RIEC Newsletter No.4

RIEC News

RIEC Newsletter
Research Institute of Electrical Communication
Tohoku University

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Tohoku University

SUMIYAGURA of SENDAI-JO castle (Photo by Miyagi Prefecture Tourism Division)

Special ISSUE

JSPS KAKENHI Grant-in-Aid for Sci. Rsch. (S) Creation of 2D-Atomically-Thin-Layered Heterojunctions and their Applications to Novel Terahertz Photonic Devices

Professor **Taiichi Otsuji**

[Purpose and Background of the Research]

Terahertz (THz) is an unexplored electromagnetic frequency band in which conventional electronic and photonic devices cannot operate well due to the substantial physical limitations originating from the transit time delays and/or phonon decoherence. In such a situation, graphene, a carbon atomic monolayer sheet, has attracted attention thanks to its extremely high carrier transport properties of relativistic Dirac Fermions. Recently, study on atomically thin van der Waals (vdW) heterostructures consisting of graphene, h-BN, and/or transition-metal dichalcogenide (TMD) like MoS_2 has been emerging. We theoretically found that a gated double-graphene-layered (G-DGL) heterostructure can mediate THz photon- and plasmon-assisted resonant tunneling between the GLs, enabling various functionalities in the THz domain with extremely higher quantum efficiencies by orders than ever. The key to make them in practical engineering is to develop the continuous hetero-epitaxial growth (C-H-Epi-G) technology.

This research project proposal has been accepted as a 5-year-term new theme of 2016 JSPS KAKENHI, Grant-in-Aid for Scientific Research (S), and is aimed to create the C-H-Epi-G technology for the 2D vdW heterojunction systems, and to devise highly efficient various THz functional devices by exploiting unprecedented physical phenomena exhibited among their complex quantum systems governed by electrons, photons, plasmons, as well as phonons (Fig. 1).

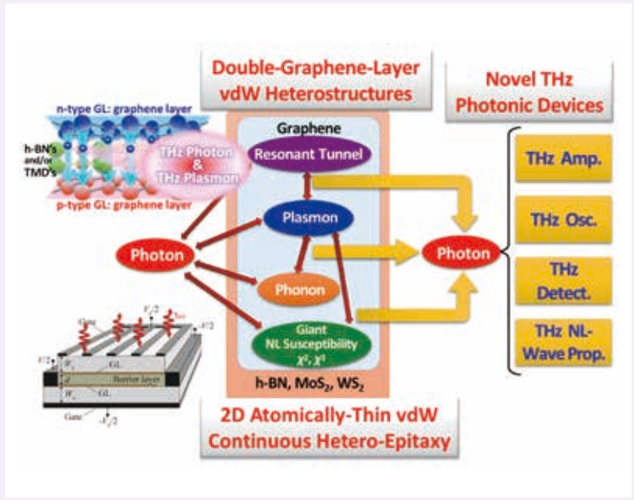


Fig. 1 Nonlinear complex quantum phenomena in G-DGL vdW heterojunctions and their applications to THz functional devices.

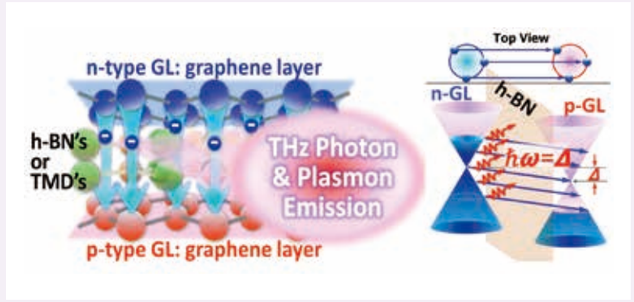


Fig. 2 Photon- and plasmon-assisted resonant tunneling in the G-DGLs for THz emitters. Its atomically scaled bird's view image (left) and a corresponding band diagram (right). By emitting photons whose energy is equal to the band offset Δ, all the excess electrons in the n-type GL can resonantly tunnel to the p-type GL throughout the h-BN tunnel barrier layer.

[Research Methods]

First, the G-DGL structure consisting of the DGL core shell and the external gate is created as the platform of device implementation. Second, the photon-assisted and plasmon-assisted resonant tunneling are introduced into the G-DGL as the physical operation mechanisms to manifest the advantage of the performances of THz amplification, oscillation, detection, and nonlinear wave control over the existing technologies. Third, the double resonance of the graphene plasmons and the tunneling is introduced as an advanced physical operation mechanism to obtain further improved performances of these functionalities (Fig. 2).

[Research Organization]

To conduct this cutting-edge research project we organize a nicest team in collaboration among the author's group at RIEC, Tohoku Univ. (PI and two Co-PIs, device modeling, process, and experiments), Assoc. Prof. H. Fukidome's group at RIEC, Tohoku Univ. (Co-PI, growth and characterization of high quality epitaxial graphene), Assoc. Prof. M. Ryzhii's group at Univ. Aizu (Co-PI, device modeling), and Dr. S. Suzuki's group at NTT Basic Research Laboratory (Co-PI, C-H-Epi-G of h-BN and TMDs with graphene). Young researchers and graduate students as well as international partners are also involved in the research as important supporting members in this project (Fig. 3).

[Expected Research Achievements and Scientific Significance]

Introduction of unprecedented physical mechanisms of complex quantum systems in the G-DGL is unique and has a great merit and impact to enable ultra-highly efficient THz functionalities. If successful this study, 100-Gbit/s-class ultra-fast THz wireless communications, such as Transfer-Jet that can transfer ultra-high-capacity media instantly, is expected to bring industrial revolution to the future of ubiquitous ICT societies

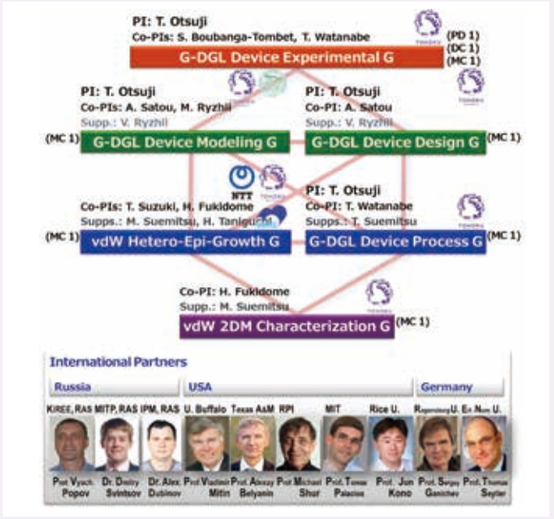


Fig. 3 Research organization. PD: PosDoc researcher, DC: Doctor Course student, and MC: Master Course student.

TOPICS 1

RIEC International Symposium on Computer Graphics and Interactive Techniques: New Horizon

SIGGRAPH Asia, a top international conference in the field of computer graphics and interactive techniques, was held in Japan on November 2nd to 5th, 2015, after 6 years' absence, and gained great success with 7,050 participants from 49 countries (http://sa2015.siggraph.org/). Many world famous researchers, engineers, and artists in this field took part in the operation of the conference, as committee members, and I was in the service of the SIGGRAPH Asia 2015 Conference Chair. So I organized a special international symposium in the Research Institute of Electrical Communication, Tohoku University, to discuss future of the computer graphics and interactive techniques, when we had a chance of the committee meeting on September 26th and 27th, which was about 40 days before the conference.

Snapshots of the symposium: invited speakers and participants.

Among variety of SIGGRAPH Asia 2015 programs, chairs of Emerging Technologies, Workshops, Symposium on Education, Symposium on Visualization in High Performance Computing, Symposium on Mobile Graphics and Interactive Applications were participated in the symposium, and 13 invited talks and demonstrations were held in the symposium. Wide variety of topics were actively discussed there, such as recognition of facial images and 3D shape modeling, digital content creation by effectively using these technologies, virtual reality and augmented reality which get public attentions recently, multimedia data visualization by both visual and auditory information, research on unique user interface techniques using newly developed devices which allow human to use computers intuitively, approaches of application of these techniques to education, software tools to support such activities, and so on. (Prof. Yoshifumi Kitamura)

TOPICS 2

The 4th RIEC International Symposium on Brain Functions and Brain Computer

URL: http://www.nanospin.riec.tohoku.ac.jp/RIEC_Sympo/2016/index.html

The 4th RIEC International Symposium on Brain Functions and Brain Computer was held on February 23-24, 2016, at the conference room in Nanoelectronics and Spintoronics building. This annual symposium was founded in 2012 with the aim to gather researchers in fields such as semiconductor engineering, computer engineering, robotics, applied mathematics and physics, cerebral physiology, neuroscience, psychophysics, nonlinear physics and so on, and to present and discuss interdisciplinarily about latest research results. With 4 invited overseas speakers from America, Germany, Spain, and Sweden, this year's symposium was composed of 12 oral and 10 poster presentations.

The topics discussed in the symposium cover a broad range of fields and include magnetic resonance imaging of neural activity, signal analysis of neuronal network activity, measurement of neural signals using high-density multi-electrode array, reconstruction of neural network upon epilepsy, deep brain stimulation for epilepsy or Parkinson's disease, circuit model of cortical neurons or thalamic neurons, visual processing hardware for motion stereo vision, quantum neuron model. Fruitful question-and-answer sessions are actively carried out in interdisciplinary atmosphere.

Because many parts of information processing mechanism of brain remain unexplained, it is expected that this kind of symposium, which provides opportunity for interdisciplinary exchange, plays a growing role in future. From an engineering viewpoint, rapid application of findings in brain science to computer technology is very important.

(Prof. Shigeo Sato)

TOPICS 3

The Joint Symposium of 10th International Symposium on Medical, Bio- and Nano-Electronics,7th International Workshop on Nanostructures & Nanoelectronics

The 10th International Symposium on Medical, Bio- and Nano-Electronics and the 7th International Workshop on Nanostructures & Nanoelectronics were jointly held on March 1-3, 2016, at the conference room in the Laboratory for Nanoelectronics and Spintronics Building. Total of 127 participants gathered from US, Germany, UK, and Japan for 20 invited talks and 16 poster presentations.

In the session for nanostructures and their applications, recent topics in nanotubes, nanosilicon, nanopores, and biological nanomembranes were actively discussed, from their fabrication and characterization to device applications including as solar cells and sensors. Notable was the broadness of the topics –biosensors based on the lipid bilayer, a biological nanomembrane, formed on a nanofabricated silicon chip, stochastic sensors, single electron devices, etc. – making us confident that this interdisciplinary field will keep on growing and developing. In the session for biomedical electronics, talks were given on the fundamentals and cutting-edge applications in biomedical engineering, including clinical imaging and therapy using ultrasound, non-invasive sensors for monitoring blood glucose level, and chemical image sensors.

Fruitful discussions were made across multiple disciplines that participants came from, such as nanoelectronics and biotechnology. This type of interactions will no doubt drive future breakthroughs.

(Prof. Michio Niwano)

TOPICS 4

Nation-Wide Cooperative Research Projects

The Research Institute of Electrical Communication has a long history of fundamental contributions in many fields of engineering and science. On the basis of this rich historical background the Institute was designated as National Center for Cooperative Research in 1994 and we organized the Nation-Wide Cooperative Research Projects. The main themes for Cooperative Research are selected annually by the Committee for Cooperative Research Projects. Each project approved by the Faculty Council of the Institute is carried out by a team of researchers that include members of the Institute as well as outside participants. The Project Selection Committee that includes members from the outside of Tohoku University has a judging function for project proposals.

In 2016, 110 projects are working as the Nation-Wide Cooperative Research Projects, and are divided in 7 categories as follows; International Cooperative Research, Intend Large Research Project, Advanced Research, Exploratory Research, Young Researcher's Project, Industry-University Cooperative Research, and Inter-Organizations. During them, the International Cooperative Research and Young Researcher's Project were newly categorized in 2015. The projects on this category received favorable funding.

Annual Meeting on Cooperative Research Project on 2016FSY takes place on 23rd Feb. 2017. On this meeting, 10 oral speakers present the research works on the projects of International Cooperative Research Projects, Inter-Organization Research Projects, and Young Researchers' Projects. In addition, more than 80 poster presentation show the results of the projects. (Prof. Kazushi Ishiyama)

INSIDE the Laboratory

Information Devices Division

Materials Functionality Design Laboratory

Masafumi Shirai, Professor
Kazutaka Abe, Assistant Professor
Masahito Tsujikawa, Assistant Professor

URL: http://www.shirai.riec.tohoku.ac.jp/

The research targets of the laboratory are as follows: (1) theoretical analyses of quantum phenomena which appear in materials for next-generation information devices, (2) computational design of materials which possess new functionalities for improvement of device performance, and (3) development of innovative design procedures based on the knowledge of materials science and information technology. Recent research activities are described below.

1. Theoretical study on transport properties of giant magnetoresistive devices

We investigated the spin-dependent transport properties of giant magnetoresistive devices with highly spin-polarized Heusler alloys as electrodes on the basis of first-principles calculations. We found that the matching of the electronic structure (Fermi surface) between the electrode and spacer materials predominantly determines interfacial resistance. In particular, Ag and Ag-Mg spacers are promising for improving the magnetoresistance of the devices.

2. Theoretical design of new permanent magnets without rare elements

The development of new permanent magnets is required due to the high cost and limited reserves of rare-earth elements. We carried out theoretical design of magnet materials possessing large magnetization and high magnetic anisotropy, focusing on Fe-Co, Co-Ni, Fe-Ni, Mn-Ga, Mn-Ge alloys. We found that the doping Ti, V, Al, or Si into FeNi stabilizes the $L1_0$-ordered phase, and that the doping B, C, or N enhances uniaxial magnetic anisotropy.

3. Theoretical study on metallization and superconductivity of hydrides

Hydrides have been predicted to have high superconducting transition temperatures (T_c) once they are metallized under compression. We have so far predicted several metallic hydrides of B, Ge, Sb, and Bi in the range from 100 to 350 GPa, which exhibit superconductivity. The values of their T_c are rather high for superconductivity driven by electron-phonon coupling; especially, the T_c' s of the B and Ge hydrides are estimated to reach about 100 K.

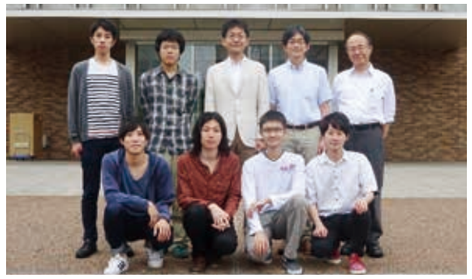
INSIDE the Laboratory

Human Information Systems Division

Electromagnetic Bioinformation Engineering Laboratory

Kazushi Ishiyama, Professor
Shuichro Hashi, Associate Professor
Yoshiaki Hayashi, Assistant Professor

URL: http://www.ishiyama.riec.tohoku.ac.jp/



Our laboratory researches high-sensitivity sensors and sensing systems, which utilize magnetic motions and functions based on electromagnetic phenomena and the character of magnetic materials. The sensing system can catch the electromagnetic signals from the human body not only from the electric devices. Our group has 13 members: Prof. Kazushi Ishiyama, Associate Prof. Shuichiro Hashi, Assistant Prof. Yoshiaki Hayashi, one research assistant, one Ph.D. course students, six master course students and two undergraduate students.

Our three representative research topics are as follows;

1. Magnetic wireless pumps for artificial heart assist blood pump

To realize fully implantable artificial heart assist blood pumps, we research wireless and battery-free pumps driven by magnetic torque and force. The simple structure composed of a pump housing and a full magnetic impeller enables us to reduce the size and weight of the blood pumps. We have succeeded in the development of small pumps which are fully implantable size and have sufficient hydrodynamic performance to assist the heart of adults.

2. High-sensitivity strain sensors and microvibration measuring systems

We work on development of high-sensitivity sensors using magnetic films. Through investigation on control methods of the magnetic anisotropy and optimum designs of the sensors, we have previously developed a strain sensor with the highest sensitivity (Gauge factor: 18,000) in the world. Currently, we also work on the development of microvibration measuring systems using the strain sensor.

3. Wireless magnetic motion capture system

We research less-invasive motion capture systems for medical and welfare applications. Our proposed magnetic system using battery-free LC markers is capable of wireless detecting the position, orientation and motion of the markers. Moreover, unlike other techniques, this magnetic system is also capable of detecting the markers in unseen spaces such as inside the living body.

Cyberscience Center

Research and Development Division of Communication Infrastructures

Takuo Suganuma, Professor
Toru Abe and Satoru Izumi, Associate Professor

URL: http://www.ci.cc.tohoku.ac.jp/

Tago-nishi VR Town Management System using iKaaS Platform

As represented by IoT systems, it is becoming more convenient, secure, and safe for people to use large-scale, super-distributed, and diverse information and communication systems in everyday life. In order to realize it, we must not only aim at improving the quality of service of individual elements at the hardware, software and network level but also create a new system design/development methodology as a whole system. In addition, it is necessary to design networks and applications by a new design paradigm beyond the concept of user-centered design. This laboratory conducts research and development to realize "a new communication environment in which diverse elements constituting human, social, mono, natural environment, and cyber space are highly harmonized". This laboratory was established in October 2010 as a research and development division of Tohoku University Cyberscience Center. This year, there are a total of 6 faculty staff members, including Professor Takuo Suganuma, Associate Professor Toru Abe, Associate Professor Satoru Izumi, one doctoral researcher, one research assistant and one administrative assistant, and a total of 18 students.

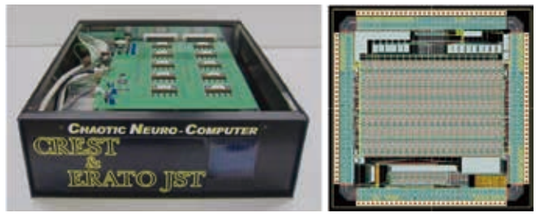
Our major research contributions include: (1) "Smart routing scheme" based on Software Defined Network (SDN) technology, which dynamically switches to a communication route for reliably and rapidly transmitting information while taking into consideration the network usage situation and the risk of disaster, (2) A knowledge intensive IoT platform with consideration of privacy (iKaaS Platform), and its daily-living support applications, (3) A new "Flexible IoT architecture" with user directionality and environmental adaptability, aiming at solving the inflexibility of traditional IoT architectures, and others.

Systems & Software Division

Soft Computing Integrated System Laboratory

Yoshihiko Horio, Professor

URL: http://www.scis.riec.tohoku.ac.jp/



A dynamics/algorithm (sub-conscious/conscious) hybrid brain-inspired computer prototype for quadratic assignment problems, and a large-scale chaotic neural network IC chip.

The Horio-lab., which is located on the 3rd floor in the Nanoelectronics and Spintronics building, was established on April 2016. Currently, Prof. Horio, and one doctorate course and two undergraduate students are starting up the lab.

Many studies have been made to unravel and utilize the flexible, robust, efficient, and high-level information processing in the brain. A recent booming of the artificial intelligence together with a stall of the Moore' s law desires a novel brain-inspired computing system, which is conceptually different from the current von Neumann-type digital computer. On the other hand, advanced semiconductor nano-devices and ultra-low power CMOS integrated circuits are going to make it possible to realize a very large-scale brain-inspired hardware system. Under this situation, we are trying to create a novel brain-inspired computing paradigm and its VLSI engineering applications. In the paradigm, we focus on rich dynamics of neurons and neural networks by regarding the brain as a complex system with a uniquely organized structure.

We have made several flexible high-performance hybrid computing hardware systems, in which dynamics and algorithms respectively correspond to sub-conscious and conscious processes in the brain. Currently, we are advancing these concepts to a brain-body whole-organism computing paradigm. A novel computational system based on the new paradigm would have a certain type of self or low-level consciousness as an integrated complex dynamics. The engineering realization of such a system needs a new brain-inspired LSI with advanced semiconductor nano-devices, which unifies processing and memory to simultaneously learn, memorize and process information. As a consequence of our research, a user-friendly, thoughtful, kind, and user-dependent brain-inspired computer as a reliable partner is expected.

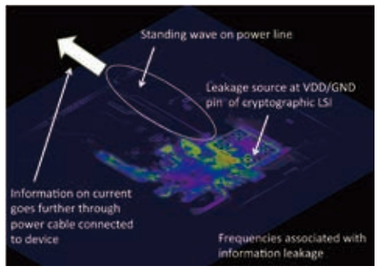
We welcome students and researchers, who have interests in this field, to join our laboratory.

Systems & Software Division

Environmentally Conscious Secure Information System Laboratory

Naofumi Homma, Professor

URL: http://www.riec.tohoku.ac.jp/introduction/organization/division/homma/



Visualization of Information Leakage via EM radiation

The Homma laboratory was established in June 2016. Officially named the "Environmentally Conscious Secure Information Systems Laboratory," it is located on the fourth floor of the main building. Currently, Professor Homma is the laboratory's only faculty member, but he is pursuing ongoing collaborative research with the Aoki Laboratory in Tohoku University's Graduate School of Information Sciences, where he was formerly a member. The Homma laboratory is pursuing research and development on the design, evaluation, and verification of security for information and communication systems, with the goal of building networked systems that enable everyone to use the next-generation communication infrastructure with confidence and to enjoy its benefits securely. The laboratory's main research theme is the development of technologies for building secure information and communication systems to ensure security and reliability at the level of vast and diverse information sources (i.e., embedded devices such as sensor terminals). Specifically, current research is focused on ultra-high-speed, ultra-low-power LSI computing to perform security functions such as encryption and error-correcting codes, secure implementation technologies to protect systems from various physical attacks (attacks carried out by physical access to the system), and security evaluation technologies tailored to the system usage environment (the information environment and electromagnetic environment). The laboratory is also actively collaborating with universities, companies, and government agencies in Japan and overseas in order to implement the results obtained from this research and development across society. In the future, the laboratory aims to establish integrated system security design and evaluation technologies that take into account everything from hardware algorithms to system implementation and the usage environment. The laboratory welcomes visitors who are interested in these kinds of information security research and/or would like to collaborate on this research.

Commendations & Awards

●Prof. Yoshifumi KITAMURA, Mr. Kasim OZACAR

/ ACM Symposium on Spatial User Interaction (SUI 2015) Best Paper Award [9 Aug. 2015]

"GyroWand: IMU-based Raycasting for Augmented Reality Head-Mounted Displays"

●Mr. Tomokazu KOIZUMI

/ 2015 Asia-Pacific Microwave Conference・Best Student Paper Award [9 Dec. 2015]

"A CMOS Series/Shunt Switching Type S/H IC for Ka-Band Direct RF Under Sampling Receiver"

●Assist. Prof. Kazuki TAKASHIMA, Mr. Takafumi OYAMA (Student), Mr. Yusuke ASARI(Student), Prof. Yoshifumi KITAMURA

/ Honourable Mention Award, ACM SIGCHI Conference on Designing Interactive Systems (DIS) 2016 [8 Jun. 2016]

"Study and Design of a Shape-shifting Wall Display"

●Prof. Miki SUEMITSU

/ International Association of Advanced Materials Medal (IAAM medal) for the year 2016 [24 Aug, 2016]

"For Outstanding remarkable contribution in the field of Advanced Materials Science and Technology"

●Assist. Prof. Akira SATO

/ IEEE NANO 2016 (16th International Conference on Nanotechnology) Best Poster Award [25 Aug 2016]

"Nanostructured Asymmetric Dual-Grating-Gate Plasmonic THz Detectors: Enhancement of External Coupling Efficiency by Array Configuration and Silicon-Lens Integration"

●Prof. Hideo OHNO, Assoc. Prof. Shunsuke FUKAMI

/ 38th International Symposium on Dry Process (DPS2016) DPS Paper Award [21 Nov. 2016]

"Plasma process induced physical damages on multilayered magnetic films for magnetic domain wall motion" (Japanese Journal of Applied Physics, vol. 53, No.3S2, 03DF03 (2014)

International Symposia organized by the Institute

Title	Date	Venue
RIEC International Symposium on Ultra-Realistic Interactive Acoustic Communications 2016 ▶ URL: http://www.foresight.riec.tohoku.ac.jp/isurac2016/	20 - 22 May 2016	Miyagi-Zao Kokusai Royal Hotel
RJUSE TeraTech-2016: The 5th Russia-Japan-USA-Europe Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies (RIEC International Symposium on Fundamental & Applied Problems of Terahertz Devices & Technologies) ▶ URL: http://www.otsuji.riec.tohoku.ac.jp/RJUSE-TeraTech-2016/	31 Oct. - 4 Nov. 2016	Sakura Hall, Tohoku Univ.
Dependable Wireless Workshop 2016	9 - 10 Nov. 2016	RIEC
14th RIEC International Workshop on Spintronics ▶ URL: http://www.material.tohoku.ac.jp/~kotaib/CCPGRIEC/CCPGRIECHP/index.html	17 - 19 Nov. 2016	RIEC Nano-Spin Build.
The 4th RIEC International Symposium on Brainware LSI	24 - 25 Feb. 2017	RIEC
The 5th RIEC International Symposium on Brain Functions and Brain Computer ▶ URL: http://www.nanospin.riec.tohoku.ac.jp/RIEC_Sympo/program.html	27 - 28 Feb. 2017	RIEC Nano-Spin Build.
The 11th International Symposium on Medical, Bio- and Nano- Electronics	[TBD] Feb. 2017	RIEC Nano-Spin Build.
The 8th RIEC International Workshop on Nanostructures and Nanoelectronics	8 - 10 Mar. 2017	RIEC Nano-Spin Build.

EVENT Calendar	Date	Venue
15th RIEC International Workshop on Spintronics	16 - 17 Nov. 2017	RIEC Nano-Spin Build.
The 6th RIEC International Symposium on Brain Functions and Brain Computer	21 - 22 Feb. 2018	RIEC Nano-Spin Build.
The 5th International Symposium on Brainware LSI	23 - 24 Feb. 2018	RIEC
The 9th International Workshop on Nanostructures and Nanoelectronics	6 - 7 Mar. 2018	RIEC Nano-Spin Build.

Editor's Note

RIEC annual report 2016-2017 is posted on our website. By looking at this, you can easily and quickly get the overviews of RIEC such as contents of research and international activities. We are looking forward to your access to our website.! (M.S.) ▶ http://www.riec.tohoku.ac.jp/archive/publication/youran/youran.pdf

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