AIMR Magazine
Advanced Institute for Materials Research

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World Premier International Research Center Initiative

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Advanced Institute for Materials Research

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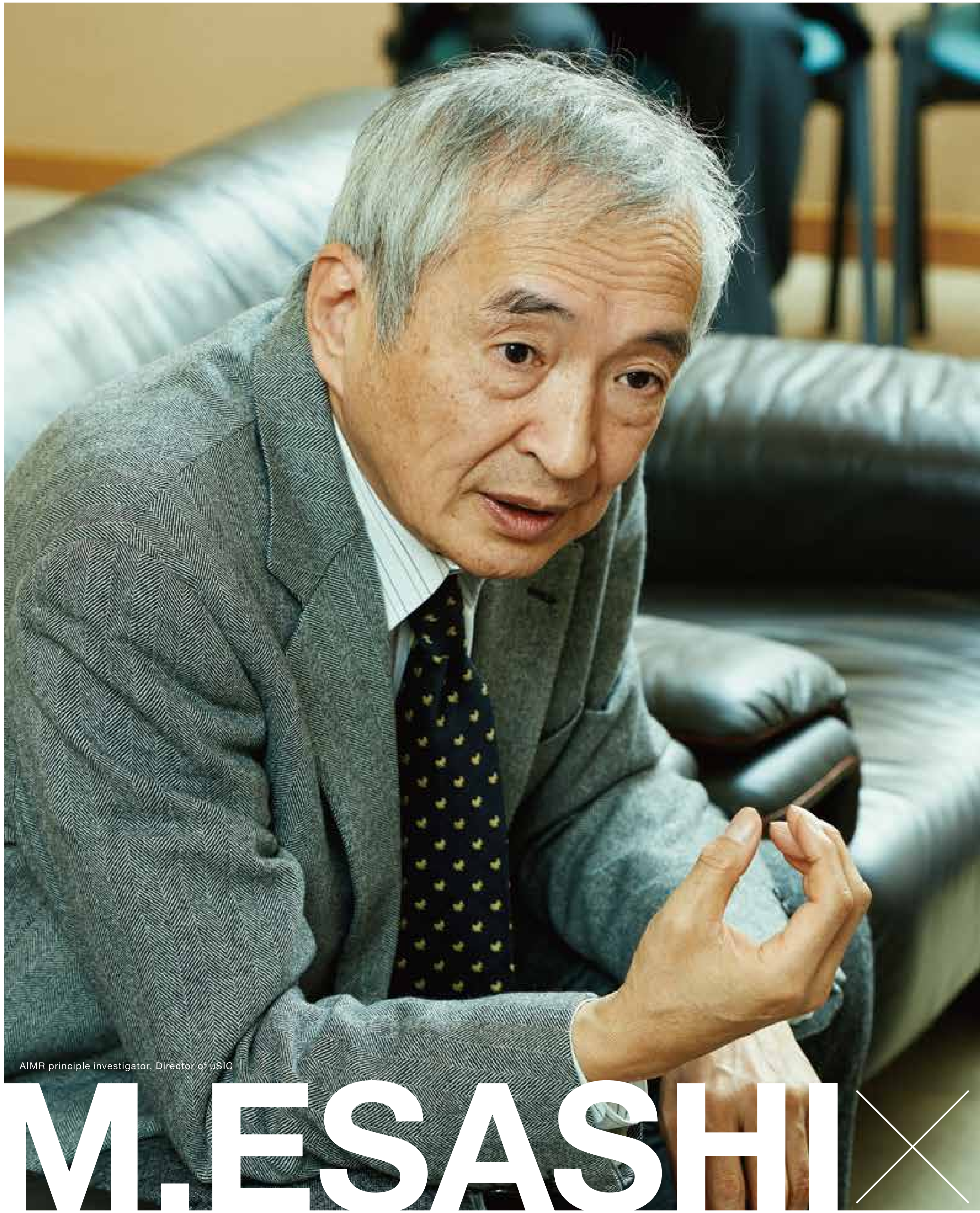
AIMR principle investigator, Director of μSIC

T.Gessner
AIMR principle investigator, Director of the Fraunhofer ENAS

Collaboration with Industry

AIMR pushes the boundaries of innovative research through its interdisciplinary approach and broad collaboration to understand and respond to the needs of industry. We spoke to the leaders of the Device/Systems Group to understand what the future holds in store in the field of MEMS (micro electro mechanical systems) and the importance of collaboration for their work.

text by Larry Greenberg, Yasufumi Nakamichi / photographs by Ken Mochizuki



AIMR principle investigator, Director of μSIC

AIMR principle investigator, Director of the Fraunhofer ENAS

M.ESASHI × T.GESSNER

Pursuing World-Leading Research

"In Japan, there are often divisions between organizations and fields of research, referred to as tatewari," pointed out Professor Esashi. "However, for research in the MEMS field, a fusion of technology is required not only between research fields, but also between companies, universities and government organizations." It was with this in mind, that back in 2006 he visited the headquarters of Fraunhofer with the mayor of Sendai and the mayor agreed a contract for collaboration, in order to learn from Germany about their very well organized and efficient collaboration systems. This agreement was the beginning of a very fruitful relationship that eventually led to the founding of a Fraunhofer Project Center for NEMS/MEMS Devices and Manufacturing Technologies at Tohoku University, the first Fraunhofer Project Center in Japan, enabling worldwide cooperation on projects to be undertaken, and expediting the commercialization of research by industry.

Professor Gessner added that for him the attraction of a collaboration with Tohoku University was Professor Esashi's standing as one of the most famous scientists in the field of MEMS, not only in Japan but worldwide, as well as the excellent level of materials science. "One priority for our collaboration is to use mathematical models for simulation and to better explain the properties of some materials. There are a lot of different programs in the institutes including finite element methods, and combining mathematics, material science, and devices," explained Professor Gessner. "AIMR is an excellent center for such activities and research."

The AIMR Device/Systems Group, led by Professor Esashi, is partnered with Chemnitz University of Technology in Germany, through the affiliation of Professor Gessner, who is a principle investigator in the group, as well as Director of the Center for Microtechnologies of Technische Universität Chemnitz, and Director of the Fraunhofer Institute for Electronic Nano Systems (ENAS).

Professor Gessner explained that the collaboration between the two organizations also takes the form of exchanges of researchers with Fraunhofer in Germany. "We only began this activity this year, but the number of applicants far exceeded the places available, and there are plans to expand the program in the future." This collaboration, he noted, was enabled by the establishment of AIMR under the World Premier International Research Center Initiative (WPI). As the WPI initiative aims to create research centers with world-leading research standards, the WPI centers operate entirely in English. In addition to attracting top class researchers from around the world, the Japanese researchers further develop their experience in an international setting, encouraging a greater number of them to participate in research at overseas institutions.

Industry Collaboration

Professor Esashi explained that the overarching mission of the Device/Systems Group in the WPI center is to provide a bridge between industry and university, focusing on mathematics based material science, including metallic glass. "Using mathematics, new materials can be forecast and simulated, and then maybe in the future those technologies can be applied in the Device/Systems Group to specific applications," he noted. "Collaboration is not only good for the industry but also the university, because it allows the university to understand the needs of the industry to focus on research that has real world application. At the same time, for the industry partners, their employees are trained in the university and can also undertake development for their new products, so it really is advantageous for both sides. That is a true collaborative relationship."

"The Fraunhofer Society regularly holds workshops with industry," explained Professor Gessner, "including the annual Fraunhofer Symposium in Sendai. The workshops then often lead to discussions and contracts for research, which creates a tremendous stimulus for our research activities at the same time as giving our industry partners a valuable extension to their research and development capacity."

"Through the collaboration with industry, we have industry people spending time in the laboratory, which is good for the students," noted Professor Esashi. "Otherwise students cannot truly grasp the needs of society. The dispatched researchers from industry also bring their requirements with them and share them with the student researchers and take back what they learn to share with their colleagues."

"The process of inventing or starting something new does not just suddenly come to you like a flash of inspiration in one instant," explained Professor Gessner. "The ideas are developed over a long period, with many scientists working untiringly to look for new devices and new applications. At Fraunhofer, we work together with industry customers, or they come to us and ask for a new device, material, or perhaps to reduce the costs by using a novel design. On one side, we have input from industry regarding new applications and devices, which we try to create. On the other side, within the university we have a lot of Ph.D. students working on topics we are interested in. We discuss areas of interest as a team, and then define new Ph.D. theses. Perhaps the application of metallic glass for loudspeakers could be a Ph.D. Then we try to apply the technology together with companies. This cultivates the creativity required to come up with ideas for new devices and applications, benefitting industry by creating the kind of human resources that they are looking to hire."

"Our collaborative efforts are not limited to innovation, but also addressing problems such as development costs and standardization," explained Professor Esashi. "The size of the market for a device can suddenly expand through a combination of reduced costs, reduced size, agreement on standards, and the development of complementary technologies. An example would be microphones, where cloud-based speech recognition technologies have created a large new market for small, cheap microphones that can be embedded into Internet-connected devices, such as smartphones and televisions. So by collaborating with industry to tackle aspects such as size and cost through creative approaches, we can help them to develop new markets."

Micro Electro Mechanical Systems (MEMS)

The field of MEMS that brought the two professors together is expected to play a crucial role in advancing the capabilities of the electronic systems of the future. "Integrated circuits function like a brain," explained Professor Esashi, "processing information signals. But systems also require inputs and outputs. For example the accelerometer plays a very important role in a smartphone. MEMS technology allows sensing and output actuation to be incorporated in silicon allowing for more versatile circuits."

"After a 60 year history of microelectronics, there is now a shift toward smart systems, of which MEMS technology is a key part," Professor Gessner added.

MEMS technology is essentially the application of silicon technology to create tiny moving devices. This technology is expected to make an increasingly important contribution toward the development of smart systems that will redefine our standards of living in the future. Professor Gessner explained "It is important to forecast the future demand for MEMS through research, and to develop so-called smart systems by combining batteries, sensors, actuators, microelectronics, and wireless communications on a single chip through system packaging. For this, we had the idea to apply metallic glass to wafer bonding, allowing the temperatures to be reduced a little bit for the wafer bonding process. Then by learning about the composition and the properties of metallic glass, we came up with the idea of trying it for large membranes for loudspeakers. Every stage of research leads to new findings and ideas for further research. And as we plan our research, we have to consider the needs for new materials and new devices in cooperation with the industry."

Professor Gessner pointed out that in the semiconductor field there is a roadmap created in discussion between industry and academia, with the large players working together to define the way forward. However, in the MEMS field such a roadmap doesn't currently exist due to fragmentation in technologies and applications. He added that there are different generations of development in the MEMS field, starting in the 1990s with the first acceleration sensors for airbags in the automotive industry. This was followed by the pacemaker, and other smart systems. "Now there are increasing medical applications and automotive applications. However, the most important driver for development was the smartphone, which contains a variety of sensors such as acceleration sensors and gyroscopes," he explained.

Professor Esashi added that part of the fragmentation comes from the difference between very high volume applications, such as microphones for smartphones, and very low volume but high value-added applications. "For example, we developed a MEMS switch, produced by a factory in Sendai, Advantest Component, used for LSI testers. The volume was quite low, but it greatly increased the reliability of LSI tests, resulting in Intel testing their microprocessors using this tester."

Regarding the research into wafer bonding and packaging technologies, Professor Esashi explained, "Metallic glass has been studied in Tohoku University for a long time, and there is a metallic glass group in AIMR. We are very interested in the application of metallic glass technology to MEMS, so we started to use metallic glass for bonding and for other mechanical devices – for springs, for mirrors, and so on. Prof. Mingwei Chen's group is developing nanoporous metals for electrical interconnections, and we developed

ceramic wafers with electric interconnections in it in collaboration with Nikko, a ceramic company located in Kanazawa. For the electrical interconnection we applied nanoporous gold, which acts like a sponge. When bonded, it collapses and makes electrical contact. We use the outcomes of other laboratories in AIMR also, such as a piezoelectric material called PZT, which is very important for actuation."

"In order to succeed," Professor Gessner noted, "we must improve the deposition of the metallic glass. We will be ordering new equipment for metallic glass in Chemnitz, and then we would like to have more ideas to improve the deposition. Also we must reduce the stress and combine all the technologies in one complete package. It is not so easy." Professor Esashi agreed, adding that "Only by bringing together the unique skills, insights, and experience of all sides can the appropriate solutions be found in an efficient manner. Collaboration with industry in steering our interdisciplinary research is therefore absolutely essential."

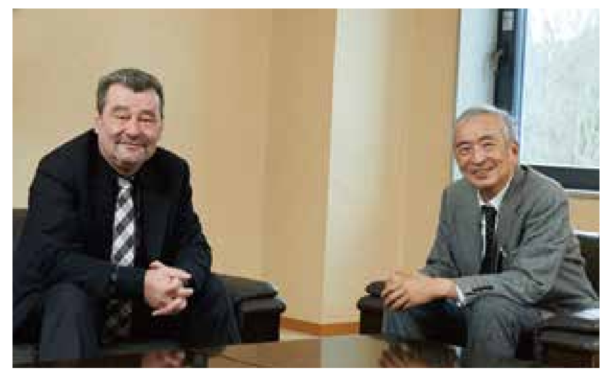
Future Applications of MEMS Technology

One dream application Professor Gessner is working on is the idea previously mentioned of a MEMS-based loudspeaker chip, which would have applications in smartphones and other portable devices, but could also find many other applications by being small enough and cheap enough to be embedded into a multitude of everyday objects. Asked what the minimum size for such a loudspeaker chip might be, he explained, "It is difficult to give an answer at this stage. In contrast to a microphone, a loudspeaker requires a certain area for acoustics, to create audio waves by moving the air, rather than simply sensing the movements of the air as a microphone does. The limits of engineering such a MEMS loudspeaker chip are only currently being investigated." He is confident however that it will be on a much smaller scale than the loudspeakers currently in existence.

"Following the Great East Japan Earthquake three years ago," Professor Esashi added, "attention was drawn to the importance of smartphones to access critical information in an emergency, and the problems caused by phones and smartphones being unusable. We are now applying our expertise to develop new technologies for reliable communications in collaboration with many companies in order to improve the resilience of society to major disasters."

"The everyday consumer applications are of course also all of the iPhones and smartphones," confirmed Professor Gessner. "All of these communication techniques. Then there is automotive. A modern car has over 50 microprocessors with lot of MEMS components such as gyroscopes, acceleration sensors, control systems, and traction control. In the future, there will be more smart electronics systems used in manufacturing to get higher productivity, reduce costs, and reduce energy consumption, making for more efficient production overall. We have a lot of work to do now in the MEMS field. The MEMS industry is large and there are many new companies wanting to apply MEMS to new applications. Perhaps high precision MEMS devices for use in space, which are not yet available on the market. Medicine is another big area of application – our society is aging, in Japan as in Germany. We will need devices in the future to assist the elderly, which will rely on MEMS. It will have an influence on all of our lives."

Professor Esashi explained how lucky he considers himself to be able to pursue his dream, having loved engineering since he was young. This love of engineering led to academic success and also interest from industry. However, he noted that the future of firms in the MEMS industry in Japan would likely be shaped by mergers and acquisitions with overseas companies in order to ensure their survival. Despite these developments, he hoped that industry would continue to be able to collaborate with universities in Japan, and that some of the barriers between universities and companies could be broken down through the tremendous opportunities created by the research activities at AIMR.



Thomas Gessner

Born 1954 in Karl-Marx-Stadt. Studied physics, received the degree in physics in 1979, the PhD degree in 1983 (both from the Technische Universität Dresden) and the Dr.-Ing. habil. degree from the Technische Universität Chemnitz in 1989. He had several positions in the industry. Since 1991 he is the Director of the Center for Microtechnologies and since 1993 Professor for Microtechnology, both at the Technische Universität Chemnitz. Moreover Prof. Gessner is the director of the Fraunhofer Institute for Electronic Nano Systems ENAS since 2008.

Masayoshi Esashi

Born in Sendai in 1949. Received his PhD in electronic engineering from Tohoku University's Graduate School of Engineering. Doctor of Engineering. After serving as Research Assistant, Associate Professor, and Professor with the School of Engineering of Tohoku University, has been in his current position of Professor at AIMR since 2007. Concurrently serves as Director of Micro System Integration Center (μSIC), Tohoku University.

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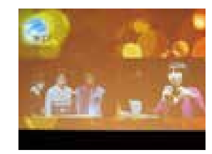

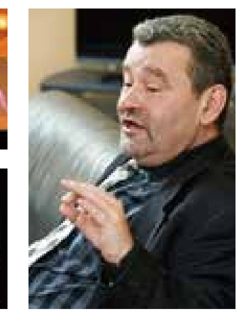

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Small MEMS Presents a Big Future

MEMS supports the advancement of motor vehicles and smartphones and are transforming our lives and social systems greatly. Here, I explain in detail about MEMS, considered the trump card in industry vitalization.

AIMR principle investigator, Director of μSIC

text by **Masayoshi Esashi**

About MEMS

If you tilt a smartphone, its screen will rotate automatically the way it was moved. This now ubiquitous function is made possible by a combination of a sensor that detects orientation and a circuit that processes information from the sensor. Technology that miniaturizes these sensors and circuits while increasing their performance has spurred rapid advancements in electronic devices, including mobile phones. Especially in recent years, the integration of sensors that have multiple functions, as well as technologies that integrate sensors and circuits, are enabling the further miniaturization of devices that have even more complex functions. This integration technology is MEMS.

MEMS stands for Micro Electro Mechanical Systems. It refers to a system that integrates sensors manufactured separately, or sensors and circuits, on a common elemental device. MEMS plays a critical role in a wide range of fields, ranging from information devices to motor vehicles, manufacturing and inspection, and medicine. The market for MEMS is increasing by 13% annually. Familiar examples include the accelerometer for inputting movement into the user interface of a smartphone as was already described, the gyro sensor used in a digital camera to prevent an image blur resulting from hand vibration, and Digital Micromirror Device (DMD) that is comprised of about one million mobile mirrors on a LSI used in video projectors.

MEMS, which already has many uses in our daily lives, has evolved by applying the manufacturing technique of the semiconductor integrated circuit (LSI) that has been developed so far. LSI is a circuit in which a vast number of circuit elements, numbering well above one billion, are integrated on a chip with an area of a mere several square millimeters, and is capable of performing sophisticated information processing. LSIs are made by integrally transferring the so-called photomask patterns that form the shape of a circuit design image en bloc optically. Multiple LSIs are manufactured simultaneously in the form of a chip with an area of several square millimeters on a 30-cm diameter silicon wafer. This process enables the mass production of LSIs, and they can thus be produced at relatively low cost. MEMs apply these LSI manufacturing techniques to realize the development of microscopic and sophisticated sensors, as well as the integration of LSIs and sensors.

Recent Research Achievements

At our laboratory, our research of the MEMS manufacturing technique focuses on “hetero integration” as shown in Figure 1. Hetero integration fuses different (hetero) elements, such as MEMS and integrated circuit. Temperature and other constraints previously created difficulties in manufacturing MEMS on LSI. In order to realize the “hetero integration” of MEMS and LSI, we developed a methodology of integrally transferring MEMS with different functions that was formed on a MEMS wafer, onto an LSI wafer by resin bonding or another method, and lastly dividing them into chips, as shown in Figure 1. Using this methodology, many diverse subsystems with sophisticated mechanisms may be created at one time without destroying the LSI. We have continued to research MEMS by using this self-made experimental manufacturing process since 1971. To date, roughly 130 companies have dispatched researchers to our laboratory and developed practical applications. Examples include the pH/CO2 sensor of a catheter tip commercialized in 1980 (Kuraray Co., Ltd. and Nihon Kohden Corporation), the integrated pressure sensor that is sealed at the wafer level (Toyoda Machine Works Ltd.), the microphone used for TV (Japan Broadcasting Corporation and Panasonic Corporation), the optical scanner used on Japan Railway (JR) station platform doors and other devices (Nippon Signal Co., Ltd.), the electrostatically levitated rotating gyro used on subways (Tokyo Keiki Inc.), the gyro and accelerometer necessary for the safety devices of motor vehicles (Toyota Motor Corporation), and the MEMS switch used for LSI testers (Advantest Corporation). I would like to explain in some detail the following three applications which we are researching with a view to commercialization.

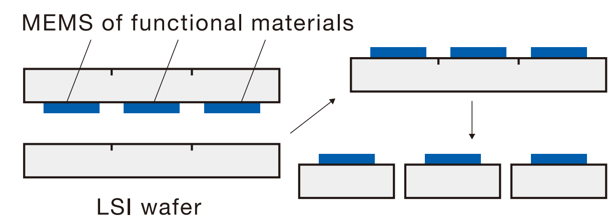


Fig. 1. Hetero Integration by Wafer Level Transcription

(1) Hetero integration device for wireless communication

The traffic of wireless communication, including smartphones, is nearly doubling every year, creating the risk of a depletion of the usable frequency band. Thus, National Institute of Information and Communications Technology (NICT), Chiba University, Murata Manufacturing Co., Ltd., Denso Corporation, among other organizations, are jointly developing a cognitive wireless technology which makes effective use of unused frequencies. This technology can solve such problems as communication disruptions caused by radio wave congestion in times of disasters. Figure 2 shows the hetero integration by transcription of multiple surface acoustic wave (SAW) filters on an LSI chip and piezoelectric MEMS switches made of lead zirconate titanate (PZT). Previously, filters and switches were assembled next to LSI on a substrate. Their formation on an LSI chip by transcription allow for further miniaturization and higher performance.

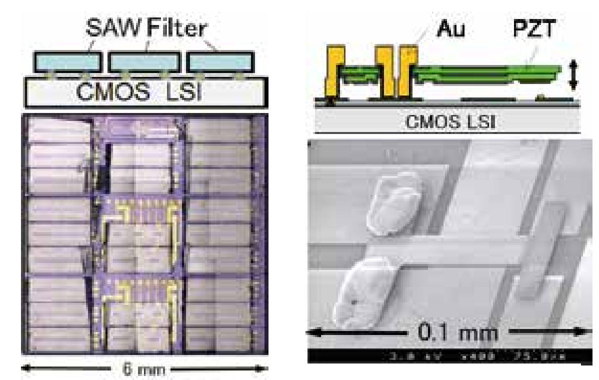


Fig. 2. Hetero Integration Device for Wireless Communication by Transcription
(Left: Multi-filter on LSI; Right: Piezoelectric switch on LSI)

(2) Tactile sensor network for robots

As the era of super aging society approaches, the development of nursing care robots that care for patients are becoming imperative to mitigate the burden on the medical system. Toyota Motor Corporation and Toyota Central R&D Labs., Inc. are conducting joint research on using the MEMS technique to distribute numerous tactile sensors onto the body surface, similar to humans, in order to ensure safety even in cases of collisions between nursing care robots and humans. Numerous tactile sensors which are hetero integrated through resin bonding are connected to a common channel formed on a thin film as illustrated in Figure 3. Sensors that sense force transmit the sensor ID and force information using the LSI's mechanisms to the computer and tell it to stop. Hence, the robot is able to feel the force without delay.

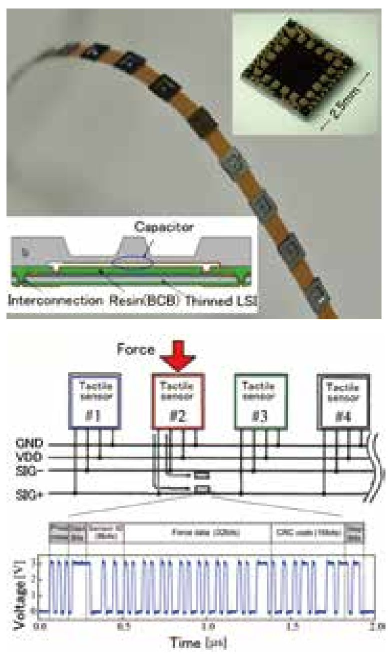


Fig. 3. Tactile Sensor Network for Robots

(3) Massively parallel direct-write electron-beam system

While the device for wireless communication in Figure 1 is mass produced, there are also hetero integration devices of which the production volume is small but nevertheless have high added value. Figure 4 shows the massively parallel direct-write electron-beam system that is currently being developed. By writing LSI patterns at high speed using multiple electron beams, LSI can be manufactured without photomasks that can cost as much as several hundred million yen per set. As a result, this system is not only profitable even by adopting a high-mix low-volume manufacturing method; it can be developed in a short period of time. We are developing an active matrix electron source in which a Si nanocrystal (nc-Si) electron source array (100×100) is formed on a LSI with Crestec Inc. and Tokyo University of Agriculture and Technology. This application also uses the hetero integration technique by resin bonding and harnesses the sophisticated functions of LSI, including electronic aberration correction.

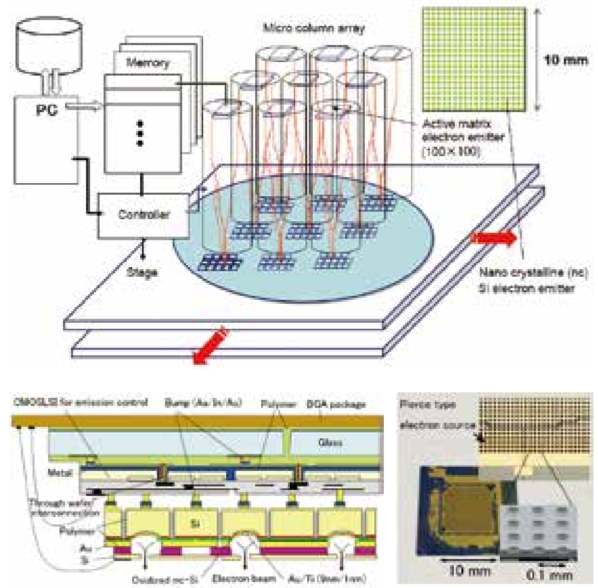


Fig. 4. Massively Parallel Direct-Write Electron-Beam System
(Top: Concept; Bottom: Active matrix electron source)

For the Vitalization of Industry

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 secondhand equipment from projects that other companies suspended.

In addition, there have been an increasing number of initiatives that cut across organizational barriers aimed at raising efficiency. For example, a company called "MEMS CORE Co., Ltd." was established in Sendai in 2003, which develops MEMS and produce small quantities of MEMS under contract using secondhand facilities and plants. Another company in Sendai called "Advantest Component, Inc." that produces MEMS switches for LSI testers, among other products, carries out MEMS foundry (high-volume production contract). To support these activities, "MEMS Park Consortium" was established with a focus on Sendai. Various efforts are also under way to provide information, including the "Sendai MEMS Show Room," which exhibits MEMS products and other items, and a three-day "MEMS Intensive Seminar," which is held every year at a different location. These activities surrounding "MEMS" have been highly commended. Dr. Kentaro Totsu (Associate Professor, Tohoku University), a key figure in the operations of "Hands-on Access fabrication facility" and President Koji Homma of MEMS CORE Co., Ltd. co-received the FY2013 Minister of Economy, Trade and Industry Award (Persons of Merit in Industry-Academia-Government Collaboration Award).

As for international efforts, Fraunhofer-Gesellschaft in Germany and the City of Sendai signed an exchange agreement in 2005, and since then, they have held the Fraunhofer Symposium in Sendai every year. At Tohoku University's AIMR, we are carrying out research in close collaboration with Fraunhofer-Gesellschaft. Prof. Thomas Gessner, Director of Fraunhofer ENAS (Institute for Electronic Nano Systems), is a Principal Investigator of AIMR. Researchers have not only been dispatched, but Fraunhofer Project Center was also launched within AIMR in 2012. Further still, Tohoku University has become the strategic partner school in Asia of IMEC (Interuniversity Microelectronics Centre) in Belgium (Stanford University is the partner school in the United States and École Polytechnique Fédérale de Lausanne in Switzerland is the partner school in Europe). Accordingly, Tohoku University conducts MEMS research and development under an arrangement which is open to the world.

In this way, we are committed to carrying out further research on MEMS in order to meet the needs of society jointly with industries, while maintaining a high technological level by collecting the latest information through activities that are open to the world and through eliminating the barriers between different sectors and organizations.

NEWS & INFORMATION

AIMR Director Motoko Kotani Appointed as a Member of Council for Science and Technology Policy

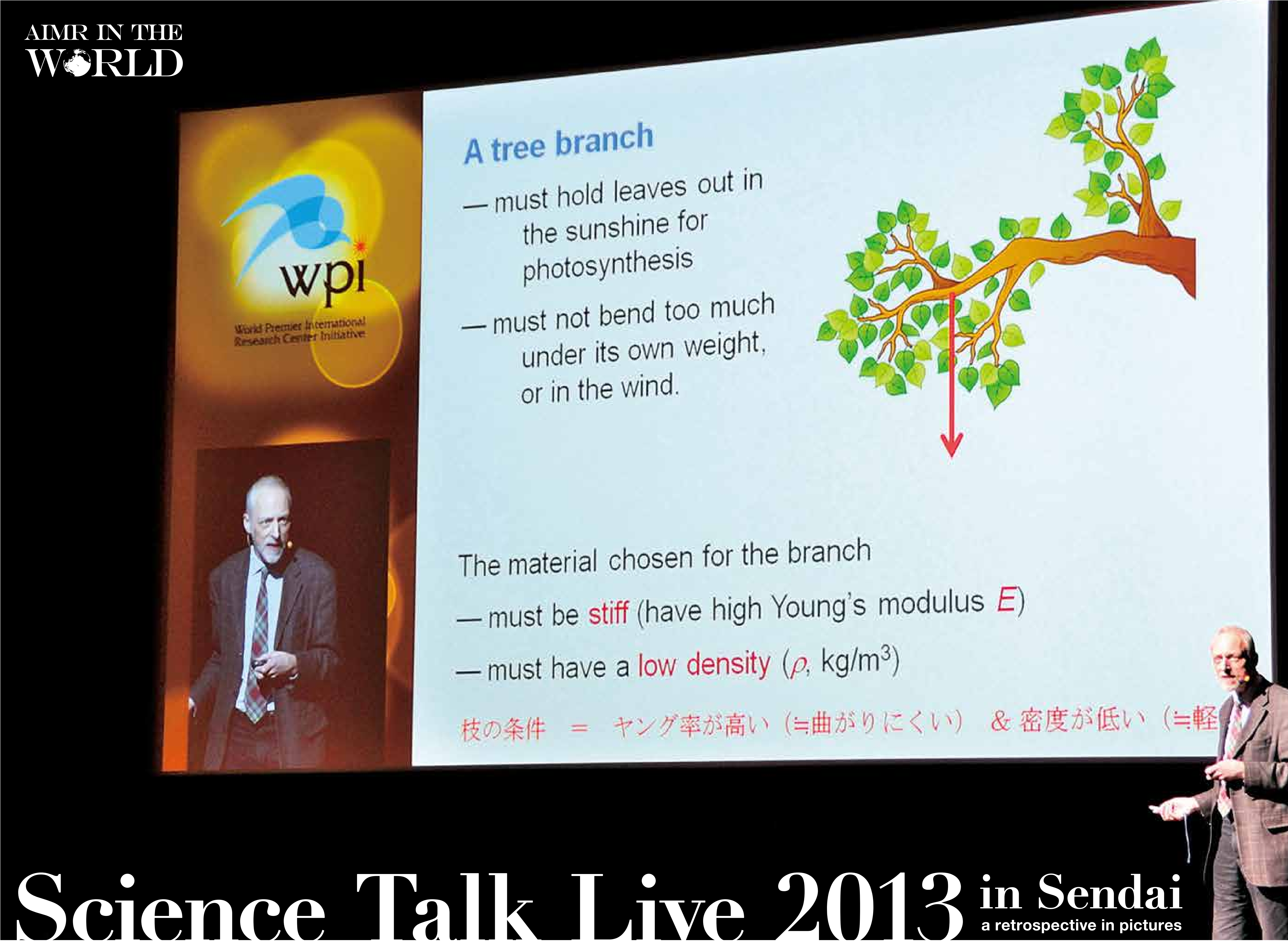
Motoko Kotani, Director of AIMR, was appointed as a member of the Council for Science and Technology Policy (CSTP) of the Cabinet Office on March 6. CSTP is one of the "councils concerning important policies" established in the Cabinet Office as a "font of wisdom" in support of the prime minister and the cabinet for the purpose of planning and overall coordination of comprehensive and fundamental science and technology policies from a perspective superior to those of the ministries, by looking at the entirety of Japan's science and technology from a commanding perspective. The prime minister chairs the council, which consists of 14 cabinet members and experts. Dr. Kotani was appointed as an expert member.

Professor Takashi Takahashi Receives Honda Frontier Award

Professor Takashi Takahashi, Principle Investigator at AIMR, received the 11th Honda Frontier Award.
The Honda Frontier Award is given to Japanese researchers who have produced outstanding research results or inventions through research in science and engineering, particularly in metals and related materials. Professor Takahashi received the award in recognition of his "elucidation of the electronic structures of strongly correlated electron systems and nano materials and the manifestation mechanisms of their physical properties using photoemission spectroscopy" paper. The award ceremony will be held in Tokyo on May 29, 2014.

Professor Kosmas Prassides Receives Royal Society Wolfson Research Merit Award

Professor Kosmas Prassides, Principle Investigator at AIMR, received the Royal Society Wolfson Research Merit Award.
The award is given to British scientists who have produced outstanding achievements. Professor Prassides is renowned as an expert on molecular superconductivity and condensed matter physics and chemistry. This award is in recognition of his research on the "New Chemistry of Functional Molecular Materials."



Science Talk Live 2013 in Sendai

a retrospective in pictures

"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.

text by Yasufumi Nakamichi

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

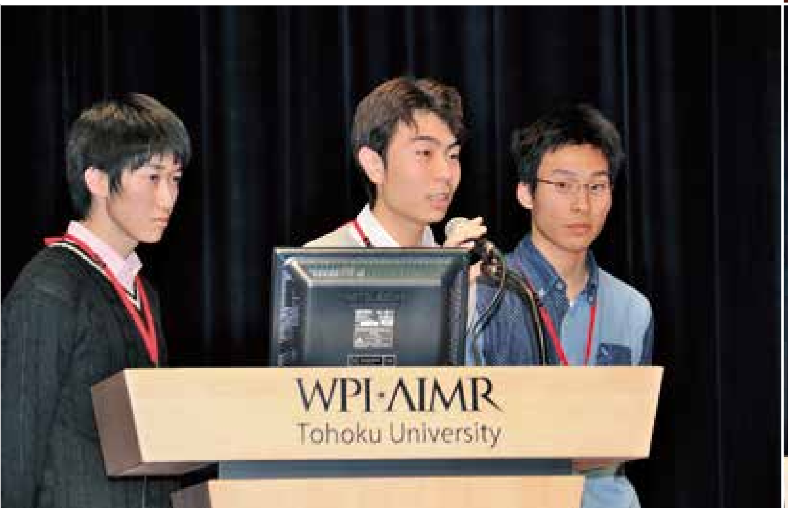
Little to nothing is known about sleep, a phenomenon that we all experience every day. Here, Professor Yanagisawa is explaining in accessible terms how he has uncovered parts of the mechanism of this mysterious phenomenon called sleep, by conducting an enormous number of experiments. Many people in the 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."

AIMR IN THE WORLD

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

Presentations in English by High School Students

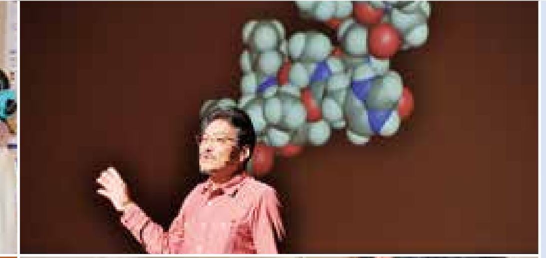
During the second half of the event, representatives from the Miyagiken Sendai Daisan High School, Miyagiken Sendai Daiichi High School, Miyagi Prefectural Furukawa Reimei High School, and Eleanor Roosevelt High School presented the results of their respective research in English.



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

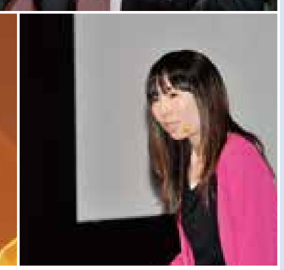
Eleanor Roosevelt High School, Maryland, United States of America
Adaptive Control Using a Neural Net (by Michael Stevens)
Cooling of Linear Induction Launcher (by Matthew Early)
Fast Single-Point Imaging Electron Paramagnetic Resonance Imaging to study fluctuating Tumor Physiology; k-space and Trajectory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

Column

A short detour MATERIALS

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).

NEW STAFF

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