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FEATURE

The 9th AIST Advisory Board Meeting

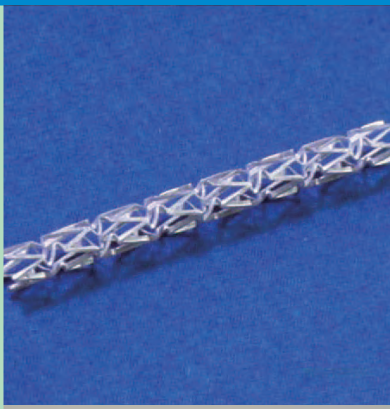
FEATURE

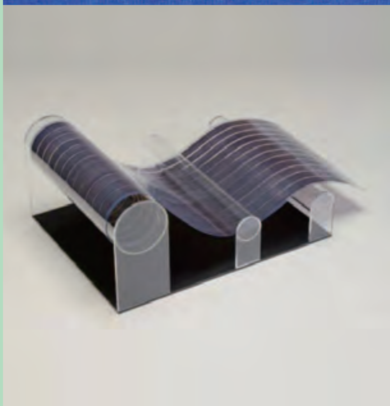
Recent Progress of Advanced Processing Technology

Research Hotline

UPDATE FROM THE CUTTING EDGE (April−June 2014)

In Brief





Cover Photos
Above: The magnesium alloy stent (p. 20)
Below: A sample of flexible film type dye-sensitized solar cell (p. 25)

The 9th AIST Advisory Board Meeting

The National Institute of Advanced Industrial Science and Technology (AIST) convenes Advisory Board meetings, with the participation of leading intellectuals of various fields from both Japan and abroad, in order to solicit and receive advice regarding AIST research activities and all areas of operations.

The first Advisory Board meeting convened since President Chubachi's inauguration was held at the Tsukuba Headquarters on January 27, 2014. (This was the ninth such meeting held since the AIST's founding.)

At present, under President Chubachi's leadership, AIST is pursuing a variety of new initiatives and conducting studies with its sights set on the Fourth Medium-term Plan, hereinafter referred to as the fourth term.

This Advisory Board meeting, held under the main theme of "Initiatives under New President Chubachi and Activities toward the Fourth Term," featured explanations of activities that were newly undertaken this fiscal year and discussions on vital issues requiring further study toward the fourth term, followed by discussions from various perspectives.

Here is a summary of the meeting and a report of the principal comments and suggestions offered by the board members.

Table 1 The Advisory Board Members

Junichi Hamada (Chair)	President, The University of Tokyo
Hiroyoshi Kimura	Chairman (presently Honorary President), Kimura Group
Sadayuki Sakakibara	Chairman of the Board, Toray Industries, Inc.
Takashi Shoda	Representative Director and Chairman (presently Senior Corporate Adviser), Daiichi Sankyo Company Ltd.
Waichi Sekiguchi	Editorialist and industrial sector editorial member, Nikkei Inc.
Kyosuke Nagata	President, University of Tsukuba
Hajime Bada	President & CEO, JFE Holdings, Inc.
Sawako Hanyu*	President, Ochanomizu University
Ei Yamada	President & CEO, AnGes MG, Inc.
Alain Fuchs*	President, National Center for Scientific Research (CNRS), France
Makoto Hirayama	Professor, State University of New York, United States
Reimund Neugebauer*	President, Fraunhofer-Gesellschaft, Germany
Thaweesak Koanantakool	President, National Science and Technology Development Agency, Thailand
Willie E. May	Associate Director of Laboratory Programs, National Institute of Standards and Technology, USA

(* not in attendance)

Table 2 Program

January 27 (Monday), 2014

10:00	Opening Introduction of board members and AIST attendees
10:10	Opening remarks
10:20	Initiatives under New President Chubachi and Activities toward the Fourth Term (Part 1)
12:00	Lunch
12:30	Inspection of research facilities and discussion with researchers
14:30	Initiatives under New President Chubachi and Activities toward the Fourth Term (Part 2)
16:50	Closing remarks
17:00	Adjournment

Summary of the 9th Advisory Board Meeting

This Advisory Board meeting was held with the participation of 11 highly erudite board members which, with the recent addition of Dr. Kyosuke Nagata of the University of Tsukuba and Dr. Reimund Neugebauer of Fraunhofer-Gesellschaft, now numbers 14 (Table 1).

First of all, various materials concerning the principal theme from AIST of "Initiatives under New President Chubachi and Activities toward the Fourth Term" were presented, with the presentations broken into two parts. Prior to the second set of presentations, participants viewed research facilities and engaged in discussions with researchers. Afterwards, board members had the opportunity to make comments and offer suggestions.

Comments and Suggestions from Board Members

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

With regard to raising the level of recognition for AIST, it would be useful to consider what image or words might be appropriate for characterizing AIST. This is a generalization, but in the case of Germany, for example, Fraunhofer-Gesellschaft, Helmholtz-Gemeinschaft, and Max-Planck-Gesellschaft, each presents a certain, individual image, while all are leading world research institutes. As to the format in which AIST should be developed, some sort of keyword that conveys AIST's prodigious research prowess directly to industry and society is needed. Additionally, since this must not be restricted to words alone, a symbolic mechanism needs to be put in place that will make this keyword concrete.

With regard to development of the Fourth Medium-term Plan, while the content described in the present Third Medium-term Plan is very good, there is something weak about its manner of appeal. Since this may have a bearing on the state of research or the state of personnel training, it would be a good idea to create a more proactive image, perhaps including a catch phrase that conveys the actual situation.

Hiroyoshi Kimura (Chairman (presently Honorary President), Kimura Group)

AIST has now come to provide research reports and other presentations at societies made up of medium-sized companies such as my own. However, AIST's level of recognition among small- to medium- sized companies is not so high and AIST seems to be somewhat passive in identifying needs. In terms of actions by AIST, closer interaction with small- to medium- sized companies is needed.While I realize that gathering information about the needs of such companies takes a lot of effort, AIST that has greater visibility and that is more capable of developing human relationships is needed.

Next, regarding renewable energy research, the high cost of renewable energy is an important issue for medium-sized companies, such as my own, in energy-intensive industries. If the use of such expensive energy is mandated, then energy-intensive industries will cease to be viable in Japan. Therefore, I sincerely hope you will aggressively pursue this research in terms of cost effectiveness, including studying the potential for methane hydrate.

Additionally, regarding scientific knowledge pertaining to the earthquake, every effort should be made to transmit raw data from Japan to researchers around the world. I hope that people around the world will receive this data that Japan transmits, so that the experiences of the Great East Japan Earthquake and the related nuclear reactor accidents will be put to use in the interest of global development.

As for the types of research that AIST should conduct, speaking from the standpoint of small- to medium- sized companies, efforts ought to be weighted on the side of applications. However, to gain standing as a world-class research institute, it is necessary to consider how applied research can be complemented with basic research. One thing that is currently missing from AIST is a policy viewpoint on Russia, which is a country that has done outstanding work in areas of basic research, and with which exchanging information is needed.

Lastly, with regard to human resources, small- to medium- sized companies such as my own have a hard time recruiting newly graduated PhDs. For that reason, we have our engineers publish papers, and encourage them to earn their PhDs under the tutelage of professors from their alma maters. In consideration of the "age of thinking" that is before us, it is clear that whether the ability to think exists within a company will hinge crucially on the number of PhDs that the company hosts.

For example, it should be noted that there are fewer and fewer university professors with expertise in the field of casting in recent years, and it is conceivable that eventually we may find ourselves in a situation where academic supervisors in this area disappear entirely. For that reason, I would like to see AIST become a body that can oversee the training of PhDs in small- to medium- sized manufacturing companies. Furthermore, in recent times, manufacturing by such companies in Japan has somewhat lost its luster. This is at least partially because small- to medium- sized Japanese companies have fallen behind in their use of information technology (IT). For example, while it is difficult to train engineers to fully utilize three-dimensional (3D) printing, this technology provides an opportunity, first of all, to provide thorough instruction in 3D data technology, and thus bolsters efforts to train engineers.

As for IT technology utilization, which is presently most problematic among small- to medium- sized companies, rather than starting out with high level research projects, training engineers who can propel forward small- to medium- sized companies by providing them with technology that is more approachable and immediately useful would be appreciated.

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

Under new President Chubachi, AIST has been undertaking cutting-edge research and technology development that meets the needs of industry and society, while addressing national issues. I strongly feel that AIST is fulfilling an important role as one of Japan's central public research institutes, and it is truly encouraging.

Among national issues, earthquake recovery is an urgent assignment, and it requires scientific knowledge and geological information. As for the major reasons why certain recovery efforts are not proceeding rapidly, there are a great many problems that stand in the way of progress, for example, a lack of scientific knowledge, a current inability to solve the problem of high radiation levels, problems related to high radiation levels in the ground, problems related to the safety of radioactive substances in waste water discarded into the ocean, and so forth.

By providing solid knowledge about how safe it truly is scientifically, agencies with responsibility can greatly speed up earthquake recovery. Accordingly, it is extremely important for AIST to responsibly transmit scientific understanding that will truly advance reconstruction from a broader standpoint than academia.

In addition, open innovation hub function of AIST can significantly promote the collaboration between industry and academia. When it comes to industry–academia collaboration, the principle of competition necessarily comes into play among private enterprises, and the manner in which this collaboration is managed becomes extremely difficult. In other words, the principle of competition may become a major obstacle to joint research. However, in the case of joint research projects with AIST, AIST acts as a hub and enterprises are able to collaborate with each other while their confidential information is carefully protected.

In particular, I am encouraged by the Tsukuba Innovation Arena and the Lithium Ion Battery Technology and Evaluation Center (LIBTEC). However, when drawing comparisons with overseas institutions such as Albany NanoTech in the United States and IMEC in Belgium, there is a strong desire in the industrial sector to see AIST grow in terms of budgeting and scale so that it can expand its areas of activity. Therefore, I strongly encourage you to look into expanding your functions and growing in scale.

Lastly, I would like to comment on the private use of AIST's research facilities. The private use rate is not so high, because of the shortage of technicians to manage and operate AIST's internal facilities. In that regard, training and expanding the number of research assistants, even as you continue working to add more researchers, is vital for making AIST's research still more robust and effective.

Takashi Shoda (Representative Director and Chairman (presently Senior Corporate Adviser), Daiichi Sankyo Company Ltd.)

First of all, with regard to the level of recognition for AIST, while I myself have of course known the name AIST for some time, it was not until I actually became a member of the Advisory Board that I acquired any real sense of the nature of its activities. Because AIST has been gaining attention in various venues, such as being awarded the Cabinet's Annual Merit Awards for Industry-Academia-Government Collaboration, it has perhaps become well known among persons in certain areas of research. However, I imagine that there are still areas where it is not very well known. Accordingly, while it will be necessary for AIST to further expand activities with those companies with which it already maintains close ties, I feel that the extent to which AIST develops new forms of collaboration with companies and academic institutions will become an important milestone in relation to name-recognition.

Additionally, with regard to AIST's Leading Engine program for Accelerating Drug Discovery (LEAD program), amid the present discussion of the Japan Medical Research and Development Organization by the country's Headquarters to promote Healthcare and Medical Strategy, I would like to see thorough discussions about potential applications of AIST's platform and technology, so that AIST's programs can be coordinated with the country's medical research and development strategy.

With respect to the manner joint research is conducted with companies and how to attract the serious interest of large corporations, I think that the approach will vary greatly depending on whether it takes place in a pre-competitive stage or in a competitive stage. For example, AIST participates in a number of technology research associations and I feel that these activities are in a pre-competitive stage. I believe that these technology research associations are extremely important, and that, utilizing these technology research associations to carry out joint research and to closely collaborate with their participants in the pre-competitive stage is always indispensable. However, only later on, when they reach a competitive stage, serious interest of large corporations will be elicited. I think that this would be the natural progression. I also think that, when setting forth the concept of joint research, it is necessary to organize things in such a stepwise fashion, and to carefully consider the sort of collaboration that will be most conducive to promoting the actual implementation in society.

Waichi Sekiguchi (Editorialist and industrial sector editorial member, Nikkei Inc.)

I think that the initiatives taken under President Chubachi to raise the level of recognition for AIST have been most appropriate, and that in the future they will need to be further strengthened. However, I feel that the issue is not simply whether AIST is known, but the level of recognition in the sense of companies that see AIST as a partner with which they can achieve things. I feel that, up to now, along with the pattern established since the time of the former Agency of Industrial Science and Technology, there has been a sort of barrier having to do with a high threshold, and the perception of a certain arbitrariness. Accordingly, raising the level of recognition will entail making efforts to remove this barrier.

In the future, I think that companies will need to cooperate in various areas, particularly in the fields of information and communication, and energy, in order to achieve standardization. However, because it is difficult for private companies to do this on their own, there needs to be an official body that can serve as an intermediary; this is where AIST has an important role to play. I believe it is necessary for AIST to demonstrate a presence as a forum for open innovation.

With regard to “plan, do, check, act” (PDCA), while this cycle is important in each subject of research, I think that PDCA in the research subjects of AIST as a whole is necessary. In other words, the reorganization of AIST’s portfolio of research subjects should be flexible. This is because, while sticking with a plan that has been formulated is important, I think that it is also necessary to have the perspective that, under certain instances, you might decide to switch to a different area, or to work out a different approach by combining one subject with another. As a member of the evaluation committee for one of AIST’s research institutes, the committee is evaluating whether the budget is being used appropriately, and whether appropriate results are being obtained within the scope of the institute. However, I do not feel that comparisons with other AIST units and evaluation of whether each subject ought to be pursued are being done. For example, when it comes to the area of big data or data science, Japan, having only just gotten started in these areas, is still virtually at the starting line. Therefore, I feel that these are areas that AIST might well pursue, and believe that there may be a need for a system that allows dynamic adjustments to be made, so that AIST can take up new areas as priority items while keeping work in areas where results have already been achieved.

I think that, while the change to viewing things in terms of “green technology” or “life technology” is very good, I would also like to suggest that rather than thinking in terms of organizations or the supply side, you become able to reorganize from the perspective of the demand side.

When considering ventures in terms of raising the AIST recognition level, if one or two AIST’s ventures became famous, I think AIST's current situation would be completely different. Therefore, while understanding that supporting ventures is not AIST’s primary mission, it still might be necessary to create a system that channels more energy in that direction.

Considerable efforts have been put into addressing the matter of diversity and I would like to commend you highly for your hard work in that regard. Regarding the target goal of increasing the number of female researchers to 15 % of the total or higher, it appears that good results have been achieved thus far. Going forward, while continuing these efforts, I urge you to raise your sights even higher so that, rather than focusing solely on numbers, you consider creating a path for qualified female candidates to enter positions of management.

Regarding career paths of PhDs, this is an issue Japan as a whole needs to address much more seriously. More specifically, while AIST’s research results achieved by accepting post-doctoral fellows are worthy of high praise, AIST must not become a post-doctoral fellow collection pan. I think that most of post-doctoral fellows who have joined AIST to date see this institution as their ultimate employment destination. However, going forward, rather than encouraging them to make AIST their final goal, you should motivate them to view their time here as a step in a process, with the ultimate goal of joining a foreign corporation or overseas university, entering a Japanese company or research institute, or joining a university faculty. Another important step is encouraging independence by starting ventures.

Thus, it is necessary to create these next steps, to build a cycle so that those who are able and willing to enter can do so, and those wishing to depart can leave. In other words, while entrance strategies seem to have been emphasized up until now, I would like to see you give some thought as to exit strategies as well.

Kyosuke Nagata (President, University of Tsukuba)

It is necessary for AIST to make major changes possibly by organization structure reform or decisions about the direction of research through budget allocation. However, various units or research fields of AIST have existed for a long time, and the efforts of these traditional areas are utilized, for example in dealing with the present Fukushima geological problems. Thus, it is not a matter of simply deciding where to scrap. While continuing to conduct basic research with minimum budgeting, it could be important to give thought on how to use remaining funds in a different manner.

In that sense, the establishment of the Fukushima Renewable Energy Research Institute, which was accomplished with great speed, is wonderful. This is a project undertaken in response to the voices of society, the country, and the region – all of whom have been striving for a way out of the present predicament. The institute is also an organization established by gathering people from so many different fields within AIST.

While AIST is politically neutral, taking on issues that beset the world and Japan is something that ought to be actively pursued. This is the reason for the basic research at AIST. However, while carrying out research in various areas and considering the measures that are presently required, AIST must also assess the needs of society and then apply its strongest efforts to those areas where there is a good match.

Only in this way will a means of introducing AIST-led industry initiatives appear. There are already instances where AIST is assisting with projects that companies want to pursue, and no doubt this will continue in the future. Thus, the way that I suggested would be the reason why AIST is AIST. When I consider the difference between AIST and companies and universities, AIST's strength is not limited to its political neutrality, so that efforts should be made to play a leading role in crafting directions for the flow of the country's budget.

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

The two themes of raising the level of recognition and better responding to the needs of industry and society can be thought of as two sides of the same coin. Regarding the first point, because any measure of change in future recognition levels must be based on the extent to which AIST is recognized at present, I suggest conducting a survey using a professional polling organization. In terms of the type of survey, rather than simply taking a recognition poll, it will be necessary to make a solid assessment of the expectations that people in various fields have for AIST.

While there will be considerable variance in the results between different research areas, and between research institutes and companies, it is important to recognize these diverse needs. Having various people actually observe, listen to, and become acquainted with the researchers is the fastest way to improve recognition levels. Inviting representatives of companies, educational institutions, research institutes, newspapers and other media, and technology analysts to an event – held perhaps once a year – to introduce AIST's results and exchange information would be one suggestion.

The second point concerns governance. While already making strides in this area, for a research body, an important part of opening technology through open innovation is to staunch the outflow of technical know-how.

My third point concerns joint research with companies. The amount of expenditures on research and development (R&D) per joint research project with companies is currently low. Indeed, the total of three billion yen per year in R&D funds that is contributed by companies is small when compared to overall corporate R&D spending, or to the amounts provided to universities for contract research. Thus, while more effort on the part of companies is necessary, it would also be desirable to see spending amounts of a magnitude higher. Since AIST is a national institute, it has the option of taking on R&D from more of a high-risk-high-return, long-term view that companies cannot afford.

Also, AIST should make efforts to coordinate applied research that combines a wide range of areas – beyond what any single company could undertake – and

thus attract attention from many different enterprises.

To attract companies, the basic approach would be to obtain patents that may be expected to yield world-class leading-edge practical applications in the future, which would later be transferred to private enterprises.

My fourth point concerns human resources. I am concerned about the decline in foreign researcher hires. In companies, generally speaking, there is a growing need to employ talented people from other countries, particularly those who have studied in Japan. More efforts should be made to hire people from abroad and, simultaneously, to increase the outward movement of people to other countries.

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

Concerning the specialized field that my company is involved in, my impression is that the LEAD project has an extraordinarily large impact. I always say that the success rate for drug discovery is the same as that of making a hole-in-one. In other words, it is that dauntingly low. Information on the genome emerged in 2000, led by efforts in the United States, and Japan has been keeping pace since then, and expectations have been for a drug discovery success rate better than one in 20,000. Later, I was extremely encouraged by the news of how AIST spent more than 10 years developing a method whereby it has become possible to increase the success rate through inclusion of a sugar chain factor.

AIST's LEAD project is world-class, and I heard earlier that it has the world's highest sensitivity in detecting sugar chains. However, with regard to recognition levels, this will eventually come down to whether this method gains currency globally. An improved level of recognition will truly hinge on the extent to which AIST's present resources can be evolved.

Next, with regard to human resources, speaking based on my experience, senior staff are extremely valuable in various areas. In the United States, my company is now conducting a clinical trial with a project leader that is

75 years old. This might seem surprising, but based on his prior experience and due to his unique way of thinking, he is truly without peer. In Japan, as well, we had a 75-year-old person complete a project. These examples speak to the need for viewing seniors as major assets.

In addition, the activities of women in our field are also impressive. In particular, women seem to have the highly meticulous disposition required for work in the area of cell systems, such as induced pluripotent stem (iPS) cells. Speaking generally, men tend to give up in the middle of something, whereas women have the tenacity to work tenaciously at something until they achieve success. I see this as an example utilizing women's aptitudes. In this light, identifying tasks where men and women excel respectively would lead to a new type of role division in each research field.

The work involving sugar chains was carried out over an extremely lengthy period, making this a research subject that could not be undertaken by an ordinary person. Frankly speaking, it would be beyond anyone but a highly eccentric individual. This might sound a little odd, but by eccentric I mean someone with outstanding abilities who possesses a perspective or outlook that is significantly different from others. Put in a positive way, this is foresight or vision, and those possessing such perspectives are, on the whole, eccentric. Accordingly, I feel that the hiring of such flexible individuals is important.

There is one person in my company who is an eccentric, but when difficulty arises, that person is the one most likely to solve any problem he tackles. My apologies for straying into such specifics, but these are important points to bear in mind when considering human resources.

Makoto Hirayama (Professor, State University of New York, United States)

Concerning the roadmap of Strategic AIST integrated R&D program (STAR), it does not contain what the goal is to be achieved, by when, and what will be the next step. Therefore, I wonder how you are going to determine your whereabouts on the roadmap.

I think you need to create a culture where you set clear goals and state how you are going to evaluate whether these goals are achieved or not. At my university, especially perhaps because it is part of the American culture, we are always asked by when something is to be done, and when it is not achieved, what will be the next step.

With regard to human resource training, there are a few things I would like to say. I have been in America for 11years now, and during that time many Japanese researchers have visited me. Their ability technologically and in their specialized field is just as good as any researcher. With some, I spend a few hours on a one-to-one basis in discussion, or some stay over 2 years at my laboratory doing research. Their problem, if any, is not their research ability or their technological knowledge but their personal manner.

There are quite a number of good researchers who do not know how to speak. Thinking of why they are the way they are, I realize that the fault does not lie with them alone. Being in their 30s, they have been influenced by their family background, school environment including university, and most of all, by their work environment. Perhaps, now there lacks a culture in Japan to say no to what should not be done.

It is good to train researchers as potential human resources, however we, as adults, also need to teach manners to those who lack them. If we do not do this, the young generation will not grow. This is what I would like to communicate to the young people of Japan, as well as to those of my generation and a little younger.

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

The key issue, number one, on the ways of industry collaboration is very interesting. I can see that you have catered the government's strategy into medium-term goals, and then a medium-term plan of AIST. We can see that there is a cascading of many national challenges into the research program of AIST, for example, you have come up with projects related to disaster recovery, nuclear waste, renewable energy, resurrecting the green innovation, and ageing society.

My first point of interest is, when you link up the government policy, the AIST enterprises, and the AIST researchers together, do you have any problems or difficulties in aligning enterprises' problems and goals with those of the government, and at least with those researchers in AIST? Have there been any difficulties in alignment? For example, in certain areas where you have a problem with a lack of researchers? Or, in the area that you have core competency but there seems to be a lack of interest in the private sector? Is there anything of a mismatch that you encounter during execution?

My second point of interest is about the way that you recognize or reward researchers and link up their success or career path with the goals of AIST. How do you get around this? Which kind of strategy that you use to align researchers' career path with what AIST would like to achieve.

Willie E. May (Associate Director of Laboratory Programs, National Institute of Standards and Technology, USA)

NIST and AIST are very similar organizations, and if I or my boss went to a small liberal arts university in the United States and asked that question, we might get a very similar answer. We would not be very disturbed at that that, because we realize, as has been alluded to, that you really need to structure your message for the audience you are speaking to. There is one audience that you have for, say the general public, and another audience that you would have to industry. You would also have a slightly different message to your legislators or the people who provide the funding for you.

I am basically in agreement with the

thematic areas that you have identified to focus on, but what is not clear to me is a clear articulation of the difference between the role and the work that AIST does in these areas versus what a world-class university would do, or the private sector. That is, if you are trying to message to your government, or at least to your funding agencies, or to the public, what is the clear unique benefit that AIST is providing, distinguished from a university or a private company.

You probably do this, but it has not been obvious in the things that I have seen, and that is an emphasis on the quality of research output and clearly articulating their impact on innovation and quality of life so that there is a value statement. In terms of metrics, there are many things that you can count. There is stuff that we count at NIST because we can count them. I am not sure if they are the best things to count, but one of the things that we count is that, at NIST, we have roughly 3000 federal employees, about 1800 of those are scientists and engineers. We have an additional 2800 people who work on our campus every day that are not NIST employees. Those are the people from industry, from other government agencies, from academia, or other foreign laboratories that come and work on problems with us because they value the research we do and they are interested. To us, that is always a valuable metric; the fact that we are working on areas that are sufficiently relevant that other people want to come and spend their resources to work on them with us.

Let me also commend you on the idea of establishing the user facilities. I think you will find that that is a very good way to relate to your industry. For example, back when the US government shut down a few months ago, we got a few comments from people that our website was down and people could not access to many of our Standard Reference Data outputs, such as our Chemistry WebBook. However, the greatest concern that we heard was from industry who were denied access to our User Facilities, (NIST Center on Neutron Research and Center for Nanoscale Science and Technology) While very important, it takes a while for the results of our more basic research to be missed. But being denied access to our User Facilities has an immediate impact.

Both very large and smaller companies use our facilities on a day-to-day basis, you might ask why IBM would want to use a NIST facility. You might wonder why very large multi national companies would find it very useful to use our facilities when they could certainly afford to purchase the tools that we have. It would be because we have a business model where we make sure we have the latest tools in there for them to use. So for a company like for example IBM, who might be trying to develop a new memory device, and would need to have access to a tool that costs, say, $5-6M, they do not have to go out and buy that until they come and demonstrate that actually the technology they are trying to develop will work, and this is the tool that they need. Then they can go back and do that investment.

I was not suggesting that all of AIST be a user facility. I was just suggesting that, for example, for NIST we have seven laboratory entities and two of those are user facilities. Of course, they conduct their own intramural research program, but they also open their facilities up to proposal-based research from industry, the private sector, and academia.

I think the notion of you having user facility that is open to the public you will find to be very valuable to you.

President Ryoji Chubachi

I would like to sincerely thank each of you for taking the time to participate in these discussions over many hours. I also appreciate your insightful views.

I would like to address a number of the opinions that have been expressed. First, in connection with raising the level of recognition for AIST, with regard to the recognition index, we are considering a variety of indicators, such as number of patent applications and the impact factor of published papers. I would like to consider dividing level of recognition into two groups: recognition among amateurs (ordinary citizens), and among professionals.

I think that I would like to carry out a level of recognition survey along the lines proposed by Mr. Bada.

Regarding AIST’s image, when explaining AIST’s activities, rather than explaining individual areas, we will use the term image or keywords when making an overall explanation of AIST, and then explain those activities using the Strategic AIST integrated R&D Program (STAR) as an example. It is extremely difficult to express what will have an impact on society by explaining individual areas of research. In response to setting a deadline that was voiced, I would like time to prepare an answer.

With regard to responding to the needs of industry and society, the current utilization of AIST by global corporations in Japan and around the world seems to be low compared with utilization by small- to medium-sized companies. In terms of numbers, of course, utilization by large corporations is higher, but the reality is that large Japanese corporations often follow a policy of self-sufficiency. Accordingly, this is an area where we need to work on in order to make further inroads. I, myself, am involved in doing business with the top managers of major corporations, but more communication is necessary.

Toward small- to medium- sized companies, we are now reaching out using AIST’s Full-fledged Research Workshops, but since these activities are limited to small- to medium- sized companies with which AIST already has ties, I would like to see us develop new relationships by reaching out to companies that we have not yet approached.

Regarding user facilities, rather than blindly responding to requests from the government or industry, we need to clearly define and promote the value of our available facilities. This is something that I want to clarify in AIST’s mission statement.

With regard to research at the Fukushima Renewable Energy Research Institute, I would like to express my gratitude for the extremely robust support backed with expectations. This research institute is invested with the aspirations of the people of the stricken prefectures, of Japan, and of the entire world. I would like to see everyone unite in working to respond to these aspirations and unerringly fulfilling our role.

I am also very encouraged by the comment about the need to transmit information based on scientific knowledge and evidence. It is clear that scientists cannot respond to the overall needs of society merely by acting within the bounds of their present capabilities. The world is watching us; therefore, we must continue striving to move forward while maintaining a sense of tension.

With regard to strengthening governance, we are now in the process of studying and identifying any risks to which AIST could be exposed. As part of this, regarding the outflow of technical know-how, the problem of how to match the activities of a global research institute tackling open innovation with the national interests of Japan is both crucial and extremely difficult. However, I would like to resolve this matter in a way that incorporates constructing systems.

I am keenly aware of the issues surrounding management of the regional research bases. Overall coordination is handled by the Research and Innovation Promotion Headquarters, but there are some areas where it is unclear whether something falls within the scope of work handled by the regional base director or by the research unit. I fully recognize the importance of this issue and will study ways of making improvements.

Toward AIST's fourth term, we have begun studying the character of the research that AIST ought to pursue. The fourth-term science and technology basic plan is characterized by a problem-solving format in which an integrated approach is taken, proceeding from basic research on through to applications. At the same time, there is a sense of apprehension from industry that problem-solving innovation will be emphasized at the expense of basic research.

However, as has been pointed out by members of this advisory board, while recognizing the importance of basic research, we are looking at the present orientation, which leans toward the application side, as appropriate. In addition, the work of fusing research together in ways that overcome disciplinary boundaries and brings out the full potential will be an issue taken up during the fourth term.

In their joint projects with AIST, private enterprises are cautious of overlapping with other companies. Therefore, with view to alleviating such concerns and forming collaborative ties, I believe that we need to make efforts to further improve communication.

With regard to technological research associations, we are now making efforts to ensure that no conflicts emerge in either the pre-competitive or competitive stages. For example, we have created a material evaluation platform in which we evaluate meterials of both manufacturer A and manufacturer B using a standard protocol, and then provide feedback. This gives both manufacturers the opportunity to hone their skills. However, it is necessary to carefully monitor the manner and extent to which companies are making use of this approach. While I am not yet confident about the degree to which companies presently provide us with topics that are truly crucial for their own future, I do expect that companies will increasingly provide subjects that are of a high degree of importance to their enterprises.

While AIST has IT groups, in reality it is difficult for IT to produce results unless it is combined with another group, such as drug discovery or transportation. With its base technology as its foundation, applications are built on top. From among AIST's six research areas, IT will be situated as a horizontal platform alongside such areas as geology, and metrology and measurement science, with applied fields such as environment and energy, and life sciences vertically integrated to these fields. In the future, I hope to maximize innovation by taking advantage of this novel vertical and horizontal integration, which I hope to establish during the fourth term, and which will entail the reorganization of our research units.

I believe that various questions are bound to arise in the course of following the PDCA cycle. "Is the organization system designed to fully reach its goal?", "Is there adequate funding?", "Do we have appropriate human resources"? I refer to these issues as the capability gap. Even with appropriate goal setting, we must, at all costs, avoid situations where we face capability gaps. For that reason, I am directing people to establish clear feasibility. In order to avoid situations where views or concerns are expressed but not followed up on, we need to thoroughly carry out the D (do), and then follow up with the C (check) parts of the PDCA cycle. I also hope to make further improvements on this basis.

Next, with regard to human resources, I completely agree that training researchers in terms of their overall character is important. In addition, the point about not being overly concerned about age is extremely encouraging, and we will carefully discuss the most appropriate approach to adopt during the fourth term.

With regard to technology succession, because universities like to try new things and are not mirrors of industrial organizations, there may be instances where difficulties arise in collaborating with industry partners. In that connection, at the Materials Fiesta in Sendai (temporary name) to be held in July, AIST will be joining forces with people from universities in Sendai, various companies, and representatives of the assembly industry which belongs to the final production process. In this fiesta, we plan to stress the importance of training human resources and of industry. Of course, one event alone will not be sufficient, so I plan to take every opportunity that arises to promote communication between the world of industry and the worlds of education and academia.

Lastly, I feel that this day of discussions by the Advisory Board members is an invaluable asset for AIST. I would like to take this opportunity to again express my appreciation to Prof. Hamada, who has served as the chair, and to all members of the board for sharing their earnest and constructive views.

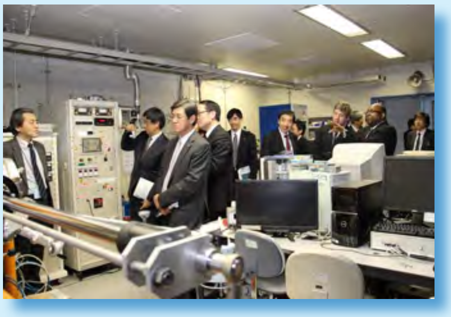
I intend to fully reflect your opinions in our daily operations, and in the fourth term, and look forward to your continued guidance and support.

Thank you all very much.

Inspection of research facilities was conducted in two groups

Inspections were conducted of six research projects, including projects of the STAR program, which is a new AIST initiative.

Course A



"Superlattice phase-change memories"
Nanoelectronics Research Institute

"Structural material diagnosis technology utilizing optical fiber sensors and digital cameras"
Research Institute of Instrumentation Frontier

"Development of technology to speed up drug discovery through use of sugar chains"
Research Center for Medical Glycoscience

Course B

"Drug discovery for treating neglected tropical diseases (NTD): International contributions through open innovation"
Biomedical Research Institute

"Hydrogeological structure and underground water system in the vicinity of the Fukushima Daiichi Nuclear Plant"
Institute of Geology and Geoinformation, Institute for Geo-Resources and Environment

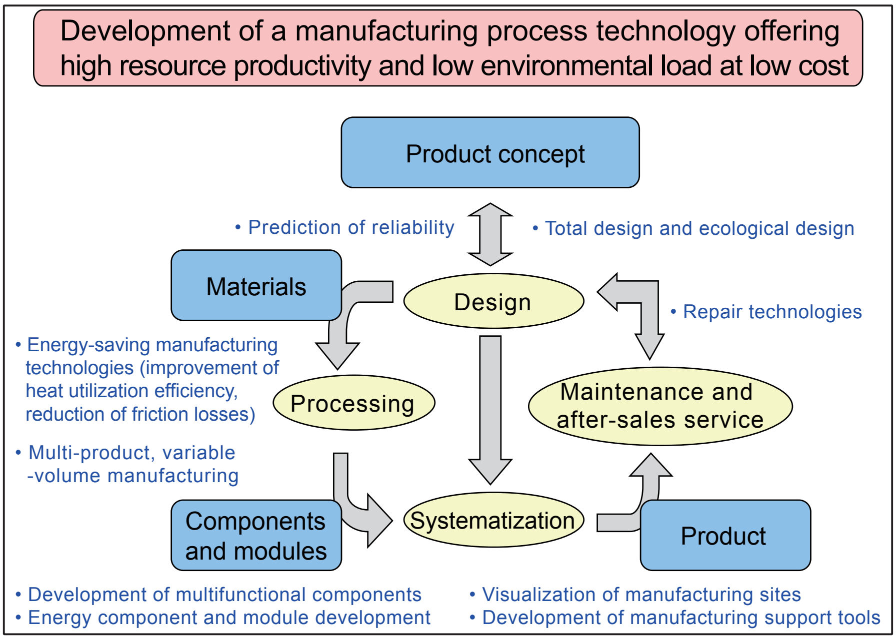
"Dynamic Optical Path Network"
Network Photonics Research Center

Recent Progress of Advanced Processing Technology

A Trailblazer in the Manufacturing Industries

The United States has recently boosted efforts to reconstruct its manufacturing industries, including the innovation of processing technologies, by setting up the Advanced Manufacturing Partnership.

In Japan, AIST's Advanced Manufacturing Research Institute (AMRI) has been promoting R&D with an emphasis on the fusion of manufacturing process technologies, such as materials technologies and processing technologies, since its establishment in 2004. The major R&D themes that AMRI has focused on include the design of entire systems ranging from production of parts and product functions to service life, the development of components and processes such as high temperature electroceramics and energy materials, and the evaluation of environmental loads. Through these R&D efforts, AMRI is helping to solve various problems in response to requests from the manufacturing industries and companies.



Cycle of R&D

AMRI intends to play a role as a contributor to the sustainable growth of the Japanese manufacturing industries by leading R&D activities centering around production process technologies (minimal manufacturing) to efficiently create products of "maximum functions and characteristics" with the "minimum resources," "minimum energy," and "minimum waste," amid the drastic changes surrounding the Japanese manufacturing industries and ongoing popularization of open innovation.

Director,
Advanced Manufacturing Research Institute
Masanobu AWANO

Recent Trends in the Manufacturing Industry

Major topics in manufacturing that have arisen over the past year or two include FabLabs, the "maker movement," and "3D printers (Additive Manufacturing)." At present, these technological developments in manufacturing are mainly being applied in the fields of private hobbies or accessory making, due to the integration of users, designers, and producers as a result of the global diffusion of high-speed internet services and the open release or production of design data by users themselves as well as the influence of on-demand manufacturing. In addition, some industrial products are applied in dental and aero-space fields. Although those movements will spread in many fields with new business models, we expect that segregation or coexistence will occur in terms of use, quantity, quality, and environmental load for the new and existing production technologies, rather than the total replacement of the old by the new. We also believe that the integration of those technologies, in which one balances or compensates for the advantages or shortcomings of the other, will also be an essential viewpoint.

AIST aims to realize a safe and secure society characterized by resource and energy saving through the development of a variety of processing technologies necessary to realize on-demand production systems for advanced industrial products. The keyword for the technologies described in this issue is advanced processing technologies. To be specific, in this issue we describe two approaches to 3D printer technology, particularly for metals, as a form of additive manufacturing and outline their future prospects. In addition, surface processing technologies designed to achieve low friction over the long term and to control wettability, as well as tube formation processing and hybrid processing technologies for medical applications, are also explained. There are high expectations that all of these technologies will make a great difference in the future as unprecedented "processing technologies creating new functions."

Deputy Director,
Advanced Manufacturing Research Institute
Naoki ICHIKAWA

Use of 3D Printers in Casting Technology

An outline of casting technology

Casting technology is a metal processing technique in which metal, such as aluminum alloy or cast iron, is melted and poured into a mold to produce metallic components with complicated shapes. Industries that make use of casting technology include transportation machinery, such as automobiles; industrial machinery, such as industrial equipment and construction machines; and the information and communication equipment industry. Although a large number of casting manufacturers have left Japan and relocated overseas, the casting industry is still active in this country centering around high-performance and high-added-value cast products that are difficult to produce in other countries. The cast products manufactured in Japan include engine cylinder heads, turbine casings, and automatic transmission hydraulic valve bodies that require high heat resistance, reliability, and durability; heat sinks that must have superior heat-dissipation properties, and propellers that need high strength and wear resistance.

One of the features of casting is that it can produce complicated shapes. Figure 1 shows an example of the casting process and its product. The casting system consists of the main mold, which forms the external shape of the product, and the core, which forms the internal shape. A molten metal is poured into the hollow part and left to solidify, thereby creating a cast product. The core is made of sand solidified with resin (binder). After casting, the core is allowed to collapse due to the heat of the metal. When the sand is broken away, the cast product remains in what was formerly the hollow part. Cast articles with various complex-shaped hollows, which cannot be made by other processing methods, can be produced by this process.

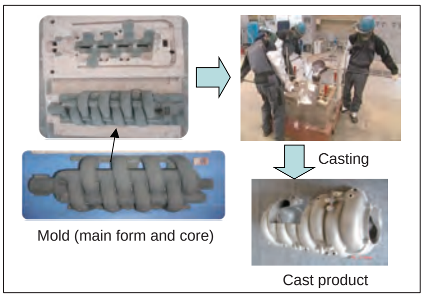


Fig .1 Casting process and product

Use of 3D printers in casting technology

AIST is currently developing a technology to produce castings of higher precision and performance by making casting molds of more complicated shapes with a 3D printer. Our focus is the type of 3D printer, based on ink jet technology etc., that solidifies only the sand necessary to form the desired 3D shape with a binder. Figure 2 shows the process.

Not only will this technology have the basic capability to form products with complicated shapes in an integrated manner, but it is also expected to offer a variety of advantages, such as (1) it can form castings using inexpensive binders and sand, without using expensive materials such as powdered metals; (2) it allows the composition of the metal, which is finally molded into the intended product, to be freely changed, as the metal casting process comes later; and (3) it realizes faster molding and production, as forming with a 3D printer involves no processes such as melting or solidification of metal.

If a casting company using the

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conventional technology newly introduces this 3D printer, the company will be able to take advantage of various benefits, as shown in Fig. 3. For example, a cast product that is conventionally formed from a combination of 22 mold components can be formed out of only four components as a result of the use of the 3D printer. As a result, a significant reduction in the prototype production time can be realized. Integration of the mold components greatly enhances the accuracy of the formed space of the mold, directly leading to higher accuracy, wall thinning, and performance enhancement of the castings. It also helps to improve the working environment and promote the employment of young personnel.

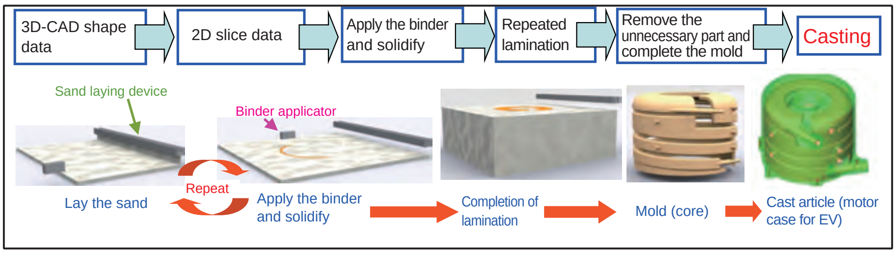

Fig. 2 Creation of a 3D sand mold by additive manufacturing

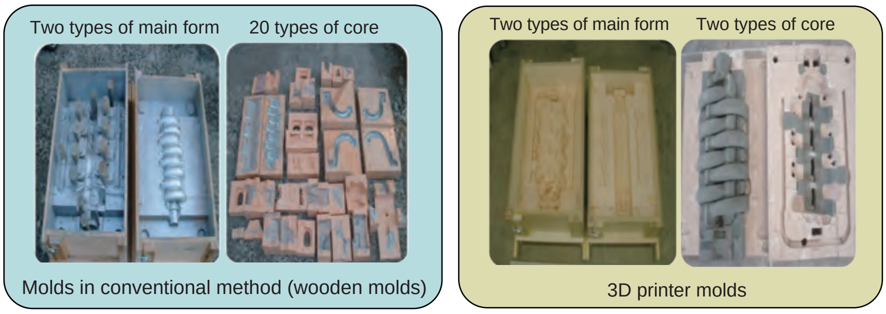

Fig. 3 Integrated production of molds by a 3D printer

Trial production of a motorcycle frame using a 3D printer

Figure 4 shows a cast article experimentally produced by a casting mold produced by a 3D printer through the joint efforts of a casting manufacturer, motorcycle manufacturer, automobile manufacturer, and university. In this trial production, the core was produced by the 3D printer. The thin wall filling technology of the casting manufacturer was used to create a cast article of one meter in size with average wall thickness of 2.5 mm. While the conventional technology produces parts by welding pressed parts, this technology realized a hollow, integrated, thin closed-shell structure and achieved a remarkable reduction in weight while maintaining sufficient rigidity.

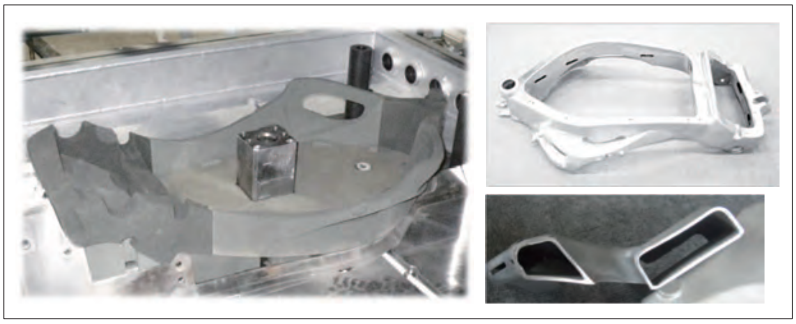

Fig. 4 Trial production of a motorcycle frame using a 3D printer lamination-formed mold

This technology is expected to find various applications including automotive components. In addition to the weight reduction of motor vehicles, it is expected to reduce injection molding cycle time by introducing optimized passage of cooling water in a die, enhance the power generation efficiency of products such as turbines and water wheels, and achieve downsizing and efficiency enhancement of diesel engines and electric vehicle motors.

There are, however, still many issues to be solved. Major hurdles to be overcome include increasing the speed of the 3D printer, and the casting of metals with higher melting points such as cast steel or titanium alloy with the 3D printed mold. We promote R&D to realize a mass production technology using 3D printers taking these issues into consideration.

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Production of New Components by Metal Additive Manufacturing Technology

Introduction

The production of components using metals is a fundamental aspect of modern industry and has been developed through a long history of human activities. Formerly, the major basic operations of processing were trimming of materials such as by cutting or grinding, and changing the shapes of materials by pressing or casting. Now additive manufacturing (AM), which builds up materials according to 3D-CAD data, has been newly added to these processing techniques. Thermal spraying and overlaying are among the specific techniques of building-up type processing. AM, which creates a shape as denoted by the design 3D data, is rapidly gaining ground in the market as a 3D printer technology, mainly in the field of resin molding. Among the specific techniques of AM, the molding of metal materials is attracting considerable attention as a direct production technique for components. The following is an outline of this method of metal component processing.

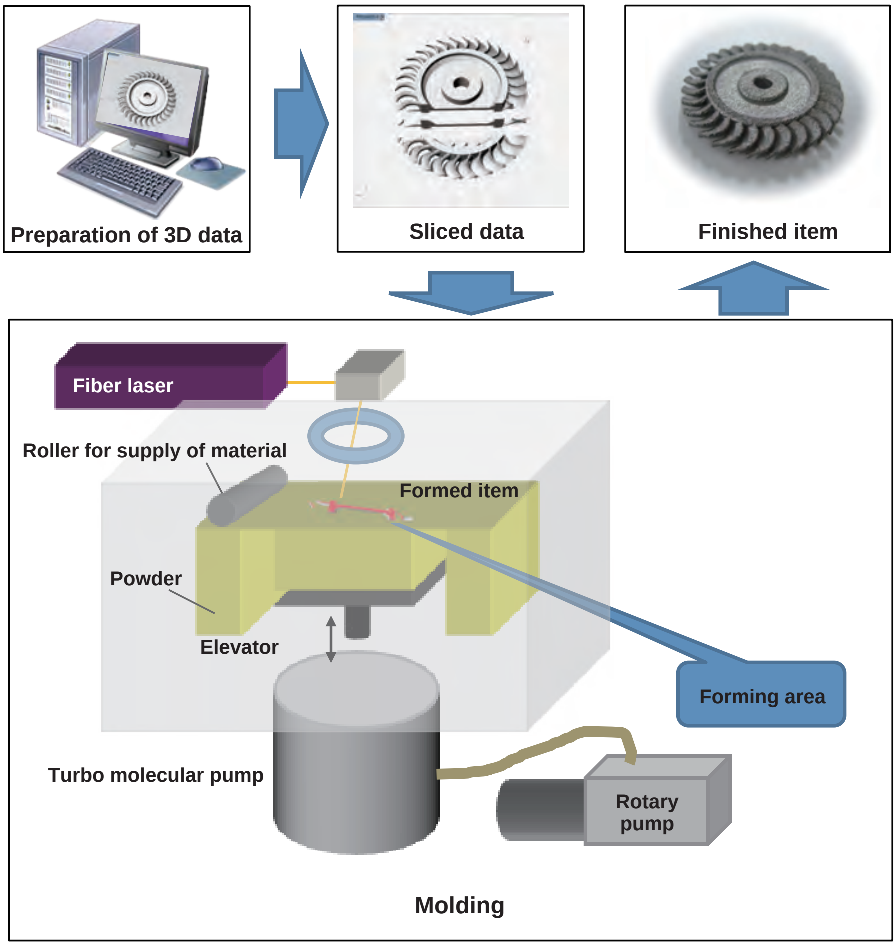

Fig. 1 Process of AM
3D data are sliced to match the thickness of the molding, and the spread powder is melted by a laser. Forming progresses layer by layer to create a 3D shape.

Features of AM

AM is referred to as the "third processing method." It is the third because there are two predecessors: one comprising the processing of an article by trimming the material, such as by cutting or grinding, and the other by pressing or casting, as mentioned above. AM creates a structure by applying a material bit by bit to the necessary part. In AM of metals, a raw material in powder form, pulverized to particles of 20 to 100 μm in diameter, is spread in a single layer; data created from 3D data, such as by 3D-CAD, finely sliced to the same thickness, are used; and a processing beam, such as a high-energy laser and an electron beam, is irradiated to the part that is to be formed into the desired shape for melting and subsequent solidification, as shown in Fig. 1. When this process is repeated to laminate the material to the necessary thickness, the final desired shape will be formed. Through this process, AM can create an article composed of two different structural features, such as a porous body and a dense body; an article with a structural shape that cannot be accessed by cutting tools; or an article with a nested structure that cannot be assembled.

Despite these great advantages, AM has its own disadvantage in that the method of sequentially accumulating a

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powdered material in a solidified state itself faces limitations and problems in terms of processing. For example, it is impossible to form a layer thinner than the diameter of the powder particles, and the tier shape will necessarily be build up in the height direction. For these reasons, AM cannot ensure a level of accuracy higher than the size of the raw material powder in the lateral direction. The smaller the powder diameter, the higher the precision that can be attained. This solution, however, inevitably increases the number of laminated layers. Since the amount of time for forming is proportional to the number of layers, the forming time doubles when the diameter is halved and the number of layers doubles. In addition, since AM involves melting and sintering with a processing beam, the place where processing takes place becomes the size of the spot diameter of the processing beam. When a large item is produced, the material is melted and solidified to mold each and every part of the item, which takes a longer time to form the shape of a single layer. The place irradiated by the processing beam is instantaneously heated up to the temperature that melts the metal, but the temperature drastically drops once the beam moves away. Thus, the process of AM results in a high thermal load at the local spot, which inevitably causes large thermal strain. The larger the product, the more difficult its processing becomes. It is therefore necessary to simultaneously perform thermal treatment to prevent warping. In addition, since metals are highly reactive and are oxidized when formed in the air, the product may fail to achieve the desired level of quality.

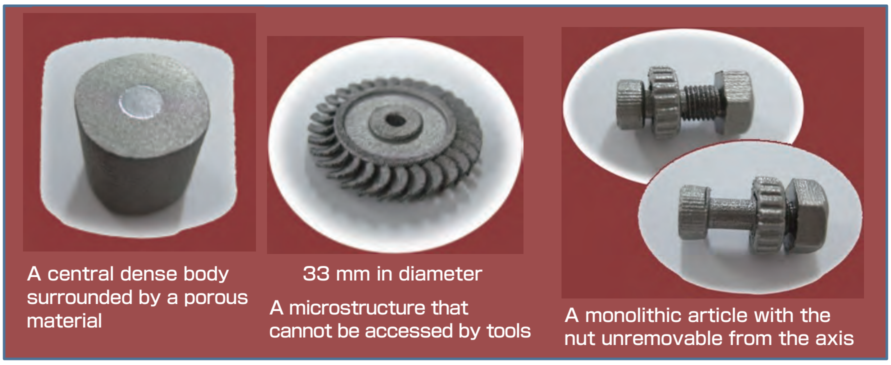

Fig. 2 Example of metal AM
From left to right: A combination of a porous body having multiple holes with a dense body, a fine 3D-shaped part that cannot be accessed by tools, and an inseparable monolithic part

Powdered metal materials can also self-ignite. Consequently, processing must be carried out in an inert gas atmosphere or in a vacuum, with strict management.

Prospects for metal AM

Considering the safety and management aspects described above, metal AM will mainly be used at production sites for the time being. AM is advantageous for the production of articles having a minute structure because of its characteristics. Further technical improvements, however, are required when larger items tending to cause strain or items with a higher molding cubic volume are produced. On the other hand, AM is a very effective method for producing highly complicated items that cannot be produced by other processing methods; that is, complicated structures unlikely to be affected by strain, such as porous structures and lattice structures or products, as well as nested structures and structures that allow no access of tools. The fact that these shapes cannot be created by conventional processing methods has restricted their availability. Hence, the best way to utilize this new technology of AM is to take advantage of its ability to realize products with a greater level of design freedom and apply it to the creation of products with new and advanced functions. When it comes to the structures of objects newly created by AM and how to use these new structures, we need to conceptualize what new structures we can create from AM and how to apply them from the ground up. Since it is considered difficult for a single company to solve such problems, AIST is ready to provide support and consultation services in this area.

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Shizuka NAKANO
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New Horizons of Manufacturing Technology Opened Up by 3D Printers

Have you heard people say, “You can make anything with only a single 3D printer” or “3D printers eliminate conventional fabrication technologies”? Such descriptions seem to come from imagination of an ultimate 3D printer. At the moment, 3D printers cannot reach that level because of various restrictions in terms of materials and throughput. However, they can make monolithic objects or parts with complicated shapes and structures that cannot be made by the conventional manufacturing method, in a single process.

Incidentally, have you ever wondered, “How is the glass marble put in a *ramune** bottle?” The answer is that the bottle is first made with a larger opening, a glass ball is inserted inside it through the mouth, and the opening is then heated and narrowed. The key point here is that the people who first created the *ramune* bottle knew glass forming techniques, envisioned the process of how to make it in advance, and designed the bottle.

When something new is made, the designer selects the material and determines the shape to realize the function required for the purpose. Simultaneously, the designer generally thinks about how to make the new object and whether it can actually be made or not, because it is nonsense to design an unrealized shape. In reality, however, this places a limitation on the mind of the designer. Physical impossibility is one aspect, and the cost or productivity can also be reasons for a designer to give up the ideal material or shape.

Figure 2 shows a sample object made by a 3D printer. It has three spherical shells arranged in a nested structure, which is made in a single process without any assembly or joint. Figure 3 shows an ivory mystery ball, a traditional type of Chinese ivory carving. This example contains 12 balls, one inside the other, with the outermost ball forming a celestial sphere. It is made by hand-carving, and some of them take two years to be completed. What if machine work should be used to create such a structure? It is not a practical design when judged by conventional wisdom. The use of a 3D printer, however, can realize a dream design that has never been materialized before.

Conventional design concepts will undergo major changes when the advantages of 3D printers are applied; namely, shapes and structures only 3D printers can make, rapid manufacturing without molds for personal customization, and their design capabilities beyond the conventional norms. Recently, some 3D printers for metal parts have been developed and practical-level aerospace components and prostheses are being produced . With its ability to materialize designers’ ideas for novel functions, 3D printers are expected to bring about a revolution in manufacturing technology. Technical developments are being progressed to realize the full-scale application of the technology.

Ingenious Micro-Manufacturing Systems Group
Advanced Manufacturing Research Institute
Kiwamu ASHIDA

Fig. 1 A *ramune* bottle with its glass marble stopper

Fig. 2 A triple spherical shell produced with a 3D printer

Fig. 3 A Chinese ivory mystery ball (ivory artifact)

Glossary

**Ramune* is a Japanese carbonated soft drink whose name is derived from the English word *lemonade*. It comes in a unique type of bottle with a narrow opening, which is sealed from the inside by a glass marble stopper held against the mouth by the pressure of the gas contained in the *ramune*. See Fig. 1.

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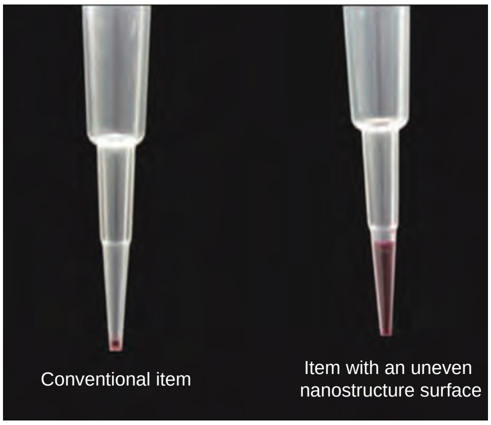
Control of Wettability of Plastic Surfaces by Uneven Nanostructure and Its Application to Disposable Items

Deployment of wettability control technology

Wettability control technology is an important technique used in product manufacturing in various fields. A typical method of wettability control involves the application of a material with a hydrophilic (water-attracting) or hydrophobic (water-repelling) property to the surface of a product. Recent analysis of the hydrophilic or hydrophobic functions of animals and plants has revealed the possibility of controlling wettability by artificially controlling the surface shape. There is an active movement toward the development of practical products using this wettability control technology. Our goal is to downsize the surface shape to the nanometer level and develop new functional devices that fuse nanostructure-based wettability control with nanostructure-based control of specific optical characteristics. We are also engaged in developing a simple, low-cost manufacturing technology necessary to industrialize such devices.

Characteristics of nanostructure transfer technology

Our newly developed nanostructure transfer technology uses a large-area die in which an uneven nanostructure is formed. By transfer-molding from the die, the nanostructure can be formed on the surface of a plastic substrate. This technology can therefore hydrophilize a hydrophobic plastic substrate. By achieving this through a single transfer-molding process, it becomes possible to create components with a large area and, by reducing the number of production processes, hydrophilize hydrophobic plastic surfaces at a low cost. As the wettability of a microscopic area, such as that of a contact angle meter, is reduced with the addition of an uneven nanostructure due to its lower surface energy, a plastic substrate with such a nanostructure shows higher hydrophobicity than a flat surface, and the hydrophilizing phenomenon will not occur on such a substrate. On the other hand, when an uneven nanostructure is realized in conjunction with the nanostructure transfer technology, the wettability of hydrophobic plastic substrate surfaces can be improved. Moreover, because the nanostructure is smaller than the wavelength of visible light, transparency is ensured.



A disposable item whose surface has an uneven nanostructure created by nanostructure transfer molding technology (surface tension: capillarity measured for a 70 mN/m droplet)

Application to disposable items

With our new technology, an uneven nanostructure is created on the surface of a die used for a disposable article (see the figure) and the article is produced by injection molding alone. The plastic surfaces of conventionally produced disposable products have poor wettability, reflecting the difficulty of the capillary phenomenon occurring by conventional molding alone. In contrast, disposable items whose plastic surface has an uneven nanostructure have improved wettability, and the capillary phenomenon can occur simply by molding. Furthermore, since transparency is assured by that fact that the nanostructure is smaller than the visible-light wavelength, it is possible to visually observe the state of a droplet inside a disposable item. As this technology makes it possible to omit certain production processes, such as hydrophilic coating of components that are required to have water-attracting properties, we believe it will contribute to the reduction of costs and enhancement of functions in the manufacturing field.

Large Scale Integration Team
Research Center for Ubiquitous MEMS and Micro Engineering
Kazuma KURIHARA

Friction Reduction by a Nanostripe Structure

Energy loss due to friction and wear

Friction and wear are among the most familiar physical phenomena that occur in our daily lives. For example, we would not be able to stand up or walk without friction. Since friction is a force that prevents movement, it impedes the efficient use of energy. Reducing friction is therefore an extremely important issue for energy saving. Various techniques for friction reduction have so far been proposed. Forming a micro-asperity on the surface (surface texturing) is one of the effective techniques for this purpose. Surface unevenness produces an effect of oil-retaining or hydrodynamic effect and improves friction characteristics. When wear occurs on the frictional interface, its micro-asperity gradually disappears. Large scale asperities formed on the surface is less likely to disappear, but the larger the unevenness, the poorer the friction characteristics become. Small scale asperities, however, can easily disappear by wear. In order to prolong the effect of surface texturing, it is necessary to develop a technique that forms a micro-structure over a wide area and creates a micropattern that will not disappear by wear.

Concept of the nanostripe structure

How do we make a micropattern that will not disappear by wear? The solution comes from a combination of existing techniques. Assuming that the friction surface becomes worn, the solution is to create a surface in which the same pattern always appears even when the surface is worn. As shown in the figure, a micropattern is formed on the surface of the substrate in advance, and two types of layers with different materials are deposited on the surface to create a multilayer film structure. Then, initial wear or grinding causes the cross-section of the multilayer film to appear on the surface. Since wear rate varies according to the material, a pattern that corresponds to the thickness of the layers should be formed on the surface. Controlling the thickness of the layers on the nanometer order allows us to form a pattern of nanometer scale. As the pattern prepared in this way is always regenerated despite the progress of wear, the original frictional characteristics should remain unchanged for a long duration.

Effect of friction reduction by the nanostructure

We conducted friction and wear tests using various combinations of materials. As a result, the combination of silicon carbide with carbon was found to be excellent in friction and wear characteristics. The current subjects being addressed toward application of this technology to sliding bearings include optimization of the micropatterns, confirmation of their adhesion with the substrate, verification of durability by means of a large-scale sliding test, and techniques for the coating of curved surfaces.

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Advanced Manufacturing Research Institute
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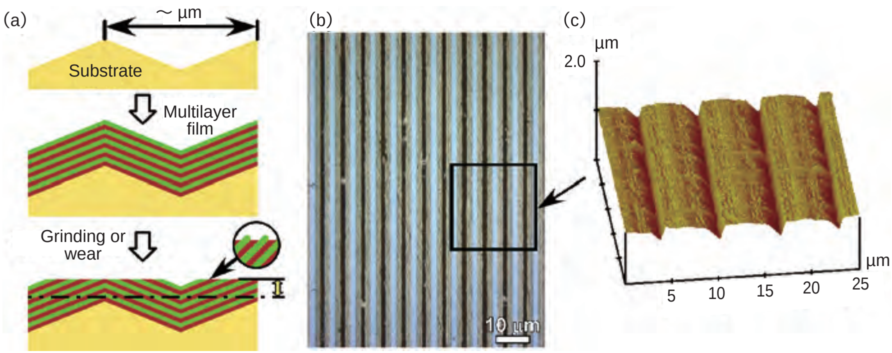

(a) Concept of production of a self-replicating nanopattern structure, (b) laser microscopic image of a prepared nanopattern structure, (c) AFM image of the nanopattern structure

Development of Laser Processing Technology and Equipment for Capillary Tubes for Expected Application to Medicine

Development of laser and electrochemical complex machinery for capillary tube processing

Expectations are being placed on the realization of a technology to process capillary tubes thinner than a hair into complicated shapes, for application to catheters and stents for brain surgery and to devices for endoscopic operations. Various problems are encountered with the conventional technique, including interference between the tube and the tool and the inability to ensure precision of the processing position because of deformation of the tube due to the force applied when holding or processing it. The inability to precisely hold capillary tubes has been a common obstacle in the processing of complicated microscopic shapes.

AIST has developed a laser electrochemical complex machining machinery capable of processing capillary tubes at high speed, with high precision, and with a low environmental load. This equipment, shown in Fig. 1, uses laser processing, a non-contact processing technique. Since the new technology employs the same laser light source for processing and measurement, it can measure and process in the same position, correct errors that may occur from holding of the tube such as deviation of the rotational center of the tube or slanting of the tube, and irradiate the laser accurately to the exact position for processing. The technology is also designed to remove burrs created by laser processing and smooth the tube surface by microscopic electrolytic processing, allowing the processing of complicated shapes to be achieved for very small stainless steel tubes of 90 μm in diameter (40 μm in inside diameter) for the first time in the world.

Development of low-heat-impact layer processing technology and DEEL complex machining technology

While we can process capillary tubes to microscopic shapes with the laser electrochemical complex machininery, when we want to process articles of higher quality, we face an inevitable issue of laser processing, which is a type of heat processing. Specifically, as the metal is melted and resolidified by the laser during this process, the resolidified material causes problems. In the case of stents, in particular, resolidified matter on the inside of the capillary tube becomes a fatal defect.

AIST developed Deep Electrochemical Eetching with Laser assistance (DEEL) complex machining. This is a new microscopic metal processing technology that mostly eliminates the generation of resolidified materials by repeatedly removing materials by means of electrolytic processing as well as removing passive films generated by electrolytic processing mainly by means of laser processing. As shown in Fig. 2, we have been able to dig a groove of about 30 μm in width and about 300 μm in depth with DEEL complex machining. It has been confirmed that almost no resolidified materials exist on the surface.

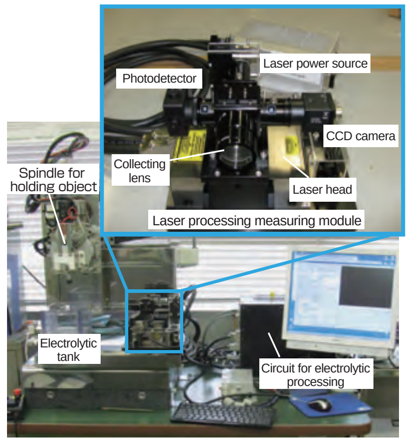

Fig. 1 Laser and electrochemical complex machinery

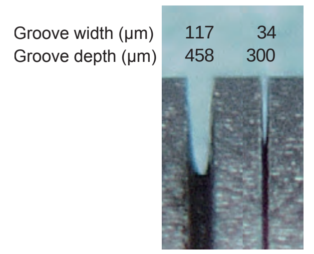

Fig. 2 Result of DEEL complex machining

Future prospects

We intend to commercialize a capillary tube microprocessing device with extremely small generation of resolidified material and to develop capillary tube devices for medical applications by clarifying the processing phenomena of the newly developed DEEL complex machining technology, optimizing its processing conditions, and utilizing the device technologies obtained through the development of the laser electrochemical complex machininery.

Ingenious Micro-Manufacturing Systems Group
Advanced Manufacturing Research Institute
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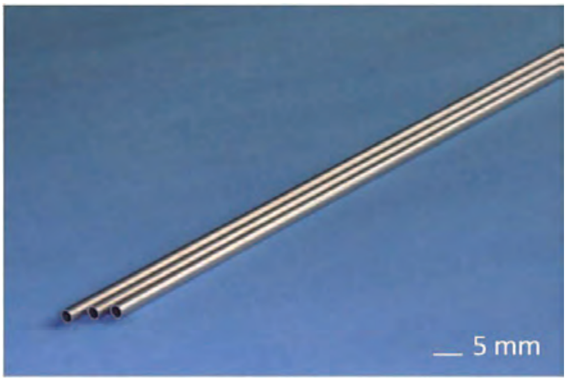
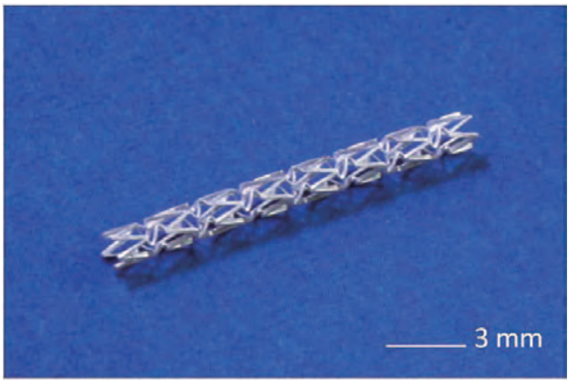
Long, Thin-Wall Capillary Tube Fabrication Technology for Biodegradable Magnesium Alloy Stents





Newly developed long magnesium alloy stent tubes (above) and the magnesium alloy stent made from such a tube (below)

Biodegradable magnesium alloy stents

The stainless steel bare metal stents (BMS) used up to now in the treatment of angina pectoris and myocardial infarction generally remain in the treated blood vessel permanently. However, restenosis (renarrowing of the blood vessel) caused by such permanent placement is a major problem to be solved. When a medical agent that inhibits cellular growth is applied to a BMS, the risk of restenosis is greatly reduced. On the other hand, this may create another problem; namely, side effects caused by thrombosis inside the stent. There is a magnesium alloy stent that is designed to decompose and be absorbed in the body after a certain length of time. This stent disappears after the diseased part is healed, and is expected to solve the problems caused by long-term placement of stents inside the body.

Development of a long magnesium alloy stent tube

Although a stent tube with a wall thickness of 150 to 200 μm is indispensable as the base material for the development of new stents, magnesium alloy is very difficult to work because of its poor room-temperature deformability. Furthermore, it is essential to develop a long stent tube, of more than 1 m in length, with high dimensional precision on the micrometer order, to ensure sufficient quality, performance, and productivity of the stents. To meet these needs, we are researching a technology to fabricate long, thin-wall capillary tubes made of magnesium alloy by means of plastic forming. In concrete terms, the principle is to process magnesium alloy billets into long capillary tubes by hot extrusion followed by repeated cold drawing and heat processing to form the final shape. The newly developed stent tube has an outside diameter of 1.8 mm, a wall thickness of 150 μm, and a length of more than 1 m. By optimizing the die shape and processing conditions, we have been able to control the inside and outside diameter error to within 0.5 % and the wall thickness error to within 5 %.

Future prospects

We plan to investigate alloy combinations that allow the functions of a stent to be sufficiently maintained for a duration of three to six months until the vascular endothelia are formed, work on the development of long stent tubes using such alloys, and demonstrate the effectiveness of the magnesium alloy stent through animal experiments.

Low-Formability-Materials Processing Group
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Research Hotline

UPDATE FROM THE CUTTING EDGE

Apr.-Jun. 2014

The abstracts of the recent research information appearing in Vol.14 No.4-6 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

Artificially designed and created luciferase

Approximately 100 times brighter than existing world-bests

We have created superluminescent luciferases with artificial design, exerting greatly prolonged bioluminescence. We have studied *de novo* luciferases derived from luminous plankton (copepods), where we aligned the amino-acid sequences of a variety of existing copepod luciferases in public databases and extracted frequently occurring key amino acids, which thermodynamically stabilize the whole sequence. Considering that the *de novo* luciferases are genetically highly unique compared to any existing luciferases, they were named artificial luciferases (ALuc™; trade mark of AIST). ALuc are up to 100 times brighter than conventional world-bests and exhibit excellent luminescence sustainability (half-life: 20 minutes). The created ALuc is advantageous over any conventional luciferases in terms of enhancement in sensitivity, reduction of the measurement time, and light permeability in the tissues of living organisms, indicating merits as an excellent luminescent marker for basic research in life science and applications to medical and environmental diagnoses.

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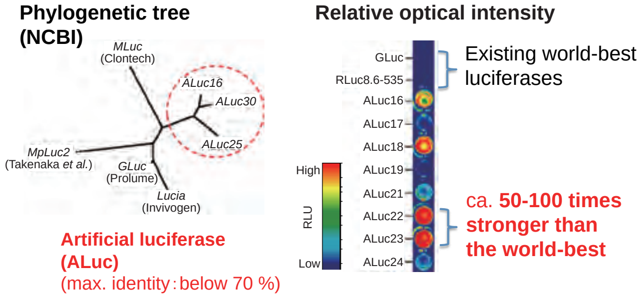
AIST TODAY Vol.14 No.5 p.14 (2014)



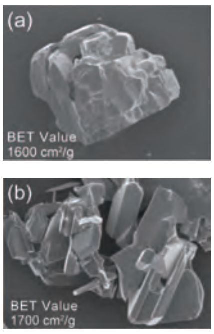
Comparison of artificial luciferases (ALuc) and conventional world-best luciferases

Powder raw material for SiC bulk single crystal growth developed to realize high sublimation rate

Possible to significantly improve the growth rate to about twice the current rate

We have developed high purity SiC powder as a raw material for the sublimation method capable of high-speed growth of silicon carbide (SiC) bulk single crystals for power semiconductors. The developed SiC powder has a particle shape capable of improving the growth rate to about twice the current rate without greatly changing the temperature condition in the current manufacturing process. Utilizing the gas permeability of the powder, sublimation gas from the SiC powder raw material can be easily released. Only the replacement of the conventional SiC powder raw material with the developed one enables high-speed growth of SiC bulk single crystals and thus enables cost reduction and process simplification due to time reduction in the high temperature process. In addition, this powder manufacturing method was developed by improving the Acheson method, which is a mass production technology for conventional SiC abrasives, featured by higher purity and higher mass production characteristics.

Enlarged photographs of (a) Acheson powder and (b) developed SiC powder having almost the same specific surface area (BET value)



Sample name	True density	Specific surface area (cm^2/g)		Sublimation ratio (%/h)
		BET method	Blaine method	
Acheson method	3.08	1600	280	8.1
Developed SiC powder	3.02	1700	540	17

True density, specific surface area and sublimation characteristics of each powder shown in Figure (a) and (b)

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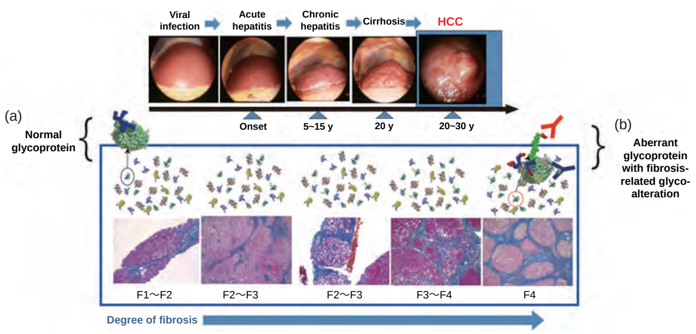
AIST TODAY Vol.14 No.5 p.15 (2014)

Simple and accurate liver fibrosis measurement system with a glyco-diagnostic agent

Evaluating the degree of liver fibrosis in patients with chronic hepatitis B/C using a fully automated immunochemistry analyzer.

We have completed the development of a glyco-diagnostic kit for the direct measurement of fibrosis adopting a doughnut-shaped and heavily glycosylated macromolecule, Mac-2 binding protein (M2BP), as a target glyco-biomarker. This molecule has a unique feature, which led us to pick it up from huge numbers of candidates assigned through glycoproteomics-based biomarker search. The diagnostic utility of M2BP is greatly owing to the favorable density and orientation of the disease-related glycans on the homomultimer resembling a "sweet-doughnut" covered with plenty of sugar of interest. We therefore selected the most robust lectin using a microarray-based method with a unique subtraction process. Subsequent biochemical studies indicated that the interaction between the resultant *Wisteria floribunda* agglutinin and the sweet-doughnuts was remarkably strong and specific, so that we could develop the rapid (17 min) and highly sensitive assay realizing "on-site diagnosis". The validation study is currently on-going, in which the assay of sera from more than 5,000 patients from 15 clinical sites has been finished so far.



Quantitative alteration of a glycoprotein isomer with fibrosis-related glycosylation change

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AIST TODAY Vol.14 No.6 p.14 (2014)

Development of high-density capacitor embedded interposer

It contributes to realizing miniaturization and reducing power consumption of a high performance electronic information device.

We have developed a new chip capacitor embedded interposer using a narrow gap chip parts mounting technology. This interposer is expected to reduce power distribution network (PDN) impedance. To investigate the efficacy of the interposer, we have fabricated other various types of capacitor embedded interposer test element group (TEG), such as a general chip capacitor embedded organic interposer, a thin film capacitor on a silicon interposer using the same design. We evaluated PDN impedances of decoupling capacitor embedded interposers for a 3-D integrated LSI system by using a developed ultralow impedance evaluation system. As a result, the chip capacitor embedded interposer shows a low PDN impedance that could be evaluated at the frequency range of up to 10 GHz. This indicates that the developed interposer shows a comparable level of PDN impedance as the thin film capacitor embedded silicon interposer.

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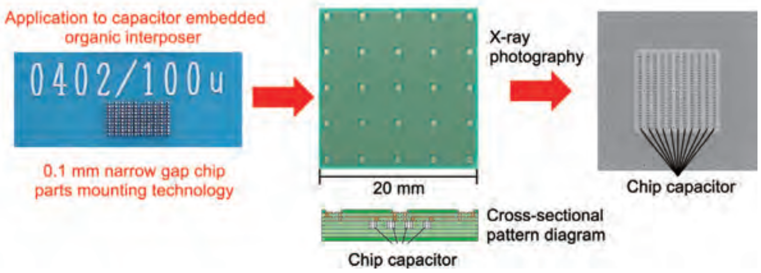

Figure decoupling capacitor embedded interposers using narrow gap chip parts mounting technology

Development of highly sensitive spin torque diode

Accelerating the applications of spintronics devices to IC tags or car radars

We have developed highly sensitive spin torque diode using a nonlinear effect. In 2005, we invented a spin torque diode by combining the large magnetoresistance effect of magnetic tunnel junctions (MTJs) and high-frequency spin precession induced by input microwave current. Because of the small spin precession, the diode sensitivity was much smaller than that of conventional semiconductor diodes. In this study, we adopted a new layer structure of MgO tunnel barrier/FeB free layer/MgO capping layers into MTJs. By manipulating the magnetic potential of the FeB layer we obtained the nonlinear effect in the MTJ. Due to the nonlinearity, spin precession was amplified greatly and the detection sensitivity of the microwave current became about three times higher than that of the semiconductor diodes. Because of the high sensitivity, small size, high frequency agility and tunability, the spin toque diode will be applied to high-frequency electronics such as communication devices, IC tags and car radars.

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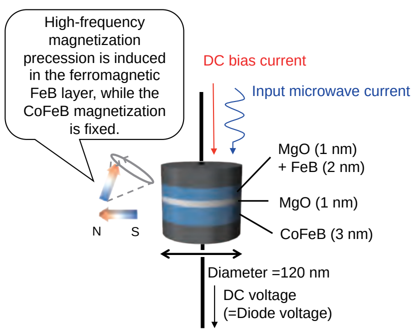
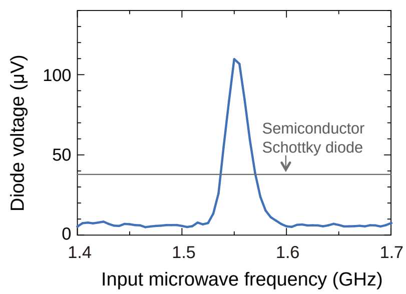


A schematic illustration of spin torque diode

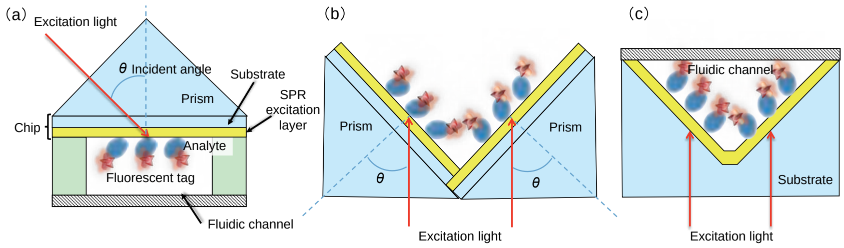


Spin torque diode spectrum
Power of the input microwave was fixed at 0.01 μW (microwave current of 4.8 μA) and DC bias current was fixed at -0.3 mA. Peak frequency corresponds to the ferromagnetic resonance frequency of the FeB layer.

A microfluidic channel for detection of low-concentration biological substances

Simple mechanism and easy operation realized by integrating a microfluidic channel and optical systems

We have developed a biosensor system with both high sensitivity of surface plasmon resonance fluorescence (SPRF) and easy operability of a microfluidic channel. The microfluidic channel has a V-shaped cross section, so the sensor was named “V-trench biosensor”. The V-shaped channel works as an optical prism for induction of surface plasmon resonance (SPR). By forming an SPR excitation layer inside of the channel and illuminating the layer under an appropriate condition, the SPRF phenomenon is induced. As a result, the V-trench biosensor can detect target biological substances with high sensitivity by enhancing light signals from fluorescent dye attached to the target substances. The sensor also has a distinctive feature of having the optical system aligned in a straight line, which makes the system very simple. In addition to enabling more accurate diagnosis at clinical sites, the sensor is expected to contribute as a biosensor for daily health management.



(a) Conventional optical system for SPRF excitation
Detection chip is affixed to the bottom of the prism; fluidic channel is bonded to the surface of the detection chip for measurement.
(b) Conceptual diagram of V-trench biosensor combining two conventional prisms to be rotated and assembled, at the time of its conception
(c) Cross section of the developed V-trench biosensor chip

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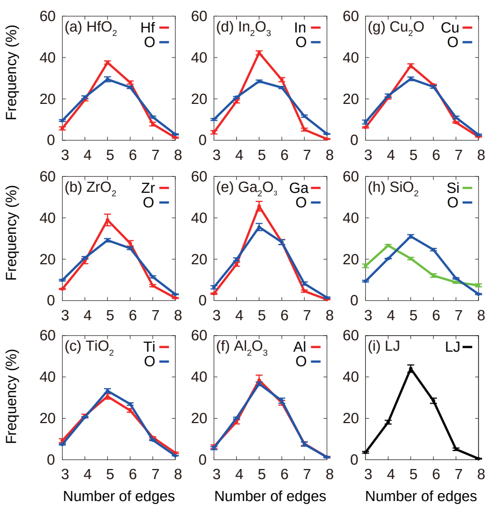
AIST TODAY Vol.14 No.6 p.15 (2014)

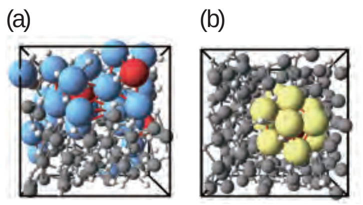
Universal medium-range order of amorphous metal oxides

Expected contribution to the rational design of insulation films, transparent electrodes, etc.

We proposed that the structure of amorphous metal oxides can be regarded as a dual-dense-random-packing structure, which is a superposition of the dense random packing of metal atoms and that of oxygen atoms. Our ab initio molecular dynamics simulations show that the medium-range order of amorphous TiO_2, ZrO_2, HfO_2, Cu_2O, Al_2O_3, Ga_2O_3, and In_2O_3 is characterized by the pentagonal-bipyramid arrangement of metal atoms and that of oxygen atoms, and prove the validity of our dual-random-sphere-packing model. In other words, we found that the pentagonal medium-range order is universal and independent of the type of metal oxide.



(a) to (g) distribution of the number of edges in a Voronoi face of metal and oxygen in the amorphous metal oxides
For comparison, results for (h) amorphous SiO_2, and for (i) an amorphous structure, in which particles interact through Lennard-Jones potential, are shown.



Icosahedral arrangements in amorphous Al_2O_3 obtained by the first-principles calculation
Large colored spheres show the icosahedral arrangement of (a) aluminum atoms and (b) oxygen atoms.

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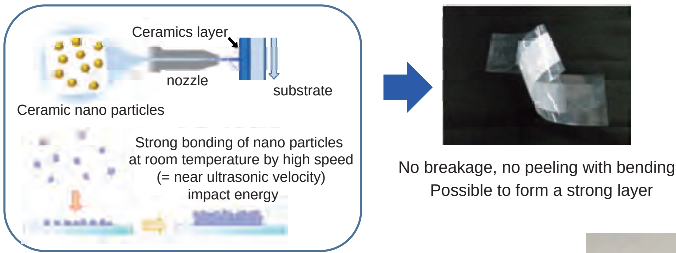
AIST TODAY Vol.14 No.4 p.16 (2014)

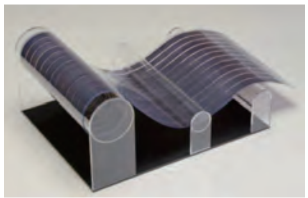
Film type dye-sensitized solar cell (DSC) fabricated at room temperature

The energy conversion efficiency of 8 % was achieved on film type DSC.

We have developed a flexible dye-sensitized solar cell (DSC) with a porous TiO_2 layer coated at room temperature. The DSC energy conversion efficiency of 8 % was achieved, which is the world record at present. In previous DSC related reports, it was very difficult to form a porous TiO_2 layer on polymer materials with good adhesion, because consolidation of TiO_2 nano powder required medium heating temperature of at least 400-500 ℃. In this report, the porous TiO_2 layer with good adhesion was obtained on a flexible polymer film by an aerosol deposition (AD) method. The AD process allows strong bonding of ceramic particles with a substrate by room temperature impact consolidation (RTIC). There was no peeling of the TiO_2 AD-layer during bending of the substrate. We confirmed the productivity of DSC by a roll to roll method using an AD process to reduce the manufacturing cost. Light-weight and flexible solar cells will open doors to innovative concepts of housing.



Deposition image of the AD process



A sample of flexible film type dye-sensitized solar cell (DSC) (Efficiency: 8%)

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AIST TODAY Vol.14 No.5 p.16 (2014)

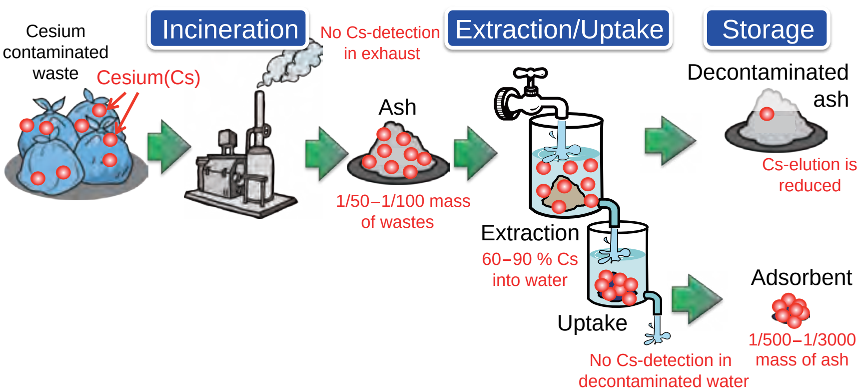
Demonstration of the effective decontamination technique for radioactive cesium

Extraction of 60-90 % of radioactive cesium from ash, and immobilization by an adsorbent

We have developed an effective decontamination method for radioactive cesium from combustible waste, i.e. incineration under appropriate conditions, extraction of radioactive cesium from ash, and finally uptake of cesium by an adsorbent with Prussian blue-nanoparticles. The plant-scale demonstration has been done in the Fukushima-area over the course of about a year.

In the demonstration test, combustible wastes over 10 tons have been incinerated with various conditions, resulting in 80 kg of ash. From the obtained ash, 60-90 % of radioactive cesium was extracted into water. All of the extracted cesium was immobilized by the adsorbent whose mass is 1/500-1/3,000 of the ash, and less than 1/10,000 of the initial combustible waste.

The developed technology will reduce the size of the required space for the interim storage facility for radioactive wastes.



The schematic image of the plant-scale test

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AIST TODAY Vol.14 No.6 p.16 (2014)

Mass production technology for single-wall carbon nanotubes

Returns the fruits of AIST's research in nanotechnology to society

We have transferred a seed technology of AIST, the Enhanced Direct Injection Pyrolytic Synthesis (eDIPS) method, for the manufacture of single-wall carbon nanotubes (SWCNTs), a cutting edge nanotechnology material, to Meijo Nano Carbon Co., Ltd. (MNC). We developed an industrial production plant through a collaborative project between the two parties, and verified the mass productivity of SWCNTs using the eDIPS method.

In the present study, various reaction conditions in the developed industrial production plant using the eDIPS method were optimized to attain a production speed 100 times that of the conventional high-quality carbon nanotubes (CNTs) manufactured and marketed by MNC. Based on this result, in 2014 MNC has become the first Japanese manufacturer to introduce SWCNTs synthesized by the chemical vapor disposition (CVD) method to the market. This will enable high-quality, high-purity samples to be placed in mass quantity on the R&D-use market and is expected to accelerate studies for commercial use of SWCNTs.

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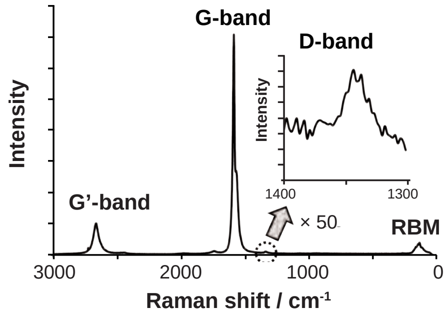
A lump of SWCNTs synthesized in the developed industrial production plant (compared to a smartphone)



Raman spectrum (laser wavelength: 532 nm)

New X-ray non-destructive inspection for industry

Investigation for effectiveness of X-ray Talbot interferometry

We investigated the effectiveness of X-ray Talbot interferometry using a laboratory X-ray tube for industrial inspection of packaged devices. Because the devices contain various components, such as semiconductors, metals, ceramics, and resins, it is difficult to inspect them. In this study, the conventional absorption image showed heavy-elemental components such as metal wires and electrodes, but the image did not reveal the defects in the light-elemental components. On the other hand, the differential phase-contrast image obtained by this method showed voids in the encapsulant of an IC package. The scattering-contrast image showed some cracks in the ceramic insulator of the power module sample. In addition, this image showed the silicon plate surrounded by the encapsulant having the same X-ray absorption coefficient. These defects and components are invisible in the conventional industrial X-ray imaging. Thus this interferometry has good potential for industrial inspection of packaged devices.

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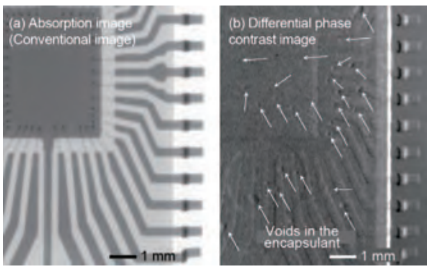
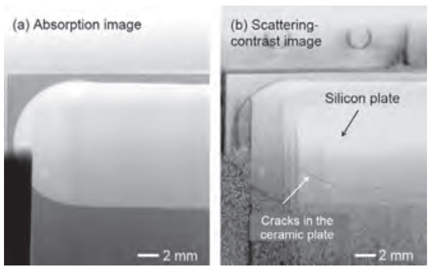


Experimental results for an IC package sample
(a) Absorption image (conventional image)
(b) Differential phase-contrast image



Experimental results for a power module sample
(a) Absorption image
(b) Scattering-contrast image

India-Japan Business Forum Science and Technology Seminar

The India-Japan Business Forum Science and Technology Seminar, sponsored by the Japan External Trade Organization, was held in Delhi on January 26, together with the official visit of Prime Minister Abe to India in late January, 2014. From AIST, Dr. Chubachi (President) and Dr. Yumoto (Vice-President) attended the seminar. In the keynote speech, the research activities of AIST to contribute to green innovation and life innovation, joint research with the Department of Biotechnology (DBT), Ministry of Science and Technology, India, to promote drug discovery, and the establishment of DAILAB, DBT-AIST International Laboratory for Advanced Biomedicine at AIST Tsukuba were introduced by Dr. Chubachi. This seminar was also attended by the leaders accompanying Prime Minister Abe of the economic world and research fields of Japan.

In the closing session, remarks were given by Prime Minister Abe in which he stated, “New drugs may also be realized by integrating the unique biological resources of India with the cutting-edge technologies of AIST in the joint research between AIST and DBT.” After the seminar, Dr. Chubachi was invited to the Hyderabad House with Prime Minister Abe, and held a friendly conversation with Prime Minister Singh of India.

In the joint statement presented by the prime ministers of both India and Japan, they welcomed the new initiative to establish a biotechnology laboratory for DBT-AIST joint research. In this statement, AIST’s achievements in international collaboration were well-recognized by both governments.

Dr. Chubachi at the press conference (right end)

Visit by Her Highness Sheikha Moza bint Nasser of the Qatar Foundation

Her Highness Sheikha Moza, Chairperson of the Qatar Foundation for Education, Science and Community Development, visited AIST on April 22, 2014.

Her Highness was welcomed by executive members and the directors of research units of AIST led by Dr. Chubachi (President) and Dr. Ichimura (Senior Vice-President). Together with executive members of the Qatar Foundation, including Mr. Al-Suwaidi, President of the Qatar Foundation Research and Development, and Dr. Khaleel, Executive Director of the Qatar Energy and Environment Research Institute of the Qatar Foundation Research and Development, many ideas were exchanged concerning future collaborative activities between the Qatar Foundation and AIST.

After greetings by Dr. Chubachi, information on AIST and Tsukuba Science City were presented by Dr. Seto (Vice-President). The research activities of battery technologies and photovoltaic technologies were introduced by the directors of research units at AIST. Greetings by Her Highness Sheikha Moza followed, after which the research activities of the Qatar Foundation were introduced by Mr. Al-Suwaidi, President of the Qatar Foundation. Many questions were asked in the ensuing discussion by the participants from Qatar concerning AIST’s model of cooperative research, the framework of research and development, and the management of facilities at AIST.

Moreover, in order to facilitate continued discussions between AIST and the Qatar Foundation with a view to future collaboration, a Letter of Intent (LOI) was concluded between the Research Institute for Ubiquitous Energy Devices and the Research Center for Photovoltaics of AIST, and the Qatar Energy and Environment Research Institute of the Qatar Foundation Research and Development.

Dr. Chubachi and Her Highness Sheikha Moza

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