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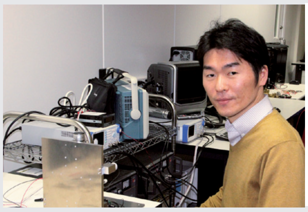
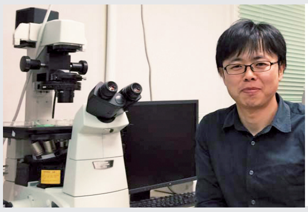
FEATURE STORY

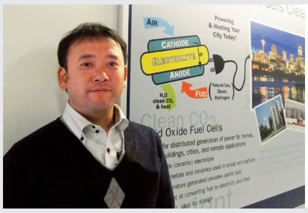
The Trick of Finding Contamination

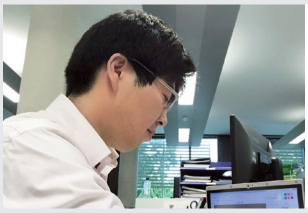
Researchers' eyes at Toyohashi University of Technology are shinning with confidence and a sense of fulfillment. It is because the objective of the engineering research is to promote the happiness of all humanity. Dr. Saburo Tanaka is one such researcher who is challenging to prevent contaminations of foods to promote the happiness of eating of all of the people in the world. Taking an unconventional approach to the challenge of preventing metal contamination. His goal is to improve food safety for people all over the world.

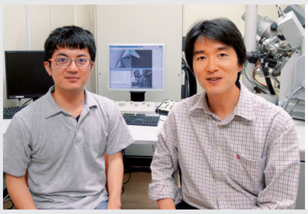
Research Highlights











Pick Up

The Trick of Finding Contamination

Saburo Tanaka

One of the major appeals of Toyohashi University of Technology (Toyohashi Tech) is that the researchers' eyes can be seen to shine with confidence and a sense of fulfillment. We believe they do so because the objective of engineering research is to promote the happiness of all humanity. For example, we feel happy when we eat something delicious. For the happiness to continue, contamination cannot be allowed. Thus, to study and endeavor to prevent contamination is to promote the happiness of all of the people in the world. Dr. Saburo Tanaka, professor of Environmental and Life Science Engineering at Toyohashi Tech, is taking an unconventional approach to the challenge of preventing metal contamination.

By Yoshio Watanabe

In Tanaka's laboratory, a method is being studied in which strong magnetism is applied to food to magnetize the metal fragments inside, so that these metals can then be detected by sensing their magnetic fields using a high-sensitivity sensor, or SQUID (Superconducting Quantum Interference Device)[1]. A functional system of detecting contaminants with this method has already been completed, and has shown excellent metal detection ability in food factories. The researchers in Tanaka's laboratory are currently working to improve the performance of this system so that even small metal fragments can be detected.

Appearance of The Food Contaminant Detection System using SQUID

The key to improving performance is to more effectively differentiate between actual signals and noise. Metal fragments are not the only sources of magnetic fields, rather space is filled with many magnetic fields generated from different sources. For example, the Earth is a giant magnet, and it emits geomagnetism. In addition, if electricity is flowing nearby, a magnetic field is generated. The aforementioned high-sensitivity sensor device requires a strong magnet to be placed close to the sensor in order to magnetize the metal fragments.

Magnetic fields that originate from sources other than the metal fragments are called noise. The fields of large metal fragments can be identified over such noise, but those of smaller fragments are masked by the noise and are thus difficult to detect. Even strongly magnetized metal fragments will have small magnetic fields if the fragments are small in size.

To reduce the impact of noise as much as possible, the sensor is placed inside a square metallic box designed so that food can be tested as it passes through this box. The box is made of 2 mm iron-nickel alloy plates. Magnetic fields have strong affinities to this iron-nickel alloy. Thus, magnetic fields around the sensor are concentrated on the walls of this box. In contrast, magnetic fields that pass through the box are decreased significantly. Furthermore, at Tanaka's laboratory, this box is surrounded by another box made of the same iron-nickel alloy, which is itself inside of another box, in order to maintain the high sensitivity of the sensor.[2]

The external magnetic fields primarily converge toward the outer box, and even if a weak magnetic field extends inside the first box, it is converged by the second box. Similarly, if remnants of the magnetic field exist inside the second box, they are further converged by the innermost box. In this system, the high-sensitivity magnetic field sensor is installed in the space in which the external magnetic fields are reduced as much as possible. If highly magnetized metallic fragments enter this box, even small fragments could be identified with very high probability even if they were contained in cheese or wrapped in aluminum foil.

To accurately detect even smaller metallic fragments, digital filters have also been used. Magnetic fields detected by the sensor are expressed as fine waveforms, but if the sensitivity is increased, signals from metallic fragments become mixed with noise, making them difficult to identify. A digital filter can be used to accentuate these signals.

The digital filter used in this method is a computational program rather than a physical device. It is applied much like a filter and has the effect of sharpening the blurry outlines. Using a technology called "moving-average processing," it detects signals that would otherwise be masked by noise. However, in food factories, foodstuff is transferred at a speed of 20 m/min on a conveyer belt; computing systems that can perform real-time calculations are necessary to keep up with this speed. This technique is possible since computers with such capabilities have become available.

The fundamental mechanism of the high-sensitivity magnetism sensor, SQUID uses the property of superconductivity. Since the sensor does not work unless it is in a superconducting state[3], it must be kept at a very low temperature at all times; thus, it is equipped with a device that provides a constant stream of liquid nitrogen. Its principal is quite interesting on its own, but it will not be presented it in this article due to the limited space.

By the way, when watching a magic trick involving a coin on a variety show on television, even if one stares closely, one cannot figure out the trick. Modern magic cannot be performed with a single trick but is instead achieved through multiple layers of tricks. Similarly, this technology, which can accurately identify small metal fragments of about 300 microns (invisible to human eyes) in cheese that is passing through at a speed of 20 m/min, also involves a careful combination of multiple "tricks" of modern technology, such as a magnetic sensor, a triple-layered box, a strong magnet, and a digital filter. In tests of this equipment for industrial purposes that use the same principle, its sensitivity has proven to be so high that metal fragments less than the width of two human hairs could be detected.

Researchers with a wide range of knowledge and technology determine what combinations of "tricks" can achieve the desired results, thanks to their superhuman creativity. Because of their achievements, television stations can safely broadcast magic shows and food factories can safely ship their products. There are no elements that can interfere with our happiness. Therefore, the eyes of Toyohashi Tech researchers still shine today, with confidence and the sense of fulfillment.

Reference

S.Tanaka, T. Ohtani, Y. Narita, Y. Hatsukade, and S. Suzuki, "Development of metallic contaminant detection system using RF High-Tc SQUIDs for food inspection," IEEE Trans. Appl. Supercond. Vol. 25, no. 3, June. 2015, Art. ID. 1601004.

Technological Remarks by Dr. Saburo Tanaka

1 When microscopic metal fragments in food are magnetized by a powerful and permanent magnet with a magnetic flux density of 0.3 T (Tesla) or higher, the magnetic domain in the metal grows and expands, lowering the slope of the magnetization curve, and leading to the saturated state. A magnetic domain that is grown in this manner does not return to its original conditions easily even if the magnetic field is removed; instead it remains in the metal as residual magnetization. The residual magnetization is weak, at several pT (picotesla, 10^{-12}), but it can be detected with a high-sensitivity magnetic sensor: SQUID (Superconducting Quantum Interference Device).

2 In magnetic shield technology, materials with high permeabilities are used.

3 Superconducting state: a state in which electrical resistance is reduced to zero by sufficiently lowering the temperature. Technically, three phenomena are known to occur in a superconducting state: 1) "perfect conduction," in which the electrical resistance becomes zero, 2) the "Meissner effect" (perfect diamagnetism) that prevents magnetic flux from entering the inside of superconductor, and 3) "quantization of magnetic flux" in which only magnetic fluxes that are integer multiples of the flux quantum ($\phi 0$ = h/2e: 2.07 × 10^{-15} Wb) can exist inside of the superconducting ring. In the high-sensitivity magnetic sensor SQUID, the third phenomenon, "quantization of magnetic flux," is utilized. When a SQUID is placed inside of a weak magnetic field, magnetic flux attempts to enter the thin-film superconducting ring that constitutes the SQUID. However, because of the quantization of magnetic flux, only magnetic fluxes that are integer multiple of the magnetic flux quantum can exist; thus, to prevent this flux from entering, the superconducting ring generates a shielding current. A gate on the superconducting ring of SQUID that is called the Josephson junction controls the current. If the current is greater than the designated current (the critical current of the junction), the gate generates a voltage. This gate converts the shielding current into a voltage, enabling the measurement of weak magnetic fields. In other words, conversions occur in the order of changes in magnetic field → changes in shielding current → changes in voltage. However, the SQUID ring detects magnetic fields as zero when it is cooled and becomes superconducting; thus, it cannot be used to obtain accurate absolute measurements. Instead, it only measures magnetic field changes. Its sensitivity is remarkable: magnetism that is 1/100 million to 1/1 billion of geomagnetism can be measured. Superconductivity was discovered by Dr. Kamerlingh Onnes of Leiden University, Netherlands, in 1911. Initially, this phenomenon could only be confirmed when materials were cooled down to 4.2 K, which is close to absolute zero. However, since then, materials have been discovered that become superconductors at about 90 K. With the device used in this study, a high-temperature superconductor is used, which becomes a superconductor at 90 K or higher.

異物混入発見のタネあかし

豊橋技術科学大学の大きな魅力の一つは、研究者たちのまなざしが自信と充実感にあふれていることです。それは、工学系の研究は人類の幸せの追究から生まれるものだからだと思います。ところで私たちは「おいしいものを食べている時」とても幸せを感じます。幸せな時間がいつまでも続くためには、絶対に異物混入なんてあってはいけないことです。異物混入防止の研究は、世界中の人たちの幸せのための研究です。技科大には金属の異物混入防止を従来にない発想で解決しようとチャレンジしている研究者がいます。
環境生命工学系教授 田中三郎氏です。

田中研究室では、食品に強い磁気を当てて、中に入っている金属片を磁化させ、そこから出る磁力線を高感度センサーで見つける方法[1]を研究しています。その方法で異物を見つける装置はすでに完成していて、食品工場で結果を出しています。今は、さらに小さな金属片でも見逃すことなくチェックできる性能アップに頑張っています。
性能アップの鍵は「ノイズとの戦い」です。磁力線を出すのは金属片だけではありません。眼には見えませんが、空間には様々な磁力線が飛び交っています。たとえば地球も巨大な磁石です。地磁気を発しています。そばを電気が流れていれば磁場ができるし、なにより金属片を磁化させる強力磁石がセンサーのすぐ近くについています。
金属片からの磁力線以外のそういった磁力線をノイズと呼んでいます。大きな金属片なら多少ノイズがあっても判別できますが小さくなるとノイズに埋もれて見つけにくくなります。強力に磁化された金属片でも、サイズが小さいと磁力も小さくなるからです。
できるだけノイズの影響を減らすように、センサーは金属製の四角い箱に入れてあって、食品もその中を通って検査される仕組みになっています。箱は厚さ2ミリの鉄板でできています。正確には鉄とニッケルの合金です。磁力線は鉄とニッケルの合金が大好きです。よってセンサー近くの磁力線はほとんどが箱の壁に集まります。逆に箱の中を通る磁力線はぐっと少なくなります。しかも田中研究室ではその箱の周りを同じ鉄とニッケルの合金の箱でさらに囲い、念のためさらにその外側を同じ箱で囲う構造で高感度センサーを守っています[2]。ほとんどの磁力線は外側の箱に収束され、それを逃れたわずかな磁力線もその内側の箱に収束され、もしまだ残っている磁力線があってもさらに内側の箱に収束され、磁力線をとことん減らした空間に磁力線を見つける高感度センサーが付けられています。その箱の中に強力磁石で磁化された金属片が入ってくれれば、かなり小さな金属片でも、チーズに入っていようがアルミの袋で包装されていようが、まず確実に見つけられるというわけです。
さらに小さな金属片を確実に見つけるために、「デジタルフィルター」も使いました。センサーによって検出された磁力線は細かい波形で表わされますが、感度を上げると、金属片からの信号もノイズにまぎれて判別しにくくなります。それを際立たせる技術が「デジタルフィルター」です。
「デジタルフィルター」は、物理的な装置というより計算プログラムのことで、フィルターのようにかけて、ぼんやりした結果の輪郭をはっきりさせる効果があります。「移動平均処理」という技術により、ノイズに混じって目立たなかった信号をはっきりつまみあげてくれます。
ただし食品工場では食品がベルトコンベアに乗せられて毎分20mというスピードで流れていくので、そのスピードに遅れることなくリアルタイムに計算するコンピュータの演算能力も必要です。その要求に応えてくれる能力を持ったパソコンがやっと普及したからこそ達成できた技術でもあります。
肝心の高感度磁力センサーの仕組みは、超伝導の性質を巧みに使ったものになっています。超電導状態[3]でないと働かないので常に極低温に冷やしておく必要があり、液体窒素が流れる装置も付いています。その原理も非常に面白いのですが、今回の限られた紙面では伝えきれません。
テレビのバラエティー番組で放送されるコインを使った手品ショーを観て、トリックを見破ろうと目を凝らしてもとてもできません。今の手品はひとつのトリックでできるわけではなく、いくつものトリックを重ねて作られているのだそうです。それと同じように、毎分20mで出てくるチーズなどに300ミクロン程度の肉眼では見えないような金属片が入っているかどうか確実に判別できるというこの技術も、磁気センサーや3重の箱、強力磁石、デジタルフィルターといった現代技術が生んだ数々の"トリック"を絶妙に組み合わせ作られています。同じ原理を用いた工業用の検査装置では、更に高感度で毛髪の太さ2本分の大きさもない金属片も検出できるそうです。
どんなトリックをどう組み合わせれば求める結果が出せるのか、幅広い知識と技術を持った研究者が超人的な発想力で解決しているのです。テレビ局は安心して手品の番組を放送できるし、食品工場は安心して製品を出荷できるのです。私たちの幸せな時間を邪魔する要素はありません。 ということで豊橋技術科学大学の研究者たちのまなざしは今日も自信と充実感にあふれているのです。
（渡辺欣生 エフエム豊橋パーソナリティー）

1 食品中の微小金属片は磁束密度0.3T（テスラ）以上の強力な永久磁石で帯磁されると、金属内部の磁区が成長拡大し、磁化曲線の傾斜が小さくなり、ついには飽和状態になります。こうして成長した磁区は磁界を取り去っても容易には元に戻らず、残留磁化として金属内部に残ります。その残留磁化は数pT（ピコテスラ、10^{-12}）微弱ですが、高感度磁気センサーSQUID（Superconducting Quantum Interference Device）で検出することが可能です。

2 磁気シールドと呼ばれる技術で、物理定数の透磁率の高い材料が用いられる。

3 超伝導状態：極低温にすることで、電気抵抗がゼロになることを指します。より、専門的には超伝導状態では、1.電気抵抗がゼロになる、つまり、"完全導体"の他に、2.内部に磁束が侵入することを妨げる"マイスナー効果"（完全反磁性）や、3.超伝導のリング内部には磁束量子（$\phi_0=h/2e$:　2.07×10^{-15}Wb）の整数倍の磁束しか存在できないという"磁束の量子化"と呼ばれる、3つの現象が生じることが知られています。
高感度磁気センサーSQUIDでは3つめの"磁束の量子化"現象を利用しています。SQUIDを微弱磁場中に置くと、SQUIDを構成する薄膜超伝導リング内部に磁束が侵入しようとします。ところが磁束の量子化の作用で内部には磁束量子の整数倍の磁束しか存在し得ないので、侵入を妨げようとして超伝導リングには遮蔽電流が流れることになります。SQUIDの超伝導リングにはジョセフソン接合と呼ばれる電流を制限するゲートが配置されており、決められた電流（接合の臨界電流）以上が流れようとすると、そのゲートで電圧を発生するようになっています。このゲート作用によって、遮蔽電流が電圧に変換されて微弱磁場を計測することが可能となります。つまり、磁場変化→遮蔽電流変化→電圧変化というように変換されます。ただし、SQUIDリングは冷却されて超伝導状態になった環境の磁場をゼロと認識するので、絶対値測定は不得意で、磁場変化のみを計測しますが、その感度は驚異的で地磁気の1億～10億分の1の感度を有しています。超伝導現象はオラン,ライデン大学のカマリン　オネス先生が1911年に発見し、当初は絶対ゼロ度に近い4.2Kまで冷却しないとこの現象を確認出来ませんでしたが、その後、90K程度で超伝導になる材料が発見されています。この装置では90K以上で超伝導になる高温超伝導材料が使用されています。

Researcher Profile

Dr. Saburo Tanaka studied until Masters level at Toyohashi Tech University, and received his PhD. degree in 1991 from Osaka University, Japan. Since 1987, Dr. Tanaka has been involved in researching high-temperature superconductors at Itami Research Laboratory, Sumitomo Electric Co., Ltd, He was involved in the development of multi-channel high-Tc SQUID systems at the Superconducting Sensor Laboratory between 1991 and 1995. He was also a visiting research associate of Professor John Clarke' s group in the Department of Physics at UC Berkeley from 1996 to 1997. Currently, Dr. Tanaka is a professor in the Department of Environmental & Life Sciences and a presidential advisor at Toyohashi University of Technology, Japan. He has more than 25 years of research experience in high-temperature SQUID applications, and has published extensively in peer-reviewed journals. Tanaka has filed more than 350 patents in Japan, of which more than 70 were granted by the U.S. Patent and Trademark Office.

Reporter Profile

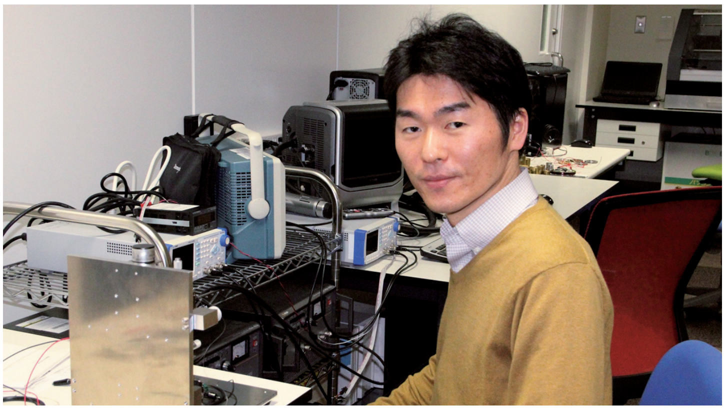
Yoshio Watanabe is a program producer and caster at "FM Toyohashi," a radio station in Toyohashi, where Toyohashi Tech is located. Since 2008, he has been broadcasting a program about Toyohashi Tech every Saturday evening and the program is still continuing on the air today. Watanabe has been responsible for spreading public awareness of talented researchers, and has covered over 350 interviews and broadcasts. He has something of an expert in the research of Toyohashi Tech, and has become very proficient at explaining it to the public.

Unveiling the world's smallest and most powerful micro motors

Realization of practical torque for a one cubic millimeter ultrasonic motor

By Tomoaki Mashimo

Piezoelectric ultrasonic motors have two significant advantages, namely their high energy density and their simple structure, which both contribute to their miniaturization. A prototype micro ultrasonic motor using a stator with a volume of approximately one cubic millimeter was built. The experiments have shown that the prototype motor generates a torque of more than 10 μNm with a one cubic millimeter stator. This novel motor is now the smallest micro ultrasonic motor that has been developed with a practical torque.



Micro actuators are needed for numerous applications, ranging from mobile and wearable devices to minimally invasive medical devices. However, the limitations associated with their fabrication have restricted their deployment at the one-millimeter scale. The most common electromagnetic motors require the miniaturization of many complicated components such as coils, magnets, and bearings, and exhibit severe torque dissipation due to the scaling. Electrostatic motors enable excellent scalability by using micro-electromechanical systems (MEMS) technology, but their weak driving force has so far limited their further development.

Piezoelectric ultrasonic motors are expected to become high-performance micromotors because of their high torque density and simple components. The smallest existing ultrasonic motor reported to date has a metallic component with a diameter of 0.25 mm and a length of 1 mm. However, its total size, including the preload mechanism, amounts to 2-3 mm, and its torque value is too small (47 nNm) for use as an actuator in many applications.

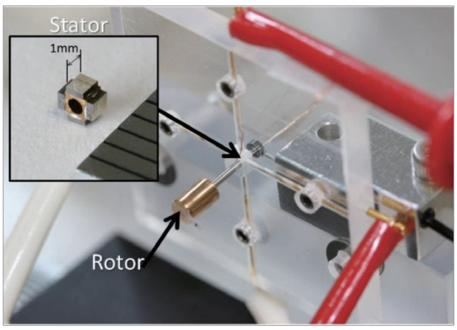
Tomoaki Mashimo , of the Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology, has been developing a micro ultrasonic motor with a one cubic millimeter stator, as shown in Fig. 1, which is also one of the smallest ultrasonic motors ever built. The stator, which comprises a metallic cube with a through-hole and plate-piezoelectric elements adhered to its sides, can be scaled down without requiring any special machining or assembly methods. The prototype micro ultrasonic motor achieved a practical torque of 10 μNm (If the pulley has a radius of 1 mm, the motor can lift a 1-g weight) and an angular velocity of 3000 rpm at approximately 70 Vp-p. This torque value is 200 times larger than that of existing micro motors, and is very practical for rotating small objects such as small sensors and mechanical parts.

According to Mashimo, "The simplicity of the stator structure enabled the miniaturization without having to use any special machining process. This prototype stator is much simpler than those of other existing ultrasonic motors."

The next goal of this research is to improve the values of performance parameters for practical applications, such as energy efficiency and lifetime. In future, the proposed micro motors may actuate micro forceps embedded in endoscopes for safe and less-invasive operations.

Reference

Tomoaki Mashimo, Asia's largest tradeshow & conference dedicated to the design & manufacture of medical devices (MEDTEC Japan 2015), Apr. 22-24, 2015, Tokyo.



Experiment of the micro ultrasonic motor

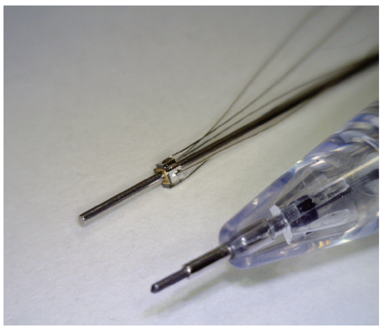


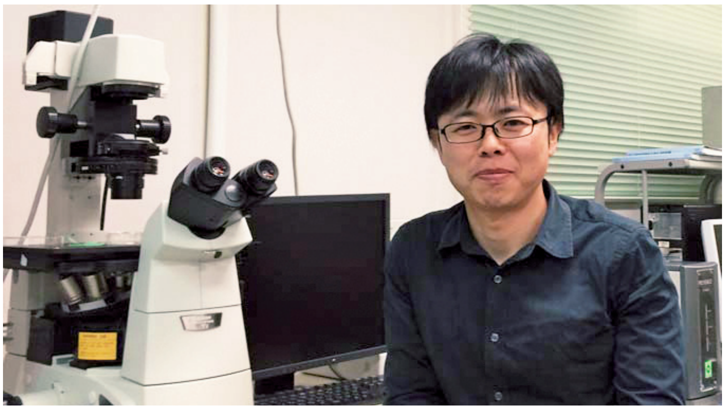
Figure 1:
Prototype micro ultrasonic motor.

Micro fingers for arranging single cells

Development of hollow microprobe array for handling single cells in a parallel layout

By Moeto Nagai

Moeto Nagai and his colleagues have developed a cell manipulation tool to trap and release single cells in a parallel arrangement in open-top microwells. Using microfabrication techniques, the researchers developed a hollow microprobe array with designed parameters. Single cells were trapped by suction and released by a flow generated through the probes. In the future, this tool will enable the reconstruction of microenvironments of stem cells, which can be employed to investigate stem cells for regenerative medicine.



Functional analysis of cells, which are the fundamental unit of life, is important for gaining new insights into medical and pharmaceutical fields. For efficiently studying cell functions, it is essential to reconstruct cellular microenvironments by parallel manipulation of single cells. Various cell manipulation techniques including fluidic, optical, and electrical techniques have been developed.

However, all these techniques lack flexibility with respect to changes in the cellular types, number, and places. In addition, the manipulations, which have been conducted in enclosed environments such as micro-channels, have limited access to the cells. It would be ideal if the handling of manipulation tools were analogous to grasping and transporting cells by one's fingers.

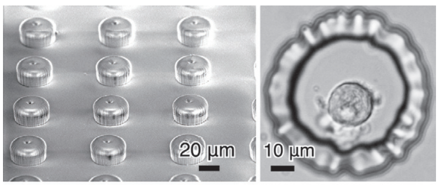


Figure 1: The developed microprobe array and a single cell placed in a microwell.

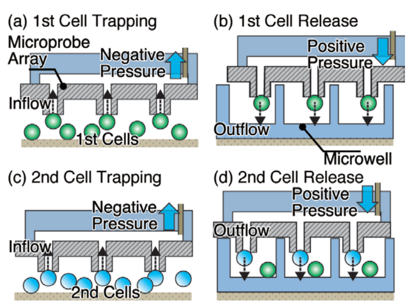


Figure 2: Principle of single-cell manipulation in an array-based format.

Moeto Nagai and his colleagues, at the Department of Mechanical Engineering, Toyohashi University of Technology, have developed a novel cell-manipulation tool that can trap and release single cells in a parallel arrangement in open-top microwells. The researchers fabricated an array of hollow microprobes to improve throughput and achieve flexibility in single-cell manipulation. The microprobes work like micro fingers picking up human cells. Single cells were trapped by suction and released by a flow generated through microchannels along the center of the probes.

"Parallel and versatile cell manipulation tools are essential for biomedical innovation", said Assistant Professor Moeto Nagai. "Microfabrication technologies offer massively parallel microstructures close to a human cell in size," he said.

"We fabricated an array of hollow microprobes with designed diameters, heights, and numbers from a silicon substrate using microfabrication techniques. Single cells were trapped on the tips of the probes using a suction flow. The cells were then released and placed in an array of microwells," Nagai said.

The research team developed a design principle for probes for minimally invasive single-cell manipulation. They conducted a cell aspiration experiment with a glass pipette and modeled a cell, thereby gaining information for designing hollow stepped probes. Based on the findings, the researchers designed and fabricated optimal probes. After a process of trial and error, the cells were placed and cultured in microwells with the probes, and the cells continued to maintain cell activity.

The proposed manipulation system makes it possible to place cells in a microwell array and observe the adherence, spreading, culture, and death of the cells. This system has the potential to be used as a tool for three-dimensional hetero cellular assays. In the future, this system will be further developed to reconstruct microenvironments of stem cells outside a living body, which would aid studies on stem cells for regenerative medicine.

Reference

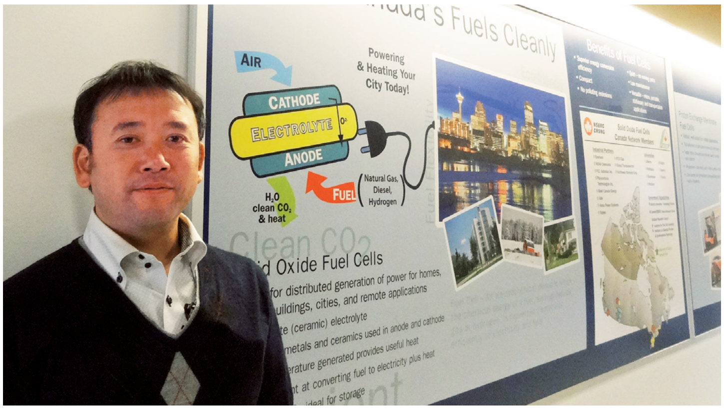
Nagai, M., Oohara, K., Kato, K., Kawashima, T., and Shibata, T. (2015). Development and characterization of hollow microprobe array as a potential tool for versatile and massively parallel manipulation of single cells, Biomedical Microdevices, 17(2):41. doi: 10.1007/s10544-015-9943-z.

High power and high safety materials for Li-ion battery

Vacuum-annealing improves electrochemical performance of Ti-Nb mixed oxide negative electrode for Li-ion battery with high safety

By Ryoji Inada

Ryoji Inada, and his colleagues at Toyohashi University of Technology, have successfully demonstrated that electrochemical Li insertion and deinsertion property of Ti-Nb mixed oxide $Ti_2Nb_{10}O_{29}$ (TNO) at high current rate is greatly improved by vacuum annealing. This is mainly attributed to enhancement of the intrinsic electronic conductivity of TNO by introducing oxygen vacancy. Vacuum-annealed TNO is promising negative electrode material of high power and high safety Li-ion battery for large scale application.



Mixed Ti-Nb oxide $Ti_2Nb_{10}O_{29}$ (TNO) is one of the negative electrode materials used in large scale Li-ion batteries with a high degree of safety because the potential (= 1.6 V vs. Li/Li$^+$) for Li storage of TNO should avoid the possible risks of Li plating or formation of Li dendrites as well as short circuiting of the battery igniting the flammable organic liquid electrolyte.

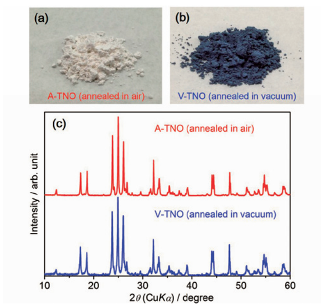


Figure 1: Photos of TNO annealed in air (A-TNO) (a) and vacuum (V-TNO) (b). X-ray diffraction patterns for both samples are also shown in (c).

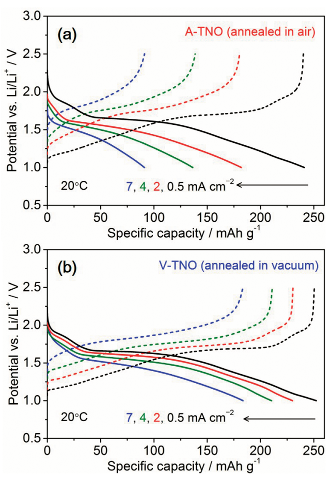


Figure 2: Charge (solid lines) and discharge (dashed lines) curves at different fixed current densities of 0.5, 2, 4 and 7 mA cm^{-2} for (a) A-TNO and (b) V-TNO electrodes.

TNO shows the reversible capacity of 250 mAh g^{-1} at low current rate and good cycle stability. However, TNO is an insulating material and its electronic conductivity is quite low, which leads to poor electrochemical performance at a high current rate.

Ryoji Inada , Yoji Sakurai , and their colleagues at the Department of Electrical and Electronic Information Engineering, Toyohashi University of Technology, have shown the improvement of electrochemical performance of TNO at high current rate by means of vacuum annealing.

The photos and X-ray diffraction patterns of TNO annealed in air and vacuum are compared in Fig. 1. Although the crystal structure is not changed by the different annealing atmosphere, the color of TNO is changed from white to dark blue by vacuum annealing, indicating the presence of the mixed Ti^{4+}/Ti^{3+} ions.

Thermogravimetric analysis clearly shows that a small amount of oxygen vacancy is introduced by vacuum annealing, which causes partial reduction from Ti^{4+} to Ti^{3+} in TNO. By addressing this fact, vacuum-annealed TNO (V-TNO) shows much higher electronic conductivity (10^{-6}-10^{-5} S cm^{-1}) than air-annealed TNO (A-TNO) at room temperature.

Fig. 2 shows a comparison of the charge and discharge curves of both A-TNO and V-TNO electrodes at various fixed current densities per unit electrode area of 0.5, 2, 4 and 7 mA cm^{-2}. The charge and discharge capacities for both electrodes are decreased monotonically with increasing current densities, but V-TNO shows larger capacity than A-TNO under the current density above 2 mA cm^{-2}. This tendency becomes more remarkable as the current density is increased.

The improved electrochemical performance of V-TNO electrode at high current rate is mainly attributed to the enhancement of its intrinsic electronic conductivity. V-TNO can potentially be used as a novel negative electrode material for Li-ion batteries capable of high power and high safety for large scale applications such as hybrid electric vehicles and energy storage systems.

Reference

Takashima, T., Tojo, T., Inada, R., and Sakurai, Y. (2014). Characterization of mixed titanium-niobium oxide Ti2Nb10O29 as anode material for lithium-ion battery. Journal of Power Sources,276, 113-119. doi: 10.1016/j.jpowsour.2014.11.109

World first prediction of the sound radiating from a recorder

Super-computer simulations explore how an air-reed instrument generates air flow and sound

By Hiroshi Yokoyama

Hiroshi Yokoyama and his colleagues have achieved a world first, in accurately predicting the sound radiating from a recorder. The calculations for this study took two weeks using about 100 nodes of supercomputers. The findings will contribute to the proposal for new designs of musical instruments which are easy-to-play or totally new musical instruments.

Hiroshi Yokoyama and his colleagues at Department of Mechanical Engineering, Toyohashi University of Technology, in collaboration with researchers at YAMAHA Corporation, have achieved a world first, in accurately predicting the sound radiating from a recorder. (Figure 1, Movie 1). The calculations for this study took two weeks using about 100 nodes of supercomputers (FX10 in Tokyo University or Kyushu University). It was a huge computational cost.

In air-reed instruments such as a recorder, the flow velocity fluctuates according to the blowing of the performer. These fluctuations generate sound (pressure and density fluctuations). It had been understood that a small change in the shape or material of the instruments could critically affect the ease of playing or how a performer felt during performance. However, the detailed relationship between the shape or material and the sound had not been clarified, and the reason why they affected the tones was unknown.

However, by these predicted results, we can now understand the way that sound radiates from flows in the recorder. Moreover, the way the sound is propagated to the far field (performer's ears or audience) around the recorder was also clarified (Movie 2). These results can contribute to the evolution of the design of future musical instruments.

Everyone knows that the instrument radiates sound when we blow it. However, the complex flow and sound phenomena had previously been hidden. In your childhood, did you find it difficult to resonate the lowest "do" in music classes? In the future, we can clarify the effects of the shape of instruments on tones clearly using computers. I believe that it will become possible to propose a new design of musical instrument which is easier-to-play, or even to invent new musical instruments.

Reference

Yokoyama, H., Kobayashi, M., Onitsuka, H., Miki, A., and Iida, A. (2014). Direct numerical simulation of flow and acoustic fields around an air-reed instrument with tone holes. 43rd International Congress on Noise Control Engineering (inter.noise 2014), November 16-19, 2014.

Yokoyama, H., Miki, A., Onitsuka, H., and Iida, A. (2015). Direct numerical simulation of fluid-acoustic interactions in a recorder with tone holes, The Journal of the Acoustical Society of America, in press.

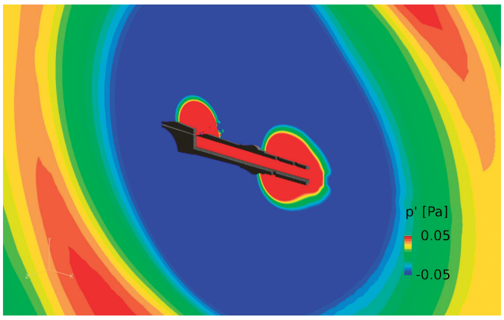
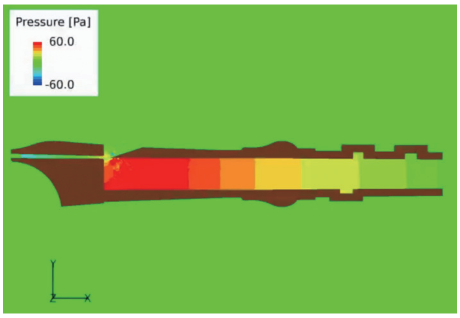


Figure 1: Contours of pressure fluctuation around recorder with opened tone holes.



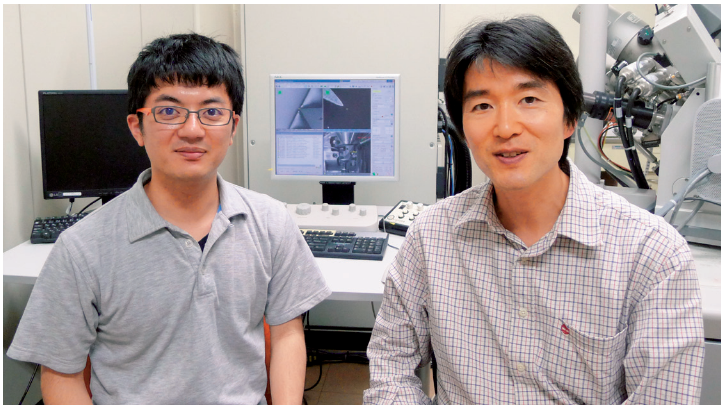
Contours of pressure fluctuation in recorder with opened tone holes and with closed tone holes.

A milestone of developing CNC-based applications

Monitoring the real-time deformation of carbon nanocoils under axial loading

By Yoshiyuki Suda

Tensile tests were performed on nine carbon nanocoils (CNCs) using a focused-ion-beam (FIB) technique. An individual CNC was picked up using an FIB, and a CNC bridge formed between a probe and the spring-table substrate. Real-time observations of the CNC elongation and subsequent fracture under prolonged stretching enabled us to estimate the elastic limit, the spring constant, the shear modulus, and the ultimate strength of each CNC and their mean values.



Yoshiyuki Suda(right) and Yasushi Nakamura(left)

Carbon nanocoils (CNCs) composed of helical shaped carbon nanofibers have many potential applications, including mechanical springs and nano-solenoids. There are already some reports which measured the spring constant of CNCs.

However, the CNC response to prolonged stretching (which includes initial elastic elongation to large-scale deformation in the plastic regime and subsequent tensile fracture followed by post-fracture contraction and the release of the applied strain), remains undetermined. It is crucially important to secure real-time measurements of CNC deformation beyond the linear elastic regime.

Taiichiro Yonemura, Yoshiyuki Suda, and their colleagues at the Department of Electrical and Electronic Information Engineering, Toyohashi University of Technology have now described the real-time deformation data that exhibited sequential change in CNC geometry after each coil was subjected to a uniaxial load at a constant rate.

CNC tensile tests were conducted as follows: The CNCs were installed into an FIB system with a tungsten (W) probe with a 500 nm tip diameter and the W probe moved until it adhered to CNC using Pt ion beam whereas the Si ion beam cut the CNC bottom; then the CNC-adhered W probe approached a spring table substrate surface, until the CNC was almost perpendicular to the substrate. The tensile tests were performed on nine CNCs by gradually changing the distance between the substrate and W probe.

The real-time data of a CNC tensile test performed using a spring table in the FIB chamber was monitored. A series of three scanning ion microscopy (SIM) images offered visualization of the geometric evolution of the CNC under a tensile load. These images were captured in the free state (t = 0 s), the maximum elongation point (t = 910 s), and a post-fracture state (t = 960 s).

To determine the elastic boundary of the CNCs, we examined the relationship between the applied strain and residual elongation ratios of CNCs after the load release. The result indicates that the CNCs were in the elastic region for elongations up to approximately 15% strain.

Tensile tests, performed on nine different CNCs, revealed that the average CNC spring constant was 1.8 N/m. Using a theoretical equation for the design of macroscopic springs, the shear moduli of the nine CNCs were estimated to be 6 GPa on average. These results may serve as a milestone for developing CNC-based applications in the future.

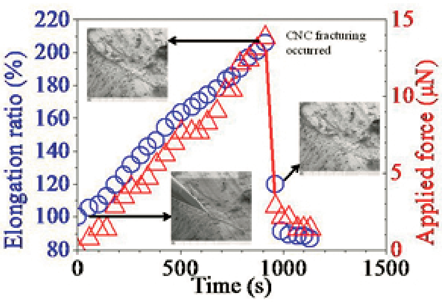
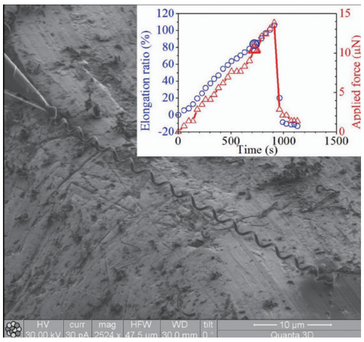


Figure 1: Real-time observation of CNC tensile tests and SIM images of variations in the coil geometry over time.



Measurement of spring constant of carbon nanocoil.

Reference

Yonemura, T., Suda, Y., Shima, H., Nakamura, Y., Tanoue, H., Takikawa, H., Ue, H., Shimizu, K., and Umeda, Y. (2015). Real-time deformation of carbon nanocoils under axial loading, Carbon, 83, 183-187.doi: http://dx.doi.org/10.1016/j.carbon.2014.11.034

Active internship abroad

Toyohashi University of Technology held various programs for students in first half of the year 2015

Overseas internships based in TUT-USM Penang

Toyohashi Tech has commenced a program of 2 month overseas internships with local and multi national companies located in Penang, Malaysia since 2014. Using our overseas education base in Penang (TUT-USM Penang), the second group of ten 4th year undergraduate students successfully completed the program, from 12 January to 25 February 2015.

TUT-USM Excellent students Penang Program 2015

A Program of overseas study and training for eighteen selected undergraduate students was implemented at TUT-USM Penang from 15 to 23 March.

The students discussed various topics with eighteen students of Universiti Sains Malaysia (USM) and had a good chance to get to know each other. In addition, they visited global companies and historical world heritage sites in Penang.

Exchange program between QC and TUT

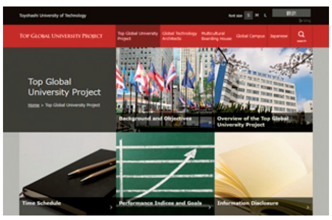
Five students from Queens College of the City University of New York (QC) experienced training as part of the exchange program from 1 to 12 June.

At Toyohashi Tech the QC students took lectures from each department as well as basic Japanese language classes. They deepened the cultural aspect of the exchange by joining the student's club activities such as robotics, traditional martial arts, animation and comics. Cultural and technological study trips included a visit to the Toyota Commemorative Museum of Industry and Technology and experiencing Japanese culture, tea ceremony and flower arrangement.

Creative campus for nurturing global technology architects

Toyohashi Tech is one of 37 Japanese universities chosen for the MEXT Program 'Top Global University Project'

Top Global University Project official website launched



http://sgu.tut.ac.jp/eng/

Background and objectives of the program published in Science Magazine

The Top Global University Project, established by Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT), was outlined in a special public announcement published on 27 March 2015 in AAAS Science Magazine. A PDF of the lead editorial summary, and the pages relating to Toyohashi Tech , can be found here:

Internationalization of University Education in Japan
http://www.sciencemag.org/site/products/advertorials/Global_Japanese_Univ_19mar15.pdf

TUT Research: e-Newsletter from Toyohashi University of Technology

The "e-Newsletter", Toyohashi University of Technology (Toyohashi Tech)'s online magazine, has been relaunched.

Toyohashi Tech's e-Newsletter was first published in October 2010 as an online magazine focusing on research review and international relations. A total of 18 issues have been published in this format. The e-Newsletter will now be rebranded as "TUT Research: e-Newsletter from Toyohashi University of Technology "with a refreshed content and web page design.

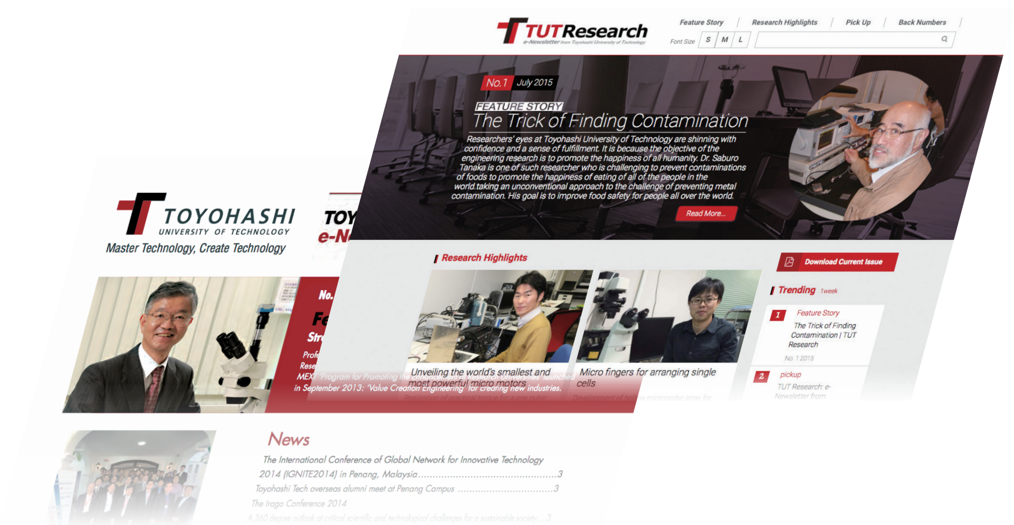
In the years since the launch of the original newsletter, Toyohashi Tech has significantly developed its international public relations capability. For example, we have created an English version of the official Toyohashi Tech Web site, established an English language presence on social media such as Facebook and Twitter, and provide university information bilingually (Japanese and English). Our efforts have been recognized and enhanced by the Japanese government, which recently awarded us Top Global University status.

Significant challenges remain however, such as the ever increasing need to publish our latest research achievements globally. In order to respond to this changing environment, Toyohashi Tech has decided to sharpen the focus of this online magazine to global research and international relations by relaunching the newsletter with a new name, content and design.

We sincerely hope that the renewed "TUT Research: e-Newsletter from Toyohashi University of Technology" will contribute to your research and technology development.

Thank you for your continuous subscription and support.

All editorial committee members of the TUT Research



Editorial Committee

The Toyohashi University of Technology (TUT) is one of Japan's most innovative and dynamic science and technology based academic institutes. TUT Research is published to update readers on research at the university.

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