MANA NEWS LETTER

CONVERGENCE

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International Center for Materials Nanoarchitectonics (WPI-MANA)

Featured Topics

Planetary Science × Life Science × Materials Science

Mission to Mars

— Is Mars migration possible? —

Earth-Life Science Institute (ELSI) Director Kei Hirose / Associate PI Tomohiro Usui

Leader's Voice

A Conversation with

Prof. Hiroshi Amano

“Developing countries have more research seeds to sow.”

WPI-MANA Research Highlights

- DRIVING SOFT MOLECULAR VEHICLES ON A METALLIC SURFACE
- INNOVATIVE TRANSISTORS BASED ON MAGNETICALLY INDUCED MOVEMENT OF IONS
- ATOMICALLY THIN PEROVSKITES BOOST FOR FUTURE ELECTRONICS

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Mission to Mars

— Is Mars migration possible? —

Forty-eight years have passed since humans first set foot on the moon. Now that the exploration of Mars by unmanned rovers is possible, the expression "colonization of Mars" is no longer considered “out of this world”. Thinking from the perspective of cutting-edge planetary science, life science, and material science – is actual migration to Mars possible? We spoke to Director Kei Hirose and Associate PI Tomohiro Usui of the Earth-Life Science Institute at Tokyo Institute of Technology (ELSI) about their prospects and technology required for the future.

Interviewer: Akio Etori / Writer: Takeshi Komori (TRIXIS FACTORY)

Kei Hirose

Director
Earth-Life Science Institute (ELSI)
Tokyo Institute of Technology

PROFILE

Kei Hirose received his doctorate in geology from the University of Tokyo in 1994. After graduating, he was a visiting researcher at the Geophysical Laboratory of Carnegie Institution for Science. He took up the position of assistant professor in Earth and Planetary Science at Tokyo Institute of Technology from 1999, and became a professor in 2006. Director of Earth-Life Science Institute (ELSI) since 2012.

He succeeded in simulating Earth's mantle with 1.2 million atm at 2,500 degrees Celsius and finding the post-perovskite phase. Received the Inoue Prize for Science, the JSPS Prize, the Japan Academy Prize, the Fujihara Prize, and more.

Is the day we stand on Mars soon?

—Mars immigration is a hot topic these days.

Hirose: NASA seems to be thinking about how we can really move to Mars, and Elon Musk of Space X is hard at work as well. A nonprofit organization in the Netherlands called Mars One has also begun recruiting hopeful migrants. Even people from the private sector are planning and working at this; it’s not a sci-fi movie. Interest in Mars is rising at a global level, and I think we’re at the stage where the roadmap is being made.

Usui: NASA alone is not enough to provide human and other resources for really learning about Mars, so we’re working in an international framework. We’re working at investigating meteorites from Mars (※1), and sending probes (※2) there to discover more. There are still plenty of knowledge gaps between us and migration, or even manned flights to Mars.

—With the current roadmap, when will immigration begin?

Hirose: If things go well, NASA plans a manned flight to Mars in 2035. Another quarter century for migration? Of course, I don’t think this plan will work so smoothly (laughs).

—Then why do you and ELSI focus on Mars?

Hirose: One main reason we study Mars is to compare it to Earth. Mars and Earth are made by basically similar processes. Mars may have been a blue planet just like Earth. It’s estimated that three hundred million years ago, 20% of Mars’ surface was covered with ocean. It’s also believed that, at that time, Mars had a high temperature core and thermal convection producing a magnetic field like that of Earth.

—Nothing like the Mars we know now.

Hirose: It is thought that a series of small meteors fell on Mars from 4.2 to 3.9 billion years ago, ultimately cooling the liquid core and causing the thermal convection to stop, setting the magnetic field like a permanent magnet. Without a magnetosphere, the solar wind (plasma particle gas) stripped the planet's atmosphere, and the water evaporated. The water molecules were ionized by radiation, hydrogen gas was released into space, and oxygen oxidized everything on the surface. The soil is covered with iron oxide, and this is the red surface of Mars.

—There is a possibility that Mars was once like the Earth, and the possibility that Earth was once like Mars is currently.

Hirose: Different processes between Earth and Mars lead them to different results as planets. Based on the knowledge we have, it's very interesting to consider if there was life on Mars at that time. Under the hypothesis that life was born on the Earth, if we apply that idea to Mars in that same period, we reach a conclusion that is verifiable. The fact that we can verify models made on Earth is one of Mars' interesting points.

—Mars is called the brother planet of Earth.

Usui: To me, Mars is more interesting than the Moon or Venus due to its rich geological diversity; volcanic topographies, traces of river flow, ancient ocean sediments, and glaciers in polar caps. There are also four seasons. Since the beginning of the 2010s, we have been able to estimate the amount of water vapor in the atmosphere using the telescopes at the Mauna Kea observatories. We are finally beginning to understand how the atmosphere moves on Mars.

To build a home on Mars

—Then, if we attain such a roadmap, what sort of lifestyle can we expect when mankind arrives to live on Mars? For example, how should we consider places to inhabit?

Hirose: It will be very difficult to live on the surface of Mars. It's impossible for human beings and other normal life forms to survive there due to high oxidation on the surface.

—There are also problems of radiation and ultraviolet rays.

Hirose: On the other hand, there are also some interesting stories. The interior of Mars is far from oxidative. Rather, it is said to be more reductive than Earth. So, it might be a good idea to dig a hole for living spaces. What I have heard is that Mars has cavities called lava tubes that can form after lava flows. Mt. Fuji in Japan also has underground caves; such dwellings may be a good start for the beginning phase.

—Let’s say we can find such lava tubes. In order to make it a good place to live, we'll need some building materials. Will Mars provide the necessary structural and functional materials?

Hirose: Cement, representative of structural materials, should be easily obtainable. First of all, as a representative of structural materials, I think that cement is probably available. Raw limestone is abundant there; of course it may have been oxidized, but it can be deoxidized. The real problem might be obtaining metal.

—Could we get iron, for example?

Hirose: Iron is common in Mars' ore deposits, but iron and steel manufacturing will be necessary. On Earth, we melt iron ore in a blast furnace to remove the oxygen.

Usui: Stones like those of Hawaii, though rusted, cover the surface of Mars. As to the question of whether the same materials can be produced as they are on Earth, the answer is YES. However, even if we stood on the lava in Hawaii, we're unable to retrieve iron ores there. In Earth's case, iron ores are created by water circulation and element concentration by biosis. Then iron ores form a vein, and then we can extract mineral resources from it. First, we need to find a vein.

Hirose: As there are traces where the river flowed, there should be a coalesced vein just like on Earth. It just hasn't been found yet.

Usui: Compared with Mars, Earth had overwhelmingly large activity in the agglomeration process and its timespan was long. There were some places with salt water flow, but not many. However, several places where hot water once circulated have been found, and I've heard that opals and concentrated heavy metals exist there.

Hirose: In the case that we want copper and to use Martian minerals, even if we find a vein we will still have to extract from Martian stone. We'd melt them on Earth, but it would be difficult on Mars. One idea being considered is a method called bioleaching, which is carried out by microorganisms such as bacteria. It is a method of conducting precipitation and dissolution by metal complex formation via the microbial redox process. There is already a copper leaching method using sulfate reducing bacteria. We could use this method on Mars. There are also cases that iron and phosphorus were extracted by using bacteria from simulated Martian soil.

—What about the atmosphere?

Hirose: The Martian atmosphere is very thin and 95% is carbon dioxide. Despite the thin atmosphere, there is more carbon dioxide than Earth. If humans are to live there, we need to consider that there is almost no water vapor and nearly no oxygen.

—We need to bring oxygen from somewhere or make it.

Hirose: Since the surface of the Mars is very oxidized, decomposing it and taking oxygen out is a reasonable way. There is the idea of making microorganisms do it, or via electrolysis.

—Do we need to bring microorganisms or bacteria that have such a function?

Hirose: Of course. Well, if you say that all microorganisms are just made of genes, in due time we may be able to synthesize DNA all over there. But, that's difficult in current synthetic biology, right?

—If there's a module similar to a kind of microorganism, is it the best? WPI-MANA has ideas about artificial photosynthesis.

Hirose: It could be. It will be easier to control. After all, no matter how useful microbes are, it doesn't mean that they do what we want them to do. Devices that humans can control properly will be more useful than microorganisms. Seems to be more energy efficient.

Water and Energy Sources

—So, we've worked out the location. We get a certain level of atmosphere. What's next?

Hirose: Energy. It is very far from the Sun, so the average temperature is 60 degrees Celsius below zero. The average

Tomohiro Usui, Associate PI

temperature of Earth is about 15 degrees Celsius. It is an extremely cold place. A nuclear battery, not a solar cell, is installed into a Mars rover. NASA also has a project to make a small nuclear reactor on Mars. We must bring such energy sources from Earth, or find it on Mars.

—It is said that water exists on Mars.

Hirose: Basically, it's expected that a lot of frozen layers exist in various places if you dig a little.

Usui: A large amount of ice has not been found, but there are electrical geophysical data that a frozen layer, dozens of meters thick, exists beneath a wide area. There is a big technical jump to actually dig up the ground, but we can access the ice if we know the location of the shallow frozen layer. Places seeping water on the surface were commonly found. In the warm equatorial crater slope, black stains cyclically appear in the summer and disappear in the winter. Looking at the spot spectroscopically, it seems that the salt water evaporates little by little and disappears in the winter time. I believe that such a seasonal cycle is very important for life activities.

Mars and the Search for Life

—For the previously mentioned bioleaching and such, we'll have to bring a lot of fungi or microorganisms from Earth to create the environment.

Hirose: From the perspective of scientists seeking the origin of life, it's no fun to bring them from Earth (laughs). If a life form was born on Mars, it must be a life different from the one on Earth. Put crudely, every single life on Earth is all the same. Although Earth seems to have a rich diversity of animals, it is possible to say that they all have only one principle.

—What's called the "central dogma" (※3)**.**

Hirose: That's right. To know the diversity of life, we want to know about life that is not from Earth.

—Does that mean that there is a possibility that Earth life will be destroyed if sent to Mars as an alien species?

Hirose: I said that there is only one kind of life on Earth, but there might have been about 100 kinds of life in the beginning. I believe that it is highly possible that our ancestors destroyed other lives and became the last survivors. Can we do the same thing on Mars? Thinking about the origin of life, I am very concerned.

—If the current DNA and RNA life forms are the only type of life on the Earth, there is a possibility that other planets have quite different forms of life.

Hirose: It could be. That is exactly what we want to know the most.

—That is the fundamental question of ELSI.

Hirose: We often talk about life in the universe, but life in the universe and the life on Earth cannot be the same. I don't think that they have the same central dogma. The Earth must have its unique character, and life exists on it in tune with the environment. We don't know the difference from others. That is the most interesting for me.

—There is the possibility that there are creatures we cannot imagine.

Hirose: Of course there is. We use 20 amino acids in our body. Let's say that we could use 25 of them. What we can do with them is very interesting question. Instead, how about narrowing it down to 15? The number 20 is definitely not a fixed number. It is also very interesting to see what happens when we get 25 different kinds of animo acids. It cannot be the same.

—From the perspective of life research, studying about Mars and other planets is important.

Hirose: It is important to explore Mars to know whether or not any life exists on it, but our main interest is to see how Martian life differs from Earth life.

—One final question. If you could go to Mars in the future, would you want to go?

Hirose: Well, it's not so appealing to me (laughs). I don't wish to live on the reddish ground over there. I'll be observing it from Earth (laughs). ■

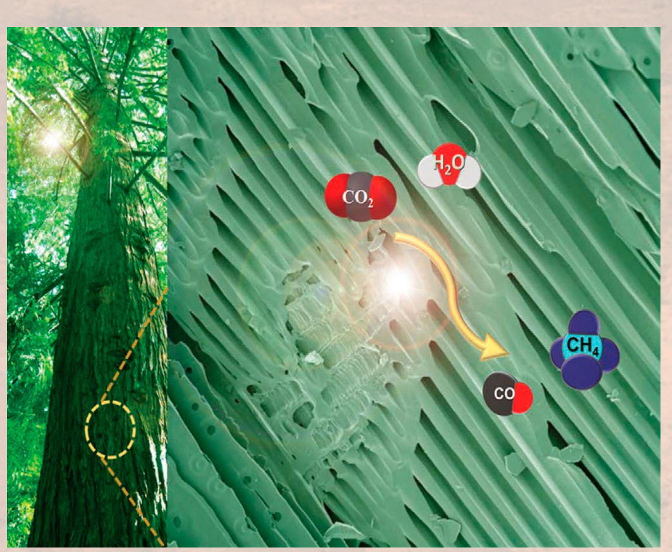
※1: As of September 2017, 198 meteorites from Mars were discovered.

※2: Eight rovers have been sent to Mars since the Mars Pathfinder succeeded in landing for the first time in 1997. NASA's Curiosity rover is in operation and sends images of Mars to Earth.

※3: An idea from molecular biology that all creatures on the Earth have the same principle. DNA becomes proteins through RNA, and the series of information transfers to create organism structures or functions can be applied from bacteria to humans and plants. Introduced by the late Dr. Francis Crick in 1958.

Related research of WPI-MANA: Artificial photosynthesis

"Artificial photosynthesis" is a technology that converts carbon dioxide into water and hydrocarbon. WPI-MANA has successfully developed new materials with the world's highest quantum efficiency approaching that of natural photosynthesis in photocatalytic water oxidation by a unique band structure engineering approach. Sophisticated control and integration of nano-metal/oxide by mimicking the nanoscale level structure of natural photosynthesis has enabled efficient light harvesting, charge separation, CO_2 gas diffusion/conversion to CH_4, making a big step towards realization of high-efficiency artificial photosynthesis.



Leader's Voice

A Conversation with Prof. Hiroshi Amano

PROFILE

Completed coursework without degree at Nagoya University Faculty of Engineering/Graduate School of Engineering in 1988, aide in Engineering Department the same year, Doctor of Engineering in 1989. Lecturer at Meijo University Faculty of Science and Technology in 1992, Associate Professor in 1998, Professor in 2002. Professor at Nagoya University Faculty of Engineering/Graduate School of Engineering since 2010. Has concurrently served as Director of Akasaki Research Center since 2011. Appointed Director of Center For Integrated Research of Future Electronics, Institute of Materials and Systems for Sustainability at Nagoya University, October 2015. Succeeded in inventing the world's first high-quality crystal creation technology for blue LEDs, along with tenured professor at Meijo University & distinguished professor at Nagoya University Isamu Akasaki and University of California Santa Barbara Professor Shuji Nakamura, earning the Nobel Prize in Physics, among many other awards.

Applied research beyond LEDs

—After winning the Nobel Prize, has your research in blue LEDs had new developments?

Yes. The fact that LEDs have become popular in general society means that its manufacturing technology has been established to some extent. Thanks to that, I think that we're now at the stage where various applications of LEDs can be considered; we're currently thinking about how to apply it to power devices in our laboratory, especially wirelessly. Gallium nitride has a very large bandgap, that is, it has high dielectric breakdown tolerance. That makes it possible to make small devices. The fact that it can be made smaller means less energy loss. I think that we're at the point where if we press on a little more, we'll see it in practical use. I believe that if wireless power transmission is realized, the world will change dramatically. Drones, for example; it can only fly for about 30 minutes at the most due to limits in battery capacity, but if we develop wireless power supply technology, longer flight periods will be possible. It's possible to revolutionize the physical distribution system centered on short distance transportation.

—Wireless power transmission technology is a very practical technology, but your career started with fundamental material research. What do you think of the relationship between basic research and applied research?

That's an important question. Using LED technology as an example, the required specifications for material reliability are entirely different in the case of LEDs and power supply circuits. LEDs as a light source will still glow without issue even with crystal defects. In extreme cases, traffic lights function as a signal light even if one of the LEDs used is not lighting up; however, this is not the case with power supply circuits. An electric car going out of control would be a dire situation. In other words, crystal defects can not be allowed. Fundamental science and basic research such as crystal growth technology, thermodynamics, statistics, and quantum mechanics are essential for establishing manufacturing technology that meets required specifications. Applied technology and the foundation are linked as one.

Stay hungry, young researchers!

—Do you have any thoughts on the state of Japan's research in comparison to the rest of the world?

After receiving the Nobel prize, opportunities to go abroad increased, bringing new discoveries. For example, I went to Silicon Valley, where their development is largely supported by AI and the Internet. Their efforts are all put into applied technology research rather than basic research, with seemingly no next step. In France on the other hand, each student is given experimental equipment devised to do basic experiments. Witnessing this hands-on approach, I truly felt that Japan doesn't match up. From my own experience however, I feel that students will be satisfied doing experiments as such. As a reaction to being unable to do experiments much upon entering college, I became absorbed in them for my graduation research, though the experiments did not go well at all. I think that my hunger for research was fostered by that reaction.

> “Developing countries have more research seeds to sow.”

—Should students pursue experiences to study abroad?

I think so. Everyone wanted to study abroad in the United States and Europe in the past, but it seems that students nowadays don't want to go anywhere. I would encourage people to go to so-called developing countries.

—What do you mean by that?

Recently, I went to Oman and India. While the culture is wonderful, there are still a lot of unresolved social problems. Researchers can see that and realize the possibilities that their work has for society. I think it is very important for young people to have such experiences. In other words, I want them to think "I want to do this, I want to change society", I want them to have that hunger. You should be aware of social issues even if you're in Japan, but that is, in fact, difficult.

For example, Guatemala is struggling to secure water. Domestic wastewater has entered the lakes where water is collected from, causing health problems. We need to clean up the water there, but since hearing that it's technically difficult I've begun looking towards cooperative efforts. We're working on ultraviolet LEDs in our laboratory, and since we've made advancements in collaborative research with enterprises on water purification, we've been able to provide informational support. Ultraviolet equipment isn't suited for large-scale purification however, so we received help from a Nagoya University professor who is researching microbe use for clean water. With this, we were able to start the project.

There are many cases where research themes can be found by focusing on the present state of developing countries, rather than watching only developed countries where cutting-edge research is happening. I think that being aware of it while young, and having a sense of purpose in my research is very important.

—You seem to be conscious of research that's useful for society. Do you always try not to lose your viewpoint as a researcher even in everyday life?

Research is on my mind on a daily basis, but since it makes up a large part of my life I don't see it as work. Just thinking about things to research is fun. Especially when going abroad and noticing problems you hadn't noticed before, it's fun to think about how you can solve it.

Leader's Voice

A Conversation with Prof. Hiroshi Amano

Research that births 1 from 0 & Research that develops 1 into 10

—By the way, you're working on collaborative research with Director Koide of NIMS. How did that come together?

We researched together at the Akasaki laboratory, and as my senior we get along great, so that's one reason. Another is that NIMS has the world's best physical property evaluation ability, which was necessary for our research. For example, if you want to investigate the structure of killer defects in gallium nitride crystals, NIMS is the only research institution that can evaluate at the atomic level. Thanks to the collaborative research, I gained a deeper understanding of several things in a short time. I think NIMS's ability in such basic fields is truly wonderful.

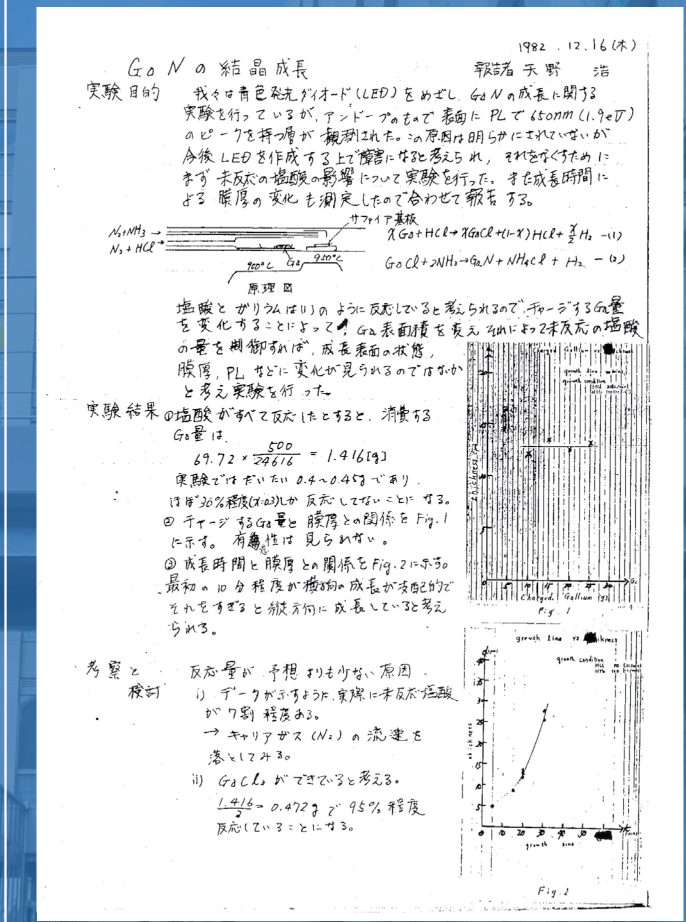
—WPI-MANA advocates a new paradigm called "nanoarchitectonics" to promote nanotechnology research. Do you have any advice for the next steps in "nanoarchitectonics"?

I think what is expected of NIMS and WPI-MANA by society is that we will produce a lot of excellent fundamental research results, and I would like to continue to meet those expectations in the future. However, in Japan there are many researchers who are now working to create 1 from 0. To that end, the job of developing 1 to 10 is starting to be more significant. What do we do with that? If we smoothly coordinate research results, which is stage one, as specialists making new things start appearing, I think that it will be possible to secure a connection with the real world. It may be necessary to have work linking the invention to the innovation.

—Can young people fulfill that role?

Rather, I think that young people are more qualified. Even if we come up with new ideas at our age, it's difficult to carry on immersed in our work. This is where youthful power and motivation are necessary. ■

The first page of the graduation research presentation materials


GaN の結晶成長
1982.12.16(木)
実験目的

"Since the experiment did not work at all and a classmate reported on the most advanced research results at the time, my report was the only one without content. My regret now is my starting point. This report was the impetus for my immersion in experiments between my master's and doctoral courses."

2017-2018

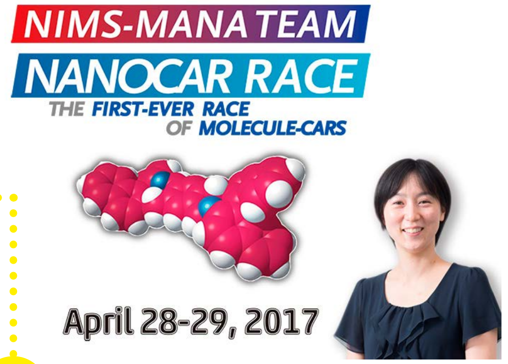
Timeline of WPI-MANA

2017.03

International Symposium on Atomic Switch: Invention, Practical Use and Future Prospects

The "atomic switch", which was invented at MANA, has come into practical use as the "NEC AtomSW-FPGA", which will soon be used in robots and space satellites for example. At the symposium, future applications have been discussed.

04



MANA participated in "Nanocar Race"

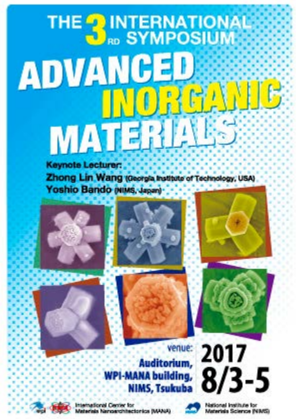
The first-ever international molecule car race "NanoCar Race" took place in April 2017 at CNRS in France. Six teams from five countries around the world competed with each other for the first place over 36 hours. From Japan, NIMS-MANA team, sponsored by TOYOTA, participated with the molecule car propelled by flapping motions of two wing-like structures on the molecule. Unfortunately, NIMS-MANA team gave up the race because of a series of machine troubles. NIMS-MANA team recieved the Fair-play award for our attitude to minimize the impact of the machine troubles for other teams.

05

06

07

08



The 3rd International Symposium: Advanced Inorganic Materials

In the field of inorganic nanomaterials like nanotubes, nanowires, and nanosheets, researchers have focused on their syntheses, analyses, and applications such as photodetectors, ion batteries, gas sensors, supercapacitors, catalysts, and many other green energy fields. At the symposium, latest research results have been reported.

09

Kazuya Terabe PI and Masakazu Aono Executive Advisor recieved the 28th Tsukuba Prize

The Science and Technology Promotion Foundation of Ibaraki awarded The 28th Tsukuba Prize to Kazuya Terabe PI, Masakazu Aono Executive Advisor, and Prof. Tsuyoshi Hasegawa, Waseda University. The award was set up to encourage researchers who are involved in research on science and technology in Ibaraki, Japan, and to honor the researchers who have achieved significant research as well as creative research accomplishments. Their research, the invention and application of Atomic switches, has been highly evaluated as a research that deserves to receive the award.

10

11

Six MANA researchers are selected as "Highly Cited Researchers 2017"

"Highly Cited Researchers (HCRs)" are authors of papers whose number of citations is in the top 1% in each research field in the Clarivate Analytics database. In 2017, six MANA researchers below were selected as HCRs.

Materials Science

K. Ariga

Materials Science

Y. Bando

Materials Science

D. Golberg

Chemistry

Y. Yamauchi

Physics

Y. Takano

Materials Science / Chemistry / Physics

Z. L. Wang

12

2018.01

"MANA International Symposium 2018" "The 2nd MANA Reunion Workshop"

The MANA International Symposium 2018 will be held in Tsukuba over 3 days. The theme of the symposium is "Towards Perceptive Nanomaterials, Devices and Systems". After the symposium, The 2nd MANA Reunion Workshop will be held in a same week at WPI-MANA over 2 days to continue exchange with researchers who have left WPI-MANA.

02

03

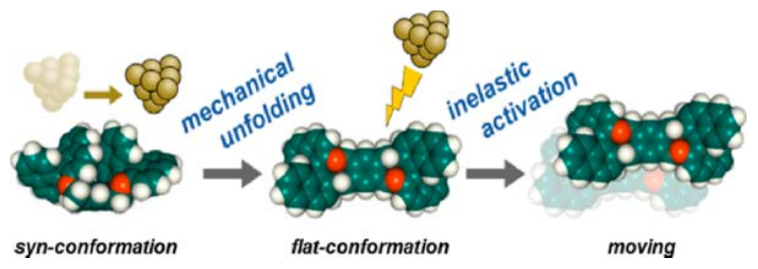
WPI-MANA Research Highlights

Driving soft molecular vehicles on a metallic surface

Soft molecules deposited on metallic surfaces were driven using a scanning tunneling microscope (STM) without mechanically pulling or pushing them, but by inducing inelastic excitations with the tunneling current.

In nanoscience, compared to rigid molecules, it is challenging to control on the surface by local STM excitations. Once they assume this configuration, the molecules are reasonably stable on the surface.

Molecules in the flat configuration were characterized to determine the spots where tunneling electrons should be injected to make them move on the surface without mechanically pushing them. Indeed,



SCHEMATIC DIAGRAM SHOWING THE INTERACTION OF TUNNELING CURRENT WITH MOLECULES.

the movement of soft molecules due to their flexibility. Notably, only one part of soft molecules is suitable for absorbing tunneling current energy that should be used for inducing motion, and not conformational changes of the molecules.

A collaboration led by Waka Nakanishi and Katsuhiko Ariga at WPI-MANA and We-hyo Soe and Christian Joachim at GNS and WPI-MANA Satellite, CEMES-CNRS in Toulouse designed, synthesized and characterized a conformationally flexible molecule consisting of two binaphtyl paddles mounted on a simple phenyl chassis. The vibration modes of the lateral paddles can be exploited to induce the motion of the molecule on an Au(111) surface using STM inelastic tunneling effects. The molecule has two different nonplanar configurations in solution that it retains when absorbed on the surface. However, on the metallic surface it is possible to switch molecules, one at a time, to a flat configuration using a specific STM mechanical manipulation protocol. The flat configuration is the most interesting one for this work, because only flat molecules can be controllably moved depending on the location at which the tunneling current enters the molecule, this can assume a nonplanar configuration (different from the original one) instead of moving. If the current is applied on the correct spot, the molecule can move in a controlled way. The experimental characterization of the molecules was complemented by molecular dynamics simulations and density functional theory calculations, which helped to uncover the energetics of the molecules. In April 2017, a 'nanocar race' took place, in which several molecular machines synthesized by groups from around the world competed with the goal of covering a set distance on a gold surface in the minimum possible amount of time, driven by STM tips. The molecule presented in this paper is one of the vehicles that took part to the race. ■

Reference

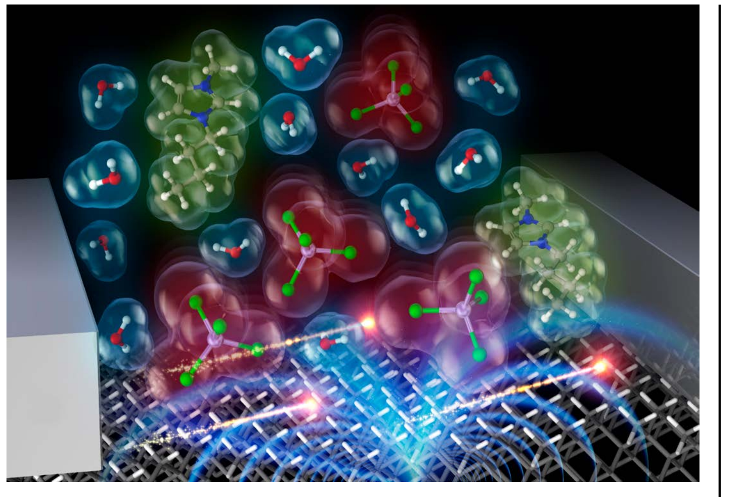
SOE W.-H., SHIRAI Y., DURAND C., YONAMINE Y., MINAMI K., BOUJU X., KOLMER M., ARIGA K., JOACHIM C. AND NAKANISHI W. CONFORMATION MANIPULATION AND MOTION OF A DOUBLE PADDLE MOLECULE ON AN AU(111) SURFACE. ACS NANO 11, 10357-10365 (2017).

Innovative transistors based on magnetically induced movement of ions

Just as magnets attract iron particles in sandpits, permanent magnetics only attract one type of ion in an electrochemical solution, constituting the basis of magnetically controlled electrochemical transistors.

Electrochemical devices find application in many technologies, including batteries, capacitors, sensors, and transistors. For such electrochemical devices to operate, they need an electric field that causes ionic transport and electrochemical processes. This simple but strict rule has long hindered innovation in electrochemistry and related technologies, however, WPI-MANA researchers recently challenged the rule with their development of 'magnetic control of electrochemical devices'.

WPI-MANA researchers Takashi Tsuchiya and Kazuya Terabe and their co-workers used a small magnet, instead of electrical equipment, to drive ions. The transport of paramagnetic $FeCl_4$ ions in a liquid electrolyte (including [Bmim]$FeCl_4$) was magnetically controlled to operate a typical electrochemical device; an Electric Double Layer Transistor (EDLT), a type of transistor that uses an EDL at a semiconductor/electrolyte interface to tune the electronic carrier density of the semiconductor. An electrical conductance of a two-dimensional hole gas (several nanometers thick) at a diamond (100) single crystal/electrolyte interface was successfully switched by a magnetic field, although the switching ratio was smaller than in conventional EDLTs that are controlled by an electric field.



The magnetic control of ions adds a new dimension to the 'nanoelectronics achieved by ions' paradigm, invented at WPI-MANA as the atomic switch*, and such control has a huge impact, even on other electrochemical devices. It has the potential to realize innovative applications that have not been possible using conventional approaches. Furthermore, this discovery stimulates the development of high performance magnetic electrolytes to support such innovation.

In electrochemistry, a branch of chemistry that has already been studied intensively, the interdisciplinary field with magnetism is one of the few great frontiers remaining. Researchers will be undeniably attracted to it, like iron sand is to a magnet. ■

* Reffers

"QUANTIZED CONDUCTANCE ATOMIC SWITCH"
K. TERABE, T. HASEGAWA, T. NAKAYAMA & M. AONO, NATURE 433, 47-50 (2005).

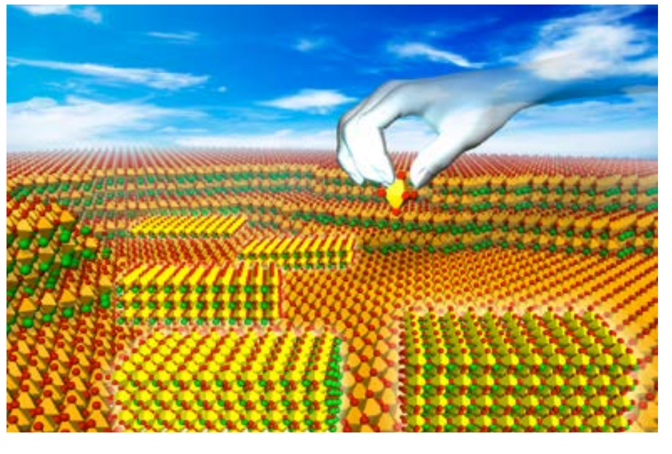
Reference

T. TSUCHIYA, M. IMURA, Y. KOIDE & K. TERABE. MAGNETIC CONTROL OF MAGNETO-ELECTROCHEMICAL CELL AND ELECTRIC DOUBLE LAYER TRANSISTOR. SCI. REP. 7, 10534 (2017)

Atomically thin perovskites boost for future electronics

WPI-MANA has developed the world's highest performance dielectric nanofilms using atomically thin perovskites. This technology may revolutionize the next-generation of electronics.

This research was conducted by a WPI-MANA research group led by Principal Investigator Minoru Osada and Director Takayoshi Sasaki of WPI-MANA at NIMS.



Electronic devices are getting smaller all the time, but there is a limit to how small they can get using current materials and technology. High-κ dielectric materials may be the key for developing electronic devices of the future.

Minoru Osada and colleagues created high-performance dielectric nanofilms using 2D perovskite nanosheets ($Ca_2Na_{m-3}Nb_mO_{3m+1}$; m = 3–6) as building blocks. Perovskite oxides offer tremendous potential for controlling their rich variety of electronic properties including high-κ dielectric and ferroelectric.

The researchers demonstrated the targeted synthesis of nanofilms composed of 2D perovskite nanosheets in a unit-cell-upon-unit-cell manner. In this unique system, perovskite nanosheets enable precise control over the thickness of the perovskite layers in increments of ~0.4 nm (one perovskite unit) by changing m, and such atomic layer engineering enhances the high-κ dielectric response and local ferroelectric instability. The m = 6 member ($Ca_2Na_3Nb_6O_{19}$) attained the highest dielectric constant, ε_r = ~470, ever realized in all known dielectrics in the ultrathin region of less than 10 nm.

Perovskite nanosheets are of technological importance for exploring high-κ dielectrics in 2D materials, which have great potential in electronic applications such as memories, capacitors, and gate devices. Notably, perovskite nanosheets afforded high capacitances by relying on high-κ values at a molecular thickness. $Ca_2Na_3Nb_6O_{19}$ exhibited an unprecedented capacitance density of approximately 203 $\mu F\ cm^{-2}$, which is about three orders of magnitude greater than that of currently available ceramic condensers, opening a route to ultra-scaled high-density capacitors.

These results provide a strategy for achieving 2D high-κ dielectrics/ferroelectrics for use in ultra-scaled electronics and post-graphene technology. ■

Reference

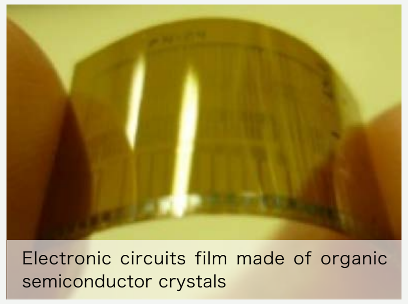
LI B.-W., OSADA M., KIM Y.-H., EBINA Y., AKATSUKA K., SASAKI T. ATOMIC LAYER ENGINEERING OF HIGH-K FERROELECTRICITY IN 2D PEROVSKITES. J. AM. CHEM. SOC. 139, 10868-10874 (2017)

● Welcome to WPI-MANA ●

Let's start new researcher life at WPI-MANA with your self-introduction!

My research interest is to realize novel semiconductors. Semiconductors are essential devices for handling electronic information with smartphones and others. Most of the semiconductors are made of silicon, but silicon semiconductors are difficult to bend and need very large facilities to produce them. If a semiconductor circuit can be made so as to draw a picture on a film, many unachieved applications could become possible like : controling the temperature of wine and ice cream during delivery, automatically checking out in a store, detecting errors on robots in a factory and so on.

Therefore, we are tackling to create semiconducting materials with organic matter and to make circuits with them. Organic matter is soft and cheap, and it is known for self-organization. When we dry an organic matter solution in a proper way, more than one billion of molecules align and crystallize to form a "crystal film" that has large area. As a result, the electronic performance becomes more than 10 times higher than before and it is about to reach a level of practical use. We launched a venture company that provides cheap semiconductor devices without operating large scale equipments. In the laboratory, we conduct research on engineering for scaling up the circuit for commercialization, chemistry to synthesize high-performance materials, and physics to find a way to improve electronic conductivity. We combine these in one to create a next-generation material.



Electronic circuits film made of organic semiconductor crystals

Junichi Takeya

Nano-Materials

Principal Investigator
The University of Tokyo
Cross Appointment with NIMS

My work at WPI-MANA started in April 2017, and I'm honored to be a member of one of the best nanomaterials research centers in the world.

I've been studying those unique liquid salts known as ionic liquids since my days at university, where I conducted research on mixing said liquids into hard resinous polymers to turn them into soft materials, such as plastic or gel. I also found a polymer that melts into an ionic liquid instantly in response to heat or light. While pursuing my postdoctorate, I was keen on creating material called block copolymers, which link polymeric ingredients that usually would not mix.

The two main actors in polymer gel and solution science are the polymers to be melted and the liquids to melt. Polymers have been long thought to play the lead role in this field, and I expect that we will discover a whole new world of soft polymer materials by putting the spotlight on liquids that were thought to be mere bystanders. I currently belong to a bio-related group, growing cells on a gel made with a slightly unique, non-water liquid. Experimental results can sometimes lift me up and other times bring me down, but I'm enjoying my new life as a researcher at WPI-MANA.

Hard polymer networks generally soften by mixing plasticizers that have low glass transition temperature. In science terms, it can be said that "relaxation time is shortened", or just "relaxed". I recently became a father, and I feel that my son is a plasticizer that mixes into the family and makes me "relaxed".

Relax time with my son

Takeshi Ueki

Nano-Systems

Senior Researcher
Mechanobiology Group

Following completion of my doctorate at Kyushu University, I worked at the Electrical Graduate School of the University of Tokyo as a researcher for a year before moving to NIMS. I am delighted to have the opportunity to work in Tsukuba, the largest research city in Japan, and in NIMS, one of the world' s leading materials research institutes.

I have been studying semiconductors since my student days. Silicon (Si), which has been widely used as brains of computers and smart phones, has low mobility of electrons. To improve the performance of computers, new materials with high carrier mobility are desired. I am researching the crystal growth technology of germanium (Ge), which is said to have higher electron mobility than Si and be applicable to the next generation high speed computing elements. Growth methods of Ge crystals and the demonstration of novel devices are both part of my current research.

Realization of nanostructures using Si has been investigated in the Nanostructured Semiconducting Materials Group. I wish to contribute to the group by combining my Ge crystal growth and devicing tecniques with the group's nanostructured technologies to realize high-performance next-generation nanodevices.

On days off, I play the viola in an orchestra; it may not stand out in the ensemble, but I love how great it works in the background. I like traveling too. I like traveling, and port town visits refresh my mind with their ocean views.

Playing the viola in the orchestra

Ryo Matsumura

Nano-Materials

Researcher
Nanostructured Semiconducting Materials Group

I received Ph.D. degree in analytical chemistry from Changchun Institute of Applied Chemistry, Chinese Academy of Sciences at the end of 2014, and continued to work there as assistant professor until April 2016. My research activities focus on the preparation, self-assembly of fluorescent nanomaterials for biosensing and catalysis. Then I moved to the Ohio State University as postdoc at college of pharmacy since May 2016. I worked on self-assembled RNA-based nanopores that insert into lipid bilayers to support a steady transmembrane flow of ions. Now I am proud of being one member of NIMS-MANA, a famous international research center in the fields of nanotechnology and material science.

Human beings are always wondering where we are from. As life originates from ocean at the earliest stage, we hope to get some clues from fluid substrates. My current research is focused on biological function of stem cells at the fluidic interface in supramolecular group. It is a totally new field for me. But I enjoy this challenged and exciting project.

In my spare time, I like travelling and outdoor sport. I feel relaxed when close to the nature.

A happy tour to
Qinghai Province in China

Xiaofang Jia

Nano-Materials

MANA Postdoctoral Fellow
Supermolecules Group

PROGRESS OF MANA

WPI Academy

Expansive World-Class Research

WPI-MANA started anew following the expiration of its 10-year funding period, combining with the WPI Program to create "WPI Academy" in 2017. Let's take a look at WPI Academy's plans to bring international research in Japan onto the fast track.

The World Premier International Research Center Initiative (WPI) was launched by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2007, reaching its decade milestone in 2017. As of this writing, 11 institutes have been adopted as part of WPI, of which 5 preliminary centers, including WPI-MANA since 2007, have been transferred to the newly established WPI Academy framework: Tohoku University AIMR, The University of Tokyo Kavli IPMU, Osaka University IFReC, Kyoto University iCeMS, and NIMS WPI-MANA. In 10 years of activity we have achieved world-class research capabilities and internationalization, thus gaining global recognition in line with our adoption as a WPI institute.

The WPI Academy was established with the aim of promoting the internationalization and expansion of the advancement of circulation of talented researchers (often called "brain circulation") by leading the internationalization of Japan's research environments and other reforms. WPI-MANA is committed to continuing its outstanding research activities while developing as an international research center, horizontally expanding its expertise in smooth operation to domestic research institutions and to position Japan as a hub of talented researchers.

The expertise in international institute operation obtained through the WPI Program is an asset that should be shared. WPI Academy institutes are expected to contribute to raising Japan's standards of research capability within WPI and subsequently nationwide, as well as expand brain circulation.

wpi World Premier International Research Center Initiative

WPI Academy Centers

AIMR	Tohoku Univ.
WPI-MANA	NIMS
Kavli IPMU	The Univ. of Tokyo
IFReC	Osaka Univ.
iCeMS Kyoto Univ.	

WPI Centers

IIIS	Univ. of Tsukuba
NanoLSI	Kanazawa Univ.
IRCN	The Univ. of Tokyo
Kavli IPMU	The Univ. of Tokyo
ELSI	Tokyo Tech
ITbM	Nagoya Univ.
I²CNER	Kyushu Univ.

※ Kavli IPMU belongs to both of WPI Academy Centers and WPI Centers.

New WPI Centers

The University of Tokyo
International Research Center for Neurointelligence (IRCN)

IRCN International Research Center for Neurointelligence

We organically link the trifecta of fundamental research of neural circuit development, pathological research of mental illness, and artificial intelligence research, and by synergistic fusion clarify the formation principle of flexible neural circuits that implement human intelligence (HI). We aim to promote the development of AI based on that principle and contribute to overcoming mental disorders due to impairment of neural circuit development.

Kanazawa University
Nano Life Science Institute (NanoLSI)

NanoLSI WPI KANAZAWA UNIVERSITY

Cells - the basic units of life. We develop nano endoscopic technology that lets us observe, analyze, and manipulate how polymers such as surface and interior proteins and nucleic acids play important roles in the body via direct video at the nano level. We aim to fundamentally understand various biological phenomena at the nano level.

Event

MANA International Symposium
Towards Perceptive Nanomaterials, Devices and Systems

"MANA International Symposium" will be held from 5-7 March, 2018 at Namiki site of NIMS. This year's theme is "Towards Perceptive Nanomaterials, Devices and Systems". Plenary and invited lectures by prominent researchers from all over the world and presentations about latest research at MANA, and numerous poster presentations will be conducted.

We hope that many researchers who are interested in the latest nanomaterial science participate in the symposium and obtain new inspiration from meaningful discussions on "nano artificial perception".

http://www.nims.go.jp/mana/2018/

Awards

Waka Nakanishi Senior Researcher
The Young Scientist Award of The Division of Colloid and Surface Chemistry, The Chemical Society of Japan (2017.3)

Guoping Chen PI
The American Institute for Medical and Biological Engineering (AIMBE) Fellow (2017.3)

Sang Liwen Independent Scientist
The Corbett Prize (2017.8)

Yutaka Wakayama Group Leader
The 39th JSAP (The Japan Society of Applied Physics) Outstanding Paper Award in the category of Award for Best Review Paper (2017.9)

Chikyo Toyohiro PI
The Japan Society of Applied Physics (JSAP) Fellow (2017.9)

Kazuya Terabe PI
Masakazu Aono Executive Advisor
The Tsukuba Prize (2017.9)

Katsuhiko Ariga PI
Yoshio Bando Executive Advisor
Dmitri Golberg PI
Yusuke Yamauchi PI
Yoshihiko Takano PI
Zhong Lin Wang PI
Highly Cited Researcher 2017 (2017.11)

WPI-MANA New Faces


J. Takeya
PI


T. Ueki
Senior Researcher


R. Matsumura
Researcher


G. Imamura
Independent Scientist


D. Umeyama
Independent Scientist


X. Jia
MANA Postdoctoral Fellow


B. Jiang
MANA Postdoctoral Fellow


S. Adachi
MANA Postdoctoral Fellow


X. Lu
MANA Postdoctoral Fellow


A. D. Alvarez
MANA Postdoctoral Fellow


S. Danial
JSPS Fellow


S. Ichinokura
JSPS Fellow


X. Li
JSPS Fellow


M. Bablu
JSPS Fellow


Z. Cai
JSPS Fellow


D.T. Payne
JSPS Fellow


F. Lu
Postdoc


Z. Y. Raza
Postdoc


S. Li
Postdoc


F. Failamani
Postdoc


H. Komatsu
Postdoc


S. Nikolaev
Postdoc


P. Sahoo
Postdoc


Y. Kakefuda
Postdoc


W. Jie
Postdoc


S. Maji
Postdoc


M. K. Chahal
Postdoc


X. Sun
Postdoc


J. Su
Postdoc


Q. Zhang
Postdoc

Editor's Column

The Forefront of Scienfitic Crowdfunding

Crowdfunding has been gaining recognition as a simple method of fundraising that anyone can try. Many advertisements and articles seeking investment for product development and the start-up of venture companies have become a part of our daily scenery by being spread between people on social media. In fact, the crowdfunding market has been growing each year; it went from raising 180 billion yen in 2012 to over one trillion yen in 2018.

One popular form of crowdfunding is "reward-based," in which investors receive incentives when the target amount is raised. Another interesting form of crowdfunding - with the goal of helping society - is "donation-based" crowdfunding, which has seen many successful projects as well. Naturally, some researchers began to ask, "If social contributions have been established, then why not raise money via crowdfunding for scientific research?". Known as "scientific crowdfunding", this practice is now gaining recognition.

In the United States, donation culture has taken root and scientific crowdfunding has been booming with projects in the range of 5 to 10 thousand dollars donations, as well as successful projects with contributions of several million dollars. Many supporters receive forwarded research reports or have their names listed in the acknowledgements as a reward. In addition to tax benefits for supporters, the feelings of accomplishment or satisfaction from giving to society seems to be succeeding in bringing in many supporters.

Scientific crowdfunding itself in Japan is in the initial stage, but annually dozens of projects achieve their target amounts via several scientific crowdfunding companies, with some projects succeeding in raising over 200 thousand dollars. According to a survey of researchers who have tried crowdfunding, gaining supporters through outreach via repeated publicity is another aim. The opportunity to raise funds while introducing one's field of research to many people seems to be a big attraction.

While there are various benefits to crowdfunding, issues such as researchers' commitment to their results after having received the funds and preventing misuse of funds also exist. Cases of fund misuse have already been discovered abroad, and introducing crowdfunding to research institutions will surely require some fine tuning.

Many claim that compared to the Kakenhi (Grants-in-Aid for Scientific Research) application, the mental threshold is high; there is a need for a clerical system that will hospitably support everything from proper incentives up to the project's public relations strategy.

While scientific crowdfunding still has a long way to go, it may be widely acknowledged as a means of fundraising for science in the future, if the environment to properly support researchers is in place.

word: Crowdfunding

Also known as "social funding", its aim is to raise funds necessary for the success of goals and projects by soliciting investment from the general public via the Internet; depending whether or not there is compensation for investors, they are classified as donation-based, investment-based, or reward-based. It is used for investment in a wide range of fields including product development, production of works, and start-up of venture companies. Cases of being used for scientific research fundraising have increased in recent years.

MANA NEWS LETTER

CONVERGENCE

No.26 Eng. Ed., Issued in February, 2018

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

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