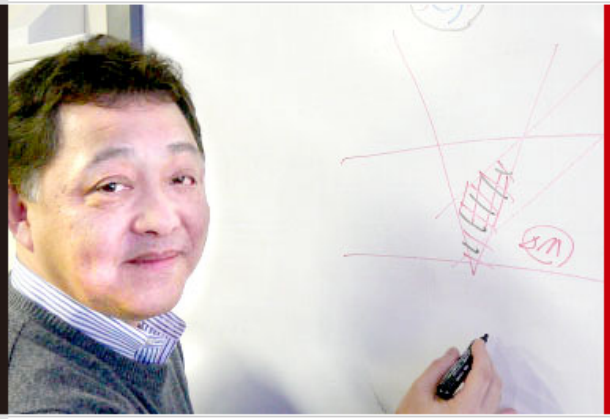
TOYOHASHI UNIVERSITY OF TECHNOLOGY
Master Technology, Create Technology

# TOYOHASHI UNIVERSITY of TECHNOLOGY e-Newsletter

News and views from one of Japan's most innovative and dynamic science and technology-based academic institutes



No. 4, September 2011

## Features

### Ultra-fast, terabyte-order holographic memory for medical applications

Toyohashi Tech's Mitsuteru Inoue describes the development of the next generation holographic memory for applications including storage of medical data of patients.

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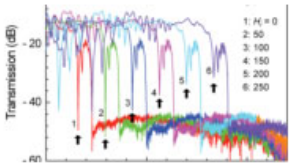


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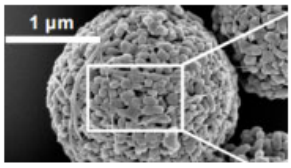


## Tech-Overtures

Innovative method for controlling the electrical conductivity of composite materials

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# Features

## Ultra-fast, terabyte-order holographic memory for medical applications

Toyohashi Tech's Mitsuteru Inoue describes the development of the next generation holographic memory for applications including storage of medical data of patients.

Every decade or so new data storage technology supersedes current ideas. Compact discs replaced audiotape, which were then eclipsed by DVDs, which are now being pushed aside by Blu-ray discs. Toyohashi Tech researchers are currently perfecting yet another technology that will take data storage to the next level.

"The era of 3D imaging is just beginning and although today's 3D TVs are little more than toys, it is clear that information displayed in 3D is going to be the way of the future," says Mitsuteru Inoue, of the Department of Electrical and Electronic Information Engineering. "This will require huge increases both in data storage capacity and in data transfer rates."

Whereas a Blu-ray disc can store 50 Gbytes of data, tomorrow's discs will be required to store 1 terabyte or more to cope with the demands of 3D imaging. Inoue is convinced that the technology to make this possible is holography.

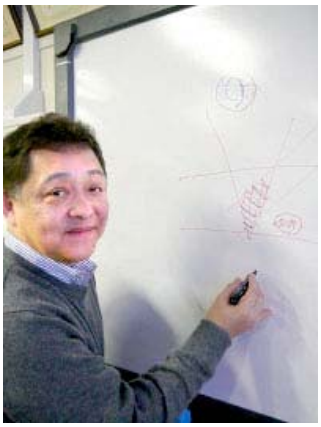
Simply put, holography uses light scattered from an object to record and reconstruct the object for viewing in three dimensions. Inoue and his team have developed a collinear phase-lock holographic memory that uses the interference caused by two overlapping laser beams—an information beam and a reference beam—to record holographic data on a disc. Moreover, the system employs a magneto-optic spatial light modulator that enables the recording of multi-level 'pages' (three-dimensional volumes) of data at the same time, and these can be represented as two-dimensional patterns on a new type of disc made of photo-polymer material also devised by the researchers.

"So instead of 1-bit sequential recording used in today's DVD or Blu-ray technologies, we can instantly record a million bits per page," says Inoue. "And because recording pages is performed simultaneously on multi-levels, the technology is capable of ultra-fast writing speeds of 1 gigabit per second to a disc with a capacity exceeding 1 terabyte—enough to store 200 movies, for example."

The technology has already been proven in the lab and Toyohashi Tech has set up a venture company called Optware to exploit its potential. Now the researchers are working to perfect data transfer rates and storage density, and are also working on a data erase technique to make rewritable discs possible.

Inoue sees the technology being used by entertainment and consumer electronics industries to replace current disc technologies, and for news media, business, and industrial archiving. In the area of medicine, hospitals will be able to store entire medical histories of patients over their lifetime.

"Hospitals don't have the space to store such records today, so doctors are forced to throw out patient data of old MRI, CT and PET images," says Inoue. "A holographic based archival system will rectify this problem."



Mitsuteru Inoue

Optical table showing the collinear phase-lock holographic memory recording system

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# News

## International Exchange Day: Exotic teas

Toyohashi Tech launched the “International Exchange Day” in 2010 in order to promote greater interaction between international students and faculty and administration staff. The themes of the Exchange Day last year were ‘tea parties around the world’ and ‘sports’.

On Friday July 8th this year the International Exchange Day focused on tea parties around the world.

International students from 16 countries prepared teas and cakes from their home countries, including *Ipoh White coffee* from Malaysia, *Lemon milk masala tea* from Bangladesh, and *Tea Talua* from Indonesia. The students prepared posters to introduce their countries.

Toyohashi Tech will hold similar events in the future.

Students gather to sample exotic teas and learn more about each other’s countries.

## Administrative exchange program with Korea University of Technology and Education

KUT visitors present their findings on the final day of their stay at Toyohashi Tech
Second from left: Shin Geonho, officer in charge of personnel affairs at KUT
Forth from left: Jang Bungil, officer in charge of educational affairs at KUT

In 1997 Toyohashi Tech and Korea University of Technology and Education (KUT) signed an agreement for an exchange program between researchers and students. Later, in 2002 the two universities signed an agreement to promote exchange of administration staff.

To-date, Toyohashi Tech has accepted five administration visitors from KUT. The first was in July 2002, when Toyohashi Tech hosted Mr. Nam Youngsun, Head of the Legal Affairs and Auditing Division. In reciprocation, KUT has accepted five administration staff from Toyohashi Tech since 2003.

This year the visitors from KUT were Mr. Jang Bungil, officer in charge of educational affairs (General Affairs Team, main campus of KUT, Cheonan City), and Mr. Shin Geonho, officer in charge of personnel affairs (Employment & Labor Institute, 3rd campus of KUT, Gyeonggi Province).

Mr Bungil and Mr Geonho stayed at Toyohashi Tech from 1–11 August visiting several administration sections for a first-hand look at Toyohashi Tech's administration system.
On August 11—the last day of the visit—Mr. Jang presented a report on his analysis of the administration systems at the two universities. Toyohashi Tech staff asked questions about publicity related to entrance exams, international students and dispatching KUT students overseas.

In 2004 the Japanese Government universities reorganized all government-run universities into 'National University Corporations'. The KUT visitors said that they were pleased to have had the opportunity of visiting Toyohashi Tech—a famous National University Corporation—because Korean education experts are now discussing whether Korean universities should be restructuring along similar lines.

In closing the meeting, Toshiaki Tsuji, Executive Trustee and Director-General for Administration thanked Mr. Jang Bungil and Mr. Shin Geonho for visiting Toyohashi Tech and he hoped that they would tell their colleagues in Korea that Toyohashi is a safe and comfortable place to live and study.

Further information about Korea University of Technology and Education
http://www.kut.ac.kr/eng/new_2010/index.jsp

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## Research highlights

**Ultra high sensitivity magnetic field sensors: The attraction of magnonic crystals**

**Bio-imaging offers insights into the relationship between circadian and ultradian rhythms.**

**Supervisory Control of Automatic Pouring Robot:**

**Spatiotemporal behavior of lipids in a cell membrane model on nanostructured substrates**

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# Research highlights

## Ultra high sensitivity magnetic field sensors: The attraction of magnonic crystals

Highly sensitivity devices for the measurement of weak magnetic fields are important in medicine for applications such as monitoring heart and brain activities. Furthermore, mapping the distributions and magnitudes of weak magnetic fields can provide a deeper insight into neuroscience and brain-machine interfaces.

Here, Mitsuteru Inoue and colleagues at Toyohashi University of Technology demonstrate that magnonic crystals—artificial magnetic crystal structures for controlling the propagation of magnetostatic waves—exhibit properties enabling the fabrication of extremely sensitive magnetic field sensors operable at room temperature.

Magnonic crystals support the propagation of magnetostatic waves through the crystal spin system or suppress the propagation of waves due to the periodicity of the crystal structure. In this research the Toyohashi Tech researchers fabricated magnonic crystals by the direct formation of one-dimensional arrays of metal strips on top of yttrium iron garnet, which serves as the propagation medium.

The metal stripes induced an attenuation band in the frequency spectra of the magnonic crystal, and the propagation of waves with the corresponding frequencies was strictly prohibited.

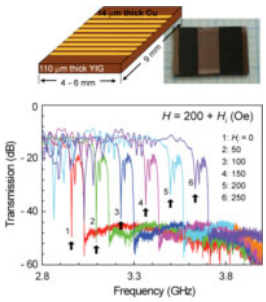
The frequency of the attenuation band was very sensitive to an external magnetic field applied to the crystal, where a 1 Oe change in the field resulted in a 2.6 MHz shift in the band gap. The maximum detection sensitivity of the magnonic crystals was more than 10 times greater that of a giant magneto-impedance element.

The next challenge for the researchers is to demonstrate the measurement of magnetic fields in three dimensions, which is possible using two-dimensional magnonic crystals.

Reference:

Mitsuteru Inoue, Alexander Baryshev, Hiroyuki Takagi, Pang Boey Lim, Kohei Hatafuku, Josho Noda, and Kenji Togo
Investigating the use of magnonic crystals as extremely sensitive magnetic field sensors at room temperature
*Applied Physics Letters* **98**, 132511 (2011)
DOI: 10.1063/1.3567940
Department of Electrical and Electronic Engineering, Toyohashi University of Technology, Japan
Department website: Inoue Lab:
http://www.maglab.eee.tut.ac.jp/eng-index.html

Mitsuteru Inoue




Enlarge Image

Figure: (a) Schematic illustration (left) and photograph (right) of the one-dimensional magnonic crystal. (b) The magnonic band gap (shown by arrows) shifts when an external field is applied in addition to a bias field of $H$ = 200 Oe.

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# Research highlights

## Bio-imaging offers insights into the relationship between circadian and ultradian rhythms.

Rika Numano

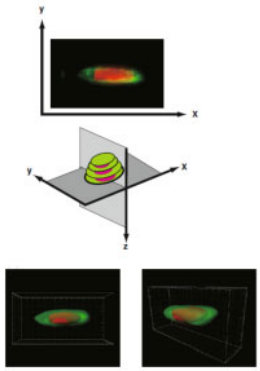

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Figure caption: Quantitative 3-dimensional fluorescent imaging on bone tissue

Living things have rhythms—for example, body temperature rhythms and segmentation clock. In the late 1990s, several clock genes were cloned to elucidate the functions and interactions of rhythms. The feedback loop of transcriptional factor with 24 h period in the suprachiasmatic nuclei (SCN) was proposed to work as a circadian central oscillator, as well as in peripheral tissues including cartilage and bone. On the other hand, the fundamental architecture of skeletal patterning is regulated by ultradian clocks that undergo cycles more than once every 24 hours in embryonic development. In 1997, the oscillatory expression of *c-hairy1*—a Notch effecter gene—was identified in chick embryos and matched the period of somite formation (every 90 minutes in chicks), called the segmentation clock.

Somitogenesis is one of the most evident events in an ultradian manner, which endows basic repetitive patterns of axial skeleton and its associated tissues during embryonic development. Long bone growth and bone metabolism also exhibit periodic activities in a circadian fashion. Core loops of circadian clock genes are also at work in bone and cartilage.

Here, collaborators at Toyohashi University of Technology and Tokyo Medical and Dental University propose bio-imaging methodology to observe both clocks. Bio-imaging detecting of luminescent and fluorescent signals enables observation of more comprehensive sets of genes and spatio-temporal regulation of these clockwork machineries during development.

In this review paper, the authors also describe the potential of three dimensional imaging for bone research. Topics covered include molecular clocks in skeletal biology and medicine, and how fluorescence imaging would contribute to widening our knowledge of biomedical science.

Tadahiro Iimura*[1], Ayako Nakane[1], Mayu Sugiyama[1], Hiroki Sato[1], Yuji Makino, Takashi Watanabe[1] , Yuzo Takagi[1], Rika Numano*[2] , Akira Yamaguchi*[1]

*to whom correspondence should be addressed
A fluorescence spotlight on the clockwork development and metabolism of bone

*Journal of Bone and Mineral Metabolism* On line July 2011

DOI: 10.1007/s00774-011-0295-3
[1]International Research Center for Molecular Science in Tooth and Bone Diseases, Tokyo Medical and Dental University, Sections of Oral Pathology
Website: http://www.tmd.ac.jp/dent/opat/opat-J.htm

[2]The Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology
Website: http://www.eiiris.tut.ac.jp/

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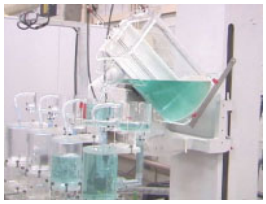
# Research highlights

## Supervisory Control of Automatic Pouring Robot:

Kazuhiko Terashima



High Speed Motion Control of Automatic Pouring Robot with Suppressing Liquid Vibration

An innovative system is described for supervisory control of a total molten-metal pouring to improve the productivity of factories, the safety of workers, and the quality of products.

High speed motion control and sloshing (liquid suppression) control problems are trade-off issues. It is difficult to use conventional control methods to achieve level control and weight control with high speed motion control in pouring processes while suppressing sloshing.

Now, Kazuhiko Terashima and colleagues at Toyohashi University of Technology describe how these problems can be solved by a novel supervisory control.

In the pouring processes model, a forward tilting control input was calculated by an adaptive feed forward control system to hold the liquid into a sprue cup at a constant level considering the change effected by the accumulating slag in the ladle. A backward tilting input was obtained by means of the proposed hybrid shape approach applied to suppress the slosh. The supervisory control system switches from the forward tilting motion to the backward tilting motion by using model predictive control to achieve the accurate poured quantity.

The validity of the proposed total control system was demonstrated through experiments. The effectiveness of a proposed supervisory control including new control methods enabled the researchers to realize the level control, weight control, and sloshing control with high performance.

The proposed supervisory control of automatic pouring robot is extremely useful for not only casting pouring process in foundries but also process and transfer systems in other industries.

Reference:

Ken'ichi Yano and Kazuhiko Terashima

Supervisory Control of Automatic Pouring Machine

*Control Engineering Practice,* **18**, 230, (2010).

Digital Object Identifier (DOI): ISNN 0967-0661

System and Control Engineering Laboratory, Department of Mechanical Engineering, Toyohashi University of Technology

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# Research highlights

## Spatiotemporal behavior of lipids in a cell membrane model on nanostructured substrates

Ryugo Tero

Lateral organization and diffusion of lipids and membrane proteins are crucial factors of biological reactions on cell membranes such as signal transduction and cell recognition. Various types and sizes of two-dimensional organizations, such as domains, clusters, and microcompartments, with scales from several nanometers to micrometers construct hierarchic structures in cell membranes.

Model lipid membrane systems mimicking the hierarchic structures on in-vivo scales are valuable for understanding the size-dependent functions of lipid organizations and how the lateral molecular transportation at microscopic regions propagates to macro scale.

Here, Ryugo Tero at EIIRIS and his colleagues have shown that a hierarchic structure with a comparable size in vivo can be introduced into an artificial lipid bilayer membrane using nanostructures on oxide surfaces as templates.

Lateral diffusion of lipid molecules in lipid bilayers on $TiO_2$(100) (Figure 1A) and SiO2/Si substrates were directly observed by the single molecule tracking (SMT) method with diagonal illumination setup (Figure 1B). This diagonal illumination system achieved the SMT independent of the substrate transparency and refractive index, while conventional SMT is available on only glass or quartz.

The diffusion of lipid molecules in the lipid bilayers were observed at the time resolution of $\Delta t$=497 $\mu$s - $\Delta t$=30 ms, and the spatiotemporal dependence of the diffusion coefficients were visualized at the range of 1 ms to 1 s (Figure 1C). The atomic steps on $TiO_2$(100) induced the diffusion barrier in the lipid bilayer, and the crossover from anomalous diffusion (= non-random diffusion) to random diffusion around 10 ms.

Fine architecture of nanostructures on solid substrates will lead to the control of the lateral structures and molecular transportation on the orders over 10 nm - $\mu$m, and of their hierarchic structures.

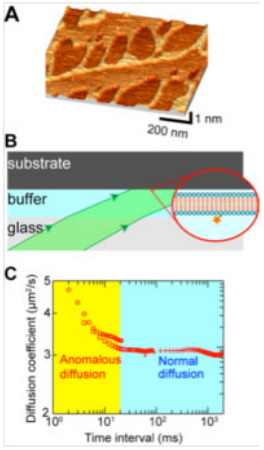


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Figure caption

Figure 1. (A) Atomic force microscope image of the step-and-terrace $TiO_2$(100) surface. (B) Schematic of diagonal illumination setup for single molecule tracking of lipid bilayers. (C) Temporal dependence of the diffusion coefficient in the lipid bilayer on $TiO_2$(100).

Reference:

Ryugo Tero, Gen Sazaki, Toru Ujihara, and Tsuneo Urisu
Anomalous diffusion in supported lipid bilayers induced by oxide surface nanostructures
*Langmuir*, Published on Web July 15, 2011.
Digital Object Identifier (DOI): 10.1021/la201474h.
Abstract: http://pubs.acs.org/doi/abs/10.1021/la201474h

Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology, 1-1 Hibarigaoka, Tempaku-cho, Toyohashi, Aichi 441-8580, Japan
EIIRIS URL: http://www.eiiris.tut.ac.jp/

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# Club Activities

## Toyohashi Tech triathlon team: plenty of pain and even more gain

Most students are satisfied to compete actively in a single sport such as swimming, bicycling or running—not so the members of Toyohashi Tech's Triathlon Club, who like to compete in all three of these sports in the day.

"The Olympic standard for the triathlon is swimming 1.5 km, bicycling 40 km, and running 10 km," explains Ryota Nakajima, club leader and fourth-year civil engineering student. "Before I joined the club, I thought it was going to grueling. And it was! Especially in the beginning. But over time it has gradually got easier."

Out of about 30 members, 15 regularly get together three times a week to train for the three sports. They also meet separately once a week to plan training sessions and prepare for competitions.

Club member Hidenori Mitsuyama, a senior studying civil engineering, happily points out one major benefit from participating in the triathlon. "I can eat as much as I want without worrying because my weight hasn't changed at all since I joined the Club. It's great!"

Other members note that their muscles have strengthened and their stamina has increased, making sports in general more enjoyable. Ryo Hirase, a fourth year mechanical engineer, says he has experienced an increase in his muscle density. "I also feel my mental stamina has increased." Hirase, like his friend Mitsuyama, has come first in the bicycling section of some recent triathlon competitions.

While the triathlon is the club's major focus, some members also make time for related activities including track and field, trail running, marathon running, and mountain biking.

"We all enjoy training together," says Nakajima. "And although the activities are very demanding, when we complete them, it gives us a great feeling of accomplishing something special."

Situated close to the Pacific Ocean and not far from the mountains, Toyohashi Tech is well located for triathlon competitions. Club members have the choice of swimming in the ocean or in swimming pools, while the mountains provide excellent terrain for tough bicycling workouts.

From left: Ryo Hirase, Ryota Nakajima, Hidenori Mitsuyama

Teppei Ono

Toshiki Matsushima swimming in the Pacific at Cape Irago

From left: Kensyu Irie and Kazumasa Uematsu in front of the famous lighthouse at Cape Irago, located about one hour from the Toyohashi Tech campus.

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# Excursions

## Toyohashi Gion Festival: An unforgettable summer

Nur Budi Mulyono is a doctoral student from Indonesia studying at the Department of Mechanical and Structural System Engineering. Here, he shares some of his experiences since enrolling at Toyohashi Tech.

Prior to leaving Indonesia I was both excited and apprehensive about studying in Japan. Excited because of the opportunity of pursuing a doctoral degree at Toyohashi Tech—one of Japan's leading science and technology based national universities—and apprehensive because Japan is prone to earthquakes and strong typoons. In fact the Tohoku earthquake struck before I departed for Japan—an event that made me even more nervous about living in Japan.

However, on arrival at Toyohashi Tech—which is located about 300 kilometers west of Tokyo in Aichi prefecture, and far from the Tohoku area of Japan—I received a warm welcome from staff and students, and was overwhelmed by Japanese culture, and the amazing high level of advanced technology prevalent in everyday life, such as the bulletin trains, smart phones, and even smarter household appliances.

One of the most important lessons that I have learnt so far can be summed up by the phrase—'ganbare'—literally means 'to do your utmost'. This expression sums up the attitude of Japanese people in the aftermath of recent earthquake and tsunami, when people in every corner of Japan joined hands to support the victims. I also recall that people in the disaster areas did not complain about their hardships, but rather concentrated on clearing up and recovery.

I admire the Japanese people for their positive attitude towards life in general, as well as for their emphasis on showing gratitude to others in daily life. There are seasonal festivals or 'matsuri' in Japan in which harmony with nature and gratitude to others are central themes. Examples of festivals include, 'hanami' or spring cherry blossom and 'tanabata' or summer star festival. I participated in the Toyohashi 'Gion Matsuri' this summer. It was one of the most wonderful experiences for me since coming to Japan four months ago.

I recently read that the Gion matsuri has roots as a purification ritual to appease the gods thought to cause fire, floods, and earthquakes. Such festivals are held all over Japan in summer.

For me, I had the opportunity to enjoy Gion in Toyohashi. The parades and firework (hanabi) displays were held near the Toyokawa River, which flows through Toyohashi. Thousands of colorful hanabi decorated the night sky accompanied with exhilarating music.

I thoroughly enjoyed the festival with many of my friends from Toyohashi Tech. It was a relaxing and enjoyable experience—one that I shall not forget for the rest of my life.

Nur Budi Mulyono (center in the white T-shirt) with other international students waiting for the fireworks at Toyokawa River during the Toyohashi Gion Festival in September 2011.

Spectacular fireworks at the Toyohashi Gion Festival.

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# Tech-Overtures

## Innovative method for controlling the electrical conductivity of composite materials

Toyohashi Tech researchers develop a low cost and time saving method for producing electrically conducting composites based on electrostatic adsorption of CNTs onto resin and ceramic particles.

Hiroyuki Muto and colleagues at the Toyohashi University of Technology (Toyohashi Tech) have developed an innovative method for producing CNT (carbon nano-tube) resin composite material [1] that only requires 1/100 [2] of the conventional amount of CNT additive to produce electrical conductivity in the composite material.

In this method, CNTs were mixed in an electrolyte solution and added to the composite, where the CNTs were adsorbed onto the surfaces of the resin particles due to electrostatic adsorption [3]. Thus, high electrical conductivity was obtained by the addition of a small quantity CNTs. Importantly, the electrical conductivity of the composite materials was readily controlled by changing the amount of electrolyte added to the composite; namely, the degree of CNT adsorption onto the resin particles.

In addition, this approach enables significant reductions in both the production costs and the production time compared with conventional methods for manufacturing conductive resins.

Notably, the use of particles with charged surfaces will enable the production of various combinations of composite materials such as metals, ceramics, and polymers. The researchers expect this method to find applications in the production of enzymes and cosmetics.

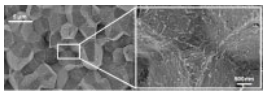
This work is supported by a Grant-in-Aid for Young Scientists at NEDO (New Energy and Industrial Technology Development Organization).

Further information

[1] This is a composite material comprising of resin particle with the addition CNTs. By utilizing the high conductivity of CNTs, practical products such as robust, anti-static components for clean rooms in the electronics industry, could be manufactured. The ability to control the electrical conductivity of the composite materials by this production method is expected to lead to a wide range of applications in the electronics industry, including use as alternatives for indium-tin-oxide transparent conductive film for displays, as plates for rechargeable batteries, and in semiconductor devices. Furthermore, the composite resin particles can be used in the production of for plastic materials, such as injection molding or extrusion.

[2] When imparting electrical conductivity to insulating ceramics or polymer materials, the introduction of conducting additive materials that can be linked within the resin structure is required. In conventional methods, the amount of additive is greater than 1% by weight. However, this new method only requires the addition of 0.01% CNT to impart conductivity.

[3] This method adsorbs CNTs onto the matrix resin particles by an electrostatic attractive force, which is a result of charging them positive or negative in appropriate electrolyte solutions. By controlling the concentration of the electrolyte solution added to the composite, the charge-volume of the surfaces of the particles can be changed, thus controlling the degree of adsorption of the CNTs.



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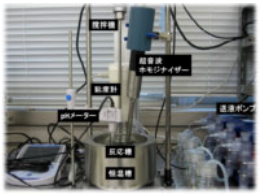
Cross-section of PMMA resin composite material showing the networks of CNTs on the surfaces of the resin particles. The CNTs are added to induce electrical conductivity.



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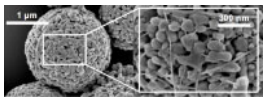
Prototype system for producing PMMA-CNT composite materials



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Ceramic particles with electrostatically attached CNTs fibers.