# Introducing our Illinois Satellite Members

I²CNER is a unique research institute housed at Kyushu University which works in cooperation with a satellite institute at the University of Illinois at Urbana-Champaign (USA).


■Hydrogen Production ■Hydrogen Structural Materials ■Fuel Cells ■Thermophysical Properties ■Advanced Materials Transformations ■CO₂ Separation and Concentration ■Carbon Capture and Storage ■Energy Analysis

## AWARDS

**Prof. Tetsuo YANAGI** (I²CNER Carbon Capture and Storage Division, Lead Principal Investigator)
Awarded the UDA Prize of the Oceanographic Society of Japan 2012

**Prof. Masanobu KUBOTA** (I²CNER Hydrogen Structural Materials Division)
Awarded FY 2011 JSMS Award for Technical Developments 2011

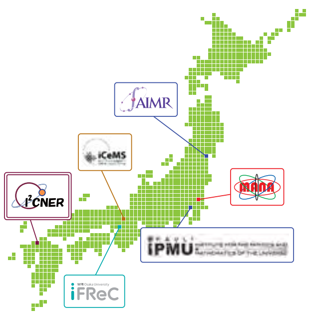
**Associate Prof. Takeshi TSUJI** (I²CNER Carbon Capture and Storage Division)
Awarded the Best Oral and Poster Presentation Awards of the 125th (2011 FALL) SEGJ CONFERENCE

**Prof. Hiroshi JINNAI** (I²CNER Hydrogen Production Division)
Awarded the 57th Japanese Society of Microscopy Award (Seto-sho) 2012

## What is WPI?

wpi World Premier International Research Center Initiative

The World Premier International Research Center Initiative (WPI) is a project that was launched by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2007. The WPI seeks to form an ideal research environment within visible research centers that maintain high research standards, where leading researchers will be attracted from all over the world.




**Kyushu University International Institute for Carbon-Neutral Energy Research (I²CNER)**
Toward the realization of a low-carbon society, I²CNER aims to resolve the challenges of the use of hydrogen energy and $CO_2$ capture and sequestration by fusing together sciences from atomic level to global scale.

Refer to :
MEXT Website http://www.mext.go.jp/english/research_promotion/1303822.htm
JSPS Website http://www.jsps.go.jp/english/e-toplevel/index.html

**Tohoku University Advanced Institute for Materials Research (AIMR)**
Integrating physics, chemistry, materials science, bioengineering, electronics and mechanical engineering, AIMR is striving to create innovative functional materials. A mathematical unit joined the team in 2011 to help establish a unified theory of materials science, aiming at the realization of a global materials research hub.

**WPI Osaka University iFReC — Osaka University Immunology Frontier Research Center (IFReC)**
An innovative research center, which pursues the goal of comprehensive understanding of immune reactions through the fusion of immunology, various imaging technologies, and Bioinformatics.

**National Institute for Materials Science International Center for Materials Nanoarchitectonics (MANA)**
A major focus of our activities is the development of innovative materials on the basis of a new paradigm "nanoarchitectonics," ground-breaking innovation in nanotechnology.

**Kyoto University Institute for Integrated Cell-Material Sciences (iCeMS)**
Established to integrate the cell and material sciences, the iCeMS combines the potential power of stem cells (e.g., ES/iPS cells) and of mesoscopic sciences to benefit medicine, pharmaceutical studies, the environment, and industry.

**Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU), Todai Institutes for Advanced Study, The University of Tokyo**
With accumulated research on mathematics, physics and astronomy, this research core works to bring light to the mysteries of the universe, such as its origin, and to provide an analysis of evolution.

### Editors' Postscript

- I²CNER holds a variety of events.
  For details, please see: ➡ http://i2cner.kyushu-u.ac.jp/en/results/seminar.php (I²CNER Event Information)
  I2CNER Search
- Now that the hot summer season has ended, a more comfortable season is upon us. Being at the forefront of ever-evolving technological advancements, not only have I felt how quick the passage of time can be, but through our interactions with high school students I also felt the importance of maintaining that same sense of youthful inquisitiveness needed to stay. Just as we have introduced our research divisions in each issue, we also plan to continue introducing our world class laboratory facilities through "Hello! I²CNER". We welcome your opinions and comments.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# Hello! I²CNER

## International Institute for Carbon-Neutral Energy Research

vol.5


01 Special Feature

## I²CNER's Outstanding Female Researchers

Advanced Materials Transformations Division, Principal Investigator
Associate Prof. Miho YAMAUCHI

Hydrogen Storage Division
Assistant Prof. Junko MATSUDA

Associate Prof. Yamauchi and Assistant Prof. Matsuda both started their careers as researchers, motivated by encounters with wonderful teachers and mentors. A strong passion for research is evident in their words.

## We can be the first people in the world to discover something!

**Yamauchi** In elementary and junior high school, I was completely absorbed in volleyball. Our team was really weak, so we were happy to win even one game. Since childhood, I have enjoyed science and mathematics and have been fascinated by the word "experiment." I originally dreamed of becoming a researcher, and entered university after graduating from high school. But my university life was not always smooth sailing. I had some failures. Then, I met a wonderful teacher who introduced me to the "allure of research where one can discover something nobody in the world has ever found before."

**Matsuda** I grew up in the countryside of Gunma Prefecture, and have enjoyed observing nature since childhood. I remember watching how a cicada emerged from a pupa and a lunar eclipse at night. After receiving my master's degree, I started working for a company that assigned me to an incorporated foundation. One of my superiors there encouraged me to pursue a career as a researcher.

## To come into contact with natural providence is a real thrill!

**Matsuda** I use an electron microscope for my research. It may be a bit of an exaggeration to say that I am trying to elucidate natural providence, but it is truly a thrill to be able to observe various phenomena such as watching how atoms are arranged or learning how physical functions are generated through the interaction of atoms or electrons.

**Yamauchi** Yes, but we researchers run into a lot of difficulties, don't we? What do you think of this?

**Matsuda** I have never thought of myself as having difficulties because I am allowed to do what I want to do.

**Yamauchi** I see. I am an impatient person, and I always want to achieve quick results. Even so, after examining many details, worrying a lot, taking a roundabout course and finally reaching an end result, I feel that my research is truly worth conducting.

Advanced Materials Transformations Division
Principal Investigator

### Associate Prof. Miho YAMAUCHI

Graduated from the College of Natural Sciences, First Cluster of Colleges, University of Tsukuba in 1996. Graduated from the Doctoral Program in Department of Chemistry, University of Tsukuba in 2001 with a PhD in Science. Served at Department of Chemistry of University of Tsukuba as an associate fellow in 2001, as Research Associate (now called assistant professor) at the Department of Chemistry, Faculty of Sciences, National University Corporation Kyushu University in 2003, and as Associate Professor at the Catalysis Research Center of Hokkaido University in 2008. She assumed her present post in January 2012.

**Research Content**

I am conducting research on catalysis development using base metals, including iron, with the aim of realizing an energy cycle with zero carbon dioxide emissions. More specifically, I am investigating how to produce alloy nanoparticles with new structures, and how to use them to develop high-performance catalyses.

Special Feature

# I²CNER's Outstanding Female Researchers

I²CNER Researchers' Talk

Researchers' Talk

Associate Prof. **Miho YAMAUCHI** × Assistant Prof. **Junko MATSUDA**

## Real feelings of female researchers

**Matsuda** To be honest, I am not usually conscious of being seen as a "female" when conducting research. Both male and female researchers face various situations, depending on their environment. It is also true that all career women have to spend much of their life on work.

**Yamauchi** That's right, it's not just researchers. All working people face difficulties in juggling their private life and their job.

**Matsuda** In order to balance my private life and research, it is very important to be free from stress. I go jogging at Ohori Park or do Kaatsu (occlusion) training to clear my mind.

## The challenge of developing new materials!

**Yamauchi** I am always thinking about research, whether I am awake or asleep. But I think it is a positive thing for me to have something to which I can devote myself entirely.

**Matsuda** I agree. What kind of research do you want to do at I²CNER in the future?

**Yamauchi** I want to create new materials with unprecedented performance and results.

**Matsuda** I am also thinking of attempting to create new materials!

**Yamauchi** As long as we use conventional materials, we can only achieve already existing results.

Hydrogen Storage Division

### Assistant Prof. Junko MATSUDA

Graduated from the Faculty of Science, Kyoto University in 1991. Completed her course in the Division of Chemistry, Graduate School of Science, Kyoto University in 1993. During her tenure at NGK Insulators, Ltd., she was assigned to the Japan Fine Ceramics Center. After serving as a research associate at the Graduate School of Engineering of the University of Tokyo, the Superconductivity Research Laboratory of the International Superconductivity Technology Center, and the Energy Technology Research Institute of the National Institute of Advanced Industrial Sciences and Technology (in 2007), she assumed her present post in April 2011. She obtained her PhD in Engineering in 2003.

**Research Content**

Focusing on hydrogen storage materials, I use a transmission electron microscope mainly to observe atomic arrays that are disturbed by the introduction of hydrogen into materials. I am working to develop alloys that will be able to absorb and emit large amounts of hydrogen. We do this by controlling the structure of materials in order to ultimately use them for hydrogen fuel tanks of fuel cell vehicles, and for other purposes.

## ~Messages to students who aim to be researchers~

Message

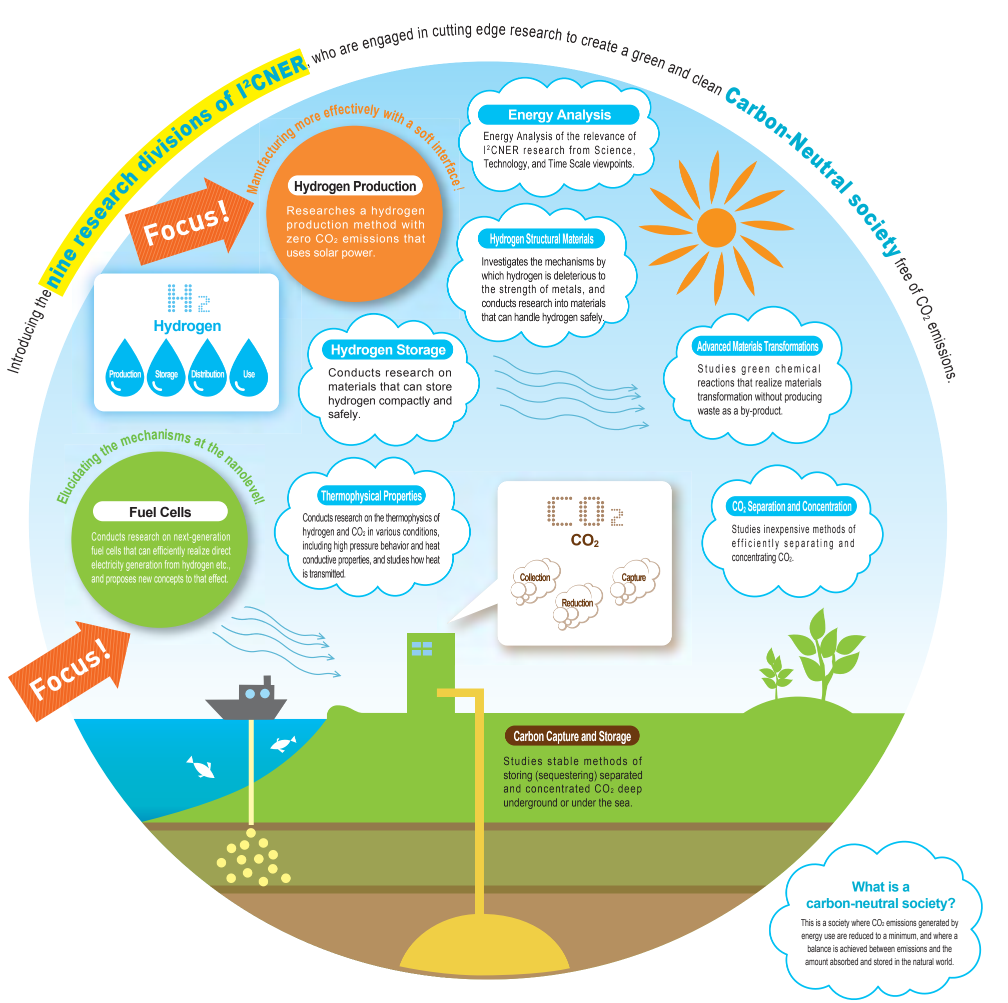
I have pursued a career as a researcher with a lot of support from many people. On my own, I could have never come so far. I am very grateful for every encounter I have had. Although "research" has an inorganic image, it is a warm world where human connections are very important.

Associate Prof. Yamauchi

There are female researchers, not only at universities, but also at companies. The social environment for women is gradually getting better, and you do not have to worry too much about being female. Cherish those things that interest you and make you wonder, and lead a wonderful school life.

Assistant Prof. Matsuda






High school students visit **Prof. Takahara** and **Prof. Nakashima** of I²CNER. >>>

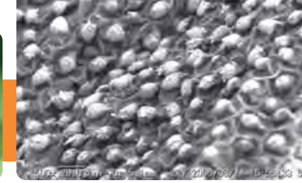
## Interviewers

Interview 01

# Hydrogen Production Division, Prof. Atsushi TAKAHARA

Principal Investigator,
International Institute for Carbon-Neutral Energy Research ($I^2CNER$), Kyushu University

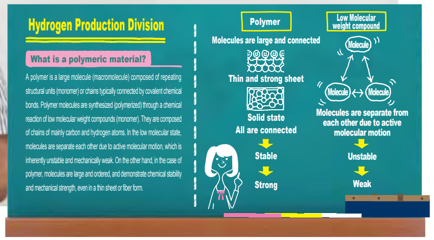
Water droplet on the surface of a satoimo leaf



Microscopic image of the surface of a satoimo leaf

## Polymeric Materials Science Learned from Nature

### —The Fusion of Various Scientific Fields Supports our Future Society—




## Advent of the polymer molecule era

**Takahara** The 19th century was the era of metals (hard materials), as represented by the first Industrial Revolution. In the 20th century, new materials called "polymer molecules" (soft materials) began to attract attention, and have been used to create various products that bring comfort and convenience to our daily lives. Among these are PET bottles, rubber, and synthetic fibers. Even proteins and DNA in our body are polymer molecules. Although they may look completely different, there are numerous examples of polymer molecules around us. In order to realize a low-carbon society, we are working hard to create next-generation polymeric materials that will support a future society, by using polymer molecule materials which are precisely designed at the molecular level.

## Focusing on the surfaces and interfaces of polymer molecules

**Takahara** We are paying special attention to the surfaces of polymeric materials. It is no exaggeration to say that the surface greatly influences the nature and function of various materials. An everyday example that demonstrates this would be water drops that become round as they drip from a faucet. This is due to a force that wants to make the surface size of a water drop as small as possible, what we call "surface tension." There are other examples, such as contact lenses that are put into the eyes, but don't cause irritations or anti-fingerprint protective film for smart phones, which all have a lot to do with the hydrophilicity and/or oil repellency of the surfaces. So, freely manipulating the surfaces and interfaces of polymeric is a very important part of producing new materials.

**Ohya** How did you come to focus on the surfaces?

**Takahara** When I was a student, I was engaged in research on fatigue life measurement of various polymeric materials. While I was studying fatigue in polyurethane film, which is used for artificial hearts, it occurred to me that the inner surfaces of blood vessels might have a function that prevents blood from clotting. This led me to begin research on the nature of the surfaces of polymeric materials and precise control of the materials surface and interfaces.

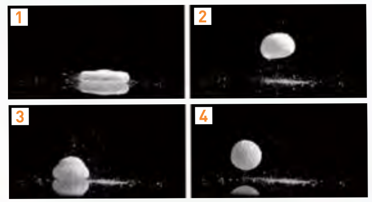
## Learning from nature

**Takahara** Functions of surfaces and interfaces can be found in nature, as well. For example, when water drops fall on the surface of a lotus or an aroid leaf, they roll and fall, wrapping up dirt and cleaning the leaf in the process. This is because air trapped in the asperities of the fine wax layer existing on the leaf surface, and repels water. Another example is greenflies living in insect galls which cover sweet and sticky nectar with wax they themselves excrete, and make spherical liquid marbles so they can be transported. We are studying how to reproduce those various functions of surfaces and interfaces found in nature using polymeric materials.

**Assistant Prof. Yuji HIGAKI**
(Department of Applied Molecular Chemistry, Institute for Materials Chemistry and Engineering, Kyushu University)

## Liquid marbles made of water-repellant microparticles

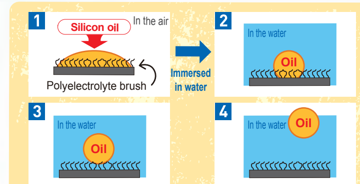
**Prof. Takahara** We have already made hydrophobic polymer microparticles. If we cover water droplet with these particles, we can make liquid marbles. As the polymer microparticles repel water, these liquid marbles float in water, despite being liquid drops. In addition, they do not wet substrate surfaces, and they bounce like a rubber ball when they are dropped. When we make liquid marbles with a liquid in which a magnetic powder has been finely dispersed, we can apply magnetic field to manipulate their motion. In this way, we are working to create environmentally friendly materials by changing the kinds of liquid droplet we wrap, and investigating the nature of the substances we obtain. We are planning to proceed with further material research so that we can apply this technology to storage containers and low energy liquid droplet transport materials in the future.




Bouncing liquid marbles covered with hydrophobic polymer microparticles

## Antifouling properties of polyelectrolyte brush

**Assis. Prof. Higaki** When we grow highly hydrophilic polymer chain directly from a solid surface to form a polymer brush on a nano-order thin film, we can achieve high hydrophilicity. The diagram below shows how oil drops change form when silicone oil is placed on the surface of a water friendly polyelectrolyte brush that is directly immersed in water. In the air, silicon oil wets the polymer brush surface and wets on the brush. However, when this polymer brush substrate is placed in water, the silicon oil quickly becomes spherical, separates from the brush surface, and float in water. As the superhydrophilic polyelectrolyte brush prefers contact with water than oil, the oil eventually converts to a sphere in order to minimize its contact area with the brush surface and surrounding water.




Silicon oil separates from the brush surface

## Aiming at the realization of a low-carbon society

**Nakamura** What fields do you expect your research to be applied to?

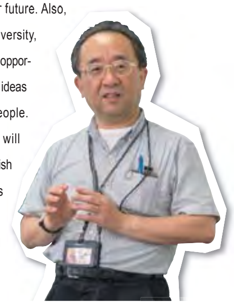
**Takahara** As there are still many unknown areas in this field, we need to learn what possibilities each substance provides. If we can create materials with excellent liquid repellency, as can be found in lotus leaves for example, windshield wipers will become unnecessary. That alone will save energy, and will be a powerful tool for $CO_2$ reduction. In addition, if we apply the hydrophilic polymer brush to water-cooling pipes at power plants, we can prevent biofouling of barnacles, resulting in higher power generation efficiency and thereby reducing environmental burdens. This could also reduce maintenance fees. In this way, we hope to be able to design surfaces freely, and expect them to be applied to a variety of materials to realize a low-carbon society.


Fabrication of liquid marbles using hydrophobic polymer microparticles


Verification of changes in oil liquid forms by water swelled polymer brush

## Message to students

**Takahara** From elementary school on, I enjoyed making electronic circuits, and was absorbed in making such things as a radio, transceiver, and other devices. The boundaries between chemistry, physics, and biology are disappearing. I would advise you to not only acquire a basic knowledge of chemistry, physics and mathematics, but also to nurture interests in various fields, and to read a lot of books. The flexible way of thinking you gain using this approach will be very useful for your future. Also, when you enter university, you will have a lot of opportunities to exchange ideas with a variety of people. From now on, you will especially need English communication skills to express your ideas. So work hard on studying English.



Interview 02

# Fuel Cells Division, Prof. Naotoshi NAKASHIMA

Principal Investigator,
International Institute for Carbon-Neutral Energy Research (I²CNER), Kyushu University

## Expanding Possibilities — Dream Materials! —

Fuel Cells Division
Fullerene
In 1985, Dr. Harold Kroto, then a professor at the University of Sussex, Dr. Richard Smalley, and Dr. Robert Curl, both at Rice University, discovered the fullerene ($C_{60}$), which consists of 60 carbon atoms with a soccer-ball-structure. This discovery strongly influenced the later discovery of the carbon nanotube.
Carbon Nanotube
In 1991, Dr. Sumio Iijima, Senior Research Fellow of NEC, discovered a nano-size tube made of carbon atoms from carbon materials while conducting an experiment, and he called it the "carbon nanotube." Since then, the carbon nanotube has been attracting attention all over the world.

### "Nanotech" is a key word of the 21st century science

Nanotechnology* is expected to have tremendous future value as a foundational science & technology that will support various industries of the 21st century. In order to build a prosperous future by taking advantage of this nanotechnology, we need to pay attention not only to its technological elements, but also to social elements, including its effects on the environment and safety issues. We must take action to realize an environmentally-friendly and sustainable society.

* "Nanotechnology"— technology whereby we work with, control, and analyze a nano-scale substance.

### A marvelous new material: the carbon nanotube

Most prominent among materials that are attracting attention as symbolizing nanotechnology is the carbon nanotube (CNT). A carbon nanotube has a cylindrical nanostructure where hexagons made of carbon atoms are connected to make a sheet (a graphene sheet) and become rolled up. [See the figure on the blackboard] The diameter of a carbon nanotube is 1nm (nanometer), 100,000 times thinner than a human hair, and it is several μm (micrometers) long. In other words, an extremely tiny substance about the size of 0.001mm. Despite being so lightweight, it is several dozen times as strong as steel, and is also flexible and very heat resistant. In addition, it transmits more electricity than silver and conducts more heat than diamonds, all of which help to make it a marvelous new material.

Pencil lead and diamonds are among the most familiar carbon substances. Pencil lead has a graphite structure, where multiple layers of graphene sheets are accumulated. We can write with a pencil because a layer of graphene comes off onto the paper when we press the pencil to it. On the other hand, a diamond has a pyramid structure of hexagons made of carbon atoms. This creates a hard and durable substance, where strong bonds are formed both vertically and horizontally. So, although carbon is an old material which has been familiar as charcoal throughout history, it is also a new material that can open new worlds if we change the arrangements and structures of the carbon atoms. We consider the carbon nanotube to be the ultimate material, and are proceeding with exploration into its possibilities.

### Aiming for a next-generation fuel cell

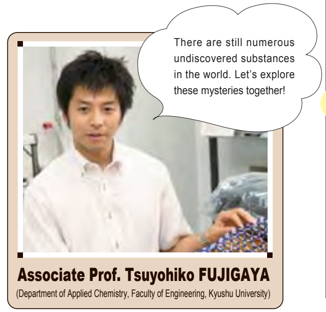
**Yamazoe** In what ways do you expect carbon nanotubes to be used in the future?

**Nakashima** I think fuel cells are an obvious application. You all know that hydrogen and oxygen are produced through the electrolysis of water, don't you?

**All** Yes, we do.

**Nakashima** Fuel cells use the energy that is generated during the process of producing water using hydrogen and oxygen. Hydrogen, which is used in fuel cells, exists abundantly on the earth, and is the ultimate clean energy, as it emits no waste other than water. Hydrogen energy is expected to be the white knight that will solve the energy issues of the planet.

**Fujigaya** Many of the fuel cells currently in application use very expensive and rare platinum as an electrode catalyst to achieve high generation efficiency. We have been looking at a fiber-state structure that can transmit electricity easily, an important property of the carbon nanotube, and are conducting research by attaching platinum minute particles to carbon nanotubes for use as a catalyst for fuel cells.




Associate Prof. Tsuyohiko FUJIGAYA
(Department of Applied Chemistry, Faculty of Engineering, Kyushu University)

### Aiming for the strongest material in the world

**Nakashima** Carbon nanotubes will not only be used for fuel cells, but also for materials for electronic parts. We have started developing nanofibers, the strongest material known, by using a hybrid of the strongest fiber and carbon nanotubes. Carbon fibers with a similar structure (micro-fibers with a diameter approx. 1000 times larger than that of carbon nanotubes) are used in materials for such advanced applications as space shuttles and the Boeing 767. They are likely to be applied to even more purposes in the future.

### A new discovery is made "by chance"

**Ohya** What is the final goal of many experiments?

**Nakashima** That's a good question. Although research at universities is a basic and fundamental process, our goal is to develop a new material that will support the science and technology of the 21st century. In other words, research that will be useful for the world.

**Nakamura** How do you feel when something you created is used in the real world?

**Fujigaya** We are very happy if our achievement is useful for people.

**Masaki** Prof. Nakashima, what were you interested in when you were a student, and why did you choose this career?

**Nakashima** I liked chemistry and was very interested in the phenomenon where a different substance is produced through a chemical reaction. On the other hand, I also wanted to be a pilot and didn't know which course I should choose for a while. I did not decide to pursue this career from the very beginning. What is important for you now is to acquire basic skills that will be useful in any field you may enter. Also, don't forget to cultivate flexible thinking.

Since the whole history of the nanocarbon was brought about "by chance," you might be the next laureate of the Nobel Prize!