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CONVERGENCE

Research Extensively with Cogitative Eyes
— Sumio IIJIMA

Atomic Switches Lead to a Brighter Future
—Tsuyoshi HASEGAWA

The Result of Joint Research with Overseas Partners through Conclusion of a MOU

MANA's Research Outcome

- SQUID Coupled with InAs Quantum Dots —— Hideaki TAKAYANAGI
- Theoretical Analysis of Nanoscale Edge Effects of Graphene —— Katsunori WAKABAYASHI
- Self-organized Core–shell Structure for High-power Solid-state Lithium Batteries —— Kazunori TAKADA
- Magneto-Responsive Soft Materials: Magnetically Reconfigurable in a Nonvolatile Fashion —— Fatin HAJJAJ

wpi
MANA
International Center for Materials Nanoarchitectonics (MANA)

Sumio IIJIMA

Professor (Meijo University)
Director (AIST/NTRC)
Senior Research Fellow (NEC Co)
Distinguished Invited University Professor (Nagoya University)

He completed his Ph.D. in solid-state physics in 1968 at Tohoku University in Sendai. Between 1970 and 1982 he developed high-resolution transmission electron microscopy (HRTEM) at Arizona State University. In 1982 he returned to Japan and worked for 5 years on an ERATO project on nano-particles, then joined the NEC fundamental research laboratories. In 1991 he discovered carbon nanotubes using an electron microscopy that have initiated nano-materials science and nanotechnology. Following the discovery, he has been honored with numerous awards and prizes that include: Franklin Medal in physics (2001), Agilent Europhysics Award (2002), Balzan Prize (2007, Italy-Switzerland), Kavli Prize (Norway, 2008), Prince of Asturias Award (Spain, 2008), Order of Culture (Japan, 2009). He is members of Foreign Associate of the National Academy of Science (USA. 2007), the Norwegian Academy of Science and Letters(2009), Chinese Academy of Sciences (2011) and also member of Japan Academy(2010).

Research Extensively with Cogitative Eyes

❖ Interviewer: Akio ETORI, Science Journalist

Products Utilizing Carbon Nanotubes Finally Reaching the Market

——Professor Iijima, you discovered carbon nanotubes in 1991, exactly 20 years ago?

Yes, you could say that carbon nanotubes have now reached the age of majority. I have often been asked when products incorporating carbon nanotubes will appear, and now at last I can point to the touch panels on smartphones as such a product. Unfortunately, these touch panels were not developed in Japan. A Chinese company has been working on practical applications for carbon nanotubes in smartphones for around 10 years, and in the end they were successful. Touch panel used in smartphone typically contains a transparent electrically conductive film made of indium tin oxide (ITO), which is now altered by a layer of flexible and transparent nanotubes.

Japan, including the national government, finally started to make a serious effort starting the year before last. Faced with concerns that rare earth metals were becoming scarce worldwide, Japanese companies started to do applied research on graphene as a possible alternative. On the other hand, it seems ironic that China, which controls most of the world's supply of rare earth metals, has been the first to come out with a finished product employing carbon nanotubes—touch panels—rather than using ITO.

Japanese people are unaware of these things; they do not grasp the way things are progressing in today's world. That's why China and South Korea are well ahead of us in the nanotube field. The case of their use in smartphones is a clear example of this, and it can be considered as an alarm bell for Japan as well.

The level of science and technology in the emerging economies has risen very high, and the top management in our country seems completely unaware of the fact that we have already been overtaken in some areas. That's why first of all we need to look carefully at the present situation and gain an awareness of who our competitors are before we proceed with our research. The competition has already started, and we need to step forward and challenge our rivals to a formal match, in which each side has due respect for the other. Otherwise Japan will really be in trouble. I think it is essential that we are fully aware of the current state of affairs.

——In global terms, I think that Japan is generally considered to be at a relatively high level in the field of materials science. Are you saying that Japan's position is really not all that strong?

Japan is losing out in the area of ideas. I feel we are lacking in the ability to generate creativity and to think up a variety of new approaches. Researchers really need to think more broadly.

For example, at the beginning we used a simple method to produce carbon nanotubes, but the way we found of synthesizing them to make into actual products was so unique and the idea was outstanding that our first paper was selected to appear in Nature. Maybe if we can find a few researchers who have individual ways of thinking, we will be able to produce good results.

A Dual-faceted Approach that Considers Both Science and Technology

——So science and scientific discovery sometimes consists of more than just discovering basic principles and mechanisms.

Yes, that's right. I think that in addition to pure science, which consists of discovering basic principles, there is also R&D, which involves using science and technology to turn those basic principles into products. This is my own personal view, but technology seems to require a different approach. For example, our current efficiency may be 10%, but if we can gather more light it will increase to 20%. The basic principle that provides 10% efficiency is known to everyone, but by adding a variety of enhancements it is possible to reach the final goal. This pyramid-like approach to R&D is truly the essence of technology. In contrast, science operates in a completely different dimension where discoveries can be made suddenly. Actually making a useful product requires both types of people. You first start with an idea, then you follow up on it, add more manpower, and use technology to create a useful product. What's more, once you've created your product it has to compete against all sorts of things including existing products. It's a cutthroat game of survival. It takes a lot of hard work to reach the stage of a successful final product.

Even if they don't do the technological development work themselves, researchers must at least be aware of its necessity. Otherwise you're just doing difficult research to satisfy your own vanity. In the case of researchers conducting material science in particular, it is essential to have a future-oriented perspective as well as an awareness of its potential to make a social contribution and of how society will evaluate your work.

Is the Goal to Contribute to Society or to Culture?

—— As a participant in the WPI Program, the mission of MANA is to create a world-class center for research. Outstanding personnel from all over the world gather there to conduct basic research that will make a contribution to society. Do you have any advice as to what MANA should be aiming for as it moves forward?

Moving away from what we discussed earlier, I think that our research has two facets.

One is research that is directly connected to actual products and provides direct benefits for the world at large. The application of carbon nanotubes in touch panels would be one example of this. In most cases where research leads to the development of actual products its results are tangible in a way that we can see.

The other is research that makes a contribution in the cultural sphere. The classic example of this would be research that is awarded the Nobel Prize. Discoveries and technologies that are passed down to later generations as part of the national culture are a supreme example of cultural activities that make one feel pride in one's country.

We must not lose sight of the need to choose between these two aims and to set a clear final goal.

The research conducted at MANA is funded by the taxpayers, so it seems natural that they should set rather high goals and do their best to meet them, but it is not as if we can expect to achieve world-class results exclusively. We can't hit the target 100% of the time, but if we can get a bull's-eye once every ten tries or so we're doing pretty well. I think that rate of success is good enough.

The Need for Serendipity in Materials Science

This is my personal view, but generally speaking fields like physics or pure science are where researchers who are the most outstanding minds among the world's really brilliant people make really big discoveries. Dr. Makoto Kobayashi and Dr. Masukawa Toshihide would be examples. This is not usually the case in fields like materials science. If you try to design new materials in your head the results won't amount to much. There are limits to what a single person can think of. Rather, I think the real possibilities for new advances lie in serendipity, discovering new things by chance as we go about other tasks.

——Are you saying that your own discovery of carbon nanotubes came about through serendipity?

Of course. There is no possible way I could have just thought up something like that. What is really important is the variety of the research. I think it's really exciting to have a variety of people using different approaches and finding out all sorts of things. Rather than running in one direction, you could, for example, discover a certain result using a computer and then, finally, confirm the same result using a different method. I think there need to be many types of research.

You know, among the great discoveries and breakthroughs in the history of science there aren't any that were designed and built according to some predetermined plans. Most of the discoveries that go down in history happen when someone is doing research in a specialized field and then notices purely by chance something more exciting that is right nearby. Considering this, I think that while research done in their heads by brilliant people is important, it is absolutely essential that there be other work that follows different paths going on as well.

——Does this mean that whether there are a large or a small number of researchers working together plays a role?

I don't think it's a simple matter of numbers. Rather, the key is now many really outstanding researchers—that is to say not people who are interested in one field only but who are flexible enough to be able to handle all sorts of things and are in the end strong minded—you manage to bring together. I think things will go well if you have several researchers like this in the mix.

That said, how do you go about bringing together such researchers? You can speak of how well equipped a particular research institution is, but this is only one condition and it is not the fundamental one. To begin with, people will not come to your institution if it is not 'producing' anything. I know it takes some time, but by producing I mean regularly publishing research findings in highly regarded journals such as Science and Nature. If you do this people will start to think, "they seem to be doing pretty interesting work there," and researchers will come to you one after another. For example, my specialty is electron microscopy, and my work is pretty well regarded internationally and is well known. We receive applications from young researchers from all over the word. Then all we need to do is select the most outstanding applicants. For a long time well-established universities and the like in Europe and North America have gathered promising people from throughout the world in just this way. If MANA could establish this sort of an arrangement they might be able to attract new personnel without even needing to advertise. As for producing lots of papers, among the researchers there must be individuals with very high potential and he/she must be at the top. This is why it is important to get a good start. It may take some time, but now MANA seems steadily to be doing good work.

Foster a Multifaceted Way of Thinking Though Encounters with Many Cultures

——To wrap up, one of MANA's missions is to train young researchers, and there is a training system in place involving independent researchers and ICYS-MANA researchers. What do you feel is necessary in the training of young researchers and what sort of message do you have for them?

When you are young is the time to strive for new things, boldly and without fear of failure. It is best to keep trying new things. Also, young people should be active. You won't get the chance to work with good teachers if you yourself don't move around to look for them. If possible go abroad to study. If the place you choose to work turns out not to be a good fit for you, it's best to go elsewhere without delay. This may make it more difficult to find new positions later on, but it's something you can do because you're young. One way is to change your environment, do a reset, and start something new.

I prefer the diversity that comes from considering things in various ways rather than from a narrow single focus. It is good to have researchers from outside Japan around because it increases the opportunities to come in contact with such diversity. MANA has a higher percentage of non-Japanese researchers than many other WPI institutions, and in times like these, with Japanese young people not going abroad, it is great that you are drawing in researchers from overseas. This provides plenty of valuable stimulus and increases the opportunities for good ideas to be born.

——Thank you for taking the time to share your fascinating thoughts with us today.

Atomic Switches Lead to a Brighter Future

Tsuyoshi HASEGAWA

MANA Principal Investigator,
Nano-System Field

Atomic switch research began with a failure

——Dr. Hasegawa, you are famous in the field of atomic switch research. What was the impetus for you to start your research?

It all began when Director-General Aono was still a director and I was a researcher. We were researching whether conductive properties could be maintained in extremely thin metal wire. We made a micro-size fountain pen that we called a "nano pen", the ink of which was made up of metal atoms. By using the nano pen we were able to draw lines of atomic scale thickness and width. However, sometimes the pen failed to draw anything. When we inspected it with an electron microscope, we discovered that the metal atoms of the ink had agglomerated on its tip. When we drew a line we were controlling the 'pen pressure' of the nano pen, so there was a tiny gap between it and the substrate. Professor Aono realized that if we could stop control of the pen pressure, the pen-point and the substrate would come into contact and the whole would work as a switch. In retrospect, if Professor Aono had simply instructed us to find the conditions that would allow the nano pen to function properly, our research on atomic switches would not have begun. Thus, Professor Aono taught us a valuable lesson; that failure often creates a stage for new discoveries.

Soon thereafter I managed to demonstrate the switch operation, but I was told by device specialists that although the phenomenon itself was interesting it had no practical applications. Fortunately for us, at that time there were no device specialists in our group conducting research using nano pens. So, we continued our research, bearing in mind that nothing is certain until proven.

——To what extent is the atomic switch now established as a practical device?

As a result of the expansion of our research, a private company became interested and we began joint research with them. The advantage of cooperating with such a company was that we could make progress in areas such as integration and reliability. Although this technology can currently only be used for certain specific applications, thanks to this joint research, technically speaking our atomic switches have reached a level at which they are marketable. In our joint research we were developing products that utilized the properties of atomic switches, but I think we need to develop new products that can only be realized by using atomic switches.

Atom transistors and neural computers

——Do you have specific objectives for the new purpose of atomic switches?

Our group currently has two goals. One is to develop atom transistors that will one day replace semiconductor transistors, which are volatile; if electricity is cut off they revert to their initial state. Atom transistors, however, are non-volatile since they can preserve their states. They also consume little electricity when switching on and off, and their standby power consumption is zero. Our goal for the near future is to utilize atom transistors to create a super energy-saving, instant-on computer.

Our other goal is to create a neural computer. Conventional computers are powerful, but consume a lot of electricity, while the human brain, fully as powerful as such computers, does not emit as much heat. This is due to the difference between the methods of calculation used by computers and the human brain. The brain's neural network is built from synapses and neurons. Last year, we developed an element which functions in exactly the same way as a synapse. The result of that research appeared in the journal Nature Materials.

To develop neural computers we need a neuron element which functions as a control tower in a network. Our far-future goal is to achieve neuronal operation by using atomic switch technology, and to create a neural computer that can work without pre-programming and can learn on its own.

——Recently, it has been said that even researchers need to think about how they can contribute to society. Do you have any comments about that?

I would like to work toward spreading our technology, in an accessible manner, not only to specialists but to a wider audience in the general public. In addition to university students, I would like high school students and even elementary school students to be able to understand the technology. Last November, a WPI symposium, targeting high school and junior high school students, was held in Fukuoka. I represented MANA at the symposium, where I talked about atomic switch research. After the talk, one of the attending students approached me to tell me how much he admired me, and asked to shake my hand. I felt both pleasantly surprised and rewarded that he had enjoyed the talk on my research. I would like to continue such activities.

The project enters the next stage

——It has been almost five years since the foundation of MANA. Please describe your research aspirations and MANA's prospects in the field of nanosystems

I think we are now entering a phase where one or more big projects will emerge, either from MANA or from the Nano-System Field. Furthermore, I believe that it is our duty to ensure that such projects will be conducted. For instance, the development of neural computers which I referred to is now entering such a phase. For Japan, which is a technology-intensive nation, leading the world with its unique technology is the only way to survive, and also to make a positive difference to the world. I hope I can play a part in that.

The Result of Joint Research with Overseas Partners through Conclusion of a MOU

MANA has been inviting top level researchers of nanotechnology from all over the world and accumulating results. It is also making great efforts to cooperate with top institutes in other countries. One of these efforts is to conclude a Memorandum of Understanding (MOU) with a partner for joint research. Some results are listed below.

* MOU (Memorandum of Understanding) is a memorandum exchanged between MANA and overseas institutions to create joint research. Main points of these memorandum are: communication between researchers, exchange of research information, and providing facility for joint research. The term of validity is for five years, and it can be extended if both institutes agree.

Organization	Country	Date of Agreement
National Center of Competence in Research (NCCR) for Nanoscale Science, Institute of Physics, University of Basel	Switzerland	Jul 22, 2008
Supramolecular Chemistry Group at the Institute for Inorganic Chemistry, University of Karlsruhe (KIT)	Germany	Jan 29, 2009
Institute of Microengineering, Ecole Polytechnique Federale de Lausanne (EPFL)	Switzerland	Jul 20, 2009
Kirchhoff Institute of Physics at University of Heidelberg	Germany	Aug 31, 2009
Laboratory of Nanotechnology (LNT), Vietnam National University (VUN), Ho Chi Minh City	Vietnam	Jan 24, 2011
Flinders University	Australia	Jul 19, 2011

National Center of Competence in Research (NCCR) for Nanoscale Science, Institute of Physics, University of Basel

Nanomechanical cantilever array sensors have been emerging as a key device for various fields. A piezoresistive read-out technology, which is critically important for practical applications of cantilever array sensors, was developed in collaboration with the cutting-edge Cantilever Array Sensor Group in University of Basel. A comprehensive development of the sensor system, including read-out circuits, chamber design, etc, led to the successful demonstration of a high potential of piezoresistive cantilever array sensors.[1]

1 G. Yoshikawa, H.-P. Lang, T. Akiyama, L. Aeschimann, U. Staufer, P. Vettiger, M. Aono, T. Sakurai, and C. Gerber, "Sub-ppm detection of vapors using piezoresistive microcantilever array sensors," *Nanotechnology*, **20**, 015501 (2009).

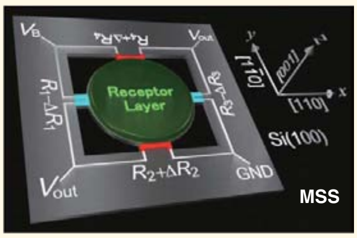
Supramolecular Chemistry Group at the Institute for Inorganic Chemistry, University of Karlsruhe (KIT)

Dr. Jonathan Hill (MANA Scientist, left) and Prof. Annie K. Powell (University of Karlsruhe, right) sign MOU.

The MOU with KIT is based on collaboration on nanomaterials including graphene.

The research has so far resulted in one major publication (S. Malik et al. Nanoscale (2010) 2, 2139) with several more in preparation including a high impact review.

Institute of Microengineering, Ecole Polytechnique Federale de Lausanne (EPFL)



This joint project CAPATEC (Cantilever and Probe Array Technology) is aimed at the development of multi-purpose sensors and probes based on the expertise and long term experience in micro- and nano-fabrication in IMT, EPFL and nano-characterization in NIMS. So far, a new nanomechanical sensor, MSS, was successfully developed[2]. Based on its high sensitivity and capabilities for miniaturization and integration, various applications including medical, environmental, and security, are expected.

2 G. Yoshikawa, T. Akiyama, S. Gautsch, P. Vettiger, and H. Rohrer, "Nanomechanical Membrane-type Surface Stress Sensor", *Nano Letters*, **11**, 1044-1048 (2011).

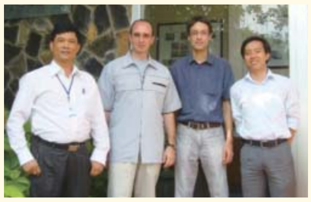
Kirchhoff Institute of Physics at University of Heidelberg

In order to explore novel optical functionality in nanometer-scale materials, we have studied the electron dynamics in ultimately small objects and its interaction with light by adopting both optical and electron probes. So far, the research team has published 7 joint papers, and Japanese side had 14 presentations at international conferences, and 10 invited lectures. The collaboration will be continued also in 2012.

Photo taken at the Summer School "Plasmonics, Functionalization and Biosensing," at Kirchhoff Institute of Physics at University of Heidelberg, Germany April 29th, 2011 (Members: 2nd from the left T. Nagao, 5th from the left A. Otto, 6th A. Pucci).

Laboratory of Nanotechnology Vietnam National University (VNU), Ho Chi Minh City

This MOU involves nanotechnology R&D for opto- and bio-electronic devices. So far, several general lectures for educational purposes have been given at various departments of VNU, Ho Chi Minh City and at an international workshop.



Dr. Lionel Vayssieres (MANA Independent Scientist, second from the left) visited the Laboratory of Nanotechnology in November 2010.

Flinders University

To examine the possibility of collaboration in research and development, two members of the faculty of Flinders University visited the MANA to discuss the current research activities with members of MANA and we held the Joint Symposium on Nanoscience and Nanotechnology. We also agreed to accept two doctoral students from Flinders University. One of them is going to carry out the research in MANA.

(From left to right) Prof. David Lewis (Director, Flinders Centre for NanoScale Science and technology), Prof. Michael Barber (Vice Chancellor, Flinders University), Dr. Masakazu Aono (MANA Director-General) and Dr. Kohei Uosaki (MANA Field Coordinator and Principal Investigator).

Since its foundation, MANA has concluded MOUs with more than thirty institutions from more than ten countries. By using various methods, MANA intends to become a true international research institute, to progress research, and to produce fruitful results.

SQUID Coupled with InAs Quantum Dots

Hideaki TAKAYANAGI MANA Principal Investigator
Nano-System Field

Recent development of nano fabrication technology enables coupling of quantum dots and a superconducting quantum interference device (SQUID) (Figure 1 (a)). This combination of a highly controllable electronic system and the most highly sensitive magnetic flux meter available opens up new possibilities for quantum information devices. Previously, this method was studied by using a nano structural one-dimensional superconductor such as a carbon nanotube or an InAs nanowire. Those studies indicate the attractiveness of study of the electronic spin state of each of two quantum dots in a SQUID.

Our SQUID showed a clear supercurrent (critical value I_c=2.5 nA) without the influence of a magnetic field. For the function for external magnetic field Φ_{ext}, it oscillated at a period of about Φ_0=1.5G and this value shows that flux quantum Φ_0=h/2e can be put in a valid SQUID field. This result proves that a loop containing Al/SAQD/Al self-assembled quantum dots (SAQDs) can function properly as the SQUID. Interestingly, we observed π-junction behavior when the side gate voltage was V_{SG1}=−0.4 V. This side gate voltage prompted π-phase shift of I_c oscillation under certain back gate voltage fields (Figure 1 (b)). This means that the side gate voltage evoked a spontaneous supercurrent in a loop, with one of two SAQDs becomes a π-junction and other a normal 0 junction.

The geometric structure of the SQUID enables us to observe directly the π-phase shift and the negative supercurrent in a current-phase relation. These are dependent not only on the SAQD energy level controlled by back gate modulation but also on the SAQD and electrode controlled by side gate modulation (Figure 1 (c)). Our result shows that the π-junction shift can be described a singlet-doublet shift in the InAs SAQD caused by a change of the coupling degree between the SAQD and the superconductor electrode caused by side gate modulation. Adopting SAQDs for a DC-SQUID opens up new possibilities of quantum information processing in various fields such as optics, spintronics and superconductors.

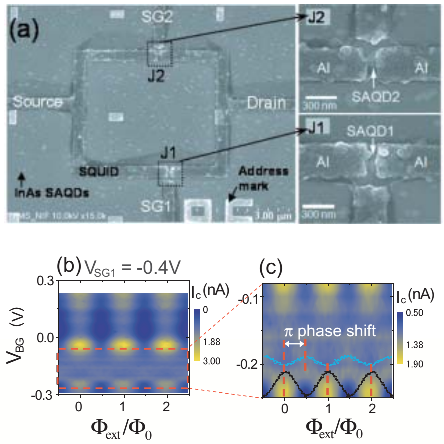


Figure 1. (a) SEM photo of SQUID coupled with InAs SAQDs. The dots randomly distributed in the picture are InAs SAQDs. (b) I_c oscillation as a function of external magnetic field and V_{BG}. V_{SG1} is fixed to be −0.4 V. (c) Enlarged plot of (b) in the range of V_{BG} from −0.08 to −0.25 V.

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S. Kim, *et.al.*, *Appl. Phys. Lett.*, **98** (2011), 063106

Theoretical Analysis of Nanoscale Edge Effects of Graphene

Katsunori WAKABAYASHI MANA Independent Scientist

Graphene is a one-atom-thick sheet consisting entirely of carbon atoms. This material was discovered in 2005 and it has attracted the attention of scientists worldwide as a candidate for a new two-dimensional electron system. Inside the sheet the carbon atoms form a honeycomb lattice structure (Figure 1 (a)). It has a unique character unlike conventional two-dimensional electron systems formed at a semiconductor interface: the fundamental equation of the electrons which move inside the graphene is not written as the Schrödinger equation but as the massless Dirac equation. In other words, the electrons in graphene behave as relativistic particles with no mass. This peculiar electronic structure causes the electrons in graphene their imperviousness to scattering by impurities and high electron mobility. And graphene is an almost completely transparent material due to its one-atom-thick structure, so we expect that it will be used for touch panels or solar cells in the near future.

The attractive property of graphene is not only a material as one-atom-thick film. Since the 1990s Dr. Mitsutaka Fujita and I have indicated that its strong nanoscale and edge shape effects cause great changes in graphene's electronic state, showing a variety of magnetic and electronic properties. For instance, considering the shape of the cut end of graphene, the difference between the cut angle makes two types of edges: one is an armchair edge (Figure 1 (b)) and the other a zigzag edge (Figure 1 (c)). With a zigzag edge, in particular, the electronic state will be very different from that of normal graphene because the electrons will form an arrangement localized at the edge.

One of edge-effects expected to be seen in the electronic characteristics of nanoscale graphene is peculiar magnetic properties caused by the edge-state of a zigzag edge. The electron-electron interaction may cause spin polarization along the zigzag edge (in other words, magnetism near the zigzag edge) (Figure 1 (d)). This theoretical prediction is now being confirmed by several experimental groups.

The diversity of physical properties among nano-carbon materials may appear quite troublesome from the viewpoint of experimenters, but things that were thought impossible in the past are now being realized by the steady progress of technology. To control a particular physical property among various others can be said to be the most interesting part of nano science/nano technology. I think the role of theorists like us is to draw up plans related to the functions and physical properties of nanoscale materials.

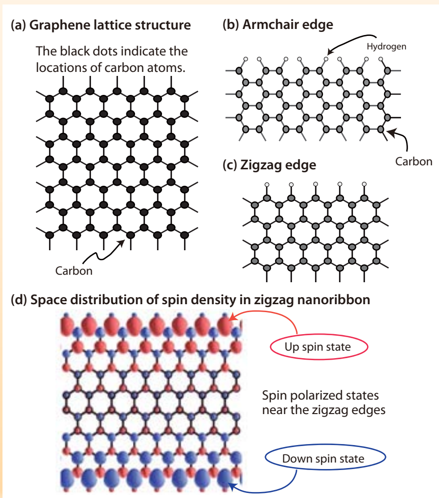

Figure 1. Graphene lattice structure and edge effects.

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K. Wakabayashi *et.al.*, *Sci. Technol. Adv. Mater.*,**11**, 054504 (2010).

Self-organized Core–shell Structure for High-power Solid-state Lithium Batteries

Kazunori TAKADA
MANA Principal Investigator
Nano-Green Field

Lithium-ion batteries have been used in portable electronic devices, e.g. notebook PC's and mobile phones. However, the safety issue arising from combustible organic electrolytes remains unsolved. In addition, they are expected to power in electric vehicles and smart-grids. Large-sized batteries are necessary in such applications; however, the increasing battery size makes the safety issue much more serious.

A fundamental solution to this issue is replacement of the organic electrolytes with non-flammable substances, one of which is a solid electrolyte. However, use of solid electrolytes decreases the power density. We indeed need highly-conductive solid electrolytes in order to increase the power density. However, the power density had not increased, even when the high-conductive sulfide solid electrolytes are used.

We found that the rate-determining step is at the interface between $Li_{1-x}CoO_2$ and the solid electrolyte, where lithium-depleted layer is formed. We coated the surface of the $LiCoO_2$ particles with an oxide solid electrolyte (e.g. $Li_4Ti_5O_{12}$) as a buffer layer for the formation. A thin film of the buffer layer with several nanometers in thickness decreased the interfacial resistance and successfully increased the power density to be comparable to that of commercial lithium-ion batteries. However, it is not easy to form such very thin and uniform layer on the surface of the $LiCoO_2$ particles, and thus an alternative technique is necessary for mass production.

In this study, we have developed the alternative technique, which is very simple and cost performing. We found that just adding an Al compound among the starting materials in the synthesis of $LiCoO_2$ enhances the power density to the same extent. When the Al compound is added, most of the Al occupied the Co sites to form $LiAl_xCo_{1-x}O_2$ solid solutions. Simultaneously, the rest of Al is segregated at the surface to form Al-enriched domains. The high Al concentration suppresses the electronic conduction at the surface; therefore, the surface itself acts as the buffer layer and reduces the interfacial resistance. When 8% of Co was substituted with Al, the power density became comparable to that observed for $Li_4Ti_5O_{12}$-coated $LiCoO_2$.

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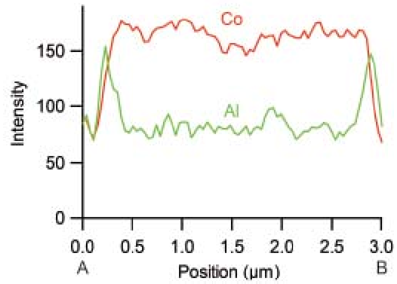
X. X. Xu *et al.*, *Chem. Mater.*, 2011, **23**, 3798–3804.



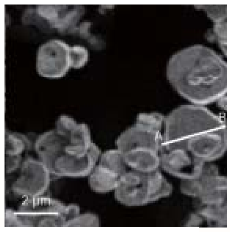


Figure 1. Al distribution in the $LiAl_{0.08}Co_{0.92}O_2$ particle. A two-dimensional image (upper) and a line profile obtained by secondary ion mass spectroscopy (right).

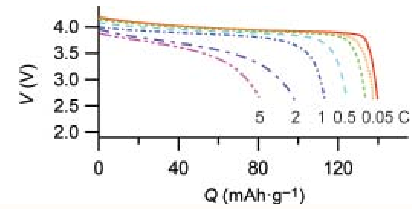


Figure 2. Discharge properties of the $LiAl_{0.08}Co_{0.92}O_2$ electrode

Magneto-Responsive Soft Materials: Magnetically Reconfigurable in a Nonvolatile Fashion

Fatin HAJJAJ
ICYS-MANA Researcher

The semiconductor industry has long sought a high-density, high-speed, low-power memory device that retains its data even when the power in interrupted. Nonvolatile memory concepts aimed at the horizon beyond 2013 are based on phase-change rather than charge storage where the transition between two different states represents the 1s and 0s of stored digital data. Responsive soft materials with phase-change capabilities under external stimuli, such as liquid crystals (LCs), are considered the most mature candidates for future nonvolatile data storage and reconfigurable electronics. The growing interest in integration of adaptive LC materials in devices brings about the need to utilize non-invasive stimuli to remotely trigger changes in the materials without induced degradation of the device performance. Among all potential external stimuli, a magnetic field has the benefits of contactless control, instant-nonharmful action, and easy integration into electronic devices, though it has only been used limitedly in manipulating supramolecular LC assemblies due to the complication of the forces that are involved. Magnetic-field-induced molecular switching is most suitable for ionic soft materials that are inconsistent with the application of electric fields. Despite these attractive features of the magnetic stimulus, up to date, there is no experimental evidence for a magnetically induced irreversible massive lattice distortion in LCs.

In this study, we demonstrated that the application of an external magnetic field can induce a massive structural transformation in ionic liquid crystalline material with orthorhombic phase structure. Due to structural features, this orthorhombic phase structure (left bright phase in Figure 1) transfers preferentially into a more thermodynamically stable cubic phase structure (right dark phase in Figure 1) upon cooling its isotropic melt in the presence of magnetic fields. The transition is irreversible and accompanied by a spectacular change in the material property that confers a memory effect to the system. Our observations suggest that this new concept of magnetic-field-driven irreversible switching, based on magneto-responsive soft materials, may open up the doors for novel magneto-optical devices.

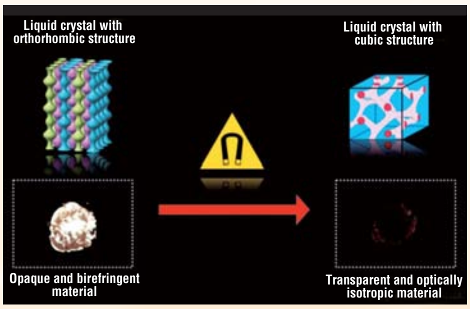


Figure 1. Schematic representation and polarizing optical microscopic images of a magneto-responsive liquid crystalline material at 300 K before (orthorhombic phase, left) and after (cubic phase, right) exposure to a magnetic field.

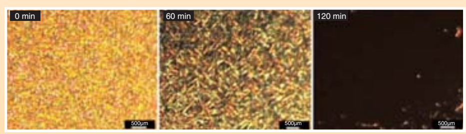


Figure 2. Time-dependent magneto-optical response of orthorhombic liquid crystalline material under a 5T field. The optical images were taken with crossed-polarizers condition of the magneto-optical microscope.

References
F. Hajjaj *et al.*, *The 10th International Conference on Materials Chemistry, Manchester*, UK. 2011

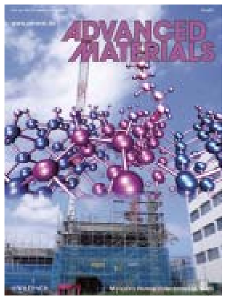
MANA given the grade "A" in the WPI Program Interim Evaluation

Results of WPI Interim Evaluation by Ministry of Education, Culture, Sports, Science and Technology, MEXT were posted on December 14, 2011. MANA was given the grade "A", which was the second highest evaluation among the five WPI centers at Kavli IPMU (University of Tokyo), iCeMS (Kyoto University), IFReC (Osaka University) and NIMS.

Interim Evaluation Meeting at MANA on October 17, 2011. Mr. Nakagawa (the Minister of MEXT, left) and Dr. Aono (MANA Director-General, right).

MANA featured in Special Issue of Advanced Materials

On January 10, 2012, the major research achievements of MANA were featured in a special issue of the journal Advanced Materials published by John Wiley & Sons, Inc. Advanced Materials is one of the highest impact factor journal in the field of materials science. This is the first time that a Japanese research institute has been featured in an own special issue of the top ranked journal Advanced Materials.



Adv. Mater. 2012, 24(2), 141

MANA researchers featured in NHK BS Premium Program

The three MANA researchers Dr. Masakazu Aono (MANA Director-General), Prof. James Gimzewski (MANA Satellite Principal Investigator) and Dr. Genki Yoshikawa (MANA Independent Scientist) were featured on NHK in the BS Premium Program "Atom changes life" aired on January 1, 2012. The program introduced the latest research results together with future applications through interviews with the three researchers.

Dr. Aono explains the development of an atomic-scale switch.

Tsukuba Biomedical Forum 2012 successfully finished

Tsukuba Biomedical Forum 2012 organized by the Biomaterials Unit, MANA, was held on January 18, 2012. The purpose of the forum was to connect needs and seeds of new technologies among medical and engineering research organizations in order to utilize them for medical treatments and diagnoses in cooperating with private corporations. There were approximately 180 participants, 17 exhibitions by private corporations and over 50 poster presentations by researchers.

The poster award winners together with MANA Principal Investigator Dr. Takao Aoyagi (second from the left in the back row).

MANA exhibited a booth at "Science Festa in Kyoto 2011"

MANA ran a booth at "Science Festa in Kyoto 2011" held at Kyoto International Conference Center on December 17th and 18th, 2012. We exhibited on "Highly Sensitive General-Purpose Sensor" where visitors are allowed to experience attractions through puzzles and a demonstration of the sensor by a MANA researcher. On December 18th, Mr. Nakagawa, Minister of MEXT, and Mr. Furukawa, Minister of State for Science and Technology Policy, visited each WPI booth at the venue.

Mr. Nakagawa (third from the left), the former Minister of MEXT, receives explanation about the sensor.

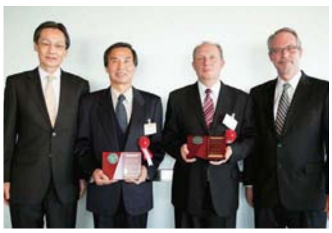
Dr. Takayoshi Sasaki awarded the CSJ Academic Prize

The Chemical Society of Japan (CSJ) announced a list of winners of the Chemical Society of Japan Prize 2012 on February 8, 2012. MANA Principal Investigator Dr. Takayoshi Sasaki was awarded the 29th Academic Prize. The award was given for his work on "Synthesizing 2D nanosheet and pioneering its functionalities".

Dr. Takayoshi Sasaki, MANA PI

Dr. Bando and Dr. Golberg received the 3rd Thomson Reuters Research Front Award

On February 14, 2012, Dr. Yoshio Bando (MANA Chief Operating Officer) and Dr. Dmitri Golberg (MANA Principal Investigator) have been selected to receive the 3rd Thomson Reuters Research Front Award for 2011 for their outstanding contributions to the field of Materials Science through their work on "Novel Syntheses of One Dimensional Inorganic Nanomaterials and their Applications".



Dr. Yoshio Bando (second from the left) and Dr. Dmitri Golberg (third from the left).

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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.