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CONVERGENCE

To Become Real COE with International Point of View

Koichi KITAZAWA

The Role of Scientists in the Future

Mark E. Welland

Young Leaders Working in the MANA

MANA's Research Outcome

- The Design of Quantum Logic Gates at the Atomic Scale ——Christian JOACHIM
- Direct-fabrication of Raman-active Nanoparticles by Top-down Physical Routes ——Jung-Sub WI
- Discovering Unknown Materials for Use in Electronics with Combinatorial Materials Synthesis ——Toyohiro CHIKYOW
- Color-tunable Eco-nanoparticles to Building a Sustainable Future——Naoto SHIRAHATA

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MANA
International Center for Materials Nanoarchitectonics (MANA)

To Become Real COE with International Point of View

Interviewer: Akio ETORI, Science Journalist

Koichi KITAZAWA

Counselor to the President, Japan Science and Technology Agency
Cooperating member of the Science Council of Japan
Honorary Professor of Tokyo University

Born in Nagano Prefecture in 1943; graduated from University of Tokyo, Department of Chemistry; graduated from Department of Materials Science and Metallurgy Massachusetts Institute of Technology; become Professor, Department of Industrial Chemistry, University of Tokyo in 1987; become Senior Executive-Director, Japan Science and Technology Agency in 2002; become President, Japan Science and Technology Agency in 2007; become Counselor to the President, Japan Science and Technology Agency in 2011; his field of specialization is Physicochemistry, Solid state physics, Materials science, Magnetic science, Superconductivity, Energy science; in 1986 he ignited the high temperature superconductor boom; his record of awards is, in 1988 Grand Prize: Ceramic Society of Japan and Society Award: Japanese Society of Applied Physics and IBM Japan Science Award (Physics Division), in 2002 a Purple Ribbon Medal, in 2009 Achievement Award: Japanese Society of Applied Physics, and others; his chief literary works is "Scientist's dream for future Japan and its economy (4th edition)" (Adthree, 2005), "Can technology save Japan – Create "the 4th Value"" (Discover21, 2010). He is a cooperating member of the Science Council of Japan. He proposes that if we can create "the 4th Value" which means "the social and mental value" with technology, we can save the earth's environment and can revitalize the Japanese economy to present.

World excited by the announcement from New York in 1986

—What first comes in thought about you is the conference in New York where you published the discovering of the high-temperature superconductivity in 1986. What makes you interested in the high-temperature superconductivity in the first place?

At that time many researchers of electronics explored for the superconductor, because after the discovering of the semiconductor, they thought the superconductor would be the next goal. But I thought from the electricity saving point of view that it could be used for building earth-wide electricity network with material which electrical resistance is zero. And that idea motivated me.

We first tried to make the superconductor by composing unexplored materials which indicate metallic property in electrical condition. So we explored the oxide superconductor. Our challenge was not so successful in the beginning, but then, the news about the discovery made by Dr. Karl Alexander Müller and his colleagues came. They were at that time not famous, and their data did not look like the one of the superconductor. So their discovery was ignored by academic society. At first, we didn't believe it either, but we ordered to our students to check it, just for their practice. And surprisingly, the result turned out to be good one. We became so sure that we could find the superconductor.

—So in a sense, half of the achievement of Bednorz and Müller can be attributed to Tokyo University.

Oh, no. We were just the first specialists to prove that the discovery of Dr. Bednorz and Dr. Müller was worth for the Nobel Prize. What we did was to identify the crystal structure, or to propose a mechanism of electrical conduction property, and so on.

—It has been 25 years since the discovery. Does the technology concerning superconductivity have progressed more than your expectation since then?

Actually, it was slower than my expectation. It is quite difficult to pass mass amount of electricity through the oxide material. Currently, the research for the practical application of the high temperature superconductor is going on for three kinds of materials. That is, bismuth-based materials, yttrium-based materials and MgB_2-based materials. Already, there are commercial products of bismuth-based materials and yttrium based materials. Things are ready for large-scale applications, many tests will be going on soon.

Good researcher attracts good researchers

—It has been four years, and almost a half of the term of WPI program has passed. MANA is struggling to stand out among worldwide contestants, but that is not easy work. The first step should be to gather good researchers. How should they do that?

That always is a problem, to know the required condition to gather good researchers. Good researcher wants to go the place where good researchers stay. MANA has so many top class researchers of material study, so MANA has already cleared one of the requirements. What still needed is to give foreign researchers the ideal environment, where they can get stimulations and can achieve certain results during their stay.

I'm sure MANA has advertised their environment as such, and I'm also sure that they can proudly say so. I think MANA is one of the three best research centers of material study. And in the condition of quality and quantity combined, MANA can be said as the world number one. To get good researchers more actively, they should not just wait and lure researchers. They need to choose certain researchers as a target with some tactics and something extra, such as passion.

In American universities, when they held international conference, professors lent a suite in a hotel and invite students who visit a conference at specified time to interview them. They do it for recruiting students to their labs. So for them, International conferences are not only for an academic exchange, but also for recruiting good researchers. I think MANA should do such thing rather intentionally.

Good "MEKIKI"* finds good researchers

—Exactly how would you find good researchers?

To find good researchers, they need a good connoisseur, "MEKIKI". And to be a good connoisseur, there are three conditions. First, he must be successful in his research career. Second, he must have respect from young researchers of his field. And third, even if that person is old, old as he is, he must continue his work eagerly.

In JST, staffs goes around to search for candidates for connoisseur, and make the list of them. When JST is given a subject as a problem solving research, the connoisseur from required field is chosen from the list. And the connoisseur and his assistants recruited by him select researchers to tackle the subject. So the process goes like this. JST advertises for researchers, papers from researchers arrive, and JST screens them. Then the connoisseur selects researchers who conduct interesting research, and finally JST interviews researchers and decides the budget for them. By such processes many researchers were picked up, such as Prof. Shinya Yamanaka of iPS cell, Prof. Hideo Hosono of transparent transistor and Prof. Kitagawa Susumu of the Integrated Pores.

What important is to pick up good researchers even before they make any successful achievement. And then, give them an ideal environment and drive them to do their research at best they can. So they will achieve the goal they have dreamed of, achieve the great result in their study. For such purpose, it is really important to have good connoisseur. Let young researchers to suggest anything they want to study, and the connoisseur picks up really interesting idea among them. We JST consider whether it has great impact and solid reasons and how much they have prepared and proceeded on its research. The best season to pick researchers is when they can get the clue right after they begin their research. If we can pick them up at that season and give them enough funds, they will grow rapidly.

* "MEKIKI": A Japanese word which expresses a great insight into intrinsic values of things or ability to find out genius or high potential of persons based on broad experiences, or someone who exerts them.

Debate and travel abroad grow researchers

—One of the tasks of MANA is to grow young researchers to be full-fledged quickly. Recently there is an attempt to choose the leader of research group from MANA Independent Scientist. What do young researchers need to grow up?

I think there are two things. The first is stimulation given by debates. So we need to give them an environment where they can have heated debate and where they can test by experiment when they really want to. The other is to visit foreign land and work in many research institutes, which recently I began to think myself very important. I hear that Japanese researchers don't venture to foreign land in these days. They have an inclination towards stable life and want to get stable position earlier in their life. So I think unless recruiting systems of research centers are changed and made it easier for visitors to be recruited, not many researchers will go around the world.

Perhaps the best way to prompt young researchers is to gather researchers who are ambition and tough and eager to travel abroad to come in touch with completely different foreign cultures. Young researchers will be affected by them, and will do the same.

MANA can become COE of the world by true internationalization

—What would you think about internationalization of research center?

To become COE of the world, then their members must be chosen from all over the world. If there is a talented Japanese candidate, there need to be no hesitation to choose him for important position. But if there is a more talented and foreign candidate, that person should be chosen. Of course, it would be difficult to change custom to such level at least they should try. Choose certain number of excellent foreign researchers for leaders for example. So I think it is better to invite some experienced researchers and give them a certain amount of power for personal affairs for a while after the research center was established.

Singapore made a model example for COE of the world. They built extraordinary bioresearch centers and hospitals. Around Singapore there are 100 millions of people living, so if research center or hospital can gain very good reputation, they can gather many people. But that reputation must be the top among neighbors. If research center achieves something great, many from around the world will come to buy its achievement. Because they built a research center that might overwhelm their capacity, they could attract researchers all over the world.

MANA has plenty of fund, and already one of the world famous COE, so they are in a good condition to become greater. What needed now is to emphasize its merit. They should have a proud that they are COE of the world, and actively recruit researchers. By doing that much they can become what they dreamed of.

—In COE of the world, should researcher's mobility be very high?

Yes. Good researchers are invited by many research institutes and will move to another place sooner or later. It is destined for COE. But on the bright side, many good researchers from one COE are spread worldwide, and become important person in so many places. So the ideal situation is that researchers from MANA are on the frontline of material study on everywhere in the world.

—Lastly, what would you expect to MANA?

Researches conducted by MANA are very unique and recognized from world as so challenging. But it is not an easy work to make all of them successful. Perhaps it would be better idea to bring in research, which already begins to achieve good result.

Thank you very much for the extremely interesting talk.

The Role of Scientists in the Future

Mark E. Welland

- Satellite Principal Investigator, Nano-System Field
- University of Cambridge

Prof. Sir Mark Welland, Professor of Nanotechnology at the University of Cambridge, is also a Satellite Principal Investigator (PI) of the International Center for Materials Nanoarchitectonics (MANA). He has been Chief Scientific Advisor to the UK Ministry of Defence since March 2008. (He was in office at this interview.) We asked him about the job as Chief Scientific Adviser and his opinion about the role of scientists.

The role of scientists in the decision-making of the government

——Would you tell me about your main job as Chief Scientific Adviser in the UK government? And what do you think of participation in politics?

The Ministry of Defence was the first Government department to have a Chief Scientific Adviser (1961) and there are now eleven Chief Scientists across Government departments. Two of these posts, my own and the Government Chief Scientist, have Permanent Secretary status which is the most senior Civil Service level in the Government. My responsibilities are specifically in Defence and Security where I work closely with International partners including Japan. In broad terms my role is to provide scientific and technical scrutiny to all our programmes, from aircraft carriers to counter terrorism.

Scientists and engineers have a critical role in supporting Government decision making in nearly all aspects of policy. Their role here is twofold: They must bring independent scientific evidence to decision makers and they must ensure that scientific advice is properly and effectively communicated. In a significant proportion of Government decisions there are often scientific/technical elements that must be properly analysed and considered; that is my job. An important aspect of this advisory process is how one translates that advice so as to be useful, relevant and effective when speaking with Government Ministers as I do regularly. One needs to explain how their policy choices can affect the science or, conversely, how the science affects their policy choices. The process of producing independent scientific analysis but then incorporating the policy dimension doesn't mean losing interpretation of the science. It simply means translating it into a relevant and effective format that allows such advice to have maximum benefit.

——After the Tohoku earthquake disaster in March, the British Government aided us so much and we really appreciate your continued support.

Scientifically, I commissioned some work to support Japan. The Ministry of Defence sent a team of experts immediately to Japan to advise and help; advising on radiation, analyzing the consequences of weather patterns and making our own radiation surveys in support of our Japanese colleagues. We provided technical assistance in any way we could to support Japanese requests; something that continues today. The British population has been extraordinarily generous and responsive in donating support to assist Japan; your tragedy touched the hearts of all of us here in the UK.

After the accident at the Fukushima nuclear power plant, the UK Government asked for a report to be made quickly about the safety of our own civil nuclear reactors. There was an initial rapid report and then, later this year a detailed report (http://www.hse.gov.uk/nuclear/fukushima/). Clear lessons were identified from the Fukushima disaster and the UK will continue to develop technology and regulation to ensure we continuously implement the very latest safety advice and experience. UK reactors were deemed safe against a Fukushima style disaster and no reasons to stop nuclear energy production or new reactor build were identified. Our general view is that you responded incredibly well to an unprecedented disaster and consequential humanitarian tragedy.

Role Expectations of the next generation scientists

——What do you think about new sources of energy?

In considering alternative sources of energy, such as wind farms, tidal power and solar it is crucial to take a systems based approach. You don't just think about how to produce energy with a piece of technology. You need to think about how energy is used, what motivates people to use energy, what the true cost of alternative energy is and how can one reduce energy demand. Storing energy is another issue. Lots of the renewable energies are produced when the sun is out or when it's windy but one needs to match energy supply with demand. Hydroelectric schemes have the advantage of being used to both produce energy and, by reversing the process, to store energy in times of low demand. One prospect might be to separate water into hydrogen and oxygen when you don't need the energy and then combining the two to produce energy when you do need it. From a scientific perspective therefore I believe it is crucial for researchers to think early on in their work about the end-to-end application of any new technology whether a new energy source or a material or device that reduces energy consumption. After all, energy is one of the greatest challenges facing mankind and the solution must come from science and technology.

——You mean that the researchers must take a broader view. So would you give further counsel to the young researchers?

I think if you look at the major problems that are facing mankind at the moment such as climate change, food shortages, water shortages, energy, all of these have to have a scientific solution. These are not just a matter of policy or regulation; all these problems have science and technology at their heart. So for young scientists, I think they have a massive challenge for the future. If we solve these problems then the world will change and move in a very positive direction, if we don't solve these problems, the world will deteriorate more. This message is not perhaps a happy one for young scientists. But I think they have an enormous opportunity and, frankly an obligation, to really change the world in a way that will bring about positive change for all. So be creative, be clever, collaborate and be serious about looking for real, viable and innovative solutions.

Prof. Mark E.Welland

Prof. Sir Mark E. Welland moved to the University of Cambridge in 1985. He began the Nanoscience research group in 1991 and has been the Head of the Nanoscience Centre at the University of Cambridge since 2003.

Director of the Interdisciplinary Research Collaboration in Nanotechnology (2002-2008). Led the UK side of the World Premier International (WPI) Research Centre Initiative in Japan. Satellite Principal Investigator of MANA since October 2007. Former Editor-in- Chief of the IOP journal, Nanotechnology. Chief Scientific Advisor to the UK Ministry of Defence (April 2007-February 2012). Awarded a knighthood in the Queen's Birthday Honours list (2011).

Young Leaders Working in the MANA

To build itself into a world class research institution, MANA invites outstanding researchers from Japan and overseas to come and contribute to the center's already impressive record of achievements. At the same time, MANA places great emphasis on the fostering of young researchers to enable them to become active on the international stage as soon as possible. As part of this process, five young researchers have recently been appointed as Group Leaders. We expect great things from them in their future careers.

Self-introductions by each of the five new Group Leaders are presented below. They tell us about their research as well as their non-work interests. (Listed in alphabetical order.)

Naoki FUKATA

Nano-Materials Field: Nanostructured Semiconducting Materials Group, Group Leader

The goals of my group are to use nanostructures in next-generation transistors to achieve 1) higher integration, 2) improved control, and 3) higher speed.

Currently, vertically structured transistors employing semiconductor nanowires are suggested as a key material for next-generation semiconductor devices. We have established a new method of property control and evaluation that will assist in the realization of such devices. These results also help the progress in our research of the next generation highly efficient solar cells.

When I have time, I like to travel to different regions of the world and experience their cultures and characteristics. I was astounded at the difference in values I observed on a visit to the Greek island of Lesbos.

As a Group Leader I feel more sense of responsibility, in a good sense.

The theme of my research is developing highly functional materials out of common, nontoxic elements. To do this I focus on covalently bonded compounds with network-like structures. These are, simply put, cluster, cage, or net-like atomic structures. In the case of carbon, graphite-related materials and fullerenes are well known, and there are many other such nanostructures. Our goal is to design and synthesize materials useful to society, like thermoelectrics, by utilizing atomic network control, for example.

In my time off I like to read. I particularly like classic mysteries.

Takao MORI

Nano-Materials Field: Atomic Network Materials Group, Group Leader

Tadaaki NAGAO

Nano-System Field: Nano-System Photonics Group, Group Leader

I don't think my consciousness has changed much since becoming Group Leader. Rather, I think the March 11 earthquake disaster has made me realize the importance of research oriented toward solving problems.

My original specialty was measurement, and I have gradually moved from the study of the vibration of atoms and electrons to the study of electromagnetic fields (light), eventually arriving at research on the utilization of electron vibration for the "controlled use of light in nano-materials". We are studying the ways to produce energy and chemical reactions by collecting light onto effective target places in nano-meter scale as if we were using funnels with macro-scale inlet and nano-scale outlet. Its sort of like the "Gulliver Tunnel" from the animated cartoon series Doraemon. (The Gulliver Tunnel has two openings, the one is large and the other is small, and all the objects that passed through it become smaller in size.) It sounds like a fantasy, but I am determined to do world class work in the field of research.

When I have the chance, I'd like to go rowing or cycling like as I was in college.

I'm mainly working on development and establishment of a novel sampling analysis based on density functional theory for redox and photoexcited reactions at solid/liquid interfaces, and elucidating microscopic mechanisms of interfacial reactions in photocatalysis and solar cells by using those techniques with supercomputers including the next-generation "K". As cutting-edge research is so fun and exciting, I usually work through the weekends. But playing with my child on holidays is also fun and making me relaxed.

Yoshitaka TATEYAMA

Nano-System Field: Nano-System Computational Science Group, Group Leader

Kazuya TERABE

Nano-System Field: Nanoionic Device Group, Group Leader

My appointment as a Group Leader has increased my freedom in doing research. At the same time I feel the pressure that comes from being able to take on new challenges that has high originality.

My research focuses on ions rather than electrons per se, and the goal of my group is to create nanoionic devices with new performance and functionality that the conventional electronic devices don't have. I want to make extremely tiny devices using ions one by one for computation and storage.

Japan leads the world in solid state ionics research, and our group is working to extend this lead still further. Ionic devices can be considered similar to analog creatures, so we want to create a unique device that mimics creatures. Although that is probably not the reason, I like to be in contact with nature, such as vegetables and flowers.

The Design of Quantum Logic Gates at the Atomic Scale

Christian JOACHIM
MANA Satellite Principal Investigator
Nano-System Field

What is the minimum number of atoms (and quantum states) a nano-sized calculating unit must be made of to perform alone a complex computation? To answer this question, we are exploring (1) quantum design of molecules and atom surface circuits able to perform a Boolean logic operation, (2) molecule synthesis and atom by atom UHV-STM construction on a surface, (3) a new surface multi-pad interconnection technology with a 10 pm precision respecting also the atomic order of the supporting surface and (4) the development of a specific quantum chemistry software (N-ESQC) able to accommodate the complete logic gate, its interconnections and the supporting surface [1].

A surface supported atomic scale logic gate can be either a molecule (Fig. 1a) or a surface dangling bond circuit (Fig. 1b). We have shown how all the known designs of atomic scale logic gates i.e. semi-classical circuits, quantum Hamiltonian circuits and qubit circuits are different facets of the same quantum system control problem. Even a well optimised and well quantum prepared 3 states quantum system can perform a NOR logic function from a formal physical point of view. It is only when a realistic surface implementation is coming into play that the number of atoms in the structure (and the required active quantum states) is increasing drastically from a few to hundreds. Our original quantum Hamiltonian logic gates [2] differ from standard molecular electronic logic gates in the way the classical input data are encoded on the quantum system and in the way the quantum to classical conversion operates to read the output. We have recently demonstrated how our quantum design fully benefits from the decoherence coming from the interconnections. We are now exploring how more complex Boolean logic functions like a full digital adder can be embedded in a single small molecule or constructed using a few dangling bond atoms on a passivated semi-conducting surface with current (or mechanically nano-gears) driven inputs and current intensity encoded outputs.

References
[1] F. Ample *et al.*, *J. Phys. Cond. Mat.*, **23**, 125303 (2011).
[2] W.H. Soe *et al.*, *Phys. Rev. B*, **83**, 155443 (2011).

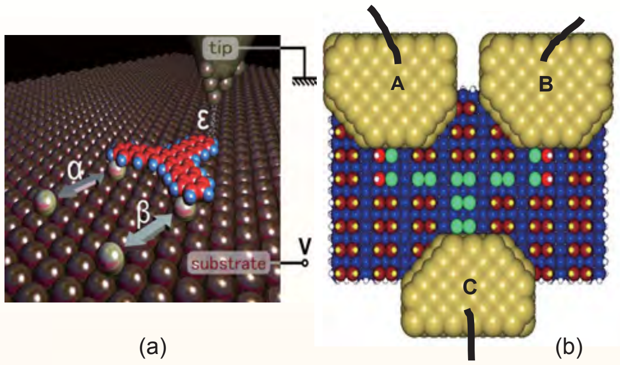

Figure 1. (a) a single molecule-NOR logic gate based on a quantum design [2]. The 2 logical inputs are single Au atoms STM manipulated to be or not in interaction with the 2 input branches of a starphene molecule. The output is obtained by probing the tunneling current intensity by an STM tip positioned on the output branch of the molecule. (b) a single surface atomic circuit OR gate based on a semi-classical design [1]. This is a current input driven logic gate with A and B the input nano-pads and C the output nano-pads. The circuit is constructed by STM extracting single H atoms on a Si(100)H. The resulting dangling bonds are in green, the remaining top H surface atom in white. For simplicity, only the active portion of the Si(100)H surface is represented.

Direct-fabrication of Raman-active Nanoparticles by Top-down Physical Routes

Jung-Sub WI
ICYS-MANA Researcher

Direct-fabrication of synthetic nanoparticles by top-down physical routes, in which materials are vacuum deposited in a nano-patterned polymer template, allows massive synthesis by a low-cost batch-type process and exquisite control over material composition, multilayer structure, particle size and shape which are not achievable with chemical nanoparticle synthesis. The wide freedom of nanostructure design from various lithographic and deposition techniques allows us to engineer unique physical properties of custom designed nanoparticles, such as sub-lithographic-feature enhanced plasmonic nanoparticles introduced here. These nanoparticles are designed to contain internal Raman hot spots where a local electromagnetic field enhanced by surface plasmon resonance reaches its maximum value.

Our Raman-active nanoparticles are fabricated using nanoimprint lithography and thin-film deposition as shown in Figure 1, and are comprised of novel internal structures with sub-lithographic dimensions: a disk-shaped Ag core, a Petri dish-shaped SiO_2 base whose inner surface is coated with Ag film, and a sub-10 nm scale circular gap between the core and the base. Confocal Raman measurements and electromagnetic simulations (Figure 2) show that Raman hot spots appear at the inside perimeter of individual nanoparticles and serve as the source of a 1000 fold improvement of minimum molecular detection level that enables detection of signals from a few molecules near hot spots. Precisely controlled dimensions and unique internal structure of these sombrero-shaped nanoparticles enable detection of a few molecules. A multi-modality version of these nanoparticles, which includes the functionality offered by magnetic elements, is also simply available by successive deposition of plasmonic and magnetic films. These results illustrate the potential of direct fabrication for creating exotic monodisperse nanoparticles, which combine engineered internal nanostructures and multi-layer composite materials. Furthermore, because the proposed method uses nanoimprint and vacuum deposition methods which are suitable for mass production, exquisite and simple control of such nanoparticle structures is expected to become routine. Considering the present results, we expect that Raman sombrero nanoparticles can be used as an ultrasensitive molecular detection platform and that released nanoparticles that contain magnetic elements, distinguishable through the use of different Raman dyes, can be useful as multifunctional *in-vitro* or *in-vivo* imaging reagents.

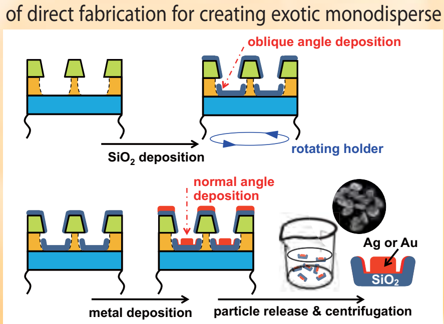

Figure 1. Schematic illustration of the overall process: nanoimprint lithography, plasma etching of residual PMMA layer, wet chemical dissolution of PMGI layer, oblique angle deposition of SiO_2, metal deposition, nanoparticle release, and centrifugation. Inset SEM image shows the fabricated nanoparticles after centrifugation.

Reference
J. -S. Wi *et al.*, "Sombrero-Shaped Plasmonic Nanoparticles with Molecular-Level Sensitivity and Multifunctionality", *ACS Nano*, **5**, 6449-6457 (2011).

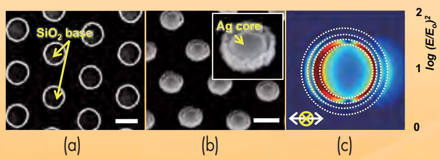

Figure 2. (a) SEM image of sombrero-shaped plasmonic nanoparticle arrays from a view angle 3° to the sample surface. (b) The squared magnitude of the local electrical field amplitude of Ag Raman sombrero nanoparticle. (c) The direction of incident light and its polarization are indicated in the inset as yellow and white colored arrows, respectively.

Discovering Unknown Materials for Use in Electronics with Combinatorial Materials Synthesis

Toyohiro CHIKYOW MANA Principal Investigator (PI)
Nano-Materials Field

Next-generation semiconductor devices are expected to combine higher speed, greater integration, and reduced power consumption. The keys to achieving this are the development of new materials and interface control. There is particular demand for the development of new gate stack materials. In order to achieve still further integration and better performance moving forward, materials with a higher dielectric constant (high-k materials) that enable direct bonding with the silicon substrate are essential.

When a high-k material, which is an oxide, is allowed to accumulate on the silicon substrate, the silicon at the interface generally becomes oxidized and a layer of silicon dioxide (SiO_2) forms. The dielectric constant of SiO_2, 3.9, is low, so when the layer of high-k material is added the overall dielectric constant or permittivity is lowered. For this reason, there is a need to eliminate the SiO_2 from the interface in next-generation integrated circuits. One way to eliminate the SiO_2 from the interface is to cause the SiO_2 to react with a high-k material to form a silicate, a compound consisting of an oxide, silicon, and oxygen. However, since the silicate is a compound containing SiO_2, which has a low dielectric constant, it still tends to have lower permittivity than transition metal oxides. This is why it is necessary to find a material that will maintain high permittivity and also allow direct bonding with silicon. With this in mind, a combinatorial materials synthesis method developed at NIMS was used to search for new materials both systematically and rapidly. It was discovered that producing the oxide CeO_2-Al_2O_3 on the surface of the silicon and subsequently subjecting it to heat treatment at temperatures exceeding 900ºC resulted in epitaxial growth of the oxide CeAlSiOx, which had reacted with the SiO_2. Figure 1 shows an image of the cross-sectional structure captured using a high-resolution electron microscope and a schematic depiction of the arrangement of atoms and molecules. It clearly shows direct bonding of the high-k to the silicon lattice. In addition, metal gate materials with compositions ranging successively from platinum (Pt) to tungsten (W) were formed in a dot-shaped configuration on top of a 10 nm layer of oxide to vary the work function, and the capacitance–voltage characteristics were evaluated. As shown in figure 2, the flat band voltage changes continuously according to the work function, indicating an ideal MOS structure. Furthermore, the capacitance–voltage characteristics show that the CeAlSiOx has a dielectric constant of 28, which makes it an excellent high-k material.

More new materials still need to be developed for integrated circuits moving forward. The authors hope to use this combinatorial method in the development of new gate stack materials and more advanced nonvolatile memory materials, for example. Materials research aimed at more advanced integrated circuits will continue.

Reference
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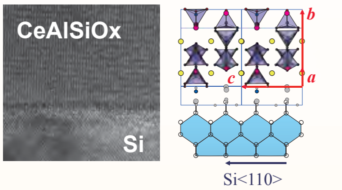

Figure 1. High-resolution electron microscope image of the high-k material CeAlSiOx discovered at NIMS and schematic depiction of crystal structure. Direct bonding of the high-k material CeAlSiOx to silicon and epitaxial growth can be seen.

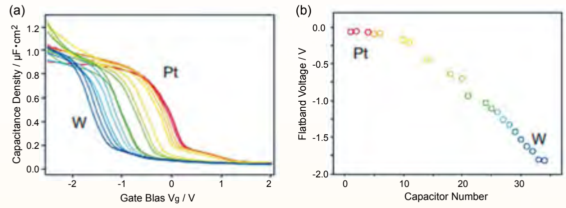

Figure 2. Change in capacitance–voltage characteristics and flat band voltage with successive changes in electrode compositions from platinum (Pt) to tungsten (W). It can be seen that the flat band voltage varies according to the change in the work function as the composition changes.

Color-tunable Eco-nanoparticles to Building a Sustainable Future

Naoto SHIRAHATA MANA Independent Scientist

Due to the photonics industry's high dependence on rare-earth elements, the unstable supply issues of these elements raises a threat to the present industry of light emitters including LED and laser devices. This is a global problem. To overcome this great difficulty, the industrial use of quantum dots of semiconductor nanocrystals (ncQDs) as alternatives have been strongly required. In addition to the role of the alternatives, the ncQDs have some peculiarities not shared by rare-earth elements, e.g., quantum confinement effect. Since the appearance of the quantum confinement effect allows the size-tunable optical absorbance and emission, the use of ncQDs simplifies the interior constitution of the device system, leading to the good cost-benefit performance and the space-saving (being smaller, thinner and lighter) of the devices. Thus, the ncQD-based light emitters of state-of-the-art demonstrations are very promising. However, efficient ncQDs always contain cadmium, lead and/or arsenic, which make them unsuitable for practical use in our human life into the future. Providing Cd-, Pb- and As-free ncQDs in amounts sufficient for the massproduction of lightning industry is needed. To realize a lightning industry for sustainable future, my attention has been paid to the use of silicon and silicide. A bulk Si shows a poorer optical performance, but Si nanoparticles show the blueshifted light emission features. A challenge to the device fabrication of a Si ncQDs-based light emitter is commonly accepted as "a crazy effort or a delusional dream", however, I believe that the appropriate use of the concept of nanoarchitectonics enables even its device fabrication. Prior to the device fabrication, I have originally proposed that the appearance of the quantum confinement effect allows a color-tunable light emission in the ultraviolet wavelength range (300 nm~), and achieved the success of highly-efficient luminescent Si by the careful control over QD size and surface chemistry based on a concept of nanoarchitectonics. The nanofabrication of Si ncQD-based color tunable light emitters has sufficient latent potential to solve absolutely the above global problem and environmental concerns.

Reference
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N. Shirahata, T. Tsuruoka, T. Hasegawa, Y. Sakka, *Small*, **6** (2010) 915-921.

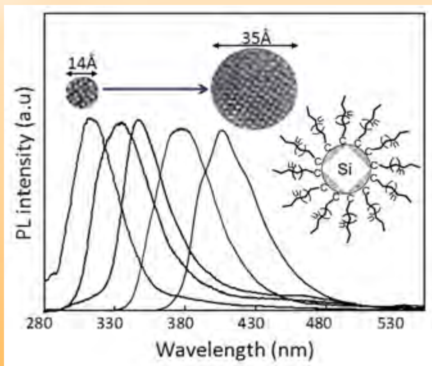

Figure 1. Size-tunable luminescence in the UV-blue range

Prof. Kroto's Science Class 2011


Prof. Kroto helps a student to make a buckyball.

MANA hosted "Prof. Kroto's Science Class 2011" for preliminary school students Grade 3 and 4 and their parents on September 17th, 2011. This program was given by Prof. Kroto, Nobel Prize laureate in Chemistry in 1996, to help children and their parents all over the world to understand the fun of science. This time, we had 50 pairs of participants.

Students were very actively involved in the class. They eagerly listened to Prof. Kroto's English during Session 1 and made a buckyball with help by their parent and Prof. Kroto in Session 2.

NIMS/MANA-Flinders Univ. Joint Symposium

—Nanoscience and Nanotechnology—

The NIMS/MANA-Flinders University Joint Symposium on Nanoscience and Nanotechnology has been successfully held at Namiki Site, MANA NIMS, on October 31, 2011. This symposium was held as a part of the MOU between MANA and Flinders University of South Australia signed on July 22, 2011.


Lecture by Dr. Tsuyoshi Hasegawa, MANA PI.

Osaka Univ. –MANA Joint Symposium

—Advanced Structural and Functional Materials Design—

The joint symposium co-organized by Osaka University and MANA has successfully been held on October 7, 2011. The Sessions had eight oral presentations and 10 poster presentations by the researchers from both of MANA and Osaka University about their latest research results.


Participants of the symposium, October 7, 2011.

7th Japan-UK-USA Nanotechnology Summer School

The 7th Japan-UK-USA Nanotechnology Students' Summer School was held at Nanoscience Centre, University of Cambridge from September 5th to 8th, 2011. The summer school was organized by the collaboration of 3 institutes, MANA of NIMS, Japan, Nanoscience Centre of University of Cambridge, UK, and California NanoSystems Institute of UCLA, USA.

Totally 26 students from Japan, UK and USA presented their latest research topics to exchange up-to-date knowledge and opinions during the school. They had active discussions during the various events as well as question and answer time.

The 8th summer school will be held at NIMS in summer, 2012.


At the Trinity Hall College, Cambridge.

Published two books

MANA published two books on October 14, 2011. The first is a cartoon guidebook entitled "The Challenging Dailey Life" from Bunkakobo inc., which supports foreigners living in Japan. The second is an illustrated book entitled "The Adventure of Neama" from Shonen Shashin Shimbunsha, which clearly explains about nanotechnology to children.

The Challenging Daily Life


The Adventure of Neama
(in Japanese)

MANA International Symposium 2012

Date: 2/29(Wed.) to 3/2(Fri.), 2012

Place: Tsukuba International Conventional Center (Epocal Tsukuba, Japan)

Registration Fee: Free

Details are available at the symposium official website:
http://www.nims.go.jp/mana_2012/

Newly Appointed Researchers

Qingmin Ji

MANA Scientist

Nano-materials field, Supra molecule unit

Specialty: Fabrication of layer-by-layer assembly

Dr. Genki YOSHIKAWA

MANA Independent Scientist

Specialty: Development of Advanced Sensors for medical, security, and environmental applications

Two ICYS-MANA Researchers also joined MANA.

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"**CONVERGENCE**" is the keyword used to symbolically describe the entire project of MANA, where outstanding researchers from around the world assemble and converge in the "melting pot" research environment to bring together key technologies into nanoarchitechtonics for the creation and innovation of new functional materials.