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FEATURE STORY

Firefighting in challenging conditions

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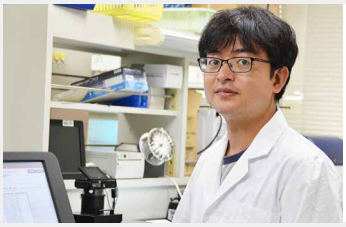
Research Highlights



Pick Up

Firefighting in challenging conditions

How do you tackle a blaze on a space station?

Yuji Nakamura

Professor Yuji Nakamura specializes in combustion science and focuses on fire and firefighting in special environments such as spacecraft and forests. Prof. Nakamura uses scale model experiments to investigate phenomena in environments that are difficult to reproduce. However, the environment and scale of these models are far removed from the actual situations. This being the case, the key to reproducing the same phenomenon is to follow "similarity rules" which act as the conditions for such experiments. In addition to his research based on this unusual approach, Prof. Nakamura is also attracting attention for his development of the unique "vacuum extinction method" that is useful for extinguishing fires in special environments such as the space station. We spoke with Prof. Nakamura about his original approach and his thoughts on university education.

Interview and report by Madoka Tainaka

Stopping forest fires can make a big contribution to reducing CO_2 emissions

At present, the mainstream of combustion science is concerned with the "use of combustion," such as how to burn fuel efficiently to extract energy. This can be seen in efforts to reduce fuel consumption in automobile engines, for example. However, Prof. Nakamura is focused on "combustion suppression" in the field of combustion science. Why does he focus on researching phenomena that are so difficult to reproduce, such as fires in special environments such as on a space station?

"Research on the use of combustion is of course an important topic, but researchers have worked to improve combustion efficiency for many years, so these days it is difficult to increase efficiency by even 1%. So, focusing on this is not very effective. On the other hand, the damage caused by forest fires, for example, is enormous. It varies from year to year, but the amount of CO_2 emitted due to forest fires is said to account for about 10% of the world's CO_2 emissions. In other words, if we can stop the spread of even one forest fire, it would be more effective than creating more efficient combustion technology.

The wildfires in California north of the San Francisco Bay Area were photographed by Expedition 61 crewmember as the International Space Station(NASA: Oct.29, 2019)

As well as its role in reducing CO_2, preventing fires is also essential for creating a safe and secure society. Fires are not limited to general buildings, but occur also in facilities such as spacecraft, submarines, or nuclear power plants, where they can cause significant damage. Of course, such facilities are fully equipped with fire protection measures, but the risk is not zero. Suppressing any fires that do occur can have a great impact on society," says Prof. Nakamura, describing the significance of his research.

A significant challenge is that the results of fire research differ greatly depending on the environment and conditions, but the conditions considered by Prof. Nakamura's work are impossible to reproduce exactly in the laboratory. Furthermore, any research that cannot be reproduced runs the risk of being considered unscientific. In fact, when Prof. Nakamura told his academic advisor that he wanted to do basic research on fires in space as the topic for his Ph.D., he was advised against it because it was not an academic topic.

"I thought, if my academic advisor, who is an authority on basic combustion science, cannot do it, I bet no one can do it. So I decided to do it! (laughs) If I was going to do something, I wanted to do something that nobody else was doing."

This sentiment captures the pioneering spirit of Prof. Nakamura, which has remained unchanged since his student days.

"Similarity rules" that help reproduce phenomena at different scales

Prof. Nakamura introduced an experimental method based on models in order to study difficult-to-reproduce fires in space. Simply put, he uses a model to try to reproduce the same conditions as space without actually going to space.

"One of the biggest problems I encountered when researching fires on space stations as a research topic was that I couldn't simulate zero gravity. Dropping a capsule to create weightlessness allows you to conduct an experiment for a few seconds and costs millions of yen each time. So that is far too expensive. Flames become round in zero gravity, but despite a great deal of thinking about the problem, I couldn't find a way to make a round flame. Just around that time, I encountered a phenomenon while studying abroad in the United States in which the shape of a flame becomes round as you

make it smaller. It came as a great shock when I found out that just reducing the flame size could create a situation that would be less susceptible to buoyancy," says Prof. Nakamura.

Just by changing the size of the flame, it is possible to reproduce zero gravity flames. Thinking about why this is the case, he discovered that he just needed to satisfy certain laws.

A round flame in a low air pressure environment

"Those are the similarity rules. If you follow the similarity rules, you can predict that if you reduce the air pressure, you can approach weightlessness. So, when I burned a flame in a partial vacuum, it really did become round. In other words, you can reproduce the same phenomenon as you would find in zero gravity if you make the flame small or reduce the surrounding air pressure and weaken the relative buoyancy. In this way, I was convinced that I could study fires in space even on earth by conducting appropriate scale model experiments."

Actually, this principle is exactly the same as the trick used to make special effects look realistic in movies. For example, in scenes of the movie "Godzilla" that include special effects, a miniature Godzilla of about 1:25 scale is used, and in scenes where Godzilla smashes or drops things, the film is shot at 4 to 5 times faster than normal speed and then reproduced in slow motion. By showing the film at a slower speed than the actual movement, you can represent movement at a different scale. Prof. Nakamura explains that the mathematical expressions for this are known as "similarity rules."

"Taking Godzilla as an example, if we assume that we must satisfy the simplest 'similarity rule,' we can easily calculate that we should shoot at 5x normal speed. Professional special effects engineers know from experience that this speed is suitable for making the movement look realistic."

Similarity rules are convenient, but it is not easy to derive them. Of course, there are many established similarity rules, and they are used in various situations such as vibration experiments for models of bridges. However, similarity rules have not been determined for all physical phenomena in the world, and similarity rules for combustion in space cannot be found in any book.

"In the case of combustion, it is particularly difficult to derive similarity rules because there are many factors that affect the phenomenon such as heat, airflow, and reactions. I thought that if I could find a way to easily derive similarity rules for specific situations, it would be of great help when solving various problems that people had given up on. It would mean that we would be able to use a laboratory to reproduce fires that occur in certain special environments, such as space, or even large-scale wildfires."

A vacuum fire extinguisher that makes it easy to return a spacecraft to normal conditions

However, even if researchers could reproduce fires under special environments through experiments and clarify the phenomenon, this would not solve all the problems. Major challenges still remain for actual firefighting.

Currently, fires inside spacecraft are extinguished by spraying an inert gas (extinguishing agent). At first glance, this may not seem to pose a problem, but the fire is occurring inside a completely sealed spacecraft. If you release a large amount of inert gas, the fire may go out, but the astronauts could suffocate and die. Also, if a small flame remains, not only will toxic gases continue to be released, but heat will also accumulate, which could damage the precise and expensive equipment and cause the spacecraft to lose its functionality.

To deal with this challenge, Prof. Nakamura proposed the "Vacuum Extinction Method." The idea is that if "blowing out" the fire is no good, why not "suck it up" to extinguish it? This is another example of a research topic that embodies Prof. Nakamura's motto of, "Let's do it because nobody else is doing it."

A vacuum fire extinguisher (video of the experiment)

"Suppose you have a high vacuum box onboard the spacecraft. When you open the suction port valve on the box, rapid suction occurs due to the pressure difference. Using this suction force, everything, including the flames inside the spacecraft, the toxic gases caused by burning, and burning objects, are confined in the box. After that, you can close the valve and discard the box as trash outside the spacecraft. You could call it a fire extinguishing vacuum cleaner. You could also extinguish the fire with water, but, while this is an effective way to put out a fire, it would be difficult to return the spacecraft to normal conditions. With the vacuum fire extinguisher, you can quickly return the spacecraft to normal conditions after putting out the fire.

"Given how unusual my idea seemed to be, I was surprised to find that a heavy industry company was working on a patent for a similar concept. Their approach was to suck out all the gases inside the spacecraft and eject them into space to put out the fire. However, with that method you would lose much of the spacecraft's functionality, so it would be too damaging. Therefore, it's better to suck only the things you don't need into a box and throw them away," says Prof. Nakamura, explaining the advantage of his approach.

He made a conceptual diagram, presented it in a paper, and released it publicly last year. He was then asked if the system could be used in sealed spaces such as clean rooms or operating rooms. If commercialized, it may also be useful for preliminary fire extinguishing at museums and art galleries.

Finally, we asked Prof. Nakamura about his future plans. He answered that he wants to turn his model experiments into an educational program.

"With the model experiments, you don't have to deal with too many mathematical formulas, but you need to hone your physical senses to discover the acting forces. You can train your observational skills and insight, which are the key skills of engineers. So it can be a very meaningful educational tool for both university students and technical college students. There is a wide range of applications. Supporting Japanese engineering education through the theory of model experiments is another major goal for me as a researcher." concluded Prof. Nakamura.

Reference

Nakamura, Y., Usuki, T. & Wakatsuki, K. Novel Fire Extinguisher Method Using Vacuuming Force Applicable to Space Habitats. Fire Technol 56, 361–384 (2020). https://doi.org/10.1007/s10694-019-00854-4

https://www.youtube.com/watch?v=_uop_1RlC-U&list=PLgJJ3SulJO9OiyjHXiMXEcpIa2Dh4HqTm (Japanese only)

Reporter's Note

Prof. Nakamura talked about his thoughts on education at the end of the interview. The conversation started from talking about his experience of studying abroad in the United States. Prof. Nakamura said that he had a tough time while studying abroad, due to both research and financial aspects as well as the language barrier.

"I went to the campus 365 days a year, studied hard, and I gained so much. There were several university faculty members who had also come from Japan, but most of them were just living abroad. When I saw that, I didn't believe we should leave Japanese university education up to those people." says Prof. Nakamura.

And, of course, while we know that not all students want to become researchers, "Education is not about filling yourself with knowledge. Real learning is when you do what you want to do and actually understand something. This is what I want to convey. That's why I think students should do interesting research at university to investigate the mysterious things in the world that interest them as an individual, no matter how seemingly trivial. When they find it interesting, everyone works on their own initiative. My aim is to win an Ig Nobel Prize! (laughs)" he says. Given Prof. Nakamura's reputation for outstanding presentations, he is sure to liven up the awards ceremony if he wins!

宇宙ステーションなど、特殊環境下での火災の抑制に取り組む

燃焼学を専門とし、宇宙船や森林のような特殊な環境下での火災と消火を中心に研究する中村祐二教授。再現が難しい環境における現象を調べるために、中村教授が採用するのが模型実験である。しかし、模型では環境もスケールも実際とは大きくかけ離れている。そうしたなかで同じ現象を再現するためのカギを握るのが、その条件となる「相似則」を導くことだという。こうした一風変わったアプローチによる研究だけでなく、宇宙ステーションのような特殊環境下での消火活動に役立つ、「吸い込み式の消火法」という独創的な開発でも注目を集めている。これらのユニークな取り組みと、大学教育にかける信念について聞いた。

森林火災を食い止めれば、CO_2削減に大きく貢献できる

現在、燃焼学のメインストリームといえば、自動車のエンジンの低燃費化に代表されるように、いかに効率よく燃料を燃やしてエネルギーを取り出すかといった、「燃焼の利用」である。一方、中村教授が手がけるのは燃焼学のなかでも「燃焼の抑制」が中心だ。宇宙ステーションのような特殊な環境下における火災のように、再現が難しい現象を研究対象とするのはなぜなのか。

「確かに燃焼の利用の研究は重要なテーマではありますが、長年にわたり燃焼効率を追究してきた結果、いまや1%の効率アップも難しい状況にあります。そこに注力してもあまり効果的ではありません。一方で、たとえば森林火災の被害は甚大で、年によっても異なりますが、排出されるCO_2は世界のCO_2排出量の約1割にも上ると言われています。つまり、一つでも森林火災の延焼を食い止めることができれば、効率的な燃焼器をつくる以上の効果が得られるわけです。

また、CO_2の削減だけでなく、火災の防止は安心安全な社会の形成には欠かせません。建物の火災はもとより、宇宙船や潜水艦、原子力発電所などでひとたび火災が起きれば甚大な被害が想定されます。もちろん、そうした施設では万全の防火対策が立てられていますが、それでもリスクはゼロではありません。万一、起きてしまった火災を最小に抑えることは、社会に大きなインパクトをもたらします」と、中村教授は研究の意義を語る。

しかし、火災の研究は環境や条件によって結果が大きく異なるうえ、再現性を求める科学としては取り上げにくい。実際に、中村教授も、博士課程で宇宙における火災の基礎研究をテーマにしたいと指導教官に告げると、「学問にならないからやめたほうがいい」とアドバイスされたという。

「指導教官は基礎燃焼学の権威で、先生ができないとおっしゃるのなら、絶対に誰もやらないだろうと思いました。それでやると決意したのです（笑）。どうせやるなら、誰もやっていないことがしたい」

この思いは、いまも変わらない中村教授の原動力である。

異なるスケールの現象の再現に役立つ「相似則」

再現しにくい宇宙での火災を研究の対象とするため、中村教授は模型を使った実験手法を導入している。簡単に言えば、宇宙に行かずして宇宙と同じ状態を、模型を使って再現しようというのである。

「宇宙ステーションの火災をテーマに研究するなかで大変困ったのが、無重力で研究できないことでした。当時、カプセルを落として数秒間だけ無重力状態にする実験の場合、一回に何百万円もかかるため、とうてい手が出せません。実は、無重力下では炎が丸くなるのですが、丸い炎を手に入れるにはどうすればいいのか、自問自答してもなかなか答えは見つかりませんでした。そんな折、留学先の米国で、炎を小さくしていくと炎の形が丸くなるという現象に遭遇したのです。炎を小さくするだけで、浮力の影響を受けにくい状況がつくり出せることを知った衝撃的な瞬間でした」と中村教授。

炎のサイズを変えるだけで、あたかも無重力での火災が再現される。それがなぜなのかを考えていくと、ある法則を満たせばよいことに行きついたという。

「それが相似則です。相似則に従えば、圧力を下げることでも無重力に近づくことが予測できます。そこで、減圧した空間で炎を燃やしてみると、確かに丸くなったのです。つまり、炎を小さくしても、圧力を低くしても、相対的に浮力を弱くすることができれば、無重力下と同じ現象が再現できる、ということ。こうして、地上でも適正な模型実験をすれば、宇宙の火災の研究ができると確信しました」

実はこの原理、特撮で「それらしく見せる仕組み」とまったく同じである。たとえば、映画『ゴジラ』の特撮の現場では、映像として表現したいゴジラの大きさの約25分の1のスケールのミニチュアを使って撮影するが、ゴジラがモノを壊したり、落としたりするシーンでは、4～5倍速で撮影してスローモーションで再現するという。実際の動きよりも速度を落として再生することで、スケールの違いで生じる動きを表現できる、というわけだ。中村教授は、これを数式で表現したものが「相似則」だと説明する。

「ゴジラを例にとれば、最も簡単な『相似則』を満たすと仮定すれば、5倍で撮ればよいということが簡単な計算で導き出せます。特撮のプロ・エンジニアたちは、動きをリアルに見せるためには、その速度が適しているということを経験的に割り出しているんですね」

このように便利な相似則だが、それを見つけ出すのは容易ではないという。もちろん、すでに確立された相似則も多数あり、橋梁模型の振動実験など、さまざまな場面で活用されている。しかし、世の中の物理現象のすべての相似則が解明されているわけではない。ましてや、宇宙での燃焼の相似則など、どこにも書かれていない。

「燃焼の場合は、熱や気流、反応など、現象を支配する要素が多いため、相似則を見つけ出すのがとくに難しい。状況に合わせて相似則を容易に導き出すことができたら、それこそ宇宙のような特殊環境下での火災だけでなく、大規模な山火事を実験室内で再現することができるなど、お手上げとなっている諸問題の解決に大いに役立つはずです」

現状復帰がしやすい吸い込み消火器

しかしながら、先述のように特殊環境下の火災の再現実験ができ、その現象が解明されたとしても、すべてが解決するわけではない。実際の消火活動には、まだ大きな課題が残されている。

現在、宇宙船内での火災には不活性ガス（消火剤）を吹き付けて消火している。一見、何の問題もなさそうに思えるが、場所は超密閉状態の宇宙船内である。そこへ大量に不活性ガスを放出すれば、火は消えるかもしれないが人も窒息して死んでしまう。また、もし小さな炎が残った場合は、有毒ガスが放出され続けるだけでなく、熱がこもるため、それにより精密で高価な機器類が損傷して、宇宙船としての機能も喪失してしまうだろう。

そこで中村教授が提案するのが、「吸い込み消火法」である。吹き消すことに問題があるなら、吸い込んで消せばいい、という逆転の発想である。まさに、「誰もやらないからやってみよう」という中村教授の研究のモットーを体現した研究テーマである。

「船内に高真空の箱があるとします。箱に取り付けられた吸引口の弁を開けると、圧力差によって急激な吸引が生じます。この吸い込み力を使って、船内の炎や燃焼時の有毒ガス、燃えている物体など「すべて」を箱の中に閉じ込めます。後は弁を閉じ、「ゴミ」として宇宙船の外に箱ごと棄てればいい。いわば消火掃除機ですね。水をかけて消すという方法もありますが、消火能力は高くても現状復帰が難しい。吸引消火方式なら消火後の現状復帰も迅速になります。

こんなくだらないことを思いつくのは自分くらいだろうと思っていたら、ある重工業会社が類似した概念特許を持っていて驚きました。これは、火災になっている宇宙船内部の気体をすべて宇宙船外に吸い出して消火させる、というもの。とはいえ、その方法では船内機能の多くを損失するため、被害が大きくなりすぎます。だったら要らないものだけを箱に閉じ込めて捨てる方がいい」と、中村教授はその優位性を主張する。

概念図を書いて論文で発表し、昨年、報道発表したところ、クリーンルームや手術室など、密閉された空間で使えないかといった相談が寄せられた。もし製品化されれば、博物館や美術館などにおける初期消火にも役立ちそうだ。

最後に、中村教授に今後の展望を聞くと、模型実験の教育プログラム化をめざしたい、という答えが返ってきた。

「模型実験はたくさんの数式を扱う必要はなく、作用する力を見つけ出すという物理的センスが期待されます。エンジニアの素養である着眼力・洞察力を鍛えることができ、大学生はもとより、高専生にもたいへん有意義な教育ツールとなります。応用範囲も広い。模型実験理論を通じて、日本の工学教育をサポートしていくことが、私の研究者としてのもう一つの大きな目標です」と、中村教授は締め括った。

（取材・文＝田井中麻都佳）

取材後記

インタビューの終盤、教育への思いを語ってくださった中村教授。きっかけは、学生時代の米国留学にある。米国では、語学をはじめ、研究も金銭面もたいへん苦労したという。

「それこそ365日、大学に通い詰めましたが、得るものもとても大きかった。ところが、日本から遊学に来ていた大学教員も少なくなかった。そういう人たちに日本の大学教育を任せておけないと思いました」と中村教授は語る。

そして、もちろんすべての学生が研究者をめざすわけではないが、と前置きした上で、「知識を詰め込む教育ではなく、自らやりたいことをやって、何か理解することが本当の学びであるということを伝えたい。だからこそ、大学では、どんなにくだらないことでも、学生個々の興味を惹くような、不思議なことを追究する面白い研究をすべきだと思っているのです。面白いと、皆、主体的に取り組みますからね。めざすはイグノーベル賞です（笑）」と、中村教授。プレゼンにも定評のある中村教授なら、授賞式も大いに盛り上げてくれるにちがいない。期待しています！

Researcher Profile

Dr. Yuji Nakamura

Dr. Yuji Nakamura received his M.S. and PhD degree in 1995 and 2000 respectively from Nagoya University, Japan. He started his carrier as an assistant professor at Nagoya University in 2003. He was a visiting researcher at University of California, San Diego in USA from2010 to 2011. He joined at Toyohashi University of Technology in 2014 as an associate professor. Now he is a professor at the Department of Mechanical Engineering, Toyohashi University of Technology.

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 (Ministry of Education, Culture, Sports, Science and Technology).

Human's sense of whole body ownership is partly dependent on spatial placement

Separation of body part ownership from body ownership using virtual scrambled body stimulation

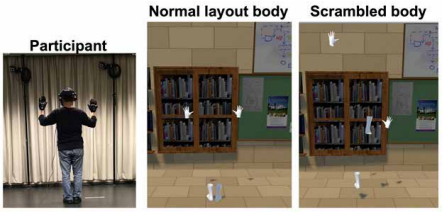
by Ryota Kondo

Differences between whole-body and body-part ownership were clarified using scrambled body stimulation in a virtual environment, wherein the hands and feet of the experiment's participants were presented in randomized spatial arrangements. While moving, the scrambled body stimulation produces a sense of possession of limbs (hands and feet), but possession of the whole body cannot be grasped. Spatial placement is important for the illusion of whole-body ownership. Any individual's sense of possessing their own bodies can thus be said to be affected by the body's spatial arrangement.

A research team consisting of Ryota Kondo (Ph.D. candidate), Yamato Tani (Graduate student), and Professor Michiteru Kitazaki from Toyohashi University of Technology, Associate Professor Maki Sugimoto from Keio University, and Professor Masahiko Inami from The University of Tokyo investigated the difference between the sense of ownership of the whole body and the sense of ownership of body parts using scrambled body stimulation. Only the hands and feet of the experiment's participants were presented, and their spatial arrangement was randomized. It was found that observing the scrambled body stimulus while moving the whole body produces a sense of possession of the body part with respect to the hands and feet, but did not create a sense of possession of the whole body. This result suggests that spatial arrangement is important for the illusion of whole-body ownership. In addition, individual sense of body self-possession may be affected by the spatial arrangement of one's own body. The results of this study were published in the open access journal Scientific Reports on 24th March 2020.

Whole-body ownership is an important phenomenon to examine bodily self-consciousness. However, differences between our sense of ownership of body parts compared to ownership of the whole body are not completely understood as there has been no effective method to separate these senses of ownership.

Therefore, the research team aimed to develop a method to separate the ownership of body parts from the ownership of whole body. Based on their previous study (Kondo et al., Scientific Reports, 2018) on transparent body stimulation, a scrambled body stimulation that randomly rearranges the positions of hands and feet was conducted. Then, in order to compare it with the stimulus of the same arrangement as the normal body, synchronization with the physical movement was controlled.



Experimental participant (left), the corresponding normal placement stimulus (center), and the scrambled body stimulus (right).

In the first experiment, 16 volunteers observed limb-only stimuli from a third-person perspective (2m behind the stimuli) on a head-mounted display. As a result, when vision and physical movement were synchronized, scrambled body stimulation produced only a partial sense of body ownership (It felt as if only the virtual limbs were part of their body), whereas normal placement body stimulation produced both body-part ownership and whole-body ownership (it felt as if the space between the limbs was their body). Similar results were obtained in the second experiment, in which 16 participants observed the stimulus from a first-person perspective.

An example of a normal placement body stimulus synchronized with the movement of the experiment participant, followed by a scrambled body stimulus.

Thus, humans can feel ownership of certain body parts even if the body parts are scrambled, but cannot get a sense of whole-body ownership in this scenario. However, there was no significant difference in any of the skin conductance response measurement for threat stimuli in the third experiment, conducted with 20 participants.

These results suggest that a spatial placement is necessary for a sense of whole-body ownership, but not necessarily for body-part ownership. Therefore, a person's whole body consciousness may be impacted by the spatial arrangement of certain body parts. However, the limitation of this study was that there was no difference in skin conductance (physiological) response to a threat stimulus.

Scrambled body stimulation provides a method to systematically examine the sense of ownership of the whole body and body parts. Moreover, it helps explore the limitations of the illusion of how much we can change our body scheme while retaining a feeling of whole-body ownership.

This research was supported by JST ERATO Grant Number JPMJER1701 (Inami JIZAI Body Project), and JSPS KAKENHI Grant Number P19J12660.

Reference

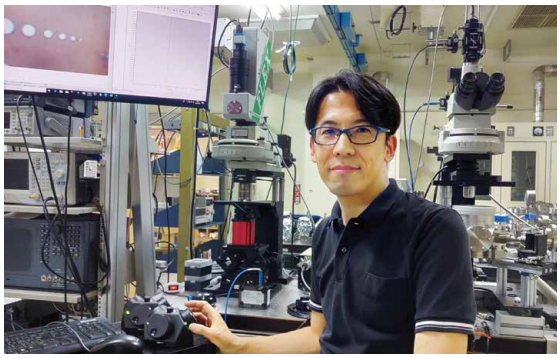
Kondo, R., Tani, Y., Sugimoto, M., Inami, M., and Kitazaki, M. (2020). Scrambled body differentiates body part ownership from the full body illusion. Scientific Reports, 10, DOI: 10.1038/s41598-020-62121-9
www.nature.com/articles/s41598-020-62121-9

Specific detection of molecules using deformation of a single atomic sheet

Towards the development of smartpone-based disease diagnosis technology

By Kazuhiro Takahashi

A research team lead by Associate Professor Kazuhiro Takahashi and Mr. Shin Kidane (Master's student) of the Department of Electrical and Electronic Information Engineering at Toyohashi University of Technology developed a test chip using graphene, a sheet material with a thickness of one carbon atom. The chip has a trampoline structure with a narrow gap of 1 micrometer or less formed under a monoatomic graphene film, and can specifically trap a biomarker, a protein included in bodily fluids such as blood, urine or saliva which is derived from a disease, on graphene. The biomarker adsorbed by the graphene generates force which deforms the graphene into a dome shape. The group thus succeeded in detecting the amount of deformation as changes in color using the interference properties of light. It is expected that viruses and diseases will be able to be simply and quickly examined using the developed test chip.



A measuring device to simply and quickly examine a disease is extremely important for accurate diagnosis, verification of therapeutic effects, and investigation of recurrence and metastasis. If diseases can be examined using a very minute amount of body fluid such as blood or urine, physical condition can be simply, quickly and cheaply controlled. A test technique for determining the presence or absence of a disease by specifically trapping a biomarker on a flexibly deformable thin film formed using semiconductor micromachining techniques, has been investigated. The research team has developed a sensor technique for detecting film deformation caused when a marker molecule is adsorbed as changes in color. As the thickness of the film to adsorb the biomarker decreases, the sensitivity of this sensor element can be increased. It is thus expected that the sensitivity of the sensor will be improved by 1000 times or more using a material called graphene, a material with a thickness of 1 nanometer or less, formed from a single atomic layer.

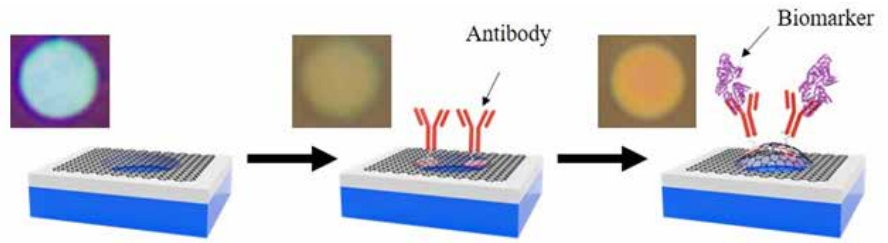
In a previous report using suspended graphene in a bridge shape, however, changes at the time of physical adsorption of a molecule to suspended graphene were measured, and it was difficult to specifically detect the molecule to be measured. As for the reason for this, it is thought that since modification using an antibody to recognize and specifically bind a molecule is commonly carried out in a solution, the suspended structure of graphene was destroyed during the solution treatment.

The research team, therefore, made a trampoline structure in which the unevenness of the substrate was covered with a graphene sheet, as a suspended structure of graphene which could withstand the solution treatment, and were able to modify graphene with an antibody molecule. The surface of the graphene was functionalized with an antibody molecule to provide the ability to recognize a molecule, and an ultrasensitive biosensor which could specifically detect a biomarker was able to be produced.

A light detection technique unique to the research team was used as a technique for detecting a biomarker bound to the surface of the graphene. In a gap of 1 micrometer or less between the suspended graphene and the semiconductor substrate, color is changed depending on the length of the gap by the interference action of light. Using this effect, the appearance of a molecule adsorbed to suspended graphene in a test solution was revealed by changes in color. According to the biosensing technique developed this time, it is expected that sensitivity per unit area will be improved to 2000 times that of conventional sensors.

In addition to blood tests, the research team has also investigated a chemical sensor to detect odors and chemical substances, and feels that the sensor can be applied to a novel compact sensor device contributing to IoT society. The sensor can be applied to the detection of various biomarkers and also to the detection of viruses by changing the probe molecules modifying the surface of the graphene.

This work was supported by Grant-in-Aid for Scientific Research (B), Innovative nano-electronics through interdisciplinary collaboration among material, device and system layers (JPMJPR1526) from the Precursory Research for Embryonic Science and Technology of Japan Science and Technology Agency, and the Uncharted Territory Challenge 2050 from New Energy and Industrial Technology Development Organization (NEDO).



Schematic images and electron microscope photograph of sulfur-carbon composites (upper). Schematic images and cycle characteristics of all-solid-state sulfur battery (lower)

Reference

Shin Kidane, Hayato Ishida, Kazuaki Sawada, Kazuhiro Takahashi, A suspended graphene-based optical interferometric surface stress sensor for selective biomolecular detection, Nanoscale Advances, 2, 1431-1436 (2020) DOI: 10.1039/C9NA00788A

Radio interference cancellation with High Precision, High Speed and Low Computational complexity

Promising Applications for Next-generation Wireless Communications

By Yuichi Miyaji

The research team of Assistant Professor Miyaji of the Department of Electrical and Electronic Information Engineering at Toyohashi University of Technology has developed a self-interference cancellation filter that is indispensable for the realization of in-band full duplex using the same frequency to transmit and receive simultaneously in wireless communications. The developed self-interference cancellation filter can estimate the distortion caused by radio and the distortion of the radio channel with high areach the solution of the filter with low computational complexity. It is expected to be applied to next-generation wireless communication technology.

In wireless communication, simultaneous transmission and reception using the same frequency (in-band full duplex) is a very challenging task. Even in the latest wireless communication standard 5G, this in-band full duplex has not been implemented. Currently, it is necessary to divide the time when transmitting and receiving at the same frequency, or to divide the frequency when transmitting and receiving at the same time. It is necessary to separate one of them (time or frequency) because the strength of the radio wave that it emits is up to several hundred million times greater than the strength of the radio wave to receive (self-interference).

The filters that have been developed so far to tackle multiple distortions remove the self-interference with high precision, but also require high computational complexity and take a long time to obtain the solution of the filter. Therefore, the research team of Assistant Professor Miyaji worked on the development of a self-interference cancellation filter that simultaneously satisfies the conditions of high precision, high speed, and low computational complexity.

The first author, Kazuki Komatsu, in the doctoral program (JSPS Research Fellow), explains, “Compared to base stations, low-cost radios such as smartphones have complex distortions, and self-interference cancellation in such devices is a very difficult problem. To solve a complex problem, it is important to boil the problem down to its essence and break it down into multiple smaller problems. We have divided the problem of self-interference cancellation due to the complex distortion of radio equipment into five smaller problems and expressed each using mathematical operators. As a result, it became clear that the solution method of each small problem and the solution method of the big problem which connected them could be derived using five operators and their inverse operators. By applying the derived solution to a filter, we were able to cancel self-interference with higher precision, higher speed, and lower computational complexity than before. The developed filter increases the feasibility of in-band full-duplex communications in small and inexpensive radios such as smartphones.”

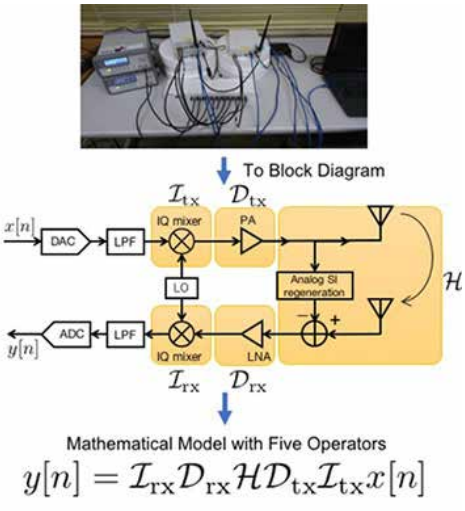
The research team is planning theoretical performance analysis and field evaluation of the developed self-interference cancellation filter. They also believe that by using the developed filter, it can be applied to wireless networks that cooperate with small mobile objects such as drones. Since it is necessary to recreate the filters periodically according to changes in the radio environment due to movement, we anticipate significant contributions from this technology, which has the features of high precision, high speed, and low calculation complexity.

This research was supported by Hoso Bunka Foundation and Japan Society for the Promotion of Science (JSPS) KAKENHI (JP18K04138, JP19K14979, and JP19J12727).

Reference

Kazuki Komatsu, Yuichi Miyaji, and Hideyuki Uehara (2020). Iterative Nonlinear Self-Interference Cancellation for In-Band Full-Duplex Wireless Communications Under Mixer Imbalance and Amplifier Nonlinearity,

IEEE Transactions on Wireless Communications, DOI:10.1109/TWC.2020.2983407.

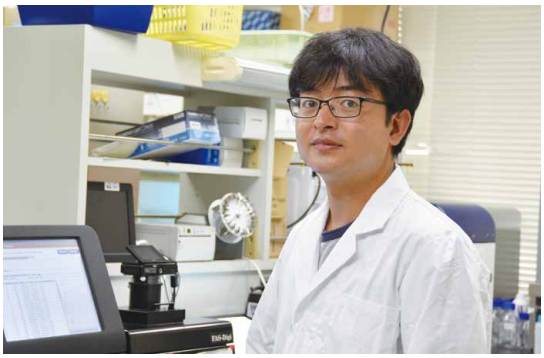


In-band full-duplex transceiver (top), circuit block model of transceiver (middle), mathematical model using five operators (bottom)

Revealed the microbial community structures around Antarctic lakes

By Yuu Hirose

Prof. Yuu Hirose of the Department of Applied Chemistry and Life Science at Toyohashi University of Technology and his joint research group, comprising members from Niigata University, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and the National Institute of Polar Research, have revealed the community structure of microorganisms living around freshwater lakes in the Langhovde and Skarvsnes ice-free areas of Antarctica. An analysis of samples collected from areas such as lake shores and puddles using a next-generation sequencer has verified that cyanobacteria and tardigrades are widely distributed and specific eukaryotic algae are dominant in certain sites. This knowledge will contribute to a better understanding of adaptation mechanisms of microorganisms to severe physical stresses in Antarctica, e.g. low temperatures, ultraviolet irradiation and freeze-thaw cycles.



Most of Antarctica is covered with thick snow and ice, but there are some ice-free areas, known as “Antarctic oases”, where the land is exposed. These ice-free areas occupy only about 0.2% of the area in Antarctica, but a variety of microorganisms have been observed. Two such areas, Langhovde and Skarvsnes, are close to Showa Station, Antarctica, and there are 50 or more lakes of various sizes in these areas (Fig.1). Water at the bottom of these lakes remains unfrozen throughout the year and a unique ecosystem called “moss pillar,” that mainly includes moss and fungi, is distributed.

Assistant Prof. Yuu Hirose and others of the Department of Applied Chemistry and Life Science at Toyohashi University of Technology focused on the shores of freshwater lakes and also puddles and streams from snow meltwater. These environments are completely frozen during the winter season and accordingly are under more extreme stress (e.g. freezing and thawing and temperature changes), than those at the bottom of lakes.

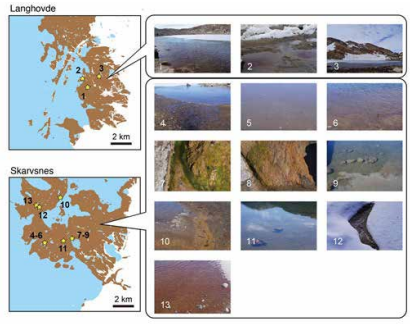


Fig. 1 Sites of sample collection

In recent years, a technique for analyzing microbial community structure in environments using a next-generation sequencer has been developed. This method has a higher sensitivity and better quantitative properties than those of conventional techniques such as microscope observation. Assistant Prof. Hirose used this method to analyze microbial community structures at a total of 13 sites in the vicinity of Antarctic freshwater lakes (Fig.2).

The results revealed that filamentous cyanobacteria were widely distributed, and also that the proportion of unicellular cyanobacteria and cyanobacteria with cell differentiation capacity (called heterocysts - cells dedicated to nitrogen fixation in filamentous cyanobacteria and formed mostly under nitrogen-deficient conditions) was small. The most widely distributed eukaryote was tardigrades with resistance to dryness and low temperatures. It was verified that specific eukaryotic algae such as cryptophyceae and green algae were dominant in some sites. There were also sites including nematodes feeding on algae. It is interesting that the fungi most dominant in moss pillars were not in the majority in these areas. The above results revealed that even in environments under extreme stress such as the borders of lakes or streams, a variety of organisms can survive.

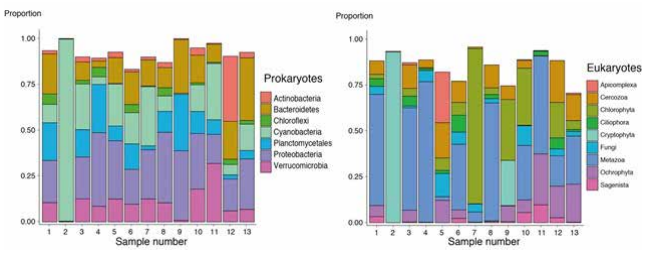


Fig. 2 Proportion of taxa of prokaryotes (left) and eukaryotes (right) identified in this study

It is expected that further study will be able to add greater clarity to the molecular mechanism that microorganisms living in these areas use to adapt to severe stresses. It is important to clarify the relationship between environmental factors, such as temperature and light conditions, and community structures of microorganisms. The monitoring and maintenance of the Antarctic ecosystem based on this information is also a valuable goal.

This work was supported by JSPS KAKENHI Grant Number JP15H05712, “Plankton in polar regions -toward an understanding of their characteristics (representative: Naomi Harada).” The collection of samples was conducted as ordinary research observations of the 60th Japanese Antarctic Research Expedition.

Reference

Investigating Algal Communities in Lacustrine and Hydro-Terrestrial Environments of East Antarctica using Deep Amplicon Sequencing. Hirose, Y., Shiozaki, T., Otani, M., Kudoh, S., Imura S., Eki, T., Harada, N., Microorganisms 2020, 8(4), 497, doi.org/10.3390/microorganisms8040497

全身所有感は身体各部位の所有感の単なる合計ではない

スクランブル身体刺激を用いた全身所有感から身体部位所有感の分離

近藤　亮太

豊橋技術科学大学と東京大学、慶應義塾大学の研究グループは、バーチャルリアリティ空間でのスクランブル身体刺激を用いて全身所有感と身体部位所有感の違いを明らかにしました。スクランブル身体刺激とは、観察者の手と足のみを提示し、それらの空間的配置をランダムにしたものです。全身を動かしながらスクランブル身体刺激を観察すると手と足に対する身体部位所有感は生じますが、全身所有感を感じることはできず、全身所有感には通常の身体と同様の空間的配置を持つ身体刺激が必要でした。この結果は、全身所有感の錯覚には空間的配置が重要であることを示唆します。また、人の身体的自己意識は、通常の人がもつ身体の空間的配置に影響を受けている可能性があります。

豊橋技術科学大学の大学院生である近藤亮太（日本学術振興会DC特別研究員）と谷大和、研究指導教員の北崎充晃教授、および慶應義塾大学の杉本麻樹准教授、東京大学の稲見昌彦教授による研究グループは、バーチャルリアリティ空間でのスクランブル身体刺激を用いて全身所有感と身体部位所有感の違いを明らかにしました。この研究成果は、2020年3月24日にScientific Reports誌に発表されました。

バーチャルリアリティを用いて、身体運動に同期させてバーチャルな身体の視覚映像を見せることで身体所有感の錯覚を生じさせることができます。研究グループは、2018年5月に手と足のみを提示して身体運動と同期させることで透明な身体を知覚させることができることを示しました(Kondo, et al., Scientific Reports, 2018)。その研究では、バーチャルな手と足に所有感を感じると同時に、それらを補間する身体全体に所有感が感じられました。

全身所有感は、人の身体性自己意識を調べるために重要な現象とされています。しかしながら、身体部位への所有感と身体全体への所有感の違いについては完全には分かっていません。それは、この2つの所有感を分離する良い方法が見つかっていないからです。

そこで、研究グループは、全身所有感から身体部位所有感を分離する方法を開発することを目指しました。彼らの先行研究の透明身体刺激をもとに、手と足の位置をランダムに再配置してしまうスクランブル身体刺激を作成しました。そして、それを通常の身体と同じ配置の刺激と比較する実験を行いました。

最初の実験では、16人の成人が手足のみの刺激をその2m後ろから頭部搭載型ディスプレイで観察しました（三人称視点）。その結果、視覚と身体運動が同期しているとき、スクランブル身体刺激は身体部位所有感のみを生じますが（バーチャルな手足のみが自分の身体の一部であると感じる）、通常配置身体刺激は身体部位所有感と全身所有感（手足の間の空間に透明な全身を感じる）の両方を生じました。一人称視点から刺激を観察した実験でも同様の結果が得られました（実験参加者16名）。つまり、身体をばらばらに分解してランダムに配置しても各身体部位に対する所有感は生じますが、全身を所有している感覚は生じません。ただし、脅威刺激に対する皮膚コンダクタンス反応計測実験については、どの条件の間にも有意な差は見られませんでした（実験参加者20名）。

これらの結果は、身体部位の空間的配置が適切であることが全身所有感に必要ですが、身体部位所有感には必ずしも必要ではないことを示唆します。したがって、人の身体性自己意識は通常の身体部位の空間的配置に制約されている可能性があります。ただし、本研究には、皮膚コンダクタンス反応では差が見られなかったという限界があります。

スクランブル身体刺激は、全身所有感と身体部位所有感について体系的に調べる方法となり得ます。そして、全身所有感の錯覚の限界、つまり人は全身所有感を保持しながらどこまで自らの身体図式を変えることが可能かを調べることに貢献します。

原子の単層シートの変形を利用して分子の特異的検出に成功

スマートフォンを利用した病気診断技術に向けて

高橋　一浩

豊橋技術科学大学電気・電子情報工学系の髙橋一浩准教授、喜種慎氏（博士前期課程）らは、炭素原子1個分の薄さでできたシート素材、グラフェンを用いた検査チップを開発しました。グラフェンの単原子膜の下には1マイクロメートル以下の狭い隙間が形成されたトランポリン構造をしており、血液や尿、唾液などの体液中に含まれる病気由来のたんぱく質であるバイオマーカーをグラフェンの上で特異的に捕まえることを可能とします。グラフェンに吸着したバイオマーカーは、グラフェンをドーム状に変形させる力を発生するため、変形した量を光の干渉特性を利用して色の変化として検出することに成功しました。開発した検査チップで、ウイルスや病気の検査を簡易かつ迅速に行えることが期待されます。

病気の検査を簡易かつ迅速に行う計測装置は、正確な診断や治療効果の検証、再発や転移の調査をするために極めて重要です。ごく微量の血液や尿などの体液から病気の検査が行えるようになれば、簡単・迅速・安価に体調管理が可能になります。半導体マイクロマシン技術を用いて形成したフレキシブルに変形する薄膜の上に、バイオマーカーを特異的につかまえて、病気の有無を判断する検査技術が研究されています。研究グループでは、マーカー分子が吸着したときに発生する膜変形を色の変化として検出するセンサ技術を開発しています。このセンサ素子はバイオマーカーを吸着する膜を薄くするほど感度を向上することができるため、原子一層で構成されているグラフェンと呼ばれる膜厚1ナノメートル以下の材料を用いることで、センサの感度を1000倍以上に向上することが期待されます。

しかしながら、グラフェンをブリッジ状に架橋した従来の報告では、分子が架橋グラフェン上に物理的に吸着した際の変化を測定しており、測定対象の分子を特異的に検出することが困難でした。分子を認識して特異的に結合する抗体の修飾は一般的に溶液中で行うため、この溶液処理中にグラフェンの架橋構造が破壊されることが原因と考えられています。

そこで、研究チームでは、溶液処理に耐えうるグラフェンの架橋構造として、グラフェンシートで基板の凹凸構造を覆ったトランポリン構造を作製し、グラフェン上に抗体分子の修飾を行うことができました。抗体分子でグラフェン表面を機能化することによって分子を認識する能力が与えられ、バイオマーカーを特異的に検出可能な超高感度バイオセンサが実現できました。

また、グラフェン表面に結合したバイオマーカーを検出する技術は、研究チーム独自の光検出技術が用いられています。架橋グラフェンと半導体基板の間に作られる1マイクロメートル以下の隙間では、光の干渉作用により隙間の距離によって色が変化します。この効果を利用して、検体溶液中での架橋グラフェンへの分子が吸着する様子を色変化から明らかにしました。

今回開発したバイオセンシング技術により、単位面積当たりの感度が従来センサと比較して2000倍に向上すると期待されます。

研究チームは、血液検査のほかにも、においや化学物質を検出する化学センサを研究中で、IoT社会に貢献する新しい小型センサ装置に適用可能であると考えています。グラフェン表面に修飾するプローブ分子を付け替えることによって、様々なバイオマーカーを検出するとともにウイルスの検出などへの応用が可能になります。

本研究は、文部科学省科学研究費（基盤研究(B)）、国立研究開発法人科学技術振興機構（JST）さきがけ素材・デバイス・システム融合による革新的ナノエレクトロニクスの創成（JPMJPR1526）及び　国立研究開発法人新エネルギー・産業技術総合開発機構（NEDO）　未踏チャレンジ2050の助成によって実施されました。

高精度、高速、低計算量で電波干渉を除去

次世代無線通信への応用に向けて

宮路　祐一

豊橋技術科学大学電気・電子情報工学系の宮路助教らの研究チームは、無線通信において、同じ周波数を使用して同時に送受信する帯域内全二重の実現に不可欠な、自己干渉除去フィルタを開発しました。開発した自己干渉除去フィルタは、無線機によって生じる歪みと無線チャネルの歪みを高精度に推定し、自己干渉を除去することができます。加えて、少ない計算回数で高速にフィルタの解にたどりつくことができます。次世代の無線通信技術への応用が期待されます。

無線通信において、同じ周波数を使用して同時に送受信すること（帯域内全二重）は非常に難しい課題です。最新の無線通信規格5Gにおいても、この帯域内全二重は実現されていません。現状、同じ周波数で送受信する場合は時間を分けるか、同時に送受信する場合は周波数を分ける必要があります。どちらか一方（時間もしくは周波数）を分ける必要があるのは、自身の放射する電波の強さが、受信したい電波の強さに対して最大で数億倍も大きいためです（自己干渉）。

これまでに開発されている複数の歪みを考慮したフィルタは、精度よく自己干渉を除去する一方で、計算回数が多く、フィルタの解を得るために長い時間を要していました。そこで、宮路助教らの研究チームは、高精度、高速、低計算量を同時に満たす自己干渉除去フィルタの開発に取り組みました。

筆頭著者である博士後期課程（JSPS特別研究員）の小松和暉は、「基地局に比べて、スマートフォンなどの低コストの無線機は複雑な歪みを有しており、そのような機器における自己干渉除去は非常に難しい問題です。複雑な問題を解くために、問題の本質を突き詰め、複数の小さな問題へ分解することが重要です。我々は、無線機の複雑な歪みを受けた自己干渉除去という問題を、五つの小問題へ分解し、それぞれを数学の演算子を用いて表現しました。その結果、各小問題の解法や、それを繋ぎ合わせた大問題の解法は、五つの演算子とその逆演算子を使って導出できることを明らかにしました。導出された解法をフィルタに応用することで、従来に比べて、高精度、高速かつ低計算量で自己干渉を除去できました。開発したフィルタによって、スマートフォンなどの小型で安価な無線機における帯域内全二重通信の実現可能性が高まります。」と説明します。

研究チームは、開発した自己干渉除去フィルタの理論的な性能解析やフィールド実験での性能評価を計画しています。また、開発したフィルタを利用することで、ドローンなどの小型移動体が連携する無線ネットワークへの適用が可能だと考えています。これらは、移動による環境の変化に合わせてフィルタを定期的に作り直す必要があるため、高精度、高速、低計算量な特長を併せ持つ本技術の貢献が期待できます。

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南極の湖沼周辺に生息する微生物の群集構造を解明

広瀬　侑

豊橋技術科学大学応用化学・生命工学系広瀬侑助教、新潟大学、海洋研究開発機構、国立極地研究所らの研究グループが、南極のラングホブデおよびスカルブスネス露岩域の湖沼周辺に生息する微生物の種類と組成（群集構造）を明らかにしました。湖沼の岸辺や水たまり等から採取した試料を次世代シークエンサーを用いて解析したところ、シアノバクテリアやクマムシが幅広く分布することや、特定の真核藻類の優占が確認されました。これらの知見は、南極大陸に生息する生物の有する低温・紫外線・凍結融解等のストレスへの適応機構の解明につながることが期待できます。

南極大陸のほとんどは厚い雪氷に覆われていますが、沿岸には陸地が露出した露岩域が存在します。露岩域は、南極大陸の面積の僅か0.2%程度ですが、微生物を中心とする多様な生物が確認され、南極のオアシスとも呼ばれています。南極の昭和基地の近辺には、ラングホブデ（Langhovde）とスカルブスネス（Skarvsnes）と呼ばれる2つの露岩域が存在し、これらの地域には大小50以上の湖沼が存在します（図1）。これらの湖沼の底は一年を通して水が凍らず、「コケ坊主」と呼ばれるコケや真菌などを中心とするユニークな生態システムが分布することが日本のグループによって発見され、研究が進められてきました。

豊橋技術科学大学応用化学・生命工学系の広瀬侑助教らは、海洋研究開発機構、新潟大学、国立極地研究所との共同研究により、コケ坊主が生息する湖沼の底よりも浅い水辺や、雪解け水によって生じた水たまりや小川に着目して堆積物の採取を行いました。これらの環境は、冬期には完全に凍ってしまうため、凍結融解や温度変化など、湖底よりも激しいストレスにさらされると考えられます。

近年、環境中の微生物の種類と組成（群集構造）を解析する手法として、次世代シークエンサーを用いて環境中に含まれるリボソームRNAの遺伝子配列を解析する手法が発展しています。この方法は、顕微鏡による観察や、生物の分離を含む手法よりも感度が高く、定量性に優れています。広瀬助教は今回、日本の研究グループとしては初めてこの解析手法を南極湖沼近辺の解析に取り入れ、合計１３地点の微生物群集構造を解析しました（図2）。

その結果、細胞が数珠つなぎに連なった形態のシアノバクテリアが幅広く分布することが明らかとなりました。また、単細胞のシアノバクテリアや、ヘテロシストと呼ばれる細胞分化能を持つシアノバクテリアの割合は少ないことが明らかとなりました。真核生物でもっとも幅広く分布していたのは、乾燥および低温耐性を有するクマムシでした。クリプト藻類や緑藻といった特定の真核藻類の優占が一部の地点で確認されました。藻類を食べるタイプの線虫が含まれる地点もありました。興味深いことに、「コケ坊主」でもっとも優先していた真菌類は、これらのエリアではあまり見られませんでした。以上の結果により、湖沼の浅い部分や、水たまりや小川といった厳しい環境条件でも、多様な生物が生息していることがわかりました。

今後は、これらの領域に生息する微生物が低温・紫外線・凍結といったストレスにどのように適応してきたのか、その分子機構の解明が期待されます。また、温度や光条件など、環境因子と微生物群集との関係の詳細を明らかにしていくことも重要です。これらの情報に基づいて、南極の生態系のモニタリングや保全を進めていくことも重要だと考えられます。

本研究は、JSPS科研費JP15H05712「極域プランクトン－その特質の理解－（代表者：原田尚美）」の助成を受けたものです。また、試料の採取は第60次南極地域観測隊の一般研究観測として実施されました。

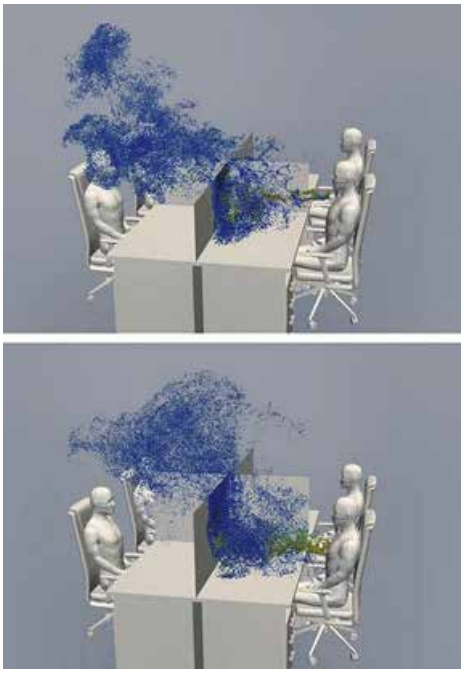
Pick Up

Tackling the challenges of the COVID-19 reality

Predicting virus droplet infection in indoor environments using the world's fastest supercomputer "Fugaku"

RIKEN (Institute of Physical and Chemical Research), in collaboration with MEXT (Ministry of Education, Culture, Sports, Science and Technology), has been providing the computational resources of the world's fastest supercomputer "Fugaku" (named after Mt. Fuji) to accelerate research and development that will contribute to countermeasures against COVID-19.

Professor Akiyoshi Iida and Assistant Professor Tsukasa Yoshinaga of the Department of Mechanical Engineering of Toyohashi University of Technology, as members of the research team of RIKEN, are making a significant contribution to the "Prevention and countermeasures of virus droplet infection in indoor environments" by using the supercomputer for simulations.



- RIKEN Channel: Prediction of virus droplet infection in indoor environments and its countermeasures (Japanese) https://www.youtube.com/watch?v=Z6EbAO3nLy8&t=179s
- The Asahi Shimbun: Supercomputer deduces partition height to prevent virus spread http://www.asahi.com/ajw/articles/13440482

Mapping the social impact of COVID-19 using social media

Assistant Professor Mitsuo Yoshida of the department of Computer Science and Engineering of Toyohashi University of Technology, has undertaken an analysis of tweets on the Twitter, in order to examine how COVID-19 has become a social topic, how it is being debated and how it is affecting people.

A study analyzing Twitter users tweets relating to COVID-19 clarified that February 28, 2020, when the first cases of coronavirus were reported in Japan and a state of emergency was declared in Hokkaido marked a crossroads moment. Whereas prior to that moment corona related tweets had only been found among specific communities (a small number of biased users), after that point such tweets became commonplace across the wider Twitter community (the end of user bias). Another study of about 186 million COVID-19-related tweets on Twitter from January to early June found that the biggest peak in the expression of negative emotions such as "scary" and "disgusting" occurred immediately after Ken Shimura's death at the end of March.

Studying emotional words included in tweets to analyze how people feel about the COVID-19 showed how the occurrence of a particular social event can change the emotions expressed on social media. Data obtained through this kind of study may help to clarify the change in people's emotions and could be a useful resource for future decisions on infection prevention measures.

- Social Emotions Under the Spread of COVID-19 Using Social Media, DOI: 10.1527/tjsai.F-K45a https://www.jstage.jst.go.jp/article/tjsai/35/4/35_F-K45/_article/-char/ja/
- Asahi DIGITAL: Immediately after Ken Shimura's death, negative tweets exploded(Japanese) https://www.asahi.com/articles/ASN6N5FDTN6CUTIL00L.html
- Japanese COVID-19 Tweets from 2020-01-17 to 2020-04-30 https://zenodo.org/record/3892867#.X3qnBi0_Cf4

TUT Research
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