2020

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NATIONAL INSTITUTE FOR MATERIALS SCIENCE

NIMS ventures

Bringing innovative R&D products to the world

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New materials and technologies are the seed of innovation to impact the world.

However, the seeds must be allowed to grow into plants and bear fruit.
Researcher-initiated ventures are a pioneering approach to putting research results into practical use.

Because researchers who developed new materials and technologies know their own products in a profound way, their involvement in business may potentially facilitate the effective and speedy commercialization of these products.

There are many challenges entrepreneurial researchers need to overcome.
Some of the technical issues can be identified only after they learn quality management and actually assemble usable products.
They need to secure production facilities,
raise capital and simultaneously serve as both a researcher and a business person.

The three venture companies launched by NIMS researchers have steadily built businesses despite many difficulties and setbacks along the way.
Their business success is attributed to their strategic approaches to problem solving and the support system offered by NIMS*.
What is the formula for successful venture companies?

***NIMS venture company support program**
Established in 2003, this program provides various types of support to NIMS employees starting a new business during the first five years of the business-building process. For example, qualified NIMS employees are entitled to use research equipment and set up an office at NIMS at a reduced fee. As of November 2020, 15 venture companies have been established with the support of this program.

NIMS Legend SPECIAL INTERVIEW

Delivering indispensable services

Creating irreplaceable products leads to a successful 20-year business operation

OXIDE Corporation, located in Hokuto City, Yamanashi Prefecture,
specializes in manufacturing highly functional single crystals and related products.
This venture company, launched with the support of the National Institute for Research in Inorganic Materials (NIRIM, currently NIMS),
has succeeded in developing optical single crystalline products major manufacturers have been unable to produce.
One of OXIDE's optical single crystalline products has been used as a component in semiconductor inspection equipment
—a vital tool for the development of high-performance smartphones. It's captured approximately 95% of the global market.
Another OXIDE product is an irreplaceable component in state-of-the-art cancer screening equipment and is always in high demand.
Long-term survival and continued business growth are common challenges for many venture companies.
What's the secret to OXIDEs remarkable success?
The source of OXIDE's strength has been its president's unshakeable conviction and patient perseverance in the face of many difficulties.

COMPANY PROFILE

Name :
OXIDE Corporation

Key Technology :
Optical single crystals

Service :
Production and sales of optical single crystals, optical devices and laser oscillators

Foundation Date :
October 2000

Crystals and optical devices manufactured by OXIDE Corporation

Dr. Yasunori Furukawa

President and CEO of OXIDE Corporation. After earning his Ph.D. from the University of Tsukuba, Furukawa joined Hitachi Metals, Ltd. in 1983. He went on to conduct research at Stanford University in the United States and joined NIRIM in 1996. In 2000, NIRIM granted him a leave of absence to launch OXIDE Corporation. He officially left NIRIM in 2003 and has been managing the corporation ever since.

Career before starting the business

"I was one of only a few people in Japan to launch a venture company with the support of a research institute," Furukawa said. "The public had a negative view of researchers starting ventures."

Furukawa initially worked at Hitachi Metals, but then-NIRIM director Shigeyuki Kimura persuaded him to join NIRIM. "I remember him saying, 'Our basic research has produced promising results and we need your support to transform our results into practical products,'" Furukawa recalled.

NIRIM succeeded in developing high-purity, high-quality optical single crystals using a crystal growth technique developed by Kitamura called the double crucible method. "Crystals created using conventional methods have many defects," Furukawa said. "However, crystals need to have extremely high levels of precision—on the order of nanometers—to be used as optical materials. The double crucible method reduced the defect rate by more than 99% compared to other crystal growth techniques. A type of single crystal called a 'stoichiometric LN/LT' fabricated using this technique had excellent optical characteristics, motivating NIRIM to convert it into a commercial product."

Optical single crystals were expected to be in high demand in three different markets at the time: Blu-ray discs, holographic memory and optical communications. Some of the private companies then working to commercialize these products approached NIRIM asked it to join forces with them to accelerate the development of commercial products. To accommodate these requests, Furukawa and others began developing a licensing business. Their efforts allowed NIRIM to conclude a licensing agreement with five companies under which NIRIM provided them with the technique for growing stoichiometric LN/LT single crystals.

However, the commercialization of crystalline products was far from being accomplished even after more than a year of collaborative effort. Market demand for new technologies can diminish quickly, like seasonal fruits and vegetables, if competitors are able to develop similar technologies more quickly. Speedy commercialization was therefore urgent. This concern inspired Furukawa to launch his own company.

"If the collaborative efforts under the licensing agreement had borne fruit, I would still be working at NIMS today," Furukawa said. "My wife was delighted when I joined NIRIM because she thought my national public servant status would guarantee a stable income," he laughed. "It took a lot of convincing to gain my family's support for the new venture."

The leave of absence system for national public servants—newly established by the Japanese government—allowed Furukawa to pursue a venture without losing his NIRIM position for up to three years. As the very first user of this system, Furukawa founded OXIDE Corporation in October 2000. He was fully ready to work toward his ambition.

Unexpected hurdles

In 2001, NIRIM and the National Research Institute for Metals merged to form NIMS. NIMS offered considerable support to venture companies despite lacking an official framework for doing so. Rather than providing direct financial support to venture companies, different NIMS sections offered active, creative support in a variety of ways, such as assistance with participation in exhibitions.

Furukawa initially worked to further enhance the double crucible method, which led him to finally achieve the 2001 commercialization of a stoichiometric LN/LT single crystals under the name "Super LN/LT." In 2003, OXIDE Corporation formed a capital alliance and a business partnership with Toshiba Ceramics, Co., Ltd. and Furukawa officially left NIMS. He has since focused on managing his company.

Although OXIDE appeared to have a perfect launch, Furukawa said he initially experienced many challenges such as recruitment and financing. Even after all the pieces necessary for production were finally in place, he struggled mightily to achieve stable production of Super LN/LT single crystals.

"I found it difficult to create uncracked wafers of sufficiently large sizes to meet client demands," Furukawa said. "I did not have to worry about this when I was a basic research scientist because our focus was collecting data from the uncracked part of a wafer; we did not have to create perfect, uncracked wafers. It was a mystery to me how manufacturing companies were not able to produce wafers without cracks. When I actually tried it myself for the first time, I realized how difficult it would be. It took me several weeks to create just one fully grown crystal and I was able to make crystals of adequate quality only 10% of the time at best. These inefficiencies remained unresolved for a long time."

Without a stable crystal production process, constant and stable delivery of products is impossible. Eventually, other companies developed practical optical single crystals for use in Blu-ray discs, holographic memory and optical communications, beating Furukawa to the punch in these three markets. Even worse, the financial condition of OXIDE's parent company deteriorated, prompting it to cease investing in OXIDE in 2005.

"Because our headquarters was located at the premises of the parent company, we had to relocate," Furukawa said. "We moved to an abandoned factory that was over 50 years old. Because we didn't have a budget for renovation, we painted the floors and walls ourselves. We joked among ourselves that we could run a painting company if the single crystal business failed."

Skills: the ultimate solution to OXIDE's predicament

The research skills Furukawa developed during his tenure at NIRIM saved OXIDE.

"We received an inquiry from NTT (Nippon Telegraph and Telephone Corporation) about the commissioning of product development. IBM had developed a so-called KTN crystal, which exhibited high performance, but was very small: the size of the tip of a pinky finger. For this crystal to be put into practical use, it needed to be increased to the size of a human palm. However, no manufacturer had been able to achieve it. NTT thought OXIDE might be capable of accomplishing it."

Furukawa was desperate, but also hopeful that he might be able to create a sufficiently large KTN crystal using the double crucible method, a technique no one else could imitate. He made an all-out effort and repeatedly fabricated crystals.

"After four years of trial and error, I finally succeeded in creating a sufficiently large KTN crystal. Our persistent efforts to determine optimum production conditions and improve our production methods paid off in the end. This experience, among others, allowed us to increase our overall crystal production efficiency from the initial 10% or so to the current 98%. In retrospect, I believe that sound skills were the key that enabled us to bounce back from our lowest point."

NTT actually commissioned the same project to several major manufacturers in addition to OXIDE, all of whom failed. This led to the formation of a capital alliance between Oxide and NTT in 2007. This was an unusual partnership between two very different companies: NTT is a household name with over 100,000 employees, while Oxide was virtually unknown and had only 10 people at the time.

OXIDE's successes continued. In 2007, it increased the size and quality of a CLBO single crystal developed by Osaka University for use in an ultraviolet laser. This attracted the attention of Nikon Corporation and a major semiconductor manufacturer in the United States, who offered to invest in OXIDE, finally putting the company back on track.

"Making our services indispensable is important in enabling us to remain a competitive venture company," Fujikawa said.

Continuous skill improvement leads to commercialization

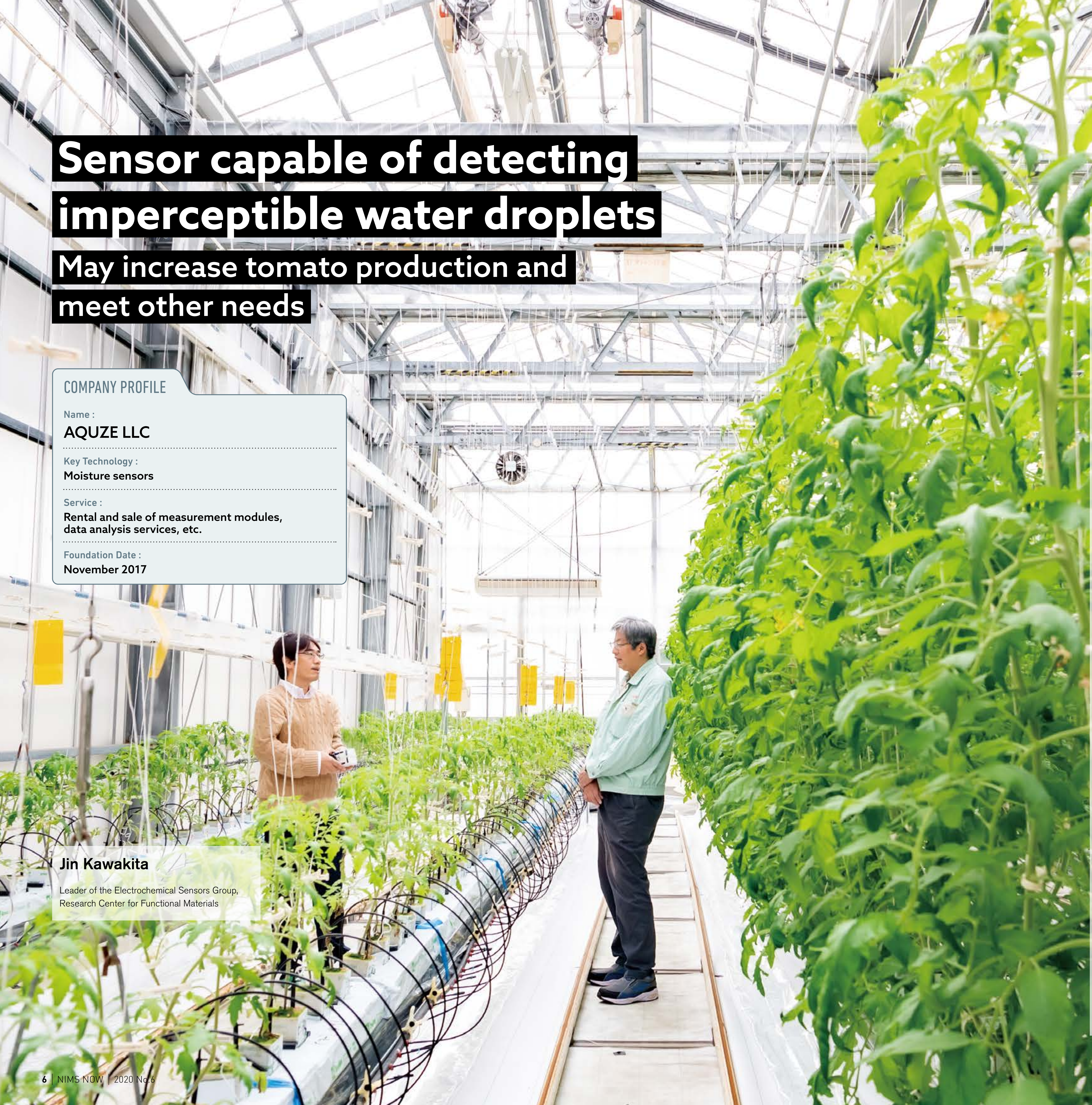
As OXIDE's business performance steadily improved, more and more major Japanese companies that were working on single crystals and related products discontinued their own development programs. As a result, many first-rate technical experts at these companies have joined OXIDE in the hope of continuing their research. OXIDE has successfully developed the types of optical devices and laser equipment major manufacturers had been unable to develop themselves, further expanding its business. Therefore, OXIDE currently has 160 employees and its cumulative sales have reached 20 billion yen. OXIDE also engages in business with many overseas clients—the source of 75% of its profits.

Based on his experience, Furukawa expressed the following views.

"NIMS has a culture of in-depth research on a single material or subject, allowing researchers to develop a high level of skill. If they continue to improve their skills, I believe that they will be able to translate their research results into practical products. I therefore encourage them to envision strategies for achieving this so that they're ready to capitalize when they get promising results. I believe that my success in business resulted from having clear strategies to transform research results into practical products and improving the skills I developed at NIRIM."

(by Takeshi Komori)

Furukawa (fourth from the left) attending the Forbes Japan Small Giants Award 2021 for the Kanto and Chubu block hosted by the Japanese edition of Forbes, a globally acclaimed business magazine. The award recognizes companies that have been operating for at least 10 years and have brought about significant changes in public life despite less than 10 billion yen in cumulative sales. OXIDE Corporation won first prize in this block. (Photo provided by Forbes Japan)



Sensor capable of detecting imperceptible water droplets

May increase tomato production and meet other needs

COMPANY PROFILE

Name :
AQUZE LLC

Key Technology :
Moisture sensors

Service :
Rental and sale of measurement modules, data analysis services, etc.

Foundation Date :
November 2017

Jin Kawakita

Leader of the Electrochemical Sensors Group, Research Center for Functional Materials

Instant detection of water droplets invisible to the human eye

Moisture and condensation cause mold growth, mites, metal corrosion and other problems. Hygrometers and dew sensors can be used to evaluate moisture. However, commercially available hygrometers are not very reliable when the relative humidity approaches more than 100% and dew sensors can only detect droplets 100 µm in diameter or greater. The Moisture Sensor product, by contrast, is capable of detecting water droplets as small as 0.5 µm in diameter—smaller than the approximately 10 µm droplets the human eye is capable of perceiving.

In addition, the Moisture Sensor is much smaller and responds much more quickly than conventional hygrometers and dew sensors: while conventional hydrometers require several seconds to respond, the Moisture Sensor responds within only 0.02 seconds.

Launching AQUZE out of necessity

Kawakita developed the Moisture Sensor in 2015. He subsequently developed a measurement module with the ability to convert electrical signals generated by the sensor into digital signals and then transmit them to computers. He also developed software to display the measurements.

Kawakita initially invited private companies to conduct joint research with the goal of commercializing these products. Although none expressed interest to produce it, many were interested in borrowing the measurement module to verify its performance.

"I initially lent out the modules under a confidentiality agreement," Kawakita said. "However, demand was too high; the module was the subject of ongoing research and I only had a limited number of them. These companies were interested in finding out whether the Moisture Sensor was appropriate for their specific needs rather than collaboration research with NIMS to develop it into a practical product. I invited several manufacturers to join us in our research, but they all declined. Their general opinion was that the purpose of the sensor was unclear, market demand for it was likely to be dismal. While developing the sensor into a practical product was technically feasible, they weren't interested."

"Although private companies expressed no interest in doing joint research with us, more and more were asking to borrow the measurement module," Kawakita went on. "I came to the conclusion that I needed to secure the necessary resources to put the sensor into practical use myself. I decided to launch a new company using the NIMS venture company support program."

Efficient research-applied development cycle

Kawakita established AQUZE LLC in November 2017. The company's main service is the rental and sale of measurement modules. It also provides sensor chips to interested clients. In addition, AQUZE analyzes sensor-generated electrical signal data for its clients.

"Working at a venture company allows me to more clearly identify specific social needs," Kawakita said. "Simultaneously serving as both a NIMS and AQUZE employee gives me the chance to engage in research and also in applied development, leading to speedy problem solving during the R&D process."

AQUZE launched a research project with

Environmental conditions vary even within a single agricultural greenhouse. Several Moisture Sensors therefore need to be placed at different locations. AQUZE and NARO have been jointly developing an actuator capable of automatically vaporizing dew drops when the sensors detect a certain level of condensation. Group leader Kawakita (right) and Tomohiko Ota (Leader of the Horticultural Robotics Unit, Institute of Agricultural Machinery, NARO).

the support of the Public/Private R&D Investment Strategic Expansion Program (PRISM) established by the Cabinet Office in FY2018. In this project, AQUZE is researching the effective use of the Moisture Sensor in preventing disease damage in greenhouse-grown agricultural plants in collaboration with NIMS, Ehime University, the National Agriculture and Food Research Organization (NARO) and private agricultural businesses. Approximately 10% of the annual production of tomatoes—one of the most common greenhouse-grown crops—is lost to disease, including powdery mildew and Botrytis cinerea, which often spread when moisture condenses into water droplets. When plants are subjected to humid conditions for a prolonged period of time, powdery mildew and Botrytis cinerea often grow on wet leaf surfaces, giving them a powdery appearance. Heaters are commonly used to reduce humidity, thereby preventing moisture from condensing, but this method is not always effective. In addition, heating costs are a huge burden for growers.

NIMS and AQUZE initiated the PRISM project to develop disease prevention measures through early detection of moisture condensation using the Moisture Sensor.

"We identified many practical issues related to placing the Moisture Sensors in agricultural greenhouses," Kawakita said. "For example, we found that a protective filter needed to be added to the sensor to prevent agricultural chemical sprays from entering and damaging it while at the same time allowing air to flow into it. To achieve this, we had to test many different filters before finally finding the optimum shape. We also needed to resolve many other smaller issues, such as preventing condensation from developing on the surfaces of electronic circuits other than the circuit in the sensor. We therefore made many improvements to the prototype sensor to make it suitable for practical use. AQUZE handled this "non-research" part of the project. In other words, I researched sensor chip performance as a NIMS employee and developed the module as an AQUZE employee. My twin positions therefore promote speedy and efficient R&D."

Forecasting disease risks in agricultural greenhouses

Experiments using the Moisture Sensors have produced some positive results in forecasting the development of diseases promoted by condensation.

"In the PRISM project, we placed existing temperature and humidity sensors in greenhouses in addition to the Moisture Sensors and compared the data they generated," Kawakita said.

One day, the grower who manages the greenhouses in which the sensors were

placed reported to Kawakita that he had observed powdery mildew growth that morning. Kawakita examined sensor data up to the time disease was detected. The existing temperature and humidity sensors were unable to detect the subtle environmental changes favorable to moisture condensation and powdery mildew growth. However, the Moisture Sensor clearly detected a subtle increase in humidity the evening before the powdery mildew appeared.

"I'm still in the process of collecting more data, but preliminary results suggest that the Moisture Sensor may be capable of detecting the very early stages of moisture condensation that lead to the development of disease," Kawakita said.

In addition to the Moisture Sensor, AQUZE is jointly developing a web-based system that can be used to remotely monitor Moisture Sensors placed in greenhouses in real time around the clock. The system allows personal computers and smartphones to display the levels of condensation in a user-friendly manner using three colors: red (large amounts of condensation), yellow (small amounts of condensation) and green (no condensation). Kawakita's next plan is to enable the system to display the risks of disease development using different colors.

"I would like to improve the accuracy of the Moisture Sensor in forecasting disease development promoted by condensation though further experiments with Ehime University and NARO," Kawakita said. "In addition to this project, AQUZE and NARO are jointly developing an actuator capable of automatically vaporizing dew drops when the sensors detect a certain level of condensation."

Identifying social needs to facilitate applied research

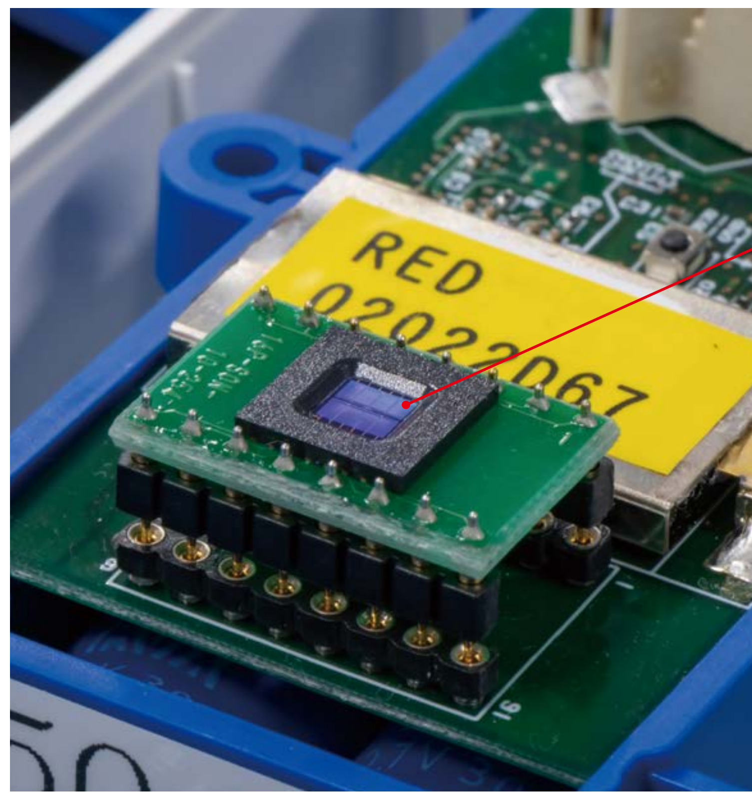
Establishing a venture company has given Kawakita two advantages: an increased ability to identify social needs and expedited R&D processes.

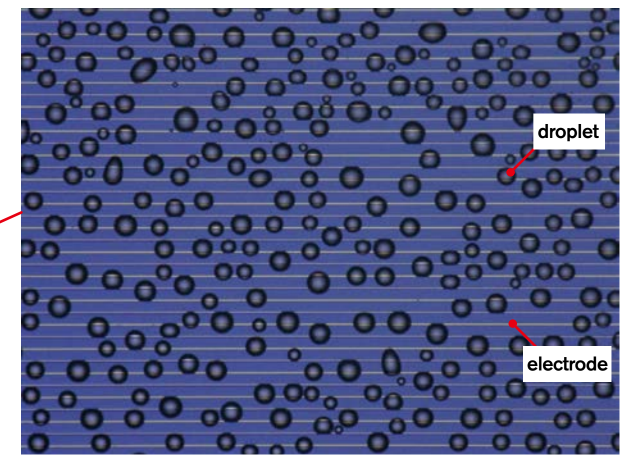
"When I communicate with private companies as an AQUZE employee, they sometimes inquire about businesses with an R&D component. To properly handle this component, I advise them to sign a joint research contract with NIMS, which allows me to engage in product development as a NIMS employee. This arrangement is very efficient. For private companies, the use of this arrangement ultimately saves time and R&D costs as they don't need to commission their R&D to other companies. NIMS also benefits from the fact that this arrangement allows it to conduct applied research in response to social needs."

According to Kawakita, NIMS has actively supported AQUZE's operations.

"For example, when the NIMS division that arranges collaboration between NIMS and private companies receives inquiries about the Moisture Sensor, it sorts AQUZE projects from research projects, helping my decision-making process. The division also provides me with other types of administrative support. As a result, AQUZE has already established collaborative partnerships with many private companies. The Moisture Sensor may be potentially useful in the cosmetic, nursing care and medical fields in addition to agriculture. I hope to contribute to the continued growth of AQUZE and accelerate the commercialization of our products."

(by Kumi Yamada)





Measurement module containing a Moisture Sensor. Two types of elongated electrodes are alternately arranged on the surface of a 5 mm × 5 mm silicon semiconductor. When a water droplet bridges two adjacent electrodes, an electric current is induced. The module determines the amount of droplets deposited by measuring the electrical current generated.

Tang is working to develop a practical graphene supercapacitor production process that employs a roll-to-roll coating machine. When the graphene/carbon nanotube (CNT) composite material—an original electrode material Tang has synthesized—is poured into the machine, it forms a thin coating over the surface of an aluminum film (photo on the lower right).

Jie Tang

Leader of the Advanced Low-Dimensional Nanomaterials Group
Center for Green Research on Energy and Environmental Materials

Expediting the introduction of safe, quick-recharging, high-power capacitors through entrepreneurship

COMPANY PROFILE

Name :
Materials Innovation Tsukuba Corp.

Key Technology :
Graphene supercapacitors

Service :
Development, production and sale of super capasitors, consulting, etc.

Foundation Date :
November 2017

Graphene supercapacitors enable smart and efficient electricity use

A capacitor is an electricity storage device that can be charged quickly and is capable of delivering high power densities over short periods of time. It has many advantages. For example, it is resistant to deterioration, durable and non-flammable. However, it also has a drawback: its energy density is low, preventing widespread uses.

"Existing capacitors employ activated carbon as an electrode material," said Jie Tang, who launched Materials Innovation Tsukuba Corp.—a venture company certified by NIMS—in November 2017. "I began research and development of graphene supercapacitors in 2008 with the vision that replacing activated carbon with graphene should increase the energy density of capacitors."

Tang has developed a graphene supercapacitor with an energy density several times greater than that of existing capacitors and is producing and selling it through Materials Innovation Tsukuba.

One potential application of this technology is in sensors that would be placed on human bodies.

"Wearable sensors capable of continuously monitoring human activities, such as location, heart rate and emotion, will be essential components in an IoH (internet of humans) that could be used to ensure public safety, manage public health and for other purposes," Tang said. "I believe that graphene supercapacitors can serve as safe power sources for these sensors. We're also planning a long-term project to pursue the use of this capacitor in electric vehicles (EVs). EVs are equipped with a so-called regenerative braking mechanism which converts inertial energy into electrical energy when a vehicle's brakes are applied. Storing this electrical energy in graphene supercapacitors could enable EVs to travel 10% farther on lithium ion batteries."

Graphene supercapacitors are therefore potentially useful as both primary and supplemental power sources.

Overcoming graphene's drawbacks through an original technical approach

Graphene is a two-dimensional sheet composed of a single layer of carbon atoms arranged in a hexagonal lattice. It has a larger specific surface area (the total surface area of a material per unit of mass) than activated carbon, enabling it to store more electric charges. Graphene also has very high electrical conductivity, making it an ideal material for the development of capacitors capable of rapidly storing electrical energy and delivering high power densities over a short period of time.

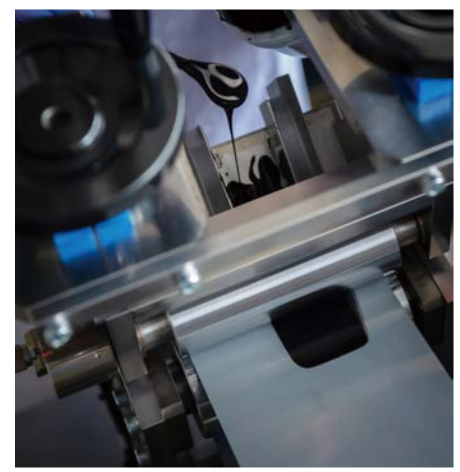
Although graphene is a promising alternative to activated carbon, it has a major problem to overcome before it can be used as a practical capacitor material: due to its extreme thinness, pieces of graphene have a strong tendency to stick together, preventing them from having high energy densities.

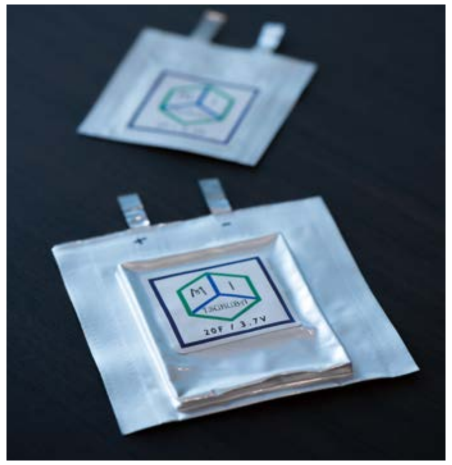
To resolve this issue, Tang initiated a research project in 2011 with the support of the Advanced Low Carbon Technology Research and Development Program (ALCA) run by the Japan Science and Technology Agency (JST). She also conducted joint research with several private companies. Through these projects, she came up with a groundbreaking structure: carbon nanotubes (CNTs)—like graphene , a highly electrically conductive material—were placed between two graphene sheets, thereby holding them together while maintaining an adequate separation between them (figure on p. 12).

Tang made further efforts to improve the performance of the graphene/CNT structure. She created extremely small pores (nanopores) on the graphene surfaces, increasing their adsorption of the electrolyte and the electrolyte's penetration into the structure. This structure exhibited an energy density as high as nickel-hydride batteries; several times that of conventional capacitors. Tang considered this product to be worthy of commercialization.

"I completed a sheet-like electricity storage device using the graphene/CNT composite material (photo on p. 12) in 2016," Tang said. "We then immediately initiated collaborative R&D with private companies to develop a method of mass producing the device. This enabling technology project under the ALCA program lasted about two and a half years from 2016."

Tang also launched Materials Innovation





Laminated, sheet-like graphene supercapacitors. The flat electrode material fabricated using the coating machine is cut out to prepare a pair of material pieces identical in shape and size. They are then stacked together and enclosed with the electrolyte between two aluminum films.

Tsukuba in 2017. Why did she start a venture company while collaborative development was ongoing?

Delivering products capable of fulfilling clients' needs

"I was eager to put the graphene supercapacitor into practical use," Tang said. "That's why I started a company that could build prototype products and sell them at a small scale initially, even though I was still developing commercialization strategies in collaboration with private companies."

According to Tang, the strength of Materials Innovation Tsukuba is full access to all of the graphene fabrication techniques needed for material and device development.

"A variety of techniques can be used to produce graphene, and some are more costly than others," Tang said. "The type of graphene used needs to be appropriate for each specific purpose. However, many device manufacturers don't understand this and often have difficulty developing graphene-based products that perform to expectations. We know how to fabricate the optimum types of graphene for different applications. In fact, we have patented 38 different graphene fabrication techniques in Japan and overseas. Establishing the venture company has given us the chance to learn the needs of graphene users directly from them and fabricate and sell product prototypes that best fit their objectives."

Support from many Tsukuba-based organizations

Materials Innovation Tsukuba received support from the Hirosawa Foundation for Technology based in Tsukuba City in December 2018—only one year after it was founded—in recognition of the superior performance of the graphene supercapacitor. Moreover, CYBERDYNE Inc. and Tsukuba Bank announced their intention to jointly provide Materials Innovation Tsukuba with financial and project support starting in March 2019.

"We were able to gain the support of CYBERDYNE because we had an opportunity to present our ongoing projects to Dr. Yoshiyuki Sankai, a University of Tsukuba who is also the president and CEO of CYBERDYNE," Tang said. "The company develops and sells robots for medical and nursing care use. Professor Sankai was keenly interested in our graphene supercapacitor because he saw its potential to serve as a safe, non-heat-generating power source for the robotic suits CYBERDYNE was developing, which need to be safe for people to wear."

Tang was able to secure more financing: her R&D projects were granted funding first by the New Energy and Industrial Technology Development Organization (NEDO) in 2019 and then by the program to support small and medium-sized enterprises and start-ups established by the Ministry of Economy, Trade and Industry* in 2020. She is currently working to develop practical product manufacturing processes.

Tang made the following remarks on Materials Innovation Tsukuba's successful launch.

"Most of scientists lack knowledge on subjects vital to building a business, such as mass-production technologies, merchandising and marketing. Fortunately, our company has an outstanding staff, including an experienced engineer who has worked as a leading capacitor researcher at a private company. I can always count on them for sound advice. Although we are grateful for the financial support we've received, we still lack a sufficient budget to make a large investment in facilities and equipment. NIMS has been helping us a great deal with this issue by giving us low-cost access to its research facilities. I go to work doing research and carrying out daily business operations motivated by a strong desire to repay NIMS and my home city of Tsukuba for their generous assistance."

(by Kumi Yamada)

* Strategic Core Technology Advancement Program (Supporting Industry Program)

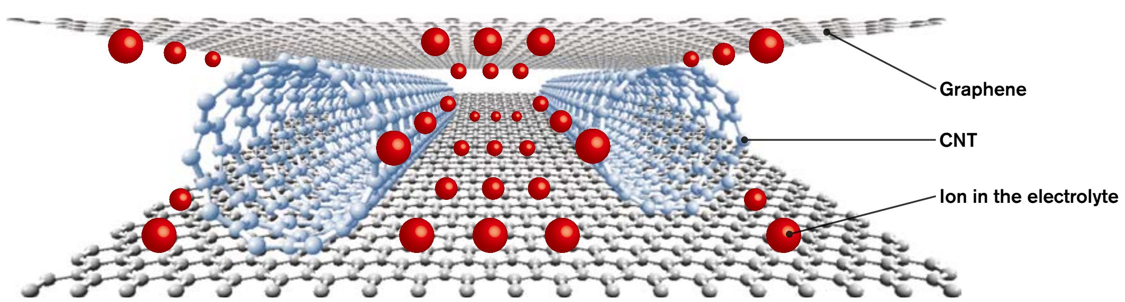


Figure. Structure of the graphene/CNT composite material
Graphene sheets have a strong tendency to stick together–the biggest drawback in using them as a capacitor material. Tang solved this problem by placing CNTs–a hexagonal lattice of carbon atoms forming a hollow cylinder–between two graphene sheets. CNTs hold two graphene sheets together while maintaining an adequate space between them. Tang then created nanopores several to dozens of carbon atoms in size in the graphene sheets to promote penetration of the electrolyte into the graphene/CNT structure, significantly increasing its energy density.

Takeo Minari
Leader of the Printed Electronics Group
Research Center for Functional Materials

Development and sale of printed electronics equipment and inks: a strategy to popularize unique techniques

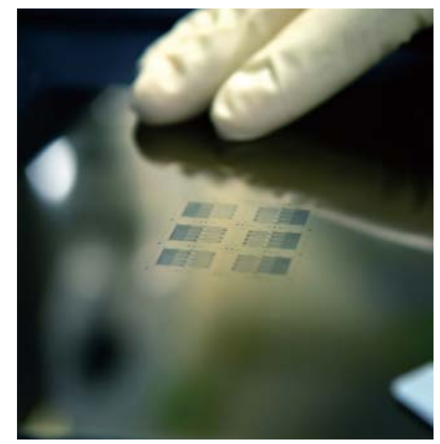
COMPANY PROFILE

Name :
Priways Co., Ltd.

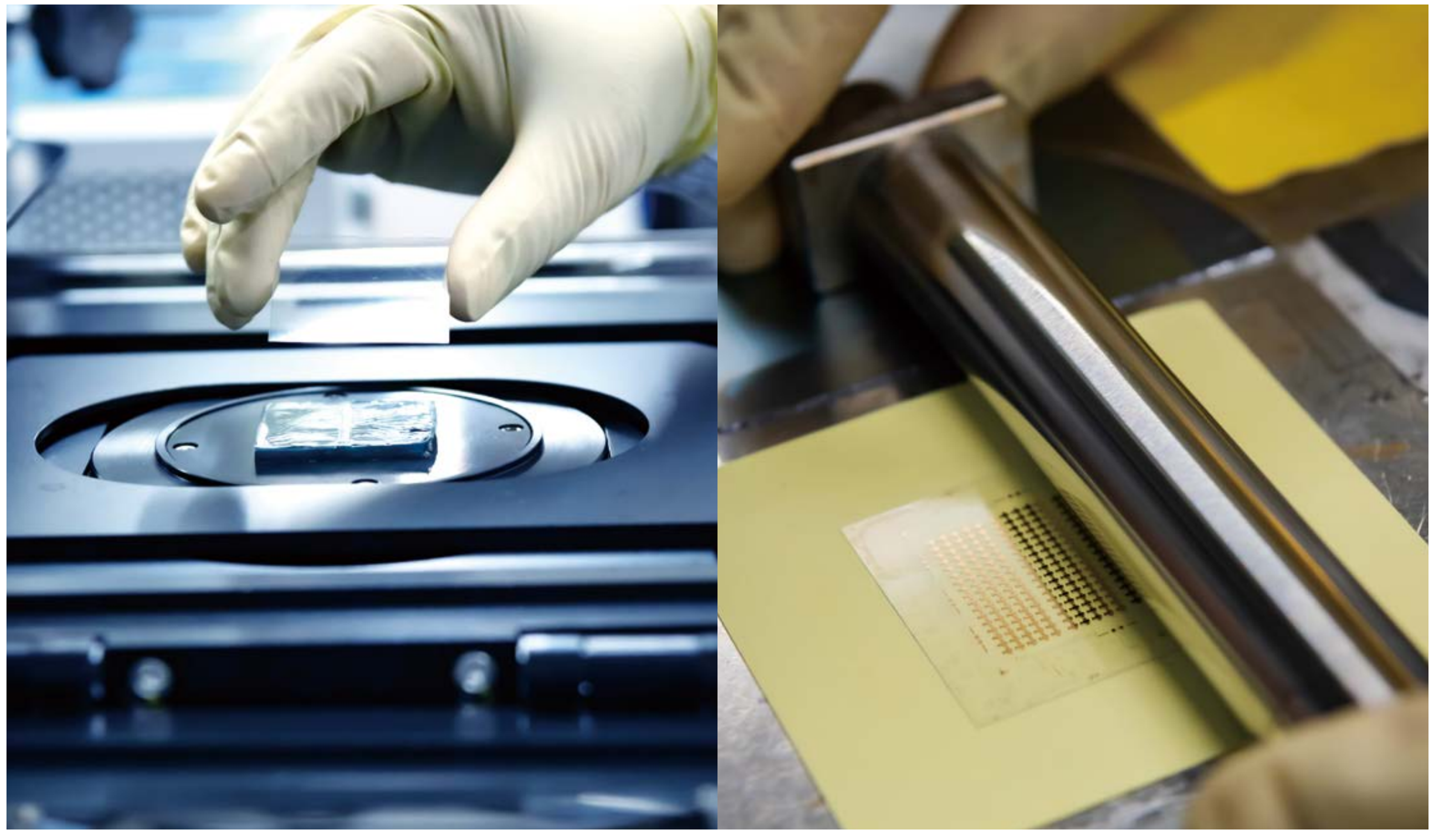
Key Technology :
Printed electronics

Service :
Electronic circuit fabrication, production and sale of circuit printing equipment and conductive inks, production and evaluation of material prototypes, etc.

Foundation Date :
April 2018



A photo mask with an intended circuit pattern etched on its surface. It is used to define the printable area of metallic ink on the substrate.



A film substrate and a photo mask with an etched circuit pattern (photo at lower right on p. 13) are placed under the ultraviolet irradiator. The substrate is irradiated with UV radiation from above, causing the portion of its surface exposed to the radiation to shift from hydrophobic to hydrophilic.
Ink is then deposited on the substrate, which adheres to the hydrophilic portion of the substrate surface but is repelled by the hydrophobic portion, thereby forming a circuit pattern with extremely narrow traces on the surface.

World's thinnest printed circuit traces

Printed electronics is a set of techniques used to print an electronic circuit on a substrate by depositing metallic or semiconductive inks on its surface. These techniques that have abilities to form wiring patterns on the surfaces of light, large-area, bendable plastic substrates are vital to the development of wearable devices. For this reason, printed electronics R&D has been very active. The printed electronics technique Takeo Minari has developed has significant advantages: it can be used to print extremely narrow circuit traces without requiring either a vacuum or high-temperature environment.

"While the use of conventional techniques allows printing of circuit traces around 100 micrometers (μm), my current technique enables them to be as narrow as 0.6 μm—the narrowest width ever achieved in printed electronics," Minari said.

This achievement was highly acclaimed. As a result, Minari started to receive a succession of inquiries about his technique and requests to fabricate printed circuits from private companies. Because each company had a different circuit pattern request, he had to fabricate each circuit in a custom-made manner, limiting the number of circuits he could produce. Eventually, the number of orders increased to the point where it became almost impossible for him to handle all orders in between his research activities. One day, he casually looked at the document describing the terms and conditions for the use of the NIMS venture company support program.

"Ever since I became a researcher, I wished to benefit a society through research," Minari said. "I thought that the best approach to achieving this would be launching my own business, although I was also aware of the huge expenses that would be needed to rent an office space and procure necessary equipment. The NIMS venture company support program was the solution to these issues; it allows qualified NIMS employees to cheaply rent rooms available at NIMS as office spaces and use lab equipment there at low cost. In addition, this program enables them to operate a business at the annual cost of only about 200,000 yen: including a corporate inhabitant tax, while maintaining their positions at NIMS. I thought, 'Why not give it a try?' and applied for the program."

Miniaturization using a unique surface alteration technique

Minari established Priways in April 2018. His main focus there is to develop original printing equipment while continuing circuit prototype fabrication and material characterization in response to inquiries and requests from private companies.

"The two key aspects of printed electronics are the physical properties of inks and the surface properties of substrates on which inks are deposited," Minari said. "The secret to printing narrow circuit traces is the technologies to control the surface properties of substrates. We are currently developing printing equipment capable of controlling the surface properties and equipment capable of uniformly depositing inks. I'm planning to make these technologies available to private companies so that they could easily print electronic circuits themselves. I hope that the techniques I have developed will serve many people."

What is unique about the techniques Minari has developed?

In conventional printed electronics, ink is directly deposited on the surface of a substrate. This method, however, causes deposited ink to spread on the surface and does not allow ink to be deposited within a very narrow area. By contrast, Minari's technique enables printing of extremely narrow circuit traces by exploiting the hydrophilic and hydrophobic natures of substrate surfaces. First, an intended circuit pattern is prepared as a photo mask, which is used for the selective modification of surface wettabilities. The substrate is then irradiated with UV light through the mask, causing the portion of its surface to shift from hydrophobic to hydrophilic. Thus, the metallic ink can be deposited only on the narrow hydrophilic area, resulting in the formation of a circuit pattern with extremely narrow traces on the surface (photo on p. 14).

"The printing equipment I am developing for commercialization is specifically designed to execute these processes with ease," Minari said. "My future business vision is that our client companies use our printing equipment products and Priways provides consulting services to them. Our more immediate goal is to improve the performance of metallic nano-inks. Silver is the most commonly used material for this type of ink, but circuits made of silver nano-ink have risks of wire breakage and the ink is expensive to produce—a setback for the widespread use of printed electronics. In addition, an electronic circuit pattern printed on a substrate surface must allow various circuit components to be mounted to it, in order for it to be appropriate for practical use. Because solder does not stick to silver very effectively, electronics experts tend to avoid using silver."

These are copper inks under development. Minari has been working to develop inks and wiring patterns that are resistant to oxidization by adding other metallic elements to the inks. The color of the ink varies widely depending on the types of metallic elements and stabilizing agents added.

To address this issue, Priways has been developing stable, solder-compatible copper-based inks (photo above). Priways has also been pursuing the development of user-friendly technologies. For example, it is researching and developing a three-dimensional integration technique which may enable electronic circuit printing without requiring circuit boards and allow users to freely stack and connect multiple sets of wiring.

Growing together as a team

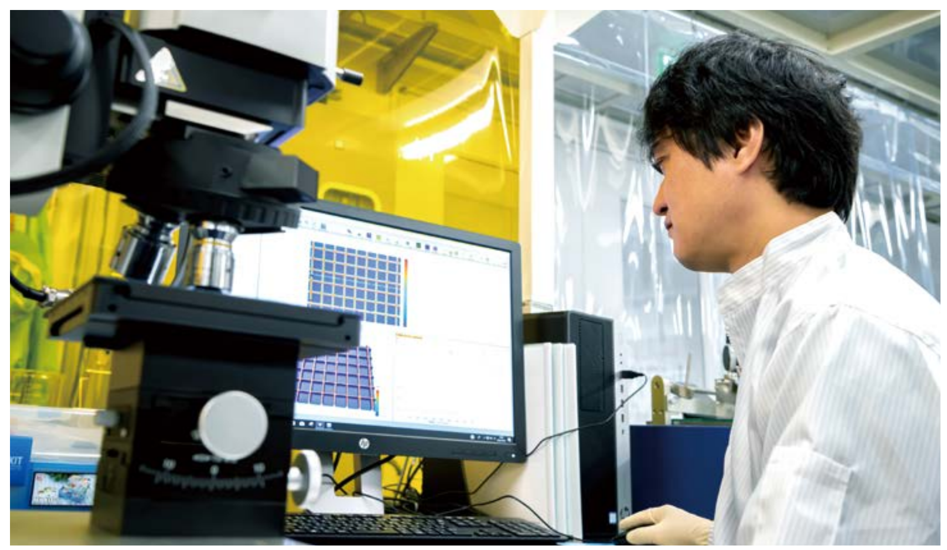
Priways currently has six members, including two NIMS members: Minari and Akitsu Shigetou (Adhesion and Surface Science Group, Research Center for Structural Materials).

"Dr. Shigetou, whose expertise is adhesion science and material connections, is carrying out research to increase adhesive strength between a printed circuit and its components," Minari said. "I hope that Priways members can work together to further enhance the technique I developed, improve each other's skills and grow together in this profession."

Minari went on to make the following remarks on the launch of Priways.

"It's meaningful for researchers to start own companies. Founding Priways has given me opportunities to meet many new people and learn directly from them. As a result, I was able to avoid falling into a pattern of self-righteous thinking—an attitude common to researchers. I will continue to pay attention to social needs and improve my skills. I hope our work at Priways will make a positive contribution to a society."

(by Kumi Yamada)



Minari is inspecting narrow circuit traces printed using a three-dimensional microscope. This is one of the services Priways offers: analyzing materials clients have developed and evaluating their usability as printed electronic materials.

NIMS NEWS

1 NIMS Researchers win the SSDM Award

SSDM (International Conference on Solid State Devices and Materials) 2020 selected this year's "SSDM Award" to Prof. Tsuyoshi Hasegawa(Waseda University), Kazuya Terabe (MANA Principal Investigator), Tomonobu Nakayama(MANA Principal Investigator), and Masakazu Aono(MANA Executive Advisor).


Prof. Tsuyoshi Hasegawa


Kazuya Terabe


Tomonobu Nakayama


Masakazu Aono

The "SSDM Award" was established to recognize outstanding contributions to academic or industrial development in the field of solid-state devices and materials. Their research "Quantum Point Contact Switch using Solid Electrochemical Reaction" was selected for the 2020 SSDM Award.

Prof.Hasegawa worked at NIMS from 2002 to 2012 and explored research on Atomic Switches together with the other winners.

2 NIMS scientist recieved the Catalyst Award at HLGC by U.S. NAM

Akihiro Okamoto (Independent Scientist at the NIMS Center for Nanoarchitectnics) won the Catalyst Award by U.S. National Academy of Medicine (NAM) at Healthy Longevity Global Grand Challenge (HLGC).

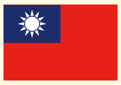
The Catalyst Awards are given as part of Healthy Longevity Global Grand Challenge (HLGC) proposed by the U.S. National Academy of Medicine (NAM). HLGC calls for outstanding ideas to promote the creation of innovations that will solve the challenges of aging societies. It consists of three phases. In the first Catalyst Phase, approximately 450 innovative ideas from around the world are selected to receive Catalyst Award for their potential to contribute to the realization of healthy longevity.

Hello from NIMS

Hello, I am Yen-Ju Wu from Taiwan. I am currently a ICYS researcher working on the data-driven study of interfacial carrier transport for thermal insulators and Li ionic conductors. My goal is to develop the practical materials applied to the energy issues, such as Li batteries and thermal insulators/diodes. NIMS provide us a good research environment where we can freely exchange ideas, share experiences, seek collaborators, and be inspired by many talented researchers.

It is also enjoyable to explore the beautiful sceneries of four seasons in Japan. My hometown, Taiwan, is at lower latitude and warm in almost whole year, so I have less experience to feel seasonal changes. I still remember how excited I was on the first snowing day in my life after I just came to Tsukuba in 2016 winter. There are many first experiences here, such as the impressive fireworks I have ever watched in summer, the incredible sakura season in spring, and the beautiful kouyo (red leaves) in autumn. I have checked the names of the colorful street trees near NIMS: toukaede at east, yurinoki at west, and tochinoki at south. Please stop by and check them in the autumn.

Mt.Fuji hiking at 3250 m in front of the sea of clouds.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