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MESSAGE

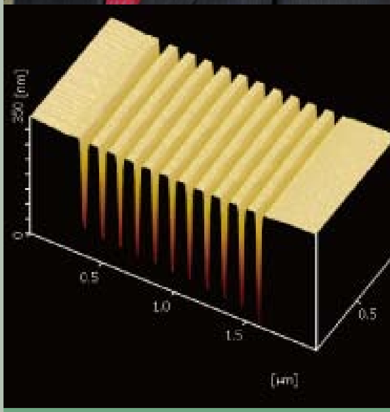
Message as the New President

FEATURE

The 8th AIST Advisory Board Meeting

FEATURE

Key Technologies for the Realization of Advanced Measurement and Analysis



Research Hotline

UPDATE FROM THE CUTTING EDGE（January−March 2013）

In Brief

Message as the New President

Ryoji CHUBACHI

President
National Institute of Advanced Industrial Science and Technology (AIST)

Introduction: My relationship with AIST

I assumed the role of President of AIST in April 2013. Having worked for Sony Corporation for 36 years, I had some trepidation about taking on this position. Immediately after I came to AIST, I visited the Geological Museum. The rocks, minerals, and everything else displayed there brought back memories of when I studied resources engineering at university. The department I belonged to was once called mining engineering, and was renamed resources engineering during my university days. The name was subsequently changed again to geo-engineering and then to environmental science through collaboration and fusion with other departments.

In my opinion, AIST shares a similar history with that department. AIST was born in April 2001 as a result of the integration of 15 research institutes under the former Agency of Industrial Science and Technology. The Geological Survey of Japan, which has the longest history among these institutes, was established in 1882, and these institutes have undergone transformations and reorganizations since then to become AIST today in response to the evolving expectations of society.

My research subject at university was the development of electronic materials from artificial minerals. More specifically, my aim was to artificially produce ultrafine particles of ferrite, and fabricate communication devices by sintering them using a powder-metallurgical method or create a magnetic fluid by stably dispersing them in a liquid. I often travelled to the Government Industrial Research Institute, Tohoku in Sendai, which is now part of AIST, to use its electron microscope to directly observe the size of the ultrafine particles. I also remember that there was a competition with the Government Industrial Research Institute, Nagoya, now also part of AIST, which was conducting similar research at the time. Upon the completion of my doctoral course, I joined Sony Corporation. The head of the Sony Research Center at that time was from the Electrotechnical Laboratory which is now part of AIST, too. In 2009, when the Tsukuba Innovation Arena for Nanotechnology (TIA-nano) was established by an industry-government-academia joint policy statement, I was on the Executive Board as the representative of industry and AIST was also a member of the Board. As such, I have been closely connected with AIST and it is therefore a great honor for me to become its president.

Growth through innovation

Japan, as an island nation in Northeast Asia without iron ore or oil resources, must aim to be a trading nation founded on manufacturing with innovation at the core in order to remain a positive presence in the world. The 4th Science and Technology Basic Plan emphasizes issue-resolving-type research that promotes science, technology, and innovation in an integrated way. *Innovation* here means the creation of economic and social values as stipulated by the Act on Enhancement of Research and Development Capacity of 2008.

Masaru Ibuka, Sony's founder, often said to us that innovation is different from invention. "When engineers come up with a new idea, they often think they can commercialize it without much effort. But this is not true. Developing that idea into mass production requires 10 times more effort, and marketing and commercializing the idea-based product requires another 10 times more effort." Dr. Ibuka named this theory the 1-10-100 rule.

Now is the time for AIST to play an active role

Apart from the work of some AIST researchers that perform basic research, the research activities conducted at AIST mainly involve innovations for the industrialization of technologies based on basic knowledge. I believe that this is why the current name, the National Institute of Advanced Industrial Science and Technology, has been given to this institute.

The Japanese economy seems to be picking up these days. However, faced with various restricting factors such as increases in electricity rates, high corporate taxes, and environmental issues, the industrial sector has to remain patient. Since many companies have reduced R&D spending and plant and equipment investment in order to secure profits since the Lehman Shock, the prospects for future growth of industry now seem quite dim.

Despite the current financial pressures, the 4th Science and Technology Basic Plan sets the target for R&D investment at 1 % of GDP in the government sector, which translates into about 25 trillion yen over a period of five years. The budget for public research organizations in Japan is not so large compared with that for private companies. Nevertheless, now that many private companies are facing difficult circumstances, society is depending on public research organizations. This is therefore the time for AIST to play a leading role in promoting science, technology, and innovation.

Moving AIST forward

The fact is, however, that the general public keeps a strict eye on public research institutes. People think that public institutes are not making sufficient contributions to society, that they do not consider cost efficiency, or that they do not meet the expectations of industry, despite the large amounts of tax money they receive.

We have to listen and respond to these voices, but it is not an easy task. This type of problem can also occur between the headquarters and branch offices of large companies, or central government agencies and local municipalities. Professor Emeritus Ikujiro Nonaka at Hitotsubashi University, for whom I have great respect, divides knowledge into two categories: explicit and tacit. The main function of universities and research institutes is to present explicit knowledge in the form of papers and patents, while industry mostly deals with tacit knowledge at work sites. Professor Nonaka has said that a dialectic dialogue between tacit and explicit knowledge is important to further increase knowledge levels.

In addition to Professor Nonaka's approach of tacit and explicit knowledge, I have proposed an approach of central and local knowledge. For example, in the relationship between the headquarters and branch offices, or between central agencies and local municipalities, explicit knowledge is often concentrated at the center, while tacit knowledge is mostly found in local offices, creating an asymmetricity of knowledge. I believe that this is one of the factors that make communication between central and local organizations difficult.

In AIST's case, its Tokyo Headquarters are located in Kasumigaseki, its largest facilities are at AIST Tsukuba, and there are regional research bases throughout the country from Hokkaido to Kyushu. If we think about the relationship between Kasumigaseki and AIST Tsukuba, or between AIST Tsukuba and the regional research bases in terms of center-local relationships, local regions should have more tacit knowledge than the center. The same is true for the relationship between AIST and industry. The voices of industry may not be fully heard at AIST, or vice versa. If this is the case, AIST should visit industrial work sites, where problems are accumulating, and listen to their voices. Collecting and integrating knowledge in this way will ultimately lead to innovation.

Concluding remarks

At present, many Japanese companies cannot develop a growth strategy because they are unable to create innovation. The recovery from the Great East Japan Earthquake is still in progress. Quite a number of countries in the world have serious problems such as environmental issues. No effective solution has yet been found for the aging of the population and declining birthrate in Japan. Finding knowledge-based solutions to these problems is one of the responsibilities of public research institutes.

Let me repeat: Now is the time for AIST to play an active role. Society has high expectations for AIST. I would like to ask each and every member of AIST to always keep this in mind when carrying out their daily tasks. I will also devote myself wholeheartedly to my duties, utilizing my past experience of working in the private sector and on government councils.

Sony's Akio Morita often encouraged the company's employees by saying, "I will do my best, so do your best, too!" I am determined and ready to work together with all of the staff to deal with the various problems facing society.

The 8th AIST Advisory Board Meeting

The AIST Advisory Board was organized to provide advice on the organization's research activities and overall operation. The board members are leading experts in a variety of disciplines from Japan and abroad. The eighth advisory board meeting was held at AIST Tsukuba Headquarters on February 8, 2013.

The last two meetings focused on discussions of the "Realization of Sustainable Society" and the "Age of Globalization." However, Japan has suffered from slow growth for two decades and simply reacting to external circumstances is not sufficient. Re-establishing steady growth will be achieved only if Japan takes innovative actions.

Therefore, AIST entitled this Advisory Board meeting, "Measures and AIST's Role to Vitalize Japan's Industry." The board members discussed enhancing AIST's functions from a variety of viewpoints. This article reports the outline of the findings of the meeting and notable comments and advice from the board members.

Table 1　The Advisory Board Members

Junichi Hamada (Chair)	President, The University of Tokyo
Hiroyoshi Kimura	Chairman, Kimura Chuzosho Co., Ltd.
Sadayuki Sakakibara	Chairman of the Board, Toray Industries, Inc.
Takashi Shoda	Representative Director and Chairman, Daiichi Sankyo Co., Ltd.
Waichi Sekiguchi	Editorial writer, Nikkei Inc.
Hajime Bada	President & CEO, JFE Holdings, Inc.
Sawako Hanyu*	President, Ochanomizu University
Ei Yamada	President & CEO, AnGes MG, Inc.
Nobuhiro Yamada*	President, University of Tsukuba
Alain Fuchs	President, National Center for Scientific Research (CNRS), France
Makoto Hirayama	Professor, Vice President and Director of Asian and Pacific Rim Strategic Alliances, College of Nanoscale Science and Engineering, State University of New York, USA
Thaweesak Koanantakool	President, National Science and Technology Development Agency (NSTDA), Thailand
Willie E.May*	Associate Director for Laboratory Programs and Principal Deputy, Office of the Director, National Institute of Standards and Technology (NIST), USA.

(*：Absent)

Table 2　The Program

Friday, February 8, 2013

10:00	Opening of the Meeting; Introduction of AIST Advisory Board members and AIST participants
10:10	Welcome address
10:15	Presentation by AIST; *"Measures and AIST's Role to 'Vitalize' Japan's Industry"*, part 1.
11:00	Laboratory tours: Exchanging views with research scientists
13:00	Lunch
13:30	Presentation by AIST; *"Measures and AIST's Role to 'Vitalize' Japan's Industry"*, part 2.
14:00	Discussion
15:50	Closing remarks
16:00	Closing of the meeting

Outline of the 8th AIST Advisory Board Meeting

The advisory board meeting was held with 10 of 13 distinguished board members in attendance (Table 1), including a new member, Mr. Takashi Shoda, Representative Director and Chairman of Daiichi Sankyo Co., Ltd.

The meeting began with a two-part presentation by AIST participants on the main theme, "Measures and AIST's Role to Vitalize Japan's Industry." Laboratory tours were conducted in between the two parts. The meeting concluded with each board member making comments and offering advice.

Comments and Advice from Board Members

Junichi Hamada (Chair) (President, The University of Tokyo)

This is the third advisory board meeting I have attended, and I feel that AIST's activities have become more dynamic since the first one. The strategies and innovations that were discussed in previous meetings are beginning to be realized. I look forward to seeing the future achievements.

I do have concerns about AIST's operations overseas. Revival of Japanese industry will only be realized by vitalizing Japan together with other parts of the world, not only Japan. A large issue in strengthening Japanese research institutes and universities is the depth and breadth of collaboration abroad.

I suggest the following. How about AIST expanding its collaborative activities with overseas companies further, as new opportunities and ideas will arise from such activities. In this era, seeing the domestic society is not enough. I hope that AIST will expand its current and future activities with a global perspective seeing global society and companies in the world.

Hiroyoshi Kimura (Chairman, Kimura Chuzosho Co., Ltd.)

I want to comment on Japanese manufacturing and say a few words on another point. I think that Japanese manufacturing has been collapsing and has been weakened, particularly during the last year due to the rising yen in the past four years. Large companies have suffered, but not nearly as much as medium- and small-sized businesses, which have been damaged more extensively.

In particular, medium- and small-sized companies in manufacturing, materials, and supporting industries have been seriously damaged. Skill succession and maintaining human resources in these areas is crucial. Universities have engaged less in these areas, and I hope that AIST will play a role in supporting R&D in such areas.

In addition, I think AIST's technology would become more widely available to industry if AIST published more academic papers. I therefore encourage AIST to publish more.

Sadayuki Sakakibara (Chairman of the Board, Toray Industries, Inc.)

The government's Industrial Competitiveness Council has discussed the need to strengthen the nation's industrial competitiveness, particularly in manufacturing industries. The fundamentals of industrial competitiveness are rapidly weakening, not only in medium- and small-sized companies, but also in large companies. The council's major concerns are strengthening competitiveness in existing industries, as well as the creation and incubation of new core industries that will lead Japan in the future. The 4th Science and Technology Basic Plan states that Green Innovation and Life Innovation are major themes as the research fields for growth in the next generation. I think the latter is especially important and ought to grow as a core industry in Japan.

Although there are public research institutes other than AIST that engage in basic research in the life sciences, the expectations for AIST in regards to industrialization in this field are quite high. As a future direction in this field, I think that the pharma-medical field should collaborate with their counterparts in precision engineering, materials, biotechnology, and IT—all areas in which Japan has competitive advantages—so that we can experience growth in applied fields such as diagnostics, medical materials, medical devices, and drug discovery. AIST engages in a wide range of research activities, and it is my hope that you will promote more interdisciplinary research, for example, in bio–IT fusion. I suggest that AIST conducts research that industry alone cannot conduct or establishes large mechanisms that enable such research.

The demands and needs for innovation are getting higher, not only in high-tech fields but also in conventional fields. However, in these fields, the basic research carried out by academia, mainly universities, is diminishing. As academic researchers are evaluated mainly by publication, they have difficulty in continuing such research on which it is difficult to publish papers. This is worrisome in terms of the Japanese industrial competitiveness. I hope that AIST will play a responsible role in the incubation and strengthening of industry in Japan, as well as supporting medium- and small-sized companies, in the fields necessary for industry such as of chemical engineering, polymer, metal, and fiber, even though it is generally hard for academia to support them.

Takashi Shoda (Representative Director and Chairman, Daiichi Sankyo Co., Ltd.)

In the sense that AIST unites universities and industry, I was very impressed with the collaborative project of TPEC (Tsukuba Power Electronics Constellations), where you conduct the research with an R&D roadmap taking mass production into consideration. I expect more of such activities of providing opportunities, and hope that AIST will do similar collaborative research in the life sciences. It is important, for example, in iPS (induced pluripotent stem) cell research, that AIST leads the way, while uniting with industry, to compile a roadmap that links the research to the industry.

Another matter is nurturing human resources. Recently, the importance of bioinformatics in life science innovations is mainly told in the context of how to interpret “big data”. However, there are too few specialists in bioinformatics. Expectation for AIST in human resource development in this field is quite high.

Finally, the field of life sciences in Japan has traditionally focused on issues related to the elderly, but issues related to younger generations, including infant and pediatric health data, are of key importance. To capture such information, I think that AIST’s technology in fields other than the life sciences will be crucial. For example, tracking health data using measurement devices can lead to preventive or preemptive medical care. I hope that AIST will take full advantage of the great diversity of its research fields.

Waichi Sekiguchi (Editorial Writer, Nikkei Inc.)

I think two factors related to R&D have led to Japan’s declining competitiveness in industry. The first is the delay in catching up to the digital age. Since the late 1990’s, there has been a huge paradigm shift in ICT, with the Internet at the center. This shift has affected various R&D and manufacturing industries, but Japan was late to adjust to the shift. The second factor is a weakened capacity to commercialize research results and the technologies. Japan has been working intensively on basic research and elemental technology development, and we have produced satisfactory results, but the issue is turning these results into products.

Three issues need to be addressed to improve these factors. One is diversity. The research community in Japan is mainly a culture of male scientists that tend to think linearly, and once the track on the research can be set, they concentrate on improving in it. This culture has not been good at catching up to paradigm shifts such as the conversion to the digital age. A greater diversity of people, including more foreign and/or female researchers, would be necessary to bring more points of view and enhance the creation of new information and technology as well as encourage greater innovation.

The second issue is the need for better project management to put one's technologies into products. This is a bit different from R&D management, but it is necessary to develop human resources capable of project management. According to circumstances, AIST should lead projects that can enhance the development of these types of human resources, involving both companies and universities.

The third issue is development of human resources in software creation. Japan has been successful in creating and manufacturing hardware. But if you look at successful companies such as Apple, they have been successful by replacing hardware solutions with software solutions. Although Japan is still strong in industries without paradigm shift such as machinery, precision equipment, automobiles, the competitiveness has been lost in industries where the paradigms have changed such as consumer electronics and IT. Japan therefore needs to develop human resources in software development, but engineering departments in Japanese universities are not doing so. To better address this software development, AIST should put an emphasis on the field of software.

In Japan, researchers often value producing papers and work on narrow research themes in which others are less interested. I think we need to take a broader look over the whole market to better understand demands, and then we need to supply the integrated technologies or products that the customers desire. I expect AIST to play a role in supporting such activities.

Hajime Bada (President & CEO, JFE Holdings, Inc.)

In the 4th Science and Technology Basic Plan of Japan, science and technology policy has been drawn up for the 5 years starting from FY 2011, where it aims for economic growth through scientific and technological innovation. Also, the economic growth strategy of Japan, which is inextricably linked with the Science and Technology Basic Plan, is, however, still not fixed in terms of direction. Moreover, its progress has been delayed. I would like AIST to take the lead in its R&D themes, make further progress and achieve the goals as they are planned.

In order to revitalize Japanese industry, to remain on top as well as to realize long-term economic growth through scientific and technical innovation, it is necessary to improve technologies in the fields in which Japan is leading the world. I think the role of AIST is in returning the achievements of R&D to society. As this policy has been well received in the past 3 years, and has been making significant achievements, I would like to ask AIST to further improve its level of performance.

In Japan, the availability of human resources and the amount of public R&D funding are currently at a low level compared to other developed countries. I would like AIST to utilize private and foreign funding and human resources for the stimulation of open innovation.

AIST works on various domestic and international standards. Since regulation can often create significant barriers to the creation of new businesses, misdirected regulations related to science and technology need to be revised through proper scientific verification. In this way, I expect AIST to contribute to society by accelerating the pace of starting up new businesses.

Ei Yamada (President & CEO, AnGes MG, Inc.)

My first concern is the extent to which AIST's works, which are highly valued among experts, have been transferred to society. As AIST is a public research organization, it is very important that its works be understood by a wide range of people. In America, there are people called science communicators who present science through writing and PR activities. Such people are few in Japan. Therefore, the way of dissemination is crucial.

Second, in the healthcare field, Japan has the Ministry of Health, Labor and Welfare (MHLW) as a very strong regulatory body. Due to its nature as a regulatory body, however, it is difficult for MHLW itself to promote the healthcare industry. In addition, facing serious issues regarding pensions, it does not have excess resources to put into R&D. Therefore, I think it is increasingly important that AIST, being under the Ministry of Economy, Trade and Industry (METI), considers fostering industries related to healthcare. In the United States, the National Institutes of Health has around 20,000 researchers and an extremely large budget, and I worry about whether Japan can compete with them. In this sense, I think that both the staff and budget of AIST are insufficient. Japan does not have many natural resources and must invest in strengthening R&D. Of course, the rationales behind the research carried out should be strong and accountable.

Developing human resources is also important, particularly utilizing female and foreign researchers. For example, female researchers lead embryology worldwide. It may be time to consider allocation of human resources in research with such a viewpoint. It is also necessary to consider what types of persons should be selected to lead projects and maximize output, and finding the best persons to promise the success of projects. In such a way, I think allocation of human resources in R&D will need multilateral views to find the appropriate persons.

Alain Fuchs (President, National Center for Scientific Research (CNRS), France)

I would mention a few words about the expectations we have in our country and comparison to the situation in Japan.

Interestingly enough, the topic of vitalization of industry is absolutely the same in my country with almost the same words. We are talking in France about transfer of science and technology being neither strong nor fast enough.

We talk a lot about building common labs with industry, which is in a sense very near what we have been talking today about open innovation hubs, fusion research, large scale joint research laboratories.

We also tend to try to identify the difficulties, the barriers that we have to overcome. For instance, circulation of researchers from academia to applied research and then to industry is rather difficult. It is difficult as it is a matter of the researchers' mind. Even we made a lot of incentive promotion, it happens that still researchers are not very enthusiastic to circulate. I am talking about France. I have heard similar things here.

The governments, France and perhaps Japanese as well, have sometimes a mixture of two expectations, one that research fundings should lead to a return to investment that will finally result in increasing GDP, growing economy, job creations, etc. Another expectation is that the governments long for science and technology to solve global issues such as global warming. These two types of expectations do not always link together. It is not obvious that working on global warming will directly lead to job creation in the country where you do the research.

I was extremely interested to hear today that you are going to launch Fukushima Renewable Energy Research Base in the next year. This is a place where both expectations, the energy R&D for the 21st century, and society expectations such as job creation, GDP growth, are certainly linked. The answers that you have suggested today, open innovation hub, etc. are certainly in my opinion very valuable.

Finally I would mention an important point. When we have improvements on science and technology, there are also external effects. However, when we are not competitive despite our scientific achievement, there may be negative effects. For instance, it is a fact that science and technology is less attractive to young bright people. We need young bright people in science and technology. In France, scientists and engineers in the top management of companies are decreasing, then people tend to believe that science is less important than finance and marketing. This is one of the external reasons why competitiveness is becoming a problem in a certain number of countries.

I am talking about France. I do not want to interfere with the Japanese case, but this is what you have asked.

Makoto Hirayama (Professor, State University of New York, USA)

AIST is well known in Japan, but in the US, it is largery unknown. Given its size, research achievements, and the unshakeable status as a research institute in Japan, I believe that AIST needs to show a greater presence and assume a more active role in the world. AIST researchers should go out into the world, show their own presence, and compete with others using their own names. It is crucial for researchers to prove their knowledge and experience, as well as their visions and perspectives of their research fields, and discuss them with their competitors. Such interactions would eventually result in enhancing AIST's ability. I expect the more than 2000 researchers of AIST to build such an attitude and take a lead in setting a global benchmark of research achievement, not just a domestic one.

To help accomplish this goal, I would ask President Nomakuchi not to reduce the budget for overseas business trips. Without face-to-face contact, it is difficult to appropriately share the ideas, no matter how good they are. Deep mutual understanding among researchers will not be developed. I know from experience that it is quite important to meet and talk to people in person. I hope all researchers at AIST take any opportunity to reach out to a wider audience, and I request AIST to support such activities. The support, in return, will clarify the role of AIST in improving Japanese industry.

Thaweesak Koanantakool (President, National Science and Technology Development Agency (NSTDA), Thailand)

Looking from overseas, I have a few comments.

The major US industry is considering relocating their manufacturing base back to the US because of the new advanced robotics, automation, and cheap energy from shale gas. However, I do not think the Japanese industry will want to do that because the Japanese case might be different from the US. Japan might use a different strategy by keeping manufacturing bases abroad with more innovation. AIST can play an important role to assist those Japanese companies.

An open innovation approach with industry should be the right way for AIST to revitalize Japanese industry. I would like to thank AIST for opening for overseas researchers including Thailand to have opportunities of research collaboration. Creating an open innovation hub overseas for corporate customers both from Japan and in the local areas might also be beneficial for both Japanese industry and AIST.

Innovation and new solutions can happen closer to the market. This can be a place where collaboration with public research organizations and companies can take place. I would also expect AIST to be a hub for the circulation of researchers between the academia and industry and possibly expanding collaborations between Japan and overseas.

My last point is about riding on the new growth in ASEAN and India. There can be new and specialized products in those markets which are different from those for Japan. But the existing capability of AIST and Japanese companies can be ready to address those markets. Some examples are farm mechanization, housing, energy saving, biotechnology including renewable energy, food safety, packaging, and more sanitized living.

Tamotsu Nomakuchi (President, AIST)

I would like to thank you all very much for your day-long discussions. We received many encouraging responses to our activities, and we realized the importance of our responsibility again. I would like to offer a few comments on some of the topics we discussed today.

Through the AIST Open Lab etc., we are aware of our responsibility to strengthen the manufacturing industries, including medium- and small-size companies. Support in both the technical side and human resources side has been requested. METI (Ministry of Economy, Trade and Industry) enforces the policy to reinforce supporting industries. In accordance to that policy we cooperate with local medium- and small-size companies to support them better.

Regarding the importance of road maps including those in existing fields, since the days when I was in industry, I have been aware that there were certain fields where academia was less engaged. For example, even if you develop a great new power electronics device, there are no university courses or laboratories that teach power electronic circuits. AIST does not play as a bystander; we actively play our role to cover such areas in our way. I think that the role and importance of public research institutes will expand increasingly. And AIST will clarify issues to be resolved and perform our mission as one such institute.

About the overseas activities that Professor Hamada pointed out, our main oversea activities are collaborations with and at foreign research institutes such as the National Center for Scientific Research of France (CNRS) and the National Science and Technology Development Agency of Thailand (NSTDA), as well as Japanese and local companies joining in such collaborations overseas.

As some of you including Professor Hirayama mentioned, “Japaneseness” is a deeply rooted matter. We say that every Japanese person has the virtue of modesty from infancy, but to make an appeal is important in international society. Recently about 10 % of AIST researchers have been involved in international standardization committees. The percentage of researchers making short-term visits for research presentations has probably been several times larger than that. We annually have about 100 researchers working in overseas laboratories for middle and long terms. I think that we have paid attention to nurturing human resources capable of international activities, but we understand this matter is very important and will continue to act accordingly.

The open innovation hub is where AIST collaborates with industry and universities, and we recognize that the entire AIST acts as an open innovation hub where AIST collaborates with industry and universities. There are divisions and groups within AIST that specifically function as the hub. In some cases they support R&D that is close to application. In other cases they lead to start new R&D. In any case, our common function is to promote R&D to get close to and reach applications.

Finally, several of you mentioned issues such as human resources and their development, diversity, and ways of creating innovation. To address these issues, we must be more proactive so that dynamic outcomes will be obtained. We will consider your opinions when implementing our activities. Again I appreciate your cooperation and contributions. Thank you.

Laboratory Tours in Two Courses

The board members visited three laboratories each, divided in two courses. There were presentations of research topics at the laboratories.

Course A

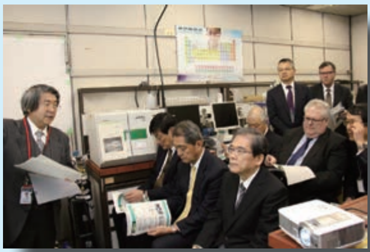
Realization of an Innovative Metrological Traceability using Quantitative NMR Technology
Metrology Institute of Japan

R&D of SiC Power Electronics
Advanced Power Electronics Research Center

Generation of High-Quality iPS Cells from Peripheral Blood
Research Center for Stem Cell Engineering

Course B

Minimal Fab System
Nanoelectronics Research Institute



Radioactive Cesium Decontamination with Prussian Blue Nanoparticles
Nanosystem Research Institute

Japan's Extended Continental Shelf (ECS) Project and Beyond
Institute of Geology and Geoinformation

Key Technologies for the Realization of Advanced Measurement and Analysis

AIST's Advanced Measurement and Analysis

Advanced measurement and analysis necessary for maintaining a scientific and technological nation

Living organisms developed (acquired) measurement techniques necessary for their sustainable growth (survival) in the process of evolution. For example, cyanobacteria, which are thought to have given the Earth its oxygen atmosphere, exhibit phototaxis (movement in response to light) to reach an environmentally favorable place for photosynthesis. They have a blue light photoreceptor protein as a photosensor for their phototaxis movement.

The photon measurement system (eyeballs) that we human beings possess is far superior to that of cyanobacteria. Two photoreceptors in our retina, namely, rod cells and cone cells, measure light. Rod cells, which are the sensors for black and white, have rhodopsin, a protein composed of opsin combined with a retinal molecule that absorbs single photons. Cone cells contain cone cell proteins that have a sensitivity to the light colors (wave lengths). The ability to perceive not only black-and-white images but also the colors of light corresponds to the invention of a "measuring device." In addition, stereoscopic vision (allowing the measurement of distance) is also possible by placing two detectors of the same type at two separate locations. This is the invention of a "measurement technique." We can recognize characters by collating the image on the retina with the information accumulated in our brain. We cannot read or write without the invention of "knowledge" (a database), namely characters or letter shapes.

In our modern society, changes are occurring so rapidly that it is impossible for DNA-based evolution to catch up with them. Such changes inevitably create various problems that cannot be solved by the existing technologies. The strategy we should therefore adopt is the development of artificial advanced measurement and analysis.[1]

RIIF Research Institute of Instrumentation Frontier

ANCF AIST Nanocharacterization Facility ISO IEC JIS

Hardware / Software / Knowledge

Research groups	Core Technology	1 Life innovation	2 Green innovation	3 Safety and Security	4 Instruments for open use	5 Industrial standards
Advanced Defect-Characterization Research Group	Positron		Positron microbeam analysis	Portable X-ray source	Defect detection	
Super-Spectroscopy System Research Group	Superconducting measurement	Mass spectroscopy	X-ray absorption spectroscopy		MS XAFS	Superconducting sensor standards
Ionization and Quantum Manipulation Research Group	Ionization		Molecule orientation SIMS	MS		
Quantum Radiation Research Group	Compact electron accelerator	Circular dichroism, X-ray imaging				
Structural Health Monitoring Research Group	Ultrasonic nondestructive method			Ultrasonic inspection		Ultrahigh-temperature properties
Active State Technology Research Group	Nanoprobe	TEM	Laser transient absorption		Laser transient absorption AFM	Nanotechnology thin-film standards AFM probe evaluation
Nano-Dynamics Analysis Research Group	X-ray and NMR		NMR X-ray diffraction software		NMR	Solid state NMR DB
Inhomogeneity Analysis Research Group	Industrial material analysis		Multivariate analysis software			Impurity analysis
Nanolabeling and Measurement Research Group	Molecular probe	Molecular probe (NMR)				ESR Concentration determination method

Relationships between three frontier fields to be explored and five strategic application plans

Evolution from measurement to analysis with the dissemination of advanced instruments

The Research Institute of Instrumentation Frontier (RIIF) is committed to exploring three frontier fields, refining advanced measurement technologies into analysis technologies, and disseminating them widely throughout society. We have set five strategic application plans for our researchers to play an active role in. The relationships between the three frontiers and the five strategic plans are shown in the figure.

Three frontier fields to be explored

1. Hardware (measuring instruments)
2. Software (measurement techniques, analysis techniques, and software applications)
3. Knowledge (databases)

Five strategic application plans

1. Measurement techniques for life innovation
2. Measurement techniques for green innovation
3. Measurement techniques for safety and security
4. Open use of advanced measurement and analysis equipment
5. Standards (ISO, IEC, JIS) and databases

Nine research groups, each having specific core technology, are in charge of the three

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frontiers. This feature article outlines their core technologies (i.e., key technologies). Please see our website for details of the groups and updated information on RIIF: http://unit.aist.go.jp/riif/index_en.html.

Reference

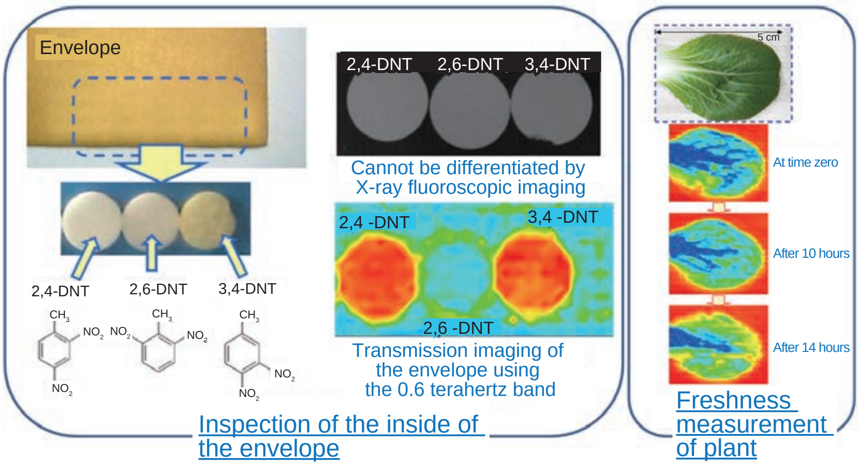
[1] http://unit.aist.go.jp/riif/ja/intro/riif_report.pdf

Director
Research Institute of Instrumentation Frontier
Masataka OHKUBO

Intense Terahertz Measurement and Analysis Technology for Safety and Security, and Life Innovation

Potential of intense terahertz measurement

Since it is very difficult to generate terahertz (THz) waves, which are located on the boundary between light and radio waves (between 0.1 and 10 THz in the frequency range and between 3 mm and 30 μm in the wavelength range), they have not been used much so far and are therefore considered to be an unexploited field. The commercialization of laser-based terahertz light sources has finally been realized in recent years thanks to the latest advances in femtosecond laser technology. These commercially available sources, however, have very weak output power and can only be applied to measurement and analysis in limited laboratory environments or under certain sample conditions. Practical use of terahertz waves for in-situ observations or actual environmental measurements has been understood to be very difficult as these waves are strongly absorbed by the moisture content of the air. Aware of such difficulties, AIST is actively engaged in R&D of intense terahertz wave generation using ultrashort-pulse electron beams of the kiloampere class generated by a compact accelerator and advanced measurement and analysis technologies using the terahertz waves such as imaging and spectroscopy in actual environment.



Inspection of the inside of an envelope (left) and measurement of the freshness of a plant (right)

Seeing things that are invisible to X-rays using terahertz waves

Terahertz waves show straightness and focusing properties like light and they pass through paper, cloth, and ceramics similarly to radio waves. This is why terahertz waves are now attracting attention as an alternative to X-rays in the field of transmission imaging. At the same time, examination of the unique absorption spectra (fingerprint spectra) attributable to the molecular vibrational and rotational levels of many materials in the terahertz range also allows us to identify materials. Because of these features, terahertz waves are expected to be used in security applications such as inspections for prohibited drugs and explosives at airports and in postal matters. Shown at left in the figure is transmission imaging of dummy explosives hidden in an envelope (three types of dinitrotoluene isomers with different nitro-group positions).[1] These three dummy explosives cannot be differentiated from each other by X-ray inspection because of their identical compositional formula. The use of terahertz waves, however, enables us to see through the different nitro-group positions of these chemicals and differentiate them. Furthermore, whereas X-ray inspection has the drawback of poor sensitivity for the detection of light-element molecules such as water, terahertz waves can measure changes in water molecular distribution over time by means of imaging, as in the example of plant observation shown at right in the figure.[2]

Development of intense terahertz wave applications

In the field of terahertz waves, spectroscopic technology has also been developed together with imaging technology. While commercial THz time-domain spectroscopy (TDS) systems are popular at the laboratory level, we are working on the development of a spectroscopic measurement technology that uses intense terahertz waves for the measurement in actual environments for the first time as an alternative to the laboratory-level spectrometers. Our technology not only identifies materials but also determines complex refractive indexes, complex dielectric constants, and complex conductivities of materials in a noncontact and nondestructive manner. Its potential applications are therefore wide-ranging. To mention some examples of applications, those in the materials field include new materials development such as solar cells, organic EL materials, and metamaterials; those in the life sciences include examinations for skin cancer and breast cancer as well as pathological diagnosis; and industrial applications include defect inspection of integrated circuits in production lines.

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Ryunosuke KURODA

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Molecular Probe Technology for CNT Bioimaging

Bioimaging

There are highly sensitive methods for bioimaging using fluorine-18 (^{18}F) labels or fluorescent labels. For bioimaging using ^{18}F labels, it is necessary to produce ^{18}F, which does not exist in nature, with a cyclotron (accelerator). Bioimaging using fluorescent labels has a drawback of its inability to make measurements deep within an organism. Magnetic resonance imaging is a well-known noninvasive imaging technique, but we at RIIF are focusing on carbon materials and are aiming to develop a new bioimaging technique using fluorine probes.

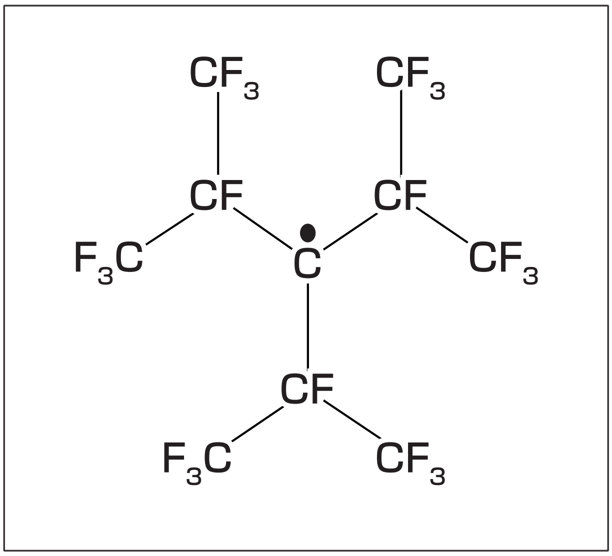
In vivo dynamics of nanomaterials

The number of carbon materials has increased remarkably due to a series of new discoveries such as fullerenes and carbon nanotubes (CNTs), and they have therefore been a focus of attention as the core material in nanotechnology. CNTs in particular are considered to be highly promising as they can have an extremely wide variety of properties due to their hierarchical structure, ranging from a single layer to multiple layers, as well as differences in size such as length or thickness and in tube winding (chirality).

On the other hand, it has been pointed out that there is a similarity in the shapes of CNTs and asbestos (i.e., the fiber paradigm). The theoretical mechanism of asbestos toxicity is that asbestos remains in an organ exposed to it and continues to stimulate the organ. Unlike an inorganic compound such as asbestos, CNTs are known to be involved in various organic reactions. In this respect, the center of interest is the in vitro dynamics of CNTs including how long they remain in an exposed organ and how they move from an exposed organ to another organ. Unfortunately, no methodology has yet been established for in vivo CNT dynamics testing.

Development of analysis technique for in vivo CNT dynamics

We are now working simultaneously on the development of a noninvasive imaging technique for analysis of in vivo CNT dynamics and the development of CNT dispersion technology. For the latter, we are currently able to disperse CNTs ranging in size from short specimens of about 1 μm to lengths of about 10 μm, the length addressed by the fiber paradigm, at a high concentration of about 1 mg/ml using a low-toxicity surfactant discovered from the screening of some 400 surfactants for cosmetics. For the former, we demonstrated the feasibility of electron spin resonance (ESR) imaging by intraperitoneal administration of extremely stable perfluoroalkyl radicals (PFR), having the structure shown in the figure, in a mouse. However, when CNTs were made into a peapod structure using PFR in order to label them, a phenomenon of broadening of the ESR signals was observed. This led to our unexpected discovery of the formation of charge-transfer complexes by PFR with aromatic compounds, but it was also found that this method has a fundamental problem as a CNT labeling method. At present, we are engaged in R&D of a in vivo dynamics analysis for CNTs using ^{19}F nuclear magnetic resonance imaging by means of the molecular design of perfluorocarbons having many magnetically equivalent trifluoromethyl groups that are related by symmetry such as the mirror plane, center of symmetry, or *n*-fold rotation axis, and labeling CNTs using the designed molecules.



Chemical formula of extremely stable radical (PFR)

Amid wavering confidence in science and technology due, for example, to the unprecedented accident at a nuclear power plant, we are determined to continue the exploration of new measurement techniques that are convincing and reliable with respect to our goal of the safety evaluation of CNTs.

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Positron Measurement and Analysis for Nanotechnology

The importance of evaluating atomic vacancies and nanospaces

Various properties of materials, such as mechanical strength, electrical insulation, and molecular permeability, are affected not only by the combinations of elements that constitute the material but also by microvoid structures ranging from the atomic to the nanometer scale, such as atomic vacancies and nanovoids in crystalline materials and molecular voids (nanospaces) in amorphous materials. Particularly in the nanotechnology field, specific properties of various materials such as metals, semiconductors, ceramics, and polymers are actively imparted changing such materials into functional components by applying surface treatments or covering them with thin films. It is therefore very important in the R&D of such materials to conduct accurate analysis of local atomic vacancies or nanospaces near the surface. However, it is generally difficult to quantitatively and selectively evaluate the size of atomic vacancies or nanospaces in a local area near the surface of a sample, and expectations have been focused on the development of new measurement tools for this purpose.

Nano-scale measurement and analysis realized by positron beams

Positrons, the electrons antiparticle and rarely found in nature, can be produced using radioactive isotopes or an electron accelerator. When positrons are injected into a substance, they emit high-energy light (gamma rays) and are annihilated. Since the time from injection to annihilation (the positron lifetime) is correlated with the size of atomic vacancies or nanospaces, measurement of the lifetime can be used to evaluate the size of voids or nanospaces. However, positrons immediately after generation have an uneven energy distribution and no discharge directionality, making it difficult to selectively inject positrons into a local area near the surface of a material. This means that positrons cannot be applied in this way to the measurement of atomic vacancies or nanospaces in device materials or functional materials. As a solution to this problem, we developed equipment that can quantitatively measure local atomic vacancies or nanospaces in a nondestructive manner.[1] Specifically, we create a focused beam of positrons by aligning the directions of the positrons, adjust the incident energy, and selectively inject the beam into any given position of a material so as to measure the positron lifetime. Called the positron probe microanalyzer (Fig. 1), this equipment is being applied to the development of device materials and functional materials that support the nanotechnology field (Fig. 2).

Shifting from measurement in a vacuum to measurement in the air

It is generally understood that the characteristics of a void or a nanospace are affected by the type of gas or humidity in the normal operating environment, depending on the material. To date, positron beam techniques have only been applied to measurements in a vacuum and could not be used to evaluate vacancies or nanospaces of materials under normal atmospheric pressure conditions. To solve this problem, we developed a device (called the controlled environment positron probe microanalyzer) that measures the positron lifetime by injecting a positron beam, which is conveyed out of a vacuum to the air, into a sample.[2] With this equipment, a variety of usage environments can be simulated by introducing various humidity-controlled gases to the sample chamber. In the future, we intend to provide efficient support for the development of advanced materials by promoting the evaluation of atomic vacancies or nanospaces in a wide range of device materials and functional materials in controlled atmospheric conditions.

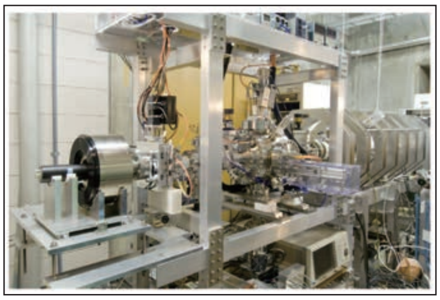

Fig. 1 Positron probe microanalyzer

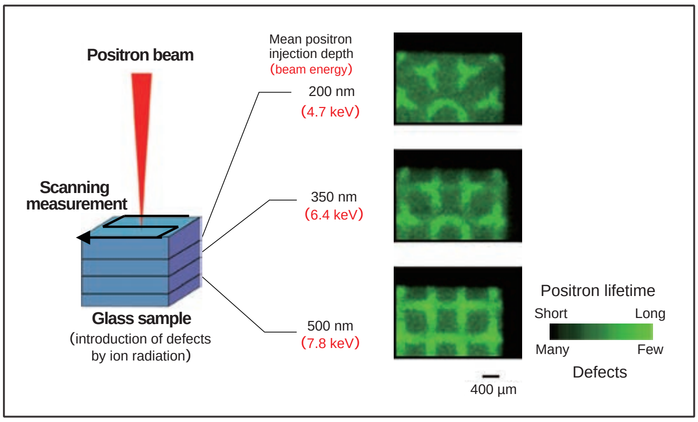

Fig. 2 Example of detection of ion radiation defect patterns in a glass sample

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Soft X-Ray Fluorescence Yield XAFS Analyzer Capable of Analyzing Trace Light Elements

Fluorescence yield X-ray absorption fine structure spectroscopy

The properties of SiC, GaN, ZnO, diamond, solar cells, and other materials are determined by light trace elements (dopants). In order to improve the properties of those materials, it is necessary to analyze the nano-scale fine structures such as the lattice locations or valence states of light trace elements.

One powerful tool to obtain the information of the nano-scale fine structures is fluorescence yield X-ray absorption fine structure (XAFS) analysis. In conventional XAFS measurement, semiconductor detectors are used for detecting fluorescent X-rays. However, the energy resolving power of the semiconductor detectors are not enough to clearly distinguish the K-lines of the light trace elements such as boron and nitrogen, and the L-lines of various elements in an energy range below 1 keV. This insufficiency makes the measurement of a low concentration of light trace elements difficult.

Superconducting tunnel junction (STJ) detector is promising for XAFS measurements in the soft X-ray region because of its high energy resolution and high sensitivity. In fact, X-ray detectors using our STJs have already exhibited much better energy resolutions than conventional semiconductor detectors.[1]-[3] Therefore, we developed an advanced soft-X-ray fluorescence yield XAFS analyzer using our STJ array detector which is called superconducting XAFS, or SC-XAFS. SC-XAFS is installed in the Photon Factory of the High Energy Accelerator Research Organization. SC-XAFS can be operated without a supply of liquid helium for cooling the STJ array detector by using a refrigerant-free cryogenic refrigerator, which makes SC-XAFS a practical analytical instrument. Using SC-XAFS, it is possible for us to analyze the nanostructures of various samples containing trace light elements.

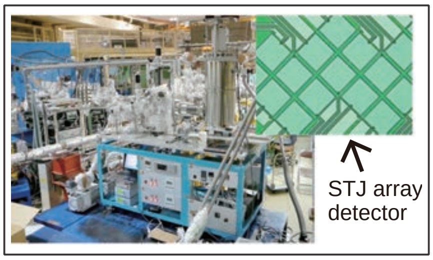

Fig.1 SC-XAFS and the STJ array detector (The size of one pixel is 200 x 200 μm.)

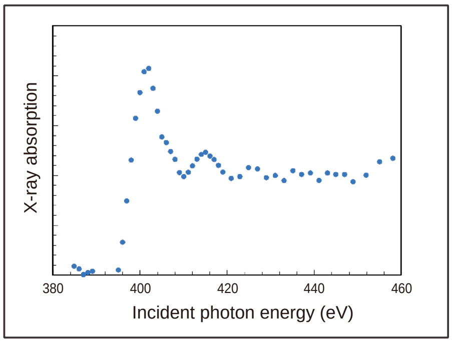

Fig.2 Example of XAFS spectrum of nitrogen dopants in SiC

Outline of SC-XAFS

Figure 1 shows SC-XAFS and our STJ array detector. SC-XAFS is constructed with a high vacuum chamber for samples, a fully automatic refrigerant-free cryogenic refrigerator, a 100-pixel STJ array detector, and signal processors. While the limit of an energy resolution of a typical semiconductor detector is 50 eV for characteristic X-rays of nitrogen or oxygen, the 100-pixel STJ array detector realizes a high energy resolution of ~10 eV and a high photon counting rate of 1 million X-ray photons per second as a result of optimization of the layer structure of the STJs. Using SC-XAFS, we succeeded in obtaining the XAFS spectrum of nitrogen dopants with a concentration of 300 ppm for the first time (Fig. 2). Structural information such as the substitution positions of nitrogen atoms or the status of defects in the SiC crystal is obtained from the measured spectrum. This information is useful for the improvement of the doping technique.

Future prospects

At present, SC-XAFS belongs to the IBEC Innovation Platform of AIST and is now open to users through the IBEC system and the Nanotechnology Platform. We receive many requests to use SC-XAFS for measurements of compound semiconductors, spintronics materials, and oxides that cannot be evaluated by conventional XAFS instruments. We intend to enlarge the detection area of the STJ array by increasing the number of pixels in the array and to realize a high energy resolution less than 10 eV@400 eV in order to realize a high throughput of XAFS measurement and the analysis of trace light elements with very low concentration.

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Powder X-Ray Crystal Structure Analysis Technique for Light-Element Material Research

Powder X-ray diffraction

Importance of light elements has been growing in recent years in terms of green innovation, such as in the green energy and eco-environment fields. For example, the electrode and electrolyte materials of lithium-ion batteries, and hydrogen storage materials for fuel cells are major research targets. Furthermore, many other materials such as organic crystals, nanomaterials, and hybrid materials are composed of light elements.

Information on crystal structures related to light elements is essential for improvement in functions of these materials. Although single-crystal X-ray diffraction is an effective method for determining crystal structures, it must be noted that high-quality single crystals are not always produced. Powder X-ray diffraction is capable of easily measuring diffraction patterns even though the samples are not single crystals, but the precision of its analysis of light elements is not as high as that obtained by single-crystal X-ray diffraction. If we can analyze the crystal structures of light elements using powder samples, we will be able to contribute to green innovation.

Software development

Since light elements have small scattering power for X-rays, it is very difficult to determine where in the crystal lattice they are located. We may choose to conduct a neutron diffraction experiment, but this requires special equipment such as a nuclear reactor, which may not always be available. We came up with the idea of using an imaging plate (IP) detector as an effective tool to maximize the detection of weakly diffracted X-rays from light-element materials. This idea led to our development of a new software application called PIP that is capable of one-dimensionalizing two-dimensional diffraction images obtained by an IP (Fig. 1). As the powder method produces diffraction lines as concentric circles, integrating the lines along the circle can improve the count on the order of one or two digits. The software can also mitigate the effect of nonuniformity of powder grain size. With these features, we can now analyze crystal structures at the laboratory level even with small-volume samples of about 0.001 mm^3 (Fig. 2).

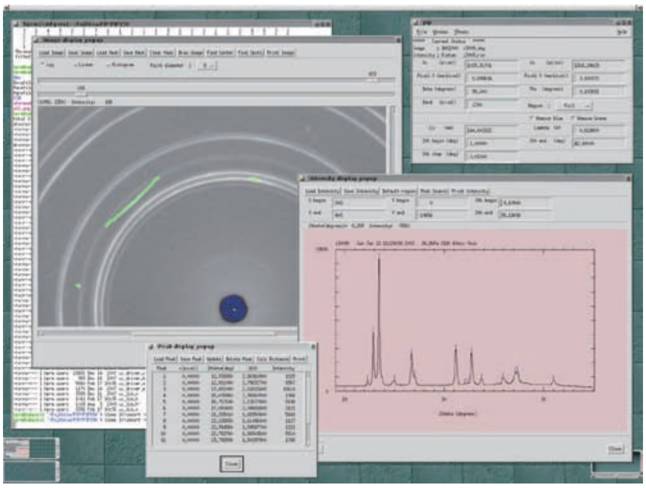

Fig. 1 Developed software, PIP, (AIST intellectual property control No. H22PRO-1100) in operation

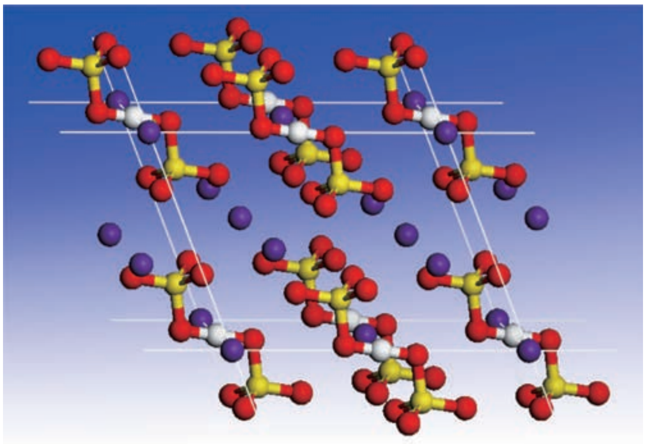

Fig. 2 Example of analysis of crystal structure (high-pressure phase of $Rb_3H(SO_4)_2$[1])
The positions of the hydrogen atoms were estimated by density functional theory (DFT) calculations.

Future prospects

This software is also available for use at universities and public research institutes in Japan, the Photon Factory at the High

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Energy Accelerator Research Organization, and SPring-8 at the Japan Synchrotron Radiation Research Institute. Efforts are still being made to realize wider applications for the software, including the development of high-temperature superconductors and thermoelectric materials other than light-element materials.

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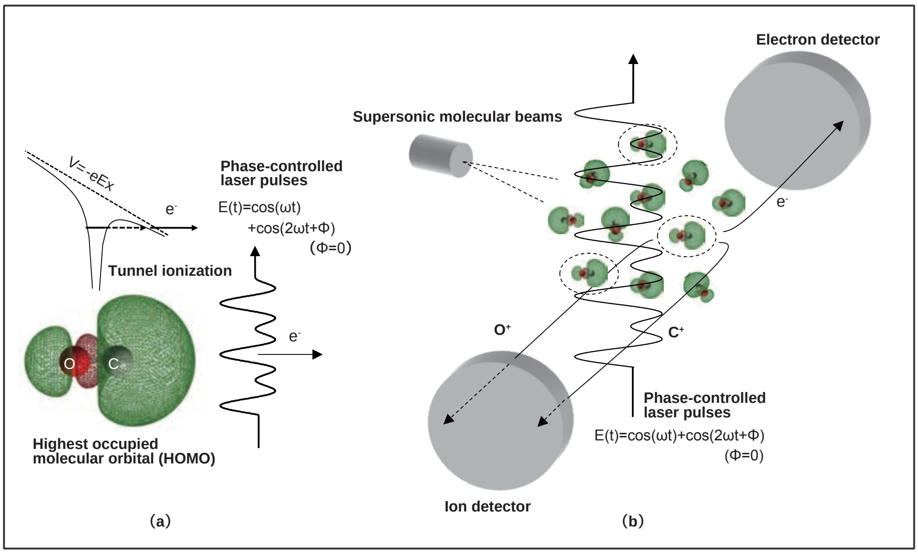
Mass Spectrometry Using Laser Pulse Molecular Manipulation Technology

Mass spectrometry

Mass spectrometry is an analysis technique widely used in analytical chemistry and life science for analysis of the constituents of various substances, detection of trace atoms and molecules, and analysis of molecular structures. Simultaneous determination of the mass and structure of a molecule is a central topic in sophistication of the functionality of mass spectrometry. We have been conducting research using laser-based molecular manipulation techniques to achieve qualitative development or functional refinement of mass spectrometry.



Schematic diagrams showing (a) control of tunnel ionization by phase-controlled laser pulses and (b) orientation-selective molecular ionization induced by the tunnel ionization

Manipulation of molecular orientation utilizing tunnel ionization of molecules by phase-controlled laser pulses

When conducting mass spectrometry of molecules, the first step is to remove the electrons from molecules and ionize them. At that time, aligning the molecules or measuring only aligned molecules remarkably increases the amount of analyzable information and realizes detailed measurement. We have recently succeeded in ionizing only molecules that are oriented in a specific direction among randomly-oriented gaseous molecules by using laser light with precisely controlled phases (phase-controlled laser pulses).[1]

In the microscopic world such as at the level of atoms or molecules, electrons spread over an atom or a whole molecule like waves. When an external field is applied to atoms or molecules, electrons come out due to the tunnel effect, which can result in ionization of the atoms or molecules. The advanced molecular manipulation technology using phase-controlled laser pulses allows us to use the tunnel effect and control what part of a molecule is deprived of electrons. As shown in (a) in the figure, the assumed condition here is that asymmetric molecules such as carbon monoxide are ionized by the asymmetric electric field of phase-controlled laser pulses composed of the fundamental harmonics and second harmonics. Since there is a higher probability of electron removal at the part of molecules whose highest occupied molecular orbital (HOMO) has a more spatially spread electron density, due to tunnel ionization by the asymmetric electric field, we were able to demonstrate the selective ionization of “molecules with their heads and tails differentiated from each other” oriented in a certain direction (oriented molecules), as encircled by the dashed lines in (b) in the figure, among randomly-oriented gaseous molecules .[2]

The photofragments-emission pattern of oriented molecules reflects the stereostructure of the original molecules. Hence, when molecular manipulation is

conducted using phase-controlled laser pulses in mass spectrometry, the ability to perform advanced analysis that can estimate not only the molecular weight but also the molecular structure is realized.[3]

From the basic level to application: Development of research seeking versatility

Our work based on the orientation-selective molecular ionization has so far revealed that (1) this technique is independent of the type of material, and (2) it can manipulate the orientation of even complex polyatomic molecules and is a versatile technique available for a wide variety of applications.[4] We are engaged in R&D of measurement and analysis techniques based on the new method using phase-controlled laser pulses, ranging from basic research on advanced laser-based molecular manipulation techniques to the development of equipment.

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[3] Patent No. 4423388: Oriented Molecule Mass Analysis Method. [4] H. Ohmura: *Molecular Science*, Vol. 5, A0039 (2011).
Related Articles
AIST Today 5 (3), 32 (2005). *AIST Today* 6 (12), 44 (2006). (In Japanese)

Full-Field Displacement Measurement Technique for Structural Health Diagnosis

Needs for a displacement measurement technique

An accurate understanding of the status of damage or deterioration of infrastructures that support our society, such as power plants, bridges, and means of transportation and of industrial products, will lead to the establishment of a safe and secure society. It is also effective in cost reduction through prolongation of the service life of such structures or products. To this end, it is necessary to detect anomalies at an early stage by constant monitoring of information on the displacement distribution of an entire structure.

There are strain gauges and laser displacement sensors that are used at work sites, but since they are sensors for point measurement, a great deal of labor and cost is expended to obtain displacement information for an entire structure. Therefore, there is a strong need for a full-field measurement technology that can realize wide-area displacement distribution measurements of a targeted structure within a short time and with high precision.

Development of sampling moiré method

We have developed a method (sampling moiré method) that simply takes each single image before and after deformation of a structure and can measure the displacement distribution with micro-order accuracy.[1] This method analyzes small-displacement from the phase of moiré fringes, which is a phenomenon of expansion of an original image, and achieves precision of displacement measurement on the order of one digit greater than the conventional image processing methods. Compared with the existing displacement distribution measurement methods, it allows measurement of a wider region more precisely, rapidly, easily, and cost-effectively.

An example of displacement distribution measurement by the sampling moiré method is shown in the figure. The left-hand photo is an image of the periodic structure on the surfaces of buildings photographed with a digital camera. When the sampling moiré method is applied, multiple moiré fringe images with different phases are obtained as shown in the middle figure. Based on these moiré fringe images, the Fourier transform is performed to calculate the phase distribution of the repeated pattern that indicates the position information with high precision, as shown in the right-hand photo. When the phase difference of the repeated pattern before and after displacement is detected, we can immediately determine the actual displacement of the object with a precision exceeding 1/500 times the pitch of the

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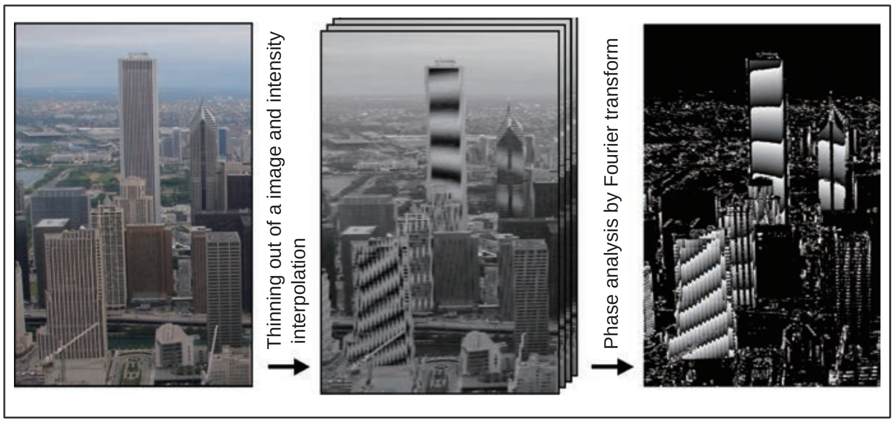
periodic pattern on the surface of the building.

When this method was applied to a large, 10-meter-long crane, a grating with a pitch of about 40 mm was attached onto the location to be measured, the same process was conducted, and submillimeter-level deflection, whose detection by the existing techniques had been difficult, was successfully detected.[2] A phase compensation technique[3] that can reduce measurement errors according to the inappropriate position of a camera during setup was also developed so that ordinary users, who may not have expertise, can easily make highly precise displacement measurements.

Future prospects

We will refine the sampling moiré method to realize a highly practical measurement and analysis system applicable to actual sites. We also intend to further develop the method of two-dimensional displacement distribution measurement using arbitrary repeated patterns into three-dimensional displacement distribution measurement method that can analyze complicated displacement behaviors, so as to establish a novel technique that makes it possible to easily evaluate the health diagnosis of large structures.



Full-field displacement measurement using the sampling moiré method

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Nanoscale Standard Materials for Atomic Force Microscope

Refinement of nanomeasurement equipment

Nanomeasurement is like touching an object in the dark to determine its shape. An atomic force microscope (AFM) causes a probe to touch the surface of a sample with weak force and creates an image from that shape by two-dimensional scanning. The limit of perception of a nanometer (nm)-scale shape is determined by the shape or sensitivity of the probe. To further improve this limit, it is considered necessary to develop a highly sensitive measurement system and a sharp probe. To increase the precision or reproducibility of shape measurement, on the other hand, it is necessary to reduce abrasion during measurement and improve scanning precision with consideration for the shape of the probe.

In order to enhance the reliability of AFM measurement, we are engaged in the development of a technique using a highly anti-abrasive diamond probe, calibration of the scanning system using standard nanoscale samples, and research on a method to systematically handle the shape characteristics of AFM probes. We report the results of these efforts through international academic conferences and international standardization organizations and promote their use for improvement of equipment performance.[1]

Development and common use of highly reliable nanomeasurement equipment

We have developed a method that selectively etches a nanometer-thickness multilayer cross-section to produce standard samples for AFMs. With this method, we have established the production technique for micropatterns down to 6 nm in line width and 3 nm in line interval.[2][3] Figure 1(a) shows an example of the production of a pattern of 6 nm in line width and 6 nm in line interval. Using this technique, we have developed standard samples that allow us to evaluate the response characteristics of probes in depth measurement. The standards are referred to as the AFM probe characterizers.

Figure 1(b) shows trench patterns ranging from 10 to 100 nm in addition to 6 nm knife edges. Using these patterns, we can measure the nanotrench structure of a semiconductor,

the measurement of which is most difficult for AFMs, with high reproducibility. The maximum depth to which an AFM probe enters is graphically shown as in Fig. 1(c) by measuring the response characteristics of the probe to the concave structure. By optimizing the control parameters of the probe using this graph and by measuring the sample while ensuring the orthogonality of the scanning system (z axis and x-y plane), the measurement of voids with an aspect ratio of 5 or higher at a line interval of 60 nm or less has become possible. An example of such measurement is shown in Fig. 2(a), for a pattern with a line width of 45 nm (line interval of 60 nm) and a depth of 350 nm. As shown in Fig. 2(b), by analyzing the diameter of a microparticle (about 100 nm) taking the shape of the AFM probe into consideration, we can evaluate it from both the height and horizontal directions. Note that although typical commercial AFMs ensure sufficient precision for height, it is difficult for them to provide high precision in the horizontal direction.

This technique is applicable to the optimization of measurement parameters in a solution in addition to those in the air. Thus, it helps to improve the reliability of measurements of shape and nanometer-level properties and can be used to evaluate probe characteristics in measurements performed in high-viscosity solutions. The achievements described here are available to general users as advanced measurement equipment in the IBEC Nanotechnology Platform.

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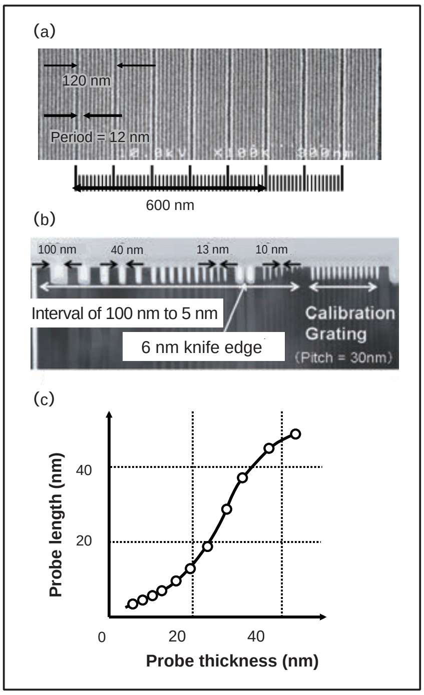

Fig. 1 (a) Grating realized with a line width of 6 nm, (b) Probe characterizer applicable to both concave and convex shapes, (c) Characteristics curve of AFM probe

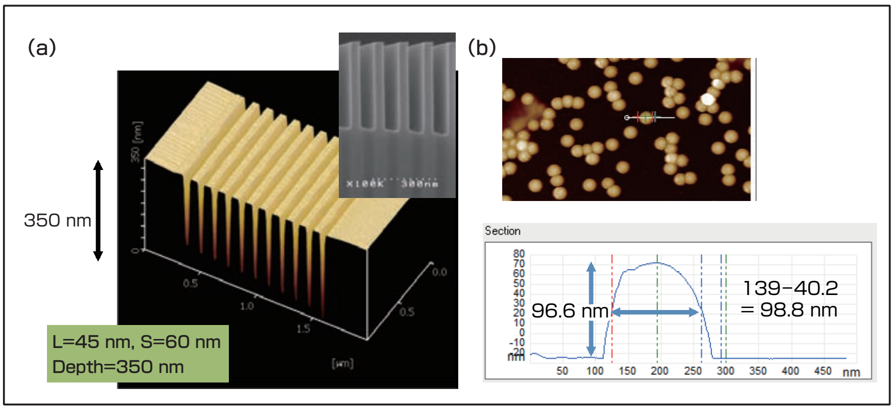

Fig. 2 (a) AFM image of nanotrench structure, (b) Measurement of the diameter of a microparticle with the AFM probe diameter duly corrected

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Multiple-Perturbation Two-Dimensional Correlation Spectroscopy –Effective analysis of complicated multiple-perturbation experiment data–

Issues relating to material development

To develop a heat-resistant polymer, it is necessary to heat the polymer and measure its deformation sequentially as it changes its form. Measurement of such thermal responses should then be conducted by systematically changing the composition of the sample. When we compare a series of these measurement data, we can clarify how thermal deformation is affected by differences in composition and obtain

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important clues for the development of a heat-resistant polymer.

This is just one example. In the actual development of new materials, procedures in which measurements are made with varied perturbations are often used. The data of measurements made with varying perturbations, however, often become highly complicated, which poses a problem because they are difficult to interpret (Fig. 1).

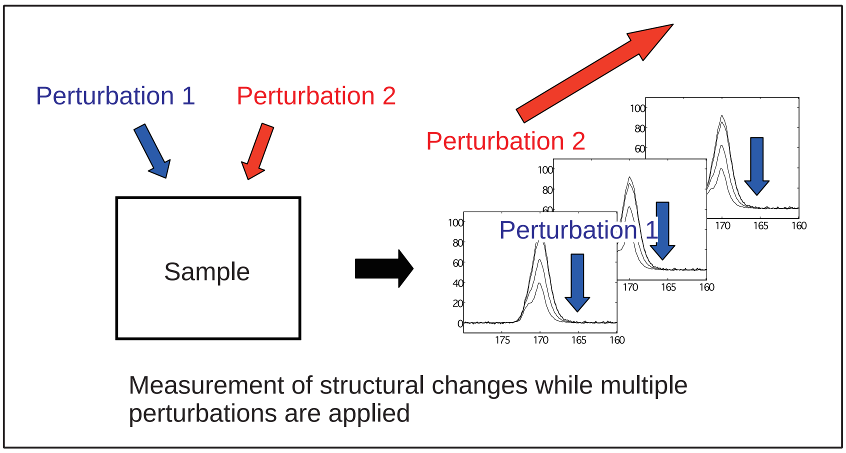

Fig. 1 Conceptual diagram of multiple-perturbation two-dimensional correlation spectroscopy

Multiple-perturbation two-dimensional correlation spectroscopy

We have developed multiple-perturbation two-dimensional correlation spectroscopy that is designed to detect changes derived by varying multiple perturbations with nuclear magnetic resonance (NMR) or other spectroscopic methods, as well as to conduct mathematical processing called cross-correlation analysis and output two-dimensional correlation diagrams. By checking the patterns on a two-dimensional correlation diagram, we can easily determine which molecular structure has been changed relative to multiple perturbations.

We conducted thermal behavior analysis of a nanocomposite composed of nano-size laminated silicates dispersed in polylactic acid using multiple-perturbation two-dimensional correlation spectroscopy. As a result of analysis with the NMR-based multiple-perturbation two-dimensional correlation spectroscopic method, it was clarified that the heat-resistance of polylactic acid is remarkably improved by a mechanism in which polylactic acid is inserted between layers of silicates and crystallization is promoted by the interface effect (Fig. 2).

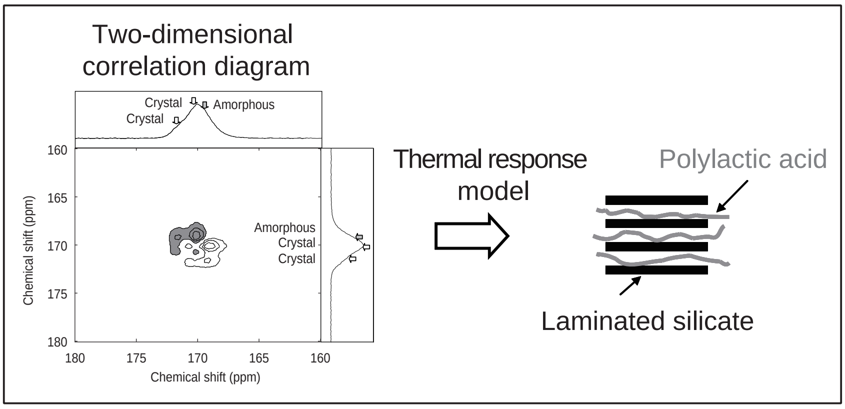

Fig. 2 Example of analysis of polylactic acid nanocomposite by multiple-perturbation two-dimensional NMR correlation spectroscopy

Future prospects

Multiple-perturbation two-dimensional correlation spectroscopy is versatilely applicable to the development of new materials. For example, it has been applied to the above-mentioned polylactic nanocomposite as well as to research on polymeric structural changes of polyethylene and cellulose. We are planning to apply this method to the development of nanocomposites using carbon nanotubes.

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Research Hotline

UPDATE FROM THE CUTTING EDGE

Jan.-Mar. 2013

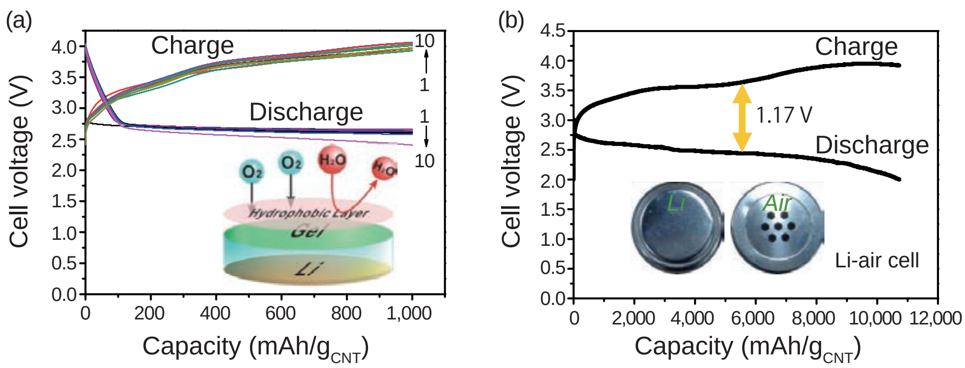
The abstracts of the recent research information appearing in Vol.13 No.1-3 of "AIST TODAY" are introduced here, classified by research areas.
For inquiry about the full article, please contact the author via e-mail.

Environment and Energy

Li-air batteries using a gel and an ionic liquid

Li-air battery based on gel air electrode with superior passages of electron, ion and oxygen

We have developed a cross-linked network gel (CNG) based on carbon nanotubes (CNTs) and ionic liquid (IL), which can be utilized as three dimensional tri-continuous passages for electron, lithium ion and oxygen gas. As a consequence, the Li-O_2 cell using the CNTs/IL CNG and the corresponding IL electrolyte exhibited an unprecedented specific capacity of about 6,000 mAh/g_{CNT} at current of 200 mA/g_{CNT}. Furthermore, a reversible 10 cycle process with 1,000 mAh/g_{CNT} and large discharge and recharge capacities of about 10,000 mAh/g_{CNT} have been also achieved even in ambient air by alleviating the H_2O contamination. It extends the Li-O_2 batteries into Li-air batteries.



(a) The discharge/charge curves of the Li-air cell with a cross-linked network gel electrode in ambient air when the state of discharge was limited to 1,000 mAh/g_{CNT}
(b) The discharge/charge curves of the Li-air cell in ambient air, at 200 mA/g_{CNT}

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Accurate 3D measurement of objects in fast motion
Measurement of object's surface shape at 30-2,000 frames/second

We have developed a method to reconstruct the shapes of moving objects. The proposed method is a projector-camera system that reconstructs a shape from a single image where a static pattern is cast by a projector; such a method is ideal for shape acquisition of moving objects at a high frame rate. The issue to be tackled is to measure the shapes with high accuracy, high density, and high frame-rate. To achieve the goal, our method has the following features: 1) implicit encoding of projector information by a grid of wave lines, 2) grid-based stereo between projector pattern and camera images to determine unique correspondences, 3) pixel-wise interpolations and optimizations to reconstruct dense shapes, and 4) a single-colored pattern which contributes to simplifying pattern projecting devices. In the experiments, we succeeded in measuring the dense shape of a person in punching motion, a deforming ball, a wave on water surface, etc.

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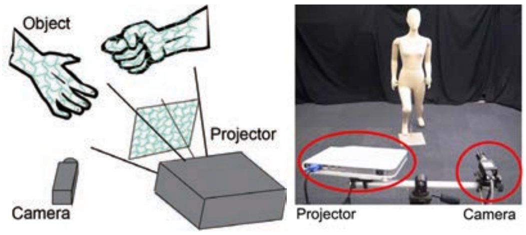

Measurement system with a projector and a camera


Measuring a person in motion by projecting wave grid pattern
Top: Input images
Bottom: Results of shape measurement

Measurement and evaluation of the internal state of an organic light emitting diode device during light emission
First-ever evaluation of molecules within a sealed organic light emitting diode device in operation

We have developed a method using a sum-frequency generation (SFG) technique that has been improved to measure the molecular vibrational spectrum at the interface of a specific organic layer inside an organic light emitting diode (OLED) device. By employing a signal enhancement phenomenon that occurs at the interface with an accumulated electric field, the method can be used to evaluate the molecular condition of the organic layer during light emission without destroying the device. This world-first has been achieved through the merger of AIST's cutting-edge fundamental measurement technology with CEREBA's practical OLED device manufacturing and evaluation technologies.

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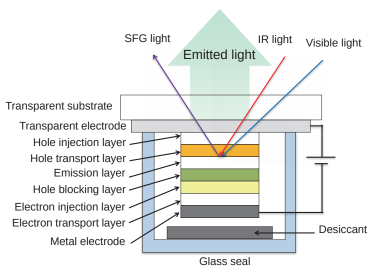
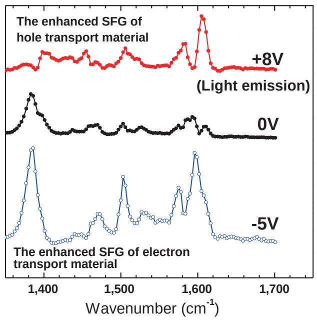


Schematic drawing of the structure of the multilayered OLED device and the directions of the incident and emitted lights used for SFG spectroscopy



Spectral changes in an operating multilayered OLED device
Starting from the top, with +8 V application (light emission), no voltage application, and –5 V application

Authentication scheme secure against eavesdropping and phishing attacks

Efficient and provably secure password-based authentication scheme

We have developed a provably secure password-based authentication scheme which requires less computation costs than those of the previous schemes. This authentication scheme was adopted as a standard of efficient password-based authentication schemes by the international standards organization IETF (Internet Engineering Task Force), and it was published as experimental RFC (Request for Comment) 6628 in June 2012. This authentication scheme is secure against various attacks including eavesdropping/modification/replay of communications, man-in-the-middle attacks, phishing scams, and server compromise impersonation attacks. In addition, its security is proven to be equivalent to a mathematical hard problem, meaning that it is almost impossible to break this scheme. Also, this authentication scheme provides high usability because users do not need to use long passwords and any complex public-key management system, i.e. key generation/confirmation/revocation procedures. Since it was published as an international standard, it is expected that this authentication scheme would be plugged into diverse internet services and applications in the near future.

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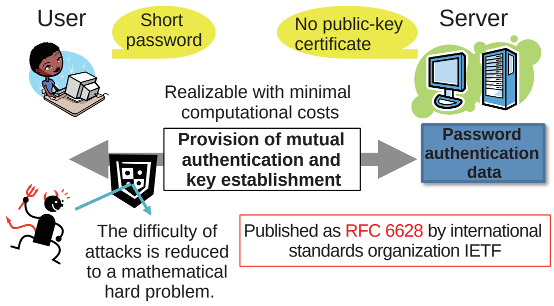

Features of the developed password-based authentication scheme

Information Technology and Electronics

Millimeter-wave oscillation by ferromagnetic nanocontact device

A theoretical proposal for a nanoscale current control-type oscillation device

Conventional giant magnetoresistive devices or ferromagnetic tunnel junction devices provide only low frequency oscillation and have been deemed unsuitable for applications requiring millimeter-wave (30–300 GHz) oscillation, including radar. However, upon analyzing precessional motion of spin induced by supplying a current to a ferromagnetic nanocontact device using a simulator developed by AIST, it was predicted that varying the current supplied to the ferromagnetic nanocontact device would cause the device to act as a current control-type oscillation device in the microwave to millimeter-wave range. If such a ferromagnetic nanocontact device is realized, it is expected to have applications in the next-generation wireless communication technology and sensor technology.

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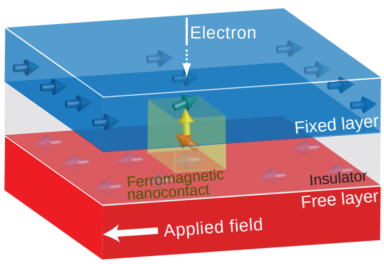
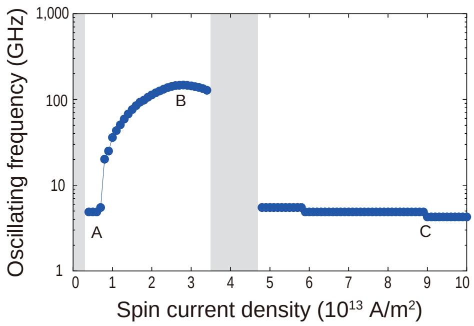
AIST TODAY Vol.13 No.2 p.13 (2013)



Schematic diagram of ferromagnetic nanocontact and ferromagnetic electrode
The magnetic wall can be enclosed in the ferromagnetic nanocontact.



Current density dependence of oscillating frequency
Oscillations can be categorized into three characteristic regions, A, B, and C. The gray area indicates a region with no oscillation.

Music listening system with automatic music content analysis

Active music listening service "Songle" is available on the Internet

We launched a public web service for active music listening, Songle (http://songle.jp), on August 29, 2012. Songle enriches music listening experiences by using our music-understanding technologies that can automatically analyze musical pieces on the web. Songle serves as a showcase, demonstrating how people can benefit from music-understanding technologies, by enabling people to experience active music listening interfaces on the web. Songle facilitates deeper understanding of music by visualizing automatically estimated music scene descriptions such as music structure, beat structure, melody line, and chords. Users can actively browse music by jumping to a chorus or repeated section during playback. When using music-understanding technologies, however, estimation errors are inevitable. Songle therefore features an efficient error correction interface that encourages users to contribute by correcting those errors to improve the web service. The error corrections by users lead to a better user experience, which encourages further use of Songle.

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AIST TODAY Vol.13 No.3 p.7 (2013)

An active music listening service "Songle" with music-understanding technologies developed by AIST.

Easy development of image-analysis systems on cloud computing

Lavatube 2 promotes the use of large-scale satellite image data

Image analysis is required in various fields, including satellite earth observation, medical services, crime prevention, and quality inspection in factories. We have developed image-analysis workflow middleware, Lavatube 2. It allows image-analysis systems requiring complex and high-speed processing of large amounts of data to be easily developed on a Web browser. Data analysis is performed by cloud computing. This makes it possible to process massive amounts of data at high speed. The user can easily access data archives of the OGC-compatible geospatial information system. Lavatube 2 will be incorporated into a satellite analysis system of GEO Grid that is being developed by AIST, and it will be provided for verification as a Web-based service to researchers and technical experts in the fields of earth observation and information technology.

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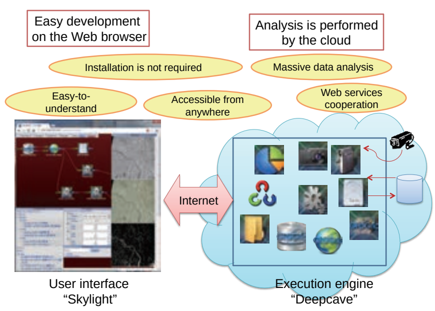
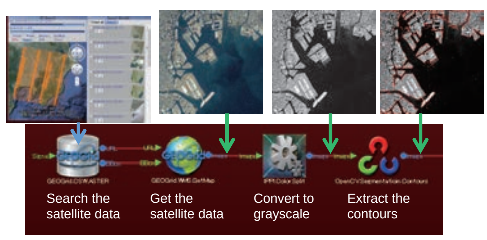


Configuration and benefits of Lavatube 2

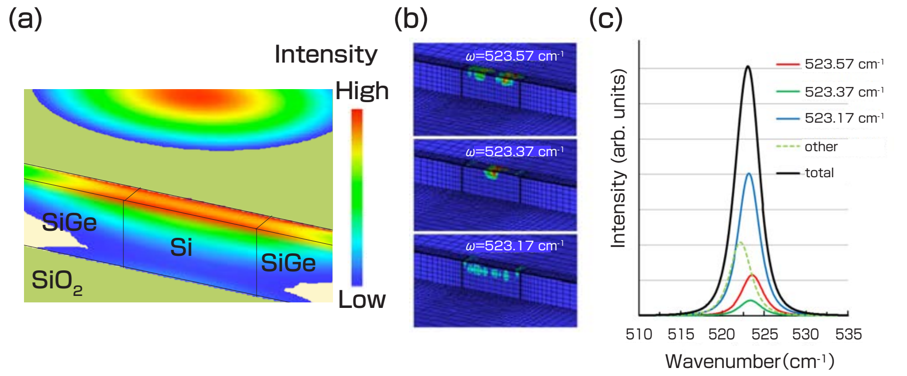


Example of an operation (Detection of coastline)

Three-dimensional stress analysis simulator for ultra-small silicon devices

Analysis at nanometer level using an optical microscope

We have developed a three-dimensional stress analysis simulator for ultra-small silicon (Si) devices. The developed simulation technology allows the analysis of the distribution of the mechanical stress (or mechanical strain) applied to ultra-small Si devices with a spatial resolution at the nanometer level by calculating the modulation of light intensity distribution caused by the device structure in the micro-Raman spectroscopy measurement using an optical microscope.



(a) Intensity distribution of excitation light calculated by the developed system
(b) Raman scattering light of each wavelength from the sidewall
(c) Spectrum of each scattering light obtained from the analysis and the combined Raman spectrum

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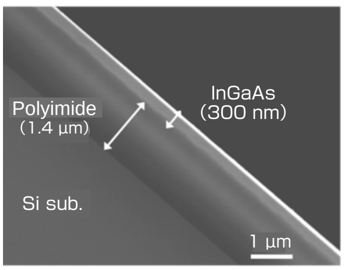
AIST TODAY Vol.13 No.3 p.9 (2013)

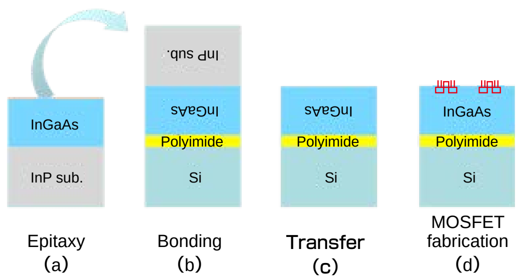
High performance transistors on polymer

A back-end integration technology for post-silicon materials

We have developed a technology for the transfer of a high performance compound semiconductor layer onto a silicon substrate using an inexpensive heat-resistant polymer as an adhesive. Transistors superior to silicon transistors were fabricated at maximum process temperatures as low as 400 ℃ on the polymer. Using the layer transfer and low-temperature device fabrication technologies, the realization of high-performance, multifunction devices integrating post-silicon materials with silicon large-scale integrated circuits is expected.



Cross-sectional SEM image of InGaAs layer on polyimide



Fabrication method of transistors on polyimide

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AIST TODAY Vol.13 No.3 p.10 (2013)

Low-cost MEMS fabrication technology using a replica molding technique

Possible development of new applications of resin MEMS devices

The developed technology makes it possible to fabricate MEMS devices by using the printing technology that enables the fabrication of large-area devices without a vacuum process and the injection-molding technology that requires small capital investment and enables low production costs. MEMS devices currently produced by using semiconductor manufacturing processes can now be fabricated inexpensively and with a small capital investment. This allows the applications of MEMS devices in fields where MEMS cannot currently be used owing to high production costs and low production volumes. For example, new applications in the lighting industry can be developed by combining active variable light distribution by a MEMS mirror and LED lighting.

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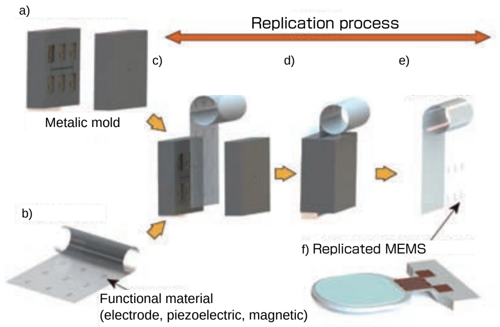
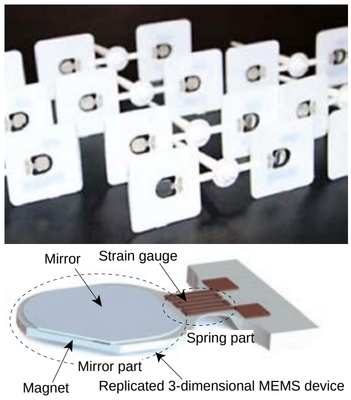


MEMS fabrication processes using printing and injection-molding



Examples of MEMS devices fabricated by using the developed technology

Determination of the absolute intensity of X-ray free electron lasers (XFELs)

Pulse energies validated through calibration of on-line monitors

The pulse energies of a free electron laser have been accurately measured in the hard X-ray spectral range using a cryogenic radiometer. The experiment was performed at the hard X-ray laser facility SACLA (SPring-8 Angstrom Compact free-electron LAser). The cryogenic radiometer is a thermal detector operated close to the liquid helium temperature of 4.2 K. They are electrically calibrated, based on the equivalence of electrical and radiant heating of a cavity absorber of almost 100 % photoabsorptance. Pulse energies up to 100 µJ were measured with the uncertainties from 1.1 % to 3.1 %, mainly due to the intensity fluctuations of SACLA. Using the absolute pulse energies, a SACLA online monitor was calibrated in the spectral range. Reliable pulse energy data are provided now for all current and future experiments at SACLA. We have a plan to develop a new radiometer operated at room temperature.

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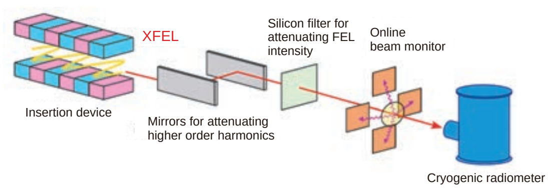

Schematic diagram of the experimental set-up at the beamline

Wavelength of the XFEL (nm)	Average pulse energy (µJ)
0.28	32.26 ± 0.35
0.21	104.2 ± 1.3
0.13	95.3 ± 2.3
0.091	42.2 ± 1.1
0.074	0.96 ± 0.03

Average pulse energy measured with the cryogenic radiometer

AIST Workshop for Innovation Ecosystem in Thailand

The workshop


The panel discussion

On October 30, 2012, "AIST Workshop for Innovation Ecosystem in Thailand" was held at the Grand Millennium Hotel in Bangkok, Thailand, in which President Nomakuchi and several executive members from AIST participated.

AIST has organized *Full Research* workshops throughout Japan to vitalize local industries bringing in company individuals. This was the first time for AIST to hold such a workshop abroad with the focus extended to Japanese companies overseas.

AIST and National Institute of Metrology Thailand (NIMT) have continuously implemented technology transfers in the field of measurement and standards for more than 10 years. In addition, the research institutes of the two countries have been implementing organizational collaboration in accordance with the memorandum of understanding (MOU), such as the collaborative research on biodiesel fuel by Thailand National Science and Technology Development Agency (NSTDA), Thailand Institute of Scientific and Technological Research (TISTR) and AIST.

Following the opening remarks given by President Nomakuchi, Mr. Iuchi, President of JETRO-Thailand, gave a speech on behalf of the sponsoring organizations. Three keynote speeches and eight case studies were given relating to collaborations between Japan and Thailand on measurement standards and standards verification, and on research collaborations on biodiesel fuel and solar power.

Having welcomed Mr. Taki, an editorial writer of Nikkei Newspaper, as a moderator, a panel discussion with seven panelists from Japanese and Thai organizations was held concerning *The Future Development of Calibration and Standards Verification in Thailand*. There were also many opinions and comments from members of the audience.

Lectures were given by representatives of NIMT, NSTDA, TISTR, Thai Ministry of Industry, and Japanese companies in Thailand, in addition to those given by AIST researchers in each session. Moreover, there were active discussions and exchange of ideas amongst the 230 or so participants; a number which far exceeded our expectations. The participants were all representatives of Japanese and other related companies and research institutions based in Thailand.

In the field of measurement standards, the domestic issue in Thailand, i.e., balancing the quality of calibration with costs, was highlighted, and the importance of disseminating measurement standard technologies to neighboring countries with Thailand as the hub in the future was confirmed. In standards verification, it was also recognized, through examples in Thailand, that standardization and product verification are important in order to ensure reliability of industrial products. Furthermore, the bilateral issues for future practical applications and standardization were recognized in the undergoing technological developments of biodiesel fuel and solar power generation, and the need for continuous promotion of further collaboration was also acknowledged.

Further collaboration reinforcement is expected among AIST, the Thai industrial sector, and public research institutes in Thailand in the future.

Cover Photos
Above: New President, Ryoji CHUBACHI (p. 2)
Below: AFM image of nanotrench structure (p. 20)

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