

M AIMR Magazine

Advanced Institute
for Materials
Research

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[Feature articles]

Small MEMS Presents a Big Future

AIMR principle investigator,
Director of μ SIC

Masayoshi Esashi

[AIMR in the world]

Science Talk Live 2013 in Sendai a retrospective in pictures

[A Friendly Discussion]

Collaboration with Industry

M. Esashi

AIMR principle investigator, Director of μ SIC

T. Gessner

AIMR principle investigator, Director of the Fraunhofer ENAS



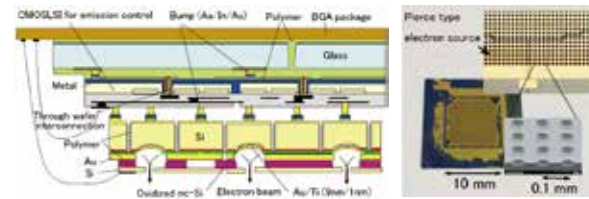


Fig. 4. Massively Parallel Direct-Write Electron-Beam System
(Top: Conce

The Japanese semiconductor industry is becoming less internationally competitive, and employment in the industry is declining. Diversification and sophistication, like hetero integration through MEMS, offers one way of evolving the Japanese semiconductor industry. Nonetheless, the configuration and manufacturing process of MEMS vary by use and creating a common configuration and manufacturing process is difficult. Each type of MEMS must be developed separately. Therefore, unless manufacturing is efficient, MEMS will not generate revenues. To increase efficiency, the barriers between different sectors, organizations, and companies must be eliminated, and the system must be open to the world.

For example, the work of LSI creation is usually outsourced to a CMOS foundry (high-volume production contract). However, as it is costly for companies to outsource individually, 16 non-competing companies, such as Toyota Motor Corporation and Ricoh Company, manufacture their respective LSIs on one shared wafer, and thereby, cut down their development costs and risks. The hetero integration device that I explained earlier was developed under this mechanism.

At Tohoku University, there is another cost-cutting initiative which is being implemented: the "Hands-on Access fabrication facility". Companies dispatch personnel to this facility, a former semiconductor plant, for carrying out prototype development. This facility is equipped with equipment donated by many companies and is available for use at a low cost. Companies can avoid capital investments by utilizing the "Hands-on Access fabrication facility" and by extension, engage in new projects at low risk. Moreover, thanks to the efforts of the stakeholders, companies are permitted to market the products they developed – something not often seen in joint-use facilities. This facility is thus utilized by small-, medium-, and large-sized enterprises, as well as venture companies that do not have their own plants, and spinout companies which received

Fig. 3. Tactile Sensor Network for Robots



A tree branch

- must hold leaves out in the sunshine for photosynthesis
- must not bend too much under its own weight, or in the wind.



The material chosen for the branch

- must be **stiff** (have high Young's modulus E)
- must have a **low density** (ρ , kg/m^3)

枝の条件 = ヤング率が高い (≒曲がりにくい) & 密度が低い (≒軽)

“Science Talk Live 2013 by WPI,” the Third Joint Symposium under the World Premier International Research Center Initiative (WPI), was held on December 14, 2013 at the Sendai International Center. The theme of the symposium was “The Power to Change the World through the Scientist’s Eyes.” Five top-flight scientists based in WPI centers gave accessible and energetic talks on their respective research activities.



The 5 Researchers Giving Talks



The World of Electrons through the Five Senses

Dr. Akari Takayama

JSPS Research Fellow, Advanced Institute for Materials Research (AIMR), Tohoku University

"Enhance your ability to detect anomalies. That will not only help you conduct research, but also in your daily lives." That was the message from Dr. Akari Takayama at the conclusion of her lecture. Dr. Takayama gave a lively and accessible talk about her highly arcane field of research, the analysis of spin states using an ultra-high-resolution spin-resolved photoemission spectrometer. Her research, from the development of the devices themselves to the analysis of the data, fully using the "five senses" strongly moved the hearts and minds of the audience, coming across in the words of one participant as "very stimulating to me, not only the substance of the experiments, but also how much Dr. Takayama appeared to enjoy her research as she talked about it."

Making Materials: Inspirations from the living world

Alan Lindsay Greer

Principal Investigator, Advanced Institute for Materials Research (AIMR), Tohoku University, Professor of Department of Materials Science & Metallurgy, University of Cambridge

Here is Professor Greer explaining how "humans strive to develop all sorts of wonderful materials, but [that] the ideas for the best materials already exist within nature," using everyday examples such as twigs, hibernating frogs and spider silk. It was a lecture that brought, material science, usually out-of-sight, closer to home, evoking responses such as, "I felt an urge to double down on my study of materials."



Quest for the New Substance 'Itamin'

Professor Kenichiro Itami

Director, Institute of Transformative Bio-Molecules (ITbM), Nagoya University

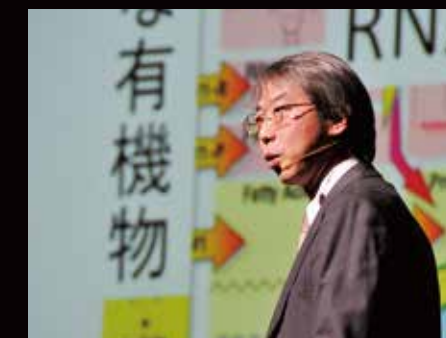
Here is Professor Itami explaining in easy-to-understand terms how he, once a boy who disliked chemistry, was drawn to synthetic chemistry and what the dream is that he continues to harbor. The following words of one high school student shows how he captured their hearts: "I thought that it was incredibly fulfilling and wonderful that you could manifest your capabilities to their fullest and moreover enjoy doing research."

The Origin of the Earth and the Birth of Life

Professor Kei Hirose

Director, Earth-Life Science Institute (ELSI), Tokyo Institute of Technology

"Today, I am here to talk about my dream." Those were Professor Hirose's opening words. His lecture gave a palpable sense of the infinite curiosity that he brings to his study of the role that the Earth played in the birth of life. He fielded an endless stream of questions from the high school students at his booth after the lectures.



Tackling the Mystery of Sleep and Wakefulness

Professor Masashi Yanagisawa

Director, International Institute for Integrative Sleep Medicine, University of Tsukuba

Little to nothing is known about sleep, a phenomenon that we all experience every day. Here, Professor Yanagisawa is explaining in accessible terms how he has uncovered parts of the mechanism of this mysterious phenomenon called sleep, by conducting an enormous number of experiments. Many people in the audience appeared to have come away "suddenly gaining interest upon listening to the lecture, although sleep had been so familiar to me that I hadn't given any mind to it."

Sendai Daiichi High School
KMnO₄-Na₂C₂O₄ Redox Titration
-The effect of Mn²⁺ as a catalyst-

Presentations in English by High School Students

During the second half of the event, representatives from the Miyagiken Sendai Daisan High School, Miyagiken Sendai Daiichi High School, Miyagi Prefectural Furukawa Reimei High School, and Eleanor Roosevelt High School presented the results of their respective research in English.



Sendai Daisan High School
A Method to Change the Color of Metals by Oxidation



Eleanor Roosevelt High School, Maryland, United States of America
Adaptive Control Using a Neural Net (by Michael Stevens)
Cooling of Linear Induction Launcher (by Matthew Early)
Fast Single-Point Imaging Electron Paramagnetic Resonance Imaging to study fluctuating Tumor Physiology; k-space and Trajectory Design (by Vishnu Rachakonda)

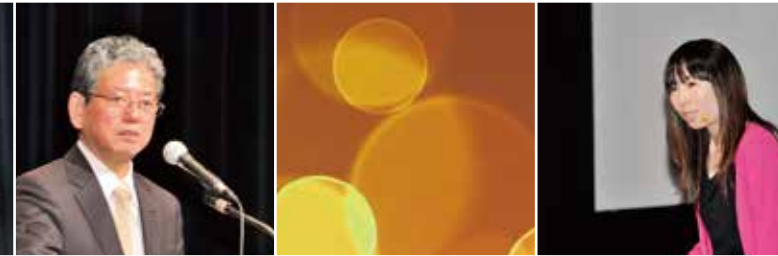


Furukawa Reimei High School
Verification of Breed Difference through Anther Culture



Booth Sessions

All nine WPI centers came together in an adjacent hall to open booths, where they offered exhibits on their world-class research environment and cutting edge research results. The booth sessions were swarmed with the large number of participants eager to see the exhibits by all nine WPI centers. The speakers went to the booth after their lectures and responded directly to questions from students.



Despite the snow piling up since the previous day, approximately 600 people, mostly high school students, heard scientists talk about their never-ending efforts to meet the challenge of the mysteries hidden on planet Earth and in the human body and materials, so close yet so obscure to all of us with their insatiable curiosity and their ability to look beyond conventional wisdom.

To watch the lectures at the symposium, please see the following page.
<http://www.wpi-aimr.tohoku.ac.jp/jp/wpi2013/>

EVENT REPORT

The AIMR International Symposium 2014

The AIMR International Symposium 2014 (AMIS2014) was held from February 17 through 19 at the Sendai International Center. The symposium opened with words of welcome from Professor Susumu Satomi, President of Tohoku University. Including Professor James Langer, University of California, Santa Barbara, and others, 32 experts gave keynote speeches and made presentations. Approximately 240 participants from 13 countries including the United States, China, and the United Kingdom took part in active discussions after each presentation.

At this year's workshop entitled "Toward Emergence of New Materials Science with Mathematics Collaboration," a large number of mathematicians also participated in a lively debate on the fusion between mathematics and materials science that AIMR is promoting.



WPI Booth and Workshop Exhibits at AAAS Annual Meeting

AIMR collaborated with the other institutions in the World Premier International Research Center Initiative (WPI) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to jointly open a WPI booth at the 2014 annual meeting of the American Association for the Advancement of Science (AAAS), held over five days from February 13 through 17, and held a workshop there. The WPI booth, located in the Japanese Pavilion hosted by the Japan Science and Technology Agency (JST), was open from the 14th through 16th at the Exhibit Hall in the Hyatt Regency Chicago. Many people visited our booth during this period and were seen listening closely to our staff explaining the research underway, as well as the terms and conditions and research environment for researchers. At the workshop "Build a Career in Japan!" held jointly with RIKEN, an outline of the WPI program and information on the supportive framework for foreign researchers living in Japan and other related matters were provided. Dr. Ali Khademhosseini, Junior Principal Investigator at AIMR, was elected AAAS Fellow and was honored as such at the AAAS Fellows Forum on February 15.



A short detour

M A T E R I A L S

This corner contains essays that cover topics relating to materials science research at AIMR, including fundamental facts, history, research trends around the world, and advanced research at AIMR.

Part 4

Electronic Devices and Materials

Today, the term 'electronic devices' has permeated throughout our daily lives and we use it extremely frequently within our conversations. Electronic devices is mainly used to indicate individual electronic parts such as transistors and light emitting diodes that are used in mobile phones and computers, but at times it is used to describe an electronic device that includes electronic equipment like a computer.

Electronic devices are used to store vast quantities of information, to calculate at high speeds using programs, and to convert information into radio waves that can be transmitted instantaneously. Electronic devices benefit us in many areas: for example, today, information that has been recorded in a book in the past can be stored compactly, such as on a hard disk or flash memory; the accuracy of weather forecasts has increased thanks to calculations by super computers; messages that would formerly be sent as letters are exchanged instantaneously and across the world by email; and wireless mobile phones have become the mainstream device for making telephone calls. If we imagine high school students who must decide on a university department and course in order to follow their dream of researching and developing these sorts of devices that support modern-day society, which should they choose? Without question, courses provided by departments of engineering, such as in electric and electronic engineering or telecommunication engineering, provide the foundation for education and research in this field. But because this article is about materials science, of course here I want to write about the direct connection between materials science and electronic devices.

For example, integrated circuits known as IC and LSI are a typical electronic device, but not only are various types of electric wiring coiled within them (aluminum wiring, copper wiring, and so on), if we looked at them under a microscope, we would also see the minute and intricate structure that has been built on top of their circuit board. Many of today's devices use a silicon monocrystal known as a silicon wafer that is sliced into boards of a thickness of between 0.5mm and 1mm. As this silicon wafer is a semiconductor, an electric current can flow through it. Through the technology known as lithography for constructing miniature structures, on the

surface of this wafer thousands and even tens of thousands of these transistor structures are constructed with a p-type region (that has many positive charges), an n-type region (that has many negative charges), and an insulator region (an oxide film of silicon). As they are made of silicon, which is a semiconductor material, materials science plays a role in their creation. For example, the electroconductivity of silicon and the differences between p-type and n-type are created through the effects of impurities known as dopants that are "doped" in a crystal, and this task is an important issue in materials science. Through the contributions of materials scientists, today we actually use various semiconductors with characteristics different than silicon as the materials for electronic devices, and the research is underway for their further use in the future.

At this point, I would like to talk about AIMR. Of course, within AIMR there are many researchers who are researching semiconductors and electronic devices. The relationship between semiconductors (materials) and electronic devices is impossible to sever. Moreover, within AIMR is the Micro Electro Mechanical Systems (MEMS) research group. MEMS are similar to the integrated circuits described above, but they differ in that the mechanical component parts, sensors, actuators, and electric circuits are made at the same time on top of the silicon substrate. Integrated circuits are devices for controlling and using the flow of electricity, but they never move. In contrast, MEMS offer higher value added as they are built to be a miniature machine that moves together with the electric circuit. For further details, please read the article by professors Esashi and Gessner in this edition. If you are interested in electronic devices, I think it is fascinating to take a look at them from the perspective of materials science.



Susumu Ikeda

Born in Saitama in 1967, Ikeda graduated from Tohoku University's Faculty of Science in 1990. After working at a cement company, he received his Ph.D. degree from the Graduate School of Science, the University of Tokyo. He became an Assistant Professor at the Graduate School of Frontier Sciences at the same university, and then moved on to become an Assistant Professor at AIMR. In 2010, he was appointed Associate Professor, and in 2011, took on a second position as the Deputy Administrative Director (for Research).

Ramin Banan Sadeghian

Ramin says he started out as an electrical engineer specializing in very large-scale integrated circuits, electron devices, and microsensors. "After gaining experience in designing chemical microsensors, I got into biosensing and gained a particular interest in developing nanoscale probes used in analyzing biotissues," says Ramin about biosensing.

"Biosensing has become a technology applied in a wide variety of fields, including medicine and pharmaceuticals. AIMR is the ideal environment for conducting such research. There are so many great researchers involved in material analysis and nanofabrication, and the facilities and equipment are top-notch. I hope to make the most of everything available and work together with these researchers in numerous areas of research."

Although it has only been some three months since he joined, he seems to already be fitting into the AIMR environment. "The environment is so professional at AIMR, with everybody very quick at responding. Junior researchers can feel free to discuss their own research topics with senior researchers and administrative staff provide an unprecedented level of support. I am absolutely enjoying interacting with everyone," says Ramin.

When asked about his hobbies, he replies with "radio-controlled toys." As if aware of the predictability of such a response coming from an electrical engineer, he then added, "I've also started learning Japanese." Then he really surprises: "By the way, after I learn to speak Japanese, I will be able to speak six languages."

Ramin Banan Sadeghian AIMR Research Associate

Ramin Banan Sadeghian, 38, was born in Iran in 1975. After receiving his PhD from Concordia University in Canada, he became a postdoctoral research scientist at the University of California, Davis/Santa Cruz. He later became an senior research engineer at the H2scan Corporation, and has been at his current post since November 2013.

text & photographs
by Yasufumi Nakamichi

