prof. Hiroshi Yamamoto (Institute for Molecular Science) 7th (Dec 10): Prof. Masaki Takata (Institute of Multidisciplinary Research for Advanced Materials, Tohoku University) 8th (Jan 29): Prof. Takafumi Ueno (Department of Biomolecular Engineering, Tokyo Institute of Technology)
	September 30, 2015	AIMR-Sparse Modeling Project Joint Symposium
	November 10 and 20, 2015	International lecture of Spintronics
	December 8-9, 2015	In-situ TEM symposium
	February 12-14, 2016	AIMR opened an exhibit booth at the AAAS Annual Meeting (Washington D.C.)
	February 21, 2016	Structure and Dynamics of Glasses
	February 22-24, 2016	The AIMR International Symposium 2016
	March 3, 2016	Prof. Yasumasa Nishiura's Last Lecture (AIMR)
	March 4, 2016	Prof. Kazue Kurihara's Last Lecture (AIMR)
Academic News	Press release: 32 articles	

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