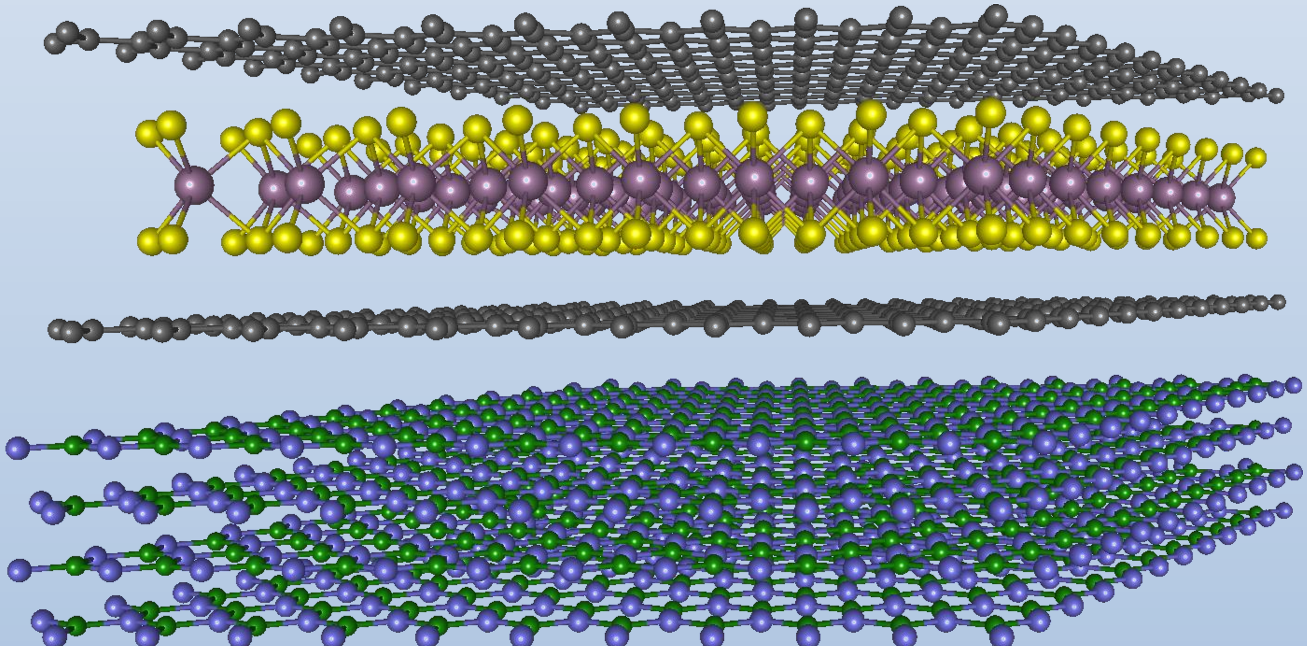
GRAPHENE FLAGSHIP

Japan Science and Technology Agency

3RD JAPAN-EU FLAGSHIP WORKSHOP ON GRAPHENE AND RELATED 2D MATERIALS

FINAL REPORT



NOV. 19TH – 21ST, 2018.

LABORATORY FOR NANOELECTRONICS AND SPINTRONICS
RESEARCH INSTITUTE OF ELECTRICAL COMMUNICATION
TOHOKU UNIVERSITY, SENDAI, JAPAN

3rd Japan-EU Flagship Workshop on Graphene and Related 2D Materials

Final Report

RIEC, Tohoku University, Sendai, Japan
Nov. 19th – 21st, 2018.

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The 3rd EU-Japan Flagship Workshop on Graphene and Related 2D Materials was held at the Laboratory for Nanoelectronics and Spintronics, Research Institute of Electrical Communication, Tohoku University, Sendai, Japan during November 19th – 21st, 2018. This workshop provided the opportunity for Japanese and European researchers to discuss and exchange on the progress in the areas of graphene and related two-dimensional (2D) materials (GRM), fundamental physical phenomena and devices. The aim was to facilitate scientific exchanges and to identify needs and mechanisms for future collaborations. This workshop was a follow up to the first Japan-EU Workshop held in Tokyo, Japan during October 31st – November 2nd, 2015, and the second EU-Japan Workshop held in Barcelona, Spain, during May 6th – 8th, 2017.

The workshop was co-organized by Japanese and European scientists and co-funded by the European Graphene Flagship and the Japan Science and Technology Agency.

The Workshop Organizing Committee was chaired by Prof. Taiichi Otsuji (Tohoku Univ., Japan), Prof. Yoshihiro Iwasa (Univ. Tokyo, Japan), Dr. Atsushi Kurobe (JST-CREST, Japan), Dr. Seiichiro Kawamura (JST-CRPD, Japan), Prof. Stephan Roche (ICREA, Spain), and Prof. Jari Kinaret (Chalmers Univ., Sweden).

The Japanese Advisory Board members Prof. Toshioaki Enoki (Tokyo Inst. Tech., Japan), Prof. Riichiro Saito (Tohoku Univ., Japan), Prof. Tohoki Machida (Univ. Tokyo, Japan), Dr. Masataka Hasegawa (AIST, Japan), and Prof. Yoshichika Otani (Univ. Tokyo, Japan) supported the workshop.

The local organizer Taiichi Otsuji and EU main representative Staphan Roche designed the workshop program so as to maximize possible interaction between Japanese and EU attendees, by selecting topics of mutual interest and well-positioned representatives on both sides (although efforts were made to bring more younger researchers compared to the past 2 editions).

The workshop gathered 46 participants (28 from Japan and 17 from Europe), coming mainly from academic and research institutions. European participants include the Graphene Flagship Director, Work Package Leaders and Deputies and senior researchers mostly from Divisions 1 and 3 (WP1 Enabling Research, WP2 Spintronics, WP3 Enabling Materials, WP5 Biomedical Technologies, WP6 Sensors, WP7 Electronic Devices, WP8 Photonics and Optoelectronics, WP9 Flexible Electronics) in the Graphene Flagship. Participants from Japan included representatives of selected projects supported by the Japan Science and Technology Agency (JST) through the CREST programme and by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) through the SATL program and the Japan Society for the Promotion of Science (JSPS) KAKENHI programme.

The workshop broadly covered the areas of:

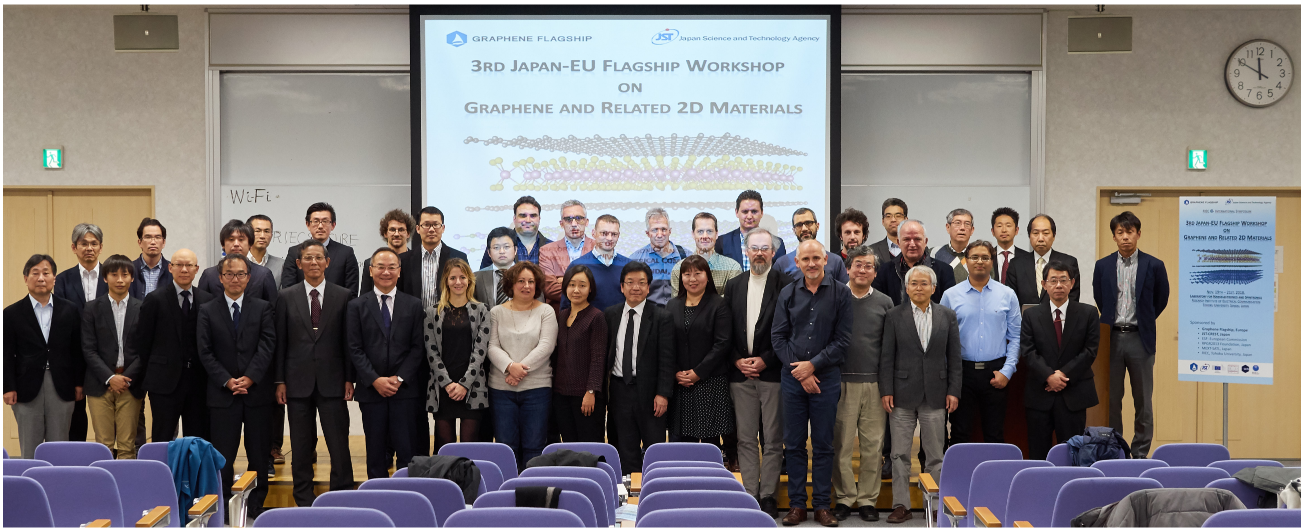
- Graphene and related 2D materials with emphasis on materials synthesis and characterisation with special focus on Boron Nitride (BN) and Transition Metal Dichalcogenides (TMDs);
- Study of fundamental physical properties of graphene/2D related (GRM) materials and heterostructures including 2D superconductivity, topological and transport properties, spin – and valley- tronics; and
- GRM-based functional device technology including terahertz, plasmonic and optoelectronic devices based on GRM including detectors, emitters, modulators and sensors.

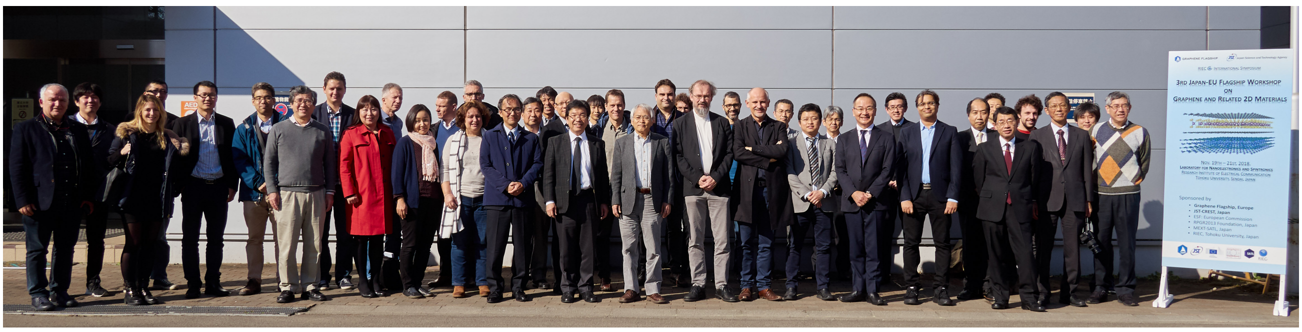
The main technical sessions were divided in physics, materials and devices (including applications), and run three days in a row delivering 34 presentations in total with various cutting-edge sciences and technologies in wide aspects of aforementioned areas. One special focused session was dedicated in which Japan and EU leading scientists presented new research trends and topics on 2D-to-1D transition in TMDs, modeling spintronics and valleytronics for Dirac fermions, and instabilities and field-enhancement effects of surface plasmons in 2D materials.

Beyond the existing regular collaboration between most EU partners and some Japanese colleagues (in particular Kenji Watanabe at NIMS), stimulating discussions between participants have been key to open novel possibilities of future collaboration in the field of material growth and device integration as well as certain types of applications such as biosensing and energy harvesting. At least five different Japanese-European intents or plans to start new collaboration have been identified.

The instrument to foster such collaboration (Graphene Flagship grant for student) has been reminded, and actually during the meeting, the second grantee (Marc Vila from ICN2-Spain) was attending the conference, and after his 2 months stay at Prof. Riichiro Saito Laboratory, Tohoku University, is now in the process of finishing a scientific paper which has been possible thanks to this collaboration frame. Another grant for Japan has been awarded just after the workshop and it is likely that other participants will apply to these EU-grants in the forthcoming months.

Concerning more general aspects of international collaboration, it was mentioned in the final round-table discussion session that bilateral programs exist between Japan and individual European countries but no such programs are available directly between Europe and Japan. At the end of the workshop the fourth workshop was discussed for 2019 in Europe and request of late 2019 from the Japanese side was made, as well as disconnection with the Graphene week. After subsequent communication, it was decided to be discussed about the dates and the location (maybe Pisa in Italy) as well as to change the EU-organizers, and two possible representatives were identified Camila Coletti from IIT (Italy) and Christoph Stampfer from RWTH in Aachen (Germany).





Sponsored by:

Graphene Flagship, Europe

JST-CREST, Japan

ESF: European Commission

RPGR2013 Foundation, Japan

MEXT-SATL, Japan

RIEC, Tohoku University, Japan

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Nov. 19th - 21st, 2018

Conference Room, Nano-Spin Bld., Katahira Campus RIEC, Tohoku University, Sendai, Japan

Scientific Program

Nov. 19th, 2018

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	9:10-9:20	Jari Kinaret	Director, Graphene Flagship Research Supervisor, JST	(Professor, Dept. Appl. Phys. Chalmers Univ. Tech., Sweden) (Chief Fellow, Toshiba Corp., Japan)	–
	9:20-9:30	Atsushi Kurobe			-
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	10:20-10:45	Takamasa Kawanago	Tokyo Tech., Japan	MoS2 FETs fabricated by adhesion lithography	4
	10:45-11:10	Ryo Nouchi	Osaka P. Univ., Japan	Surface chemical reactions on field-effect transistors based on two-dimensional materials	5
	11:10-11:35	Yifeng Fu	CUT, Sweden	Graphene-CNT hybrid material as potential thermal solution in electronics applications	6
	11:35-12:00	Taishi Takenobu	Nagoya Univ., Japan	Light-emitting devices of transition metal dichalcogenide monolayers	7

(WORKING LUNCH)

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(WORKING DINNER)

Nov. 20th, 2018

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(LUNCH)



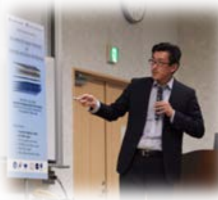




















Access to the Venue

Katahira Campus, Tohoku University

Venue: Laboratory for Nanoelectronics and Spintronics (E04)
Research Institute of Electrical Communication

Access

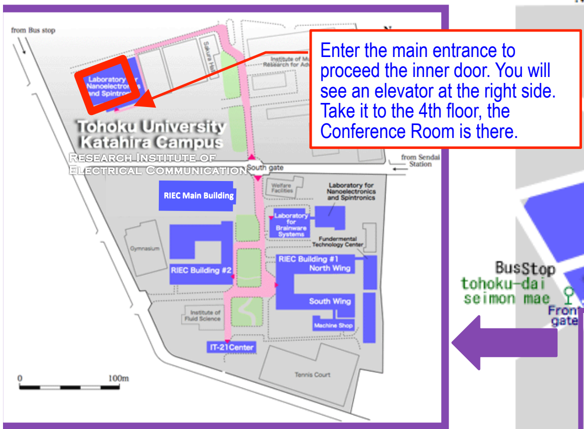
Coming on foot
About 20 minutes from JR SENDAI Station

Municipal bus
Get on bus by way of OTAMAYABASHI
(terminal:SENDAI Station the West bus terminal No. 11)
Get off at "TOHOKU-DAI SEIMON MAE"

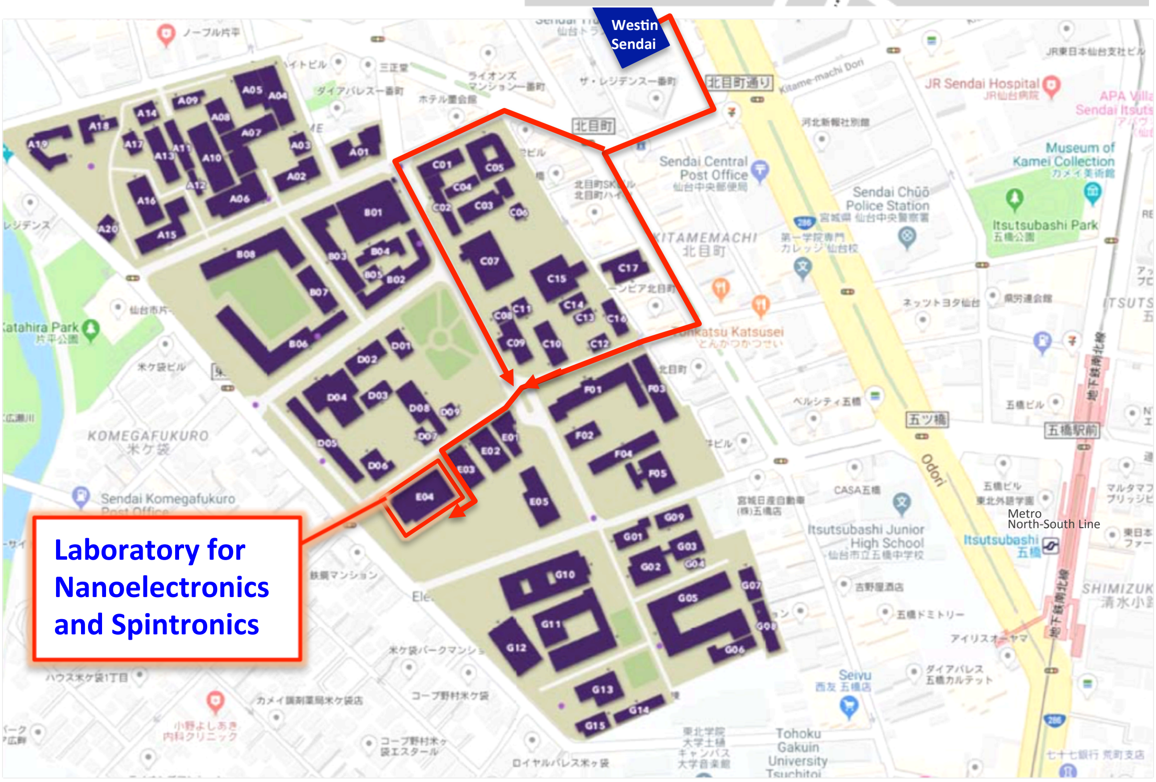
Miyagikotsu bus
Get on bus for NAGAMACHI Terminal by way of DOBUTSU-KOEN
(terminal:SENDAI Station the West bus terminal No. 12)
Get off at "TOHOKU-DAI SEIMON MAE"

Subway
Get on train for direction of TOMIZAWA (terminal:SENDAI Station)
Get off at ITSUTSUBASHI Station
The exit : North exit No.2

Taxi
Give instruction "Tohoku University KATAHIRA Campus"
About 5 minutes from JR SENDAI Station



Research Institute of Electrical Communication
Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai 980-8577, JAPAN



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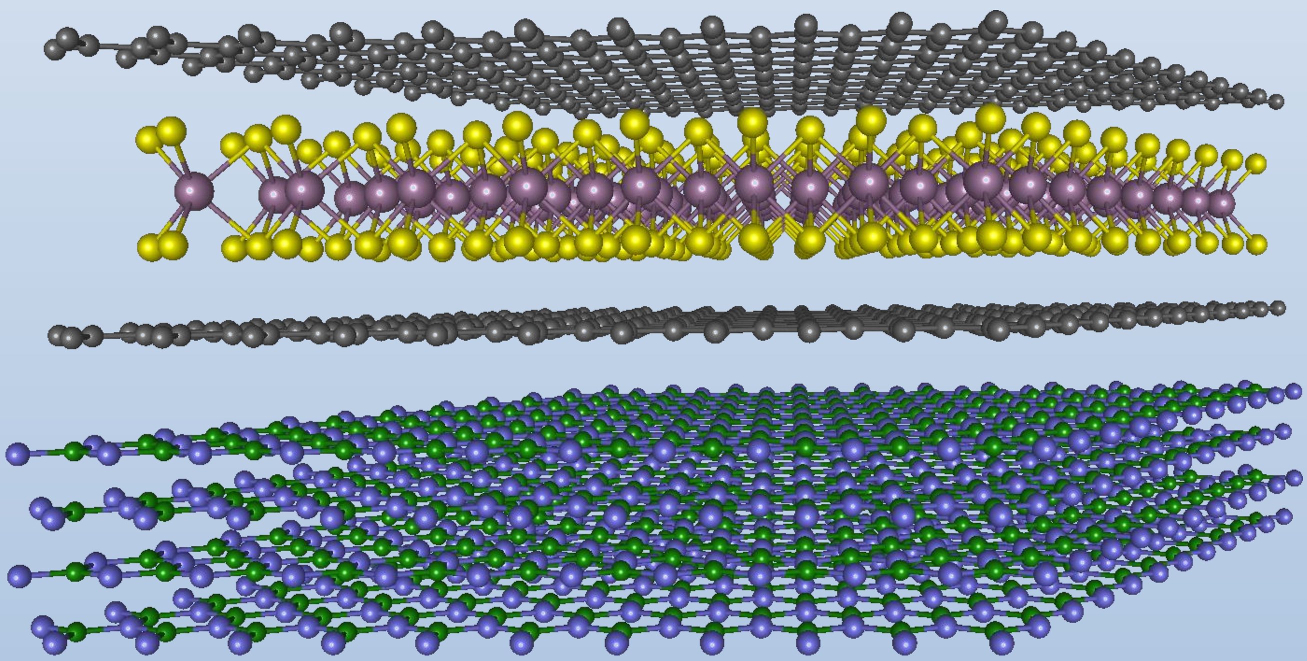
BOOK OF ABSTRACTS



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Session DEV1

Nov. 19th, 2018

Title of the Presentation: Graphene based electronic devices and integrated circuits for RF communication

First Name: Daniel

Last Name: Neumaier

Affiliation: AMO GmbH, Aachen, Germany

Email: neumaier@amo.de

Short Biography:

Daniel Neumaier studied physics and obtained his PhD degree from the University of Regensburg (2009). Since 2009 he is head of the graphene group at AMO GmbH. His research interests are two-dimensional materials for applications in microelectronics and photonics.

Abstract:

Radio frequency integrated circuits (RF ICs) built the core of modern information and communication systems. Graphene based devices like transistors, diodes or varactors have been recognized from the very beginning as promising candidates in future RF ICs, having the potential to significant outperform established devices based on Silicon or III/V semiconductor materials in terms of speed, functionality or flexibility.

However, so far the potential of graphene in RF electronics has mainly been demonstrated on a single device level because the realization of more complex integrated RF circuits was limited by a non-mature fabrication technology and large variations in the device performances.

In this presentation I will present the MMIC (monolithic microwave integrated circuit) process for graphene based RF circuits developed at AMO [1,2] and discuss especially the challenges and possible solutions related to device variability and yield.

Different RF ICs have been realized so far, which are designed for future WiFi communication systems in 5G and for IoT applications [3].

As one example, a double balanced mixer designed for operation from 6-12 GHz has been realized using a graphene based diode ring and metal based passive components (figure 1). This integrated circuit was fabricated on a glass substrate and provides a down-conversion loss of only 10dB, which is identical to GaAs based mixers, but achieved with a much more flexible and cheaper production technology.

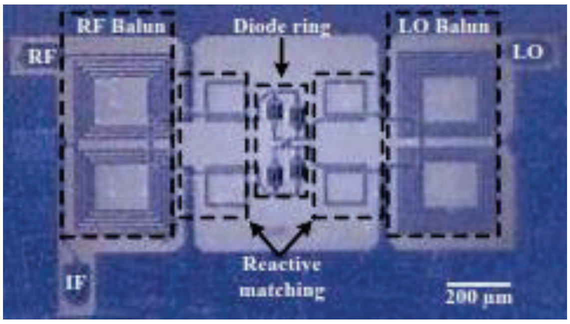


Fig. 1. Optical micrograph of an integrated RF circuit (double balanced mixer operating at 6-12 GHz). The different parts of the circuit are indicated.

[1] A Askar et al. Microwave Conference (GeMiC), 2015 German 299 - 302 (2015).
[2] M Shaygan et al. Nanoscale 9, 11944 (2017).
[3] MS Elsayed et al. Nanoscale 10, 93 (2018).

Title of the Presentation: Electrically inert interface in 2D heterostructure devices

First Name: Kosuke

Last Name: Nagashio

Affiliation: The University of Tokyo, Tokyo, JAPAN

Email: nagashio@material.t.u-tokyo.ac.jp

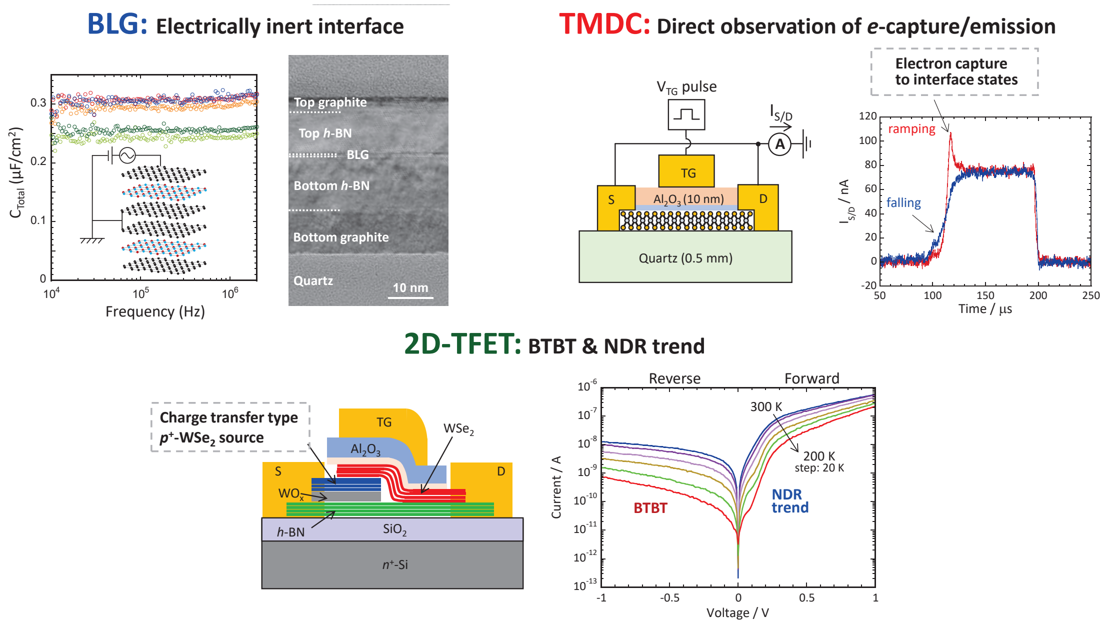
Short Biography:
Kosuke Nagashio received the B.E. degree in Materials Science & Engineering from Kyoto University in 1997 and the M.E. and Ph.D. degrees in Materials Engineering from The University of Tokyo in 1999 and 2002, respectively. He is currently an Associate Professor with the Department of Materials Engineering, The University of Tokyo. His research interests presently focus on the carrier transport in 2D materials and the crystal growth of semiconductors. Dr. Nagashio is a member of the Japan Society of Applied Physics (JSAP), the Materials Research Society (MRS), the IEEE Electron Device Society (EDS) and the American Physics Society (APS).

Abstract:

To realize the electronic and optical devices, the researchers have tried to passivate the interfaces so far for long time, such as dangling bonds at SiO_2/Si interface and lattice mismatch in GaN/AlN heterointerfaces. Contrary to these conventional cases, 2-dimensional layered heterostructure devices have attracted great attentions because the electrically inert interfaces are “expected" without considering the lattice mismatch due to the ideally dangling bond free surface and van der Waals interface. However, the electrical characterization of 2D interface properties have not been conducted in detail by the capacitance measurement. This is due to the large parasitic capacitance of electrode pad and Si substrate.

In this study, by using the quartz substrate, the parasitic capacitance was completely removed. We focus on interface properties for bilayer graphene, MoS_2 and the heterostructures toward the 2D tunneling electronics. Based on the recent results, the perspective on the 2D electronics will be discussed.

[1] BLG: ACS Appl. Mater. Interfaces (2018) in press.
[2] MoS_2: ACS Appl. Mater. Interfaces (2018) in press.
[3] TFET: J. He, et al, Adv. Electronic Mater. 4, 1800207 (2018).



Title of the Presentation: MoS_2 FETs fabricated by adhesion lithography

First Name: Takamasa

Last Name: Kawanago

Affiliation: FIRST, Tokyo Institute of Technology, Tokyo, Japan

Email: kawanago.t.ab@m.titech.ac.jp

Short Biography:

Takamasa Kawanago received the Ph.D. degrees in electronics and applied physics from Tokyo Institute of Technology, Yokohama, Japan, in 2011. He is an Assistant Professor in FIRST at Tokyo Institute of Technology. His current interests include two-dimensional inorganic and organic materials for device applications. His research is recognized national and international awards (e.g. 63th JSAP Outstanding Poster Award, 26th Ando Incentive Prize for the Study of Electronics, 41th ESSDERC Best Paper Award, 32th JSAP Young Scientist Presentation Award, 11th Funai Young Researcher's Award).

Abstract:

Two-dimensional (2D) materials, such as layered transition metal dichalcogenides (TMDC) semiconductors, are emerging research areas that involve multiple fields ranging from fundamental scientific interests to practical device applications [1]. Nowadays, molecular chemistry approaches to 2D TMDC have considerable attention since amazingly rich chemistry and structure of organic molecules enables not only the tailoring of the properties of TMDC but also the fabricating of the functional devices [2]. This study describes our experimental results regarding the hybrid systems based on TMDC and organic self-assembled monolayer (SAM) for functional device applications [3]. The SAM is 2D organic molecular monolayer that spontaneously organizes at specific surface [4]. The SAM is applicable to the fabrication of molybdenum disulfide (MoS_2) field-effect transistor (FET). The self-aligned-gate structure can be prepared by "adhesion lithography" that relies on the ability of SAM to reduce adhesion strength between two objects [5], [6]. Besides, the SAM can be utilized as an ultrathin gate dielectric for MoS_2 FET. The fabricated MoS_2 FET shows remarkable characteristics including in subthreshold slope of 69 mV/dec, no hysteresis and low operating voltage (Fig. 1) [6]. This studies open up interesting directions for research on the functional devices based on 2D materials.

Acknowledgements:

This study was supported by JST CREST (Grant No. JPMJCR16F4), JSPS Grant-in-Aid for Research Activity Start-up (Grant No. 15H06204), Young Scientists (B) (Grant No. 17K14662) and Yazaki Memorial Foundation for Science and Technology.

[1] Q. H. Wang et al., Nat. Nanotechnol. 7, 699 (2012).
[2] S. Bertolazzi et al., Chem. Soc. Rev. 47, 6845 (2018).
[3] T. Kawanago et al., Appl. Phys. Lett. 108, 041605 (2016).
[4] J. C. Love et al., Chem. Rev. 105, 1103 (2005).
[5] D. J. Beesley et al., Nat. Commun. 5, 3933 (2014).
[6] T. Kawanago et al., Appl. Phys. Lett. 110, 133507 (2017).

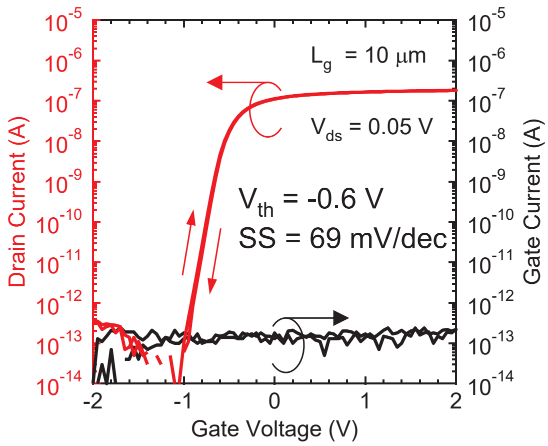


Fig. 1. I_d-V_g characteristics of fabricated MoS_2 FET.

Title of the Presentation: Surface chemical reactions on field-effect transistors based on two-dimensional materials

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Short Biography:

I received my PhD (engineering) at Kyoto University in 2005. I worked at Okayama University from 2005 to 2007 as a postdoc, at Osaka University from 2007 to 2008 as a specially appointed assistant professor, and at Tohoku University from 2008 to 2012 as an assistant professor. In 2012, I moved to Osaka Prefecture University as a lecturer, and was promoted to an associate professor in 2017. I received Incentive Award for Excellent Presentation (2010) and Young Scientist Award (2012) from The Japan Society of Applied Physics. My research interest is surface/interface sciences based on electronic devices of organic semiconductors and low-dimensional materials.

Abstract:

Two-dimensional (2D) materials that can be obtained by exfoliation of layered crystals are very sensitive to surface phenomena owing to their ultimate thinness. Their ultrathin body enables us to control the whole body by means of a field-effect-transistor (FET) configuration because the gate electric field is not completely screened. Thus, it is expected that surface phenomena are controllable by means of FETs with a channel of 2D materials. I will talk on such gate-controlled surface phenomena, especially on gate-controlled chemical reactions at 2D materials surfaces.

FET-related parameters such as the drain voltage and the gate voltage are shown to control surface chemical reactions (Fig. 1). The drain voltage should raise the temperature of the 2D channel through Joule heat generation. The gate voltage can tune the charge carrier density/type in the 2D channel, and control surface adsorption phenomena by the gate electric field. If reactants come from the surrounding environment (e.g., oxygen molecules in oxidation reactions), the adsorption of the reactants onto 2D channels can be a rate-limiting process. In this case, we can control the whole reaction by controlling the adsorption process [1].

In this talk, such controllability of FET-related parameters will be discussed based on various surface reactions of mechanically exfoliated graphene flakes and catalytic reactions at surfaces of transition-metal oxide nanosheets [2].

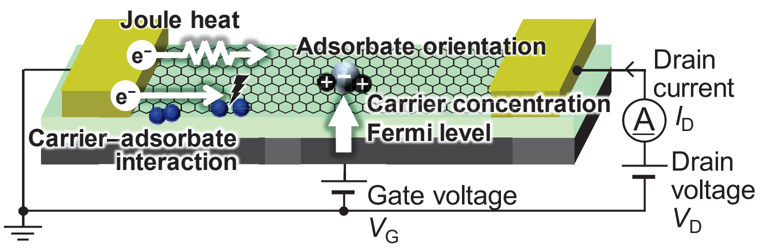

Fig. 1. FET parameters for controlling surface chemical phenomena.

[1] N. Mitoma and R. Nouchi, Appl. Phys. Lett. **103**, 201605 (2013).
[2] R. Nouchi et al., submitted.

Title of the Presentation: Graphene-CNT hybrid material as potential thermal solution in electronics applications

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Last Name: Fu

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Short Biography:

Yifeng Fu received his BS degree (2006) in Thermal Energy and Dynamic Engineering from Central South University, China. He received his PhD degree (2012) in Microsystem Integration from Chalmers University of Technology, Sweden. From 2012 till 2013, he worked as Project Manager and from 2013 till 2015 as Research Manager in SHT Smart High Tech AB, Sweden. In 2015, he joined the Department of Microtechnology and Nanoscience, Chalmers University of Technology, where he is presently Assistant Professor. His research interest covers nano-materials synthesis and processing for microsystem integration. This includes the synthesis and processing of carbon nanotubes, carbon nanofibers, nano wires, graphene and related 2D materials for thermal management and interconnect applications as well as for fundamental research. He has published more than 80 papers in journals and conferences.

Abstract:

Graphene and carbon nanotubes (CNTs) have received great attention for thermal management in electronic systems due to their unique thermal performance. Theoretical simulation suggests that covalent bonds can combine 1D CNTs with 2D graphene to extend the excellent thermal property to three dimensions for heat dissipation. However, this was not experimentally demonstrated due to difficulties in material synthesis. This talk will summarize our recent progress on graphene-CNT hybrid material based thermal management solution. Two technical routes to synthesis the hybrid materials will be presented, various thermal characterizations are carried out to examine the thermal performance of the graphene-CNT hybrid materials, and the high heat dissipation capability of the materials will be demonstrated using a hotspot test platform.

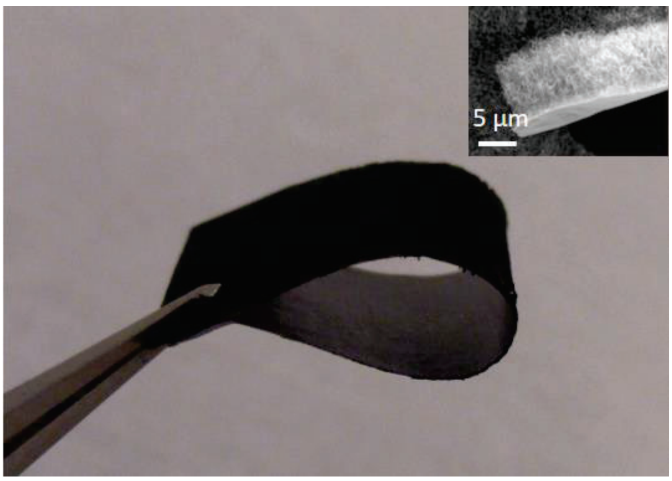

Fig. 1. Graphene-CNT hybrid material synthesized for thermal management application.

Title of the Presentation: Light-emitting devices of transition metal dichalcogenide monolayers

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Short Biography:

Taishi Takenobu received his Ph.D. (materials science) from Japan Advanced Institute of Science and Technology (JAIST) in 2001. Since April 2001, he has worked in SONY corporation. From December 2001, he was assistant and associate professor of Tohoku University. From 2010, he was associate professor and professor of Waseda University, and, from March 2016, he is currently a professor of Nagoya University. His current research interests include (1) realization of electrical driven organic laser devise, (2) flexible, stretchable and printable electronics based on organic and nano materials, and (3) solid state physics and functional devices of TMDC monolayer.

Abstract:

One of the most interesting properties of Transition metal dichalcogenide (TMDC) monolayers is spin-valley coupling, due to a non-centrosymmetric two-dimensional crystal, strong spin-orbit interaction, and non-zero Berry curvature [1]. Actually, circularly polarized light emission has been demonstrated [2,3]. Although the optical properties of TMDCs are very promising, light-emitting devices require intentional doping techniques to form p-n junction. However, reliable doping methods for TMDCs have not yet been fully established. Therefore, the fabrication of TMDC light-emitting devices are still limited, and this fundamental barrier has made investigating electroluminescence (EL) properties of TMDCs inevitably difficult. To overcome this issue, we recently developed the electrochemical method to dope both holes and electrons [4-9], and proposed a simple approach to form p-n junction universally in TMDCs [10-12].

Here, we use this technique to form p-n junction and apply this method into various forms of TMDCs [4], such as monolayer polycrystalline films, single crystalline flakes, and lateral heterojunctions, to achieve photo-detection [10] and EL emission [11,12]. Particularly, using single crystal samples, we have performed temperature and position dependent measurements of EL and investigated their optical properties. Very interestingly, we observed robust circularly polarized EL emission, arising from spin-valley coupling in TMDCs. Our approach paves a versatile way for using TMDCs in discovering new functional optoelectronic devices.

[1]D. Xiao, et al., PRL 108, 196802 (2012)., [2] K.F. Mak et al., Nat. Nanotechnol. 7, 494 (2012).,
[3]Y. J. Zhang, et al. Science 344, 725 (2014)., [4] J. Pu and T. T, Adv. Mater. 30, 1707627 (2018).,
[5]J. Pu, T. T, et al., Nano Lett. 12, 4013 (2012).,
[6] J. Pu, T. T, et al., APL 103, 23505 (2013).,
[7]J.-K. Huang, T. T, et al., ACS Nano. 8, 923 (2014).,
[8] Y.-H. Chang, T. T, et al., ACS Nano. 8, 8582 (2014).,
[9]J. Pu, T. T, et al., Adv. Mater. 28, 4111 (2016).,
[10]D. Kozawa, T. T, et al., APL 109, 201107 (2016).
[11]J. Pu, T. T, et al. Adv. Mater. 29, 1606918 (2017).,
[12]M.-Y. Li, J. Pu, T. T, Adv. Funct. Mater. 28, 1706860 (2018).

3rd Japan-EU Flagship Workshop on Graphene & 2D Materials

Nov. 19th - 21st, 2018
Conference Room, Nano-Spin Bld., Katahira CampusRIEC, Tohoku University, Sendai, Japan

Session PHYS1

Nov. 19th, 2018

Session	Time	Name	Affiliation	Title of presentation	page
PHYS1-1	1:30-1:55	Thomas Ihn	ETH Zurich, Switzerland	Gate-defined bilayer graphene constrictions and quantum dots	10
PHYS1-2	1:55-2:20	Shuichi Murakami	Tokyo Tech., Japan	Two-dimensional electrides as topological materials	11
PHYS1-3	2:20-2:45	Bernard Placais	ENS-Paris, France	Phonon cooling pathways of hot electrons in graphene	12
PHYS1-4	2:45-3:10	Tomoki Machida	Univ. Tokyo, Japan	Robotic assembly and quantum transoprt of van der Waals heterostructures	13
PHYS1-5	3:10-3:35	Felix Casanova	CIC-Nanogune, Spain	Manipulating spin currents with graphene-based heterostructures	14

3rd Japan-EU Workshop on Graphene and Related 2D Materials PHYS1-1

Title of the Presentation: Gate-defined bilayer graphene constrictions and quantum dots

First Name: Thomas

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Short Biography:

Thomas Ihn obtained his PhD degree from the Technical University of Munich for experimental work performed at the Paul-Drude-Institute in Berlin, worked as a postdoc with Prof. L. Eaves at the University of Nottingham, and joined the research group of Prof. Ensslin at ETH Zurich in 1997. He is a professor for Experimental Physics at the Physics Department of ETH since 2007. He worked mainly on transport in nanostructures made from III-V semiconductors, graphene, and recently also on van der Waals heterostructures.

Abstract:
So far, nanostructures in graphene have been mostly realized by etching. This fabrication technique leads to edge-disorder induced localized states at the edges impairing the transport properties of quantum devices [1]. This problem can be overcome by electrostatic definition of nanostructures in bilayer graphene. In this material a vertical electric field opens a band gap [2]. Here we fabricate electrostatically tunable barriers on bilayer graphene devices with graphite as a back gate. Temperature dependent measurements of the resistance show that a band gap of 47 meV is induced, leading to GΩ resistances at temperatures below 4.2 K. With a split-gate structure we define one-dimensional channels which show quantized conductance [3]. The mode quantization in the channel shows a fascinating transition between zero magnetic field and the quantum Hall regime with lifted and restored degeneracies. We also investigate electronic transport through electrostatically defined quantum dots in bilayer graphene [4]. This is an important step towards the promising implementation of spin qubits. In transport direction, charge carriers are confined by pn junctions forming natural tunnel barriers, thus creating a p-type quantum dot coupled to n-type leads, or vice versa. In this ambipolar system, we can realize both single electron and single hole occupation of the respective quantum dots showing charging energies on the order of 10 meV. The extracted single particle energy level spectrum of the quantum dots shows a clear fourfold level bunching originating from the spin and valley degeneracies of bilayer graphene. In parallel magnetic fields we measure a spin g-factor of $g = 2.08$, agreeing well with the predicted value of $g = 2$ for carbon-based devices. In perpendicular magnetic fields, we observe a pronounced valley splitting that is 40 times stronger than the Zeeman splitting observed in parallel fields. The valley splitting predicted theoretically for circular dots, which is approximately linear in the perpendicular magnetic field [5], agrees qualitatively with the experimentally observed splitting.

[1] For a review see D. Bischoff *et al.*, Applied Physics Reviews 2, 031301 (2015).
[2] J.B. Oostinga *et al.*, Nature Materials 7, 151 (2008).
[3] H. Overweg *et al.*, Nano Letters 18, 553 (2018).
[4] M. Eich *et al.*, Phys. Rev. X 8, 0310223 (2018).
[5] P. Recher *et al.*, Phys. Rev. B 79, 085407 (2009).

Title of the Presentation: Two-dimensional electrides as topological materials

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Last Name: Murakami

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Short Biography:

Shuichi Murakami obtained his Ph. D.(1999) degree from University of Tokyo. He moved to Tokyo Institute of Technology as associate professor in 2007, and became professor in Department of Physics and in Materials Research Center for Element Strategy in 2012. He has been working on theories of spintronics and topological phenomena in condensed matter physics. He received Young Scientist Award of the Physical Society of Japan in 2007, Young Scientists' Prize of the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology and Sir Martin Wood Prize in 2010, IBM Japan Science Prize in 2011, JSPS Prize in 2012, and APS Fellow in 2017.

Abstract:

We have been studying topological materials by various theoretical approaches [1-4]. For example, we proposed that a bismuth bilayer film should be a two-dimensional topological insulator [1], and this proposal has been verified experimentally. By looking at various materials from a new perspective we have found that even well-known materials are topological insulators or topological semimetals [1-4]

Recently we proposed that the two-dimensional electrides are good candidates for various kinds of topological materials [5]. In electrides, electrons serve as anions, and the bands occupied by the anionic electrons lie near the Fermi level, because the anionic electrons are weakly bound by the lattice. This property is favorable for realizing band inversion, which is necessary for topological phases. In the presentation we show several examples of two-dimensional topological electrides. Among them, Sc_2C is a layered material having anionic electron layers between the Sc_2C layers. We found that it is an insulator with Zak phase equal to π, similar to the Su-Schrieffer-Heeger model, and thus there should be in-gap states forming a topological surface band. Indeed, the band structure calculation (Fig. 1(a)) show existence of the topological surface states, and they are located at interstitial sites, resulting in “floating surface states” shown in Fig.1(b).

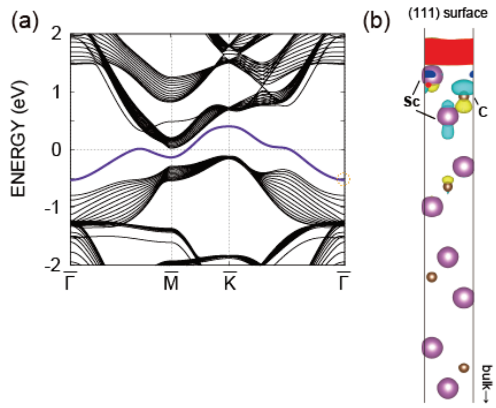

Fig. 1. Topological surface states in Sc_2C. (a) Band structure (b) Spatial profile.

[1] S. Murakami, Phys. Rev. Lett. 97, 236805 (2006).
[2] M. Hirayama, R. Okugawa, S. Ishibashi, S. Murakami, and T. Miyake, Phys. Rev. Lett. 114, 206401 (2015).
[3] M. Hirayama, R. Okugawa, T. Miyake, and S. Murakami, Nat. Commun. 8, 14022 (2017).
[4] S. Murakami, M. Hirayama, R. Okugawa, and T. Miyake, Sci. Adv. 3, e1602680 (2017).
[5] M. Hirayama, S. Matsuishi, H. Hosono, and S. Murakami, Phys. Rev. X 8, 031067 (2018).

Title of the Presentation: Phonon cooling pathways of hot electrons in graphene

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Short Biography:

Bernard Plaçais (61 y.), CNRS research director, is leader of the Mesoscopic Physics team at the Laboratoire Pierre Aigrain of the Ecole Normale Supérieure (8 faculties, 8 PhD students and 3 post-docs), and former director of the French Quantum Mesoscopic Physics Network. Its current research interests range from electron quantum optics in quantum Hall edge conductors, graphene electronics and topological insulators.

Abstract:

Graphene is a versatile platform to investigate electron-phonon relaxation in 2D. It can be investigated by combining high-frequency noise thermometry and Joule heating to access the power-law dependence $P \propto T_e^{\alpha}$ of acoustic-phonon cooling power P with the electronic temperature T_e. In the low-temperature Bloch-Gruneïsen regime we observe $\alpha = 4$ [1], whereas a supercollision mechanism ($\alpha = 3$) circumvents the one-phonon bottleneck ($\alpha = 1$) at high temperature. Optical-phonon cooling shows up at high energy, with an activation law observed in bilayer graphene [3,4].

The weak acoustic phonon scattering provides a Dirac fluid becoming essentially decoupled from the host lattice in high-mobility graphene. It becomes subject to interactions with its environment. At current to saturation, where heat conduction is suppressed and interband Zener-Klein transport prevails, we observe *a drop-down of* T_e (Fig.1) signaling the ignition of a new and very efficient cooling pathway. It is associated with the black-body *emission of hyperbolic phonon-polaritons* in the h-BN substrate [5] under Zener-Klein population inversion.

Phonon emission is suppressed in the quantum Hall regime as electrons are localized along cyclotron orbits. The noiseless ballistic quantum-Hall regime breaks down at a critical field associated with inter Landau level tunneling. Above that field we observe *a steep increase of* T_e which is ultimately limited by the biasing window [6]. We show that breakdown velocity and noise are controlled by electron-electron interactions with the spontaneous *emission of magneto-excitons* in the bulk.

[1] A. Betz et al., Phys. Rev. Lett. 109, 056805 (2012)
[2] A. Betz et al., Nat. Phys. 9, 109-112 (2013)
[3] A. Laitinen et al., Phys. Rev. B 91, 121414(R) (2015)
[4] D. Brunel al., J. Phys. Cond-M. 27, 164208 (2015)
[5] W. Yang et al., Nat. Nanotech. 13, 47-52 (2018)
[6] W. Yang et al., arXiv:1805.05770v1 (2018)

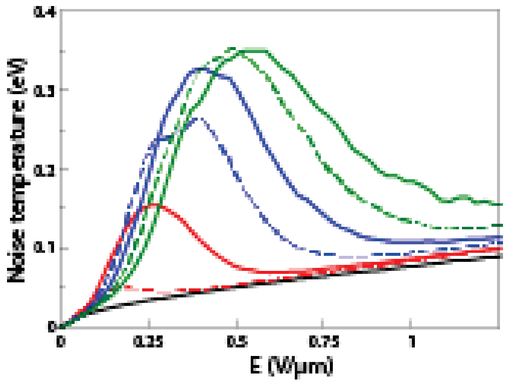

Fig. 1. Hyperbolic phonon-polariton cooling.

Title of the Presentation: Robotic assembly and quantum transport of van der Waals heterostructures

First Name: Tomoki

Last Name: Machida

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Short Biography:

2017-present Professor, Institute of Industrial Science, University of Tokyo
2004-2017 Associate Professor, Institute of Industrial Science, University of Tokyo
2002-2004 PRESTO Researcher, Japan Science and Technology Agency
1998-2002 PD Researcher, CREST/SORST, Japan Science and Technology Agency

Abstract:

Recent advances in mechanical exfoliation and transfer techniques of atomic layers have enabled one to fabricate van der Waals junctions of various two-dimensional (2D) materials, such as graphene, hexagonal boron nitride (h-BN), and transition-metal dichalcogenides (TMDs). The most distinct feature is that lattice matching is not necessary at the interface, because each of layers is stacked only by van der Waals force. As a result, this system has wide variety of choices in materials and almost infinite combinations as the junctions. Furthermore, van der Waals junctions provide an extra degree of freedom that is not possible in conventional heterostructures, i.e., modulation of band structure by controlling the relative twist angle between the crystals at the interface.

Here, we present our recent experiments on robotic fabrication, quantum transport, and optoelectronic applications of van der Waals junctions of various 2D materials: (i) a robotic system for building van der Waals super lattices, (ii) van der Waals Josephson junctions built by assembling two $NbSe_2$ crystal flakes, (iii) van der Waals magnetic tunnel junction built by assembling $Cr_{1/3}TaS_2$ and $Fe_{1/4}TaS_2$, (iv) Dirac fermion reflector in ballistic graphene/h-BN, (v) cyclotron resonance absorption in trilayer graphene.

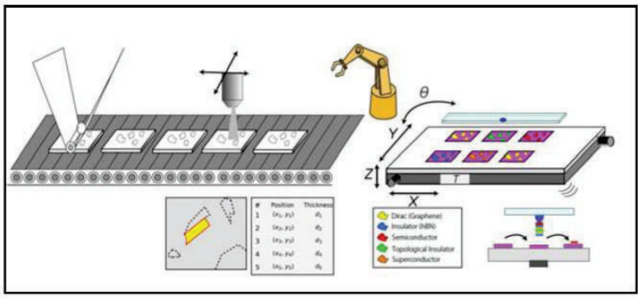

Fig. 1. Schematics of autonomous robotic searching and assembly of 2D crystals to build van der Waals superlattcies.

[1]S. Masubuchi, TM *et al.*, Nat. Commun. **9**, 1413 (2018).
[2]N. Yabuki, TM *et al.*, Nat. Commun. **7**, 10616 (2016).
[3]Y. Yamasaki, TM *et al.*, 2D Mater. **4**, 041007 (2017).
[4]S. Morikawa, TM *et al.*, Semicond. Sci. Technol.**32**, 045010 (2017).
[5]Z. Dou, TM *et al.*, Nano Lett. **18**, 2530 (2018).
[6]Y. Asakawa, TM *et al.*, Phys. Rev. Lett. **119**, 186802 (2017).
[7]Y. Sata, TM *et al.*, Phys. Rev. B **98**, 035422 (2018).
[8]Y. Hoshi, TM *et al.*, Phys. Rev. B **95**, 241403(R) (2017).
[9]Y. Hoshi, TM *et al.*, Phys. Rev. Mater. **2**, 064003 (2018).

Title of the Presentation: Manipulating spin currents with graphene-based heterostructures

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Short Biography:

Ph.D. in Physics (Universitat de Barcelona, 2004). Postdoctoral researcher at the University of California, San Diego (2005-2009). Since 2009, he is an Ikerbasque Research Professor and the coleader of the Nanodevices Group at CIC nanoGUNE. His current research interests are focused on spin-dependent phenomena (including spin transport and spin-orbit effects) in metals, insulators and novel two-dimensional materials. His pioneering studies on spin-charge interconversion in metals have led to an R+D contract with Intel Corp., the world-leading microelectronics company. He is Editorial Board member of Physical Review Applied, published by the APS.

Abstract:

The integration of the spin in charge-based electronic devices has revolutionized both sensing and memory capability in microelectronics. Further development in spintronic devices requires electrical manipulation of spin current as well as spin-charge interconversion for logic operations. Graphene has raised as an outstanding spin transporter due to its weak spin-orbit coupling (SOC) [1]. However, a strong SOC is required for an electrical control of the spin state, as in the seminal proposal of Datta and Das [2], or to achieve spin-charge interconversion, via the spin Hall effect.

In this talk, I will show how SOC can be induced in graphene by proximity with another material, allowing us to manipulate spin currents. A very simple approach by combining Pt with a graphene channel already shows a very large spin-to-charge voltage output at room temperature [3], opening up exciting opportunities for spin-orbit logic circuits. A radically different approach is by engineering a van der Waals (vdW) heterostructure which combines graphene with MoS_2, a transition metal dichalcogenide with strong SOC and semiconducting properties (Fig. 1). The spin transport in the graphene channel is modulated between ON and OFF states by tuning the spin absorption into the MoS_2 layer with a gate electrode [4]. Our demonstration of a spin field-effect switch using 2D materials identifies a new route towards spin logic operations for beyond CMOS technology. Furthermore, the vdW heterostructure at the core of our experiment (Fig. 1) allows us to unveil other phenomena, such as a predicted large spin lifetime anisotropy [5] or a predicted spin Hall effect [6] in graphene due to spin-orbit proximity with the MoS_2. These effects add new functionalities for spin control in graphene.

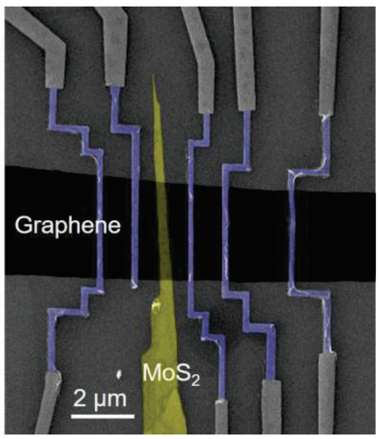

Fig. 1. SEM image of the vdW heterostructure used for switching the spin current.

[1] J. Ingla-Aynes et al., Nano Lett. 16, 4825 (2016).
[2] S. Datta and B. Das, Appl. Phys. Lett. 56, 665 (1990).
[3] W. Yan et al., Nat. Commun. 8, 661 (2017).
[4] W. Yan et al., Nat. Commun. 7, 13372 (2016).
[5]A. W. Cummings et al., Phys. Rev. Lett. 119, 206601 (2017).
[6] J. H. Garcia et al., Nano Lett. 17, 5078 (2017).

Session MAT1

Nov. 19th, 2018

Session	Time	Name	Affiliation	Title of presentation	page
MAT1-1	4:00-4:25	Kenji Watanabe	NIMS, Japan	Deep UV photoluminescence microscopy system for exploring luminous properties of hexagonal boron nitride crystals	16
MAT1-2	4:25-4:50	Camila Coletti	IIT, Italy	Synthesizing 2D materials for optoelectronics: approaches and prospects	17
MAT1-3	4:50-5:15	Hiroki Ago	Kyushu Univ., Japan	Controlled CVD synthesis of high-quality 2D materials for electronic and photonic applications	18
MAT1-4	5:15-5:40	Christoph Stampfer	RWTH, Germany	Going beyond the intrinsic limit of graphene’s carrier mobility	19
MAT1-5	5:40-6:05	Shintaro Sato	Fujitsu, Japan	Synthesis and application of graphene nanoribbons	20
MAT1-6	6:05-6:30	Hiroshi Nishihara	Univ. Tokyo, Japan	Synthesis and applications of coordination nanosheet (CONASH)	21

Title of the Presentation: Deep UV photoluminescence microscopy system for exploring luminous properties of hexagonal boron nitride crystals

First Name: Kenji

Last Name: Watanabe

Affiliation: Chief Researcher, Electroceramics Group, Research Center for Functional Materials, National Institute for Materials Science (NIMS), Tsukuba, Japan

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Short Biography:

1990: PhD, Hokkaido Univ., 1990-1993: Oki Electric Industry Co., Ltd., 1993-2001: National institute for Research in Inorganic Materials (NIRIM), 2001-present: NIMS

Abstract:

hexagonal boron nitride (h-BN) single crystal is a kind of layered materials, in which each layer is composed of an atomically flat layer with sp^2 bonding between boron and nitrogen atoms. From the early stage of the graphene study, it was found as a substrate dielectric for use in significantly improved graphene-based devices [1]. As extending the researches from graphene to other 2D materials, the importance of the material is still keeping high and many researchers are now focusing on the quality and size of h-BN.
As for the quality, h-BN is one of luminous materials for the exciton (215 nm) and impurity related bands (around 340 nm). Utilizing this property, it is possible for screening on the defective area. Figure 1 shows the photo of our homemade DUV photoluminescence (PL) microscope system. It has two filter combinations, which show selectively high transmittance in 220 nm Far UV for the exciton PL, or in 340 nm for the impurity PL. Fig. 2 shows the microscope image, and PL images for 220 nm in the exciton and 340 nm by the impurities.
In our presentation, we will introduce our DUV PL microscopy system and show some of examples to exploring luminous properties of h-BN single crystals.

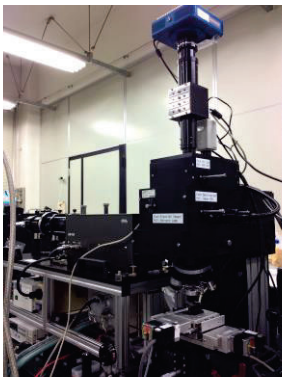

Fig.1 DUV PL microscope.

This research was partially supported by JSPS KAKENHI Grant Number JP17H02748, the Elemental Strategy Initiative, and CREST (JST, JPMJCR15F3).

[1] C.R. Dean, et al., Nat. Nanotech. 5, 722 (2010).

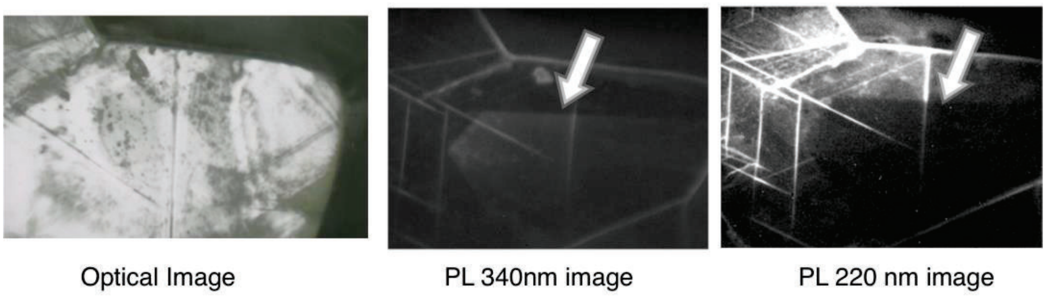

Fig. 2 Optical image and PL images for impurity sector @340 nm and @220 nm; impurity sector, which shows brighter @340 nm and darker @220 nm, is indicated by each arrow.

Title of the Presentation: Synthesizing 2D materials for optoelectronics: approaches and prospects

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Short Biography:

Camilla Coletti received her PhD degree in Electrical Engineering from the University of South Florida (USA) in 2007. After working at the Max Planck Institute of Stuttgart (Germany) as an Alexander von Humboldt postdoctoral fellow from 2008 to 2011, she joined the Istituto Italiano di Tecnologia in Pisa (Italy). There she set-up and developed a laboratory for the synthesis and the characterization of graphene and other 2D materials. Since April 2016 she is Tenure Track Researcher, leading the research line 2D Materials Engineering. Her research is currently focused on: (i) the scalable synthesis of 2D materials for optoelectronic applications; (ii) interface engineering of 2D heterostacks. She is author of more than 70 peer-reviewed publications, 4 book chapters and holds 2 international patents.

Abstract:

In this talk recent advances on the synthesis and applications of large-scale highly-crystalline 2D van der Waals heterostacks will be presented. The electronic performance of single-crystal graphene arrays obtained via patterned growth [1] will be discussed in terms of homogeneity and repeatability. Particular focus will be put in the heterostack obtained by directly synthetizing via chemical vapor deposition (CVD) tungsten disulfide (WS2) on graphene. It will be shown via microstructural and electronic characterization that WS2 aligns on top of graphene with a 0° orientation, the interface is atomically sharp and the spin-orbit splitting of monolayer WS2 on graphene is the largest reported to date [2]. Superlubric sliding of WS2 flakes on graphene triggered by scanning probe microscopy will be discussed [3]. In virtue of its band alignment and remarkable spin-orbit splitting, this system gains strong appeal for optoelectronic and optospintronic applications. Indeed, the fabrication and performance of an entirely scalable hybrid WS2/graphene photodetector will be presented [4].

[1] V. Miseikis, F. Bianco, J David, M. Gemmi, V. Pellegirni, M. Romagnoli, C. Coletti, 2D Materials 4 (2), 021004, 2017.
[2] S. Forti, A. Rossi, H. Büch, T. Cavallucci, F. Bisio, A. Sala, T.O. Mentes, A. Locatelli, M. Magnozzi, M. Canepa, K. Müller, S. Link, U. Starke, V. Tozzini, C. Coletti, *Nanoscale* 9 (42), 16412-16419 (2017).
[3] H. Büch, A. Rossi, S. Forti, D. Convertino, V. Tozzini, C. Coletti, Nano Research 2018 https://doi.org/10.1007/s12274-018-2108-7
[4] A. Rossi, D. Spirito, F. Bianco, S. Forti, F. Fabbri, H. Büch, A. Tredicucci, R. Krahne, C. Coletti, Nanoscale, 10, 4332 - 4338 (2018).

Title of the Presentation: Controlled CVD synthesis of high-quality 2D materials for electronic and photonic applications

First Name: Hiroki

Last Name: Ago

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Short Biography:

After PhD in Kyoto University, he stayed at Cavendish Laboratory, Cambridge University for one and half year and, then moved to National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba as a researcher during 1999-2003. In 2003, he moved to Kyushu University as an associate professor of Institute for Materials Chemistry and Engineering and became a professor of Global Innovation Center of Kyushu University in 2016. He received Iijima Award from the Fullerene-Nanotube Research Society of Japan (2006), Young Scientist Award from MEXT (2008), and Best Paper Award from Japan Society of Applied Physics (JSAP).

Abstract:

Recent development of graphene research has opened a new field of atomically thin, 2D layered materials. We have developed our original heteroepitaxial CVD method to synthesize very high quality, monolayer graphene with controlled orientation by using Cu(111) catalyst deposited on c-plane sapphire. This method has been further applied to the growth of uniform bilayer graphene by employing Cu-Ni(111) alloy catalyst [1]. Furthermore, the intercalation of $MoCl_5$ was performed for this large-area bilayer graphene, obtaining low sheet resistance with high air stability. Interestingly, twisted bilayer graphene was found to show a higher degree of intercalation than AB-stacked bilayer [2].
The epitaxial CVD growth of TMDCs as well as the controlled growth of vertically stacked and lateral in-plane heterostructures of graphene and TMDC will be also presented [3-5].
Finally, our recent achievement on the CVD growth of multi-layer hexagonal boron nitride (hBN) is demonstrated [6]. The enhanced PL intensity and peak narrowing were observed for the WS_2 grown on multi-layer hBN, as compared with that on SiO_2. In addition, Raman spectrum of monolayer graphene was clearly improved by inserting multilayer hBN between graphene and SiO_2. Our uniform hBN is expected to boost various applications utilizing 2D materials.

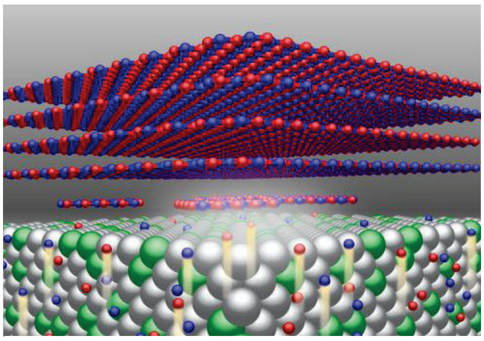

Figure 1. Schematic of CVD growth of uniform multi-layer hBN on alloy catalyst.

References:

[1] Y. Takesaki et al., Chem. Mater., 28, 4583 (2016).
[2] H. Kinoshita et al., Adv. Mater., 29, 1702141 (2017).
[3] H. G. Ji et al., Chem. Mater., 30, 403 (2018).
[4] H. Ago et al., ACS Nano, 10, 3233 (2016).
[5] K. Suenaga et al., submitted.
[6] Y. Uchida et al., ACS Nano, 19, 8230 (2018).

Title of the Presentation: Going beyond the intrinsic limit of graphene's carrier mobility

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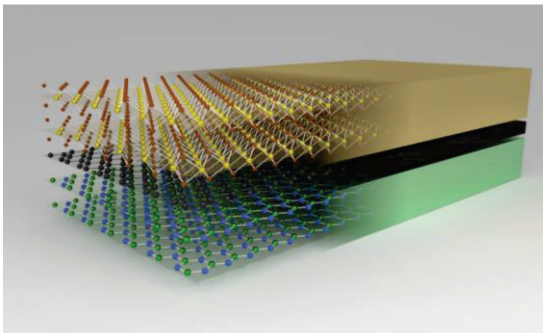
Short Biography:

Christoph Stampfer is currently Professor of Experimental Solid State Physics at the RWTH Aachen University and researcher at the Forschungszentrum Jülich. He is primary interests include graphene and 2D materials research, mesoscopic transport, and micro electromechanical systems. He holds a Dipl.-Ing. Degree in Technical Physics from the TU Vienna and a Ph.D. in Mechanical Engineering from the ETH Zurich. He was a staff member at the Institute for Micro and Nano Systems of the ETH Zurich from 2003 to 2007 and staff member of the Institute for Solid State Physics (ETH Zurich) from 2007 to 2009. From 2009 till 2013 he was JARA-FIT Junior Professor at the RWTH Aachen and the Forschungszentrum Jülich. He has been awarded with an ERC Starting Grant to work on "Graphene Quantum Electromechanical Systems" in 2011 and is member of the Young Scientist community of the World Economic Forum since 2014.

Abstract:



Accessing high carrier mobility and a widely tunable charge carrier density makes graphene a promising material for many potential applications such as for example ultra-sensitive Hall sensors [1], spintronics and high frequency electronics. Using a contamination-free dry transfer technique [2] we can fabricate vdW heterostructures based on CVD graphene with electronic properties indistinguishable from those of mechanically exfoliated natural graphene. The devices show charge carrier mobilities on the order of 100,000 $cm^2/(Vs)$ with maximum values exceeding 500,000 $cm^2/(Vs)$. In addition to the diffusive transport in such samples, we demonstrate an elastic mean free path exceeding one micrometer at temperatures of up to 200 K using Hall cross devices. By investigating large samples we furthermore conclude that the mean free path can exceed 25 micrometer at 2 K [3]. Importantly, we demonstrate not only hexagonal boron nitride as a very suitable substrate [4] for high mobility graphene devices, but also show that the TMD WSe_2 allows also for ultra-high mobility graphene at room temperature, when covering graphene with hBN (see Figure). The enhancement compared to state-of-the-art devices can be understood in terms of the suppression of electron-phonon scattering due to the mechanical coupling between graphene and WSe_2, which converts graphene's acoustic phonon branches into interlayer shear modes [5].

[1] J. Dauber et al. Appl. Phys. Lett. 106, 193501 (2015)
[2] L. Banszerus et al. Science Advances 1, e1500222 (2015)
[3] L. Banszerus et al. Nano Letter 16, 1387-1391 (2016)
[4] C. Neumann et al. Nature Communications 6, 8429 (2015)
[5] L. Banszerus et al. manuscript submitted (2018)

3rd Japan-EU Workshop on Graphene and Related 2D Materials MAT1-5

Title of the Presentation: Synthesis and application of graphene nanoribbons

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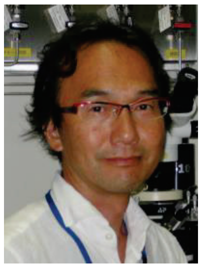
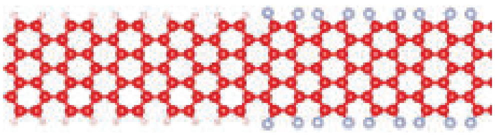


Short Biography:

Shintaro Sato received his PhD from the University of Minnesota in 2001. He joined Fujitsu Limited in 2001. He was a group leader at National Institute of Advanced Industrial Science and Technology from 2010 to 2014. He is now a project director at Fujitsu Laboratories Ltd. and works on research and development of nanoelectronics devises using graphene and carbon nanotubes.

Abstract:

We work on bottom-up growth of graphene nanoribbons (GNRs), and their application to electronic devices, such as transistors, interconnects, and sensors. We here describe our recent progress. Graphene can be used for high-frequency wave detection [1]. We actually proposed a diode consisting of a GNR heterojunction (Fig. 1) for such a purpose [2] The heterojunction consists of a hydrogen-terminated armchair-edge GNR (H-AGNR) and fluorine-terminated armchair-edge GNR (F-AGNR). Since there is a difference in electron affinity between them, we can construct a staggered-type lateral-heterojunction p-n diode. Simulations show that, due to band-to-band tunneling, the diode has a nonlinear reverse current of the order of kA/m. The junction capacitance is extremely small due to the small junction area. It has been found that the diode can have a much better sensitivity for terahertz wave than a GaAsSb/InAlAs/InGaAs heterojunction diode [3]. We also try to form GNRs having various edge-terminations using a bottom-up approach. In fact, we used a precursor shown in Fig. 2 (HFH-DBTA), aiming at synthesizing partially F-terminated AGNRs [4] The F atoms at the edges, however, were detached during the cyclodehydrogenation of partially-edge-fluorinated polyanthrylenes to form GNRs. We have found, by first principles calculations, that a critical intermediate structure, obtained as a result of H atom migration to the terminal carbon of a fluorinated anthracene unit in polyanthrylene, plays a crucial role in significantly lowering the activation energy of carbon−fluorine bond dissociation [4]. Incidentally, we have found that locally aligned GNRs are obtained when we use these precursors [5]. Simulations show that this alignment is related to the relative strengths of precursor-precursor and precursor-substrate interactions. This research was partly supported by JST CREST Grant Number JPMJCR15F1, Japan



H-AGNR F-AGNR

Fig. 1. Heterojunction of F-AGNR and H-AGNR.

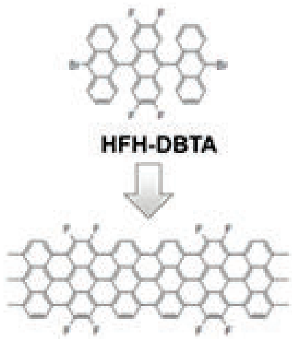


Fig. 2. New precursor (above; HFH-DBTA)) for synthesizing a partially F-terminated AGNR (below).

[1] X. Cai, et al., Nat. Nanotech., 9, 814 (2014).
[2] N. Harada, et al., Appl. Phys. Express, 10, 074001 (2017)
[3] M. Patrashin, et al., IEEE Trans. Electron Devices, 62, 1068 (2015).
[4] H. Hayashi, et al., ACS Nano, 11, 6204 (2017).
[5] M. Ohtomo, et al., ACS Appl. Mater. Interfaces, DOI: 10.1021/acsami.8b11017

Title of the Presentation: Synthesis and applications of coordination nanosheet (CONASH)

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Short Biography:

Hiroshi Nishihara received his D. Sc. degree in 1982 from The University of Tokyo. He was appointed research associate at Keio University in 1982, and he was promoted lecturer in 1990, and associate professor in 1992. Since 1996, he has been a professor of Department of Chemistry, School of Science at The University of Tokyo. His research has been focused on creation of new electro- and photo-functional materials comprising both transition metals and π-conjugated chains, and invention of unidirectional electron transfer systems utilizing molecular layer interfaces. He received The Chemical Society of Japan Award for Creative Work in 2003, Docteur Honoris Causa from University of Bordeaux in 2011, Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology in 2014, Japan Society of Coordination Chemistry Award in 2015, and Chemical Society Japan Award in 2016.

Abstract:

A new type of two-dimensional materials, coordination nanosheets (CONASHs) comprising metal ions and organic ligands have attracted much recent attention because of their unique physical and chemical properties "1-5". We have developed interfacial reaction to synthesize high-quality CONASH films. For example, a liquid−liquid interfacial reaction of nickel(II) acetate in an aqueous phase with benzenehexathiol in an organic phase produced electro-conducting multilayered sheets containing bis(dithiolato)nickel (NiDT) moieties with one micrometer thickness. A single-layer nanosheet was synthesized using a gas−liquid interfacial reaction. CONASHs composed of bis(dithiolato)palladium (PdDT), bis(aminothiolato)nickel (NiAT), bis(imminothiolato)nickel (NiIT), and bis(diimmino)-nickel (NiDI) were also synthesized and their electro-functionalities such as electronic conductivity switching, electrocatalytic activity and energy storage behaviors were revealed.

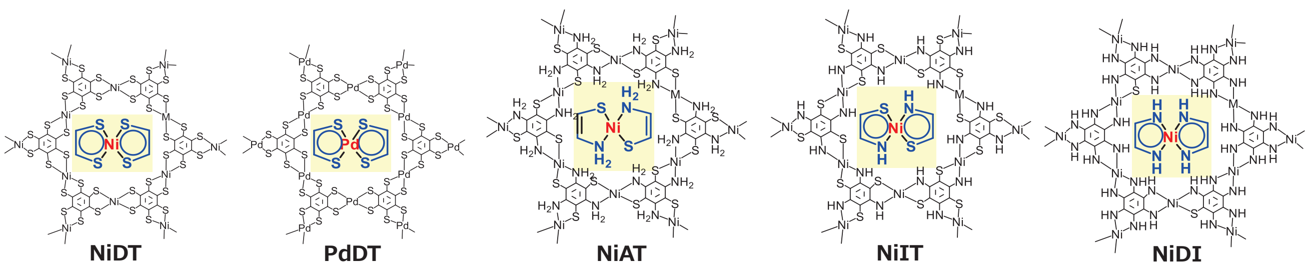

Fig. 1. Chemical structures of coordination nanosheets

[1] R. Sakamoto et al., Coord. Chem. Rev. 320-321, 118-128 (2016).
[2] H. Maeda et al., Langmuir 32, 2527-2840 (2016) (Feature Article).
[3] H. Maeda et al., Coord. Chem. Rev. 346, 139-149 (2017).
[4] R. Sakamoto et al., Chem. Commun. 53, 5781-5801 (2017) (Feature Article).
[5] T. Pal and H. Nishihara, Encyclopedia of Interfacial Chemistry: Surface Science and Electrochemistry, edited by K. Wandelt, vol. 4, 2018, pp 453–471.

3rd Japan-EU Flagship Workshop on Graphene & 2D Materials

Nov. 19th - 21st, 2018
Conference Room, Nano-Spin Bld., Katahira CampusRIEC, Tohoku University, Sendai, Japan

Session PHYS2

Nov. 20th, 2018

Session	Time	Name	Affiliation	Title of presentation	page
PHYS2-1	9:30-9:55	Ignacio Gutiérrez-Lezama	Univ. Geneva, Switzerland	Very large tunneling magnetoresistance in layered magnetic semiconductor CrI_3	24
PHYS2-2	9:55-10:20	Masashi Kawasaki	Univ. Tokyo, Japan	Magnetic heterostructures of topological insulator	25
PHYS2-3	10:20-10:45	Saroj P. Dash	Chalmers Univ. Tech., Sweden	Spin transport in van der Waals heterostructures	26
PHYS2-4	10:45-11:10	Sunao Shimizu	RIKEN, Japan	Electric field control of thermoelectric properties in layered two dimensional materials	27
PHYS2-5	11:10-11:35	Sergio O. Valenzuela	ICN2, Spain	Enhanced spin-orbit interaction in graphene due to the proximity of metals and transition metal dichalcogenides	28

Title of the Presentation: Very large tunneling magnetoresistance in layered magnetic semiconductor CrI_3

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Short Biography:

Ignacio Gutiérrez-Lezama (born in Mexico D.F. in 1981) obtained his PhD in Physics from the University of Geneva in 2013, were since 2018 he acts as a staff member (Research Associate) in the group of Prof. Alberto Morpurgo. His research interests include transport and optoelectronic properties of 2D van der Waals materials, novel phenomena emerging from low-dimensionality and heterostructure formation, effects of electronic coupling and interactions and the study of coupling between transport and magnetism for the realization of novel spintronic devices.

Abstract:

Magnetic layered van der Waals crystals are an emerging class of materials giving access to new physical phenomena, as illustrated by the recent observation of 2D ferromagnetism in $Cr_2Ge_2Te_6$ and CrI_3. Of particular interest in semiconductors is the interplay between magnetism and transport, which has remained unexplored. Here we report magneto-transport measurements on exfoliated CrI_3 crystals "[1]". We find that tunnelling conduction in the direction perpendicular to the crystalline planes exhibits a magnetoresistance as large as 10,000%. The evolution of the magnetoresistance with magnetic field and temperature reveals that the phenomenon originates from multiple transitions to different magnetic states, whose possible microscopic nature is discussed on the basis of all existing experimental observations. This observed dependence of the conductance of a tunnel barrier on its magnetic state is a phenomenon that demonstrates the presence of a strong coupling between transport and magnetism in magnetic van der Waals semiconductors.

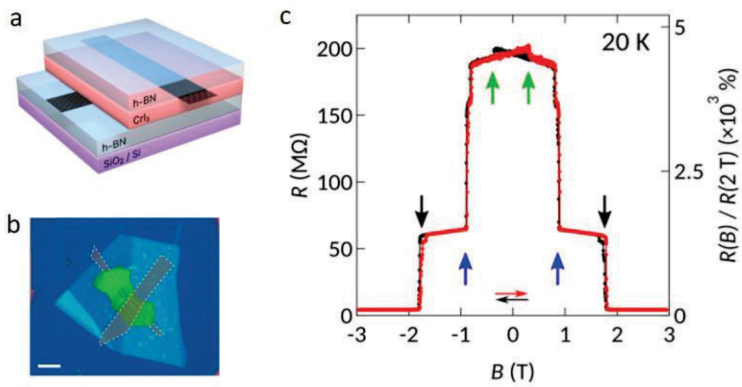

Figure 1. Schematic illustration a) and optical microscope image b) of a few-layer graphene/CrI3/few-layer graphene tunnel junction encapsulated in h-BN. c) Large step-like tunneling magnetoresistance caused by the transition between different magnetic states.

[1] Z. Wang et al., Nat. Commun. 9, 2516 (2018).

Title of the Presentation: Magnetic heterostructures of topological insulator

First Name: Masashi

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Short Biography:

Soon after Masashi Kawasaki received Dr. of Eng. in 1989 from the University of Tokyo, he worked at IBM Thomas J. Watson Research Center as a postdoc. He then moved to Tokyo Institute of Technology in 1991 as an assistant and later associate professors. He was a full professor from 2001 at Institute for Materials Research in Tohoku University until he moved to the University of Tokyo in 2011. He is a member of the Board of Reviewing Editors of Science (AAAS) from 2015.

Abstract:

Three-dimensional topological insulator (TI) is a new state of matter that is characterized by topologically nontrivial bulk insulating state and a Weyl electron surface state. Quantum Hall effect (QHE) on this surface state exhibits various phenomena that are not seen in conventional semiconductors. One of the prominent features is QHE under zero magnetic field called anomalous QHE realized in ferromagnetic TI [1-3]. However, one needs so far not only very low temperature (~ 50mK) but also high magnetic field in order to achieve full quantization. We have systematically examined Landau quantization and QHE in non-magnetic TI to reveal quantization at□□ = 0 in addition to □ = □ 1 [4, 5]. This fact gives us a simple idea of combining non-magnetic and magnetic TIs in order to achieve full quantization at higher temperature as well as under zero magnetic field. This kind of modulation doping of magnetic impurities opens tremendous opportunities in designing electronic states of Weyl system. We present stabilization of anomalous QHE at higher temperature [6, 7], quantum magneto-electric effect [8], a possible realization of Axion insulator [9,10], and direct detection of topological current [11]. Besides these phenomena related with QHE, there are numbers of interesting physics emerging in TIs, such as formation of magnetic skyrmions [12], spontaneous photocurrent [13], highly efficient spin-charge conversion [14], and current induced magnetization reversal [15]. Also explored are novel phases based on polar-ferromagnet (GeMn)Te [13] and quantum Hall effect in Dirac semimetal Cd3As2 [17, 18]. This work is supported by JST-CREST JPMJCR16F1.

[1] C.-Z. Chang et al., Science 340, 167 (2013). [2] J. G. Checkelsky et al., Nat. Phys. 10, 731 (2014). [3] X. Kou et al., Phys. Rev. Lett. 113, 137201 (2014). [4] R. Yoshimi et al., Nat. Mater. 13, 253 (2014). [5] R. Yoshimi et al., Nat. Commun. 6, 6627 (2015). [6] R. Yoshimi and K. Yasuda et al., Nat. Commun. 6, 8530 (2015). [7] M. Mogi et al., Appl. Phys. Lett., 107, 182401(2015). [8] K. N. Okada et al., Nat. Commun. 7, 12245 (2016). [9] M. Mogi and M. Kawamura et al., Mat. Mater. 16, 516 (2017). [10] M. Mogi et al., Sci. Adv., 3 eaao1669 (2017). [11] K. Yasuda et al., Science, 358 1311 (2017). [12] K. Yasuda et al., Nat. Phys. 12, 555 (2016). [13] N. Ogawa et al., Nat. Commun. 7, 12246 (2016). [14] K. Kondo et al., Nat. Phys. 12, 1027 (2016). [15] K. Yasuda et al., Phys. Rev. Lett., 119, 137204 (2017) [16] M. Kriener et al., Sci. Rep. 6, 25748 (2016) [17] M. Uchida et al., Nat. Commun. 8, 2274 (2017). [18] S. Nishihaya et al, Sci. Ad. 4, eer5668 (2018).

Title of the Presentation: Spin transport in van der Waals Heterostructures

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Short Biography:

Associate Prof. Saroj Dash at the Dept. of Microtechnology and Nanoscience, Chalmers University of technology, perform experimental research in the fields of electronic and spintronic device physics in two-dimensional materials such as graphene, semiconductors and topological materials. He holds a PhD degree in Physics from Max Planck Institute, Stuttgart, Germany, in 2007. His previous positions include postdocs at Uni. of Twente and Uni. of Groningen in Netherlands. He is now a permanent faculty member and research group leader at Chalmers. His contributions includes publications in Nature, Nature materials, Nature communication, Science Advances and Nano Lett., and given >40 invited talks in international conferences. He has attracted funding from EU and Swedish grants, such as Graphene Flagship, Graphene FlagEra, VR young researcher, VR project grant, Marie Curie Career Integration, Career-starting grant at Chalmers.

Abstract:

Exploiting the spin degrees of freedom of electrons in solid state devices is considered as one of the alternative state variables for information storage and processing beyond the charge based technology. Here we demonstrate an efficient creation, transport and control of spin polarization at room temperature in two-dimensional (2D) atomic crystals and their heterostructures. Large area CVD graphene is shown to be an excellent material for long distance spin transport over 16 µm with spin lifetimes of 1.2 ns [1]. Insulating 2D CVD h-BN tunnel barriers on graphene is shown to have a large tunnel spin polarization up to 65 % [2,3]. We further used 2D semiconductor MoS_2 in heterostructure with graphene for electrical gate control of spin polarization and spin lifetime [4,5]. Topological insulators exhibit spin-momentum locking of massless Dirac Fermions in their surface states. Recently, we employed heterostructures of graphene and topological insulators to reveal enhanced spin-orbit coupling and an emerging spin texture in graphene [6]. These findings demonstrate all-electrical 2D materials based spintronic devices at room temperature, which can be key building blocks in future device architectures.

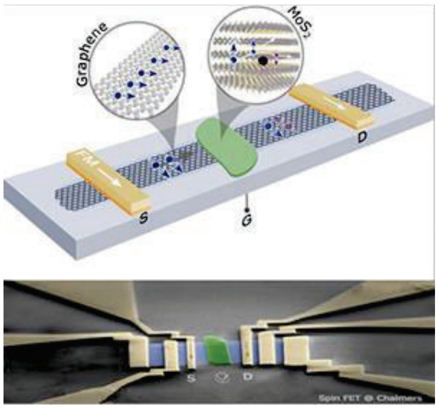

Fig. 1. Schematic and scanning electron microscope image of a fabricated graphene-molybdenum disulfide heterostructure spintronic device.

[1] Kamalakar, et al., Nature Communication, 6, 6766 (2015).
[2] Kamalakar, et al., Scientific Reports, 4: 61446 (2014).
[3] Kamalakar, et al., Scientific Reports, 6, 21168 (2016).
[4] Dankert, et. al., Nature Communication 8, 16093 (2017).
[5] Dankert et. al., Nano Lett.15, 7976 (2015); PRB 97, 125414 (2018).
[6] Khokhriakov et. al., Science Advances, 4:eaat9349 (2018).

Title of the Presentation: Electric field control of thermoelectric properties in layered two dimensional materials

First Name: Sunao

Last Name: Shimizu

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Short Biography:

S. Shimizu got his D.Sc degree from Osaka University in 2009. He was a research fellow of the Japan Society of the Promotion of Science at Osaka University (2008-2010). He worked as a research fellow (2010) and as a research associate (2011) at Osaka University. He joined RIKEN in 2011 and now works as Research Scientist in the Emergent Device Research Team of RIKEN Center for Emergent Matter Science. His research is focused on novel electronic properties found in devices and interfaces.

Abstract:

The reduction of the dimensionality leads to the manifestation of quantum phenomena and the development of electronic correlation. Such low dimensional effects often become even more pronounced in nano-scale materials including exfoliated atomic layers and their hetero structures, triggering the emergence of the novel electronic, optical, and magnetic properties.

One important characteristic of low dimensional systems can be found in thermoelectric effect, which has been theoretically proposed to be favorably controllable by reducing the dimensionality [1]; the thermoelectric effect would be improved due to the low dimensional confinement effect of conduction carriers. The recent progress in materials fabrication has enabled us to systematically investigate the thermoelectric properties in nano-scale materials.

We report the thermoelectric transport of the 2D systems formed in electric double layer transistor (EDLT) configurations. Due to the strong electric field at the electric double layer, the effective thickness of the channel is reduced to several nanometers [2]. Another approach to create 2D systems is to utilize chemical etching, which is induced by applying large gate bias, resulting in the actual thinning of channel materials in a layer-by-layer manner [3]. We have systematically investigated the Seebeck effect in ZnO [2] and FeSe-based EDLTs [4], where the thermoelectric performance of gate-induced 2D electrons was significantly higher than that of 3D bulk. Our approach opens up a novel route to exploit the peculiar behavior of 2D electronic states and realize thermoelectric devices with advanced functionalities.

This work was partly supported by JSPS KAKENHI Grant Numbers JP25000003, JP16H00923, JP16H06345, JP17H02928, JP17K19060.

[1] L. D. Hicks and M. S. Dresselhaus, Phys. Rev. B 47, 12727 (1993).
[2] S. Shimizu et al., PNAS 113, 6438 (2016).
[3] J. Shiogai et al., Nature Phys. 12, 42 (2016).
[4] S. Shimizu et al., submitted.

Title of the Presentation: Enhanced spin-orbit interaction in graphene due to the proximity of metals and transition metal dichalcogenides

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Last Name: Valenzuela

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Short Biography:

Sergio O. Valenzuela is an ICREA Prof. at the Catalan Institute of Nanoscience and Nanotechnology (ICN2), The Barcelona Institute of Science and Technology. He leads the Physics and Engineering of Nanodevices group, which focuses on quantum transport, spintronics, and thermoelectricity in materials such as graphene and topological insulators. He has pioneered the use of nonlocal devices to study the spin Hall effect, thermopiles to isolate the magnon drag in ferromagnetic materials, and implemented novel qubit control and spectroscopy methods. Prof. Valenzuela received a PhD in Physics at the University of Buenos Aires and held research positions at Harvard University and MIT. He is recipient of the Giambiagi and IUPAP Young Scientist Prizes and of a ERC Consolidator Grant.

Abstract:

Identifying the main microscopic process for spin relaxation in graphene and graphene-based heterostructures is one of the most fascinating puzzles for the spintronics community. Key information can be obtained from the spin-lifetime anisotropy, which is determined by the preferential direction of the spin-orbit fields that may cause the spin relaxation and can be quantified by the ratio between the spin lifetimes for perpendicular and parallel spin components to the graphene plane. We have recently developed a reliable experimental approach to measure such anisotropy ratio [1]. We found that the spin-lifetime in graphene on SiO_2 or hBN is isotropic and independent of carrier density and temperature down to 150 K. Current understanding indicates that the spin relaxation is driven by magnetic impurities or weak random spin-orbit or gauge fields [1]. On the other hand, a large spin-orbit coupling (SOC) enhancement has been predicted when graphene is interfaced with transition metal dichalcogenides (TMDC). Signatures of the enhancement have been reported, but the nature of the spin relaxation remained unknown. Here we observe strongly anisotropic spin dynamics at room temperature in bilayer heterostructures comprising graphene and tungsten or molybdenum disulphide [2]. The spin lifetime varies over one order of magnitude depending on the spin orientation and is largest when the spins point out of the graphene plane, suggesting that the strong spin–valley coupling in the TMDC is imprinted in graphene and felt by the propagating spins [3]. Related experiments on large spin-to-charge conversion in graphene/Pt devices indicate that that a SOC enhancement might also be achieved in the proximity of metals [4].

[1] B. Raes *et al.,* Nat. Commun. 7, 11444 (2016); *ibid*, Phys. Rev. B 95, 085403 (2017).
[2] L. A. Benítez *et al.* Nat.Phys. 14, 303 (2018). See also T. Ghiasi *et al*., Nano Lett 17, 7528 (2017).
[3] A. Cummings *et al*., PRL 119, 206601 (2017); M. Gmitra *et al*., PRB 93, 155104 (2016).
[4] W. Savero-Torres, *et al*., 2D Mater. 4, 041008 (2017); W. Yan *et al.,* Nat.Commun. 8, 661 (2017).

3rd Japan-EU Flagship Workshop on Graphene & 2D Materials

Nov. 19th - 21st, 2018
Conference Room, Nano-Spin Bld., Katahira CampusRIEC, Tohoku University, Sendai, Japan

Session DEV2

Nov. 20th, 2018

Session	Time	Name	Affiliation	Title of presentation	page
DEV2-1	1:00-1:25	Emmanuel Kymakis	Crete, Greece	Graphene and related 2D materials interfacial and device engineering for perovskite photovoltaics	30
DEV2-2	1:25-1:50	Toshiaki Kato	Tohoku Univ., Japan	Schottky solar cell using few-layered TMDs	31
DEV2-3	1:50-2:15	Jie Tang	NIMS, Japan	Graphene supercapacitors	32
DEV2-4	2:15-2:40	Arben Merkoci	ICN2, Spain	Graphene-based biosensors for diagnostics	33
DEV2-5	2:40-3:05	Yuhei Hayamizu	Tokyo Tech., Japan	Nano-bio sensing using graphene composite	34
DEV2-6	3:05-3:30	Kazuhiko Matsumoto	Osaka Univ., Japan	Sugar chain functionalized graphene FET for biological application	35

Title of the Presentation: Graphene and related 2D materials interfacial and device engineering for perovskite photovoltaics

First Name: Emmanuel

Last Name: Kymakis

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Short Biography:

Emmanuel Kymakis is a full Professor and Head of Department of Electrical Engineering at the University of Applied Sciences (TEI of Crete). He received the B.Eng. (First Class Honours) degree in Electrical Engineering & Electronics from Liverpool University in 1999 and the Ph.D. degree in Electrical Engineering from Cambridge University in 2003. He and Prof. Gehan Amaratunga are the inventors of the polymer-nanotube solar cell. His research is focused on the synthesis and solution processing of graphene and other two-dimensional materials with tailored properties, for the development of next generation, solution processed electronic and photovoltaics, compatible with roll-to-roll large area manufacturing methods. He has 100 SCI publications and over 6.000 citations with an h-index of 41. He has been an honorary lecturer at UConn and a recipient of an Isaac Newton and an EPSRC studentship. He was named as a 2014 ChemComm Emerging Investigator and has received two National Excellence Awards. He has served as a member of the general assembly of the Greek Foundation of Research & Innovation. He is currently the deputy leader of the Energy Generation WP of the FET-Flagship Initiative Graphene and a member of Engineering sectoral scientific council of the National Council for Research & Innovation of Greece.

Abstract:

Perovskite photovoltaics (PV) devices has attracted enormous attention in the last decade and quickly ranked as the number one emerging technology, mainly due to the rapid increase in their efficiency from 3.8 to 23.3%, exceeding that of polycrystalline silicon solar cells. However, the breakthrough into the commercial marketplace is still uncertain and high risk. The major technical hurdle for the commercialization of perovskite PVs is the lack of stability over prolonged continuous irradiation under ambient conditions. In this talk, I will summarize the recent research to address this issue in my group, through the utilization of solution processed graphene related materials (GRMs) in the PV structure, and moreover provide an insight into the industrialization of this technology through the implementation of a 1kWp Solar Farm consisting of GRM-perovskite PVs in Crete. The latter is a pivotal step toward successful and eventual large-area device fabrication and assembly into PV panels. Interface/contacts engineering based on GRMs was applied in perovskite PVs, resulting to a significant enhancement in both performance and stability. The adaptation of universal work function tunable charge transport layers based on GRMs provides a perfect energy match for either hole or electron extraction, enhancing both the performance and reproducibility of the devices. While, at the same time, the GRMs charge transport layer prevents the migration of In ions from the ITO electrode, inhibiting the degradation of the perovskite buried interfaces and captures water molecules migrating from the electrodes and buffer layers, into the inner components of the device.

Title of the Presentation: Schottky solar cell using few-layered TMDs

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Short Biography:

Dr. Toshiaki Kato has completed his Ph.D from Tohoku University, Japan, in 2007. He was a visiting researcher at Stanford University from 2008 to 2009. He joined the faculty of the Tohoku University in 2007 and he is currently an associate professor of Electrical Engineering. His research interests have ranged from structural-controlled synthesis to optoelectrical device application of layered nano materials such as carbon nanotubes, graphene, graphene nanoribbon, and transition metal dichalcogenides.

Abstract:

Layered-semiconductor materials with atomic thickness attract intense attention due to its outstanding electrical and optical features. Graphene nanoribbons (GNRs) and transition metal dichalcogenides (TMDs) are known as such atomic-scale and layered-semiconductor materials. We have studied about the structural-controlled synthesis and optoelectrical device applications of those novel nanomaterials. Up to now, we obtained the following innovative results. (i) A novel method for the integrated synthesis of suspended GNRs is established with rapid heating plasma CVD using Ni nanobar as a catalyst [1,2]. GNRs can be grown at any desired position on an insulating substrate without any post-growth treatment, and the wafer-scale synthesis of suspended GNR arrays with a very high yield (over 98%) is realized [3,4]. The growth dynamics of suspended GNR is also investigated through the systematic experimental study combined with molecular dynamics simulation and theoretical calculations for phase diagram analysis. (ii) A new fabrication process of TMD-based transparent and flexible solar cell has been developed (Fig.1) [5-7]. In our process, Schottky type device configuration is utilized, which can be simply formed by asymmetrically contacting electrodes and TMD. The power conversion efficiency (PCE) clearly depended on the work function difference between two electrodes (ΔWF). Based on the optimizations of electrodes and distance, the PCE can be reached up to 0.7 %, which is the highest value for solar cell with similar TMD thickness. Since our simple fabrication process includes high potential for large scale fabrication, this achievement is very important for realizing the industrial application of TMD as a transparent and flexible solar cell.

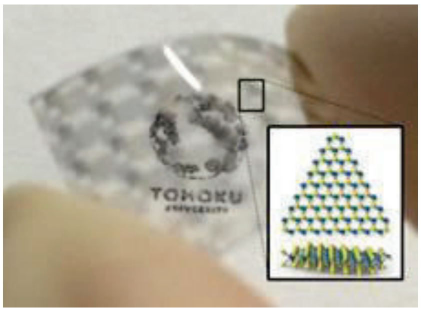

Fig. 1. Typical optical image of transparent and flexible solar cell fabricated with few-layered TMD.

[1] T. Kato and R. Hatakeyama, Nature Nanotech. 7, 651-656 (2012).
[2] T. Kato and R. Hatakeyama, ACS Nano 6, 8508-8515 (2012).
[3] H. Suzuki et al., Nature Comm. 7, 11797-1-10 (2016).
[4] H. Suzuki, N. Ogura, T. Kaneko, and T. Kato, Sci. Rep. 8, 11819-1-9 (2018).
[5] T. Kato and T. Kaneko, ACS Nano 8, 12777-12785 (2014).
[6] T. Kato and T. Kaneko, ACS Nano 10, 9687-9694 (2016).
[7] T. Akama, W. Okita, R. Nagai, C. Li, T. Kaneko, and T. Kato, Sci. Rep. 7, 11967 (2017).

Title of the Presentation: Graphene supercapacitors

First Name: Jie

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Short Biography:

Jie Tang is a chief researcher and group leader of the Advanced Low-Dimensional Nanomaterials Group at the National Institute for Materials Science (NIMS), a professor at Tsukuba University, Japan, and an adjunct professor at the University of North Carolina at Chapel Hill (USA). She received her BEng degree in materials science from Tsinghua University, China, and her PhD degree in materials physics from Osaka University, Japan. Her research interests include high-pressure physics, electron-emission materials, and graphene super-capacitors for energy-storage applications. She has published more than 100 research papers and holds numerous patents.

Abstract:

Graphene offers a new opportunity to boost the performance of supercapacitors [1]. However, the individual graphene sheets usually tend to restack due to the van der Waals forces between them, which often cause significant decrease in the electrochemical active surface area as well as the inter-graphene channels accessible to the electrolyte ions. Over the past ten years we have explored several strategies including uses of single-walled carbon nanotubes (Fig. 1) as spacers inserted in between the stacked graphene sheets to reduce the agglomeration of graphene sheets and have found that the electrochemical properties of the graphene electrode were indeed improved significantly for device applications [2-3]. The material preparation, electrode structure, and device performance of graphene supercapacitors will also be presented and discussed [4-5].

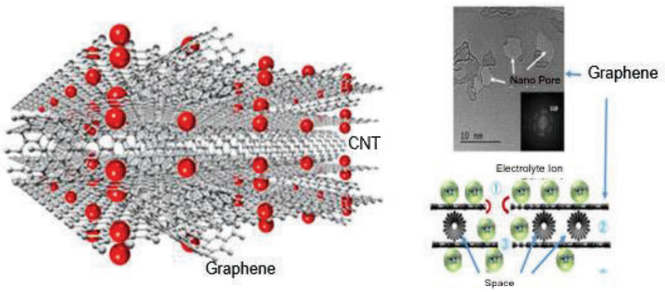

Fig. 1 Single-walled carbon nanotubes in between graphene sheets in porous graphene electrodes for supercapacitors.

This research was supported by the JST-ALCA Program (Advanced Low Carbon Technology Research and Development Program).

[1] Q. Cheng et al., Phys. Chem. Chem. Phys. 13, 17615-17624 (2011).

[2] F. Zhang et al., Chem. Phys. Lett. 584, 124-129 (2013).

[3] J. Li et al., Electrochim. Acta 197, 84-91 (2016).

[4] J. Li et al., Electrochim. Acta 258, 1053-1058 (2017).

[5] J. Li et al., Chem. Phys. Lett. 693, 60-65 (2018).

Title of the Presentation: Graphene-based biosensors for diagnostics

First Name: Arben

Last Name: Merkoçi

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Short Biography:

Arben Merkoçi is ICREA Professor and director of the Nanobioelectronics & Biosensors Group at ICN2. After his PhD (1991) at Tirana University (Albania), in the topic of Ion-Selective-Electrodes (ISEs) Dr. Merkoçi worked as postdoc and senior researcher/invited professor in the field of nanobiosensors and lab-on-a-chip technologies in Italy, Spain, USA and since 2006 at ICN2. Prof. Merkoçi research is focused on the design and application of cutting edge nanotechnology and nanoscience based cost/efficient biosensors. The paper/plastic-based nanobiosensors involve integration of (bio)receptors with micro- and nanostructures/motors and applied in diagnostics, environmental monitoring or safety and security. He has published around 270 peer review research papers, supervised 27 PhD students and has been invited to give plenary lectures and keynote speeches in around 100 occasions in various countries. He is co-founder of two spin-off companies, PaperDrop dedicated to nanodiagnostics and GraphenicaLab to electronic printing.

Abstract:

Graphene oxide (GO) and graphene quantum dots (GQDs) display advantageous characteristics with interest for building innovative biosensing platforms and even smart devices such as nano/micromotors for a myriad of uses including sensing. Quenching of the fluorescence induced by GO or photoluminescence of GQDs can easily operate in synergy with various other nanomaterials and platforms opening the way to several unprecedented biosensing strategies and unique nanomotor technologies. Taking advantage of GO, GQDs we are developing simple, sensitive, selective and rapid biosensing platforms that include: a) GO – based microarray & laterals flow technologies taking advantages of high quenching efficiency of GO. A "turn ON by a pathogen" device will be shown as a highly sensitive detection system using plastics or paper/nanopaper substrates; b) GQDs–based sensors for contaminants detection based on the use of multifunctional composite materials that enable rapid, simple and sensitive platforms in connection to smartphone; c) A water activated GO transfer technology using wax printed membranes for fast patterning of a touch sensitive device with interest for electronic devices including sensing as well as for a cost-efficient nanomotor building technology for several applications. This work is supported by EU (Graphene Flagship), CERCA Programme / Generalitat de Catalunya.

[1]. Merkoçi et al., Adv. Mater. 24, 3298–3308 (2012).

[2]. Merkoçi et al., Angew. Chem. 52, 3779–13783 (2013).

[3]. Merkoçi et al., Adv. Mater. 29, 1604905 (2017).

[4]. Merkoçi et al., Progr. Mat. Sci., 1–24 (2017).

Title of the Presentation: Nano-bio sensing using graphene composite

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Last Name: Hayamizu

Affiliation: School of Materials Science and Engineering,
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Short Biography:

Yuhei Hayamizu is an associate Professor in Materials Science and Engineering at the Tokyo Institute of Technology. He received his phD degree in physics from the University of Tokyo in 2005. Then, he joined the Nanotube Research Center in the National Institute of Advanced Industrial Science and Technology Japan (AIST) as a post-doctoral researcher. In 2009, he moved to Genetically Engineered Materials Science and Engineering Center (GEMSEC) at the University of Washington to study solid binding peptides. He has been in a current position since 2012.

Abstract:

Developing elegant hybrid systems of biological molecules on two-dimensional nanomaterials, such as graphene, is a key in creating novel bio-nanoelectronic devices, where versatile biological functions are integrated with electronics of nanomaterials. Biomolecules self-assembling into organized structures on these nanomaterials offer a novel bottom-up approach, where biomolecular architectures spatially govern the electronics of nanomaterials. Despite the enormous potential in bridging nano- and bio-worlds at the molecular scale, no work has yet realized a way to control electronic and/or optical properties of nanomaterials by the biomolecular structures.

Our research target is the control of the interface between biotechnology and nanotechnology. More specifically, we employ solid binding peptides or artificially-designed peptides [1-4], which have specific binding affinities to 2D nanomaterials and an ability to form peptide nanostructures on atomically flat surfaces. These peptides spontaneously organize into coherent monolayer-thick nanostructures on surfaces of graphene and other 2D nanomaterials with a thickness of one layer of atoms. These peptides can work as a molecular scaffold for future biosensors using 2D nanomaterials. Furthermore, the organization of peptides modify the electronic property of 2D nanomaterials spatially based on the nanostructures of self-assembled peptides [4]. On the other hand, the organization of peptides can be also tuned by applied electrochemical potential on the 2D nanomaterial [5]. In this talk, the details of peptide designing for molecular scaffold and its experimental characterizations will be discussed.

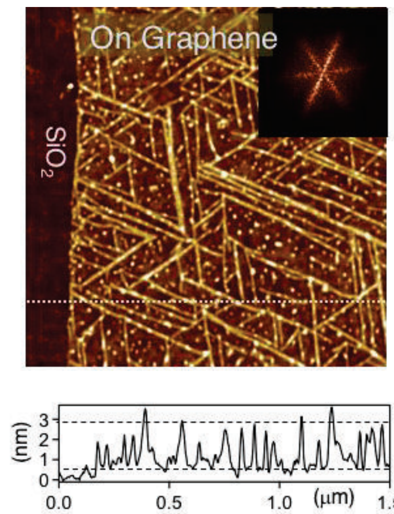

Fig. 1. Atomic force microscope image of self-assembled peptides on graphene surface. The inset shows the Fast Fourier Transform (FFT).

[1] C. R. So, Y. Hayamizu, H. Yazici, C. Gresswell, D. Khatayevich, C. Tamerler, and M. Sarikaya, ACS Nano, **6** (2) (2012) 1648-1656.
[2] D. Khatayevich, C. R. So, Y. Hayamizu, Carolyn Gresswell, and Mehmet Sarikaya, Langmuir, **28** (2012) 8589.
[3] D. Khatayevich, *et al.*, Small 10.8 (2014): 1505-1513.
[4] Y. Hayamizu, *et.al.*, *Scientific Reports* **6**, Article number: 33778 (2016).
[5] T. Seki, *et.al.*, Langumuir **34**(5), 1819-1826 (2018).

Title of the Presentation: Sugar chain functionalized graphene FET for biological application

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Short Biography:

Kazuhiko Matsumoto received the Ph.D. degrees from Tokyo Institute of Technology in 1981 in Electronics Engineering. 1981~2002,he has been working with Electrotechnical Laboratory, Tsukuba, 1988~1990, he was a research associate of the Stanford University, and since 2003 he is a professor at Osaka University, Osaka, Japan. He has studied the compound semiconductor devices, single electron devices, carbon nanotube and graphene devices and their applications. He was awarded the Pioneering Research Prize of the Science and Technology Agency of Japan government, and is a Fellow of the Japan Society of Applied Physics.

Abstract:

The avian influenza virus and the human influenza virus are selectively detected using the sugar chain modified graphene FET. The avian influenza which can infect to human has the highly pathogenic and quite dangerous. So, we should know whether the avian virus has the human infection or not.

The structure of the sugar chain for human and avian which cover the cell has the difference at the end of their structures, i.e., for the human sugar chain, sialic acid is connected to the α 2-6 galactose, and for the avian sugar chain, to the α2-3 galactose. When the avian flu virus changes its structure and get the human infection, it can connect both the avian and the human sugar chains.

In order to selectively detect the human infection, the surface of graphene FET was modified by the human sugar chain which can selectively combine to the human virus and not combine to avian virus.

Figure shows the selective detection of the human influenza virus. By increasing the concentration of human virus, human virus which has minus charge connects to the human sugar chain, and the shift of the Dirac point of the graphene FET increases. On the other hand, avian influenza virus could not connect to the human sugar chain and does not change the Dirac point shift. Thus, we have succeeded in the selective detection of human type and avian type influenza virus by the sugar chain modified graphene FET.

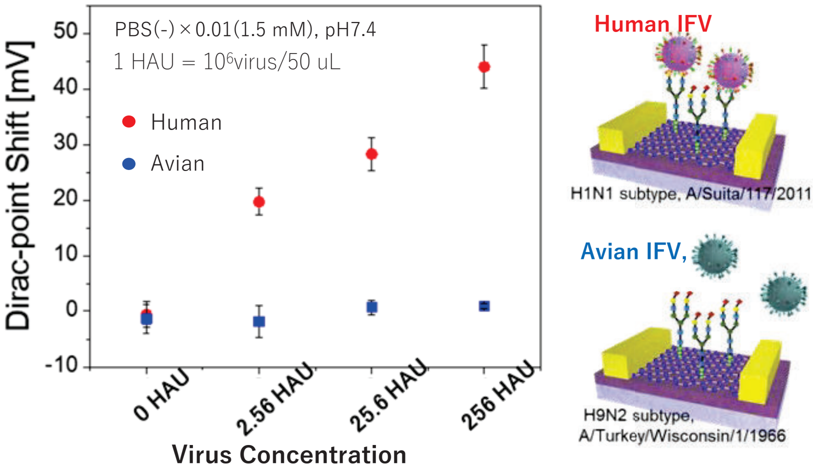

Fig. 1. Dependence of Dirac point shift on concentration of human & avian virus.

Session MAT2

Nov. 20th, 2018

Session	Time	Name	Affiliation	Title of presentation	page
MAT2-1	4:00-4:25	Catherine Journet-Gautier	Lyon Univ., France	Polymer-derived boron nitride nanosheets	38
MAT2-2	4:25-4:50	Yasumitsu Miyata	Tokyo M. Univ., Japan	Growth of in-plane heterostructures based on layered chalcogenides	39
MAT2-3	4:50-5:15	Katsuaki Sugawara	Tohoku Univ., Japan	High-resolution ARPES studies of atomic-layer transition-metal dichalcogenides	40
MAT2-4	5:15-5:40	Hanako Okuno	CEA, France	Structural investigation of 2D materials: From growth to controlled properties	41
MAT2-5	5:40-6:05	Camila Coletti (Paul V. Wiper)	IIT, Italy (AIXTRON, UK)	Advances in 2D materials production: from R&D to commercialization	42
MAT2-6	6:05-6:30	Kazu Suenaga	AIST, Japan	Atomic resolution analysis of 2D materials	43

Title of the Presentation: Polymer-derived boron nitride nanosheets

First Name: Catherine

Last Name: Journet-Gautier

Affiliation: Laboratoire des Multimatériaux et Interfaces (LMI),
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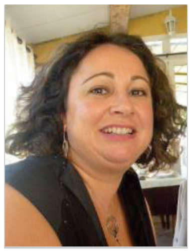
Email: catherine.journet@univ-lyon1.fr



Short Biography:

Professor Catherine Journet received her PhD in Condensed Matter from the University of Montpellier in 1998. In 1999, after a post-doctoral position at the Max Planck Institute for Solid State Research in Stuttgart, Germany, she was recruited as an Assistant Professor at the University of Lyon to work on Physics of Nanostructures and Field Emission. Since 2011 she is a full professor at the Laboratory of Multimaterials and Interfaces (LMI) from the University of Lyon. Currently, her research interests include synthesis and characterization of 2D and 1D boron- and carbon-based nanomaterials as well as Van der Waals heterostructures.

Abstract:

With the aim of preparing chemically pure and crystallized h-BN nanosheets, a new and original synthetic route combining pyrolysis of preceramic polymers (Polymer Derived Ceramics, PDCs) with Spark Plasma Sintering (SPS) has been developed. In this sense, a molecular precursor, borazine ($B_3N_3H_6$) is converted into a preceramic polymer, polyborazilene (PBN). This latter, additivated with a crystallization promoter, Li_3N, is then introduced into the chamber of the SPS furnace. This innovative and original approach opens the possibility of obtaining h-BN flakes with very high chemical and structural purity, that can be easily exfoliated into h-BN nanosheets. Here I will present the latest results obtained in terms of synthesis conditions optimization; sintering temperature and percentage of crystallization promoter. Thus new experiments were conducted between 1200 and 1950°C, incorporating from 0 to 10% by weight of Li_3N. Structural analyzes by Transmission Electron Microscopy and Raman spectroscopy were carried out on all the samples and demonstrate an excellent crystalline quality, attested by a FWHM of the Raman signal at 9 cm^{-1}, close to the lowest value recorded up to date in the literature [1]. Other characterizations of interest have also proven the excellent chemical and crystalline purity of h-BN nanosheets synthesized this way.

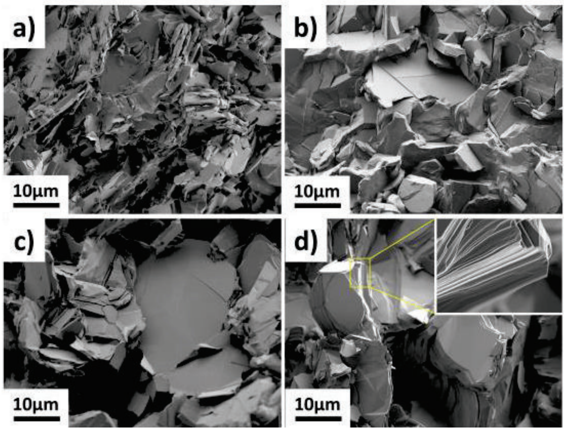


Fig. 1. SEM images of h-BN flakes obtained at 1200 (a), 1500 (b), 1800 (c) and 1950°C (d).

[1] L. Schué L et al., 2D Mater. 4, 015028 (2017).

Title of the Presentation: Growth of in-plane heterostructures based on layered chalcogenides

First Name: Yasumitsu

Last Name: Miyata

Affiliation: Department of Physics, Tokyo Metropolitan University, Hachioji, Tokyo 192-0397, Japan

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Short Biography:

Dr. Miyata received his Ph.D. in Physics from Tokyo Metropolitan University, Japan, in 2008. He was a research fellow of the Japan Society for the Promotion of Science (JSPS) (2008-2009), and was an assistant professor at Nagoya University (2009-2013). Since 2013, he has been an Associate Professor of Tokyo Metropolitan University. During 2013–2016, he had been a JST-PRESTO researcher in the field of "Innovative Nano-electronics through Interdisciplinary Collaboration among Material, Device and System Layers".

Abstract:

Conventional semiconductor heterojunctions with two-dimensional (2D) interfaces have been an important topic, both in modern solid state physics and in electronics and optoelectronics applications. Recently, the in-plane heterostructures based on two-dimensional materials are expected to provide a novel one-dimensional (1D) interface with unique physical properties and applications. Even though there have been many reports on the growth and device studies of such heterostructures, it is still an important challenge to develop a sophisticated growth process of novel heterostructures/superlattices and high quality samples without interface degradation, contamination and/or alloying. Here, we report on our recent progresses of chemical vapor deposition (CVD) growth of in-plane heterostructures based on transition metal dichalcogenide (TMDC) atomic layers (Fig.1) [1-4]. We show that the introduction of alkali metals improves various parameters, which includes grain size, uniformity of layer number, nucleation density, and defect density of TMDCs such as MoS_2, WS_2, $MoSe_2$, and WSe_2 monolayers. Furthermore, controlling the precursor supply and limiting air exposure enable the formation of in-plane heterostructures with atomically sharp and zigzag-edge straight junctions without defects or alloy formation around the interface. The present findings pave way for the simple and rapid preparation of large scale, high quality TMDCs, and TMDC-based heterostructures, quantum wires, and surperlattices.

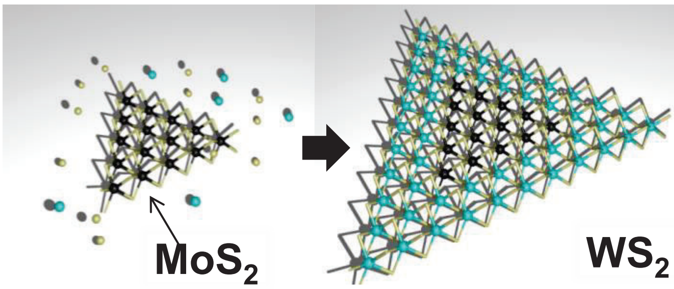

Fig. 1. Growth process of MoS_2/WS_2 in-plane heterostructure by CVD.

[1] Y. Kobayashi et al., ACS Nano 9 (2015) 4056.
[2] Y. Kobayashi et al., Nano Res. 8 (2015) 3261.
[3] Y. Kobayashi et al., Sci. Rep. 6 (2016) 31223.
[4] Y. Kobayashi et al. submitted.

Title of the Presentation: High-resolution ARPES studies of atomic-layer transition metal dichalcogenides

First Name: Katsuaki

Last Name: Sugawara

Affiliation: Department of Physics, Tohoku University, Sendai, Japan

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Short Biography:

Ph. D of Physics, Tohoku University, Japan (2009). Recent research interests are the electronic structure of graphene and related atomic-layer materials (graphene superconductor, TMDs).

Abstract:
The two-dimensional (2D) atomic-layer materials have been a target of intensive studies by the discovery of Dirac fermion in thinnest limit of graphite and its related anomalous physical properties such as integer quantum Hall effect and valley polarization [1]. Amongst 2D layer materials, transition-metal dichalcogenides (TMDs) MX_2 has been also studied more than 40 years ago since it shows various strong-correlated electron phenomena such as Mott insulator, magnetic ordering, and superconductivity [2]. On the other hands, the physical properties in atomic-layer TMDs have not been investigated because of the difficulty to grow high-quality well-ordered atomic-layer materials. However, we have recently succeeded for obtaining the various atomic-layer TMDs films by constructing molecular beam epitaxy systems and elucidated these anomalous electronic structures by spin/angle-resolved photoemission spectroscopy with the world-best resolution [3-5]. Our obtained results are as follows.

(1) We find the insulating band dispersions in monolayer $NbSe_2$ different from band structures of bulk 2*H*-$NbSe_2$, which indicate Mott-insulator by strong coulomb repulsion. [3].

(2) We find the insulating ground state at low temperature in monolayer VSe_2 which different from the metallic of bulk 1*T*-VSe_2. In addition, we also find the Fermi arc with pseudo gap at room temperature, which indicate the strong-correlated electron systems in the analogous to high-T_c cuprate superconductivity [4].

In this talk, we will introduce these recent results more details on monolayer TMDs.

[1] A. H. Castro Neto, *et al*, Rev Mod. Phys., 81, 109 (2009).
[2] M. Chhowalla, *et al,* Nature Chem., 5 263-275 (2013).
[3] Y. Nakata, *et al*, NPG Asia Mater., **8**, e321-1-5 (2016).
[4] Y. Umemoto, *et al*, Nano Res., *in press.*

Title of the Presentation: Structural investigation of 2D materials: From growth toward controlled properties

First Name: Hanako

Last Name: Okuno

Affiliation: CEA-Grenoble/INAC and Université Grenoble Alpe, Grenoble, France

Email: hanako.okuno@cea.fr

Short Biography:

Hanako Okuno obtained her master degree from Tokyo Institute of Technology in 1999. She received her Ph.D. in Materials Science from Louvain catholic University in Belgium in 2006. She was a postdoctoral fellow in National Institute for Materials Science in Japan (2006–2008) and in French atomic energy commission (CEA) in France (2008–2009). She has specialized in growth and structural characterization of carbon based materials. She joined the technological research division in CEA to develop carbon based nano-electronic devices in 2009. Since 2013, she has been working in the advanced electron microscopy lab, where she specializes in advanced microscopy for investigating 2D materials using low-voltage aberration corrected TEM technologies.

Abstract:

Structural defects are known as a parameter-tuning knob for material properties in 3D bulk materials. 2D materials, with their unique infinitely large basal planes and atomic thickness, exhibit a vast range of atomic defects that present unparalleled degrees of freedom for tailoring physical properties. The ability to engineer atomic defects at nanometer scale opens up unique opportunities to alter and enhance electrical, optical, mechanical and magnetic properties [1]. Despite the growing interest in 2D materials, growing defect-free 2D materials on desired substrates remains a challenge. Identification and characterization of these inevitable intrinsic growth defects are thus an essential process. Further exploitation of possible defect modification and manipulation might shed light on potential utilization of defect structures in device processing. Aberration Corrected Transmission Electron Microscopy (AC-TEM) is one of the most suitable techniques to study the atomic structure of 2D materials. AC-TEM imaging is used to visualize atomic structures of atomically thin 2D layers and simultaneously to form defects by electron irradiation.

In this work, we study the atomic defects in various synthesized 2D layers, as grown and after processing such as annealing and irradiation, using multiple advanced AC-TEM techniques to explore their defect behavior. For instance, the intrinsic defects in MBE grown TMD layers are observed directly on their growth substrate. The formation, migration and elimination of intrinsic and extrinsic defects are studied with respect to the substrate. The transformation of these defects into other structures via defect diffusion on the substrate surface are also investigated using the electron irradiation [2].

[1] Z.Lin et al., 2D Mater. 3, 022022 (2016).
[2]C. Alvarez et al., Nanotech. 29, 425706 (2018).

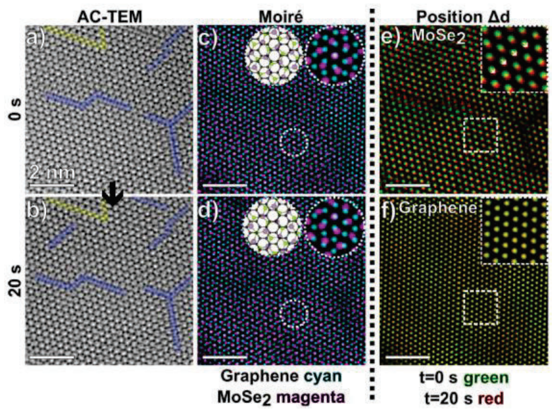

Fig. 1. Formation of line defects in $MoSe_2$ on graphene growth substrate and direct analysis of vdW interface.

Title of the Presentation: Advances in 2D materials production: from R&D to commercialization

First Name: Paul, V.

Last Name: Wiper

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Short Biography:

Paul is the business development specialist at Aixtron Ltd, UK, responsible for the BM PECVD System range for the growth of CNTs, graphene and 2D materials. Prior to this role he was employed at The National Graphene Institute, The University of Manchester with a joint role of Business Development and Research Scientist. He holds a PhD in Chemistry from the University of Liverpool and has published over 20 research articles related to advanced materials and characterisation methods.

Abstract:

Over the past decade there has been considerable research focus on 2D materials. In particular, graphene, hexagonal boron nitride (hBN) and the family of transition metal dichalcogenides (TMDs), to name a few, exhibit unique electronic, optical and physical properties which can be exploited within various technologies and new application areas.

Besides the extraordinary advances in 2D materials research, their commercialization still remains challenging, especially for applications like electronic/optoelectronics, advanced coatings and energy-storage systems, where high quality, large scales, high throughput and reproducibility are required. From the available growth techniques, which play an important role on the materials properties, chemical vapor deposition (CVD) has proved to meet the aforementioned requirements.

This presentation puts into perspective thin film graphene growth technology by CVD at AIXTRON, where we have developed and scaled up wafer-based and roll-to-roll graphene growth with an emphasis on which market these tools can penetrate.

Title of the Presentation: Atomic resolution analysis of 2D materials

First Name: Kazu

Last Name: Suenaga

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Short Biography:

Kazu Suenaga got his Ph.D in Materials Science at the University of Tokyo in 1994. He was a postdoctoral fellow at Ecole Nationale Superieure des Mine de Paris and at the Solid State Physics Laboratory in the University Paris-Sud. Then he is a Prime Senior Researcher at National Institute of Advanced Industrial Science and Technology (AIST). He has published over 290 scientific papers and delivered more than 100 invited lectures over the past ten years. His papers have more than 15,000 citations. A recipient of the Honda Memorial Promotional prize (1997) and the Seto award (Japanese society of Microscopy 2005). Grantee par Sumitomo Foundation (1997) and JST-CREST/ACCEL (2006-2011, 2011-2016). His major research theme involves the atomic level characterization of low-dimensional materials by means of electron microscopy and spectroscopy. His h-index is 65.

Abstract:

Properties of low-dimensional materials are largely influenced by its structural imperfections, such as defects, impurities, edges or boundaries. Hence, analytical technique at single atom level is becoming crucial to fully understand the physical/chemical performance of nano-devices. In my presentation, single atom spectroscopy by means of electron energy-loss spectroscopy (EELS) will be shown to discriminate individual atoms in low-dimensional materials at their interrupted periodicities. It is emphasized here that information of the bonding/electronic states has become accessible for single atoms through the EELS fine-structure analysis [1] as well as the spin state [2]. Large variations of local electronic properties of 1D and 2D materials with different atomic coordinates will be investigated. Furthermore, a high-energy resolution EELS offers us possibilities to obtain local optical/vibrational properties. Some of the recent examples for such experiments on low-dimensional nanomaterials will be also presented [3].

[1] Y.-C. Lin et al., *Nano Letters,* **15** (2015) 7408-7413, L. Tizei et al., *Phys. Rev. Lett.*, 114 (2015) 197602, R. Senga and K. Suenaga, *Nature Communications,* (2015) 6:7943

[2] Y.-C. Lin et al., *Phys. Rev. Lett.*, **115** (2015) 206803

[3] J. Lin et al., *Nano Lett.*, **16**, (2016), 7198-7202, L. Tizei et al., *Phys. Rev. Lett.,* **114** (2015) 107601, R. Senga et al., *Nano Lett.*, **16**, (2016), 3661-3667

[4] This research was supported by JSPS KAKENHI (JP16H06333 and JP25107003).

3rd Japan-EU Flagship Workshop on Graphene & 2D Materials

Nov. 19th - 21st, 2018
Conference Room, Nano-Spin Bld., Katahira CampusRIEC, Tohoku University, Sendai, Japan

Session FOC

Nov. 21st, 2018

Session	Time	Name	Affiliation	Title of presentation	page
FOC-1	9:00-9:25	Yoshihiro Iwasa	Univ. Tokyo	Rolling transition metal dichalcogenides to nanotubes	46
FOC-2	9:25-9:50	Stephan Roche	ICN2, Spain	Modelling spintronics and valleytronics: Bulk versus edge transport	47
FOC-3	9:50-10:15	Taiichi Otsuji	Tohoku Univ.	Plasmon instabilities in graphene-based van der Waals heterostructures	48
FOC-4	10:15-10:40	Riichiro Saito	Tohoku Univ.	Enhancement of electric field for measuring optical response in two-dimensional materials	49

Title of the Presentation: Rolling transition metal dichalcogenides to nanotubes

First Name: Yoshihiro

Last Name: Iwasa

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Short Biography:

Team Leader, RIKEN, 2010-present
Professor, Quantum Phase Electronics Center, University of Tokyo, 2010 - present
Professor, Institute for Materials Research, Tohoku University, 2001 - 2009
Associate Professor, Japan Advanced Institute of Science and Technology, 1994 - 2001
Visiting Researcher, AT&T Bell Laboratories, Murray Hill NJ, 1993 - 1994
Lecturer, Department of Applied Physics, University of Tokyo, 1991 - 1994
Research Associate, Department of Applied Physics, University of Tokyo, 1986 – 1991

Ph.D., Department of Applied Physics, University of Tokyo, 1986
M.E., Department of Applied Physics, University of Tokyo, 1983
B. E., Department of Applied Physics, University of Tokyo, 1981

Abstract:

Due to their favorable and rich electronic and optical properties, group-VI-B transition-metal dichalcogenides (TMDs) have attracted considerable interest. They have earned their position in the materials portfolio of the spintronics and valleytronics communities. The electrical performance of TMDs will be enhanced by rolling up the two-dimensional (2D) sheets to form quasi-one-dimensional (1D) tubular structures. Actually, the TMD nanotubes were first synthesized back in 1992 [1], but only recently device related researches have been conducted [2].In this presentation, we discuss transport and optoelectronic properties ranging from field effect transistor (FET) operation to solar cell actions in tungsten disulfide multiwalled nanotubes (WS_2-NT).

We first fabricated electric double layer transistor (EDLT) of an individual WS_2-NT and found an ambipolar operation, in sharp contrast to the solid gated FET devices which exhibits only n-type conduction. Furthermore, we found that gating with $KClO_4$/polyethylene glycol electrolyte, induce superconductivity at T_c = 5.8 K. This is the first superconductivity in the individual nanotube structure. Importantly, this superconductivity of gated WS_2 exhibited peculiar transport properties arising only from tublar and chiral structure [3].

Using the EDLT devices, we were able to fabricate a p-n junction in an individual WS_2-NT, and found that this p-n junction shows current-driven light emission, and photovoltaic actions. Both of these actions are linearly polarized along the NT axis, and more importantly, the *external* quantum efficiency for the photovoltaic effect reaches a value as high as 4.8%, exceeding by far that of 2D TMDs and even approaching the internal quantum efficiency of the 2D TMDs [4].

[1] R. Tenne et al., Nature **360**, 444 (1992).
[2] R. Levi et al., Nano Lett. **13**, 3736 (2013).
[3] F. Qin et al., Nat. Comm. **8**, 14465 (2017).
[4] Y. J. Zhang et al., 2D Mater. **5**, 035002 (2018).

3rd Japan-EU Workshop on Graphene and Related 2D Materials **FOC-2**

Title of the Presentation: Modelling spintronics and valleytronics: Bulk versus edge transport

First Name: Stephan

Last Name: Roche

Affiliation: Catalan Institute of Nanoscience & Nanotechnology, Campus UAB, Bellaterra and ICREA, Institució Catalana de Recerca i Estudis Avancats, Spain

Email: stephan.roche@icn2.cat

Short Biography:

S. Roche received PhD in Physics in 1996 at French CNRS. After several postdocts in Japan (Tokyo University 1996-1999) and Spain, he was appointed Assistant a Professor at UJF, in 2000, researcher at the Commissariat à l'Energie Atomique (CEA) in 2004, and ICREA Research Professor at ICN2 in 2010, leading the "Theoretical and Computational Nanoscience Group" at ICN2. He was awarded in 2009 Awardee the *Friedrich Wilhelm Bessel prize* by the Alexander Von-Humboldt Foundation (Germany).

Abstract:

The physics of graphene can be strongly enriched and manipulated by harvesting the large amount of possibilities of proximity effects with magnetic insulators, strong SOC materials (TMDC, topological insulators, etc.). Simultaneously, the presence of extra degrees of freedom (sublattice pseudospin, valley isospin) points towards new directions for information processing [1,2], extending the playground to valleytronics, multifunctional electronic devices or novel quantum computing paradigms harnessing all these degrees of freedom in combination with electromagnetic fields or other external fields (strain, chemical functionalization) [3,4]. Here I will present some ***foundations of spin transport for Dirac fermions*** propagating in supported graphene devices or interfaced with strong SOC materials. The role of entanglement with "*valley and sublattice pseudospins*" in tailoring the spin dephasing and relaxation mechanisms will be explained as well as the impact of strong SOC proximity effects on spin lifetime anisotropy (Fig.1), weak antilocalization and Spin Hall effect [4-8]. I will also refute the recent interpretation of giant non-local resistance in terms of bulk valley Hall currents in graphene/hBN heterostrcutures [9]. Such analysis is fundamentally flawed, whereas the understanding of non-local transport properties requires advanced and realistic quantum transport calculations [10].

[1] S. Roche et al. 2D Materials 2, 030202 (2015).
[2] D.V. Tuan et al. Nature Physics 10, 857 (2014).
[3] D.V. Tuan & S. Roche, Phys. Rev. Lett. 116, 106601 (2016).
[4] A.W. Cummings, J. H. García, J. Fabian and S. Roche, Phys. Rev. Lett. 119, 206601 (2016).
[5] J. García, A. Cummings, S. Roche, Nano Lett. 17, 5078 (2017).
[6] K. Song et al. Nano Lett. 18 (3), 2033 (2018).
[7] J.H. García et al. Chem. Soc. Rev. 47, 3359-3379 (2018).
[8] D. Khokhriakov, A. Cummings, M. Vila, B. Karpiak, A. Dankert, S. Roche & S. Dash, Science Advances (in press)
[9] A. Cresti et al. Riv. Nuovo Cimento 39, 587 (2018).
[10] J. M. Marmolejo-Tejada et al., arXiv:1706.09361; J. Phys. Materials (in press).

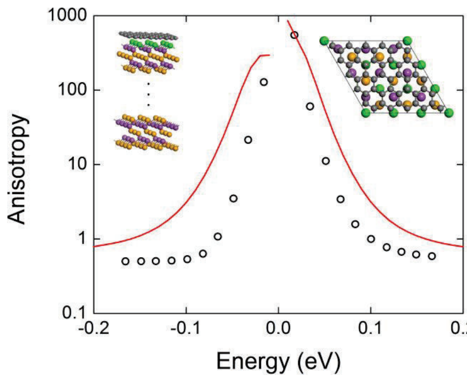

Fig. 1. Giant spin transport anisotropy in graphene/Bi_2Se_3 heterostructures.

Title of the Presentation: Plasmon instabilities in graphene-based van der Waals heterostructures

First Name: Taiichi

Last Name: Otsuji

Affiliation: Research Institute of Electrical Communication, Tohoku University, Sendai, Japan

Short Biography:

Taiichi Otsuji received the Ph.D in Electron. Eng. from Tokyo Inst. Tech., Japan, in 1994. After working for NTT Lab. (1984-1999) and Kyushu Inst. Tech. (1999-2005), he has been working at RIEC, Tohoku University as a full professor. He has been served an IEEE Electron Device Society Distinguished Lecturer since 2013. He is a Fellow of the IEEE, OSA, and JSAP, and a member of the MRS, SPIE, and IEICE.

Abstract:

Graphene has attracted considerable attention due to its massless and gapless energy spectrum. Carrier-injection pumping of graphene can enable negative-dynamic conductivity in the terahertz (THz) range, which may lead to new types of THz lasers [1]. We designed and fabricated the distributed feedback (DFB) DG-GFET [3]. Broadband rather intense (~10~100 μW) amplified spontaneous emission from 1 to 7.6 THz and weak (~0.1~1μW) single-mode lasing at 5.2 THz [2] were observed at 100K in different samples [3].

Present issues of poor gain overlapping and substantially low quantum efficiency can be resolved by an introduction of graphene surface plasmon polaritons (SPPs) [4]. One particular case is graphene-SPP instability driven light amplification of stimulated emission of terahertz radiation is feasible [5]. We recently succeeded in experimental observation of such a phenomenon in asymmetric dual-grating gate (ADGG) GFETs [6]. The monolayer graphene was sandwiched with a thick h-BN buffer layer and a thin h-BN gate insulation layer. The ADGG-GFETs introduces periodically modulated carrier-density profiles by applying a high bias to one GG and a charge-neutral-point bias to the other GG. The finger width of the highly biased GG defines the SPP cavity size so that a SPP resonant absorption is obtained to the THz radiation when drain is unbiased. The most striking phenomenon is a resonant amplification with a maximum gain of 9% at 300K when the drain bias exceeded a high-end threshold level, exhibiting a blue shift with increasing the drain bias. Such an overall response from absorption to amplification with respect to the drain bias perfectly traces the graphene SPP instability theory [6]. Integrating the graphene SPP amplifier into a current-injection graphene THz laser transistor will be a most smart solution towards room-temperature intense THz lasing.

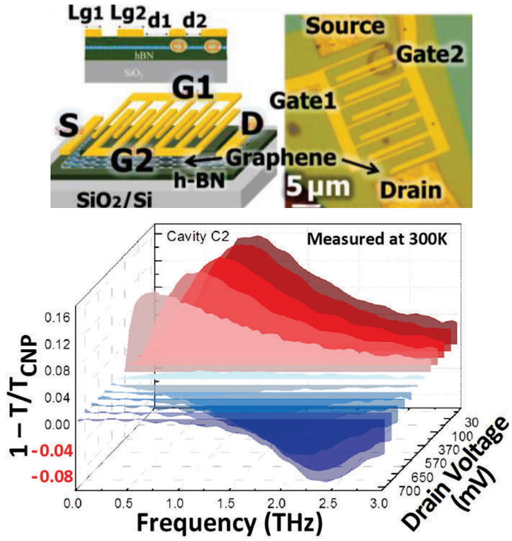

Fig. 1. ADGG-GFET and its transfer spectra.

This work was supported by JSPS-KAKENHI No. 16H06361, 16K24374, and 18H05331, Japan.

[1] V. Ryzhii et al., J. Appl. Phys. 101, 083114 (2007).
[2] T. Otsuji et al., IEEE J.S.T.Q.E. 19, 8400209 (2013).
[3] D. Yadav et al., Nanophoton. 7, 741-752 (2018).
[4]V. Popov et al., Phys. Rev. B 86, 195437 (2012).
[5]Y. Koseki et al., Phys. Rev. B 93, 245408 (2016).
[6]S. Boubanga-Tombet et al., arXiv: 1801.04518.

Title of the Presentation: Enhancement of electric field for measuring optical response in two-dimensional materials

First Name: Riichiro

Last Name: Saito

Affiliation: Department of Physics, Tohoku University, Sendai Japan

Email: rsaito@flex.phys.tohoku.ac.jp

Short Biography:

Riichiro Saito was born in 1958, and received his Ph. D. at The University of Tokyo in 1985. He became Research Associate at The University of Tokyo (1985), Associate Professor at The University of Electro-Communications (1990), and Professor at Department of Physics, Tohoku University (2003).

Abstract: We frequently use the enhancement effect of electric field of the electro-magnetic wave for measuring the Raman spectra or optical absorption in two-dimensional materials since the obtained signals are relatively weak compared with those from three-dimensional materials. The methods of the enhancement of electric field consists of (1) generating near-field electric field on the surface of metal [1], (2) interference effect by multi-reflection of light in the stacked dielectric multilayers [2-4], and (3) exciting surface plasmon [5,6].

In this presentation, we will review our recent calculation of the enhancement of electric field by the above methods. In particular, we will give not only the analytical expression of results [1-6] but also numerical simulation by finite-difference time-domain (FDTD) method for which we adopted the MEEP (MIT Electromagnetic Equation Propagation) package [7]. Since MEEP is very useful and free software, reproducing some results as examples of our previous analytically solved problems (100% absorption of light by doped monolayer graphene [8] by surface plasmon, 50% absorption of light by undoped monolayer graphene by dielectric multilayers [2] etc), by MEEP should be beneficial to the community of 2D materials for designing optical devices.

Key words: surface plasmon, interference effect, electromagnetic wave, THz, tip-enhanced Raman spectroscopy, optical absorption, graphene,

Reference:

[1] Master thesis, Pratama Fendy Rizky, Tohoku University (2018).
[2] S. A. Nulli, M. S. Ukhtary, R. Saito, Appl. Phys. Lett. 112, 073101 (2018).
[3] H. Liu, M. S. Ukhtary, R.Saito, J. Phys. Condens. Matter , 29, 455303, (2017).
[4] J. W. Blumberg, M. S. Ukhtary, R.Saito, unpublished.
[5] M. S. Ukhtary, R.Saito, in press, Phys, Stat. Solidi B (2018).
[6] M. S. Ukhtary, Ph. D thesis.
[7] https://meep.readthedocs.io/en/latest/.
[8] M. S. Ukhtary, E. H. Hasdeo, A. R. T. Nugraha, R. Saito, APEX, 8, 055102 (2015).

Round-Table Discussion

Nov. 21st, 2018

Session	Time	Name	Affiliation	Title of presentation	page
RTD-1	10:50-11:30	Francesco Bonaccorso	ITT, Italy	Toward the large scale production of 2D-materials for energy applications	52

Title of the Presentation: Toward the large scale production of 2D-materials for energy applications

First Name: Francesco

Last Name: Bonaccorso

Affiliation: Istituto Italiano di Tecnologia, Graphene Labs, Genova, Italy

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Short Biography:

Francesco Bonaccorso gained the PhD from the University of Messina after working at the Italian National Research Council, the University of Cambridge and the University of Vanderbilt. In June 2009 he was awarded a Royal Society Newton International Fellowship at Cambridge University, and elected to a Research Fellowship at Hughes Hall, Cambridge, where he also obtained a MA. He is currently leading the processing and prototyping group at the Istituto Italiano di Tecnologia (IIT), Graphene Labs. He was responsible of the scientific and technological roadmap for the European Graphene Flagship. He is now Deputy of the Innovation of the Flagship. He was featured as 2016 Emerging Investigator by J. Mater. Chem. A. His research interests encompass solution processing of nanomaterials and their technological applications. He is Co-founder of BeDimensional Srl.

Abstract:

2D materials are emerging as promising materials [1-5] to improve the performance of existing devices or enable new ones [1-5]. A key requirement for the implementation of 2D materials in applications as flexible (opto)electronics and energy is the development of industrial-scale, reliable, inexpensive production processes [2], while providing a balance between ease of fabrication and final product quality.

The production of 2D materials by solution processing [2,6] represents a simple and cost-effective pathway towards the development of 2D materials-based (opto)electronic and energy devices, presenting huge integration flexibility compared to other production methods. Here, I will first present our strategy to produce 2D materials on large scale by wet-jet milling [7] of their bulk counterpart and then an overview of their applications for flexible and printed (opto)electronic and energy devices [3,8,9,10,11,12,13,14].

The author acknowledges financial support from the European Union's Horizon 2020 Graphene Flagship.

[1] A. C. Ferrari, F. Bonaccorso, et al., Nanoscale 7, 4598-4810 (2015).
[2] F. Bonaccorso, et al., Materials Today 15, 564-589, (2012).
[3] F. Bonaccorso, et. al., Nature Photonics 4, 611-622, (2010).
[4] F. Bonaccorso, Z. Sun, Opt. Mater. Express 4, 63-78 (2014).
[5] G. Iannaccone, et al., Nature Nanotech 13, , 183, (2018).
[6] F. Bonaccorso, et. al., Adv. Mater. 28, 6136-6166 (2016).
[7] A. E. Del Rio Castillo et. al., Mater. Horiz. 5, 890 (2018).
[8] F. Bonaccorso, et. al., Science 347, 1246501 (2015).
[9] J. Hassoun, et al., Nano Lett. 14, 4901-4906 (2014).
[10] F. Bonaccorso, et al., Adv. Funct. Mater. 25, 3870-3880 (2015).
[11] F. Biccari, et al., Adv. Energy Mater. 7, 1701349 (2017).
[12] S. Casaluci, et al., Nanoscale 8, 5368-5378 (2016).
[13] A. Capasso, et al., Adv. Ener. Mater. 6, 1600920, (2016).
[14] L. Najafi, et al., ACS Nano 2018 DOI: 10.1021/acsnano.8b05514.



















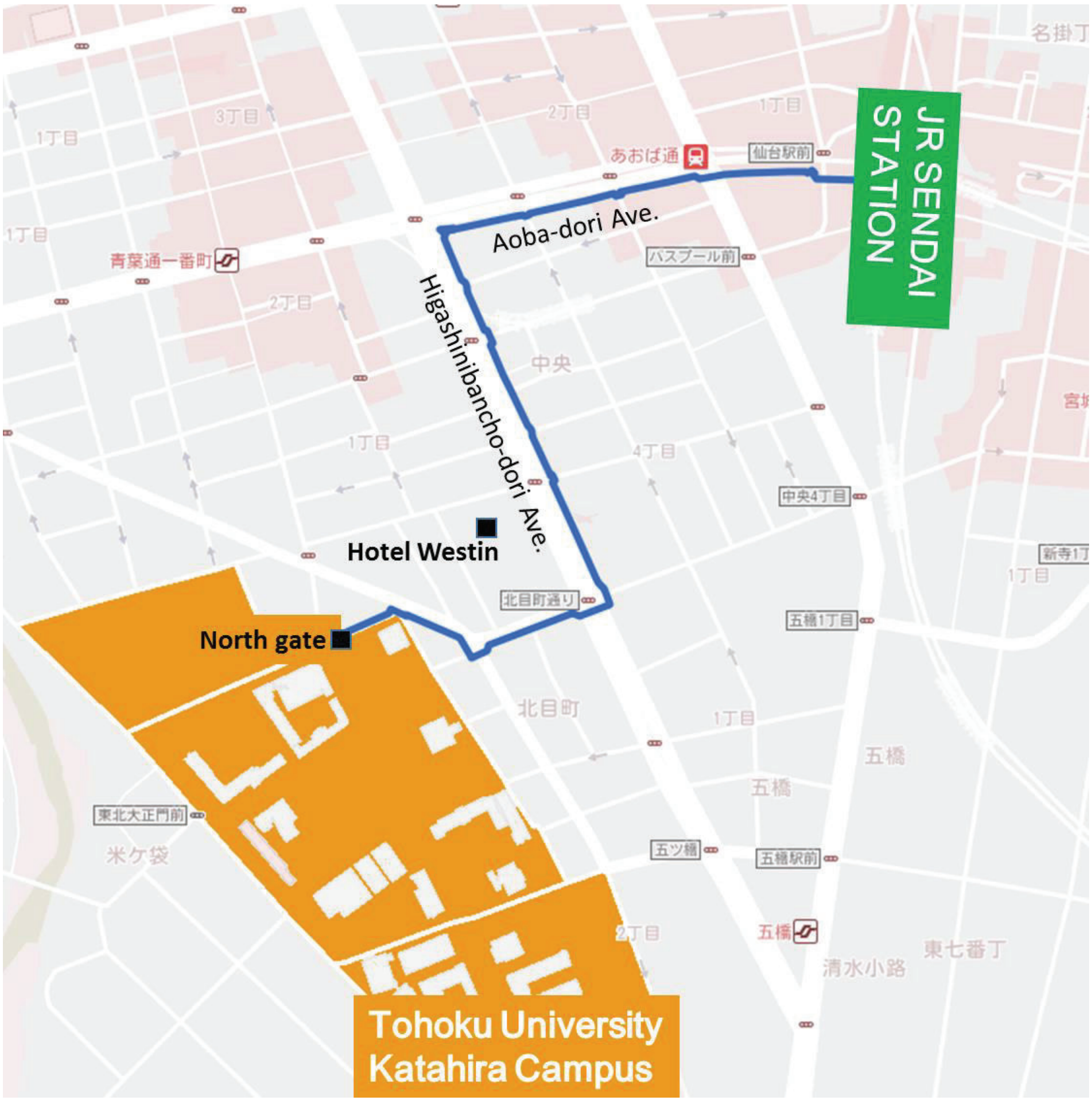







Access Map (Sendai City)

By foot: About 15 minutes from the Sendai Station west exit.
By taxi: 5 minutes from Sendai Station. 40 minutes from Sendai Airport.
By bus: Catch a bus from platform 11 at the west entrance in front of Sendai Station bound for the "Miyagi University of Education/Aobadai" or "Dobutsukoen Circle via Aoba-dori" get off at "Aoba dori ichibancho 1-A" Approx. a 5 min ride, 10 min walk from the bus stop.



Access Map (Katahira Campus, Tohoku University)

Banquet Venue
The Westin Sendai
1-9-1 Ichiban-cho, Aoba-ku, Sendai, Miyagi 981-0811 Japan

Symposium Venue
RIEC Nano-Spin Laboratory Building 4F Conference Room, Katahira Campus
Research Institute of Electrical Communication, Tohoku University
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