TUT Research
e-Newsletter from Toyohashi University of Technology

No.5 Jun. 2016

FEATURE STORY

# Machine Translation Opening Japan to the World

Machine translation technology is making progress every year, and against the backdrop of big data technology development, hopes are high for achieving ever greater accuracy.

## Research Highlights

New bimetallic alloy nanoparticles for printed electronic circuits .....5

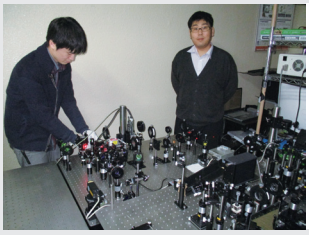
Production of oxidation-resistant copper alloy nanoparticles by electrical explosion of wire for printed electronicsr

Wirelessly Supplying Power to Brain .....6

Implantable device composed of a flexible antenna and silicon large-scale integration chips

Intracellular recordings using nanotower electrodes ...7

Nanoscale-tipped high-aspect-ratio vertical microneedle electrodes for intracellular recordings



Nano-magnets produce three-dimensional images ... 8

Wide-view three-dimensional holographic display composed of nano-magnetic pixels

## Pick Up

TUT established a new research institute to accelerate innovations in technology..... 11

TUT Academic Year 2016 Matriculation Ceremony ..... 11

Building a new on-campus global student accommodation ..... 12

# Machine Translation Opening Japan to the World

Hitoshi Isahara

Machine translation technology is making progress every year, and against the backdrop of big data technology development, hopes are high for achieving ever greater accuracy. However, while machine translation among Western languages is approaching the level of practical use, there are still many hurdles which hamper machine translation from Japanese to other languages. We talked about this topic with Professor Hitoshi Isahara, who has been tackling these issues in his work at the cutting edge of machine translation research since the 1980s.

Interview and report by *Madoka Tainaka*

## Obstacles to Effective Japanese Machine Translation

Professor Hitoshi Isahara came to Toyohashi University of Technology in 2010 to further his pursuit of machine translation research. This research was a continuation of his work with the Ministry of International Trade and Industry's (MITI) Electrotechnical Laboratory, and the Ministry of Posts and Telecommunications' Communications' Research Laboratory (currently the National Institute of Information and Communications Technology, NICT).

"I have worked on a variety of research projects, such as machine translation of Japanese into Chinese, Thai, Malay, and Indonesian, the creation of a database of spoken Japanese and the development of Japanese-Chinese and Chinese-Japanese language processing technology, etc. However, unfortunately, while the accuracy of machine translation from Japanese into those other languages is improving, it is still inadequate. For example, when translating from Japanese to English, in addition to the differences in word order, Japanese has the peculiarity of context dependence. For example, Japanese often omits subjects, and this becomes an obstacle for translation. In order to use the machine translation for information outbound transmission, the quality needs to be fully guaranteed, but in reality the output of machine translation systems can not yet be relied upon. In order to make the output useful, we need to employ all kinds of ingenuity," says Professor Isahara.

In fact, in the 1980s, Japan was the world leader on machine translation research. In addition to academic research by universities, many major electronics companies also invested in machine translation system development. Before long however, business interest in the field petered out. Professor Isahara says that the reason behind this they lacked the concept of providing a "service" to users. Companies simply applied the existing business model of creating, packaging and selling a system to the process of commercialization of machine translation technology, but this model produced unsatisfactory results for users.

"In addition one must consider the fact that in Japan there was little concept of systematically documenting and recycling information, so there was no structure in place for incremental system development and the provision of continuous service. Even for professional translators, knowledge of the domain and prior detailed information are essential. Likewise, for machine translation, the construction of a frequently updated user friendly database as well as development of operating techniques and mechanisms are just as indispensable as improvements in the accuracy of the translating engine."

## The three essential steps for machine translation

In this context, Professor Isahara cites the following three elements are essential to the process used in machine translation: (1) create Japanese text that is easy to translate by machine, (2) extract salient terms that fit with the field, and (3) build a post-editing environment.

"First of all, just following Step 1, making the Japanese input easy to translate, is quite effective. I then researched what kind of input sentences would make the machine translation go smoothly, without lowering the quality of the Japanese."

To test this, he asked for cooperation from a local business, getting them to rewrite their company manual based on his rules for easy-to-translate Japanese, so-called "controlled language," and conducted an experiment to measure the accuracy of the translation. The rules were simple: to include subjects and objects wherever possible, to avoid long sentences, and to avoid complex expressions. In the context of such research developments, and given the essential role of controlled language, the International Organization for Standardization is currently promoting international standardization in this field.

Step 2, the extraction of terms, means ac-

cumulating a large volume of documents related to a particular field, and from that list, semi-automatically extracting often-used "moderately long phrases". "For example, these are phrases such as 'the effect of carbon dioxide on global warming' or 'gas decompression characteristics when fissures occur in the pipeline'. These are automatically extracted and carefully examined by those well versed in the field. Appropriate parallel translation glossaries are prepared in advance."

The final step is Step 3, post-editing. For this, Professor Isahara has incorporated the use of social crowdsourcing. Currently the task of post-editing cannot be omitted, since the quality of the document will suffer without adjusting the translated text. However, relying on professional translators is very costly. Therefore, as a cost effective solution, he recruits volunteers with suitable knowledge in the field assist with the work. The Toyohashi University of Technology website (English version) has been equipped with a machine translation engine and editing tools, and he found that with the help of foreign students in post-editing, it is possible to get an accurate translation.

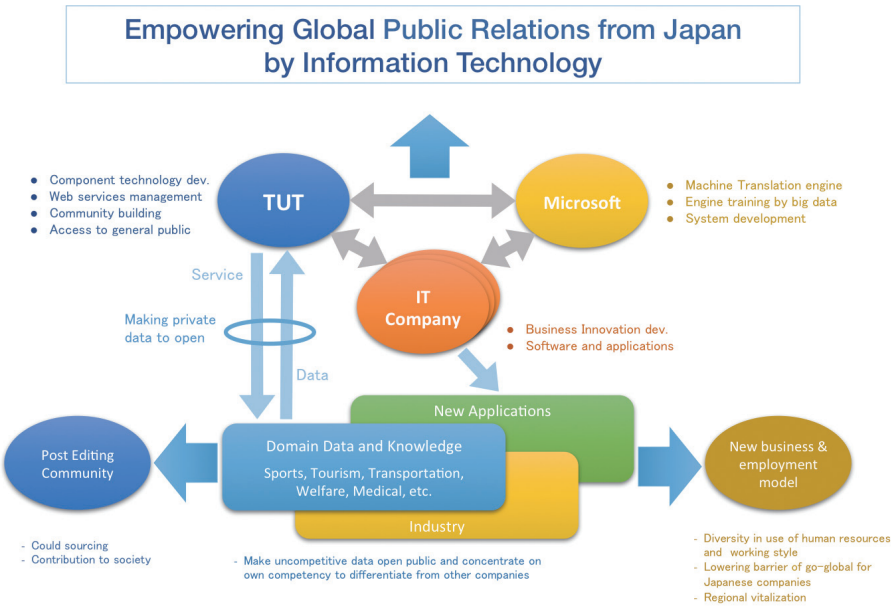
"Our foreign students know a lot about the university, and so well able to manage quality control. For example, several students collaborated to correct a text translated from English into Indonesian, with the result that they were able to achieve a level of accuracy close to that of a professional translator."

## Involving social communities of various fields

Presently, in the business world, translation is generally left up to professional translators from the get-go, but the merit to bringing in machine translation is that even if the accuracy is modest, you can speed up the process without incurring any costs. In the current context of trends such as globalization and an influx of foreigners to Japan, as well as a revitalized inbound market, the demand for outbound information through machine translation will surely continue to rise.

"For example, Japan is getting ready to host the Rugby World Cup in 2019, and from now, there will certainly be more and more articles posted in Japanese. When that happens, if we can get help with post-editing by rugby fans, we anticipate that we will be able to transmit information fairly well in English. By gathering and studying the results of those translations, we will also be able to further improve translation accuracy. In particular, I would be so happy if senior citizens who have a lot of knowledge and ability and want to contribute to society, would participate in social crowdsourcing. Although it is basically volunteer work, we might need to prepare some incentives, such as giving autographs of famous players for each contribution," says Professor Isahara. In fact, a joint research project on the topic of translating rugby articles, has already been commenced by Toyohashi University of Technology in collaboration with Rikkyo University and NICT.

In the future, Professor Isahara says that he would like to facilitate better public relations in English between Japan and the world through volunteer networks in various fields of interest to foreigners, such as railways cameras and ramen. Furthermore, he is concentrating on developing links with IT companies to create shared databases for manuals for business use, and other purposes. He has already launched such a joint project with Microsoft Japan and BroadBand Tower, Inc. Regarding future prospects, Professor Isahara says that the translation of various languages will expand from the base of Japanese-English translation, which may eventually result in the creation of a new international community. Although the issue of quality assurance remains a challenge, Professor Isahara will continue to strive to make machine translation more useful to society.




Collaborative Research Project on Machine Translation

**[Reporter's Note]**

Professor Isahara, having initially worked on natural language processing, eventually switched to translation engine research and has been devoting his energies to this field ever since. He is currently shifting the basis of his research to more directly practical applications, through the extraction of terms and the creation of a framework that aims for practical use.

"I have been engaged in Japanese machine translation since the early days, and I am still continually searching for ways to make it more usable. As I have gotten older, I think that my inclination to be useful to society has gotten stronger. If we do nothing, Japan's information outbound transmission is going to fall increasingly behind. Even if the accuracy of current machine translation is insufficient, it is far better than not having it at all. Therefore, I am always striving to improve this," says Professor Isahara.

I want to be optimistic about how much we can contribute to machine translation technology innovation, through the framework that Professor Isahara presents and through crowdsourcing, with the power of social communities brought to life by science.

**References**

1. Hitoshi Isahara et al. (2014). ISO Language Resource Management Technical Specification Proposal for Controlled Natural Language: Basic Concepts and General Principles, Fourth Workshop on Controlled Natural Language (CNL 2014).

2. Takako Aikawa, Kentaro Yamamoto, and Hitoshi Isahara. (2012). The Impact of Crowdsourcing Post-editing with Collaborative Translation Framework, JapTAL2012, pp.1-10.

3. Hitoshi Isahara. (2012). Toward Practical Use of Machine Translation, JapTAL2012, pp.23-27.

4. Midori Tatsumi, Anthony Hartley, Hitoshi Isahara, Kyo Kageura, Toshio Okamoto, Katsumasa Shimizu. (2012). Building Translation Awareness in Occasional Authors: A User Case from Japan, 16th Annual Conference on the European Association for Machine Translation (EAMT2012), pp.53-56.

5. Anthony Hartley, Midori Tatsumi, Hitoshi Isahara, Kyo Kageura, Rei Miyata. (2012). Readability and Translatability Judgments for "Controlled Japanese", 16th Annual Conference on the European Association for Machine Translation (EAMT2012), pp.237-244.

# 機械翻訳の精度向上に向け、手法開発としくみ構築に取り組む

機械翻訳の技術は年々進歩を遂げ、ここへきて、ビッグデータ技術の進展を背景に、さらなる精度の向上に大きな期待が寄せられている。しかし一方で、欧米言語間の機械翻訳は実用レベルで活用されているのに対して、日本語から他言語への機械翻訳にはまだ多くの課題が残る。その課題を克服しようと、1980年代から機械翻訳の研究に従事してきた井佐原均教授に、先端の機械翻訳研究について聞いた。

## 日本語翻訳がうまくいかない理由

井佐原均教授は、通商産業省工業技術院電子技術総合研究所、郵政省通信総合研究所（現・情報通信研究機構：NICT）を経て、2010年からは豊橋技科大において、一貫して機械翻訳の研究に従事してきた。

「日本語から中国語、タイ語、マレーシア語、インドネシア語への機械翻訳や、日本語の話し言葉のデータベースの構築、日中・中日言語処理技術の開発研究など、さまざまな研究を手がけてきました。ただ、残念なことに、日本語からその他言語への機械翻訳の精度は向上してきたとはいえ、まだまだ不十分です。たとえば日英翻訳なら、語順の違いに加え、主語省略など、文脈に依存する日本語特有の性質が障壁となっています。情報発信のための翻訳であればなおのこと、品質を十分に担保しなければなりませんが、現実には機械翻訳システムの出力をそのまま使えるレベルにありません。実用化のためには、さまざまな工夫を凝らす必要があります」と井佐原教授は言う。

実は80年代、機械翻訳研究は日本が先行していた。大学などの公的研究機関に加え、多くの大手電機メーカーが機械翻訳システムの開発に参入したが、やがてほとんどの企業が撤退してしまう。その原因は、「サービス」を提供するという意識が足りなかったことにあると井佐原教授は指摘する。技術開発の過渡期にある機械翻訳の場合、一度、システムを構築してパッケージ化して売ればいいという従来型の製品提供では、ユーザを満足させることはできなかった。

「日本では情報を文書化して再利用するという発想が少ないことに加え、システムを発展させつつ、サービスを続けていくためのしくみが整っていませんでした。プロの翻訳者であっても、その分野に通じていることや事前知識は欠かせませんよね。同様に、機械翻訳においても翻訳エンジンの精度向上に加えて、使うことを前提としたデータベースの構築や更新、手法の開発、しくみづくりが欠かせないのです」（井佐原教授）

## 機械翻訳に必要な3つのステップ

そうした中、井佐原教授が、機械翻訳を用いた翻訳プロセスに不可欠な要素として挙げるのが、以下の三つである。①翻訳しやすい日本語の作成、②分野に応じた最適な用語の抽出、③後編集のしくみの構築だ。

「まず①の日本語の入力文を翻訳しやすいようにコントロールするだけでも、かなり効果があります。そこで、日本語の品質を落とすことなく、どのような入力文をつくれば機械翻訳がうまくいくのか、研究してきました」

その検証のため、地元企業に協力を仰ぎ、社内のマニュアルをルールに従って翻訳しやすい日本語、いわゆる「制限言語」に書き換えてもらい、翻訳精度を測る実験も行った。ルールは、主語や目的語をできるだけ省略しない、長文にしないといったもので、さほど煩雑なものではない。こうした研究の動きを背景に、現在、制限言語の必要性から、国際標準化機構（International Organization for Standardization：略称ISO）でも国際標準化が進められているところだ。

②の用語の抽出とは、その分野に関する大量の文書を蓄積し、その中から半自動的に、よく使われる「長めの語句」を抽出していくのである。「たとえば、『地球温暖化における二酸化炭素の影響』や『パイプラインにおける亀裂発生時のガス減圧特性』といった語句です。それらを自動的に抽出し、分野に通じた人が精査し、適切な対訳の用語集をあらかじめ用意しておくわけです」

最後は③の後編集だが、ここで井佐原教授らが取り入れたのがクラウドソーシングである。現状は後編集をして、翻訳文を整えなければ完璧な文書にはならない。ただし、プロの翻訳者に頼むと相当なコストがかかる。そこで効率化のために、プロの翻訳者ではないが、それなりにその分野に通じている人々にボランティアベースで作業をしてもらうわけだ。実際に、豊橋技科大のホームページ（英文）に機械翻訳のためのエンジンと編集ツールを搭載して、留学生に後編集をしてもらったところ、精度のいい翻訳ができることがわかった。

「うちの留学生であれば、本学のことはよく知っていますし、品質もそれなりにコントロールできます。たとえば、英語からインドネシア語に機械翻訳された文を数人で連携しながら直していくのですが、最終的にはプロの翻訳家の文章に近い精度に仕上げることができました」（井佐原教授）

## 分野ごとのコミュニティに参加を促す

現状、ビジネスの現場では、翻訳はーからプロの翻訳家に委ねることがほとんどだが、機械翻訳を入れるメリットは精度はそこそこでも、コストをかけずにスピードアップを図れることにある。今後、グローバル化や、外国人観光客の誘致などインバウンド市場の活性化を背景に、情報発信のための機械翻訳への期待はますます高まっていくだろう。

「たとえば、2019年に日本で開催が予定されているラグビーW杯に向けて、今後、どんどん日本語の記事がアップされていくでしょう。その際に、ラグビーファンによる後編集ができれば、かなり使える英語で情報発信できると期待しています。その翻訳結果を蓄積して学習することにより、さらに翻訳の精度を上げることもできます。とくに知識や能力があり、社会貢献をしたいと思っていらっしゃるシニア層の方に、クラウドソーシングに参加していただけたらと嬉しいですね。もっともボランティアとはいえ、貢献度に応じて有名選手のサインがもらえるなど、なんらかのインセンティブを用意する必要はあるでしょう」と井佐原教授。すでに、ラグビー記事の翻訳については、豊橋技科大と立教大学、NICTによる共同研究がスタートしている。

今後は、鉄道、カメラ、ラーメンなど、さまざまな分野のボランティア・ネットワークによる、日本語から英語への情報発信へと発展させていきたいという。さらには、IT企業と組んで、ビジネス分野でのマニュアル等のデータベースの共有化も視野に入れる。日本マイクロソフト株式会社や株式会社ブロードバンドタワーとの共同プロジェクトも始まった。日英翻訳を端緒にさまざまな言語への翻訳が広がり、新たな国際コミュニティが構築できるのではないかと、井佐原教授は展望を語る。品質の保証などの課題はあるものの、機械翻訳を社会に役立てるために、井佐原教授の奔走は続く。

取材・文＝田井中麻都佳

## 取材後記

井佐原教授は、自然言語処理から始まって、長く翻訳エンジンの研究を手がけてきた。現在は用語の抽出や実用化へ向けた枠組みづくりなど、より実社会に根ざした取り組みへと研究をシフトさせている。「ずっと日本語の機械翻訳に携わってきて、もっと使えるものにしたいと思い続けてきました。歳とともに、社会の役に立ちたいという気持ちも強くなっていったように思います。このままでは日本の情報発信はますます遅れをとってしまう。現状の機械翻訳の精度が十分でなかったとしても、ないよりははるかにマシですからね。そのためにできることを考えているのです」と、井佐原教授。

井佐原教授が提示する枠組みとともに、一般の人の力を科学に生かすクラウドソーシングが、今後どこまで機械翻訳の技術革新に貢献できるのか、大いに期待したい。


### Researcher Profile

**Dr. Hitoshi Isahara** studied natural language processing until Master level at Kyoto University. After graduation, he was engaged in research for machine translation and natural language processing, then received PhD (Engineering) in 1995. He held following various important posts: President of Asia-Pacific Association for Machine Translation and President of International Association for Machine Translation. These achievements were recognized, then he has been appointed to conference ambassador by Japan National Tourism Organization in 2015. Currently, Dr. Isahara is a Director of the Information and Media Center at Toyohashi University of Technology. His research interests are Machine translation, Lexical semantics, and Association by human.

### Reporter Profile

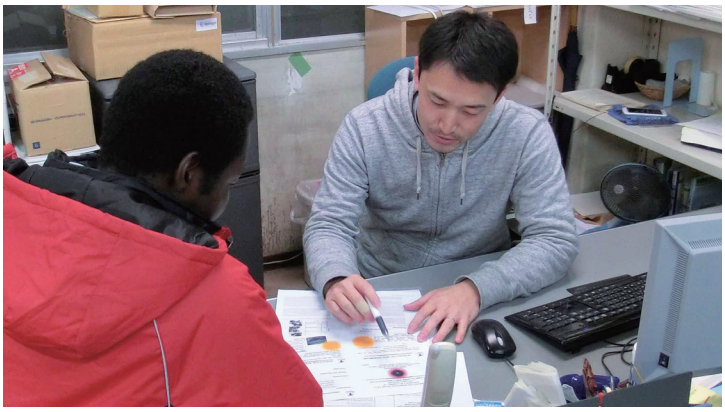
**Madoka Tainaka** is a freelance editor, writer and interpreter. She graduated in Law from Chuo University, Japan. She served as a chief editor of "Nature Interface" magazine, a committee for the promotion of Information and Science Technology at MEXT.

# New bimetallic alloy nanoparticles for printed electronic circuits

Production of oxidation-resistant copper alloy nanoparticles by electrical explosion of wire for printed electronics

By Go Kawamura

Go Kawamura, in cooperation with researchers at Duke University, has invented a production method for oxidation-resistant copper alloy nanoparticles for printed electronics. These novel nanoparticles were produced by an environmentally friendly and economical "wire explosion" method. This invention will expand the application range of printed electronics.

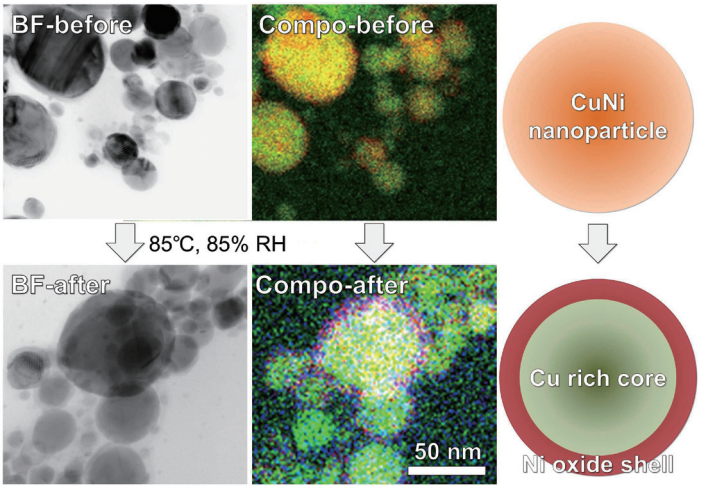


Go Kawamura (right of picture) working with one of his students.

"Printed electronics" has the potential to enable low-cost fabrication of electronics on flexible or curved surfaces, which will lead to the use of electronics in more varied applications. We will be able to fabricate homemade mobile phones or smart watches using a printer in the future. However, the low performance and high cost of current conductive inks have been limiting the advancement of printed electronics.

Now, Go Kawamura and his collaborators at Duke University have found a way to produce new copper alloy nanoparticles, which can be used as the main component of affordable conductive inks with high oxidation resistance. The researchers electrically exploded alloy or twisted metal wires in water with a mild reducing agent (Vitamin C) in order to produce the nanoparticles. The reduction in conductivity was subsequently measured under harsh conditions (high temperature and high humidity).

"We had been working on developing a 'wire explosion' method to produce novel metal nanoparticles. Then, we found that some of the produced copper alloy nanoparticles possessed both high oxidation resistance and low electrical resistance," explains Assistant Professor Go Kawamura. "Moreover, the nanoparticles have the advantage of being inexpensive because the production process is very economical and environmentally friendly."




Bright-field (BF) scanning transmission electron microscope images, composed (Compo) elemental mappings, and illustrations of Cu alloy nanoparticles containing 30% Ni before and after oxidation treatment at 85 °C and 85% relative humidity.

As a result, copper nanoparticles alloyed with 1% Sn, 5% Ag, 5% Ni, or 30% Ni had electrical conductivities similar to that of copper; however, unlike copper, the nanoparticles remained conductive after 24 h at 85 °C and 85% relative humidity. With further improvement of the electrical conductivity and oxidation resistance, copper alloy nanoparticles prepared by wire explosion could be used for the production of high-performance affordable conductive inks, which will contribute to the advancement of printed electronics. The researchers also hope this work will encourage further study combining wire explosion with chemical modification of the explosion medium to control the composition and surface chemistry of nanoparticles.

**Reference**

Go Kawamura, Samuel Alvarez, Ian E. Stewart, Matthew Catenacci, Zuofeng Chen & Yoon-Cheol Ha (2015). Production of oxidation-resistant Cu-based nanoparticles by wire explosion, Scientific Reports, 5:18333, 1-8. 10.1038/srep18333

# Wirelessly Supplying Power to Brain

Implantable device composed of a flexible antenna and silicon large-scale integration chips

By Ippei Akita

Ippei Akita and his colleagues have developed a technique to implement silicon large-scale integration chips in a very thin (10 μm) film . This fabrication method has the potential to realize a low-invasive flexible device for monitoring brain activity. This study will contribute to the development of brain-machine interface systems.

Ippei Akita (right of picture) with one of his students

Human and animal movements generate slight neural signals from their brain cells. These signals obtained using a neural interface are essential for realizing brain-machine interfaces (BMI). Such neural recording systems using wires to connect the implanted device to an external device can cause infections through the opening in the skull. One method of solving this issue is to develop a wireless neural interface that is fully implantable on the brain.

However, the neural interface implanted on the brain surface should be of small size and minimally invasive. Furthermore, it requires the integration of a power source, antenna for wireless communication, and many functional circuits.

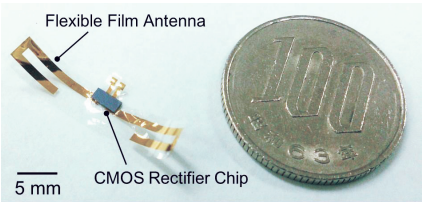
Now, Ippei Akita and his colleagues have developed a wafer-level packaging technique to integrate a silicon large-scale integration (LSI) chip in a very thin (10 μm) film. Using flip-chip bonding, the researchers have managed to fabricate a Wireless Power Transmission (WPT) device including a flexible antenna and rectifier chip.

The first author PhD candidate Kenji Okabe said, “We have investigated how to integrate flexible antenna and high-performance circuits and tried this fabrication method with process conditions obtained through experiments.” Assistant Professor Ippei Akita, who is leading the project, said, “Using flexible device technology is a good solution to implement biocompatible passive devices such as antennas or sensor electrodes. On the other hand, silicon-based integrated circuit technology, which has long history, is suitable for ultra-low-power systems with many functionalities. So, we believe that combining these technologies is essential to establish such minimum invasive implantable devices.”

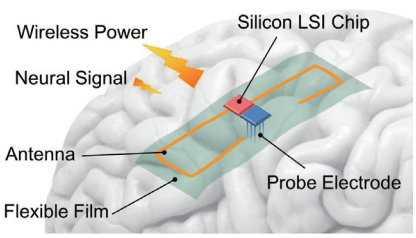
The fabricated device is of size 27 mm × 5 mm, and 97% of the device area is composed of a flexible film as the silicon chip has a small area. Therefore, it has sufficient flexibility to fit the shape of the brain surface. In addition, the researchers achieved WPT to the device immersed in saline.

This WPT device can supply electricity to other circuits included in the neural interface. The researchers are trying to integrate more functions (e.g., amplifiers, analog-to-digital converters, signal processors, and radio frequency circuits) to an LSI chip. This study may contribute to the development of safer BMI systems.

This work is partially supported by Grants-in-Aid for Scientific Research (A) #25249047, Young Scientists (A) #15H05525, and (B) #25820141 from the Japan Society for the Promotion of Science.




Fabricated wireless power transmission device with a flexible antenna and a CMOS rectifier chip (97% of the flexible device area is composed of a flexible film of thickness 10 μm)




Proposed architecture of the implantable device composed of flexible antenna and CMOS circuits for wireless-powered neural interface systems

**Reference**

Kenji Okabe, Horagodage Prabhath Jeewan, Shota Yamagiwa, Takeshi Kawano, Makoto Ishida, and Ippei Akita (2015). Co-design method and wafer-level packaging technique of thin-film flexible antenna and silicon CMOS rectifier chips for wireless-powered neural interface systems, Sensors, Article first published online: 16 Dec., 15(12), 31821-32. DOI: 10.3390/s151229885.

# Intracellular recordings using nanotower electrodes

Nanoscale-tipped high-aspect-ratio vertical microneedle electrodes for intracellular recordings

By Takeshi Kawano

Takeshi Kawano and his colleagues have developed an intracellular recording device, which has > 100-µm-long three-dimensional nanoscale-tipped microneedle-electrodes. Moreover, they demonstrated the needles' penetration into muscle cells and measured the signals. The nanoelectrode, whose size is longer than the conventional intracellular nanoelectrode (< 10-µm long), has the potential to be used in cells that are deep within a tissue, such as cells in brain slices or brain *in vivo*, thus accelerating the understanding of the brain.

Takeshi Kawano (left of picture) with one of his students

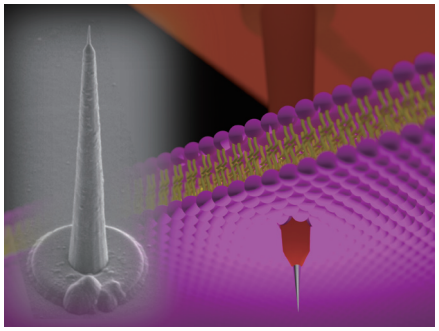
Our current understanding of how the brain works is very poor. The electrical signals travel around the brain and throughout the body, and the electrical properties of the biological tissues are studied using electrophysiology. When measuring the voltage or current across the cell membranes, intracellular recording outperforms extracellular recording in terms of amplitude and quality of neuronal signals. Nanowire-and nanotube-based devices have been developed for the intracellular recording applications to demonstrate the advantages of these devices having high spatial resolution and high sensitivity.

However, the length of these nanowire/nanotube electrode devices is currently limited to less than 10 µm due to process issues that occur during fabrication of high-aspect-ratio nanoscale devices, which are more than 10-µm long. Thus, conventional nanodevices are not applicable to neurons/cells within thick biological tissues, including brain slices and brain *in vivo*.

A research team in the Department of Electrical and Electronic Information Engineering and the Electronics-Inspired Interdisciplinary Research Institute (EIIRIS) at Toyohashi University of Technology has developed three-dimensional microneedle-based nanoscale-tipped electrodes (NTEs) that are longer than 100 µm. The needle length exceeds that of the conventional nanowire/nanotube-based intracellular devices, thus expanding the range of applications of nanodevices in intracellular recording, such as deep tissue penetration. Additionally, they perform intracellular recordings using muscle cells.

"A technological challenge in electrophysiology is intracellular recordings within thick biological tissue. For example, a needle length of more than 40 µm is necessary for performing brain slice experiments. However nanoscale diameter needles with a high-aspect-ratio have a long hair-like nanostructure which makes it almost impossible to penetrate thick tissue due to insufficient stiffness. On the other hand, our NTE, which is a 120-µm-long cone-shaped electrode, has sufficient stiffness to punch tissues and cells", explains the first author PhD candidate, Yoshihiro Kubota.

The leader of the research team, Associate Professor Takeshi Kawano said "Although we demonstrated the preliminary results of our NTE device, the batch fabrication of such intracellular electrodes, which have a needle length more than 100 µm, should lead to an advancement in device technologies. This will eventually lead to the realization of multisite, depth-intracellular recordings for biological tissues, including brain slices and brain *in vivo*, which are beyond the capability of conventional intracellular devices."



120-µm-height 'nanotower' electrode punching a cell membrane. This kind of high-aspect-ratio intracellular electrodes are now possible thanks to silicon growth technology and three-dimensional nano/microfabrication techniques .

As addressed by the research team, the NTE has the potential to be used in cells that are deep within a biological tissue, including brain slice and brain *in vivo*, thus accelerating the understanding of the brain.

This study was supported by

- Grants-in-Aid for Scientific Research (S) (No. 20226010) and (A) (No. 25249047) from JST
- Grants-in-Aid for Young Scientist (A) (No. 26709024) and (B) (No. 22760251) from JST
- The PRESTO Program from JST
- Leading Graduate School Program R03 of MEXT
- Grant-in-Aid for Scientific Research (C) (No. 24590350) from JST
- the Asahi Glass Foundation and the Takeda Science Foundation

**Reference**

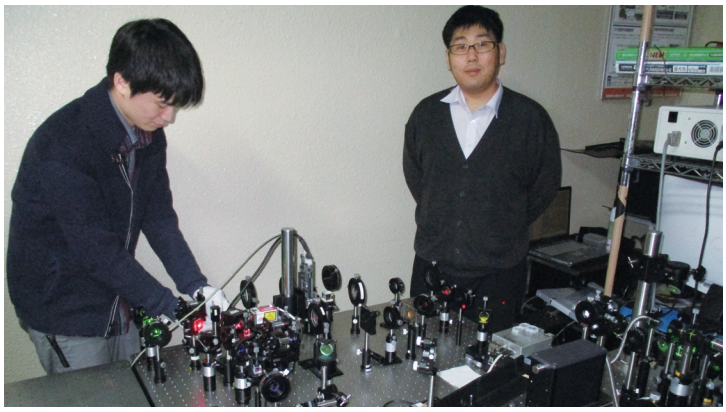
Yoshihiro Kubota, Hideo Oi, Hirohito Sawahata, Akihiro Goryu, Yoriko Ando, Rika Numano, Makoto Ishida, and Takeshi Kawano (2016). Nanoscale-tipped high-aspect-ratio vertical microneedle electrodes for intracellular recordings, Small, Article first published online: 8 April 2016 I DOI: 10.1002/smll.201600172

# Nano-magnets produce three-dimensional images

Wide-view three-dimensional holographic display composed of nano-magnetic pixels

By Hiroyuki Takagi

Hiroyuki Takagi and his colleagues have developed a wide-view three- dimensional (3D) holographic display composed of nano-magnetic pixels. This 3D display, with 1-μm-pitch pixels, can show holographic images over viewing angles of 30 degree. This display is an attractive option for visualizing 3D objects with a smooth motion parallax and without using special glasses.



Hiroyuki Takagi (right of picture) with one of his students

Conventional 3D displays, such as stereo displays with glasses and glass-free autostereoscopic displays, show two-dimensional images for each eye. Therefore, users experience incongruity and eyestrain because actual 3D images are not shown. A holographic display produces an exact copy of the wave front of scattered light from an object, and hence, a realistic 3D display is expected. Holographic displays can reconstruct realistic 3D images, thereby eliminating the need for special glasses.

However, construction of holographic displays is difficult, as nano-sized pixels are required for reconstructing 3D images with a wide viewing-angle. Conventional holographic displays have a viewing angle of <3 degree. In addition, conventional displays have a pixel pitch of 10–100 μm.

Associate Professor Takagi and his research team have recently developed wide-viewing 3D holographic displays composed of nano-magnetic pixels.

These displays are driven by thermomagnetic recordings, and wide viewing-angles are achieved through the use of in-house-developed magneto-optic spatial light modulators (MOSLMs) composed of nano-sized pixels.

According to Associate Professor Takagi, “The advantages of this approach are that the focused spot of a laser defines the pixel size, the MOSLM does not require special current or voltage drivelines, and the switching speed is about 10 nsec/pixel , which is enough for real-time display. Therefore, the MOSLM can represent 3D movies because the display media is made of a rewritable magnetic material. In addition, the magnetic hologram is stored for magnetic materials semi permanently. The viewing angle depends on pixel pitch size. In this study, we adjusted to the pixel pitch size of 1 μm after obtaining the pixel size of 1 μm.”

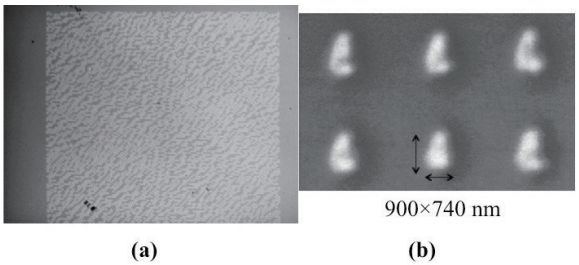
This confirms, as previously stated, that a 3D display with 1-μm-pitch pixels can display holographic images over viewing angles of 30 degree. Therefore, this display constitutes an attractive option for visualizing 3D objects with a smooth motion parallax and without special glasses.

This work was supported by

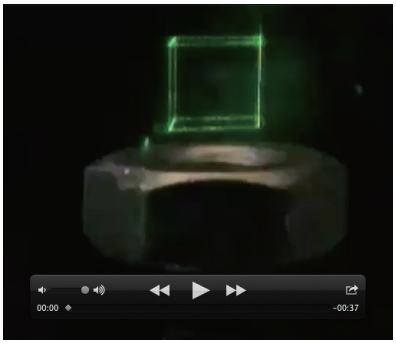
- SPS KAKENHI Grant Numbers 26220902, 25820124, 15J05710 and 26706009
- SCOPE, 152106003
- JST PRESTO.

**Reference**

K. Nakamura, H. Takagi, T. Goto, P. B. Lim, H. Horimai, H. Yoshikawa, V. M. Bove and M. Inoue, “Improvement of diffraction efficiency of three-dimensional magneto-optic spatial light modulator with magnetophotonic crystal”, Appl. Phys. Lett., 108, 022404 (2016).




An image composed of nano-magnetic pixels. (a) A 256×256-pixel 1μm-pitch image obtained via polarization microscopy and (b) a 3×2-pixel 2.5-μm-pitch image obtained via magnetic force microscopy.



3D wireframe-cube image from nano-magnetic pixels above a real nut

## プリンテッドエレクトロニクス用の新しい合金ナノ粒子

### ワイヤーエクスプロージョン法による高酸化耐性銅合金ナノ粒子の作製とプリンテッドエレクトロニクスへの応用

河村　剛

河村剛助教は、米国Duke大学との共同研究を行い、プリンテッドエレクトロニクス用の高酸化耐性銅合金ナノ粒子の新しい合成法を開発した。得られる新規ナノ粒子は、環境負荷が小さく、安価な手法で生産される。この発見により、プリンテッドエレクトロニクスの応用範囲が大きく広がることが期待される。

“プリンテッドエレクトロニクス”はフレキシブル基盤上に安価に電子装置を製作できるため、電子装置の応用範囲を大きく広げる技術として期待されている。しかし、現在の導電インクの低性能と高価格のために、プリンテッドエレクトロニクスは広い応用に至っていない。

河村剛助教と米国Duke大学の研究者らは、安価で高い酸化耐性を有する導電インクの主原料となりうる新規銅合金ナノ粒子の合成方法を新たに開発した。研究者らは、弱い還元剤（ビタミンC）を含む水中で、電気的に金属細線を爆発させてナノ粒子を得た。その粒子を用いて作製した導電ラインの導電性劣化過程は、厳しい環境下（高温、高湿度下）において測定された。

「我々は“ワイヤーエクスプロージョン法”を用いた新規金属ナノ粒子の合成に関して研究を行ってきました。その中で、得られたいくつかの新規銅合金ナノ粒子が高い酸化耐性と低い電気抵抗率を示すことを発見しました。」と河村剛助教は話す。「さらに、低環境負荷で低コストな手法で合成されるこれらのナノ粒子は、きわめて安価に供給できるメリットを有します。」

結果として、1%の錫、5%の銀、5または30%のニッケルと合金化された銅ナノ粒子は、銅単体のナノ粒子と同等の導電率を有しながら、85°C、85%相対湿度の厳しい環境下においても、24時間後に高い導電率を維持していた。さらなる導電率と酸化耐性の向上が達成されれば、ワイヤーエクスプロージョン法で合成される銅合金ナノ粒子が、安価で高性能な導電インクの作製に利用され、プリンテッドエレクトロニクスの広い応用に繋がると期待される。研究者らは、今回のワイヤーエクスプロージョン法と液相化学反応を組み合わせた新しいナノ粒子合成法が、組成や表面化学状態の制御された新規ナノ粒子の合成を目指す研究にも寄与できると期待している。

## 脳に電力を送る

### フィルムとシリコンチップの一体化によるフレキシブルな埋め込みデバイス

秋田　一平

秋田一平助教らは、神経インターフェイスの開発に向けて、フィルムデバイスにシリコン基板による回路チップを実装する手法を開発しました。厚さ10μmのフィルムアンテナに小型の整流器を集積することで、脳表面に張り付けられる柔軟さを持った、無線電力伝送デバイスを実現しました。この実装手法は、脳機能を解明するための無線神経インターフェイスの開発に貢献します。

ヒトや動物は、手足を動かした際に、脳の神経細胞から微弱な神経電位を生じます。この神経電位の解析は、ヒトとロボットを繋ぐブレインマシンインターフェイス（BMI：Brain　Machine　Interface）の実現に向けて盛んに研究されています。現在、ワイヤを用いて脳表面に埋め込まれた電極から神経電位の計測が行われていますが、頭蓋骨の開口部から感染症を引き起こす懸念があります。そのため、長期間にわたって脳の信号を観測するために、生体内に完全に埋め込む無線神経インターフェイスの開発が要求されています。

しかし、頭部へ埋め込む神経インターフェイスは、埋め込む際に生体にダメージを与えないために、小型かつ低侵襲でなければなりません。また、増幅器や信号処理等の高機能な回路と、通信をするためのアンテナ、さらにデバイスを駆動する電源が必要になります。

秋田一平助教らの研究チームは、半導体デバイスのパッケージ技術を用いて、シリコン基板による高機能かつ小型な回路チップを、厚さ10μmのフレキシブルフィルムに実装する手法を開発しました。研究者らは、無線神経インターフェイスに電力を伝送するために、提案した製作手法を用いて、整流器チップとフィルムアンテナを一体化した無線電力伝送デバイスを製作しました。

「我々は、無線電力伝送デバイスを実現するために、如何にして高効率なアンテナを実現し、回路機能を集積するかを検討した。そして、今回、薄膜かつ大面積のフィルムアンテナに対して、シリコン基板で製作した回路チップを実装する手法に挑戦した。」と、第一著者の岡部は述べています。また、本プロジェクトを先導する秋田助教によると、「近年盛んに研究が行われているフレキシブルデバイス技術は、アンテナやセンサ・電極などの実現に非常に有用である。一方で、長い歴史を持つシリコン集積回路技術は、低消費電力・高機能なシステムを実現できるため、それぞれの技術が得意とする領域を適切に融合させることで、最適なシステムを実現することができると考えている」と方向性の意義について述べています。

製作されたフレキシブルデバイスは、5mm×27mmの面積であり、シリコン基板による回路面積は全体の3%を占めています。そのため、本デバイスは、大部分がフレキシブルフィルムで構成されており、脳の形状に対して柔軟に密着します。また、製作したデバイスを水槽に浸して、10cmの距離で無線電力を伝送することに成功しました。

埋め込みデバイスに無線電力を供給する事により、様々な回路を駆動する事が可能になります。研究者らは、今後、シリコンチップに更なる回路機能を搭載し、無線で脳の信号を取り出す事を目指しています。無線神経インターフェイスは、ヒトに不自由の無い義肢を提供するBMIシステムの構築に貢献します。

本研究は、文部科学省・日本学術振興会科研費・基盤研究(A)25249047、若手研究(A)15H05525並びに若手研究(B)25820141の支援を受けて遂行されました。

## 細胞内電位計測のための‘ナノタワー’電極デバイス

### 細胞内電位計測のための高アスペクト比・ナノスケール先鋭化マイクロニードル電極

河野　剛士

河野剛士准教授らは、細胞内電位計測応用として、長さが100μm以上、先端の直径がナノサイズに先鋭化された3次元的マイクロプローブ電極デバイスを開発した。また、彼らは開発した電極を用いたマウスの筋細胞への電極刺入及び細胞内からの信号計測を実証した。

研究グループが開発したナノ電極は、長さが10μm程度以下に留まっていた既存のナノ電極デバイスの長さを大きく上回るもので、脳スライスや生体内（*in vivo*）計測での組織深部の細胞における細胞内電位計測の可能性を拡大し、脳計測技術さらには私たちの脳の理解を加速させるツールとして今後期待される。

脳に対する私たちの理解は未だもって不十分であり、今後の脳計測のさらなる進展が必要である。その中でも電気生理学的手法は脳組織の神経回路網を理解するための有力な方法である。細胞外電位計測と比較すると、細胞内電位計測は信号の電圧値の大きさや信号の質（シナプス後電位等）などの点において優れた方法である。既存のガラス管電極の空間分解能や感度を上回る技術として、ナノテクノロジーを駆使したナノワイヤやナノチューブによる細胞内電位計測用のデバイスが近年開発されてきている。

しかしながら、これらのナノ電極デバイスは製作手法の制約からその電極長が10μm以下に留まっている。そのため、これら従来のナノデバイスでは、脳スライスや生体内（*in vivo*）脳組織などの厚さのある生体組織の深部に位置する細胞への応用が困難であった。

豊橋技術科学大学の電気・電子情報工学専攻の学生・研究者たちとエレクトロニクス先端融合研究所の研究者たちは長さ100μmを超える三次元的ナノスケール先鋭化マイクロニードル電極（Nanoscale-tipped electrode, NTE）デバイスを開発した。開発した電極ニードルの長さは、従来の細胞内電位計測用ナノ電極の長さを大きく上回り、ナノデバイスによる細胞内電位応用の応用範囲を大きく広げる。彼らはまた、開発したNTEによる筋細胞への電極の刺入及び信号計測を実証した。

「従来のナノ電極を用いた電気生理学的手法における技術的な課題は、組織深部の細胞に対する細胞内電位計測である。例えば脳スライスの場合、損傷の少ない細胞は、切片表面から深さ約40μm以上に位置する。しかし、40μm長の高アスペクト比のナノ電極では、そのナノ構造の不十分な剛性のために刺入が困難であった。一方で、私たちが開発した120μm長のNTEは、その円錐に近い電極形状により、細胞や組織を貫くのに十分な剛性を実現できる」と筆頭著者である博士後期課程の久保田吉博は説明する。

本研究のチームリーダーである河野剛士准教授は「今回は、提案するNTEデバイスの基礎的な特性結果を示したに過ぎないが、長さ100μm以上のナノ電極を一括製作が可能な今回の技術は、細胞内用のデバイス技術をさらに発展させるもので、また本提案デバイスにより最終的にはこれまでの細胞内計測では困難とされてきた脳スライスや*in vivo*（生体内）脳組織を含む組織深部での多点、同時における細胞内電位計測の実現が可能性である」と考えている。

今回開発されたNTE電極は、脳スライスや生体内（*in vivo*）脳組織などの組織深部における細胞内電位計測の可能性を拡大させるもので、脳計測技術さらには私たちの脳の理解を加速させるツールとして今後期待される。

本研究は、以下の助成を受けて行われました。
文部科学省・日本学術振興会科学研究費基盤研究S（20226010）、基盤研究A（25249047）、若手研究A（26709024）、若手研究B（22760251）
科学技術振興機構さきがけ（PRESTO）
文部科学省・日本学術振興会博士課程教育リーディングプログラム（R03）
文部科学省・日本学術振興会科学研究費基盤研究C（24590350）
公益財団法人武田科学振興財団、公益財団法人旭硝子財団

## ナノ磁石から3次元像

### ナノ磁石で形成した広視野角3次元ディスプレイ

髙木　宏幸

髙木宏幸准教授と研究グループは、ナノ磁石で構成された広視野角の3次元ディスプレイを開発した。画素サイズが1μmであり、視野角が30度以上の3次元像を再生できる。このディスプレイは特別なメガネが不要で視野角内の任意の角度、場所から3次元像を見る事が出来る。

自然な3次元(3D)像の表示技術は医療、教育、放送など幅広い分野において需要があり、応用が期待されている。従来のディスプレイはメガネが必要であったり、見る位置や角度が固定されていた。これらは2次元(2D)イメージによるもので、眼精疲労を生じる課題があった。ホログラフィーは実際の物体と同一の波面状態を持つ光を再現できるため、裸眼で3次元像を見ることができ、かつ輻輳と焦点の不一致による眼精疲労が生じないといった特徴を有している。

ホログラフィーにおいて3次元像を再生できる角度の最大値は視野角と呼ばれ、記録されたホログラムのピクセルサイズに依存している。これまで極めて多くのナノスケールの画素を有するディスプレイが開発することが困難で、また視野角は数度と限られていた。

今回開発されたディスプレイは、高密度および高速記録に優れる磁性体と熱磁気記録方式を用いる事で、ナノスケールの画素を有し、広視野角の3D像の再生を可能とした。

髙木宏幸准教授によれば、「磁性体の磁化を制御するレーザ径によって、画素サイズをナノからマイクロメータまで制御することが可能である。磁性体の磁化のスイッチング速度は10nsec/pixelであり、ディスプレイ表示には十分である。今回はこの方法によって1μmの磁気の画素を形成することが出来た。」

今回の3Dディスプレイは1μm-pitchの画素を持つため、30度の広視野角を持つ3D像を再生することが出来る。今後、このディスプレイにより特別なメガネが不要で、視野角内の任意の位置から見る事ができる3Dディスプレイの開発が可能となる。

本研究は、JSPS科研費(26220902,25820124,15J05710,26706009)とSCOPE(152106003)、JSTさきがけの助成を受けて行われました。

# Pick Up

## TUT established a new research institute to accelerate innovations in technology

On April 1st 2016, Toyohashi University of Technology (TUT) opened a new on-campus research organization, “Research Institute for Science & Technology Innovation”.

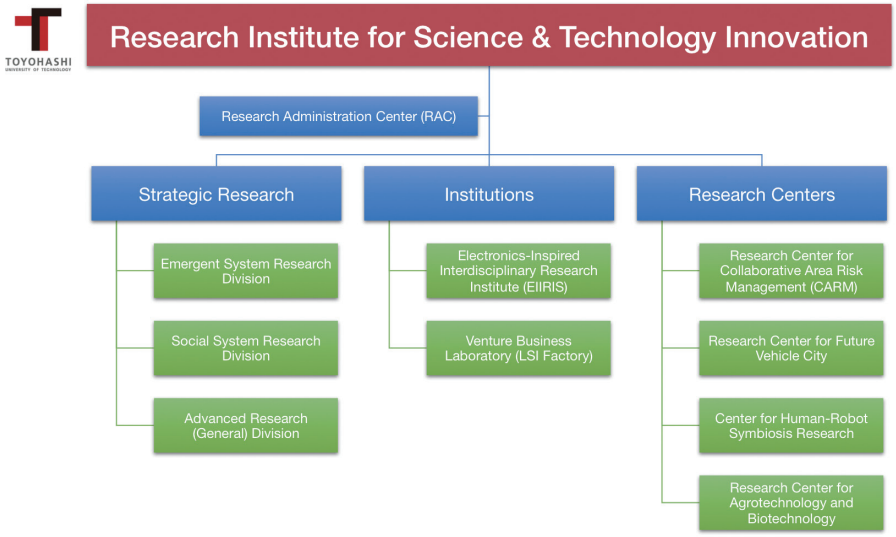
The mission of TUT is to contribute to global development by creating new values which will help to shape our future society. In order to achieve this, TUT conducts research aimed at developing new technologies through scientific investigation and innovation.

In order to accelerate and maximize its contribution to society, TUT integrated the existing on-campus research institutes and centers under a single new organization of “Research Institute for Science & Technology Innovation”.

The mission of the new Institute is;

1. Strategic promotion of cutting-edge and innovative research by collaboration with national and international leading companies and top research institutions.
2. Promotion of value creation type of emergent systems-led research fused with growing artificial intelligence technology.
3. Promotion of and recommendations for problem-solving social system research.

The newly established Department of Strategic Research and the existing Electronic-Inspired Interdisciplinary Research Institute (EIIRIS) as well as four other research centers are now integrated under this new organization.




## TUT Academic Year 2016 Matriculation Ceremony

On April 4th 2016, Toyohashi University of Technology held its 2016 Academic Year spring matriculation ceremony to welcome a total of 877 new undergraduate and graduate school students.

In keeping with TUT’s unique admissions profile, 373 graduates of “Kosen” (Japan’s unique institutes of technology) were admitted as 3rd year undergraduate students and 371 graduates of TUT’s on-campus undergraduate program were admitted into the graduate school.

About 6% of the new students (53 students), including visiting or research students, were international students. They come from the following diverse countries; Bangladesh, Egypt, Finland, Guinea, Indonesia, Malaysia, Mexico, Mongolia, Sri Lanka, Tanzania, and Vietnam.

At the end of a long day including the matriculation ceremony, guidance and orientation sessions, a welcome party for new international students was held in TUT’s student lounge. About 150 students, faculty and university staff welcomed the new international students from all over the world.

## Building a new on-campus global student accommodation

As part of the Top Global University Project, a new style of student accommodation will be built. The key point of this new style accommodation is that it will create a multicultural environment which will enable international and Japanese students to live, eat and study together on campus.

The design concept was created by an on campus competition, while the design details and the construction company were determined through public bidding. The concept is “En - connections“, where “En” is the Japanese word for meaningful social relations. It aims to connect people to people through the use of a boundary free multicultural space.

Six buildings of shared-house style accommodations where 5 students share each unit (living & dining room, kitchen and bath room) will be built. The total capacity will be 180 students. A common balcony connects pairs of units on the same floor, and all buildings are connected through a community square.

Residence in this new accommodation is guaranteed to all undergraduate international and Japanese students who enroll as part of the new “Global Technology Architect Course” which will commence from April 2017. As long as rooms are vacant, they may be made available to other TUT students.

http://www.sgu.tut.ac.jp/eng/student-life/

Artist’s impression of the new global student accommodation


Floor plan


Area Plan

TUT Research
e-Newsletter from Toyohashi University of Technology
http://www.tut.ac.jp/english/newsletter/



**Toyohashi University of Technology**

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.

1-1 Hibarigaoka, Tempaku, Toyohashi, Aichi, 441-8580, JAPAN
Inquiries: Committee for Public Relations
E-mail: press@office.tut.ac.jp
Website: http://www.tut.ac.jp/english/