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Research Trend Information
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Set New Challenges

Utilizing a soft cling film only one-millionth of a millimeter thick

Tokai University Micro/Nano Technology Center and the Invention of Functional Ultra-thin Polymer Film

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After being initiated by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to develop a project supporting strategic research foundations at private universities in FY2014, the Micro/Nano Technology Center at Tokai University is a research and development base established at Tokai University in January 2015. The center brings together young researchers from the medical, physics, and engineering departments who are aiming to establish a new generation of biomedical technologies based on ultra-thin polymer films with a maximum thickness of 100 nm. Ultra-thin polymer films display many unique properties not seen in films thicker than 100 nm, and competition among such films for biomedical applications and industrial use is intensifying. In addition, based on statements given by Professor Kita of the Department of Physics, School of Science and Associate Professor Okamura of the Department of Applied Chemistry, School of Engineering, we introduce the achievements and future prospects of the center, which has only been operating for the past five years.

Ultra-thin polymer films: A great achievement resulting from an accidental failure

Okamura: First, if you take a look inside this small bottle (Photo 1), you'll see an ultra-thin film made from a polymer; this film is only approximately 20-nm thick, and hence, is 1/1,000 thinner than ordinary paper. It appears to have a whitish hue under visible light; however if it adheres to your skin it is neither detectable nor visible.

An ultra-thin film of less than 100 nm is characterized by extreme softness, and can be applied to the skin or internal organs without the use of an adhesive agent. It can be removed from the skin by simply rinsing it with water, and because it is made of biodegradable plastic, it naturally degrades and disappears over time, even when applied to internal organs.

Although it is extremely easy to make, certain know-how regarding its development is required. When fourth-year students of the department join our laboratory, we begin by having them conduct a thin-film production experiment allowing them to experience the wonder and mystery of an ultra-thin film.

Kita: Dr. Okamura, you were not originally specializing in ultra-thin films, is that correct?

Okamura: Yes, it is. Originally, my former laboratory was studying methods for creating spherical nanoparticles. Our goal at the time was to artificially reproduce platelets, which are a type of cell suspended in blood. The platelets are shaped like disks, and we had planned to fabricate dot-shaped patterns onto the surface of a substrate, and using a spin-coating method (a film formation method using centrifugal force), apply a polymer as a raw material around only the dots to create disk structures. One day, however, we coated an entire substrate with a polymer, and when we tried to peel off the film that had formed, we were able to recover the film with the same size as the substrate. We could see it floating in the water, but we originally had no idea how thin it actually was. We thought the experiment was erroneous, but when we measured

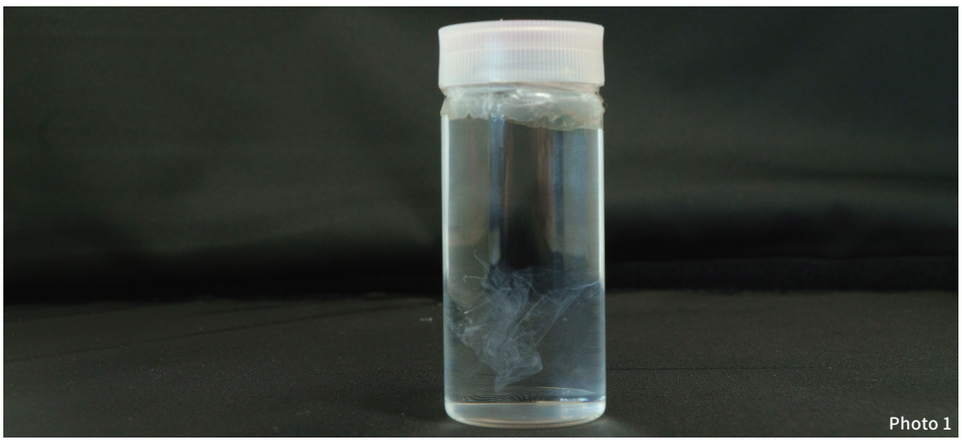

Photo 1

the thickness of the film, we were surprised to discover that it was thinner than 100 nm. We had assumed that a thin film would essentially be invisible. When we tried applying it to skin, we discovered that it adhered naturally and became invisible. It was then that we realized it might have certain applicability.

Kita: Your ongoing success started with an accident, didn't it?

Assembling of a team triggered by mutual understandings

Kita: I think it was in 2013, which is slightly before the establishment of the center, that I got an offer to attend a seminar which aimed to promote a new project of Tokai University to bring together researchers from several different departments. After the seminar, a few young researchers gathered together and discussed our research project extensively. The Tokai University Micro/Nano Enlightenment (Tμne), which is the predecessor of the center, was established following an exchange of ideas and was based on mutual understanding between each researcher.

Okamura: I recall your use of a chopstick envelope.

Kita: Because there was no paper in the room, whenever a good idea came to mind at that particular get-together, I had to write it down on the envelope of my chopsticks. I was picking up a lot of information, and I was sure that I would forget it. Initially, we held academic lecture meetings to promote mutual understanding among the Enlightenment (Tμne) members (faculty of the School of Science, School of Engineering, and School of Medicine), but we also held regular academic lecture meetings with the participation of professors aiming to realize interdisciplinary fusion or intramural collaboration. We prepared programs and abstract collections, and students gave presentations at poster sessions, creating an atmosphere like a small academic association. To link the campuses, we held programs at the Isehara, Shimizu, and Kumamoto campuses, and even at the Tokai International College in Hawaii. Academic exchanges with professors at the Sapporo Campus are scheduled in August of this year (2019).

Shortly after the launch of the Enlightenment (Tμne) program, board members of the university suggested that we apply for a research foundation, which gave me the idea for creating the center. To submit an application, it was necessary to have a main subject, and as I recall, we decided relatively quickly to focus on Dr. Okamura's ultra-thin film. We not only asked the members who started the Enlightenment (Tμne) program, we also invited other people who might be interested. Being extremely eager to participate, they gathered together almost every day for about two months to prepare the application. We were finally able to realize various ideas in a concrete form; for example, the researchers were able to communicate with each other easily and place their desks close to the laboratories.

The project period, or in other words, the research period, was set to five years, and we therefore divided the major research theme into the development of three biomedical technologies:

- "next-generation adhesive bandages without needles or sutures" that can be applied to treat organs without stitches;
- "a disease model without the need for animal experimentation" using microfluidic devices; and
- a "non-surgical blood-clot cleaner" that removes blood clots by introducing ultra-thin films into blood vessels.

The challenge of large-scaled production and advancing the functionality of ultra-thin polymer films

Kita: For the past five years, eight faculty members and an average of seven post-docs have worked at the center as researchers, divided into three teams, namely, "Create," "Test," and "Know" teams, focusing on further development of ultra-thin polymer films. The "Create" team handles the large-scaled production of the ultra-thin films and manages the design of new films with new functions, the "Test" team is in charge of the biomedical applications of the ultra-thin films, and the major role of the "Know" team is evaluating their properties. We set up and are still studying many different subjects that would be impossible to achieve without the cooperation of the teams.

Okamura: On the "Create" team, Junior Associate Professor Yuta Sunami from the Department of Mechanical Engineering, School of Engineering) developed a technology for instantly creating a thin film several tens of meters long using a commercial poly(ethylene terephthalate) (PET) film. The equipment looks like a rotary press used in a newspaper plant, and first prepares a roll of film followed by coating the film with a solution of poly(lactic acid), a biodegradable polymer. As the film is gradually laid out, the solution is applied, and a blade is used to remove the excess solution; the system is then adjusted such that an extremely small quantity of the solution is left on the PET film at a stipulated thickness. This solution is dried to form a thin film that is then completely wound around a spool. It is possible to control the thickness by varying the transported speed of the film and the concentration of the solution. This method has already produced films of 60 or 80 nm thick, which is almost equal to the thickness created through spin-coating. Research into advanced functionality has also been conducted to provide ultra-thin films with a variety of functions. For example, devices such as micrometer size pin-holders were used to open extremely tiny holes in the film. These holes are slightly smaller than cells and slightly larger than drugs including proteins with a relatively low molecular mass. Inside our bodies, there are platelets and other cells suspended in our blood; however, when attempting to investigate the response of such cells to various medicines, if a medicine is administered and when observed through a microscope, the cells flow out of the field of vision and cannot be observed. If the cells can first be enclosed using this type of perforated film, they will be unable to pass through the holes, fixing them in place, while allowing the medicine to pass through the holes to reach the cells inside the film.

Texture patterns can be controlled on the surface of the film using a metal mold. Assistant Professor Asako Otomo of the Faculty of Medicine, School of Medicine has researched the cerebral nerve cells of patients with amyotrophic lateral sclerosis (ALS), which have long axons (long slender projection-shaped structures used to transmit information between cerebral nerve cells). When these cells

are cultured in a normal petri dish, they cannot be observed because their axons are extended in a disorganized fashion. If a microfluidic device can create routes for the axons to extend through, they can extend in a straight line; in addition, we recently learned that the irregularities on an ultra-thin film can act as a substitute for such routes.

Kita: My research theme has been taken up by the "Know" team, namely, learning the properties of ultra-thin films. The "Know" team members include Associate Professor Kazuya Kabayama (formerly of the Institute of Glycochemistry of Tokai University, and currently at Osaka University), whose specialty is live cell imaging for investigating the cell functions in a living state, and Junior Associate Professor So Nakagawa (Faculty of Medicine, School of Medicine), who has been investigating the functions of cells, viruses, and other biological elements by analyzing their gene sequences. The "Know" team has conducted research investigating the interactions of ultra-thin films and cells, and this information has been fed back to both the "Test" team and "Create" teams.

We recently learned that, if an ultra-thin film is cut into pieces of a few tens to a hundred micrometers in size to form a suspension, the pieces display interesting properties. Their unique characteristics as suspension fluids is a theme that has been tackled by numerous researchers for many years. Even Einstein investigated the relationship between the concentration and viscosity of suspensions of spherical particles. Ultra-thin films differ from spherical particles, being extremely thin in one direction but wide in the other directions. No research has been conducted to investigate the effect of those unique shapes.

Okamura: The suspension of an ultra-thin film flows smoothly at a low concentration; however, when the suspension becomes viscous, if the concentration is increased and its container is shaken (mixed by shaking its container from vertical to horizontal and back again), the flow of suspension stops abruptly.

Kita: Rheology is an area of science dealing with the deformation and flow of matter. If we apply the rheology to ultra-thin film suspension, the phenomenon whereby the flow suddenly stops, as mentioned by Dr. Okamura, can be explained using physical parameters considering the characteristics of an ultra-thin film.

Position of industry–university cooperative research facilities and greater interdisciplinary fusion research

Kita: In 2016, Tokai University entered into a comprehensive agreement with Nikon Co., and Nikon Instech Co., Ltd., under which the university receives optical instruments that can be used widely in the fields of medicine, science, and engineering; in addition, the Tokai Imaging Center for Advanced Research (TICAR) was launched. Nikon's other imaging centers are focused on bio-related research. A major and unique feature of TICAR is that, unlike the other centers, it is equipped with industrial instruments that can be used for research in the fields of engineering and science. As a joint research facility of our university, it is used not only by members of the Micro/Nano Technology Center, but also by many of Tokai University's researchers and students, researchers and students of other universities, and even to members of various corporations.

For example, Associate Professor Kyoko Yamahana of the School of Cultural and Social Studies, who is a specialist in the archeology of Egypt and the countries of South America, has used an X-ray CT system and a scanning electron microscope installed by TICAR to study archeological artifacts. In addition, the Specially Appointed Junior Associate Professor Kaori Taguchi of Tokai University Institute of Innovative Science and Technology, a specialist in the preservation and restoration of paintings and modern art, has used the same X-ray CT system to study the state of paintings and canvases prior to restoration. I am fascinated and delighted by such examples of its use by researchers from different fields, such as archaeology and art preservation and restoration. As a researcher in science, I could never have imagined such applications.

Aiming for technology that can be introduced worldwide: Founding of Tune Co., Ltd.

Okamura: Ultra-thin polymer films have attracted a great deal of interest, and we have received various requests from other universities and research institutes to use our technology.

Kita: We have also received many invitations to take part in joint research projects; however, with a limited amount of time and staff members, we cannot accept all of them. Thus, as an alternative to joint research, we have considered launching a university-led start-up company allowing the ultra-thin films to be commercially available.

Okamura: The present version of the product is a highly functional ultra-thin polymer film, which we call "nano-wrapping." This film permits observations that would be difficult to achieve using a conventional coverslip. For example, you can wrap a specimen to be observed with a microscope in an ultra-thin film, preventing it from shaking or drying. Or, as I stated earlier, by perforating this film with tiny holes, it is possible to administer medicine to suspended cells while holding them within the field of vision.

Kita: Led by Dr. Okamura, we have submitted patents. I think that in the future, Tokai University will have the opportunity to earn patent royalties. The center was founded and is being operated with the support of the university, and I hope that the benefits from such research will be directed toward the society, especially in the fields of education and research. Our goal for the future is to establish a scholarship fund for students, as well as another fund supporting biomedical science and engineering projects.

Rio Kita

Professor, Department of Physics, School of Science, Tokai University and Director of the Micro/Nano Technology Center

He specializes in polymer physics, nonequilibrium thermodynamics, and rheology. As the leader of the "Know" team regarding ultra-thin polymer films, he is in charge of evaluating the fundamental physical properties of polymers and the interaction of ultra-thin films with biological cells.

Yosuke Okamura

Associate Professor, Department of Applied Chemistry, School of Engineering, Tokai University and the Micro/Nano Technology Center

In addition to polymer chemistry, his specialties are biomaterials science and nanomaterials engineering. During an experiment, he accidentally created an ultra-thin polymer film. As the leader of the "Create" team, he is working on the design and creation of ultra-thin films and the development of their various applications.

NEWS & EVENTS

The exhibition, "Impressionism—Light and Memory," supported by the Institute of Innovative Science and Technology has opened.

The Joint Exhibition "Impressionism—Light and Memory" (sponsors: Pola Art Foundation, Pola Museum of Art; Hiroshima Museum of Art) held by the Pola Museum of Art and Hiroshima Museum of Art, planned with support from the Tokai University Institute of Innovative Science and Technology (IIST), has been open to the public at the Pola Museum of Art in Hakonemachi, Kanagawa Prefecture, since March 23. This exhibition displays 74 masterpieces by Delacroix, Corot, Picasso, Matisse, and other artists chosen from the collections of the two art museums to explore the travels and memories, perspective on scenes of cities and watersides, impression of landscapes, and shapes and colors of nineteenth century artists. Specially Appointed Junior Associate Professor Kaori Taguchi of the IIST helped plan this exhibition.

Dr. Taguchi was in charge of the optical analysis of Van Gogh's Clumps of Grass, Flower Vase with Thistles, and the Gleize Bridge over the Vigueirat Canal. She used Tokai University's fluorescence X-ray analysis device, an optical microscope, and other instruments to participate in a joint survey with the Mori Art Conservation Studio and Horiba Techno Services Co., to analyze the constituents of the materials Van Gogh used and the process of the creation of these works. In particular, her examination of Clumps of Grass, which is a rare work without backing done to reinforce the back surface of the work and was painted in 1889 when Van Gogh was repeatedly hospitalized due to mental illness, revealed that he probably painted it without first preparing a rough draft. Moreover,

she found traces showing that after Van Gogh painted it, he removed it from its wooden frame and stored and shipped it between other works. She also clarified how he recoated the work while painting it.

On June 15, Dr. Taguchi presented a special gallery talk entitled, "Van Gogh from the perspective of an engineering survey—focused on works in the collection of the Pola Museum of Art" at the Pola Museum of Art.

Time/Place: March 23 (Sat.) to July 28 (Sun.), 2019, Pola Museum of Art. *At the Hiroshima Museum of Art, August 10 (Sat.) to October 27 (Sun.), 2019.

Experimental performance with 3D printed Andean musical instruments

On May 27th, a research group led by Associate Professor Kyoko Yamahana of the School of Cultural and Social Studies, conducted an experimental musical performance with 3D printed musical instruments, which were a reproduction of the Andean pottery collection from the Tokai University Institute of Civilization Research. The group has been studying the internal structures of Andean pottery since last year, using X-ray CT scanning at the TOKAI Imaging Center for Advanced Research (TICAR). Consequently, they discovered that a number of the pottery vessels in their collection were in fact musical instruments. With the help of Professor Yasunobu Akiyama of the Department of Applied Chemistry, School of Engineering, they have created identical 3D resin replicas of four Andean pottery musical instruments: a pan flute (Nazca culture), a conch (Mochica culture), a trumpet (Recuay culture), and a double-chambered bottle (Wari culture). The X-ray scanned data were first calculated and the theoretical sound values were determined by some students of Professor Rio Kita, a director at the Micro/Nano Technology Center. The experimental musical performance took place on May 27th and was performed with the 3D printed replicas to compare the calculated sound values with the actual sounds of the replicas.

Ranked 301+ in the THE Impact Ranking 2019

The Times Higher Education Impact Ranking 2019 was released on April 3, 2019 (JST).

Tokai University was ranked 301+ overall.

The newly launched Impact Ranking assesses the university's efforts towards SDGs (the "Sustainable Development Goals" adopted by the United Nations). More than 450 institutions from 76 countries (42 from Japan) participated in the survey.

In the ranking, 11 out of 17 SDG target categories were surveyed, with Tokai University being ranked in all 11 categories.

GLOCAL MONITORING PROJECT

International Workshop on Glocal Monitoring

The Tokai University Glocal Monitoring Project, in partnership with the University of the Philippines, held the "2nd International Workshop on Glocal Monitoring" on February 21-22 at the University of the Philippines' Diliman Campus.

At the workshop, 10 researchers from Japan, the Philippines, China, Taiwan, and the United States presented their work on the monitoring of natural disasters and environmental changes using remote sensing. Around 100 participants, including members of various institutions throughout the Philippines, held discussions with the researchers.

Professor Uchida appearing on the Tokyo FM program "Future Lesson"

Professor Osamu Uchida appeared on the Tokyo FM program "Future Lesson" from March 4 to 7 to lecture on the utilization of SNS in the event of a disaster.

1st: Disasters and SNS

2nd: Selectively using SNS in a disaster

3rd: The hashtag "#--- disaster"

4th: Disaster prevention training using Twitter and disaster prevention in the age of SNS

https://www.tfm.co.jp/future/

Lecturing on disaster prevention at Sendai Technical High School

On March 11, 2019, Professor Cho Kohei and Professor Osamu Uchida were invited to deliver lectures on disaster prevention at Sendai Technical High School, which is an event held annually on the date of the Great East Asian Earthquake. They lectured on the theme "Global Monitoring, a new disaster monitoring initiative."

Global Monitoring Project
https://glocal.u-tokai.ac.jp/

DITS/DIMS
http://glocal-dits.u-tokai.ac.jp/

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