Industry UCB UEC Keio Workshop 2019

IUUKWS 2019

Symposium space and
large meeting room, Raiosha,
Keio University Hiyoshi campus

December 10–11

[Tue] 9:30

[Wed] 17:20

CONTENTS

WELCOME

Welcome to the Industry-UCB-UEC-Keio Workshop 2019 (IUUKWS 2019). This workshop follows the Industry-UCB-UEC Workshop 2017 (IUUWS 2017) held at the University of Electro-Communications (UEC) in Tokyo, Japan in March 2017 and IUUWS 2018 held at the University of California, Berkeley in November 2018. The motive for holding this workshop and the previous workshops is globalization, which is part of the strategic plan of UEC and a part of the tradition of UC Berkeley's College of Engineering. I am pleased that Keio University is joining us this year. Keio is a special institution for Berkeley colleagues. I myself am an alum of Keio, Professor Kohei Ito and Professor Tomoko Shimizu, Faculty of Science and Technology at Keio, who contributed to the planning of this year's workshop obtained their PhD degrees from Berkeley, and there have been many visitors and exchange students from Keio at Berkeley in various departments.

I consider this workshop as a step towards developing a bottom up collaborative relationship between UCB, UEC and Keio. Presentations will be made by UCB, UEC, Keio faculty members and industrial leaders in selected areas of common interest: Bio-Engineering, Future luminary for sustainable society, Semiconductor Materials and Systems, Robotics and Engineering for High-Quality Life Services.

I hope that you will find this workshop stimulating and rewarding both technically and socially.

Again, welcome to the Industry-UCB-UEC-Keio Workshop 2019.

Masayoshi Tomizuka
Cheryl and John Neerhout, Jr. Distinguished Professor
Associate Dean for Faculty
College of Engineering
University of California, Berkeley

Welcome to
The INDUSTRY-UCB-UEC-KEIO WORKSHOP 2019

Takashi Fukuda
President
The University of Electro-Communications

Welcome to the Industry-UCB-UEC-KEIO Workshop 2019 (IUUKWS 2019). As one of the organizers, I would like to extend my appreciation to all of you for attending this workshop.

The University of Electro-Communications celebrated its 100th anniversary last year, and I have declared my determination "to continue to be a knowledge creation base under the dynamism of education and research related to Comprehensive Communication Sciences Initiatives, and continue to return that knowledge to society."
Also, we are pursuing our "D.C.& I" education and research strategy to promote multifaceted collaboration and co-creation based on the recognition that open innovation is indispensable for the advancement of education and research, with the long term goal of creating disruptive innovation (I) based on multidimensional diversity (D) and communication (C) to catalyze mutual inspiration.
The University of California, Berkeley (UCB) is of course one of the top universities in the United States, and has contributed to the promotion of innovation as a leading academia institution that played a leading role in the Internet revolution that started in Silicon Valley in the 1980s and even now, UCB has an excellent track record for creating new industrial models that are represented by "GAFA".
Based on the mutual respect between UCB and UEC for their research and development efforts, in September 2015 the two universities concluded a "Comprehensive Agreement" and decided to co-organize the "Workshop on Constructing a Service Infrastructure Technology Platform for Realization of 'Ultra- Smart Societies'". The first IUUWS 2017 was held at UEC in March 2017, and IUUWS 2018 at UCB in November 2018. Both workshops were very successful.
And this third workshop (IUUKWS 2019) is being held at Keio University, one of Japan's top private universities, and like UEC, Keio University was selected by the Ministry of Education, Culture, Sports, Science and Technology for "the program for promoting the enhancement of research universities".
The IUUKWS2019 is being held at the Hiyoshi Campus of Keio University with the participation of the Keio University Faculty of Science and Technology, which is widely recognized for its contributions to the advancement of science and engineering. Notably, this year is the 80th anniversary of the Keio University Faculty of Science and Technology and this workshop is one of its commemorative events.

This workshop is being sponsored by Keio Mirai-sendo Program and Keio University Spintronics Research Center, with support from Keio Engineering Foundation and UEC Alumni Association MEGUROKAI. I am deeply grateful for this support for IUUKWS2019.

In addition to Plenary lectures by researchers from companies, the workshop will include presentations on recent advances in areas such as material science, bioengineering, control systems, optoelectronics, and quantum information.
Notably, this time we have established a student poster session to give students the opportunity to interact with researchers and industrialists to present and discuss their research findings.
I am confident that IUUKWS2019 will be fruitful experience for all.

November 25, 2019

Welcome from Keio

It is our pleasure to welcome you to Keio University for the Industry-UCB-UEC-Keio Workshop 2019. This workshop follows the Industry-UCB-UEC Workshop 2018 held at UC Berkeley and the Industry-UCB-UEC Workshop 2017 held at University of Electro-Communications. We are especially delighted to host this event because the Chair of the Workshop, Professor Tomoko Shimizu, and I obtained our master's and Ph. D. degrees from UC Berkeley College of Engineering. We are also happy to welcome two distinguished plenary speakers, Mr. Peter Fitzgerald of Google Japan and Dr. Koji Sato of Hitachi Metals.

The following famous lead sentence of the book *An Encouragement of Learning* written by Yukichi Fukuzawa in 1871, represents the spirit of establishment of Keio University. "It is said that heaven does not create one man above or below another man. Any existing distinction between the wise and the stupid, between the rich and the poor, comes down to a matter of education." Fukuzawa founded Keio in 1858, to teach the importance of freedom, equality, and human rights in the transition from a feudal nation to modern Japan. He also stressed the important role of scientific and logical thinking for advancing our civilization. This educational philosophy continues to lie in the heart of every member of Keio University today and resonates with the spirit of the San Francisco Bay Area.

This Workshop is also a part of a series of events held in commemoration of the 80th anniversary of Faculty of Science and Technology of Keio University. We are delighted to host this workshop and thank UEC and our UCB colleagues who have helped us greatly to host this event.

Kohei Itoh
Professor, Faculty of Science and Technology
Keio University

TOPICS: Each topic is listed in accordance with "Society 5.0"

I. Control Systems
II. Bio Engineering
III. Quantum Information
IV. Materials Science 1
V. Materials Science 2

SPEAKERS

Industry
Plenary Lecture
Peter Fitzgerald, Google Japan

Closing Session
Koji Sato, Hitachi Metals Ltd.

Session
1) Pushkar Hingwe, Intuitive Surgical G.K.
2) Rudy Raymond, IBM Japan Ltd.

UCB
1) Masayoshi Tomizuka, Mechanical Engineering,
2) Gerald Marriott, Bio Engineering,
3) Hannah Stuart, Mechanical Engineering,
4) Junqiao Wu, Materials Science an Engineering,
5) Oscar Dubon, Materials Science an Engineering,

UEC
1) Osamu Kaneko, Mechanical Engineering and Intelligent Systems,
2) Masayuki Katsuragawa, Applied Physics and Chemistry,
3) Takeyoshi Tajiri, Computer and Network Engineering,

Keio
1) Seiichiro Katsura, System Design,
2) Kosuke Tsukada, Applied Physics and Physico-Informatics,
3) Kento Sasaki, Applied Physics and Physico-Informatics,
4) Takasumi Tanabe, Electrical Engineering,

Santa Clara University
Yuling Yan, Bio Engineering,

RIKEN
Satoshi Iwano, Bio Engineering,

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- Sponsorship Coordinator ---------- Kazushi NAKANO
Kazuo UCHIDA
- Local Arrangement ----------All committee members

＜Committee Members＞

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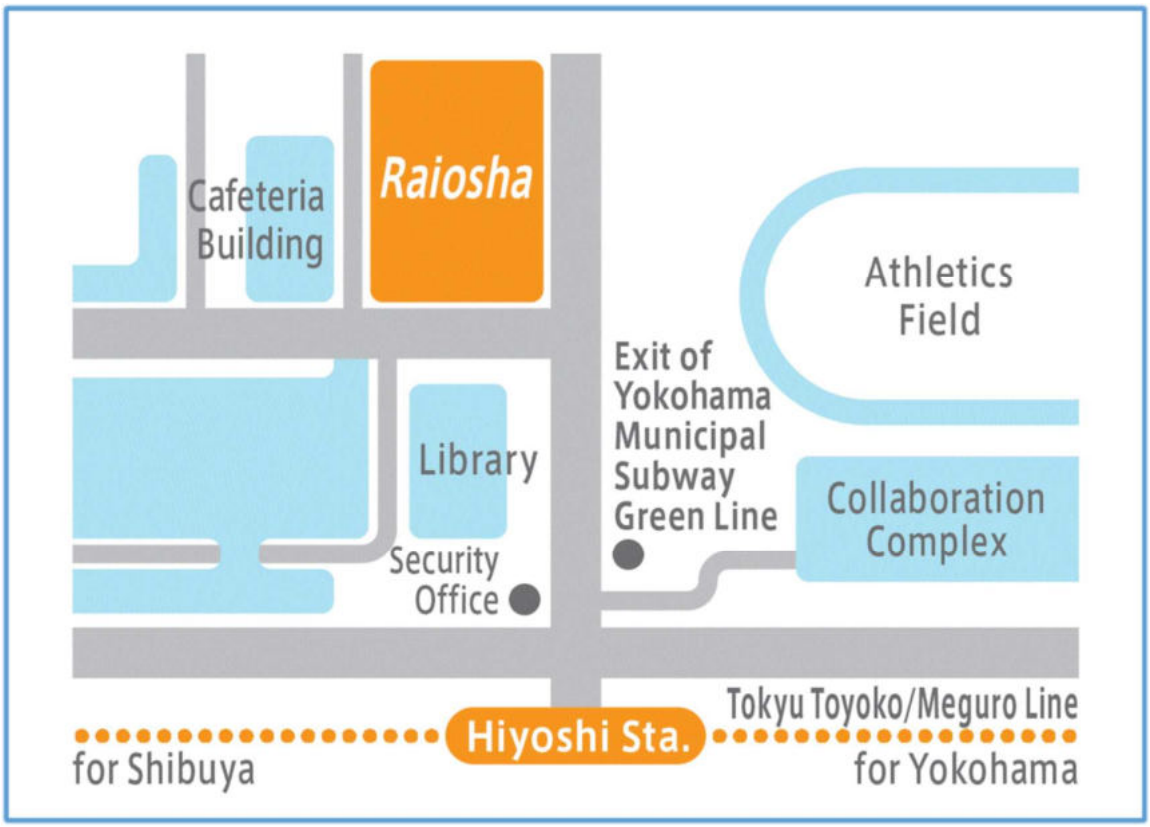
Takashi FUKUDA
Kazushi NAKANO
Kohei M. ITOH
Kazuo UCHIDA
Tomoko K. SHIMIZU
Shojiro MAKI

VENUE



Raiosha Symposium Space,
Hiyoshi campus,
Keio University, Yokohama

WORKSHOP SCHEDULE

Workshop Day 1: December 10

9:30-10:00 Registration
10:00-10:05 Opening Address Prof. Fukuda, President, UEC
10:05-10:15 Welcome Speech Prof. Okada, Dean of Faculty of Sci. & Tech., Keio
Prof. Nakano, Member of the Board of Directors, UEC

Session 1 (Topic: Control Systems) Chair: Kiminao Kogiso, UEC
10:15-10:45 Masayoshi Tomizuka, Mechanical Engineering, UCB
10:45-11:05 Seiichiro Katsura, System Design, Keio
11:05-11:25 Osamu Kaneko, Mechanical Engineering and Intelligent Systems, UEC
11:25-11:55 Pushkar Hingwe, Intuitive Surgical G.K.

11:55-12:00 Group Photos

12:00-13:20 Lunch Break

Session 2 (Topic: Bio Engineering) Chair: Shojiro Maki, UEC
13:20-13:50 Gerald Marriott, Bio Engineering, UCB
13:50-14:10 Kosuke Tsukada, Applied Physics and Physico-Informatics, Keio
14:10-14:40 Yuling Yan, Bio Engineering, Santa Clara University

14:40-15:10 Coffee Break

15:10-15:40 Hannah Stuart, Mechanical Engineering, UCB
15:40-16:00 Satoshi Iwano, UEC-RIKEN

16:15-17:45 Poster Session@ Large meeting room

18:00-20:00 Banquet (Faculty Club)

Workshop Day 2: December 11

Session 3 (Topic: Quantum Information) Chair: Tomoko Shimizu, Keio
9:30-10:00 Rudy Raymond, IBM Japan Ltd.
10:00-10:20 Kento Sasaki, Applied Physics and Physico-Informatics, Keio
10:20-10:40 Masayuki Katsuragawa, Applied Physics and Chemistry, UEC

10:40-11:00 Coffee Break

Session 4 (Topic: Materials Science 1) Chair: Kazuo Uchida, UEC
11:00-11:30 Junqiao Wu, Materials Science an Engineering, UCB
11:30-11:50 Takasumi Tanabe, Electrical Engineering, Keio
11:50-12:10 Tetsuo Kan, Mechanical Engineering and Intelligent Systems, UEC

12:10-13:30 Lunch

Session 5 (Topic: Materials Science 2) Chair: Tomoko Shimizu, Keio
13:30-14:00 Oscar Dubon, Materials Science an Engineering, UCB
14:00-14:20 Takeyoshi Tajiri, Computer and Network Engineering, UEC

14:20-14:45 Moving to Bldg. 4

Plenary Lecture Bldg.4 - B39 Chair: Kohei Itoh, Keio
14:45-16:15 Peter Fitzgerald, Google Japan

16:15-16:30 Moving back to Raiosha

Closing Session Chair: Kohei Itoh, Keio
16:30-17:15 Koji Sato, Hitachi Metals Ltd.
17:15-17:20 Concluding Remark: Shojiro Maki & Tomoko Shimizu

ABSTRACT

Session 1 (Topic: Control Systems)

1. Machine Learning and Model-based Control for Autonomous Vehicles
   Masayoshi Tomizuka, Mechanical Engineering, UCB

2. Applied Abstraction and Integrated Design for Skill Acquisition
   Seiichiro Katsura, System Design, Keio

3. Data-driven prediction of state feedback systems
   Osamu Kaneko, Mechanical Engineering and Intelligent Systems, UEC

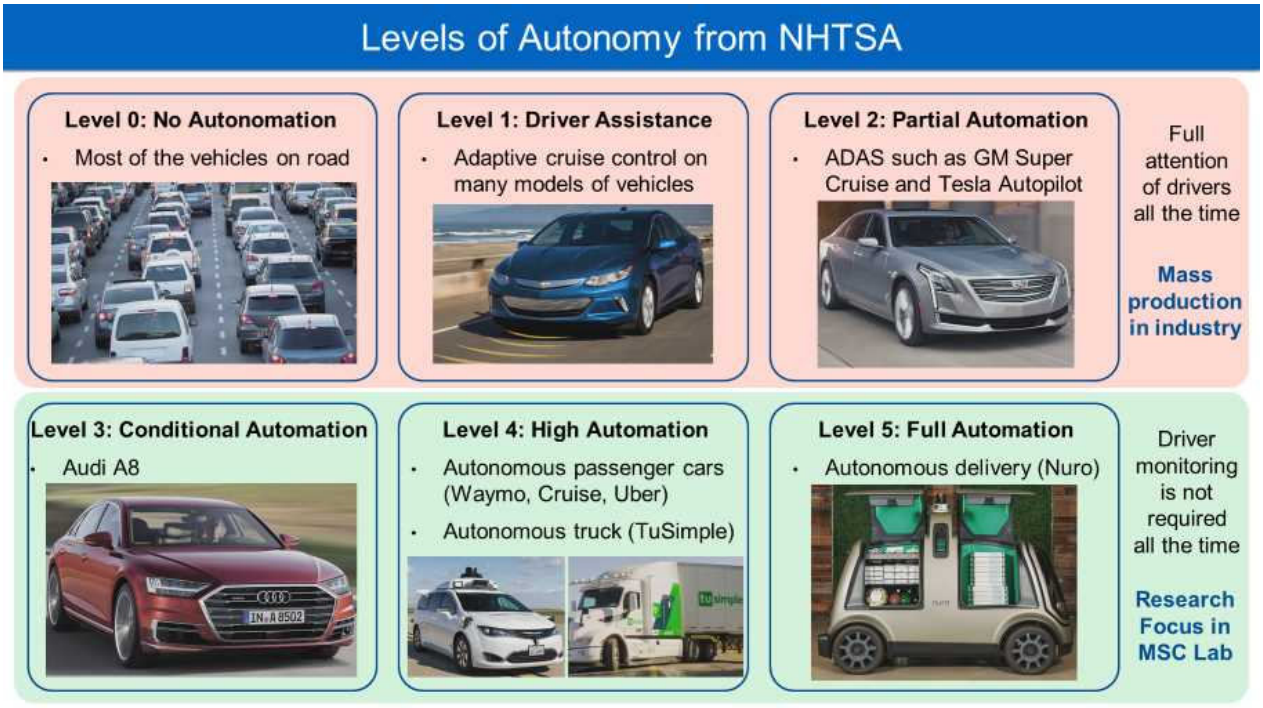
4. Robotic Surgery - Past and Future
   Pushkar Hingwe, Intuitive Surgical G.K.

Machine Learning and Model-based Control for Autonomous Vehicles

M. Tomizuka
Mechanical Systems Control (MSC) Laboratory
Department of Mechanical Engineering, University of California
Berkeley, California 94720, U.S.A.

Key words: Model based control, Machine learning, autonomous vehicles.

An autonomous car senses its environment, plans the motion for safe and efficient driving and move to follow the plan with minimal or no human intervention. Currently, cars on the road have not yet reached to the stage of complete autonomous driving, but intensive research and development efforts are taking place in automotive industry, information technology industry, national research laboratories and university laboratories. Society of Automotive Engineers (SAE) defines the level of driving automation from Level 0 to Level 5. At Level 5, no human intervention is required, and at Level 4, no driver attention is required for safety. Forefront research efforts focus on the level 4 and level 5 automation. Functions of autonomous cars at Level 4 include: 1) Detection, Tracking, Localization & Mapping, 2) Motion Prediction & Behavioral Planning and 3) Motion Planning & Control. The leading enabling technology for autonomous driving is machine learning and AI. Traditional model-based control also plays a significant role, and merging machine learning and model based-control is an exciting research topic. We will examine fundamental issues in autonomous driving and the use of the enabling technologies to address the issues.



NHTSA: National Highway Traffic Safety Administration

Applied Abstraction and Integrated Design for Skill Acquisition

Seiichiro Katsura[1*]

[1]Department of System Design Engineering, Keio University, Japan

*E-mail: katsura@sd.keio.ac.jp; +81-45-566-1724

Key words: Applied Abstraction, Motion Control, and Element Description Method.

"Applied abstraction" is a new concept for integrating next-generation science and engineering. Science is the infinite analysis of natural phenomena based on discovery. On the other hand, engineering is a study of the synthesis of functions based on development. The target of "applied abstraction" is to reveal solutions that build a bridge between the infinite analysis of science and the synthesis of engineering by conducting integrated systems design, aimed at creating simple and strong ideas for the construction of future human-support systems and robots instead of creating different solutions for each individual. The concept is summarized as Fig. 1.

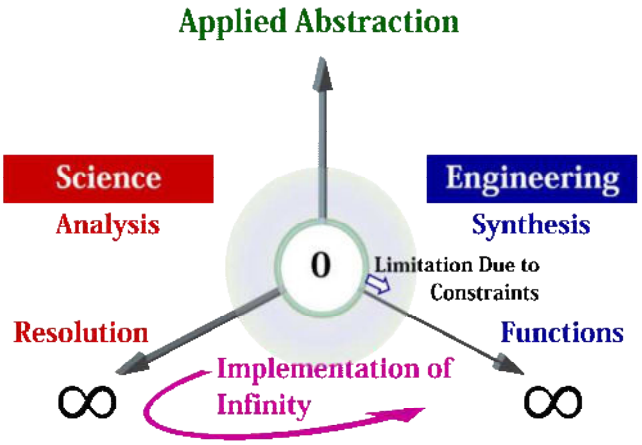


Fig. 1. "Applied Abstraction and Integrated Design"

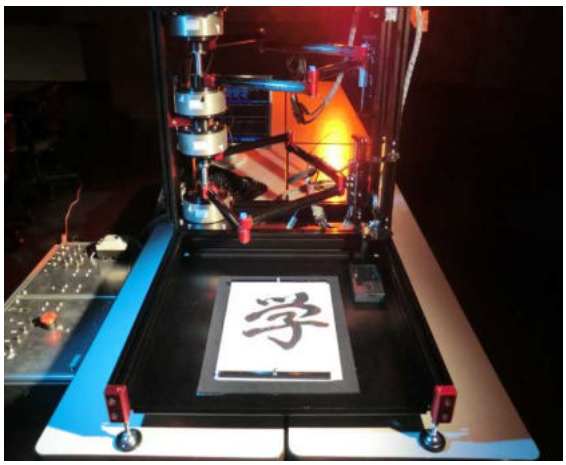


Fig. 2. MCS for Calligraphy Reproduction

Applied abstraction of infinity and zero in engineering will be increasingly important in the future. One application is the preservation and reproduction of human motion using a robot. We have succeeded in developing a novel method based on haptic technology called a "motion-copying system" (MCS), a spatiotemporal coupler of real-world haptic information as shown in Fig. 2 [1]. As with sound and visual information, the MCS is capable of preserving and reproducing the raw force and position information of human operators. As for motion reproduction, both the force and position are controlled using a robust acceleration control. It is possible to integrate zero control stiffness (force control) and infinite control stiffness (position control) based on the dimensions of acceleration.

Since the concept is highly simple and original, "applied abstraction" will have impact on future industrial applications.

References

[1] Seiichiro Katsura, Wataru Yamanouchi, Yuki Yokokura: "Real-World Haptics: Reproduction of Human Motion," *IEEE Industrial Electronics Magazine*, Vol. 6, No. 1, pp. 25-31, March, 2012.

Data-driven prediction of state feedback systems

O.Kaneko[1*]

[1]The University of Electro-Communications, Chofugaoka 1-5-1, Chofu, Tokyo, 182-8585, Japan

*E-mail: o.kaneko@uec.ac.jp; +81-(0)442-43-5394

Key words: Data-driven approach, state feedback systems, prediction, linear time-invariant systems .

In this note, we propose a new method for the prediction of the response of the conventional state feedback system. Our proposed method here is to predict the state variables of state feedback system without mathematical model. Alternatively, we utilize only one-shot experimental data on the input and state. Particularly, it should be noted that our prediction method enables us to know the response of the closed loop system before performing any experiment.

The key of our method is to introduce the fictitious exogenous signal, which is generated by using the input experimental data, the state experimental data and the feed back gain to be implemented. By using this, we construct the cost function which was provided for the update of the state feedback gain to achieve the desired closed loop property [1]. We replace a tunable transfer function for the desired close loop transfer function to the prediction. As a result, the optimal transfer function in the minimization of this cost function gives us the predicted closed loop property.

References

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Robotic Surgery - Past and Future

Pushkar Hingwe[1*],
[1]Intuitive Inc. 1020 Kifer Road, Sunnyvale, CA, 94086
.
*E-mail: pushkar.hingwe@intusurg.com; +1 650 450 1988
Key words: Robotic Surgery, da Vinci Surgery.

Robot assisted surgery is bringing the advantages of minimally invasive surgery to complex procedures that were previously done open. The historic motivation and benefits of minimally invasive robot assisted surgery will be presented. The original technology pillars: 3d Vision, intuitiveness, dexterity and safety have worked together to make a safe and effective robotic surgery platform. The importance of these pillars will be explained. While these pillars have been key in adoption of the robotically assisted surgical procedures, future benefits to the patients and surgeons will be coming from many different innovations. Innovations in fundamental minimally invasive techniques will continue. These will likely be enhanced by complementary innovations and advances in machine learning and artificial intelligence. The talk will attempt to present the perspective on some future innovations from author's perspective.

ABSTRACT

Session 2 (Topic: Bio Engineering)

1. Engineering new hydrogels for multiplexed detection of disease biomarkers and for passive release of medications
   Gerald Marriott, Bio Engineering, UCB

2. Engineering for Hypoxia Research: Quantitative Oxygen Measurement and MEMS-type Cell Culture Devices
   Kosuke Tsukada, Applied Physics and Physico-Informatics, Keio

3. Medical Image Analysis and AI-assisted Disease Classification
   Yuling Yan, Bio Engineering, Santa Clara University

4. The Design of Mechanized Hands for Real World Operations
   Hannah Stuart, Mechanical Engineering, UCB

5. AkaBLI: An all-engineered bioluminescence system for highly sensitive in vivo imagingSatoshi Iwano, Bio Engineering, RIKEN

Engineering new hydrogels for multiplexed detection of disease biomarkers and for passive release of medications

Yuhui Gong and Gerard Marriott

Department of Bioengineering, ‡University of California-Berkeley, Berkeley, CA 94720

ABSTRACT

I will present new findings from projects related to the engineering of hydrogels to detect disease biomarkers for at-home diagnostic devices, and for passive and long-term release of drugs to manage diseases of the eye. First, I introduce a novel bead-based immunocomplex entrapment assay (ICEA) and a related enzyme-linked ICEA (ELICEA) that allow for rapid and selective sequestration and entrapment of disease biomarkers with minimal needs for user-intervention and equipment. For example, in ICEA, target molecule-entrapment is achieved simply by injecting a bond-cleaving buffer, while in ELICEA, one also injects a chromogenic substrate. In both cases, sedimented beads generate brilliantly colored or fluorescent signals whose intensity correlates linearly with the amount of biomarker in the sample. In proof-of-practice studies, we used ICEA and ELICEA platforms to rapidly detect the kappa-light chain, a biomarker of the Bence-Jones disease, which we detected at a concentration that would correspond to an early stage of the disease. We also show the ICEA and ELICEA platforms can be used for multiplexed detection of biomarkers within individual beads. In the second part of my presentation, I will discuss a new type of hydrogel for long-term release of drugs to the eye, including glaucoma. In these studies, we use betadine, an FDA-approved medication to bring about specific chemical reactions in the eye that lead to the formation of drug-entrapped hydrogel from fluid precursors. Further optimization of the composition and structure of the hydrogel is used to delay the rate of drug release allowing passive and sustained release of the medication for up to 30 days. At the end of the therapy, the hydrogel is removed from the conjunctiva simply by bathing the eye in a dilute solution of cysteamine, which is also approved by the FDA to manage ocular conditions.

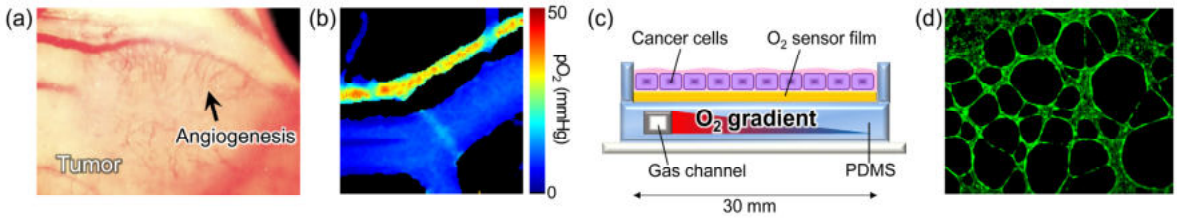
Engineering for Hypoxia Research: Quantitative Oxygen Measurement and MEMS-type Cell Culture Devices

Kosuke Tsukada
Department of Applied Physics and Physico-Informatics, Faculty of Science and Technology,
Keio University, Yokohama, 223-8522, Japan
*E-mail: ktsukada@appi.keio.ac.jp; +81-45-566-1513
Keywords: Hypoxia, Tumor, Oxygen measurement, Bio-MEMS.

Abnormal and dysfunctional microvessels in the tumor microenvironment together with cellular oxygen consumption cause heterogeneous hypoxic conditions in solid tumors. Such abnormal blood flow reduces drug delivery during chemotherapy, and hypoxic conditions reduce the effectiveness of radiation therapy. Controlling tissue hypoxia is essential for the effective treatment of cancer, but the lack of methods for quantifying hypoxia *in vivo* and *in vitro* delays the comprehensive understanding of tumor biology.

Non-invasive measurement of partial oxygen tension (pO_2) was performed *in vivo* and *in vitro* by the oxygen quenching method. A palladium-based oxygen-sensitive dye was excited by a short-pulsed laser, and the oxygen-dependent lifetime of the phosphorescence of the dye was converted to pO_2 [1]. For *in vivo* experiments, the dorsal window chambers were surgically implanted in mice and a 0.5-mm tumor was implanted in the chambers. Tissue hypoxia was imaged by laser scanning around the tumor under the microscope after injection of dye into the mouse tail vein.

Then, to mimic the *in vivo* microenvironment *in vitro*, we developed a microfluidic cell culture device that generates an oxygen gradient on the cell culture layer using the MEMS technique [2]. Specifically, the culture device was fabricated using dimethylpolysiloxane (PDMS) with high gas permeability as the base material, and an oxygen sensor film was installed in the culture layer [3]. Cells can be cultured directly on the film, and the O_2 gradient can be monitored in real time by using the laser-assisted pO_2 measurement system. We present the experimental results obtained when applying these devices as micro-environmental models of liver and cancer.



Figures (a) A microscopic image of tumor growth and angiogenesis, (b) laser-assisted pO_2 imaging *in vivo*, (c) a schema of the microfluidic device with oxygen gradient and (d) a vascular network formed in the device.

References

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Medical Image Analysis and AI-assisted Disease Classification

Yuling Yan
Department of Bioengineering, Santa Clara University, Santa Clara, CA 95053, USA
*E-mail: yyan1@scu.edu; +1-408-554-4485
Key words: medical image, machine learning, disease diagnosis

With automated image diagnosis in health care industry it is predicted that the image analysis could create $3 billion annual savings by giving specialists more time to focus on reviews that require greater attention and judgement [1]. My primary research interest has been focusing on signal/image analysis and visualization for biomedical applications. Since early 2000, I have been collaborating with clinicians in the development of laryngeal image analysis methods for computer-aided diagnosis (Fig. 1; supported by NSF) and visualization tools for virtual laryngoscopy [2, 3]. Recently, my lab extended earlier work on applications of neural networks in machine fault diagnosis to machine learning/deep learning based approaches to medical image and biosignal analyses for the detection and diagnosis of human diseases that include skin cancer [4], brain aneurysm, and heart diseases. In this talk I will present some of the preliminary results on the classification of various types of diseases via deep learning with convolutional neural networks.

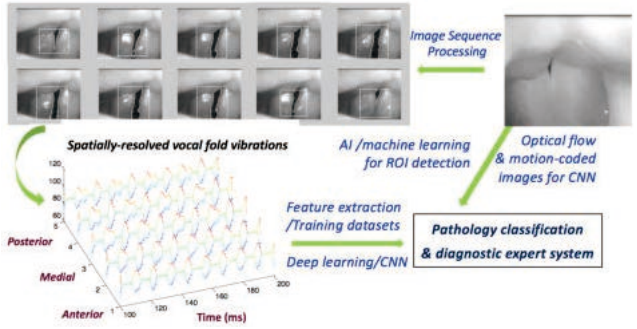

Figure 1 Laryngeal image-based classification of voice pathology

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The Design of Mechanized Hands for Real World Operations

H. Stuart
Department of Mechanical Engineering, University of California Berkeley,
5138 Etcheverry Hall, 2521 Hearst Ave, Berkeley, CA 94709, USA
E-mail: hstuart@berkeley.edu; +1-510-631-2993

Key words: Dexterous Manipulation, Robotics, Design, Mechanisms, Contact Conditions, Tactile Sensing.

Robots face a rapidly expanding range of potential applications beyond the lab, from remote exploration and search-and-rescue to household assistance, agriculture and industry. The focus of physical interaction is typically delegated to end-effectors, or hands, as these machines perform manual tasks. Yet, effective deployment of robot hands in the real world is still limited to few examples, despite decades of dedicated research. In this presentaiton I will review hands that found application in the field, aiming to discuss open challenges, novel trends and perspectives. The hope is to encourage swift development of capable robotic hands for long-term use in real world settings. The first part of the talk centers around progress in artificial hand design, identifying key functions for a variety of environments. The final part focuses on how performance and resiliency are qualified for real world deployment. I will draw examples from recent developments in robot hand design for remote field operation in the ocean, e.g. [2], and other natural environments, e.g. [3], to illuminate the overall trends and active research areas in mechanized hands today.

Figure 1 Real-world hand capabilities, including key elements for the function or behavior of the device during real-world operations, from [1].

Pressing areas of research include characterization and benchmarking of grasping capabilities across disparate designs, the understanding and specification of contact conditions for highly underactuated soft mechanisms, and scalable robust tactile sensing for smart haptic interactions.

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AkaBLI: An all-engineered bioluminescence system for highly sensitive in vivo imaging

Satoshi Iwano[1*], Shojiro Maki[2], Atsushi Miyawaki[1]

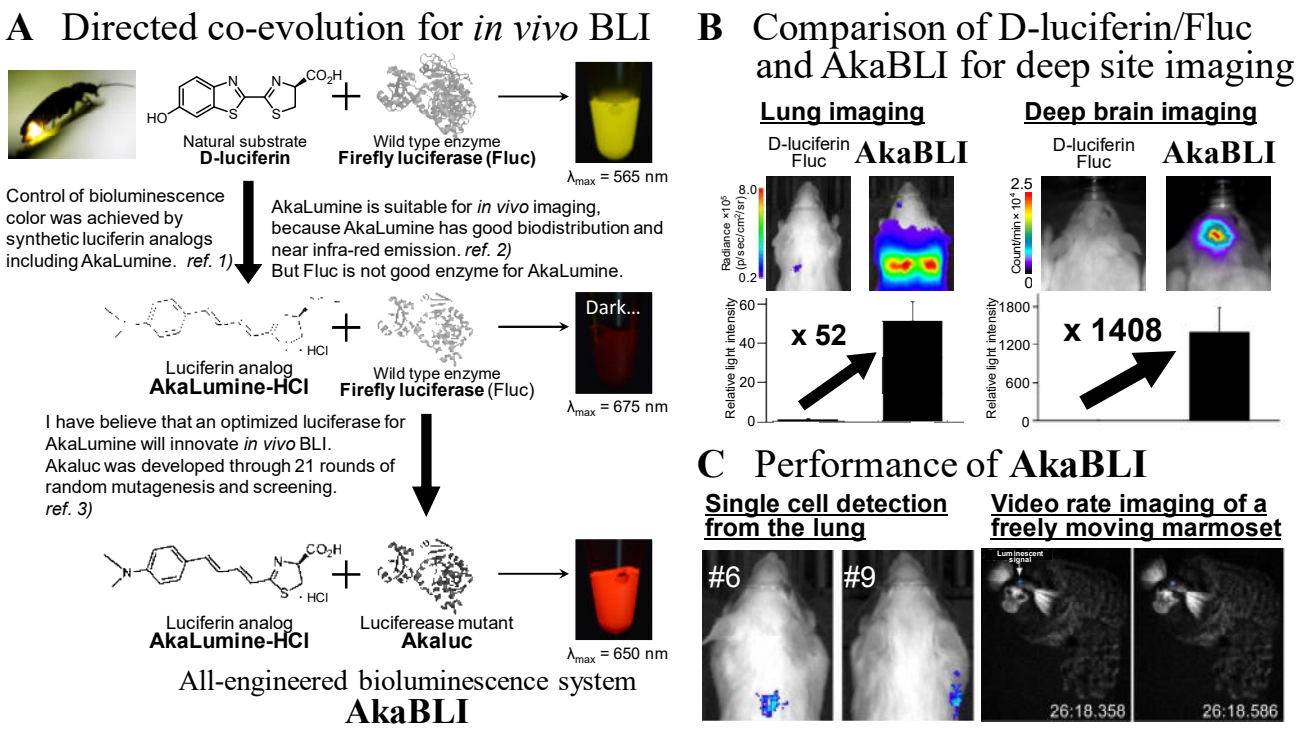
[1]Laboratory for Cell Function Dynamics, Center for Brain Science, RIKEN, Saitama, Japan

[2]Graduate School of Informatics and Engineering, The University of Electro-communications, Tokyo, Japan

E-mail address: satoshi.iwano@riken.jp

Key words: Bioluminescence, Bioimaging, in vivo imaging

Bioluminescence is a natural light source based on luciferase catalysis of its substrate luciferin. We performed directed evolution on firefly luciferase using a red-shifted and highly deliverable luciferin analog to establish AkaBLI, an all-engineered bioluminescence *in vivo* imaging system (**A**). AkaBLI produced emissions *in vivo* that were brighter by a factor of 100 to 1000 than conventional systems (**B**), allowing noninvasive visualization of single cells deep inside freely moving animals. Single tumorigenic cells trapped in the mouse lung vasculature could be visualized (**C**, left). In the mouse brain, genetic labeling with neural activity sensors allowed tracking of small clusters of hippocampal neurons activated by novel environments. In a marmoset, we recorded video-rate bioluminescence from neurons in the striatum, a deep brain area, for more than 1 year (**C**, right). AkaBLI is therefore a bioengineered light source to spur unprecedented scientific, medical, and industrial applications.



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ABSTRACT

Session 3 (Topic: Quantum Information)

1. Quantum Information and Computing with Near-term Quantum Devices
   Rudy Raymond, IBM Japan Ltd.

2. Magnetometry with nitrogen-vacancy centers in diamond
   Kento Sasaki, Applied Physics and Physico-Informatics, Keio

3. Nonlinear optical process tailored with a wide freedom
   Masayuki Katsuragawa, Applied Physics and Chemistry, UEC

Quantum Information and Computing with Near-term Quantum Devices

Rudy Raymond [1, 2,*]

[1]Quantum Computing Center, Keio University, Yagami Campus, 223-8522, Japan

[2]Quantum Algorithms and Software, IBM Research -- Tokyo, Japan

*E-mail: rudyhar@jp.ibm.com

Key words: quantum computing, quantum information, quantum advantage, near-term quantum devices

Recent days have witnessed the availability of near-term quantum devices, such as those provided by IBM through IBM Q Experience and Qiskit, with the promise of quantum advantage over their classical counterparts. Although examples of quantum advantages have been known since many years ago, most of them require fault-tolerant quantum devices, and therefore they are difficult to implement with the near-term quantum devices whose qubits are limited in number, connectivity, and coherent time. In this talk, we will present research efforts at the Keio University Quantum Computing Center to demonstrate quantum advantages on near-term quantum devices in the area of quantum information and quantum computation.

Quantum Random Access Codes (QRACs) are codes for encoding n bits into m qubits, for n > m, so that any one of the bits can be extracted with success probability better than half. QRAC is one of examples that demonstrate the advantage of quantum communication systems. It is also used in various quantum computation models, such as, quantum finite automata and state learning. We investigate the construction of QRACs by heuristics based on semidefinite programming (SDP), show those that are previously unknown, and demonstrate them on quantum devices [1].

In the area of quantum computation, we show how to reduce the complexity of implementing quantum circuits for amplitude estimation, an important primitive for many quantum advantages for sampling problems, by combining parallel executions of near-term quantum devices and classical post-processing [2]. Transforming and compiling the quantum circuits with our novel circuit transformation [3] can hopefully further reduce the time to obtain quantum advantages for practical problems.

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Magnetometry with nitrogen-vacancy centers in diamond

K. Sasaki[1*], K.M. Itoh[1], and E. Abe[1,2]

[1]School of Fundamental Science and Technology, Keio University, 3-14-11 Hiyoshi, Kohoku-ku, Yokohama 223-8522, Japan.

[2]RIKEN Center for Emergent Matter Science, Wako, Saitama 351-0198, Japan.

*E-mail: dnkn@keio.jp; +81-(0)45-566-1594

Key words: quantum sensing, diamond, magnetometry.

Electron spins of nitrogen-vacancy (NV) centers in diamond have been utilized as magnetic field sensors for nanoscale investigation, owing to their unique properties that allow for optical initialization/readout and microwave control at room temperatures. In this talk, we introduce basic techniques for NV-based magnetometry [1], and discuss how they are applied to recent researches on materials science and NMR.

Simplest DC magnetometry with NV centers is achieved by detecting the shift of the spin resonance frequency due to the DC magnetic field to be detected. NV centers have four possible symmetry axes pointing along <111> crystallographic directions, and the shift is proportional to the projection of the field vector onto a symmetry axis. With ensemble NV centers, the field components along all the four directions are obtained, and thereby the vectoral information of the DC field can be extracted. This technique has been, for instance, employed to image stray magnetic fields generated from a biased graphene device, from which the spatial distributions of electric currents were reconstructed [2].

AC magnetometry is realized by periodical flips of the NV spin, with the timing set to half the oscillation period of the AC signal. A simple modification of this technique has been shown to significantly improve the spectral resolution, and we demonstrate 304-μHz resolution, corresponding to the inverse of 1-hour measurement time. With this method, chemical shifts and J couplings of organic molecules have been resolved with a picolitre detection volume, which is much smaller than previously achieved in conventional NMR [3].

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Nonlinear optical process tailored with a wide freedom

M. Katsuragawa[1,2*], C. Ohae[2], and J. Zheng[1]
[1]Department of Engineering Science, The University of Electro-Communications,
Chofugaoka, Chofu, Tokyo 182-8585, Japan
[2]Institute for Advanced Science, The University of Electro-Communications,
Chofugaoka, Chofu, Tokyo 182-8585, Japan
*E-mail: katsuragawa@uec.ac.jp; +81-(0)42-443-5475
Key words: Nonlinear optical process, Optical phase, Single frequency tunable laser.

Nonlinear optical process is strongly governed by the phase relationships among electromagnetic fields relevant to its optical process including phase of nonlinear polarization produced through a light-matter interaction. Here, we show how attractively can we tailor nonlinear optical processes to a variety of ways by implementing arbitrary manipulations of such relative phases at arbitrary interaction lengths in nonlinear optical processes [1, 2].

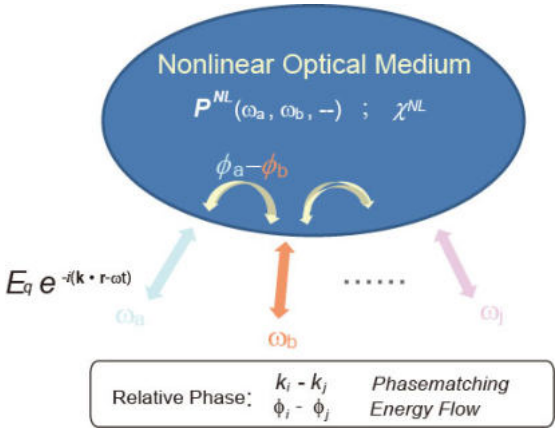

Fig. 1. Conceptual illustration of nonlinear optical processes.

As a typical example, we apply the above idea to a Raman-resonant four-wave mixing process [3]. We numerically show that on the basis of this idea, a single-frequency tunable laser which covers an entire wavelength region of vacuum ultraviolet to mid infrared (120 nm – 30 μm) is possible [1]. We also demonstrate, as a proof of principle, the Raman-resonant four-wave mixing process in para-hydrogen can be tailored to a variety of ways [4] according to the results of the numerical predictions.

Finally, we briefly comment on a future prospect. The physics of laser cooling followed by Bose-Einstein condensation has been explored on the basis of matured single-frequency tunable solid-state laser technology "in the near infrared region". If the above-mentioned single-frequency tunable laser technology is established in the extreme wavelength regions of vacuum ultraviolet and/or mid infrared, it will open an attractive research frontier. We believe that this work will be of interest, in both its fundamentals and potential applications, to a broad range of researchers in the field of optical science including "quantum information".

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ABSTRACT

Session 4 (Topic: Materials Science 1)

1. Enhancing thermal infrared imaging sensitivity with phase change materials
   Junqiao Wu, Materials Science an Engineering, UCB

2. Breaking the limit of nanophotonic devices by deep learning
   Takasumi Tanabe, Electrical Engineering, Keio

3. Plasmonics Based Photodetector Devices and Applications
   Tetsuo Kan, Mechanical Engineering and Intelligent Systems, UEC

Enhancing thermal infrared imaging sensitivity with phase change materials

Junqiao Wu

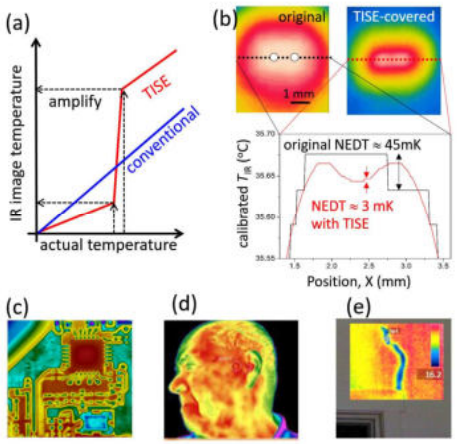
Department of Materials Science and Engineering, University of California, Berkeley, CA, USA

*E-mail: wuj@berkeley.edu; +1-510-642-4391

Key words: thermal imaging, infrared camera, radiative cooling.

Thermal infrared (IR) is a very important spectral range with wavelengths of approximately 5 to 15 μm where numerous advanced civil and military technologies are focused on, such as night vision, thermography, remote sensing, medical imaging, building inspection, and radiative cooling. Despite extensive efforts devoted to, innovations are sought to increase temperature sensitivity of IR imaging to meet the needs of our rapidly advancing modern society.

We engineer phase change materials to enable a drastic amplification of small temperature variation into a large change in IR imaging temperature, achieving an enhancement of sensitivity by a factor over 15 (Ref.1). Such an enhancement would find wide applications in, for example, defects diagnosis in IC packaging, early skin/breast cancer detection, and hidden building cracks inspection.



Caption: (a) Mechanism of the Thermal Imaging Sensitivity enhancer (TISE): due to a phase transition in a narrow temperature window, small temperature variation of the material would be drastically amplified when viewed from an infrared camera. (b) Experiments showing that two small point heater, originally unresolved in an infrared camera, is now well resolved when coated with the TISE, leading to improvement of noise-equivalent differential temperature (NEDT) from 45mK to 3mK. The TISE can find wide thermographic application in: defects diagnosis in IC packaging (c), early skin/breast cancer detection (d), and hidden building cracks inspection (e).

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Breaking the limit of nanophotonic devices by deep learning

Takasumi Tanabe

[1]Department of Electronics and Electrical Engineering, Keio University, 223-8522, Japan

*E-mail:takasumi@elec.keio.ac.jp; +81-(0)45-556-1730

Keywords: Photonic crystal, deep learning

The use of nanophotonic technologies allows us to miniaturize various devices, such as spectrometers. However, the performance of these devices are always limited by the fabrication accuracy. In this talk, I will introduce a compact spectrometer based on chirped photonic crystal waveguide (WG) structure, where I show that the resolution could be improved by taking advantage of the fabrication error by combining deep learning. Since the mode-gap frequency of a PhC-WG is dependent on the width [Fig. 1(b)], we can design a spectrometer by using a chirped PhC-WG [Fig. 1(a)]. When light enters into a chirped PhC-WG, it scatters out from the slab when it reaches the WG at the mode-gap. We fabricated the device by using standard silicon photonics fabrication techniques. When we input single wavelength laser light, we observed a clear difference in the far-field image [Fig. 1(c)], which enables us to resolve the wavelength. However, the wavelength resolution is always limited by the fabrication resolution So the question is: can we beat this limit? It is known that a fabricated PhC-WG exhibits Anderson localization of light when the input light frequency is close at the mode-gap. The localization occurs randomly due to the fabrication error, and the field pattern is sensitive to the frequency of input light, as shown in Fig. 1(d). By taking advantage of this phenomenon, we should be able to increase the frequency resolution. To reconstruct the spectrum information from the acquired camera image, we need to have a calibration image database, since the localization pattern changes randomly. Therefore, we built a database by inputting single wavelength laser light and employ deep learning algorithms [Fig. 1(e)]. We successfully reconstructed the spectrum information by feeding the algorithm with training images. Figure 1(f) shows the training process. We trained the software with a 0.2 nm resolution dataset, which is higher than the designed wavelength resolution of the device (1.5 nm). Due to the random localization, the picture of the light pattern in the waveguide is slightly different when the wavelength is changed, though the difference is so small to distinguish for humans. The accuracy rises to 95%, which shows that the deep learning algorithm is capable of detecting these wavelengths. This study shows that the use of deep learning is really powerful if we want to increase the resolution of a nanophotonic device. Even the fabrication error could be used to increase the performance.

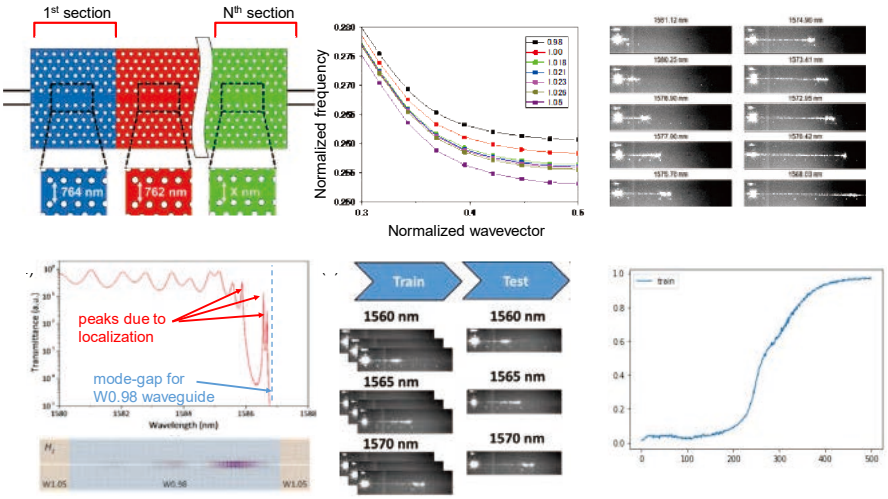

Fig. 1 (a) Chirped PhC-WG to enable spectrometer operation. (b) Mode-gap frequencies for different wavelength width. (c) Acquired camera image from top of the slab when different wavelength is input from the left. (d) Anderson localization of light close at the mode-gap frequency. (e) Schematic illustration of the deep-learning algorithm. (f) Learning curve of the deep learning with 0.2-nm resolution datasets.

Plasmonics Based Photodetector Devices and Applications

Yosuke Yamamoto, Yoshiki Saito, Masaaki Oshita, Shun Yasunaga, Tetsuo. Kan
Department of Mechanical Engineering and Intelligent Systems, Graduate School of Informatics and Engineering, The University of Electro-Communications
*E-mail: tetsuokan@uec.ac,jp; +81-42-443-5423
Key words: Surface Plasmon, MEMS, Spectrometry, Chemical Sensor

Plasmonics technologies have recently been attracting much attention. In this workshop, we review research topics regarding plasmonics in the University of Electro-Communications (UEC), Japan. A micro fabrication environment in UEC is also introduced.

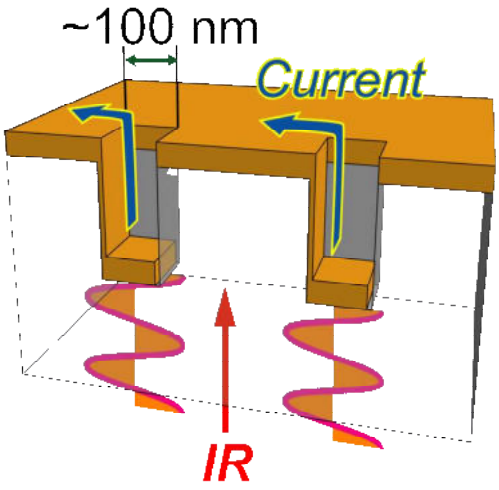

Fig. 1 SPR based photodetector

Surface plasmon resonance (SPR) is a charge density oscillation that exists at the interface of two media with opposite dielectric constants. Because its resonant nature is highly sensitive to permittivity of the medium facing the metal, it is used in various sensors. Moreover, when the plasmonic structures are formed on a silicon, the state of SPR can be electrically monitored as an electric signal. It can offer infrared light detection possibility with a silicon, a simple and versatile chemical sensor system, and a compact spectroscopy system. We are trying to expanding this possibility by employing MEMS (Micro Electro Mechanical Systems) technology.

We are currently applying the SPR electric detection for developing a silicon-based infrared photodetector[1] (Fig. 1). The incident light coupled to SPR excites free electrons in the metal film. Since a Schottky barrier formed between the gold and the n-Si transduces SPR into photocurrent. Since the height of Schottky barrier is smaller than the bandgap of Si, Si-based infrared photodetection becomes possible. We are investigating an optimal device configuration using this scheme.

This SPR electrical detection scheme can also be applied for chemical sensing and spectroscopy. In the last workshop (IUUWS 2018), we showed a proof-of-principle device composed of an Au grating formed on an n-Si substrate to perform spectroscopic measurement in near-infrared region[2, 3]. In this workshop, we will show some progresses regarding the spectroscopy device based on the same principle. In addition, a SPR chemical sensor that potentially does not require optical system will be discussed[4]. These MEMS SPR devices have basically been developed using a nano/micro fabrication environment in UEC.

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ABSTRACT

Session 5 (Topic: Materials Science 2)

1. Gallium-monochalcogenide semiconducotrs: structure-property relationship
   Oscar Dubon, Materials Science an Engineering, UCB

2. A nanocavity laser and waveguides simultaneously integrated in a three-dimensional photonic crystal
   Takeyoshi Tajiri, Computer and Network Engineering, UEC

Gallium-monochalcogenide semiconducotrs: structure-property relationship

O.D. Dubon

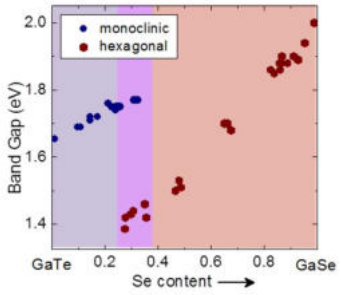
Department of Materials Science and Engineering , University of California, Berkeley, CA, U.S.A.

Materials Sciences Division, Berkeley Lab, Berkeley, CA, U.S.A.

E-mail: oddubon@berkeley.edu

Key words: Semiconductors, Defects, van der Waals Bonding

Understanding and controlling the electronic structure of materials has been a longstanding pursuit in semiconductor science and technology. Alloying has been the central paradigm to achieve this in group IV and III-V semiconductors. The emergence of layered semiconductors has opened new opportunities to explore the combination of alloying, crystal thickness, defects and crystal structure to achieve the ultimate control of electronic properties. I will demonstrate the relationship among the crystal structure, composition, bandstructure in layered monochalcogenides and the impact of growing mesostructures (rather than bulk crystals) in achieving otherwise inaccessible compositions. For $GaSe_xTe_{1-x}$ alloys the addition of selenium to the monoclinic GaTe-structure results in the linear increase of the band gap energy from 1.65 eV (*m*-GaTe) to 1.77 eV (x = 0.32). Meanwhile the addition of Te to the hexagonal GaSe-structure results in a bowing trend for the band gap reducing it from 2.01 eV (*h*-GaSe) to 1.45 eV (*h*-GaTe).



Dependence of band gap on composition and crystal structure in $GaSe_xTe_{1-x}$ alloys.

While bandgap engineering has been achieved principally by alloying and quantum confinement, layered semiconductors enable an alternative paradigm through the hybridization of adsorbates to the semiconductor surface. Our investigations of exfoliated *m*-GaTe paint a picture in which oxygen chemisorbed at the tellurium-terminated surface induces a transformation in the electronic structure from a direct (1.7 eV) to indirect (0.8 eV) band gap. The surface nature of the chemisorption process allows for the reversal of the transformation and a recovery of the original electronic structure. Collectively, these results open opportunities to produce new layered materials with technologically impactful properties.

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A nanocavity laser and waveguides simultaneously integrated in a three-dimensional photonic crystal

T. Tajiri[1*], S. Takahashi[2], Y. Ota[3], K. Watanabe[3], S. Iwamoto[3,4] and Y. Arakawa[3]
[1]University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan
[2]Kyoto Institute of Technology, Matsugasaki, Sakyo-ku, Kyoto 606-8585, Japan
[3]NanoQuine, the Univ. of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
[4]IIS, the Univ. of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan

*E-mail: ttajiri@uec.ac.jp; +81-(0)42-443-5365
Key words: three-dimensional photonic crystal, nanolaser, waveguide, quantum dot

Three-dimensional (3D) integration of various photonic devices is an ultimate route towards densely integrated photonic circuits. 3D photonic crystals (PhCs) with 3D periodicity in refractive indices are one of attractive platforms for this 3D integration, because of their complete photonic band gaps (cPBGs) where light propagation is prohibited for any wave vectors and polarizations. By introducing designed line and point defects into perfect 3D PhCs, passive devices such as waveguides and cavities have been realized at near-infrared wavelengths [1, 2]. In addition, embedding quantum nanostructures such as quantum wells and dots, active devices such as nanocavity lasers [3] and light emitting diodes [4] have also been experimentally demonstrated. However, simultaneous integration of active and passive devices in single 3D PhCs is still a challenging issue.

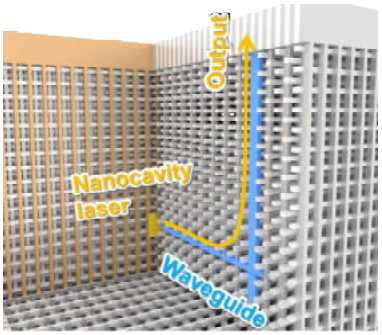

Figure 1: Cutaway image of the 3D PhC integrating a nanocavity laser (yellow) and waveguides (blue). Light is guided as shown by the arrow.

In this study, we experimentally demonstrated a nanocavity laser and waveguides simultaneously integrated in a 3D PhC with a cPBG at near-infrared wavelengths using a micro-manipulation technology [5, 6]. The 3D PhC illustrated in Fig. 1 is a so-called woodpile structure composed of 61 layers of periodically stacked line-and-space patterns. A nanocavity laser connected to two orthogonal waveguides are integrated inside the 3D PhC. We succeeded in fabrication of the 3D PhC by using the plate-insertion stacking method which is developed for stacking the large number of layers using the manipulation technique [6]. Laser light guided through the waveguides from the photo-excited nanocavity laser was observed from the output port of the waveguides. This work will be a foundation for 3D integrated photonic circuits using 3D PhCs with cPBGs.

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ABSTRACT

Closing Session

1. Creation of a Global Base for Advanced Metal Materials -Next Generation TATARA Project-
   Koji Sato, Hitachi Metals Ltd.

Creation of a Global Base for Advanced Metal Materials -Next Generation TATARA Project-

Koji Sato

Hitachi Metals, Ltd., 2-70 Konan 1-chome, Minato-ku, Tokyo 108-8224, Japan

In October 2018, the project called "Creation of a Global Base for Advanced Metal Materials -Next Generation TATARA Project-" was adopted by the Cabinet Office for "Subsidy for Regional University / Regional Industry Creation" which Shimane prefecture, Japan, applied for and Shimane University participates in.

In the "Next Generation TATARA Project" at Shimane University, the goal is set to become the Shimane as a precious ground of advanced metal materials, hoping to inspire young people by promoting cutting-edge research with industry-government-academia collaboration, and developing specialized human resources. In the process of creation, the centre will make full use of the local strength which Shimane University and the companies in the area have been cultivating in the field of materials such as the special steel, winning the support and collaboration with/from universities both inside and outside of Japan, national research institutes, etc.

The centre is named as "Next Generation Tatara Co-Creation Centre" after the traditional "Tatara iron-making" which has been passed down in Shimane area and still producing "Tamahagane"(steel made from iron sand), the material used in Japanese swords.

This centre and the industry-government-academia consortium will contribute to the regional industry creation with the support and cooperation with domestic and overseas universities and research institutes.

Dr. Koji Sato, Project Manager, Special Adviser of Shimane University, President and CEO of Hitachi Metals, Ltd. with Dr. Roger Reed, Director of the Next Generation Tatara Co-creation Centre, Professor of Materials Sciencce in University of Oxford will lead the project.

POSTER SESSION

P1 Automatic follicle cells detection in ovarian tissue visualized by optical coherence tomography using convolutional neural network
Kasumi Saito

P2 Application of Programmable System on a Chip to Acceleration Control
Hiroki Kurumatani

P3 Periodic/Aperiodic Motion Control
Hisayoshi Muramatsu

P4 Data-driven Approximation of Optimal Controller with Guaranteeing Closed-loop Stability
Keita Hara

P5 Distributed optimization for aircraft trajectory planning
Yuki Saito

P6 Coactivation Method of Antagonistic Muscle Pairs Using Common and Differential Modes for Functional Electrical Stimulation Control
Akari Takada

P7 A microfluidic actuator for dynamic control of biomolecular reactions
Ayaka Wakamei

P8 Gain Control of Genetic Circuits using Decoy Promoters
Tatsuya Yamamoto

P9 Parameter set identification for uncertainty quantification of muscle mechanical models
Risako Morita

P10 Outer approximation of solution sets for uncertain dynamic polynomial systems
Ryosuke Uemura

P11 Improvement and Quantitative Evaluation of Dual-comb based Asynchronous Optical Sampling Method
Tomohito Saito

P12 Position feedback control of micro particles using dielectrophoresis
Daichi Imai

ABSTRACT

ABSTRACT

Automatic follicle cells detection in ovarian tissue visualized by optical coherence tomography using convolutional neural network

K. Saito[1*], Y. Motani[1], S. Takae[2], N. Suzuki[2] and K. Tsukada[1,3]

[1]Graduate School of Fundamental Science and Technology, Keio University, 223-8522, Japan

[2]Department of Obstetrics and Gynecology, St. Marianna University School of Medicine, 216-8511, Japan.

[3]Department of Applied Physics and Physico-Informatics, Faculty of Science and Technology, Keio University, 223-8522, Japan

*E-mail: kasumisaito@keio.jp; +81-(0)455-66-1513

Key words: Follicle cells, Ovarian tissue, Convolutional neural network, Optical coherence tomography

To preserve the fertility of young female cancer patients, ovarian tissue cryopreservation and transplantation have been focused as next-generation reproductive medical technologies [1]. For effective transplantation and their future pregnancies, it is necessary to visualize follicle cells in tissue non-invasively and quantify their density because of a localization of follicle cells is heterogeneous [2]. However, a method for quantifying cell density has not yet been established because of the lack of techniques.

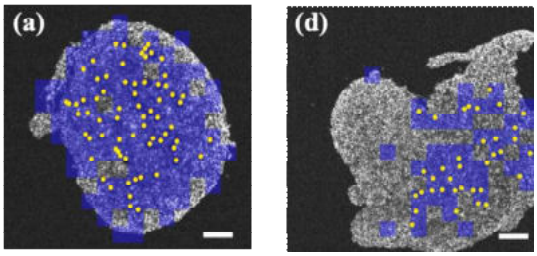

Fig. Detection result images by using only CNN method. Yellow dots indicate doctor's detection and blue areas indicate detection by proposed method. (a) and (b) are images of 10-day-old mouse ovarian tissue, each from a different mouse (Bar: 100 μm)

Therefore, we proposed to use optical coherence tomography (OCT) that can noninvasively visualize the internal structure of tissue. Additionally, we proposed to use a convolutional neural network (CNN) to extract small features from OCT images and to detect follicle cells automatically. First, we collected ovarian tissues from 4-day-old mice and acquired OCT images using a full-field-type OCT. Then, acquired images were analyzed by three detection methods: filter processing, filter processing combined with the CNN, and only CNN. Finally, to verify accuracy of each method, the detection rate and coincidence rate were calculated by using the doctor's detection as the correct result.

In the Figure, blue areas show the detection result by proposed method using only CNN. This method achieved a detection rate of 1.00 and a coincidence rate of 1.15; this indicated the possibility to detect follicle cells effectively using proposed method. Furthermore, it became clear that the occupancy of follicle cells in tissue surface part differs depending on the tissue. In the future, we aim to quantify follicle cells three-dimensionally and further accelerate next-generation reproductive medicine.

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Application of Programmable System on a Chip to Acceleration Control.

H. Kurumatani[1*], and S. Katsura[1]

[1]Department of System Design, Keio University, 3-14-1 Hiyoshi, Yokohama, 223-8522, Japan

*E-mail: kurumatani@katsura.sd.keio.ac.jp; +81-045-566-1724

Key words: FPGA, System-on-a-chip, Motion control.

A control platform is a critical component which strongly relates to control performance. A bandwidth of control, and implementation feasibility of a controller depend on capabilities of the controller. To attain high functionality, a novel platform should be emerged. We designed a platform with a field-programmable-system-on-a-chip (FPSoC), which accelerates collaboration of a field-programmable-gate-array (FPGA) and a stored-program machine [1, 2]. This provides capability of time-critical and short-time processing and flexibility in calculation. However, to make the best use of this device, appropriate implementation techniques for each platform are required, because each has advantages and disadvantages. Here, task-partitioning, i.e. the right process on the right hardware, is a key task for implementation, and it requires knowledge about application. In motion control, robustness is better to be secured by a high-speed controller, while versatility of motion should be maintained even if calculation process takes a time to some extent. In response to this, we propose to design a robust acceleration controller on the FPGA while the others on the processor, as shown in Fig. 1. Controlling acceleration makes problems on the motion control trivial. The processor can concentrate on calculating a reference to the acceleration controller which determines a motion. Therefore, both a wide control bandwidth and versatility in motion can be attained. This controller will contribute to enhance control performance of machines in industry.

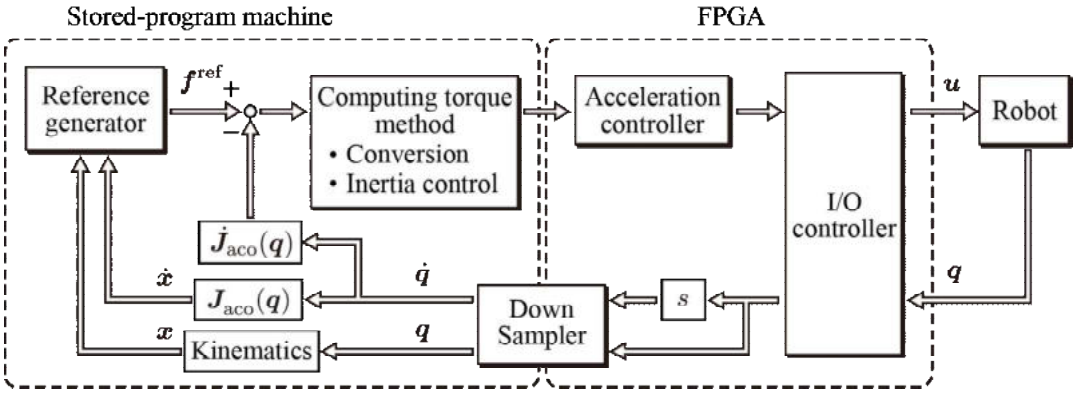

Fig. 1. Implementation diagram of the acceleration controller on FPSoC.

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Periodic/Aperiodic Motion Control

H. Muramatsu[1*] and S. Katsura[1]
[1]Department of Electronics, Keio University,
3-14-1 Hiyoshi, Kohoku, Yokohama, Kanagawa, 223-8522, Japan
*E-mail: muramatsu@katsura.sd.keio.ac.jp
Key words: Motion Control, Periodic/Aperiodic Separation Filter, Periodicity.

Motion control is used for mechatronics and robotics systems to control motion elements: velocity, force, and impedance. Typically, velocity control is used for precise operations of industrial robots, and force and impedance controls are used for adaptive operations of support robots against human contacts. In the motion controls, there is an issue that the velocity, force, and impedance controls cannot be simultaneously realized, with the result that precise positioning and adaptive response against human contacts cannot be simultaneously achieved.

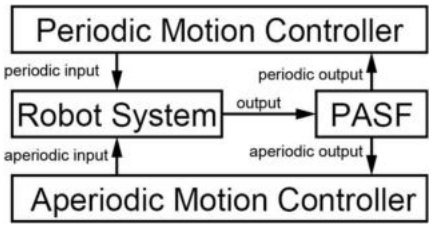

Fig. 1. Conceptual block diagram.

We focused on periodic motion and aperiodic motion can be separately controlled by using a periodic/aperiodic separation filter (PASF)[(1)], which separates a signal into periodic and aperiodic signals. Then, we proposed periodic/aperiodic motion control (Fig. 1) that assigns the velocity, force, and impedance control to periodic motion and aperiodic motion[(2)]. The PASF is used to separate velocity and force into periodic velocity, aperiodic velocity, periodic force, and aperiodic force to adjust the periodic motion and aperiodic motion. In particular, the periodic-velocity-and-aperiodic-impedance control, that assigns the velocity and impedance control to periodic and aperiodic motions, respectively, achieved precise repetitive operations and aperiodic adaptive response simultaneously. This solved the problem that the conventional motion controls cannot realize precise and adaptive controls simultaneously, and the periodic/aperiodic motion control facilitates use of robots under human contacts. We validated the practicality of the proposed periodic/aperiodic motion control using a multi-axis manipulator.

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Learning Koopman Operator under Dissipativity Constraints

K. Hara[1*], M. Inoue[1], and N. Sebe[2]
[1]Department of Applied Physics and Physico-Informatics, Keio University,
3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa, Japan
[2]Department of Artificial Intelligence, Kyushu Institute of Technology,
680-4 Kawazu, Iizuka, Fukuoka, Japan.
*E-mail: reds@z3.keio.jp; +81-(0)543-56-3489
Key words: Dissipativity, Koopman Operator, Linear Matrix Inequality.

This presentation addresses a learning problem for nonlinear dynamical systems with incorporating any specified dissipativity property. The nonlinear systems are described by the Koopman operator[1)], which is a linear operator defined on the infinite-dimensional lifted state space.

The problem of learning the Koopman operator under specified quadratic dissipativity constraints is formulated and addressed. The learning problem is in a class of the non-convex optimization problem due to nonlinear constraints and is numerically intractable. By applying the change of variable technique and the convex over-bounding approximation[2)], the problem is reduced to sequential convex optimization and is solved in a numerically efficient manner.

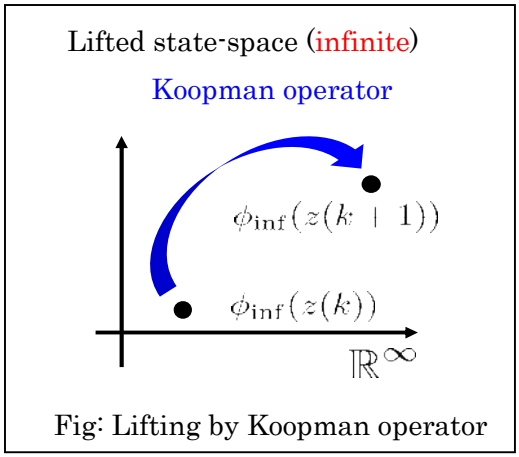

Fig: Lifting by Koopman operator

Finally, a numerical simulation is given, where high modeling accuracy achieved by the proposed approach including the specified dissipativity is demonstrated.

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Distributed Optimization for Aircraft Trajectory Planning

Y. Saito[1*], Masaki Inoue[1]

[1]Department of Applied Physics and Physico-Informatics, Keio University,
3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa, 221-0045, Japan

*E-mail: s.yuki@keio.jp; +81-(0)90-9245-7705

Key words: Trajectory planning, distributed optimization, flow corridor.

In this presentation, we propose a novel trajectory planning method for collision avoidance of aircraft. The method is specifically for aircraft flying in a flow corridor (1), as shown in fig.1. Since there is no instruction from air traffic control (ATC) in the corridor, we aim for each aircraft to design his own trajectory autonomously and distributedly. In the proposed method, trajectories are designed by solving an optimization problem with primal-dual gradient algorithm (PDGA (2)). Besides, to hide airline strategies and to reduce the communication frequency between aircraft, we propose the method for distributed PDGA. The effectiveness of the method is verified in a numerical experiment with toy models.

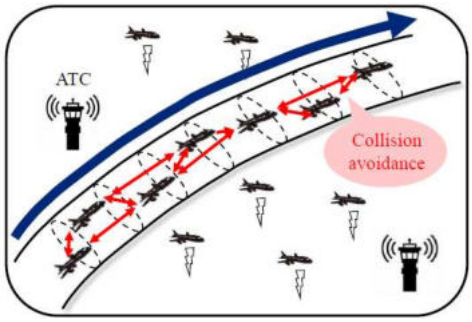

Fig.1：Flow corridor

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Coactivation Method of Antagonistic Muscle Pairs Using Common and Differential Modes for Functional Electrical Stimulation Control

A. Takada[1*], A. Hirata[1], and S. Katsura[1]

[1]Department of System Design Engineering, Keio University,

3-14-1 Hiyoshi, Kohoku, Yokohama, Kanagawa, 223-8522, Japan

*E-mail: takada@katsura.sd.keio.ac.jp; +81-(0)45-566-1724

Key words: Functional electrical stimulation (FES), Antagonistic muscle pairs, Coactivation.

Functional electrical stimulation (FES) refers to the application of short electrical impulses to peripheral motor neurons, which causes muscle contraction. It is a promising technique used widely in neurorehabilitation for patients with partial paralysis due to spinal cord injury, stroke, etc.

The control of FES systems is challenging not only because electrically stimulated muscles have highly nonlinear and time-varying characteristics, but also because musculoskeletal systems are redundant[1]. Most limbs in the human body are controlled with a pair of antagonistic muscles that consist of the flexor and the extensor. In order to move the limb in one direction, both the flexor and the extensor need to be controlled simultaneously. Since the number of activated muscles exceed the degrees of freedom of the joint, the stimulation intensity of the two muscles cannot be determined by the control signal alone.

With some inspiration from theories in motor control[2], this study proposes a coactivation method to determine the stimulation intensities of the antagonistic muscle pairs using common and differential modes as shown in Fig. 1. The common mode, which is the addition of the two stimulation intensities, correlates with the stiffness of the joint, while the differential mode, which is the difference of the two stimulation intensities, correlates with the torque of the joint. By associating the characteristics of the joint directly with the stimulation intensities of the muscles, the proposed method achieves high tracking performance and stability even with a PID controller, which infers simple implementation with a variety of controllers.

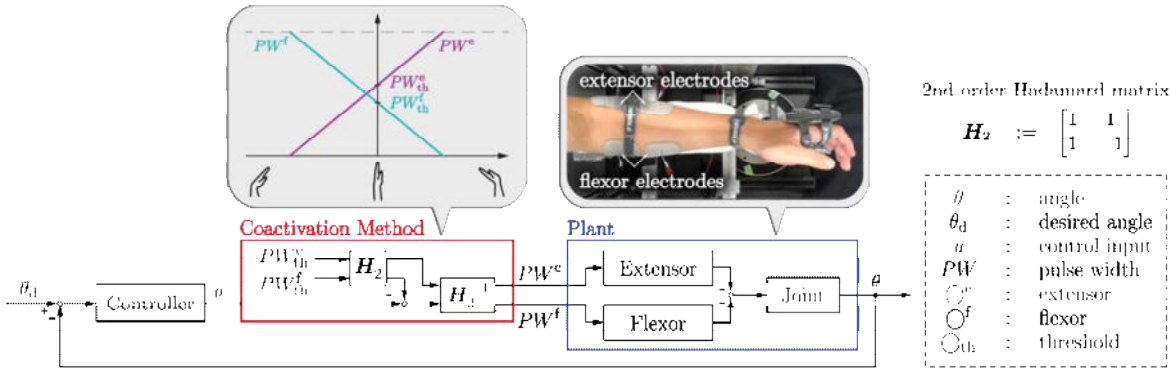

Fig.1. Overview of proposed coactivation method.

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A microfluidic actuator for dynamic control of biomolecular reactions

A. Wakamei*, Y. Hori

Department of Applied Physics and Physico-informatics, Keio University, Yokohama, Japan

*E-mail: a-yaka.fukuda_155555@keio.jp; +81-45-566-1458

Key words: synthetic biology, microfluidics, feedback control, genetic circuits.

Understanding the input-output response of genetic circuits is important to build reliable systems in synthetic biology. Specifically, it is important to understand dynamics of biomolecular systems. However, adding and diluting nanoliter-scale chemicals over a long period of time in a reaction mix is tedious and challenging. To overcome this challenge, we propose a microfluidic platform capable of controlling the input chemicals and measuring the dynamics of biomolecular systems. In this study, we built and verified our platform using DNA circuits.

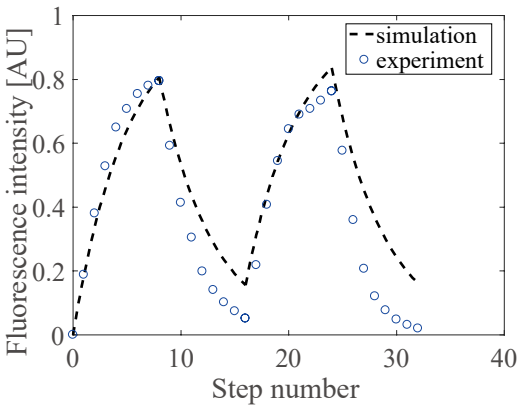

Fig. 1 An example of oscillating input: simulation and experiment.

Specifically, we first built a microfluidic device made of PDMS (poly-dimethylsiloxane) to control the amount of input reagents by on-chip peristaltic pumps. We confirmed that the proposed microfluidic platform input method is capable of highly precise modulation of the input volume by controlling the number of pump cycles. Then, we made a simulator for controlling the amount of input reagents to the microfluidic device. DNA circuits were used to verify the constructed platform. For this purpose, the reaction rates of DNA circuits were optimized using a plate reader (Biotek). Using these DNA circuits, we confirmed that the simulator could assist the decision of the number of pump cycles of the microfluidic platform. The optimized DNA circuits also showed expected functions in the microfluidic device for verification of this platform, implying that the circuits can be used for a proof-of-concept control experiment that we are planning.

Gain Control of Genetic Circuits using Decoy Promoters

T. Yamamoto[1*] and Y. Hori[1]

[1]Department of Applied Physics and Physico-Informatics, Keio University,
3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522, Japan

*E-mail: yama.tatsu9919@keio.jp; +81-45-566-1548

Key words: Synthetic biology, Genetic circuit, Feedback control

In synthetic biology, the robustness of genetic circuits is enhanced by introducing feedback pathways in the reaction networks. To date, controlling feedback gain of genetic circuits has primarily been achieved by protein-based transcription control. In contrast, this paper proposes a novel gain controlling mechanism for genetic circuits by utilizing decoy promoters. Decoy promoters are DNAs on a plasmid whose sequences are the same as those of promoters. Decoy promoters competitively bind with some of their cognitive transcription factors instead of actual promoters, but have no involvement in protein synthesis. As a result, decoy promoters are expected to control the number of effective transcription factors, enabling fine tuning of transcription rates.[1)]

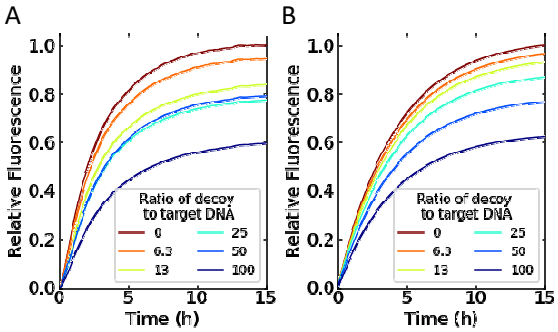

Fig. 1 Expression level of GFP
(A) experiment (B) simulation

We performed a preliminary experiment in order to check whether decoy promoters repress the level of gene expression. Target genes and decoy promoters were mixed in E. coli lysate and expressed. A cell-free protein expression system was used to titrate the concentration of decoy promoters. Additionally, we also constructed a mathematical ODE model of the reaction system. Both of the experimental results and the output of the model showed graded repression of the target gene with the increase of the decoy promoter concentration. This result suggests that the proposed method is capable of tuning the gain of genetic circuits.

Further experiments would be required to tune the gain in real time. This goal is expected to be realized by generating decoy promoters from RNA in cells and controlling the rate of production by external inducer.

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Parameter set identification for uncertainty quantification of muscle mechanical models

R. Morita[1*] T. Uchiyama[1] and Y. Hori[1]

[1]Department of Applied Physics and Physico-informatics, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522, Japan

*E-mail: risako.morita@keio.jp; +81-45-566-1548

Key words: parameter set identification, muscle mechanical models, floor reaction force

Modeling of biological systems requires careful assessment of uncertainty. In this research, we propose a set-based parameter identification method for quantifying the uncertainty of muscle mechanical models. The proposed method allows for obtaining mathematically rigorous parameter sets with which the output of the model matches the measured data. The proposed method was applied to the identification of stiffness (k), viscosity (d) and the conversion factor (α) of electrical stimulation to force of the medial gastrocnemius muscle (MG) during quiet standing. Specifically, a subject was instructed to stand on a force plate, and impulse-like electrical stimulation was applied to the MG to induce contraction which was measured as the floor reaction force. We identified a parameter set with which the normalized square integral error between the model of the MG and the measured data is less than a given tolerance value γ. Specifically, the blue shaded area in Fig. 1 represents the identified parameter sets for two different values of γ. We further proposed a systematic method to determine the value of γ that quantifies the uncertainty due to the variable measurements of a single subject.

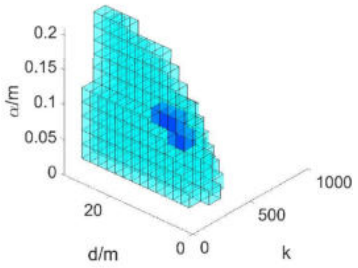

Fig. 1 An identified set of parameters for the model of MG

Outer approximation of solution sets for uncertain dynamic polynomial systems

R. Uemura[1*], Y. Sakurai, Y. Hori[1]

[1]Department of Applied Physics and Physico-informatics, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522, Japan

*E-mail: uem0531@keio.jp; +81-45-566-1548

Key words: dynamic polynomial system, semidefinite programming

This work proposes an algebraic method to obtain the upper and lower bounds of transient solution sets for dynamic polynomial systems that have uncertainty in their initial conditions.

Dynamic polynomial systems provide an appropriate tool for analyzing a wide class of nonlinear processes such as biomolecular reactions and population dynamics.

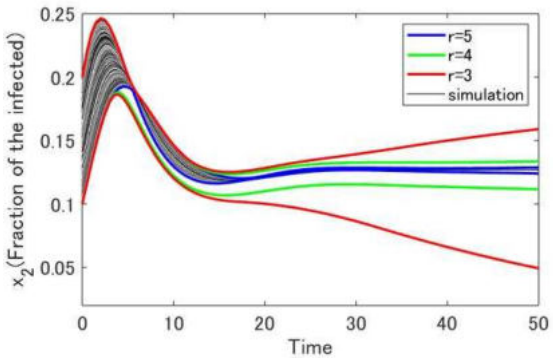

Fig. 1 A demonstration example of the upper and the lower bounds with an epidemic model

Since trajectories of dynamic polynomial systems vary due to the uncertainty in their initial conditions, it is important to analyze their solution sets considering initial uncertainty.

To overcome the difficulty of nonlinear analysis, we introduce a linear system representation of dynamic polynomial systems by replacing monomials with new variables that are independent of each other. The resulting linear equations, however, are underdetermined. To narrow the possible solution to the equations, we introduce positive semidefinite conditions associated with the new variables. By combining the semidefinite conditions with the linear equations, we propose a semidefinite programming for computing the upper and lower bounds of system's output. The output, which provides theoretically rigorous intervals of transient solutions for given uncertainty of initial values. Finally, the proposed method is demonstrated with an epidemic model (Fig. 1).

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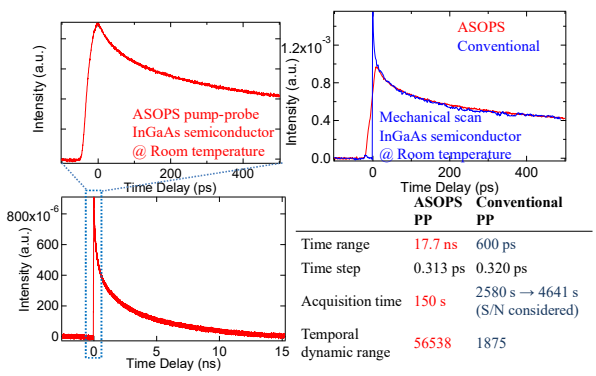
Improvement and Quantitative Evaluation of Dual-comb based Asynchronous Optical Sampling Method

Tomohito Saito[1], Akifumi Asahara[2,3], Kouichi Akahane[4], Kaoru Minoshima[2,3], Junko Ishi-Hayase[1]
[1] Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522, Japan
[2]The University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan
[3]JST, ERATO MINOSHIMA Intelligent Optical Synthesizer (IOS), [4]NICT
*E-mail: tomohitosaito@keio.jp; +81-(0)80-3410-9760

Key words: Pump-probe, Dual comb, Asynchronous optical sampling, quantum dots.

It is important to measure transient responses of excitons in quantum dots (QDs) from fundamental and application points of view. Ultrafast nonlinear spectroscopies such as pump-probe (PP) and photon echo (PE) techniques have been traditionally used to measure population and coherent dynamics of QDs[1]. However, as traditional PP and PE techniques use mechanical stages to scan the time delay between excitation pulses, there has been problems such as a short measureable time range, long acquisition time, and low signal-to-noise (S/N) ratio.



	ASOPS PP	Conventional PP
Time range	17.7 ns	600 ps
Time step	0.313 ps	0.320 ps
Acquisition time	150 s	2580 s → 4641 s (S/N considered)
Temporal dynamic range	56538	1875

Transient responses of InGaAs sample for comparison between ASOPS PP and conventional PP methods with S/N comparison. Short (ps) and long (ns) time range are shown in ASOPS PP method.

In order to resolve these problems, we develop asynchronous optical sampling (ASOPS[2]) technique using dual-comb light sources with slightly different repetition rate to automatically scan the time delay without using a mechanical stage[3,4]. In this presentation, we demonstrate PP ASOPS measurement in strain-compensated InAs QDs to study excitonic population dynamics with long-time range, short acquisition time, high temporal resolution, and high S/N ratio. Using dual-comb with ultralow relative timing jitter, temporal resolution of ASOPS can be achieved to the limit determined by the temporal width of excitation pulses. In the experiment, we measured the relative timing jitter of the dual-comb light source to quantitatively evaluate the temporal resolution of our experimental system. In addition, we discuss the application of ASOPS technique to PE to investigate coherent dynamics of excitons in QDs. The time range, acquisition time, S/N ratio is evaluated and discussed to show the usability of dual-comb ASOPS technique.

This work was supported by JST ERATO MINOSHIMA Intelligent Optical Synthesizer Project (JPMJER1304), Grant-in-Aid for Scientific Research (15H05868) and Center for Spintronics Research Network (CSRN), Keio University. The QD sample was made by the support from NICT.

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Position feedback control of micro particles using dielectrophoresis

D. Imai[1*], S.H. Kim[2], A.J. Genot[3], Y. Monnai[1], T. Fujii[2], and Y. Hori[1]
[1]Department of Applied Physics and Physico-informatics, Keio University
Yokohama 223-8522, Japan.
[2]Institute of Industrial Science, The University of Tokyo, Meguro 153-8505, Japan.
[3]LIMMS/CNRS-IIS, The University of Tokyo, Meguro 153-8505, Japan.
*E-mail: daichi_101@keio.jp; +81-(0)45-566-1548
Key words: Dielectrophoresis, Position control, Feedback control

Position control of micro-scale particles has many potential applications in synthetic biology. This work aims to develop a feedback control law for position feedback control of micro-scale particles, and build an experimental platform to systematically measure and control the interactions of micro-scale particles, using dielectrophoeresis.

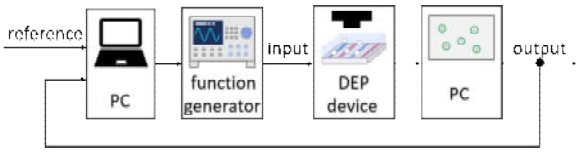

Fig. 1 Conceptual diagram of position feedback control system

Dielectrophoretic force applied to particles can be controlled by the magnitude and the frequency of the AC voltage between electrodes[1)]. To enable model based feedback control of dielectrophoretic force, we made a mathematical model and an experimental equipment. A nonlinear state space representation with AC voltage as input and a position of a micro particle as output was derived by combining fundamental laws of electromagnetism and fluid mechanics, enabling the design of feedback control law based on nonlinear feedback control theory.

The position feedback control system consists of a function generator, pairs of Indium Tin Oxide (ITO) electrodes on a glass substrate, a camera attached to a microscope that acquires the positions of micro particles, and a controller which determines the optimal input. The electrode geometry was determined based on the mathematical model in order to efficiently apply dielectrophoretic forces, and electrodes were fabricated on an ITO glass substrate using photolithography. We compared the motions of particles obtained by an experiment with those obtained by simulations.

The authors are currently working on designing optimal feedback controller to close the feedback loop in Fig. 1.

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Search for low molecular weight compounds showing proliferation inhibitory effect on acute T lymphoblastic leukemia (T-ALL) cells

Chihiro Yoshida[a], Yoshifumi Hachiro[a], Kazuya Miyashita[b], Takuya Yagi[b], Azusa Takechi[b], Ryohei Saito[a], Nobuo Kitada[a], Takashi Hirano[a], Takahiko Hara[b], Shojiro Maki[a]

[a] Engineering Science, University of Electro-Communications, Japan

E-mail address: s-maki@uec.ac.jp

[b] Stem cell project, Tokyo Metropolitan Institute of Medical Science, Japan

E-mail address: hara-tk@igakuken.or.jp

Keywords: Leukemia, Drug Discovery, Organic Synthesis, T-ALL

1. Background

Acute T lymphoblastic leukemia (T-ALL) is a leukemia affecting approximately 1 in 400,000 Japanese people, mostly in childhood. Due to its low prevalence and refractory nature, it is designated as a rare and intractable disease. There are few researches for these diseases, and drug development is very slow. However, patients are eagerly waiting for the silver bullet. In this research, we are trying to develop possible treatment methods for T-ALL.

2. Method

With the cooperation of AIST and others, the group of Dr. Takahiko Hara conducted the high throughput screening for natural products, that have specific growth inhibitory effects on cell lines derived from T-ALL. We successfully identified 3 natural products (31D-F005, 21D-D016 and 44D-L008) showing such effects. We investigated the active site based on the structures of 31D-F005 and 44D-L008, and found that compounds with a lower molecular weight than the seed compounds exhibit the similar growth inhibitory activity (JPA. 2019-118990). Based on this compound, we have synthesized several types of stable compounds.For the synthesized derivatives, cell growth assays were carried out using cell lines derived from T-ALL and other leukemia patients.

3. Expected Results

As a result of the cell growth assays, the following facts were revealed: the activity on T-ALL increased with the number of C = C bond, and we succeeded in improving the stability of the compound by chemically modifying the C = C bond part. We show the useful structure-activity relationship for the T-ALL growth suppressive compounds.

Creation of chemical compounds with higher growth inhibitory activity for T-cell acute lymphoblastic leukemia-derived cells

Tomoya Higashi[1*], Chihiro Yoshida[1], Yoshifumi Hachiro[1], Chihiro Nakata[2,3], Takuya Yagi[2,3], Azusa Takechi[2,4], Takahiko Hara[2,3,4], Shojiro Maki[1,5]

[1]Department of Information Science, Graduated School, University of Electro-Communications, Chofu, Tokyo, 182-8585, Japan

[2]Stem Cell Project, Tokyo Metropolitan Institute of Medical Science, Setagaya, Tokyo, 156-8506, Japan

[3]Department of Medical and Dental, Tokyo Medical and Dental University, Bunkyo, Tokyo, 113-8510, Japan

[4]Department of Stem Cell reguration, Tokyo Metropolitan University, Hachioji, Tokyo, 192-0397, Japan

[5]Center for Neuroscience and Biomedical Engineering, University of Electro-Communications, Chofu, Tokyo, 182-8585, Japan

*E-mail: h1933109@edu.cc.uec.ac.jp; +81-(0)42-443-5493

Key words: Leukemia, Drug discovery, Natural compounds.

T-cell acute lymphoblastic leukemia (T-ALL) affects approximately 1 in 400,000 Japanese people, which in many cases die after relapse. Unfortunately, clinically effective drugs for T-ALL are not currently available. In 2014, T-ALL was designated as a rare and intractable disease by Japanese government. Since there are more T-ALL patients in Europe and United States of America, research and development of T-ALL-specific drugs are ongoing by academia and pharmaceutical companies.

We previously screened natural chemical libraries and identified two hit compounds 44D-L008 and 31D-F005. They strongly inhibited the growth of human T-ALL-derived cell line CCRF-CEM, but did not affect the growth of B-lymphoma-derived cell line Raji. Since 44D-L008 and 31D-F005 share a common chemical structure, we chemically synthesized numbers of related analogues based on the core structure and evaluated their cytotoxic activities for CCRF-CEM and Raji cells.

We found that compounds having a specific N atom including heterocycle and polyene structure exhibit T-ALL-specific growth inhibitory activity[1]. Furthermore, a certain chemical modification made them more effective in terms of the growth inhibitory activity for CCRF-CEM cells. The T-ALL cell killing activity of one compound was about 5 times higher than that of 31D-F005, and its IC50 value for CCRF-CEM was 90 nM. This study provides a promising proof for the development of a novel anti-T-ALL drug.

References

1) Japanese Patent Application 2019-118990, “Pharmaceutical composition for the treatment of acute T lymphoblastic leukemia or lymphoma or acute myeloid leukemia”

Enhancement of Raman scattering light using Au coated magnetic nanoparticles controlled via a magnetic field

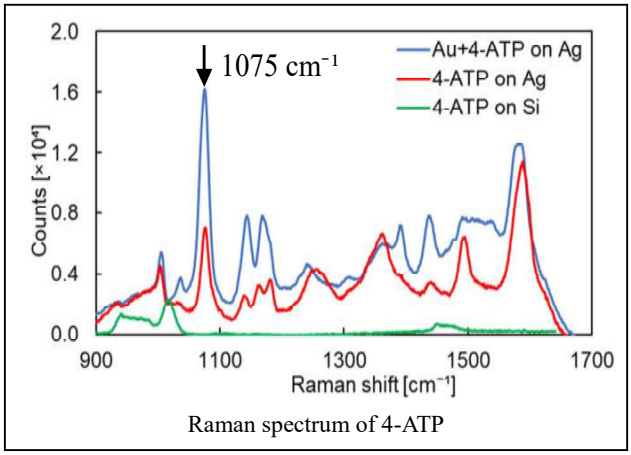
M. Fujino[1], K. Shibusawa[1], and K. Tsukada[1*]

[1]Department of Applied Physics and Physico-Informatics, Keio University, Hiyoshi, 223-8522, Japan

*E-mail: **ktsukada@appi.keio.ac.jp**; +81-(4)5566-1513

Key words: Raman scattering, Magnetic nanoparticle, Surface-enhanced Raman scattering.

Raman spectroscopy is expected to be a noninvasive technique for detecting biomolecules and cells. However, since the intensity of the scattered light is weak, it's necessary to increase the sensitivity by using an enhancement mechanism such as surface-enhanced Raman scattering (SERS)[1]. In this study, SERS-expressing nanoparticles were prepared by coating magnetic nanoparticles with gold for the purpose of flexible control of the SERS enhancement field and highly sensitive detection of target molecules by controlling magnetic nanoparticles.



Raman spectrum of 4-ATP

By repeatedly adding $HAuCl_4$ and NH□OH·HCl to Fe_3O_4@Au (Micromod) with stirring, the magnetic nanoparticles were coated with gold several times[2]. For further enhancement of Raman scattering light, a silver nanoparticle substrate (Ag-NS) with hexagonal close-packed structure was made[3]. As a Raman marker, 4-ATP (4-Aminothiophenol) was labeled onto gold-coated magnetic nanoparticles (Au-MNPs), and Raman spectrum was measured using an in Via Raman microscope (Renishaw). For comparison, Raman spectrum of 4-ATP solution on Si and on a silver nanoparticle substrate was also measured. For 4-ATP on the Ag-NS, its characteristic spectrum was observed. And the signal intensity of 1075 cm^{-1} was more increased by using both Au-MNPs and Ag-NS. It's known that magnetic force acting on magnetic nanoparticles is proportional to magnetic field gradient. So, Au-MNPs can be controlled in a liquid by an external magnetic field, and it is expected that the SERS-enhanced field can be freely formed and the application to sensitive detection of biomolecules can be done in the future.

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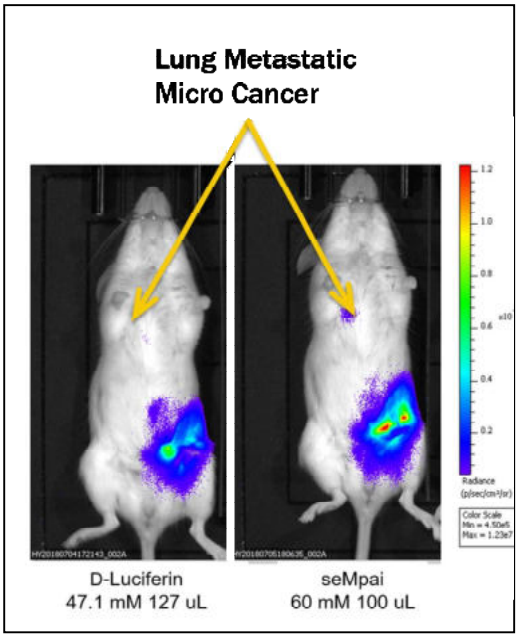
NIR Luciferin Analogues for *in vivo* Optical Imaging

Nobuo Kitada[1], Ryohei Saito1, Masahiro Kiyama1, Satoshi Iwano, Rika Obata, Takashi Hirano, Shojiro Maki

[1]Department of Engneering of Science, University of Electro-Communications, Tokyo, Japan
[2]Center for Neuroscience and Biomedical Engineering, University of Electro-Communications, Tokyo, Japan
[3]Brain Science Institute, RIKEN, Saitama, Japan
*E-mail: kitada@uec.ac.jp; +81-(0)42-443-5494
Key words: *in vivo* imaging, Luciferin, Firefly.

We were able to detect a micro-cancer in lung of mice using the new luciferin analogue "seMpai".



We are innovating new imaging technologies by using organic chemistry. For innovating advanced medical technology, in vivo optical imaging is crucial. Therefore, we have been developing luciferin analogues suitable for deep in vivo optical imaging.

It is very difficult to conduct *in vivo* optical imaging in deep tissues, due to absorption and scattering of light in living tissues. It is well known that the light in the near-infrared region (NIR) has high permeability for living tissues. It is a challenge to develop an imaging material that has NIR emission for *in vivo* deep optical imaging. We have obtained structure-activity relationship data on the firefly luciferin-luciferase reaction. Utilizing the data on luciferin analogues reacting with Ppy luciferase, we have designed and marketed NIR probe “TokeOni” (SIGMA-ALDRICH). TokeOni emits a higher brightness compared with the natural firefly luciferin (D-Luciferin) because of high permeability of TokeOni in tissue.

Based on the TokeOni structure, three new luciferin analogues have been designed and synthesized. One of the analogues emits light in the NIR and has high water-solubility in PBS, named “seMpai” (SIGMA-ALDRICH). seMpai made it possible to detect a micro-cancer in the lung of mice that D-luciferin could not detect.

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Structure-activity relationship of AMP-luciferin analogues for optical imaging

Ryohei Saito[1, 2], Nobuo Kitada[1], Satoshi Iwano[1], Rika Obata[1],
Takashi Hirano[1] and Shojiro A. Maki[1]
[1]Department of Engineering Science, The University of Electro-Communications,
1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan
[2]School of Pharmacy, Tokyo University of Pharmacy and Life Sciences,
1432-1 Horinouchi, Hachioji, Tokyo 192-0392, Japan
Key words: Firefly Bioluminescence, Luciferin-Luciferase reaction, Near-Infrared light.

Firefly bioluminescent system is attracting widespread attention as an *in vivo* imaging tool. Recently, Near-InfraRed (NIR) light (650–1000 nm) is hot topic due to high living body permeability. Although many NIR fluorescence imaging tools are commercialy available, these are not self-luminescent.

We study the relationship between structure modification and the firefly luminescence wavelength, that the luciferase of *Photinus pyralis (Ppy)* was used. And we have succeeded in development of Akalumine® which is a world's first near-infrared light *in vivo* imaging tool of bioluminescence.[1, 2, 3]

Firefly biouminescence is two stepwise reaction. Luciferase convert luciferin into AMP-luciferin (intermediate) by adenylation reaction, and then AMP-luciferin is converted into oxyluciferin by oxygenation reaction. It is known that emission efficiency increase 1000 fold by using the AMP-luciferin, instead of lucifein. So the emission efficiency of luciferin can be raised when AMP-luciferin is used. However, it is very unstable. Then, I will make more stable AMP-luciferin analogues compared with willdtype AMP-luciferin, and I try to clear practical problem by establishing structure-activity relationship of AMP-luciferin analogues

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Droplet based characterization of temperature dependent kinetics of DNA circuits

A. Koshi[1*], and Y. Hori[1]

[1]Department of Applied Physics and Physico-Informatics, Keio University,

3-14-1 Hiyoshi, Kohoku-ku, Yokohama 223-8522, Japan

*E-mail: asuka.koshi@gmail.com; +81-(0)45-566-1548

Key words: Synthetic Biology, DNA circuits, Droplets.

Current design of synthetic biomolecular systems often hinges upon the precise regulation of extensive variables, variables that depend on the size of the system such as molecular concentrations. As a result, many of existing circuit design toolkits are oriented to the optimization of molecular concentrations. On the other hand, intensive variables, variables that do not depend on the system size such as temperature are often overlooked in the design of synthetic biomolecular systems.

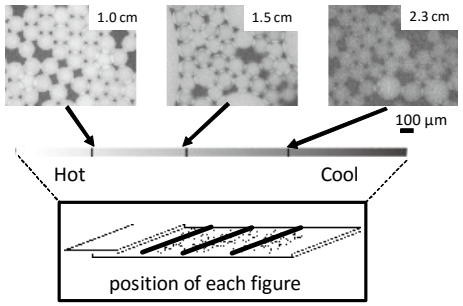

Fig. 1 Fluorescence images of droplets on the glass slide

Here, we present a computer-controlled experimental platform that enables characterization of temperature dependent kinetics of biomolecular circuits using droplet reactors. Specifically, we designed a droplet incubation chamber that can generate a continuous gradient of temperature using a controlled peltier element, enabling screening and characterization of temperature dependent kinetics of biomolecular reactions. The spatiotemporal profile of the temperature gradient can be monitored either with thermocouples on the chamber or a DNA thermometer, a temperatureresponsive hairpin DNA with fluorophore, encapsulated in droplets. [1)] Thereby, it is possible to directly measure the temperature of a reaction mix using the fluorescence intensity of the DNA thermometer. As a proof-of-concept demonstration, we performed a parallel temperature screening of a simple hairpin DNA circuit and characterized its temperatureresponsive output.

Furthermore, we also created a computational model of the heat transfer kinetics of the spatially distributed droplet reactors to enable model-based analysis of the temperature dependent kinetics of biomolecular circuits. Combining this model with the proposed experimental platform, we envision model-based designing of biomolecular reactions considering temperature dependence,

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I Development of Scanning Probe Quantum Sensing System using Nitrogen-Vacancy Center in Diamond

M. Gotoh[1*], T.An[2], and J.Ishi-Hayase[1]

[1] School of Fundamental Science and Technology, Keio University, 223-8522, Japan

[2] School of Materials Science, Japan Advanced Institute of Science and Technology, 923-1292, Japan.

*E-mail: gotoh.9593@keio.jp; +81-(0)080-6046-7273

Key words: Diamond, Nitrogen-vacancy center, Atomic force microscopy.

A nitrogen-vacancy (NV) center in diamond is a promising candidate for highly-sensitive nano-scale magnetometer. High sensitivity and high spatial resolution can be achieved by using unique properties of electron spin states of NV center; the long coherence time under ambient condition, easy initialization and manipulation by irradiating laser and microwave[1]. The sensitivity and spatial resolution of magnetometer using NV centers are significantly dependent on the distance between the NV center and the measurement target[2]. However, it is difficult to control and scan the distance between the NV center and target when we use the NV center in bulk diamond. In this research, we aim to develop the scanning magnetometer using NV centers by combining atomic force microscope (AFM) and laser confocal microscope to precisely control the distance between NV centers and the target. In the experimental setup, diamond probe containing NV center ensemble is located at the apex of the AFM tip to precisely control the position of NV centers. In the presentation, we will show the present status of our scanning magnetometer using diamond probe under development.

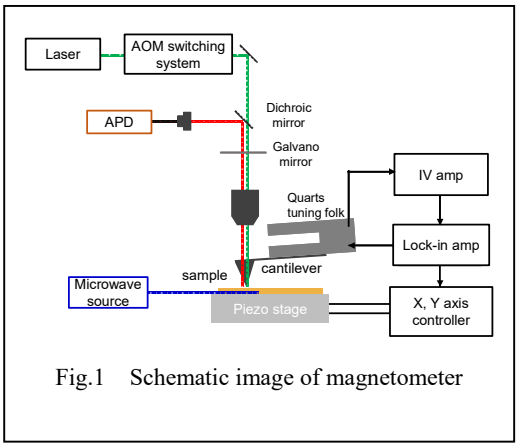

Fig.1 Schematic image of magnetometer

This work was supported by JSPS KAKENHI (Grant No. 15K17732) and MEXT KAKENHI (Grants No. 18H01502, 15H05868, 15H05870, 15H03996, 26220602, and 26249108), and Q-LEAP. The samples were fabricated in collaboration with NIMS nanofabrication platform.

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Construction and operation of a tabletop system for nanoscale magnetometry with single nitrogen-vacancy centers in diamond

Daiki. Misonou[1*], Kento.Sasaki[1], Shuntaro.Ishizu[1] Yasuaki.Monnai[1]
Kohei M. Itoh[1,2] and Eisuke.Abe[1,3]

[1] School of Fundamental Science and Technology, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama 223-8522, Japan

[2] Center for Spintronics Research Network, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama 223-8522, Japan

[3] RIKEN Center for Emergent Matter Science, Wako, Saitama 351-0198, Japan

*E-mail: daiki.miso15199@keio.jp; +81-(0)45-566-1594

Key: words: nitrogen-vacancy (NV), ODMR, NMR

Because of its long coherence time at room temperature, capability of driving it using microwave and optically detecting its state, the single electron spin associated with a nitrogen-vacancy (NV) center in diamond is a prime candidate for a solid-state quantum magnetometer capable of detecting single nuclear spins with prospective application to nuclear magnetic resonance (NMR) at the nanoscale.[1]

Nonetheless, an NV magnetometer is still less accessible to many chemists and biologists, as its experimental setup and operational principle are starkly different from those of conventional NMR.

Here, we design, construct, and operate a compact tabletop-sized system for quantum sensing with a single NV center, built primarily from commercially available optical components and electronics.

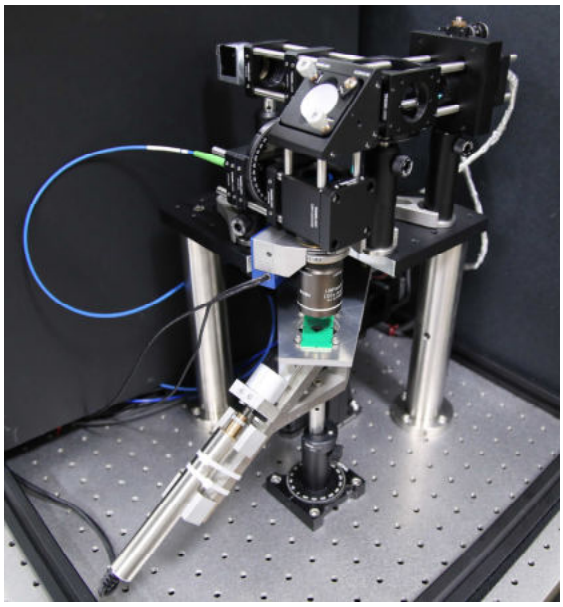

FIG. 1. Photo of our tabletop system

We show results of basic operation of our setup and quantum sensing with a single NV center. Photoluminescence imaging, continuous-wave optically detected magnetic resonance (CW ODMR), Rabi measurement, pulsed ODMR, Ramsey interferometry and Hahn echo can characterize a single NV center. As an example of quantum sensing with a single NV center, we show the detection of single ^{13}C nuclear spins which is located around the NV center in diamond. From results of measurement, we can characterize their interaction parameters. We also detect a small ensemble of proton nuclear spins on the diamond surface as an example of detection of external spins. Through these results, we prove that our setup can implement state-of-the-art quantum sensing protocol of internal and external nuclear spins.

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Molecular nano-spintronic devices utilizing magnetic thin-film edges

Y. Sasaki[1,2*], R. Msiska[1,2], T. Misawa[1], S. Mori[1], T. Komine[3], N. Hoshino[4],
T. Akutagawa[4], M. Fujioka[1], J. Nishii[1], and H. Kaiju[2,5]
[1]Research Institute for Electronic Science, Hokkaido Univ., Hokkaido 001-0020, Japan
[2]Faculty of Science and Technology, Keio Univ., Kanagawa 223-8522, Japan
[3]Graduate School of Science and Engineering, Ibaraki Univ., Ibaraki 316-8511, Japan
[4]Institute of Multidisciplinary Research for Advanced Materials,
Tohoku Univ., Miyagi 980-8577, Japan
[5]Center for Spintronics Research Network, Keio Univ., Kanagawa 223-8522, Japan
*E-mail: ysasaki@es.hokudai.ac.jp; +81-(0)45-566-1428
Key words: Spintronics, Nanoscale junctions, Organic molecules, Magnetic thin film.

Long spin coherent length in molecules, which realizes large magnetoresistance (MR) ratio, has attracted considerable interest in spintronics [1,2]. Recently, we have proposed nanoscale junction devices, which consist of molecules sandwiched between crossed edges of two magnetic thin films [3]. In this study, we fabricate $Ni_{78}Fe_{22}/Mq_3$ (M = Al, Er, q = 8-hydroxyquinolinato) $/Ni_{78}Fe_{22}$ junction devices and investigate electric and magnetic properties.

$Ni_{78}Fe_{22}$ (permalloy, Py in the following) thin films were deposited on low-softening-point (LSP) glass substrates using ion beam sputtering. Then, LSP glass substrates with the same composition were stacked on the fabricated Py films at 513°C and 0.25–1.0 MPa using the thermal pressing technique. The obtained samples were cut in half, and their cross-sectional surfaces were polished. Finally, an Mq_3 thin film with a thickness of 20 nm was spin-coated on the polished glass/Py/glass surface, and another glass/Py/glass sample was orthogonally stacked on the Mq_3 film with two Py edges crossed. The current-voltage characteristics and MR effect of the devices were evaluated by a four-probe method at room temperature.

Fig. 1 shows a typical MR effect of Py/Alq_3/Py devices at room temperature. In the both cases of Py/Alq_3/Py and Py/Erq_3/Py devices, the bias voltage dependence of MR ratio agreed well with calculation results performed using Zhang's theory [4]. This means that spin flips mainly occur due to hot electrons in parallel magnetization of devices. Our theoretical and experimental works will provide new understanding on molecular spintronic devices.

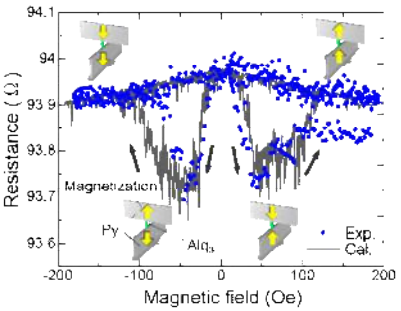

Fig. 1 MR effect of Py/Alq_3/Py at room temperature.

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Upgrades of scanning probe microscopy for higher resolution and wider applications

Y. Shoji[1*] and T. K. Shimizu[1,2]

[1]School of Fundamental Science and Technology, Keio University, Japan

[2]Department of Applied Physics and Physico-Informatics, Keio University, Japan

*E-mail: yuhi402@keio.jp

Key words: Surface science, Scanning probe microscopy, Instrumentation, Atomic resolution.

Scanning probe microscopy (SPM) is one of the powerful techniques to investigate structures of material surfaces as well as adsorbed species at the atomic and submolecular scale. One drawback of the high resolution SPM is that the sample must be atomically flat and homogeneous. Therefore, it is very challenging to observe surfaces with many steps or three-dimensional objects, e.g., nanoparticles, porous materials, and nanoscale devises, which are technologically relevant. In order to overcome this challenge, we have developed an SPM instrument that is capable of scanning lager area with lager height variation than conventional ones. We are currently working on improvement of this instrument to solve two technical problems.

The first problem is its resolution. Because of its capability of large scanning area, the scanner is not mechanically rigid, which hampers atomic resolution. We confirmed atomic steps (~200 pm), but could not observe smaller features i.e., atoms and herringbone reconstruction on the Au (111) surface (Fig.1). To tackle this problem, we are constructing a new scanner with higher mechanical stability. Its eigenfrequency is 4.8 kHz, which is high enough to reduce the mechanical noise level at low frequency ranges to achieve atomic resolution. We expect that its scanning range is approximately 4.5 μm horizontally and 360 nm vertically, wide enough for various samples.

The other problem is that we cannot observe insulating materials. Because we use it as a scanning tunneling microscope (STM), the sample should be electrically conductive. By exchanging the sensor to a quartz sensor called KolibriSensor (SPECS^{TM}), we will also be able to scan over insulators by performing atomic force microscopy (AFM). The advantage the Kolibri sensor is the capability of accessing short-range forces due to its small amplitude, high resonance frequency, and high quality factor (1).

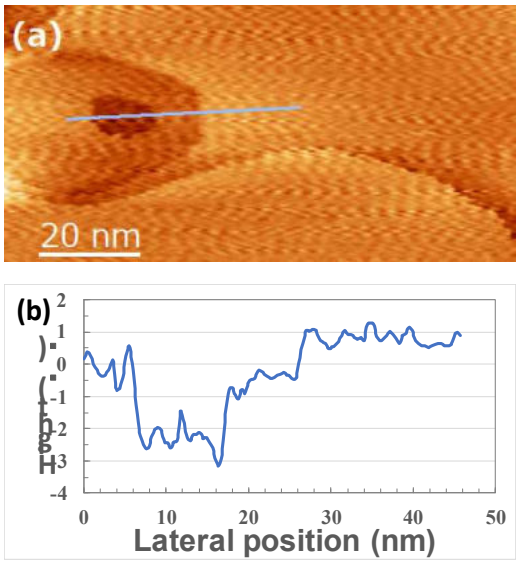

Fig.1 (a) STM image (100×50 nm^2) of Au (111). Atomic steps (~200 pm) are clearly shown. A fine pattern over the surface are caused by mechanical noise (~3 Hz). (b) Height profile along the blue line indicated in (a).

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Scanning tunneling microscopy study of photochromic diarylethene on noble metal surfaces

S. Mabuchi[1*], and T. K. Shimizu[1]

[1]Department of Applied Physics and Physico-Informatics, Keio University,
3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa, 223-8522, Japan

*E-mail: shunichirou@keio.jp

Key words: Scanning tunneling microscopy, Photochromic molecules, Raman spectroscopy.

Photochromic molecules are expected to be applicable to organic memory devices. For that purpose, it is necessary to understand the properties of the molecules on solid surfaces. Photochromic diarylethene (DAE) molecules transform between two isomeric states, open-form and closed-form (Fig. 1(a)), by the irradiation of UV and visible light. In this study, we report investigations of structures of DAE molecules adsorbed on noble metal surfaces using scanning tunneling microscopy (STM) and vibrational spectra using Raman spectroscopy

Figure 1 (b) and (c) show STM images of DAE molecules adsorbed on Cu(111). We found that the molecules were randomly distributed over the surface (Fig. 1(b)). When we co-adsorbed NaCl followed by annealing, a superstructure was formed (Fig. 1(c)). In order to obtain an insight into the substrate-molecule and intermolecular interactions in the superstructure, density functional theory (DFT) calculations were carried out. The optimal structure for the molecular row suggests the inclusion of Na^+ ions that interact with the electronic dipole of closed-form DAE molecules.

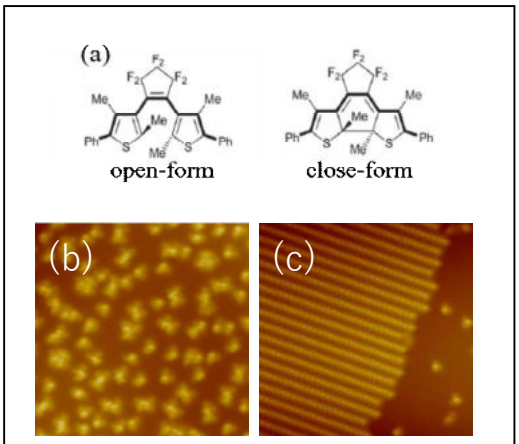

Fig. 1: (a) Two isomeric states of DAE molecules. (b) and (c) STM images of DAE adsorbed on Cu(111) without NaCl (b) and with NaCl (c).

We also performed Raman spectroscopy of DAE in powder form to confirm whether the method is applicable to the distinction of their two isomeric states. The DAE molecules possibly alternate by irradiation with Raman laser. To avoid the undesirable isomerization, we used near-infrared laser (785 nm), but couldn't observe clear difference between two isomeric states in Raman spectra. We plan to compare our results with theoretically predicted Raman peak energies to assure the vibrational energies of two isomeric forms.

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Synthesis method and transport properties of $LaCu_{1-\delta}S_{0.5}Se_{0.5}O$

N. Azuma[1*], H. Sawada[1], R. Sakagami[1], M. Matoba[1], and Y. Kamihara[1]

[1]Department of Applied Physics and Physico-Informatics, Faculty of Science and Technology, Keio University, 3-14-1 Hiyoshi, Yokohama 223-8522, Japan

*E-mail: ubon.mza@keio.jp; +81-(0)45-566-1611

Key words: Thermoelectric material, $LaCu_{1-\delta}S_{0.5}Se_{0.5}O$, Electrical resistivity, Optical band gap.

Thermoelectric exchange (TE) materials is expected to convert thermal current (or temperature gradients) to electric voltage without chemical reaction. The efficiency of them are verified by the material-specific dimensionless figure of merit *ZT*, which is defined as $ZT = S^2T\rho^{-1}\kappa^{-1}$, where *S* is the Seebeck coefficient, ρ is the electrical resistivity, κ is the thermal conductivity, and *T* is the absolute temperature [1,2].

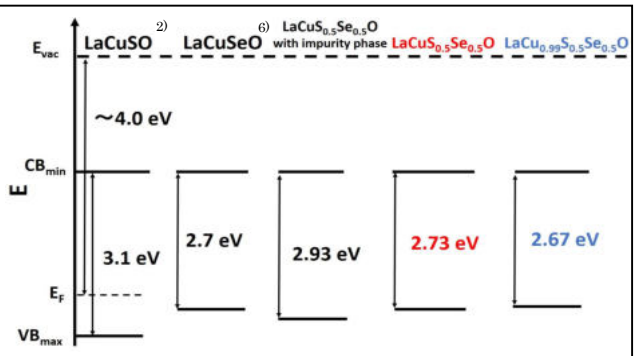

Fig. 1 Electronic structure models for $LaCu_{1-\delta}ChO$ (*Ch*=Chalcogen).Work function was roughly estimated as ~4 eV from density functional calculations.

Layered mixed anion compounds with ZrCuSiAs-type structure exhibit various electronic functional properties. E.g. electrical resistivity of LaCuSO drastically decreases down from ~10^5 Ω cm to ~10^{-1} Ω cm as a result of Cu deficiency at 300 K[2]. Materials with ZrCuSiAs-type structure may contain new thermoelectric materials with higher *ZT*. $LaCu_{1-\delta}S_{0.5}Se_{0.5}O$ is a typical ZrCuSiAs-type material, which has a layered structure composed of carrier blocking layer of La_2O_2 and carrier conducting layer of Cu_2S_2/Se_2 alternately stacked along the c axis[3]. K. Ueda *et.al.* reported thin film $LaCuS_{0.5}Se_{0.5}O$ has high mobility, and doping S/Se may cause low thermal conductivity. So $LaCuS_{0.5}Se_{0.5}O$ is expected to attain high *ZT*.

In this study, we revealed the synthesis method of polycrystalline $LaCuS_{0.5}Se_{0.5}O$ bulk and $LaCu_{0.99}S_{0.5}Se_{0.5}O$ bulk by solid-state method, and demonstrated the electrical properties by measuring resistivity and reflectivity. Optical band gap was analyzed by using Kubelka-Munk equation[4] and Tauc plot[5]. Resistivity of $LaCuS_{0.5}Se_{0.5}O$ with impurity phase is $6(2)\times10^6$ Ω cm, $LaCuS_{0.5}Se_{0.5}O$ is 4.6(3) Ω cm and $LaCu_{0.99}S_{0.5}Se_{0.5}O$ is 8(2) $\times10^{-1}$ Ω cm. Electrical band structure of $LaCu_{1-\delta}S_{0.5}Se_{0.5}O$ is represented in Fig. 1.

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Study on nitride semiconductor device with ZnO tunnel junction electrodes

Masaya Daikoku*, Takeyoshi Tajiri and Kazuo Uchida
Department of Computer and Network Engineering Graduate School of Informatics and Engineering, The University of Electro-Communications, Chofu, Tokyo 182-8585 Japan
*E-mail: daikoku@semidevicelab.es.uec.ac.jp;
Key words: p-GaN, ZnO, RF magnetron sputtering

Recently, the performance of AlGaN as an ultraviolet light source has been improved remarkable, except for its low power efficiency caused by the high ohmic contact resistance of p-AlGaN. This is because AlGaN is a wide bandgap semiconductor and has high electron affinity so that no metal could form good ohmic contacts[1].

Thus, the purpose of this study is to investigate a tunnel junction electrode using n-ZnO that is an alternative of metal ohmic contacts and could improve I-V characteristic of AlGaN devices.

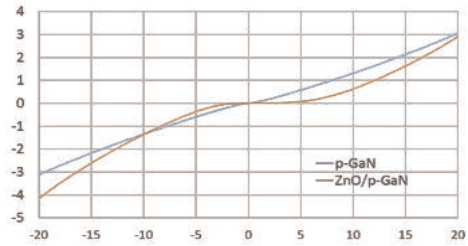

Fig.1.Th I-V characteristic of ZnO/p-GaN and p-GaN samples

The sample used in this study was MOVPE grown p-GaN with ZnO as a tunnel junction electrode on top that was sputtered by RF magnetron sputtering. The I-V characteristics of this device comparing with that of p-GaN sample are shown in Figure 1. In this figure, the applied voltage was ranging from -20V to 20V for both samples. The sample current of this device is larger than that of p-GaN in the reverse voltage and details will be shown and discussed in this workshop.

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Structural analysis of carbon black using atomic force microscopy

A. Takekoshi and T. K. Shimizu
Department of Applied Physics and Physico-Informatics, Keio University, 3-4-1, Hiyoshi, Kohoku-ku, Yokohama, Kanagawa, 223-8522, Japan
*E-mail: aoi-kstk16@keio.jp; +81-(0)45-566-1669
Key words: carbon black, surface, atomic force microscopy, dispersion.

Carbon black is used in various applications such as rubber and ink. We chose two types of carbon black, A and B, with different size and properties for the structural characterization using atomic force microscopy (AFM) and scannig tunneling microscopy (STM).

Five kinds of organic solvents, acetone, ethanol, mathanol, hexane, and toluene were used as dispersion solvents to perform drop drying, and AFM images of five samples were compared. Among these, the best dispersibility was achieved with ethanol. The height of the carbon black varies depending on each aggregate. The height ranges from 20 nm to 300 nm for the carbon black A, and from 5 nm to 150 nm for the carbon black B. These observations indicate broad particle-size distribution.

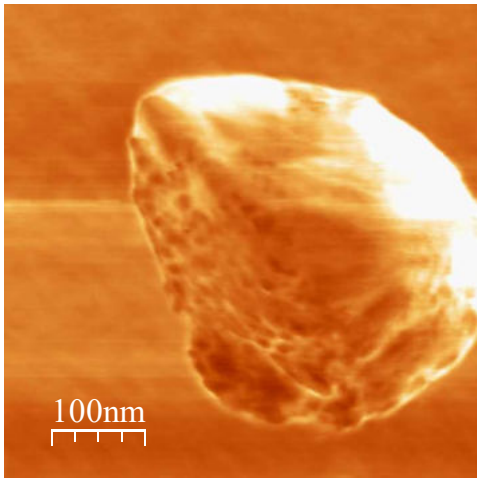

Fig.1 AFM image of carbon black dispersed by ethanol

STM images of the same samples exhibited small particles or protrusions on the surface. As is evidenced by the usability of STM, these aggregates were conductive.

In the future, we plan to investigate the correlation between surface structures and chemical species by combining AFM and vibrational spectroscopy. We expect that vibrational spectra is useful for the identification of functional groups present on the surface of carbon black.

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Control of nanoscale superlubricity of graphene using anisotropy at stacking interface

K. Hirao[1*], R. Okamoto[2], S. Ohmuki[2], and N. Sasaki[2]
[1]Fac. Inform. and Eng., Univ. Electro-Commun.,
[2]Grad. Sch.Inform. and Eng., Univ. Electro-Commun.

The realization of a novel superlubric system leads to an energetically effective control of machines on the nanometer scale. Superlubricity of graphite has been reported based on observed and simulated anisotropies of atomic scale friction [1-3]. Previous studies showed that the superlubric state appeared along the scan direction for the incommensurate stacking structure.

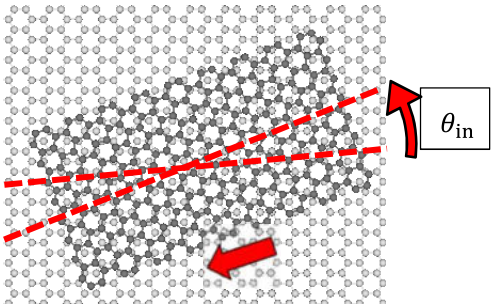

Figure1. A simulation model of the monolayer graphene sheet physically absorbed onto the graphite substrate surface.

Macroscopic Amonton-Coulomb's law states that the friction force is proportional to the real contact area. However, the nano-scale friction force changes depending on the orientation angle θ_{in}, although the area of the graphene sheet is kept constant, which means the breakdown of Amonton-Coulomb's law at nanometer-scale. Therefore it is important to discuss "nano-scale real contact area" of the graphene sheet. In order to define the nano-scale real contact area, we focused on the moire patterns produced by anisotropic stacking of the two periodic crystal structures. In this study we investigated whether nano-scale contact area can be mathematically described by moire patterns.

In this work, the monolayer graphene sheet absorbed onto the graphite substrate surface is numerically studied by molecular mechanics simulation (Fig. 1). The covalent bonding energy described by Tersoff potential energy function V_{cov} and nonbonding van der Waals interaction energy function V_{vdw} described by modified Lennard-Jones potential energy function. Total energy $V_{\mathrm{total}} = V_{\mathrm{vdw}} + V_{\mathrm{cov}}$ is minimized by using the conjugate gradient (CG) method to obtain optimized structure. First anisotropy of the moire patterns is simulated as a function of the initial orientation angle θ_{in} ($0\ \mathrm{deg.} \leq \theta_{\mathrm{in}} \leq 10\ \mathrm{deg.}$) between graphene sheet and graphite substrate surface (Fig. 1). Then the relationship between lateral forces acting on the graphene sheet and moire patterns during the sliding process is investigated.

It is clarified that, for the finite orientation angle θ_{in}, the energetically stable AB stacking region forms a hexagonal lattice and the unstable AA stacking region forms a triangular lattice. Furthermore it is found that evaluated area of AB stacking region reduces as orientation angle θ_{in} increases. It is also found that the maximum lateral force($\max f_{\mathrm{x}}$) takes a behavior similar to the area of AB stacking region.

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Elementary Process of Peeling of Graphene Sheet for Commensurate and Incommensurate Contacts

P. A. Lozen[1*], S. Ohmuki[1], and N. Sasaki[1]

[1]Department of Engineering Science, The University of Electro-Communications, 1-5-1 Chofugaoka, 182-8585, Japan

*E-mail: philzn@uec.ac.jp

Key words: Nanotribology, Friction, Peeling, Graphene, Molecular Mechanics Simulation.

Anisotropy of atomic-scale peeling of monolayer graphene sheet adsorbed onto graphite substrate surface is specifically studied by using both simulation [1] and experiment [2], and anisotropy of the peeling process was found during the surface contact region [3]. The incommensurate contact between the graphene sheets and the graphite surface inducing ultralow frictional state due to superlubricity is studied, but the elementary peeling process is yet to be studied.

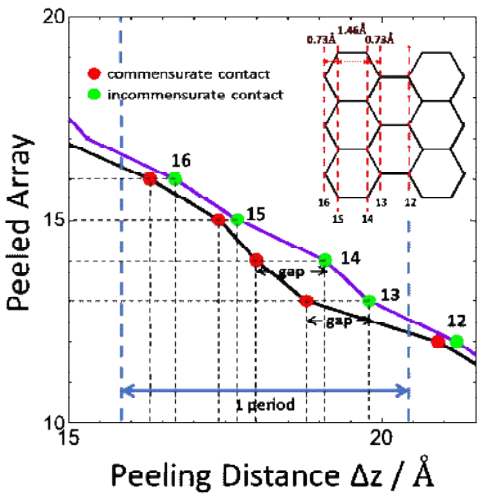

Figure: Peeling curves of the 16th-12th carbon atom arrays of the graphene sheet, for the commensurate and incommensurate contacts.

Therefore, in this work, the elementary process of peeling occurring at the graphene/graphene interface along the commensurate and incommensurate sliding directions was studied by molecular mechanic simulation. This peeling process strongly depends on the initial contact orientation angle θ_{in} between the graphene sheet and the graphite surface within the lateral plane. In commensurate sliding direction, graphene sheet was set in AB stacking orientation, $\theta_{in} = 0^{\circ}$, while in incommensurate sliding direction, the initial orientation angle $\theta_{in} = 30^{\circ}$.

In this work, the entire graphene sheet was regarded as a series of its component, four nearest neighboring arrays of carbon atoms, as illustrated in inset of figure. The peeling proceeded from the leftmost array, labeled as 36th array, to the rightmost array, labeled as 1st array. Here, the peeling behavior of the 16th-12th carbon atom arrays, one pseudo behavior, for the commensurate and incommensurate contacts, is shown in figure. It was clarified that 16th-13th carbon arrays can be regarded as a unit of the peeling mechanics and the unit showed quasiperiodic peeling behaviors. Here, as the peeling distance gradually increased, arrays were peeled in order. Furthermore, there appeared a relatively large gap between commensurate and incommensurate contacts for both the 14th and 13th arrays in peeling curves. However, despite the gap was noticeable in the 2 arrays, the peeling process did not show identical behavior in 12th array. This revealed the elementary peeling process of carbon array for commensurate contact occurred earlier in each period than that for incommensurate contact. Similar peeling features were obtained for all pseudo periods during the process.

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Load Dependence of Friction of C_{60}/Graphene Interface

A. Kaji[1*], R. Okamoto[1], A. Watanabe[1], K. Miura[2], M. Suzuki[1], N. Sasaki[1]
Dept. Eng. Sci., Univ. Electro-Commun. [1], Dept. Phys., Aichi Univ. Educ.[2]

The graphene/C_{60}/graphene interface (Fig.1), developed for controlling friction on nano- or microscale, exhibits excellent ultralow frictional properties[1]. In addition, it was revealed that Amonton-Coulomb's law ($F=\tau A$: friction force is proportional to the real contact area) breaks down in this system[2,3].

In this study, the load dependence of friction of this interface was simulated using molecular mechanics simulation in order to clarify whether another Amonton-Coulomb's law ($F=\mu N$: friction force is proportional to the vertical load) is satisfied or not.

The loading force F_z was obtained by changing the distance between the upper and lower graphene sheets, and the lateral force F_L was obtained by moving the upper graphene sheet laterally. In addition, the Tersoff potential and the Lennard-Jones potential were used as covalent bonding and non-bonding energies, respectively[4-6]. Furthermore, the total energy was minimized by using the Polak-Rebiere-type conjugate gradient method (CG method).

The simulated results showed that $\langle F_L \rangle$ increased rapidly and nonlinearly under the higher loading region ($\langle F_z \rangle \geq 4$ nN) as shown in Fig. 2. However, this characteristic behavior of the graphene /C_{60}/graphene interface did not appear in the case of the graphene /graphene/graphene interface, which contained no three-dimensional elastic nanostructures like C_{60} molecule. Therefore, the relationship between the loading force and deformation of C_{60} molecule was discussed.

In order to investigate the physical origin of the load dependence of $\langle F_L \rangle$, the effective vertical stiffness was evaluated by compressing the C_{60} molecule, and the interface between the C_{60} molecule and the graphene sheet. By comparing effective stiffness of k_{C60} and k_{int}, it was revealed that the C_{60} molecule deformed relatively more easily and largely under the higher loading region (Fig.3).

In this work, it was clarified that the mean lateral force at the C_{60}/graphene interface increased nonlinearly and rapidly under the higher loading region, which means the breakdown of Amonton-Coulomb's law ($F=\mu N$). This characteristic load dependence can be successfully explained by the load dependence of the effective stiffness of C_{60} molecule.

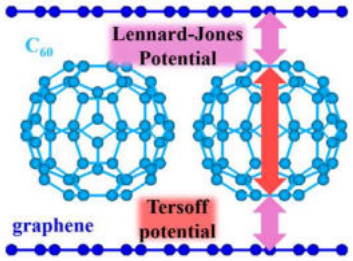

Fig.1 Model of simulation

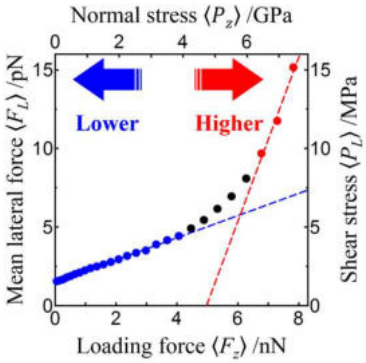

Fig. 2 Load dependence of mean lateral force

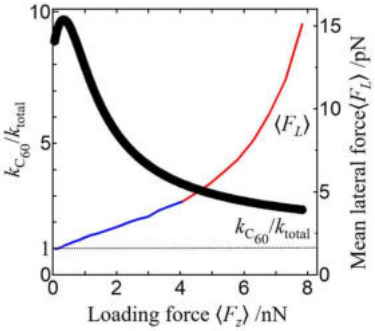

Fig.3 Ratio of stiffness of C_{60} molecule to that of interface between C_{60} molecule and graphene

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Miniaturization of SPR Chemical Sensor Using Electrical Detection and Backside Illumination to Au grating

Yoshiki Saito, Tetsuo Kan

Department of Mechanical Engineering and Intelligent Systems, Graduate School of Informatics and Engineering, The University of Electro-Communications, Japan

*E-mail: saitou@ms.mi.uec.ac.jp; +81-42-443-5423

Key words: Surface Plasmon Resonance, Schottky barrier, Chemical sensor, Near Infrared, Au Grating,.

This paper is a study on miniaturization of Surface Plasmon Resonance (SPR) chemical sensor. SPR is a charge density oscillation that exists at the interface of two media with opposite dielectric constants. Because its resonant nature has high sensitivity to permittivity of the medium facing the metal, and real-time responsiveness, it is being widely used in chemical sensing field[1]. However, conventional SPR chemical sensor relies on a prism and a photodetector to excite and detect SPR, so its whole system is balky[2].

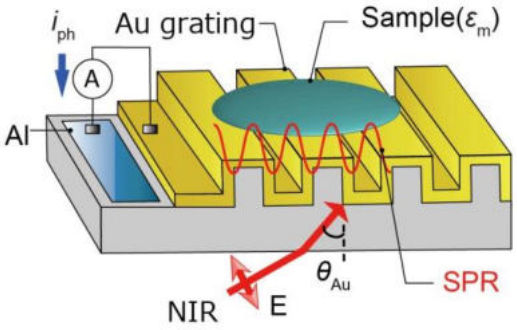

Fig. 1 Structure of proposed device

In this paper, we proposed an electrical detectable SPR chemical sensor has a silicon-based Au grating using the backside illumination method from the n-Si side (Fig. 1). An Au grating is formed on the n-Si wafer to make the sensor excite and detect SPR electrically. Backside-illumination toward the substrate of n-Si is realized using near-infrared light. Since the energy of near-infrared light is smaller than the energy bandgap of Si (~1.1 eV), the incident light propagating through the Si substrate does not attenuate and is able to reach the Au film from the backside. The excitation light is diffracted by the grating. SPR can be coupled to an interface of Au/sample and the excitation light is absorbed. The absorbed energy excites free electrons on the Au surface so that the SPR can be detected electrically by a Schottky barrier diode formed on the Au/n-Si interface[3]. In such a method, SPR is detected as a current peek depending on the temporary current flowing through the Schottky junction.

We demonstrate the function as the chemical sensor from the behavior of SPR peaks in current response curve by changing the refractive index of sample using air and pure water. In experiment, depending on the change of the sample, peaks appeared at different angles in the currents response curve. Additionally, angle of SPR peaks consist with theoretical one, so we verified that the proposing device can behave as a sensor for the sample species on the Au.

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