Research Activities in NTT Basic Research Laboratories

Volume 16

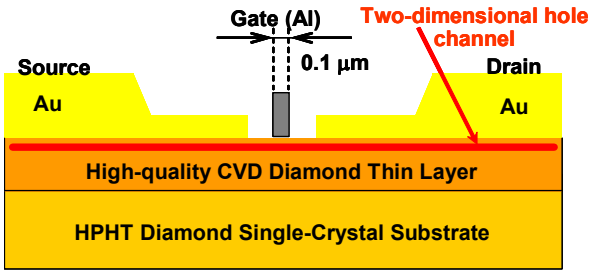
Fiscal 2005

September 2006

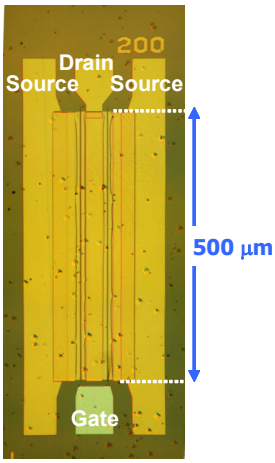
NTT Basic Research Laboratories,

Nippon Telegraph and Telephone Corporation (NTT)

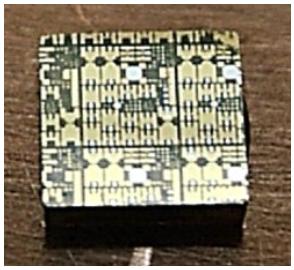
http://www.brl.ntt.co.jp/



Diamond FET structure



Diamond FET
(Gate width; 1mm)

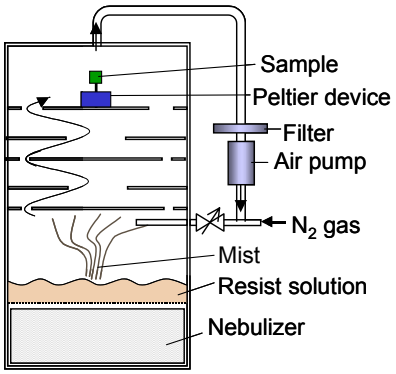


Fine lines transferred to SiO_2 film.

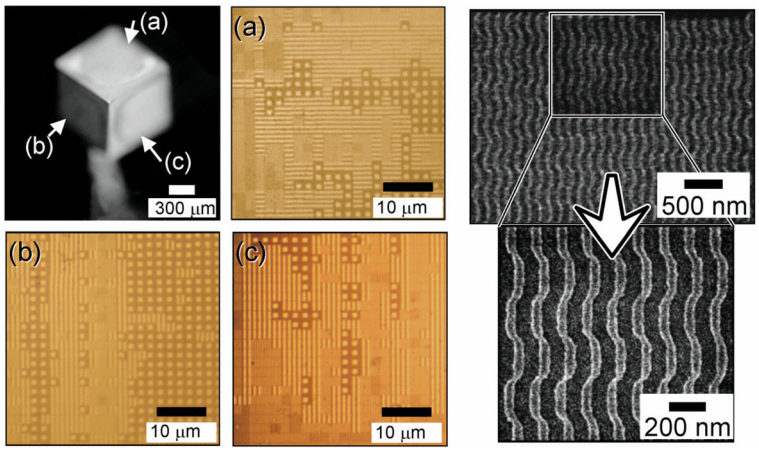
Diamond FET
(3mm x 3mm)

High-Power Operation of Diamond FETs in Gigahertz Range

Diamond semiconductor possesses exceptional properties for high-frequency high-power characteristics. NTT fabricated diamond FET (field-effect transistor), which showed the world's highest RF output power density of 2.1 W/mm at 1 GHz. (Page 18)



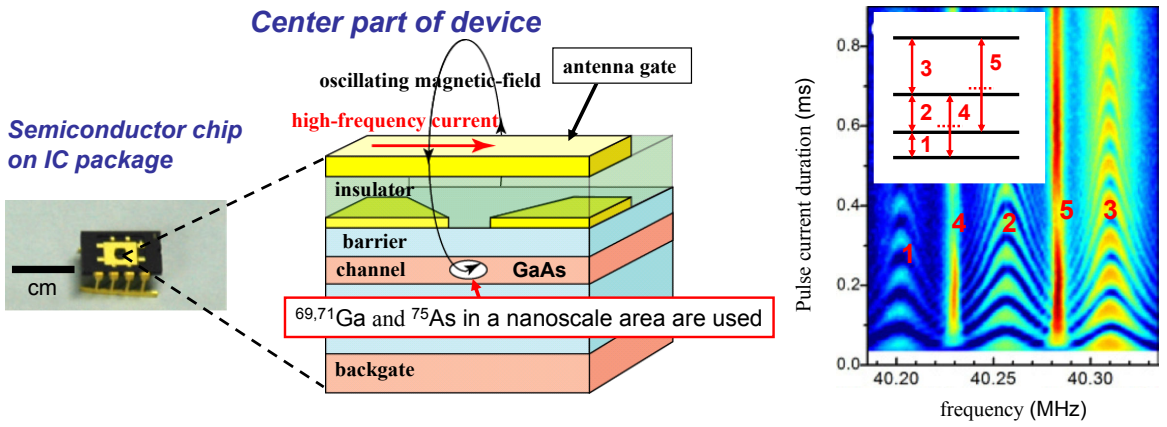
Setup.



Patterns formed on a cube.

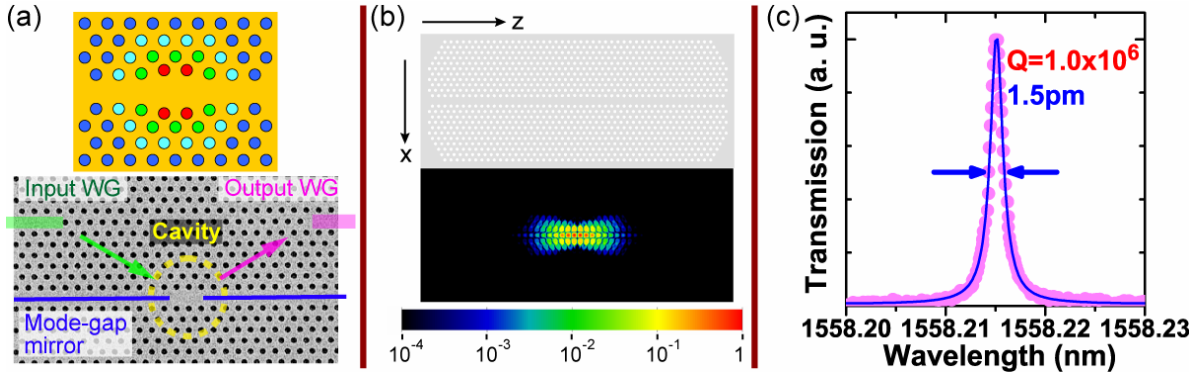
Three-Dimensional Resist-coating Technique Using Fine Mist and Nanopatterning on a Si Cube

We have developed a new technique for coating resist on a three-dimensional (3D) substrate for 3D nanofabrication of various materials. A quasi-static ambient of a very fine mist of resist solution is produced using a ultrasonic nebulizer. By putting a 3D substrate in the ambient, resist film was successfully coated on it with good uniformity and small surface roughness. 3D electron beam lithography on a SiO_2/Si cube produced similar patterns on each face of the cube. Moreover, a resolution 50 nm or less was confirmed by fine lines transferred to the SiO_2 film. (Page 32)



Controlled Quantum Coherences of Nuclear Spins in a Nanoscale Device

Controlled quantum coherence of nuclear spins has been demonstrated by using a semiconductor point contact device. These figures show the semiconductor chip used in the experiment, schematic diagram of the nanodevice incorporated inside, and color plot of the variation in the resistance of the nanodevice measured near the NMR resonance frequency of As. Various quantum-mechanical transitions between four states, which are typical of As, are controlled with high precision, and clear oscillation is observed.(Page 36)



(a) Schematic and microscope image of nanocavity. (b) Calculated electromagnetic field distribution. (c) Experimental resonant spectrum.

Ultrahigh-Q Photonic Crystal Nanocavity Realized with Locally Modulated Line Defect

It is known that a “point defect” in a photonic crystal acts as an optical cavity and a “line defect” acts as an optical waveguide. We found that a local weak width modulation of a line defect can form an ultrasmall, ultrahigh-Q nanocavity. In the Si photonic crystal nanocavity sample shown in the above figures, some of the holes surrounding the line defect are shifted away by several nanometers (too small to see in the figures) to create the cavity. The nanocavity has overcome the experimental one million Q barrier for the first time. This was believed to be impossible to achieve with photonic crystal cavities only a few years ago. (Page 48)

From Science to Innovative Technology

We at NTT Basic Research Laboratories (BRL) are extremely grateful for your interest and support with respect to our research activities.

The missions of BRL are 1) to create new concepts and guiding principles for network and information-processing technologies that will allow us to overcome capacity and security related limitations, and 2) to extend our knowledge of the science and technology that will lead to medium and long-term innovations. We believe that this will both contribute to the success of NTT's business and promote advances in science that will ultimately benefit all mankind. To achieve these goals, we must continuously deliver research output in a timely and well-directed manner. To this end, we adopt a three-tier research theme classification with appropriate management strategies tailored for each:

- *High-priority research*: Work where speed is critically important and that is generally pursued as strategic projects in collaboration with in-house or outside partners.
- *Exploratory research*: Exploratory work that is likely to evolve into high-priority research projects.
- *Innovative research*: Work that goes beyond conventional technology to achieve fundamental and innovative breakthroughs.

BRL's high-priority research themes are currently focused on quantum information processing and nano-bio research. The former aims at clarifying the nature of electrons and photons, which are the basis for the quantum mechanics of light and matter. The goal is to develop practical applications such as quantum cryptography and quantum computing to overcome capacity and security limitations. By exploiting our expertise in quantum optics, quantum solid-state physics, nano-fabrication, and other key technological areas, BRL has achieved remarkable successes in unraveling the mysteries that lie behind a variety of systems including quantum dots, superconducting devices, and cold atoms. Based on these achievements, we are examining the practical viability of quantum cryptography and quantum computers in collaboration with many research institutes, both in Japan and overseas. The aim of our nano-bio research is to create a new area of science through the fusion of neuroscience, biomolecular science, and nanotechnology. This should enable the realization of novel devices that integrate molecular structures, proteins, and artificial nanostructures.

As an example of exploratory research, one project is investigating quantized mechanical motion in nanometer scale structures together with their quantum electronic properties. BRL researchers are also undertaking exploratory work on techniques that will allow us to manipulate nanostructures at will. These techniques include a method for cutting carbon nanotubes at desired points. Researchers working on spintronics are seeking better

understanding and control of electron spin states with a view to achieving revolutionary developments.

Lastly, we are also pursuing highly innovative research that has the groundbreaking potential to overturn conventional technologies in the near future. The great progress made on wide-bandgap semiconductors, single-electron devices, and photonic crystals convinces us that they will ultimately displace existing technologies.

To conduct these research activities, BRL is collaborating with many universities and research institutes in Japan, US, Europe, and Asia as well as other NTT laboratories. BRL also regularly organizes international symposia and conferences at NTT Atsugi R&D Center. In February 2006, we hosted the International Symposium on Mesoscopic Superconductivity and Spintronics, which attracted the participation of more than 100 researchers from around the world. In October 2005, we sponsored the BRL School dedicated to students from abroad, with a special theme of Decoherence and Noise in Quantum Systems. We invited seven distinguished researchers as lecturers, giving young researchers from 17 countries the opportunity to learn from the foremost authorities in these fields and share ideas with them. It gives us immense pleasure to fulfill our mission of being an open laboratory in this way, and to disseminate our research output throughout the world.

This report highlights the main achievements and research activities of NTT Basic Research Laboratories in 2005. We hope that it will help to promote awareness of the work undertaken at NTT BRL, and enhance future collaboration.

Junji Yumoto

Director

NTT Basic Research Laboratories

3-1 Morinosato-Wakamiya, Atsugi,

Kangawa, 243-0198, Japan

Phone: +81 46 240 3300

Fax : +81 46 270 2358

Contents

II. Data

Cover photograph:

Coherent Control of Nuclear Spins in a Semiconductor Nano-scale Device.

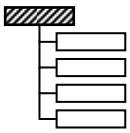
Nuclear spins in a nano-structure fabricated in gallium arsenide are controlled and detected all electrically. Our approach enables the direct detection of (otherwise invisible) multiple quantum coherences between levels separated by more than one quantum of spin angular momentum.

The color plot shows the time evolution of As spins under a radio-frequency irradiation.

Member List

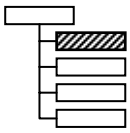
As of March 31, 2006
(*/ left NTT BRL in the middle of the year)

NTT Basic Research Laboratories



Director, **Dr. Junji Yumoto (April 1, 2006 ~)**
Dr. Hideaki Takayanagi*

Research Planning Section



Senior Research Scientist, Supervisor, **Dr. Itaru Yokohama**

Senior Research Scientist, Supervisor, Dr. Akira Fujiwara

Senior Research Scientist, Dr. Tadashi Nishikawa

NTT R&D Fellow

Prof. Yoshihisa Yamamoto
(Stanford University, U.S.A)
Dr. Hideaki Takayanagi
(Director, Bacic Research Laboratories)

NTT Research Professor

Prof. Masahito Ueda
(Tokyo Institute of Technology)
Dr. Fujio Shimizu
(The University of Electro-Communications)
Prof. Yoshihisa Yamamoto*
(Stanford University, U.S.A)
Prof. Shintaro Nomura
(University of Tsukuba)
Prof. Kyo Inoue
(Osaka University)

Materials Science Laboratory

Executive Manager, **Dr. Keiichi Torimitsu**

Dr. Hisashi Sato

Dr. Katsuhiro Ajito Dr. Yuko Ueno
Dr. Isao Tomita Dr. Rakchanok Rungsawang

Thin-Film Materials Research Group:

Dr. Toshiki Makimoto (Group Leader)

Dr. Makoto Kasu	Dr. Yasuyuki Kobayashi	Dr. Hideki Yamamoto*
Dr. Hiroyuki Shibata	Dr. Shin-ichi Karimoto	Dr. Tetsuya Akasaka
Dr. Kazuhide Kumakura	Dr. Kenji Ueda	Dr. Yoshitaka Taniyasu
Dr. Haitao Ye*	Dr. Atsushi Nishikawa	Dr. Alexandre Tallaire

Low-Dimensional Nanomaterials Research Group:

Dr. Yoshihiro Kobayashi (Group Leader)

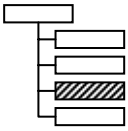
Dr. Fumihiko Maeda	Dr. Hiroki Hibino	Dr. Kawamura Tomoaki
Dr. Prabhakaran Kuniyil*	Dr. Hiroo Omi	Dr. Satoru Suzuki
Dr. Kenichi Kanzaki	Akio Tokura	Dr. Jeong Goo-Hwan

Molecular and Bio Science Research Group:

Dr. Keiichi Torimitsu (Group Leader)

Dr. Keisuke Ebata	Dr. Kazuaki Furukawa	Dr. Koji Sumitomo
Dr. Nahoko Kasai	Dr. Akiyoshi Shimada	Dr. Yoshiaki Kashimura
Dr. Hiroshi Nakashima	Touichiro Goto	Dr. Chunxi Han*
Dr. Mime Kobayashi	Dr. Tobias Nyberg	

Physical Science Laboratory



Executive Manager, **Dr. Yoshiro Hirayama**

Dr. Hiroyuki Tamura

Takeshi Karasawa

Nanodevices Research Group:

Dr. Hiroshi Inokawa (Group Leader)

Dr. Masashi Uematsu	Dr. Yukinori Ono	Dr. Hiroyuki Kageshima
Dr. Katsuhiko Nishiguchi	Dr. Nicolas Clement*	Dr. Kazuyuki Uchida

Nanostructure Technology Research Group:

Dr. Hiroshi Yamaguchi (Group Leader)

Dr. Masao Nagase	Dr. Kenji Yamazaki	Toru Yamaguchi
Junzo Hayashi	Dr. Hajime Okamoto	Dr. Imran Mahboob

Quantum Solid State Physics Research Group:

Dr. Yoshiro Hirayama (Group Leader)

Dr. Toshimasa Fujisawa	Dr. Koji Muraki	Dr. Kiyoshi Kanisawa
Dr. Satoshi Sasaki	Dr. Akihito Taguchi*	Dr. Kyoichi Suzuki
Dr. Toshiaki Hayashi	Dr. Norio Kumada	Dr. Go Yusa*
Dr. Kei Takashina	Dr. Vincent Renard	Dr. Paula Giudici

Superconducting Quantum Physics Research Group:

Dr. Kouichi Semba (Group Leader)

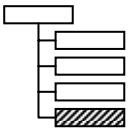
Dr. Hayato Nakano	Dr. Tetsuya Mukai	Hirotaka Tanaka
Dr. Shiro Saito	Dr. Kousuke Kakuyanagi	Dr. Taro Eichler*
Dr. Alexander Kasper		

Spintronics Research Group:

Dr. Tatsushi Akazaki (Group Leader)

Dr. Yuichi Harada	Dr. Yoshiaki Sekine	Dr. Masumi Yamaguchi
Toshiyuki Kobayashi	Dr. Yuan-Liang Zhong	

Optical Science Laboratory



Executive Manager, **Dr. Yasuhiro Tokura**
Dr. Masao Morita*

Dr. Makoto Yamashita

Quantum Optical State Control Research Group:

Dr. Yasuhiro Tokura (Group Leader)

Dr. Kaoru Shimizu	Kazuhiro Igeta	Masami Kumagai
Dr. Hiroki Takesue	Dr. Fumiaki Morikoshi	Toshimori Honjo
Dr. Kiyoshi Tamaki	Dr. Akira Kawaguchi*	Dr. Jens Tobiska

Quantum Optical Physics Research Group:

Dr. Hidetoshi Nakano (Group Leader)

Dr. Tetsuomi Sogawa	Hidehiko Kamada	Dr. Hideki Gotou
Dr. Kouta Tateno	Dr. Takehiko Tawara	Katsuya Oguri
Dr. Atsushi Ishizawa	Dr. Haruki Sanada	Dr. Stephen Hughes
Dr. Yasuaki Okano	Dr. Nicholas Cade	

Photonic Nano-Structure Research Group:

Dr. Masaya Notomi (Group Leader)

Dr. Satoki Kawanishi	Dr. Atsushi Yokoo	Dr.Eiichi Kuramochi
Dr. Hideaki Taniyama	Dr. Akihiko Shinya	Dr. Takasumi Tanabe
Dr. Masao Kato	Dr. Tetsu Ito*	

Distinguished Technical Member

Hiroshi Yamaguchi was born in Osaka on October 30, 1961. He received the B.E., M.S. in physics and Ph.D. degrees in engineering from the Osaka University in 1984, 1986 and 1993, respectively. He joined NTT Basic Research Laboratories in 1986. He was a visiting research fellow in Imperial College, University of London, UK during 1995-1996. Since 1986 he has engaged in the study of compound semiconductor surfaces prepared by molecular beam epitaxy mainly using electron diffraction and scanning tunneling microscopy. His current interests are mechanical and elastic properties of semiconductor low dimensional structures. He is a research coordinator of NEDO international joint research project (Nano-elasticity) during 2001-2004, and also a guest professor in Department of Physics, Tohoku University since 2005. He is a member of the Japan Society of Applied Physics and the Physical Society of Japan. He was awarded the paper awards of the Japanese Society of Applied Physics in 1989 and 2004.

Distinguished Technical Member

Toshimasa Fujisawa was born in Tokyo on May 23, 1963. He received the B.E., M.S. and Ph.D. degrees in electrical engineering from Tokyo Institute of Technology in 1986, 1988 and 1991, respectively. He joined NTT Basic Research Laboratories in 1991. He was a guest scientist in Delft University of Technology, Delft, the Netherlands during 1997-1998. Since 2003, he is also a guest associate professor at Tokyo Institute of Technology. Since 1991 he has engaged in the study of semiconductor fine structures fabricated by focused-ion-beam technique and electron-beam lithography technique, transport characteristics of semiconductor quantum dot. His current interests are single-electron dynamics in quantum dots, and their application to quantum information technologies. He received Sir Martin Wood Prize in 2003 and JSPS (Japan Society for the Promotion of Science) Award in 2005. He is a member of the Japan Society of Applied Physics, and the Physical Society of Japan.

Distinguished Technical Member

Masaya Notomi was born in Kumamoto, Japan, on 16 February 1964. He received his B.E., M.E. and Dr. Eng. degrees in applied physics from University of Tokyo, Tokyo, Japan in 1986, 1988, and 1997, respectively. In 1988, he joined NTT Optoelectronics Laboratories. Since then, his research interest has been to control the optical properties of materials and devices by using artificial nanostructures, and engaged in research on semiconductor quantum wires/dots and photonic crystal structures. He has been in NTT Basic Research Laboratories since 1999, and is currently working on light-propagation control by use of various types of photonic crystals. From 1996-1997, he was with Linköping University in Sweden as a visiting researcher. He is also a guest associate professor of Tokyo Institute of Technology (2003-). He received 2006/2007 IEEE/LEOS Distinguished Lecturer Award. He is an associate editor of Japanese Journal of Applied Physics. He is a member of the Japan Society of Applied Physics, the American Physical Society, and IEEE/LEOS.

Distinguished Technical Member

Makoto Kasu was born in Tokyo on May 30, 1961. He received the B.E., M.S. and Ph.D. degrees in Electrical Engineering from Kyoto University in 1985, 1987 and 1990, respectively. He joined NTT Basic Research Laboratories in 1990. He was a guest scientist in University of Ulm, Germany from 2002 to 2003. Since 1990 he has engaged in scanning tunneling microscope (STM)-based nanostructure fabrication, widegap semiconductors such as aluminum nitride (AlN) and diamond. He received Electronic Materials Symposium (EMS) award for his nitride works. He is a member of the Japan Society of Applied Physics, and the Institute of Electronics, Information and Communication Engineers of Japan, the Surface Science Society of Japan. He is the leader of SCOPE project "Diamond RF Power Devices for Microwave, Millimeter-Wave Range Power Amplifiers" (from 2006 to 2011) of the Ministry of Internal Affairs and Communications, Japan.

Advisory Board (2005 Fiscal Year)

Name	Title Affiliation
Dr. Boris L. Altshuler	Professor Department of Physics Princeton University, U.S.A.
Dr. Michel H. Devoret	Professor Department of Applied Physics Yale University, U.S.A.
Dr. Serge Haroche	Professor Department de Physique De l'Ecole Normale Superieure, France
Dr. Mats Jonson	Professor Department of Applied Physics Chalmers University of Technology, Sweden
Dr. Anthony J. Leggett	Professor Department of Physics University of Illinois at Urbana-Champaign U.S.A.
Dr. Johan E. Mooij	Professor Department of Applied Physics Delft University of Technology, The Netherlands
Dr. Klaus H. Ploog	Director Paul-Drude-Institut für Festkörperelektronik Germany
Dr. John F. Ryan	Professor Clarendon Laboratory University of Oxford, U.K.
Dr. Klaus von Klitzing	Professor Max-Planck-Institut für Festkörperforschung Germany

Invited / Guest Scientists (2005 Fiscal Year)

Name	Affiliation Period
Dr. Hiroshi Yaguchi	Kyoto University, Japan December 03 – December 05
Dr. Jan Johansson	Japan Science and Technology Agency (JST), Japan February 04 – January 06
Dr. Tobias Bergsten	Japan Science and Technology Agency (JST), Japan April 04 – March 06
Dr. Satoshi Mitsugi	Tokyo Institute of Technology, Japan April 05 – July 05
Dr. Hidetoshi Miyashita	University of Tokyo April 05 – March 06
Dr. Shirou Kawabata	National Institute of Advanced Industrial Science and Technology (AIST), Japan April 05 – May 05
Dr. Stefan Fölsch	Paul Drude Institute for Solid-State Electronics, Germany April 05
Prof. Rui-Rui Du	Rice University, U.S.A. July 05 – August 05
Prof. Jian Chen	Nanjing University, R.O.C. July 05 – August 05
Dr. Takaaki Koga	Hokkaido University, Japan August 05 – July 06
Dr. Akio Tsukada	Tokyo University of Agriculture and Technology, Japan June 05 – March 06
Dr. Chandra Ramanujan	University of Oxford, U.K. October 05 – November 05

Dr. Go Yusa	Japan Science and Technology Agency (JST), Japan October 05 – September 08
Dr. Yasuyoshi Miyamoto (Interchange Researcher)	NHK Science & Technical Research Laboratories, Japan December 05 – November 06
Dr. Masaya Kataoka	University of Cambridge, U.K. January 06
Prof. Yong-Hang Zhang	Arizona State University, U.S.A. January 06 – July 06
Prof. Alexey Ustinov	University of Erlangen-Nürnberg, Germany January 06 – March 06
Prof. Mats Jonson	Göteborg University, Sweden February 06 – March 06
Prof. Eleanor Campbell	Göteborg University, Sweden February 06 – March 06
Dr. Christopher Bäuerle	CNRS-CRTBT, France February 06 – March 06
Dr. Fabio Taddei	Scuola Normale Superiore, Italy February 06 – March 06

Trainees (2005 Fiscal Year)

Name	Affiliation Period
Frank Deppe	Technische Universität München, Germany May 02 – July 05
Simon Perraud	University of Paris 6 / CNRS, France October 04 – September 07
Huang-Ming Lee	National Chiao Tung University, Taiwan R.O.C. November 04 – November 05
Yueh-Chin Lin	National Chiao Tung University, Taiwan R.O.C. November 04 – August 05 October 05 – January 06
Arnaud Valeille	SUPAERO (École Nationale Supérieure de L'aéronautique et de L'espace), France January 05 – August 05
Wouter Naber	Delft University of Technology, The Netherlands January 05 – June 05
Shih-Chieh Huang	National Chiao Tung University, Taiwan R.O.C. February 05 – February 06 March 06 – September 06
Taryl Leaton Kirk	Universität Stuttgart, Germany Max-Planck-Institut für Festkörperforschung, Germany March 05 – April 05
Samir Etaki	Delft University of Technology, The Netherlands April 05 – September 05
Rémi Rivière	INSA (Institut National des Sciences Appliquées de Toulouse), France May 05 – September 05

Na Young Kim	Stanford University, U.S.A. June 05 – June 05
Andreas Winkler	Darmustadt University of Technology, Germany July 05 – December 05
Jennifer Chan	University of Oxford, U.K. July 05 – August 05
Carole Planchette	ESPCI (Ecole Supérieure de Physique et de Chimine Industrielles), France July 05 – December 05
Pierrick Balestriere	ESPCI (Ecole Supérieure de Physique et de Chimine Industrielles), France July 05 – December 05
Rebeca Alonso	"Miguel Hernández" University of Elche, Spain January 06 – August 06
François Chabrol	University of Newcastle Upon Tyne, U.K. January 06 – February 06
Jean-François Morizur	ENS (Ecole Normale Supérieure), France February 06 – July 06
Raphael de Gail	ENS (Ecole Normale Supérieure), France February 06 – August 06
François Parmentier	ENS (Ecole Normale Supérieure), France February 06 – July 06
Benjamin Gaillard	INSA (Institut National des Sciences Appliquées de Toulouse), France February 06 – September 06
Wan-Cheng Zhang	Chinese Academy of Sciences, R.O.C. February 06 – August 06

Lars Tiemann	Max-Planck-Institut für Festkörperforschung, Germany March 06 – June 06

Japanese Students (2005 Fiscal Year)

Name	Affiliation (Period)
Yuichi Igarashi	University of Tokyo, Japan (Apr. 05 – Mar. 06)
Tomohiro Inoue	Osaka University, Japan (Jan. 06)
Shoko Utsunomiya	University of Tokyo, Japan (Jun. 05, Oct. 05－Mar. 06)
Kuniaki Endo	Tokyo University of Science, Japan (Apr. 05 – Mar. 06)
Akira Oiwa	University of Tokyo, Japan (Apr. 05 – Mar. 06)
Yohei Okubo	Hokkaido University, Japan (Aug. 05 – Sep. 05)
Satoru Ohno	Keio University, Japan (Apr. 05 – Mar. 06)
Hiroshi Okutani	Hokkaido University, Japan (Aug. 05 – Sep. 05)
Junya Ono	University of Tsukuba, Japan (Apr. 05 – Mar. 06)
Tatsuaki Orihara	Keio University, Japan (Jul. 05 – Aug. 05)
Kang Sunggu	University of Tsukuba, Japan (Apr. 05 – Mar. 06)
Koya Kitagawa	Tokyo University of Science, Japan (Apr. 05 – Mar. 06)
Yosuke Kitamura	University of Tokyo, Japan (Apr. 05 – Mar. 06)
Shuichiro Kihara	Waseda University, Japan (Jun. 05 – Mar. 06)
Tatsuya Kutsuzawa	Tokyo University of Science, Japan (Apr. 05 – Mar. 06)
Marika Gunji	Keio University, Japan (Apr. 05 – Mar. 06)
Tetsuo Kodera	University of Tokyo, Japan (Apr. 05 – Mar. 06)
Shingo Kondo	Tokai University, Japan (Apr. 05 – Mar. 06)
Kouta Sakakibara	Toyohashi University of Technology (Jan. 06 – Feb. 06)
Yosuke Sasaki	Tokyo Institute of Technology, Japan (Apr. 05 – Mar. 06)
Go Shinkai	Tokyo Institute of Technology, Japan (Apr. 05 – Mar. 06)
Jun Sugawa	University of Tokyo, Japan (Apr. 05 – Mar. 06)
Hiroyuki Suzuki	University of Tokyo, Japan (Apr. 05 – Mar. 06)
Akihiro Souma	University of Tokyo, Japan (Apr. 05 – Mar. 06)
Atsushi Sogabe	Shonan Institute of Technology, Japan (Apr. 05 – Mar. 06)

Toshitake Takahashi	Keio University, Japan (Apr. 05 – Mar. 06)
Masaya Tazawa	Tokyo University of Science, Japan (Apr. 05 – Mar. 06)
Shinya Tanaka	Toyohashi University of Technology (Jan. 06 – Feb. 06)
Masashi Tanaka	Nagaoka University of Technology (Oct. 05 – Feb. 06)
Daniel Ioan Moraru	Shizuoka University (Oct. 05 – Feb. 06)
Masaru Tsuchiya	Keio University, Japan (Apr. 05 – Aug. 05)
Katsuhiko Degawa	Tohoku University, Japan (Apr. 05)
Ritsuya Tomita	Tokyo Institute of Technology, Japan (Apr. 05 – Mar. 06)
Hiromasa Nakano	Tokyo University of Science, Japan (Apr. 05 – Mar. 06)
Tomohiro Nakamura	Shonan Institute of Technology, Japan (Apr. 05 – Mar. 06)
Masumi Noda	Tokyo University of Science, Japan (Apr. 05 – Mar. 06)
Junichi Hashimoto	Yokohama National University (Aug. 05 – Mar. 06)
Kenichi Hidachi	University of Tokyo, Japan (Aug. 05 – Mar. 06)
Yusuke Furukawa	University of Tokyo, Japan (Apr. 05 – Mar. 06)
Rumiko Horie	University of Tokyo, Japan (Apr. 05 – Sep. 05)
Munekazu Horikoshi	The University of Electro-Communications, Japan (Apr. 05 – Mar. 06)
Takahiro Horiguchi	Kyoto University (Nov. 05)
Kazuomi Masuhara	University of Tokyo, Japan (Oct. 05 – Mar. 06)
Tetsunori Matsumoto	Tokyo University of Science, Japan (Apr. 05 – Mar. 06)
Yuki Maruta	University of Tokyo, Japan (Oct. 05 – Mar. 06)
Kenji Miyakoshi	Tokyo University of Science, Japan (Apr. 05 – Mar. 06)
Hiroshi Miyazaki	Waseda University, Japan (Jun. 05 – Mar. 06)
Tetsuya Miyawaki	Tohoku University (Feb. 06 – Mar. 06)
Masakazu Morita	Tokyo Institute of Technology, Japan (Apr. 05 – Mar. 06)
Shin Yabuuchi	Keio University, Japan (Apr. 05 – Mar. 06)
Takao Yamaguchi	Tokai University (Aug. 05 – Mar. 06)
Michihisa Yamamoto	University of Tokyo, Japan (Apr. 05 – Mar. 06)

Kazuhiro Watanabe Osaka University (Oct. 05)

Ⅰ. Research Topics

Overview of Research in Laboratories

Materials Science Laboratory Keiichi Torimitsu

The Materials Science Laboratory (MSL) aims at producing new functional materials and designing of advanced device based on novel materials and biological function. Controlling the configuration and coupling of atoms and molecules is our approach to accomplish these goals. Bio-nano research is set as our principle research in this laboratory.

We have three research groups covering from inorganic materials, such as semiconductors, to organic materials, such as neurotransmitters. The characteristic feature of MSL is the effective sharing of the unique nanofabrication and measurement techniques of each group. This enables fusion of research fields and techniques, which leads to innovative material research for the IT society.

We set up European laboratory in UK for bio-nano research, our principal research, in last year and strengthen our research activities. We promote collaborations with international organizations to develop a firm basis of basic science.

Physical Science Laboratory Yoshiro Hirayama

We are studying solid-state quantum systems and nanodevices, which will have revolutionary impact on communication and information technologies in the 21st century. In particular, we are making firm and steady progress in the pursuit for solid-state qubits, and related physics and technology for future quantum information processing. We maintain an open-door policy and engage in collaborations with many outside organizations to enhance our basic research.

The five groups in our laboratory are working in the following areas: quantum coherent control of semiconductor and superconductor systems, carrier interactions in semiconductor hetero- and nanostructures, spintronics manipulating both electron and nuclear spins, precise and dynamical control of single electrons, nanodevices operating at ultimately low power consumption, atom traps, and novel nanomechanics based on compound semiconductors. These studies are supported by cutting-edge nanolithography techniques, well-controlled nanofabrication processes, high-quality crystal growth, and theoretical studies including first-principle calculations.

Optical Science Laboratory Yasuhiro Tokura

This laboratory aims the development of core-technologies that will innovate in optical communications and optical signal processing, and also seeks fundamental scientific progress.

The three groups in our laboratory are working for the quantum state control of light, the quantum state control of materials using light, the analysis of high speed phenomena using very short pulse laser, the optical properties of semiconductor nano-structures, and very small optical integrated circuit realized with two-dimensional photonic crystals.

This year, we made great strides in the speed of quantum cryptography, generation of quantum entangled photon pairs, absolute control of carrier envelope phase, time-resolved absorption spectrum with wide-band x-ray pulse, and realizing very low-loss wave-guide and very high Q-value point-defect resonators.

High-Power Operation of Diamond FETs in Gigahertz Range

Makoto Kasu and Kenji Ueda
Materials Science Laboratory

The data transfer rate in communications is increasing very rapidly. Therefore, electronic devices that can operate in the gigahertz (GHz) range with higher output power are urgently needed. Among semiconductor materials, diamond has the highest thermal conductivity and the highest breakdown electric field. It also offers extremely high carrier mobility and saturation drift velocity. Therefore, diamond electronic devices are expected to exhibit the best performance in high-frequency and high-power operation.

Diamond films formed by the currently available growth techniques contain high-density crystalline defects and impurities, so that it has been very difficult to obtain high-purity diamond. Recently, we have developed technologies for the pre-growth treatment of the substrate surface and for CVD growth using highly pure methane source gas.

Figure 1 shows the diamond field-effect transistor (FET) structure. A diamond homoepitaxial layer was grown by CVD on high-temperature high-pressure (HTHP)-synthesized diamond substrate, and then a hole channel was formed near the surface by hydrogen surface passivation. Finally, using electron-beam lithography and self-alignment technologies, a submicron-long Al gate was formed. Recently, by improving these technologies, we were able to reduce the gap between the source and gate contacts to ~0.5 μm and the gate length to 0.1 μm, which results in improvement of FET RF characteristics.

Figure 2 shows input-output power characteristics obtained at 1 GHz in the class-A operation for a diamond FET with gate length (Lg) of 0.1 μm and gate width (Wg) of 100 μm. The maximum output power density (P_{out}) was 2.1 W/mm, which is seven times higher than the highest value we reported previously and two times higher than that of GaAs FETs commonly used in present systems. The linear power gain of 10.94 dB for a wide input power range and the power-added efficiency (PAE) of 31.8% are similar to those of devices in present systems.

We are studying ways to boost the operating frequency and output power and, at the same time, devoting much effort to improving the reliability of diamond FETs.

[1] M. Kasu, K. Ueda, H. Ye, Y. Yamauchi, et al., Electronics Letters **41** (2005) 1249.
[2] M. Kasu, K. Ueda, H. Ye, et al., Diamond and Related Materials **15** (2006) 783.

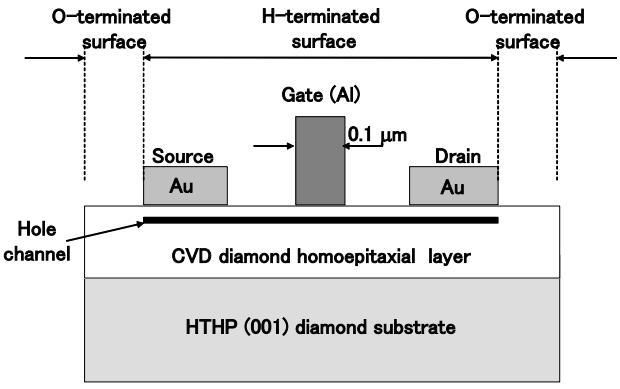


Fig. 1. Cross section of diamond FET.

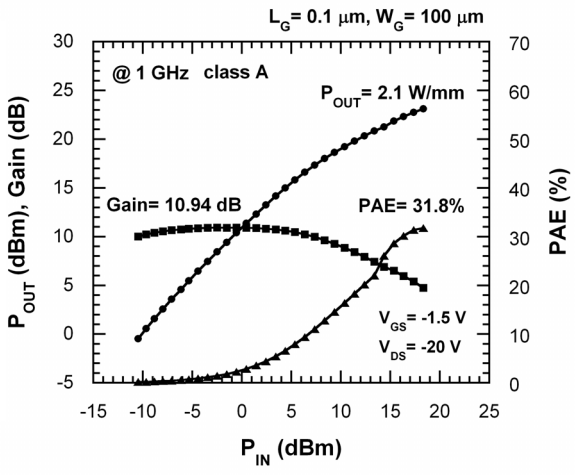


Fig. 2. RF power characteristics at 1 GHz.

BGaN Micro-Islands for Growth of High-Quality GaN Films

Tetsuya Akasaka, Yasuyuki Kobayashi and Toshiki Makimoto
Materials Science Laboratory

Sapphire is attractive for a substrate of GaN growth, because it is inexpensive and has a large area, compared with alternatives, such as SiC and GaN substrates. However, a large number of crystal defects (threading dislocations) are formed in GaN films because of the large mismatches in the lattice constants and thermal expansion coefficients between GaN and sapphire. In addition, GaN films grown on sapphire generally contain many residual carriers and have low carrier mobilities. The techniques normally used to reduce crystal defects in GaN or improve its electronic properties are complicated. A novel simple method that can solve these problems simultaneously is therefore highly desired. We have obtained GaN films with low threading dislocation density (TDD) as well as with few residual carriers and high mobility using BGaN micro-islands as novel buffers for the first time [1].

The BGaN (B~2%) formed micro-islands as shown in Fig. 1, because BGaN caused the phase separation due to the low solubility of B atoms in GaN. Such a three-dimensional structure is not favorable for device application. However, epitaxial lateral overgrowth (ELO) of a GaN film on the BGaN micro-islands resulted in the smooth and continuous surface. Figure 2 shows a cross-sectional transmission electron micrograph (X-TEM) for a GaN film grown using double layers of BGaN micro-islands. ELO of GaN reduced the TDD by two orders of magnitude and the TDD near the GaN surface became $2x10^8$ cm^{-2}. Threading dislocations were annihilated by bending and lateral propagation and by the formation of half-loops and fused dislocations. We confirmed that the residual carrier concentration in the GaN film was very low. Using BGaN micro-islands, we fabricated an AlGaN/AlN/GaN heterostructure, which is a basic component of GaN-based transistors. This heterostructure exhibited two-dimensional electron gas mobility of 1910 cm^2/Vs at room temperature, which is among the highest ever reported for heterostructures on sapphire.

The present technique can grow GaN films with smooth surfaces, low TDD, and excellent electronic properties on sapphire in just a single crystal growth process. Therefore, it is very promising as a core technology for reducing the fabrication costs and prolonging the lifetimes of GaN-based transistors and light emitting devices.

[1] T. Akasaka and T. Makimoto, Jpn. J. Appl. Phys. (*JJAP Express Letter)* **44** (2005) L1506.

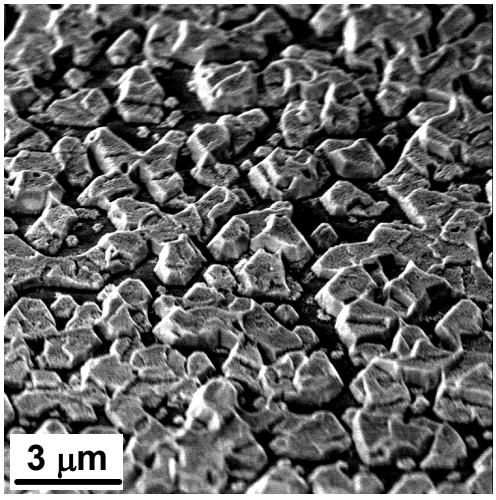


Fig. 1. Scanning electron micrograph of BGaN micro-islands.

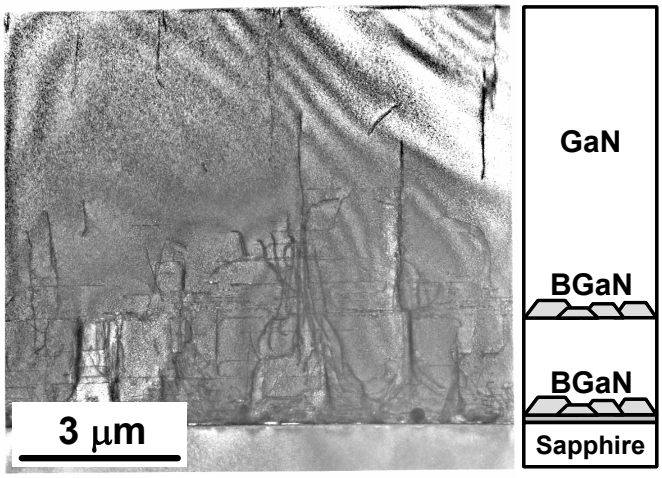


Fig. 2. X-TEM of a GaN film grown using BGaN micro-islands.

High-Quality Hexagonal Boron Nitride Heteroepitaxial Layers Grown by Flow-Rate Modulation Epitaxy

Yasuyuki Kobayashi, Tetsuya Akasaka and Toshiki Makimoto
Materials Science Laboratory

Hexagonal boron nitride (h-BN) is one of the promising material systems for optical device applications in the ultraviolet spectral region and for exciton-based quantum information processing because of its wide bandgap and large exciton binding energies of 5.97 eV and 149 meV, respectively. However, a high-quality h-BN epitaxial layer on an appropriate substrate has not been reported. Only a few papers have described the growth of BN by conventional metalorganic vapor phase epitaxy (MOVPE), and there are many unsolved fundamental problems.

One of the problems is the occurrence of gas phase parasitic reactions between group III and V sources. It is expected that flow-rate modulation epitaxy (FME) is the most efficient method for reducing the parasitic reaction because the group III and V sources are alternately supplied to the growing surface. The use of Ni (111) substrate could provide a high-quality h-BN layers because the lattice constant of Ni (111) substrate is very close to the in-plane constant of h-BN. Here, we demonstrated heteroepitaxial growth of h-BN on Ni (111) substrates for the first time using FME.

Figure 1 shows the growth-rate of BN grown by MOVPE and FME as a function of ammonia (NH_3) flow-rate. For BN growth by MOVPE, the growth rate decreased monotonically with increasing NH_3 flow-rate. The growth rate of BN by FME decreased in small steps with increasing NH_3 flow-rate. However, the degree of the decrease in FME growth was much smaller than that in MOVPE. These results indicate that FME can reduce the parasitic reaction effectively [1]. Figure 2 shows the X-ray diffraction (XRD) pattern obtained in a normal 2θ/ω configuration for h-BN on Ni (111) substrates grown by FME. Apart from the substrate Ni (111) peak, the distinct sharp h-BN (0002) and weak (0004) peaks from the (0001) planes of h-BN can be clearly observed, indicating that the film is pure single-phase (0001) h-BN with the c axis normal to the Ni (111) surface [2].

The present results pave the way for future optical device applications.

[1] Y. Kobayashi and T. Makimoto, Jpn. J. Appl. Phys. **45** (2006) 3519.
[2] Y. Kobayashi et al. Abstracts of 13th International Conference on Metal Organic Vapor Phase Epitaxy, Th-A1.1 (2006).

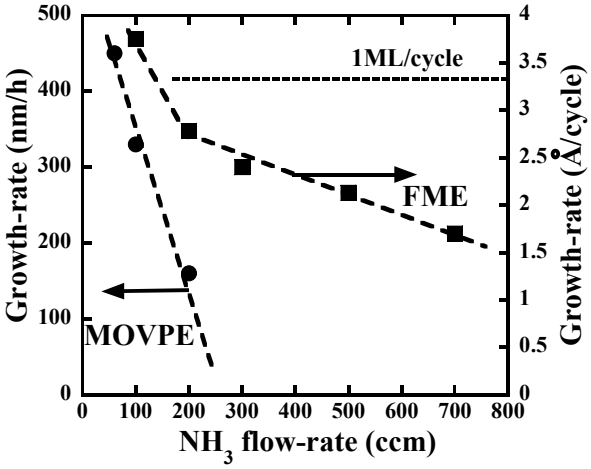


Fig. 1. Growth-rate of BN films by MOVPE and FME as a function of NH_3 flow rate.

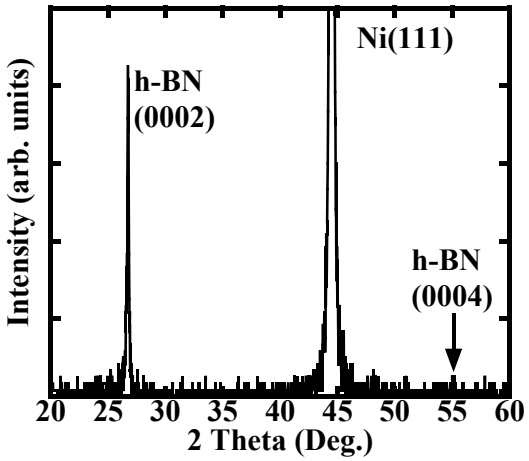


Fig. 2. XRD patterns of h-BN.

High-Temperature Operation of Nitride-Based HBTs

Kazuhide Kumakura and Toshiki Makimoto
Materials Science Laboratory

Nitride-based semiconductors are promising materials for high-temperature or high-voltage operation devices because of their wide band gap. Heterojunction bipolar transistors (HBTs) are normally-off devices and can be operated with large current densities. Therefore, nitride-based HBTs are expected to operate at high temperature and with high power. However, dislocations or process-induced damage in nitride-based HBTs results in large leakage current and low breakdown voltage.

We have developed a buffer layer for the growth of high-quality nitride-based semiconductors on sapphire substrates [1]. Using the buffer layer and a low-damage etching process, we have succeeded in the first operation of *Pnp* AlGaN/GaN HBTs with a common-emitter configuration. In order to clarify the transport mechanism at high-temperature, we investigated the current-voltage (*I-V*) characteristics of the *Pnp* HBTs at temperatures ranging from room temperature (RT) to 590 °C.

We deposited Al_2O_3/graded-AlON/AlN/Al_2O_3 as a buffer layer on sapphire substrates by electron cyclotron resonance (ECR) plasma sputtering at RT. The total layer thickness was 20 nm. Figure 1 shows the layer structure of the *Pnp* AlGaN/GaN HBTs grown on the substrate by metalorganic vapor phase epitaxy. Emitter and base mesas were defined by lithography and ECR plasma etching. Pd/Au and Al/Au were used as the ohmic contact metals for the *p*-type and *n*-type layers, respectively.

Figure 2 shows the common-emitter *I-V* characteristics of the *Pnp* AlGaN/GaN HBT at 550 °C [2]. Good saturation properties were observed at this high-temperature and the leakage current was less than 1 μA without the base current. The operation temperature is the highest among semiconductor devices. The reason for this high-temperature operation is ascribed to our techniques for high-quality growth of nitride-based semiconductors and the low-damage process. These results indicate that nitride-based HBTs are promising for high-power electronics.

[1] K. Kumakura, M. Hiroki, and T. Makimoto, Int. Workshop on Nitride Semiconductors 2004, **P5.1**, Pittsburgh, USA, 2004; J. Crystal Growth **292** (2006) 155-158.

[2] K. Kumakura and T. Makimoto, 2005 Int. Conference on Solid State Devices and Materials, Kobe, Japan, **I-6-2**, 2005.

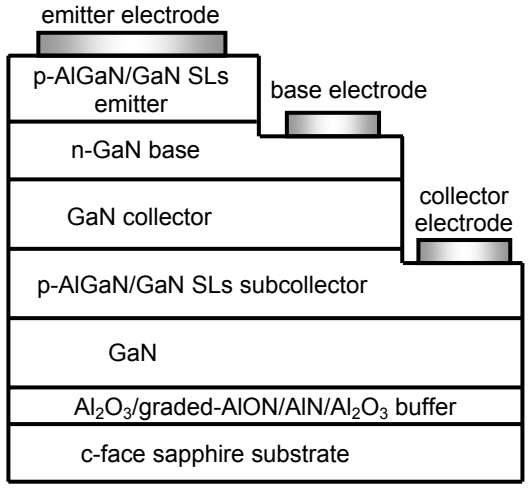


Fig. 1. Layer structure of the HBT.

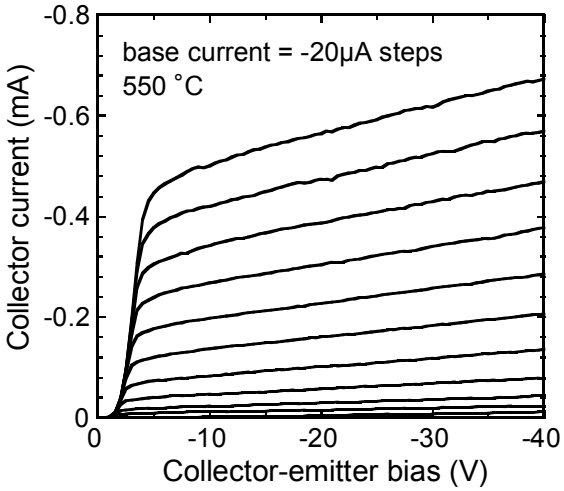


Fig. 2. *I-V* characteristics at 550 °C.

Metal-Semiconductor Transition in Carbon Nanotubes Induced by Low-Energy Electron Irradiation

Satoru Suzuki, Kenichi Kanzaki and Yoshihiro Kobayashi
Materials Science Laboratory

A carbon nanotube can be metallic or semiconducting depending on its chirality. The band gap of semiconducting nanotubes strongly depends on their diameter. No technique has yet been established for controlling the chirality and diameter. This is a big problem in terms of nanotube applications for nanoelectronics. For example, a metallic nanotube does not work as a field effect transistor (FET).

Recently, we have developed a simple technique for converting the electric properties of a metallic nanotube to semiconducting [1]. The gate characteristics of a single-walled carbon nanotube (SWNT) FET at 28 K are shown in Fig. 1. The SWNT was originally metallic, so that there was no off-region in the gate characteristics [panel (a)]. The oscillation of the conductivity is caused by a Coulomb blockade specific to such a low temperature measurement. When the device was irradiated by electrons of 1 keV up to a dose of ~10^{-4} C/cm^2, an off-region appeared [panel (b)]. Such gate characteristics are specific to semiconducting SWNTs. Further irradiation widened the off-region [panel (c)]. The irradiation-induced change of the gate characteristic is, in appearance, similar to the change that would be caused by changing the chirality and diameter. Moreover, as shown in Fig. 2, intensive irradiation finally makes a SWNT almost completely insulating [2]. These results show that the electric properties of SWNTs can be widely changed from metallic to insulating by controlling the irradiation dose. Defects created in the SWNTs by the irradiation play an essential role in the irradiation-induced electric property change [3,4].

[1] A. Vijayaraghavan et al., Nano Lett. 5 (2005) 1575.
[2] S. Suzuki et al., Jpn. J. Appl. Phys. **44** (2005) L1498.
[3] S. Suzuki et al., Jpn. J. Appl. Phys. **43** (2004) L1118.
[4] S. Suzuki et al., Jpn. J. Appl. Phys. **44** (2005) L133.

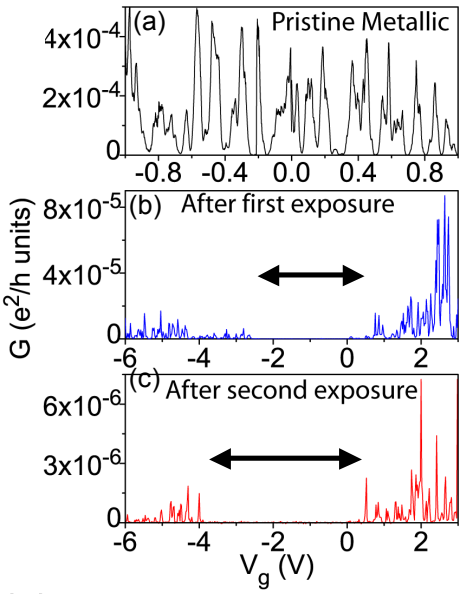


Fig. 1. Gate characteristic of the SWNT device before and after the first and second irradiation.

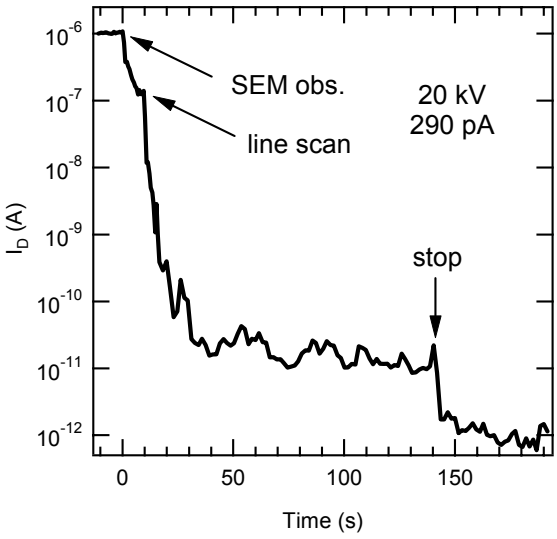


Fig. 2. Results of in-situ electric measurement of the SWNT device during electron irradiation.

Diameter-Controlled Growth of Carbon Nanotube Using Ferritin Catalysts

Goo-Hwan Jeong, Satoru Suzuki and Yoshihiro Kobayashi
Material Science Laboratory

The electrical properties of carbon nanotubes (CNT) are highly dependent on their geometric structures, such as their diameter or chirality. Thus, for the application of CNT-based nanoelectronics, it is essential to develop growth methods in which diameter or chirality can be controlled. Here, we introduce our recent work for diameter-controlled CNT growth, in which we used catalytic nanoparticles instead of a thin-film catalyst [1].

As the catalyst source, we used ferritins, which are covered with protein shell and contain Fe (ferritin) or Co clusters (Co-ferritin) in their core (6-8 nm in diameter). We also used Dps protein, which contains Fe clusters in its core (4-nm in diameter). Catalytic nanoparticles were obtained by calcination of ferritin-family molecules. We grew CNTs on flat or pillar-patterned substrates by means of ferritin-casting, calcination, and successive methane CVD.

Figure 1 shows a result of atomic force microscopy (AFM) measured after CNT growth using ferritins and Co-ferritins [2]. Considering that the nanoparticles are 2-7 times larger than the CNT diameter, we can suppose that thin CNTs grow from the large catalytic nanoparticles. The inset is schematic illustration of the base-growth mechanism. Fe-catalyst embedment in SiO_2 substrates was confirmed by transmission electron microscopy.

The Raman profile and a scanning electron microscopy (SEM) image of a suspended CNT (inset) grown from Dps are shown in Fig. 2. From the Raman spectra, we know that the CNT diameter is about 1 nm and that structural quality of the CNT is very high.

The results of size changes of ferritin-family catalysts and resultant CNT diameters are summarized in Fig. 3. The ferritin-family molecules (10.2-4.0 nm) are changed to catalytic nanoparticles (5.3-2.4 nm) by calcination and finally give rise to thin CNT (1.6-1.1 nm). We found that the diameter differences between catalysts and CNT become smaller as the catalyst size decreases. Further, the CNT diameter itself becomes smaller. These suggest that smaller catalysts than those used in the present work will provide critical clues for diameter control of CNTs. Investigating not only the catalyst behavior during CVD growth [3] but also the size-relationship between catalysts and CNT is critical for diameter-controlled CNT growth.

[1] G. H. Jeong et al., J. Am. Chem. Soc. **127** (2005) 8238.
[2] G. H. Jeong et al., J. Appl. Phys. **98** (2005) 124311.
[3] G. H. Jeong et al., Chem. Phys. Lett. **422** (2006) 83.

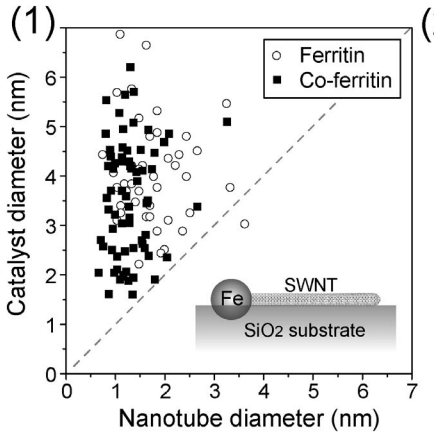


Fig. 1. Size relationship between catalysts and CNTs. Inset: Schematic drawing of the growth feature.

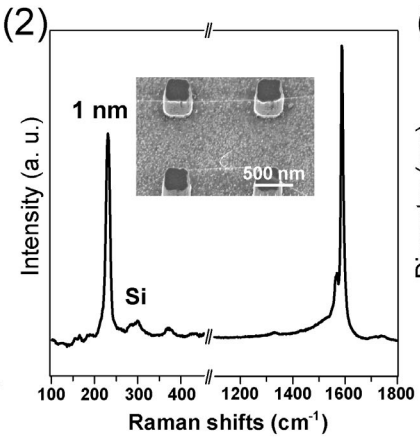


Fig. 2. Raman profile of suspended CNT grown from Dps. Inset: SEM image of a suspended CNT.

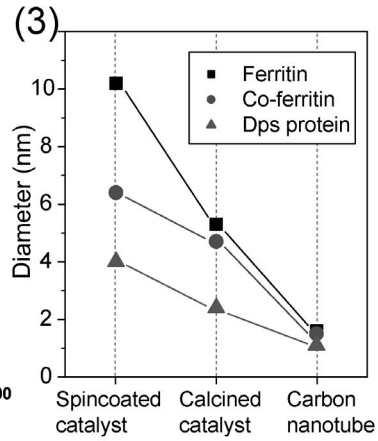


Fig. 3. Size changes of ferritin-family catalysts and resultant CNT diameters.

Strain Analysis of Si Nanolayers by Ultra-Small-Angle Grazing Incidence X-ray Diffraction

Hiroo Omi and Tomoaki Kawamura
Materials Science Laboratory

Nanoscale ultra-thin Si films exhibit quantum size effects when their thickness becomes smaller than several nanometers. In order to control nanoscale silicon devices based on the quantum size effect, it is essential to achieve high-quality silicon nanolayers without strain distribution. Ultrathin silicon nanolayers are usually fabricated by thermal oxidation and HF etchback processes on silicon-on-insulator wafers. In this method, the silicon layers are subjected to strain due to the difference in the thermal expansion coefficients between Si and SiO_2 during the thermal silicon oxidation. As a result, the strain significantly increases as the silicon nanolayers become thinner, as has been observed by X-ray diffraction and Raman spectroscopy. However, with these conventional apparatuses, we can only detect information about the average lattice strain in the silicon nanolayers; it is difficult to detect information about the localized strains existing on the surface of the thin silicon nanolayers or at the Si/SiO_2 interfaces.

We developed a new apparatus for grazing incidence X-ray diffraction (GIXD) using the syncrotron radiation source at SPring-8 (Fig. 1) and established a method for evaluating such spatially localized strain on a surface. The new apparatus can be used at the incident angle below the critical angle of Si (0.18°). Consequently, for the first time, we succeeded in detecting small strain localized on the surface of silicon nanolayers with this apparatus.

We probed in depth the strain on the surface of the Si nanolayers by changing the incident angle of GIXD. The diffraction patterns obtained at the incidence angles of 0.01º and 0.1º are originated from 2 nm and 6 nm in depth from the lattice of surface region (Fig. 2(a)). From the intensity analysis based on the two-layered-strain model (two layers with different states of strain), we found that the surface region of the silicon nanolayers has finite strain domains and that the degree of the strain is on order of 10^{-4} (Fig. 2(b)). Moreover, by applying this method to a thermally annealed sample, we found that a high annealing temperature of 1000ºC is required in order to obtain uniform silicon nanolayers on which strain does not localize.

[1] H. Omi, *et al.*, Appl. Phys. Lett. **86** (2005) 263112.

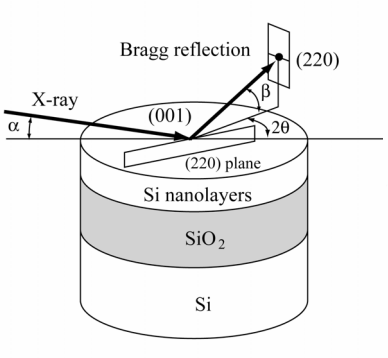


Fig. 1. Schematics of ultra-small-angle GIXD.

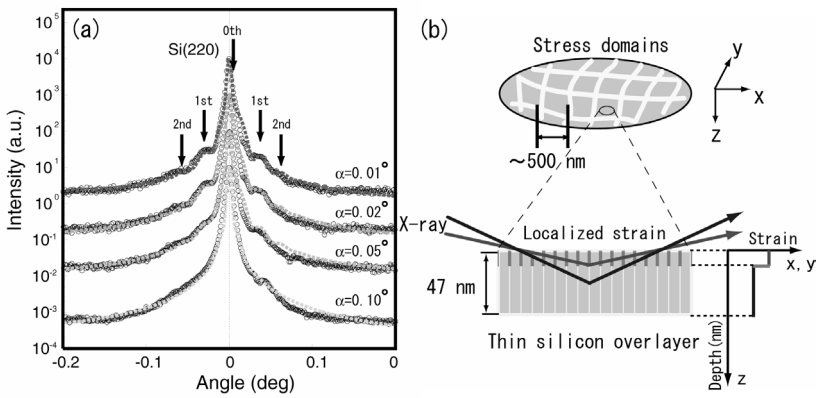


Fig. 2. (a) Si(220) Bragg diffraction, (b) Two layer strain model.

Electronic State of Molecular Devices at Room Temperature

Touichiro Goto and Yoshiaki Kashimura
Materials Science Laboratory

Molecular devices with a few molecules have attracted considerable attention as next generation electronic devices because of their high-density and low-power nature. The characteristics of molecular devices can be tuned by controlling molecules. However, there have only been a few reports about molecular devices operating at room temperature. In addition, the instability of the junctions between electrodes and molecules has prevented research on the characteristics of molecular devices.

In this study, we fabricated gold nanogap electrode devices with conjugated molecules. Conjugated molecules have a functional group at each end, which selectively chemisorbs to gold. First, we measured the electronic properties of molecular devices with terphenyldithiol (TPDT), which is 1.5 nm long. We observed a Coulomb diamond, i.e. the single-electron charging effect, at room temperature [Fig. 1]. A simulation based on single-electron circuits showed that the device characteristics can be explained on the basis of a multi-metallic-island system. We consider that gold islands between the electrodes work as single-electron islands, and TPDT bridging metallic islands and the electrodes work as tunnel junctions [1](In cooperation with Nanodevices Research Group).

Next, we synthesized rigid conjugated polymer poly(*p*-phenylene-ethynylene)s (PPEs) with thioacetyl end groups (TA-PPE). TA-PPE self assembled in the gold nanogap electrodes (18-nm gap) and we measured its electronic properties. The room temperature current-voltage (conductance-voltage) characteristics exhibited periodic, repeatable, and identical stepwise features [Fig. 2]. First-principle calculations based on the resonant tunneling effect suggest that the equidistant steps result from the opening of different conducting channels that correspond to the unoccupied molecular orbitals of TA-PPE [2].

It is intriguing that molecular devices show Coulomb diamond and quantized electronic structures at room temperature. As the next stage, we will study the characteristics of biomolecules in nanodevices.

[1] T. Goto et al., Jpn. J. Appl. Phys. **45** (2006) 4285.
[2] W. Hu et al., Phys. Rev. Lett. **96** (2006) 027801.

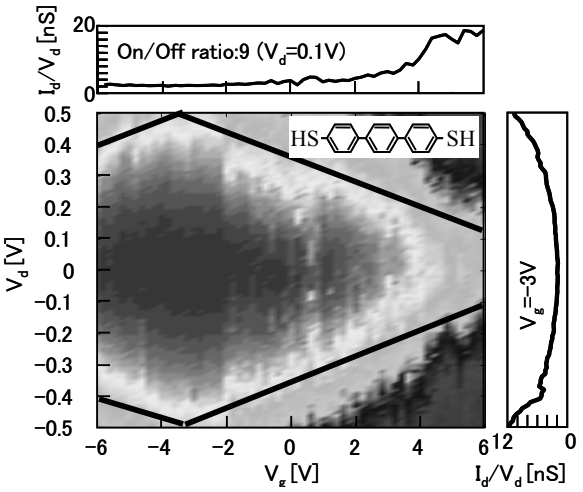


Fig. 1. Conductance coutour plot of TPDT at room temperature. The inset shows the TPDT structure.

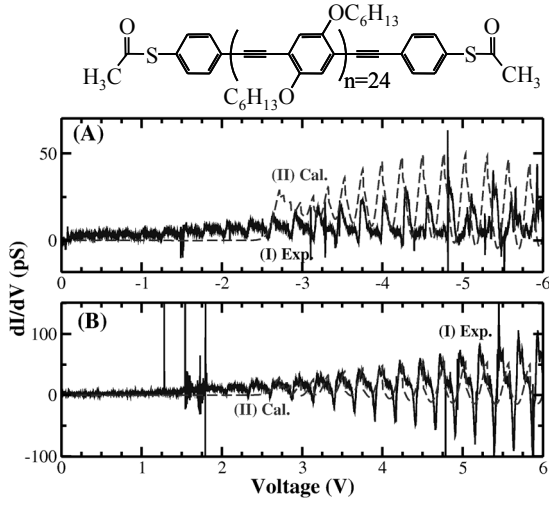


Fig. 2. TA-PPE structure and current-voltage characteristics at room temperature. The solid lines are experimental results and the broken lines are calculations.

Real Time H_2O_2 Imaging and Neuronal Cell Death

Nahoko Kasai, Chunxi Han, Akiyoshi Shimada, Tobias Nyberg and Keiichi Torimitsu
Materials Science Laboratory

Hydrogen peroxide (H_2O_2) has been recognized in association with the pathology of neurological diseases because it is a by-product of a degenerative reaction of reactive oxygen species, one of the major causes of oxidative stress in mammalian cells. Because it is relatively stable comparing to the other reactive oxygen species, it has been used as a target molecule for detecting oxidative stress.

Hippocampus has widely been examined and it is well understood that the epilepsy relates to the cell death in its specific regions. We have recently found that by bicuculline (Bic), GABAA receptor antagonist, also causes neuronal cell death in specific regions in hippocampus [1]. However little has been investigated on its details.

We have recently established a multichannel H_2O_2 monitoring system to monitor the real time H_2O_2 distribution in a tissue. In this study, we examined the cell death caused by Bic in terms of the oxidative stress [2].

We fabricated the sensor array, and we monitored the real time H_2O_2 distribution in a cultured rat hippocampal slice placed on the array. When we introduced bicuculline into the solution as a stimulant, in the presence of a catalase inhibitor, we could observe a distinct increase in the H_2O_2 concentration (B) and increase in calcium influx (C) at the same regions as neuronal cell death (D). This implies that the Bic causes cell death through oxidative stress.

This real time H_2O_2 distribution monitoring system will be a powerful tool with which to explore the neuronal cell death mechanism in biological systems and to manage the neuronal disorders.

[1] C. Han, N. Kasai, K. Torimitsu, NeuroReport **16** (2005) 333-336.
[2] N. Kasai, C. Han, K. Torimitsu, Sens. Act. B **107** (2005) 746-750.

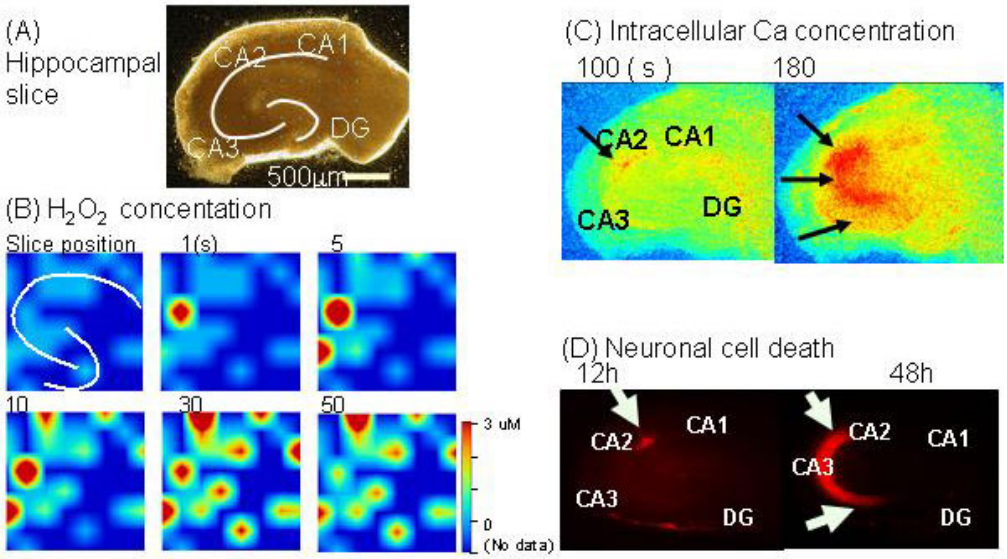


Fig. By Bic application to a hippocampal slice (A), H_2O_2 release (B) and increase in Ca influx (C) were observed at the same region of the cell dearh (D).

Static and Dynamic Structural Analysis of Biomolecules Using Atomic Force Microscopy

Koji Sumitomo[1], Mime Kobayashi[1], Hiroshi Nakashima[1], C. S. Ramanujan[2], Keiichi Torimitsu[1], and J. F. Ryan[2]
[1]Materials Science Laboratory, [2]University of Oxford

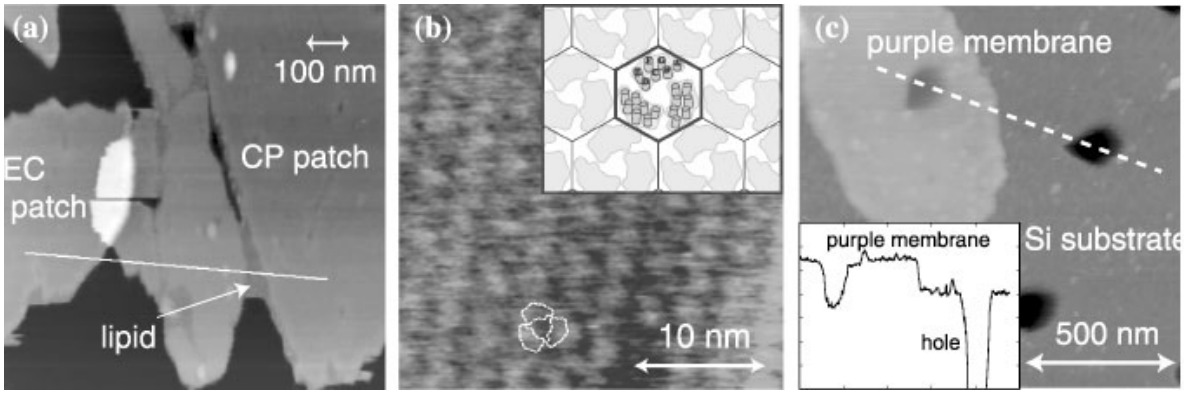
To make a novel bio-nanodevice, uniting nanotechnology with biotechnology, it is vital to investigate individual biomolecular structures and dynamics at molecular-scale in physiological conditions. Only then can we hope to understand how to control the functions of such a device. Atomic force microscopy (AFM) is one of the most powerful tools to observe the biomolecules in their native liquid environment. In this study, we successfully visualized the static crystalline structures of membrane proteins and the dynamic molecular motion of DNA by liquid-state AFM measurements.

Fig. 1(a) shows topographic AFM image of purple membrane patches on mica. We can distinguish either extracellular (EC) side or cytoplasmic (CP) side of purple membrane from their surface morphology such as the smoothness and from the mechanical characteristics like the stiffness. High-resolution AFM imaging clearly exhibits the 2D crystal of bacteriorhodopsin (bR) protein in the purple membrane, as shown in Fig.1 (b). Recently, we have succeeded in imaging the suspended membrane over artificially fabricated, nano-scale cells on a silicon substrate (Fig. 1(c)). In its native cell membrane, the bR proteins functions as a channel that opens by irradiation of light and pumps protons out of the cell through the membrane. This proton gating function, working on the nano-scale cell, has promising applications in optoelectronic nanodevices [1]. We are now exploring the detailed correlation between the conformational change and optical function of bR on the cell by AFM.

On the other hand, by using a high-speed AFM that is capable of catching video-rate images, we have succeeded in observing biotinylated DNA binding to/dissociating from a streptavidin protein [2]. High-speed imaging enables us to visualize the short DNA strands in motion. We successfully captured real-time images of a biotin of the DNA end binding to a streptavidin. The results indicate that high-speed scanning of AFM is potentially available for the observation of biomolecular dynamic events such as chemical reaction or response to external stimuli in liquid.

Based on the combination of the static and dynamic analysis by AFM with electrochemical approach, we are aiming to design and fabrication novel bio-nanodevices.

[1] K. Sumitomo et al., NTT Technical Review (in press).
[2] M. Kobayashi et al., Ultramicroscopy (in press).



(a) AFM image of purple membrane on mica.
(b) High-resolution image of 2D crystal of bR in purple membrane.
(c) Nano-scale cell on silicon substrate covered by purple membrane.

Fig. 1.

New Function of IP3 Receptor Binding Protein that Regulates pH

Ichiro Fujimoto[1], Kyoko Shirakabe[1], Hidetoshi Miyashita[1], Katsuhiko Mikoshiba[1,2], and Keiichi Torimitsu[1,3]
[1]Divisions of Neural Signal Information NTT-IMSUT and [2]Molecular Neurobiology, The Institute of Medical Science, University of Tokyo, [3]Materials Science Laboratory

The pH in the cell changes dynamically and the pH balance is regulated by carbon dioxide *in vivo*. It is converted into bicarbonate and transported through the transmembrane, and the cellular pH is adjusted. Bicarbonate is mainly secreted from gland cells of pancreas and works as an acid neutralizer in the stomach. Kidney cells control arterial blood pH. Several diseases or conditions such as, glaucoma, cataract, cornea disease, stunted growth, and mental retardation have been associated with the collapse of the pH balance.

Inositol 1,4,5-trisphosphate (IP_3) receptors (IP_3Rs) are IP_3-gated Ca^{2+} channels located on intracellular Ca^{2+} stores. We previously identified an IP_3R binding protein, termed IRBIT (IP_3R binding protein released with inositol 1,4,5-trisphosphate). Since IRBIT is released from IP_3R by physiological concentrations of IP_3, we hypothesized that IRBIT is a signaling molecule that is released from IP_3R and regulates downstream target molecules in response to the production of IP_3. We therefore attempted to identify the target molecules of IRBIT in this study and succeeded in identifying Na^+/HCO_3^- cotransporter 1, NBC1, as an IRBIT binding protein. Of the two major splicing variants of NBC1, pancreas-type NBC1 (pNBC1) and kidney-type NBC1 (kNBC1), IRBIT was found to specifically bind to pNBC1 and not to bind to kNBC1 at all. IRBIT binds to the N-terminal pNBC1-specific domain, and its binding is dependent on the phosphorylation of multiple serine residues of IRBIT.

Furthermore, an electrophysiological analysis in *Xenopus* oocytes revealed that pNBC1 requires co-expression of IRBIT to manifest substantial activity comparable to that of kNBC1, which displays substantial activity independently of IRBIT. These results strongly suggest that pNBC1 is the target molecule of IRBIT and that IRBIT plays an important role in pH regulation through pNBC1.

In addition, our findings raise the possibility that the regulation through IRBIT enables NBC1 variants to play different physiological roles.

[1] K. Shirakabe et al., Proc Natl Acad Sci USA **103** (2006) 9542-9547.

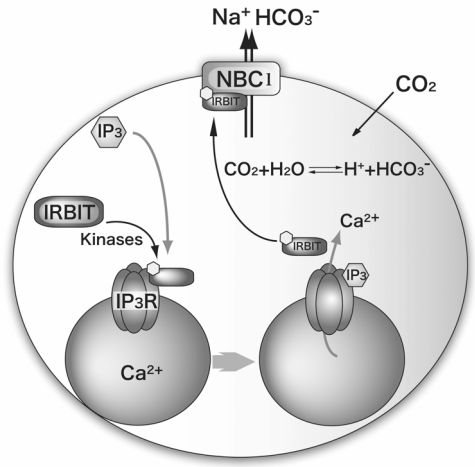


Fig. 1. New concept of signal information.

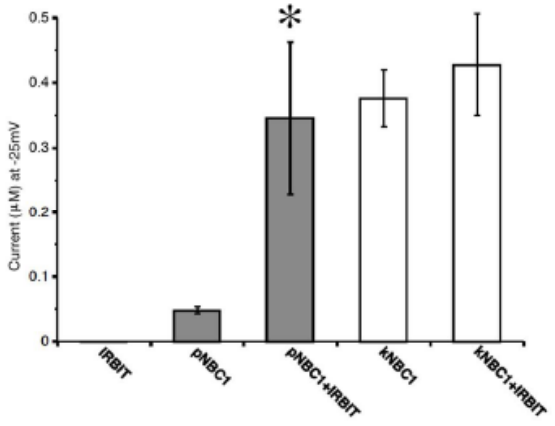


Fig. 2. Activation in *Xenopus oocytes*.

Single Molecule Photonics

Katsuhiro Ajito[1], Rakchanok Rungsawang[1], Yuko Ueno[2], and Isao Tomita[3]
[1]Materials Science Laboratory,
[2]NTT Microsystem Integration Laboratories, [3]NTT Photonics Laboratories

Terahertz (THz, 10^{12} Hz) spectroscopy is used in the field of biological molecule analysis. This is because information on weak inter- and intra-molecular interactions can be obtained as low frequency vibration modes in the THz range. We showed that THz time-domain spectroscopy (THz-TDS) using THz wave pulses has a wide spectral range and exhibits sufficient sensitivity to molecules to be used as a tool in analytical chemistry. Furthermore, we successfully characterized amino acids using the low frequency vibration modes that appear in THz spectra.

Figure 1 shows the pulse width dependence of the THz absorption spectra of tryptophan, an essential amino acid, pumped by ultra-short pulse lasers. Since a mode-locked Ti:sapphire laser is usually used to pump photoconductive dipole antennas for emitting and detecting THz electromagnetic pulses in a THz-TDS system, the upper limit of the spectral range is related to the pulse width of the pump laser. The use of ultrashort pulse lasers with pulse widths of 10 femtoseconds (fs) or less enables us to measure the spectral region expanded up to 5 THz and obtain more molecular information. Furthermore, we showed that THz spectroscopy is advantageous for determining molecular orientation and molecular interaction by employing the angle dependent THz-TDS spectroscopy of amino acid single crystals [1].

Moreover, when dried myoglobin was measured as a typical protein, there was an absorption increase in the THz range corresponding to the myoglobin concentration as shown in Fig. 2 [2]. We can expect to acquire information about the hydrogen bonds related to the high order structure of proteins by controlling the protein water content. Moreover, further development of a semiconductor THz-wave source employing difference frequency generation [3] will be applied to the analysis of single biological molecules and imaging measurement.

[1] R. Rungsawang, K. Ajito, Y. Ueno, I. Tomita, Extended Abstracts: International Workshop on Terahertz Technology, Nov. 16-18, 199-200, 2005
[2] R. Rungsawang, Y. Ueno, H. Takenouchi, I. Tomita, K. Ajito, Proceedings of IRMMW-THz2005, Sep 19-23, Williamsburg (2005) 211-212.
[3] I. Tomita, H. Suzuki, H. Ito, H. Takenouchi, K. Ajito, R. Rungsawang, and Y. Ueno, Appl. Phys. Lett. **88** (2006) 071118.

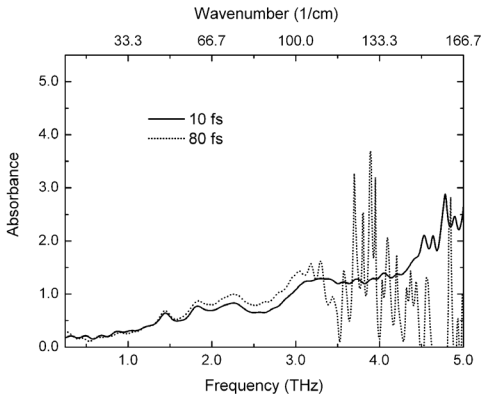


Fig. 1. Pulse-width dependence of THz absorption spectra of tryptophan.

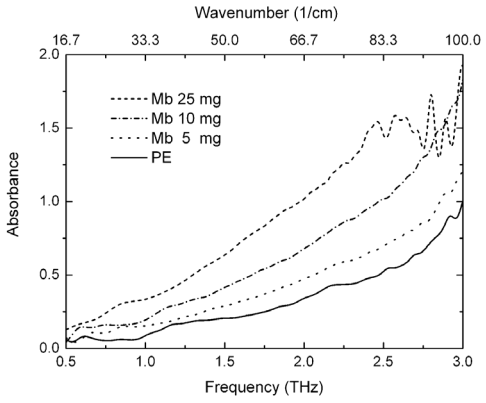


Fig. 2. Concentration dependence of THz spectra of myoglobin.

Theoretical Study on Material Dependence of Nano-Capacitance

Kazuyuki Uchida, Hiroyuki Kageshima and Hiroshi Inokawa
Physical Science Laboratory

It is expected that novel physics appear in nano-scale devices, while many studies are needed to clarify such physics. For example, it is not clear what happens on the capacitance characteristics, one of the fundamental characteristics of FETs (field effect transistors), when the device size is decreased in nano-scale. We developed a new method, the EFED (enforced Fermi-energy difference) method, with which we can calculate the capacitance characteristics from first principles if only we provide the atomic distribution and the element type for each atom. We then applied the method for nano-capacitors and discussed physics in the nano-capacitance dependence on the material.

Since only the most stable electronic states are calculated in usual first-principles methods, electrons distributed extensively in the system to screen the positive charges of the atomic nucleus. To calculate capacitance characteristics, the electrons should be localized. We divided the system's space into two, and applied external virtual work on the two spaces to redistribute electrons. We minimize the total free energy for the electrons with this additional work and obtained a Schrödinger equation for the electrons to polarize in the system. This is the principle of our EFED method.

We applied this method on a nano-capacitor and calculated the dependence of the differencial capacitance on the Fermi energy difference. The system consists of repeated-parallel-planes with 3-atomic-layers films of $SrTiO_3$(001). The inverse of the differencial capacitance is shown in the vertical axis of Fig. 2. Classical capacitance of parallel planes is written as $C = eS/d$, which means that it depends only on the distance of the electrodes, d, and the dielectric constant of the material between the electrodes, e. In nano-structure capacitors, however, the electronic states of each electrode prefer to be discretized because of space quantization and the Coulomb interaction between the electrons. Therefore, the capacitance strongly depends on the difference of the Fermi energies as well as on the distance of the electrodes and the material between the electrodes.

[1] K. Uchida, et al., e-J. Surf. Sci. & Nanotechnol. **3** (2005) 453.

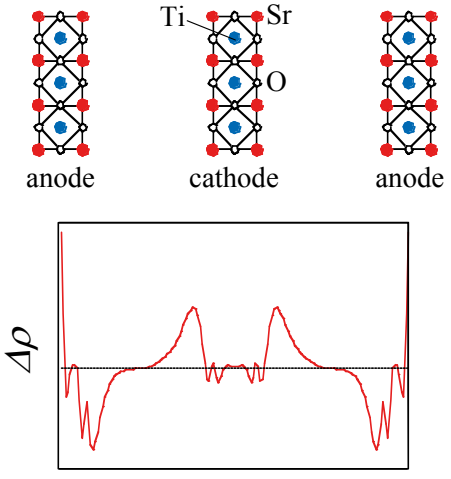


Fig.1 $SrTiO_3$ nano-capacitor.

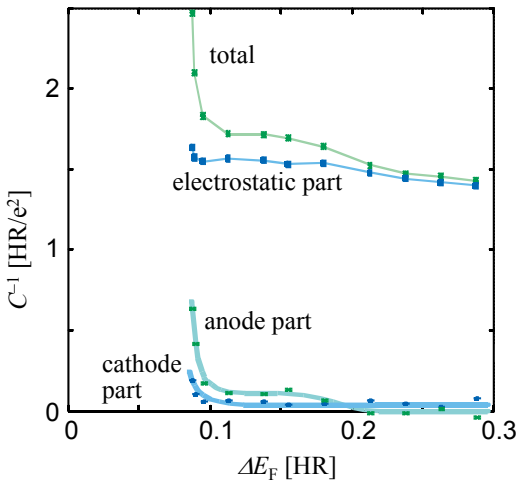


Fig.2 Capacitance characteristics.

Room-Temperature-Operating Digital-Analog Converter with Silicon Nanodevices

Katsuhiko Nishiguchi[1], Yukinori Ono[1], Akira Fujiwara[1],
Hiroshi Inokawa[1*] and Yasuo Takahashi[2]
[1]Physical Science Laboratory, [2]Hokkaido University

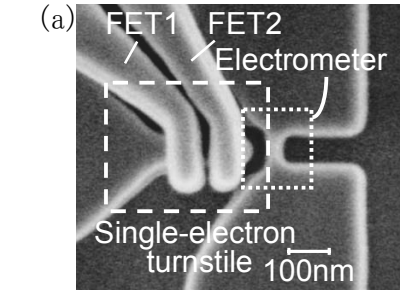
The single-electron turnstile, which transfers electrons one by one, is promising for ultra-low-power-consuming circuits that treat one electron as 1 bit of information. As a step towards to realize such a circuit, we have successfully demonstrated precise control of electron movement and detection of single electrons at room temperature using silicon nanodevices [1]. In this work, we demonstrated a new data information circuit using this device.

On a silicon-on-insulator wafer, we fabricated the silicon nanodevice, which can transfer and detect single electrons (Fig. 1) [2]. The single-electron turnstile is composed of two wire-FETs. A single-electron box (SEB) is electrically defined between the FETs. By turning on FET1 and FET2 alternately, the single electron is transferred to the memory node (MN) through the SEB (inset of Fig. 2). By repeating this transfer cycle, the electrons are transferred one by one. The single electrons transferred into the MN are detected by an electrometer capacitively coupled to the MN. The electrometer is carefully positioned close to the MN so that the sensitivity of the electrometer is high enough to detect single electrons in the MN.

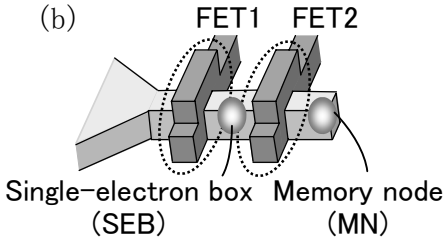
The size reduction of the SEB and optimization of the operating conditions provided single-electron transfer with high speed (<10 ns) and precise detection (0.005 e/Hz$^{0.5}$) at room temperature. When the number of electrons with one transfer cycle is adjusted to be 0, 1, 2, or 4, this device serves as a digital-analog converter, in which binary 3-bit signals are converted to the number of electrons in the MN and then to eight-level electrometer current. This is a demonstration of a new application using a single-electron-based architecture and means that the fabricated device is a basic component that can act as a bridge between conventional binary signals and single-electron-based ones.

[1] K. Nishiguchi, et al., International Electron Devices Meeting (IEDM) (2004) 199.
[2] K. Nishiguchi, et al., Appl. Phys. Lett. **88** (2006) 183101.
[3] A. Fujiwara, et al., Appl. Phys. Lett. **84** (2004) 1323.

*Present address: Shizuoka university



(a) SEM image.



(b) Schematic view of the single-electron turnstile.

Fig. 1.

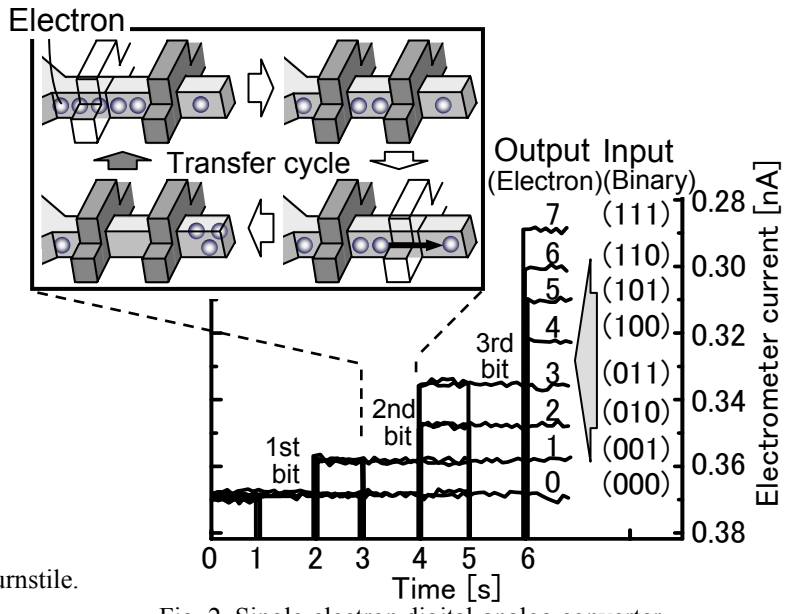


Fig. 2. Single-electron digital-analog converter.

Three-Dimensional Resist-Coating Technique Using Fine Mist and Nanopatterning on a Si Cube

Kenji Yamazaki and Hideo Namatsu*
Physical Science Laboratory

Creating three-dimensional (3D) structures with resolutions on the order of nanometers (i.e., 3D-nanofabrication) has been focused for various nanotechnology applications such as NEMS (nano-electromechanical systems). We have already achieved 3D nanofabrication/ nanopatterning of resist material using electron beam lithography (EBL) and obtained a resolution as high as 10 nm and reasonable speed [1]. We have recently succeeded in developing a new resist-coating technique that enable us to apply the 3D technique to various materials. In addition, we obtained good results on patterning and etching of a 3D-resist-coated Si cube.

Figure 1 shows the setup for our resist-coating technique. The ultrasonic nebulizer produces a mist of resist solution, and only fine particles in the mist are transported to the sample chamber using N_2 gas, resulting in quasi static ambient of very fine mist there. Coating PMMA (polymethylmethacrylate) resist on a Si cube of 1 mm was investigated. We found that the solvent of the resist solution, the temperature of the sample, and the flow rate of the transportation gas are important factors for uniformly coating resist with small surface roughness on each face. For example, we found that methyl isobutyl ketone, which has lower solubility for PMMA and thus provides smaller surface/interface energy, is a good solvent, and that careful adjustment of the temperature to around the dew point resulting in a thin film of resist solution on the substrate. Errors of less than 50-60% in resist film thickness among faces and within a face were obtained after optimizing the conditions [2]. Figure 2 (left) shows the patterns delineated by EBL on different faces of a Si cube. It is clear that similar patterns were fabricated on each face. Moreover, the patterns were transferred to SiO_2 layer by dry etching, and the resulting micrograph [Fig. 2 (right)] shows a resolution 50 nm or less.

This resist-coating technique enables us to coat resist on various 3D substrates, and thus makes possible 3D nanofabrication with a high degree of freedom, combined with 3D EBL and etching. Therefore, it promises to become a key technique for 3D nanotechnology.

[1] K. Yamazaki et al., Jpn. J. Appl. Phys. 43 (2004) L1111-L1113.
[2] K. Yamazaki and H. Namatsu, Tech. Digest 19th IEEE Conf. MEMS (2006) 254-257.
[3] K. Yamazaki and H. Namatsu, Jpn. J. Appl. Phys. 45 (2006) L403-L405.

*Present address: NTT-AT

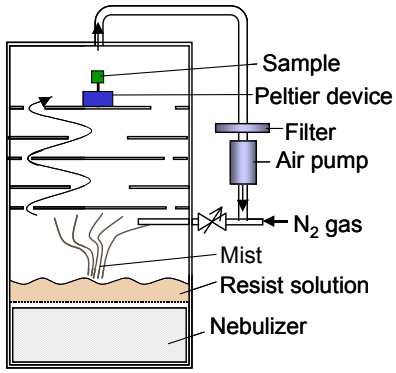


Fig. 1. Setup.

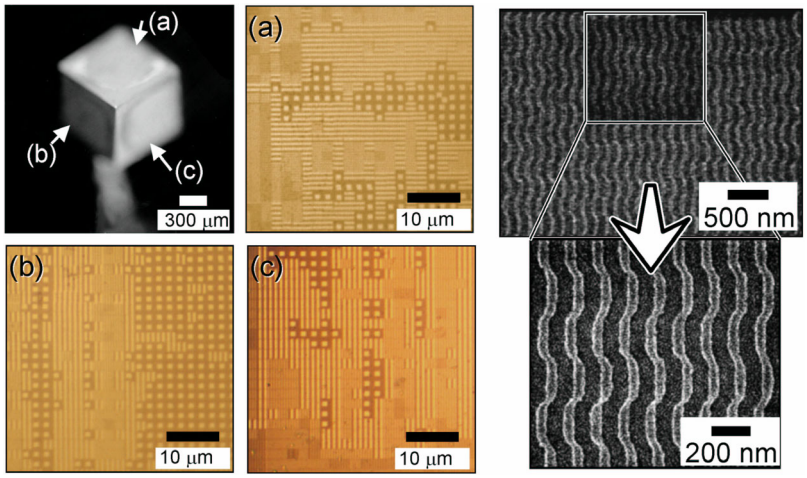


Fig. 2. Patterns formed on a cube (left) and fine lines transferred to SiO_2 film (right).

Force and Displacement Sensing Using the Superconducting Proximity Effect

Hajime Okamoto, Tatsushi Akazaki and Hiroshi Yamaguchi
Physical Science Laboratory

Techniques for detecting small forces and displacements using semiconductor cantilevers are being applied to various sensing tools, such as acceleration sensors, gas detectors, and atomic force microscopes. The detection is based on either optical or electrical methods. The latter needs no external detectors like laser optics, which makes it very advantageous for miniaturization and integration. A notable self-sensor based on a purely electric method is the piezoresistive cantilever, which detects its deflection as a change in the electrical resistance. We have reported that piezoresistive cantilevers using semiconductor low-dimensional structures enable highly sensitive detection of force and displacement due to the enhancement of piezoresistance caused by the quantum mechanical effect [1]. Recently, we fabricated a new type of piezoresistive cantilever that integrates a superconductor-semiconductor-superconductor junction [2]. Here, we describe mechanical sensing using the superconducting proximity effect in this junction.

Figure 1a shows a scanning electron microscope image of the fabricated cantilever. The cantilever is 200-μm long and 60-μm wide and contains a junction formed by the superconductor (Nb) and semiconductor (InAs) (Figs. 1b and 1c). At low temperature, a supercurrent flows between the Nb electrodes via the InAs layer, which is the superconducting proximity effect. We found that the maximum supercurrent (the superconducting critical current) is modulated by the deflection of the cantilever. This indicates that, when the bias current is set to the critical current value, the deflection of the cantilever induces a transition between the superconducting state and the resistive state, providing a large resistance change, i.e., large piezoresistance. Low temperature measurements using a dilution refrigerator revealed that the piezoresistance around the critical current (~327 mA) is larger than that in the resistive state by more than a factor of ten (Fig. 2). This suggests that small forces and displacements can be detected by using the transition between the superconducting state and resistive state.

[1] H. Yamaguchi, et al., Phys. Rev. Lett., **93** (2004) 036603.
[2] H. Okamoto, et al., Physica E, **32** (2006) 512.

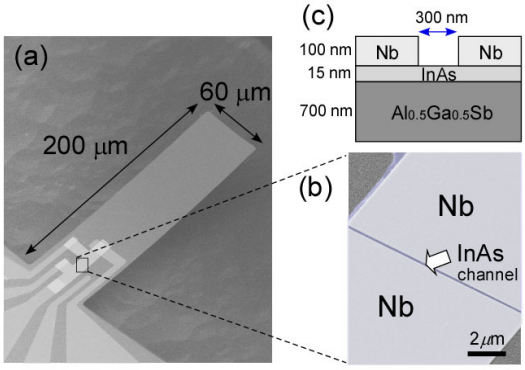


Fig. 1. (a) SEM image of the fabricated cantilever and (b) a magnified view of the Nb-InAs-Nb junction. (c) Schematic of the cross section of the junction.

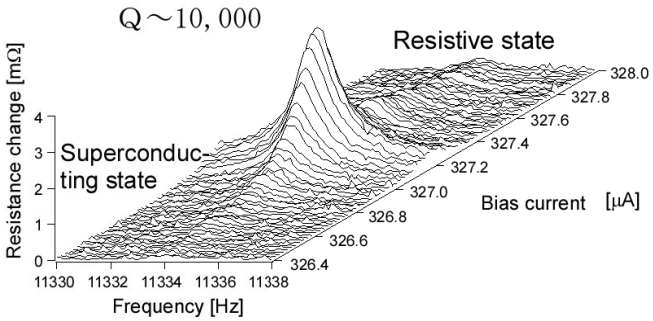


Fig. 2. Dependence of the resonance characteris-tics (resistance change) on the bias current at 30 mK. The quality factor (Q) is about 10,000.

Selective Spin Relaxation in a Quantum Dot

Satoshi Sasaki, Toshimasa Fujisawa, Toshiaki Hayashi and Yoshiro Hirayama
Physical Science Laboratory

Coulomb interaction between electrons produces spin singlet and triplet states in a semiconductor quantum dot hosting an even number of electrons. We have measured the spin relaxation time from a triplet excited state to a singlet ground state by applying fast pulse signals to the gate electrode (electrical pump-and-probe), which reveals a selection rule for the spin-orbit interaction.

Figure 1(a) shows the spin relaxation time, τ_s, as a function of the singlet (S)- triplet (T) energy difference, Δ_{ST}, when the spin relaxation occurs via spin-orbit interaction followed by phonon emission. For Δ_{ST} = 300 μeV, the number of tunneling electrons, n_t, decays exponentially as a function of the wait time, t_h, after an electron is injected to the triplet state, as shown in the upper panel of Fig.1(b). The spin relaxation time is determined to be τ_s =160 μs for this case. When Δ_{ST} is changed to 400 μeV by adjusting magnetic field, the triplet state crosses another singlet state (S') as schematically shown in the inset to Fig.1(a). Then, the initial relaxation time drops to 60 μs and the decay characteristics is given by a double exponential function as shown in the lower panel of Fig.1(b). This double exponential behavior reflects the selection rule for the spin-orbit interaction which allows transition only from S_Z (z component of the spin) = ±1 states out of the three triplet sublevels. Then, the forbidden S_Z = 0 triplet state involving opposite spins in two different orbitals can be extracted by waiting long enough time, t_h. This scheme could be utilized to obtain spin entanglement state by separating the two electrons composing the S_Z = 0 state.

[1] S. Sasaki et al., Phys. Rev. Lett. **95** (2005) 056803.

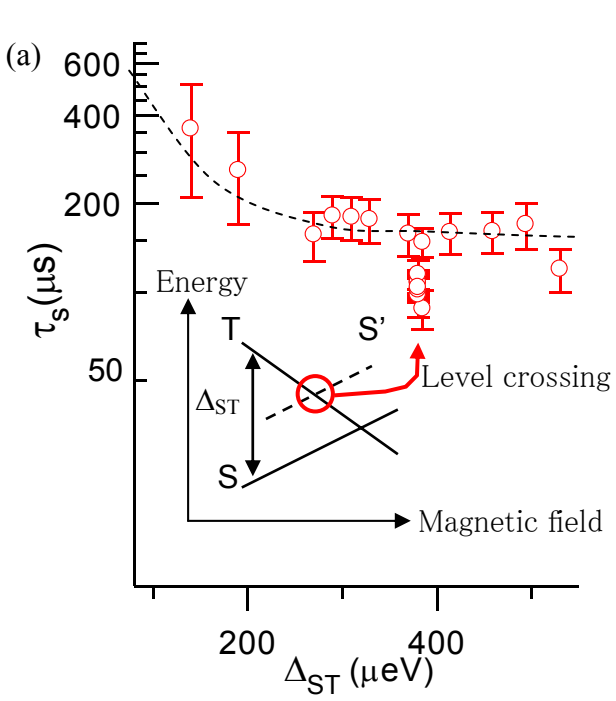
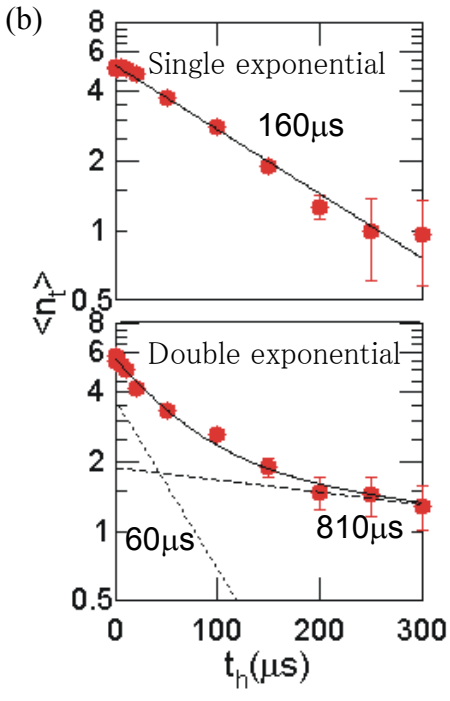


Fig. 1. (a) Energy dependence of the spin relaxation time.



(b) Double exponential decay characteristics at T-S' crossing point compared with the normal single exponential decay.

Two-Dimensional Electron Spin System Investigated by Nuclear Spin Measurements

Norio Kumada[1], Katsushi Hashimoto[2*], Koji Muraki[1] and Yoshiro Hirayama[1]
[1]Physical Science Laboratory, [2]SORST-JST

Nuclear magnetic resonance (NMR) is a powerful technique to detect dynamic and static properties of electron spins, and is commonly used not only in physics, but also in chemistry, biology and medicine. For two-dimensional electron systems (2DESs) realized in semiconductor heterostructures, however, a small number of nuclei in contact with the 2DES and the overwhelming background due to the thick substrate have restricted those experiments to multiple layer samples with fixed electron densities. To carry out nuclear spin measurements in a single density-tunable 2DES, we use a specific electronic state in a quantum Hall (QH) system, which allows for the current-induced nuclear spin polarization and, at the same time, facilitates its resistive detection. With this new experimental technique, we can investigate various electronic states. Followings are recent results.

In a bilayer system consisting of two closely separated 2DESs, we investigate ν_{tot}=1 QH state, which can be viewed as a superfluid of interlayer excitons. Nuclear spin-lattice relaxation rate, which probes electron spin fluctuations, changes around the bilayer ν_{tot}=1 QH state [Fig. 1(a)]. This result demonstrates that, as opposed to common assumption, the electron spin degree of freedom is not completely frozen in the QH state [1]. Furthermore, we show that the current-induced nuclear spin polarization in semiconductor heterostructures is strongly modified by their potential inversion asymmetry (Fig. 2). This finding strongly suggests that even a very weak spin-orbit interaction can play a dominant role in determining the electron-nuclear spin coupling [2].

The experimental technique for the high-sensitive nuclear spin measurement established in this work, and the new findings obtained by using the technique are important for future low-dimensional electric devices.

[1] N. Kumada et al., Phys. Rev. Lett. **94** (2005) 096802.
[2] K. Hashimoto et al., Phys. Rev. Lett. **94** (2005) 146601.

*Present address: Hamburg University

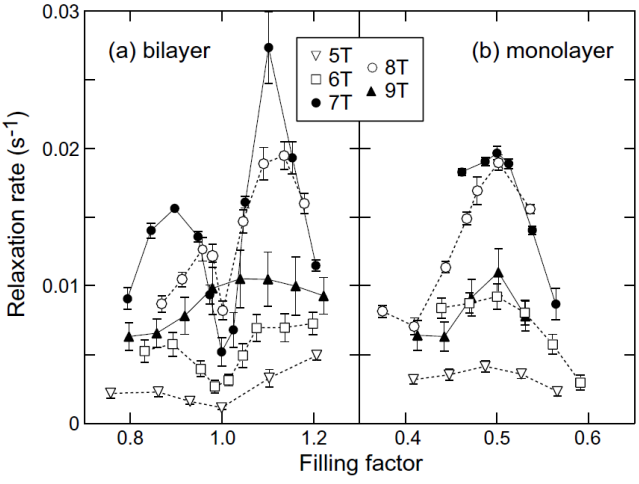


Fig. 1. Nuclear spin relaxation rate around (a) bilayer ν_{tot}=1 and (b) single-layer ν=1/2 systems.

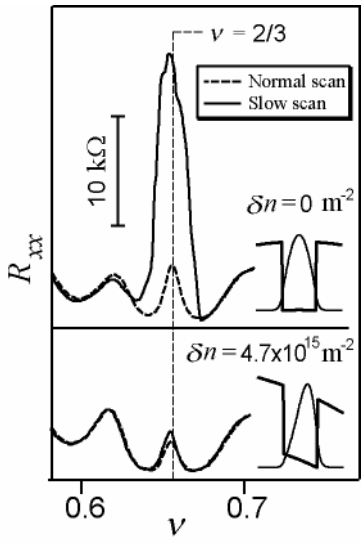


Fig. 2. Effects of potential asymmetry on the current-induced nuclear spin polarization.

Controlled Quantum Coherences of Nuclear Spins in a Nanoscale Device

Go Yusa*, Koji Muraki, Kei Takashina, Katsushi Hashimoto† and Yoshiro Hirayama
Physical Science Laboratory

The analytical technique of nuclear magnetic resonance (NMR) is based on coherent quantum mechanical superposition of nuclear spin states. Recently, NMR has received considerable renewed interest in the context of quantum computation and information processing, which require controlled coherent qubit operations. However, standard NMR is not suitable for the implementation of realistic scalable devices, which would require all-electrical control and the means to detect microscopic quantities of coherent nuclear spins. Here we present a self-contained NMR semiconductor device that can control nuclear spins in a nanometer-scale region.

We has verified that strong interactions between electron and nuclear spins are produced under certain conditions where two-dimensional electrons enclosed in GaAs quantum well has a degenerate state between spin polarized and unpolarized n=2/3 states. This phenomenon has been successfully applied to precision control of nuclear spins in a nanoscale semiconductor device. The compactly integrated structure has opened the way for nuclear spin control with unprecedented precision. The quantum-mechanical superposition between four separated states peculiar to the nuclei of gallium (Ga) and arsenic (As) can be fully controlled in our device.

The successful control of nuclear spin with a nanoscale device, which is notably an all-electrical control, is a significant step forward towards scalable nuclear spin quantum computers. Our approach also enables the direct detection of (otherwise invisible) multiple quantum coherences between levels separated by more than one quantum of spin angular momentum. This microscopic high sensitivity NMR technique is thus especially suitable for probing materials whose nuclei contain multiple spin levels, and may attractive as a nanoscale NMR technology using an extremely small volume of material.

[1] G. Yusa, K. Muraki, K. Takashina, K. Hashimoto, and Y. Hirayama, Nature **434** (2005) 1001.

Present address: *Tohoku University, †Hamburg University

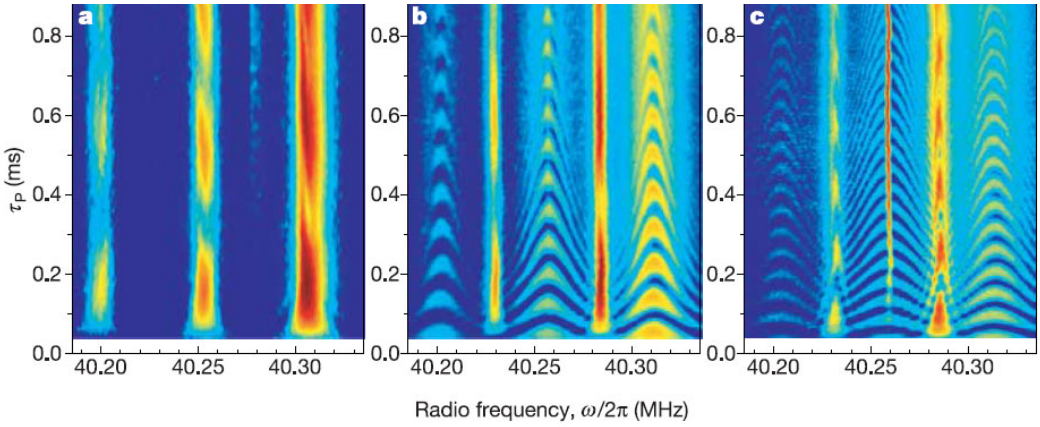


Fig. 1. Color plot of resistance change DR as a function of pulse duration t_P for ^{75}As at three different intensities B_1, which is proportional to the square root of the output power $P_{r.f.}$ from an r.f. generator. The measurement was performed at B_0=5.5T at 0.1K. DR, which is proportional to the magnetization of nuclear spins, is color coded on a logarithmic scale for clarity. a: $P_{r.f.}$= 0 dBm, b: 13 dBm and c: 20 dBm.

Vacuum Rabi Oscillations in a Macroscopic Superconducting Qubit LC Oscillator System

Jan Johansson[1], Shiro Saito[1], Hayato Nakano[1], Masahito Ueda[2] and Kouichi Semba[1]
[1]Physical Science Laboratory, [2]Tokyo Institute of Technology/NTT Research Professor

Superconducting circuit containing Josephson junctions is one of the promising candidates as a quantum bit (qubit) which is an essential ingredient for quantum computation [1]. A three-junction flux qubit [2] is one of such candidates. On the basis of fundamental qubit operations [3,4], the cavity QED like experiments are possible on a superconductor chip by replacing an atom with a flux qubit, and a high-Q cavity with a superconducting LC-circuit (Fig.1). By measuring qubit state just after the resonant interaction with the LC harmonic oscillator, we have succeeded in time domain experiment of vacuum Rabi oscillations, exchange of a single energy quantum (photon), in a superconducting flux qubit LC harmonic oscillator coupled system [5]. The observed vacuum Rabi frequency 140 MHz is roughly 3×10^3 (1×10^7) times larger than that of Rydberg (ordinary) atom coupled to a single photon in a high-Q cavity [6]. This is a direct evidence that a strong coupling condition can be rather easily established in the case of macroscopic superconducting quantum circuit. It is explained by the reasons that the circuit is huge compared with the atomic scale and also the super-current of μA order flows in the qubit. We have also obtained evidence of level quantization of the superconducting LC circuit by observing the change in the quantum oscillation frequency when the LC circuit was not initially in the vacuum state (Fig.2). We are also considering this quantum LC oscillator as a quantum information bus by sharing it with many flux qubits, then spatially separated qubits can be controlled by a set of microwave pulses just like the method used in the quantum optics.

[1] F. Wilhelm and K. Semba, in "Physical Realizations of Quantum Computing: Are the Divincenzo Criteria Fulfilled in 2004?", (World Scientific Publishing Company; April, 2006)
[2] J. E. Mooij et al., Science **285** (1999) 1036.
[3] T. Kutsuzawa et al., Appl. Phys. Lett. **87** (2005) 073501.
[4] S. Saito et al., Phys. Rev. Lett. **96** (2006) 107001.
[5] J. Johansson et al., Phys. Rev. Lett. **93** (2006) 127006.
[6] J. M. Raimond, M. Brune, and S. Haroche, Rev. Mod. Phys. **73**(2001) 565.

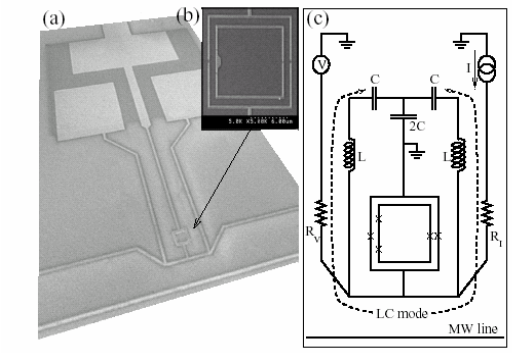


Fig. 1. (a) Scanning Electron Micrograph of the sample (qubit, SQUID, and an on-chip LC harmonic oscillator). (b) close-up view of a qubit and a SQUID detector (c) Equivalent circuit of the sample.

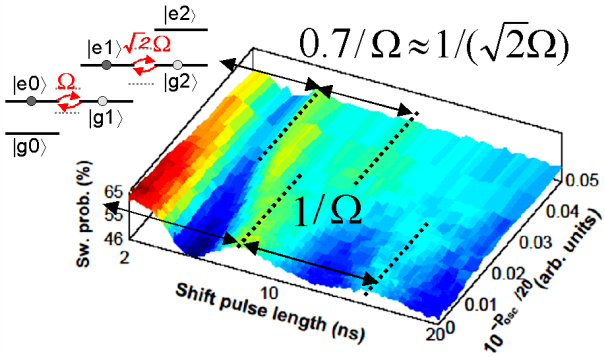


Fig. 2. Rabi oscillations as a function of the duration of the flux bias shift pulse and the amplitude of an LC-oscillator weak resonant pulse. The lowest two quantized Rabi periods are observed.

Parametric Control of a Superconducting Flux Qubit

Shiro Saito[1], Masahito Ueda[2], Hirotaka Tanaka[1] and Kouichi Semba[1]
[1]Physical Science Laboratory, [2]Tokyo Institute of Technology/NTT Research Professor

Quantum state engineering has become one of the most important areas in quantum physics. In particular, the coherent control of quantum two-state systems, which are applicable to quantum bits (qubits), has attracted increasing interest in the context of quantum computing and quantum information processing. Of the recently realized solid-state qubits, the superconducting flux qubit has the advantages of scalability and a long coherence time. Multiphoton transitions have been demonstrated in the flux qubit [1]. In this study, we achieved the parametric control of a flux qubit by using two-frequency microwave pulses [2]. We observed Rabi oscillations stemming from parametric transitions between the qubit states when the sum of the two microwave frequencies or the difference between them matched the qubit Larmor frequency f_{qb}.

Our device is fabricated by lithographic techniques that define the structure of an inner aluminum loop forming a qubit and an outer enclosing dc-SQUID loop for the readout (see Fig. 1). Two currents circulationg in opposite directions in the qubit loop correspond to the ground state $|g\rangle$ and an excited state $|e\rangle$ of the qubit. First a qubit operation is performed by applying a two-frequency (f_{MW1} = 11.1 GHz, f_{MW2} = 18.5 GHz) microwave pulse of length t_p to the qubit (f_{qb} = 7.4 GHz). After the operation, we immediately apply a dc readout pulse to the dc-SQUID and measure whether or not the SQUID switches to a voltage state. By repeating the measurement 8000 times, we obtain the SQUID switching probability P_{sw}, which is directly related to the probability with which we find the qubit in $|e\rangle$. Figure 2(a) shows the microwave amplitude of the MW1 V_{MW1} dependence of Rabi oscillations when the microwave amplitude of the MW2 V_{MW2} is fixed at 50.1 mV. Figure 2(b) shows Rabi frequencies $W_{Rabi}/2p$ at various V_{MW1} and V_{MW2} values, which are well reproduced by Rabi frequencies derived by using a semiclassical model.

By utilizing the parametric processes, we can control a qubit with much higher frequencies than the qubit Larmor frequency. This implies that we can filter out the noise around and lower than the qubit frequency from the microwave line by using a high-pass filter. This will greatly improve qubit coherence.

[1] S. Saito, et al., Phys. Rev. Lett. **93** (2004) 037001.
[2] S. Saito, et al., Phys. Rev. Lett. **96** (2006) 107001.

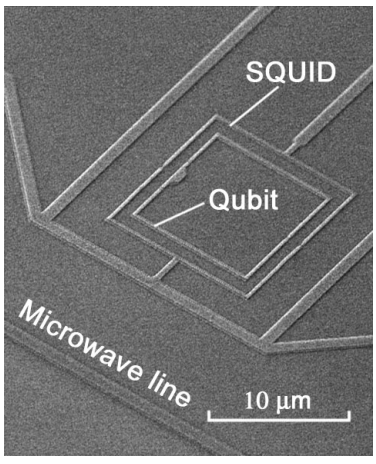


Fig. 1. Electron microscope image of superconducting flux qubit.

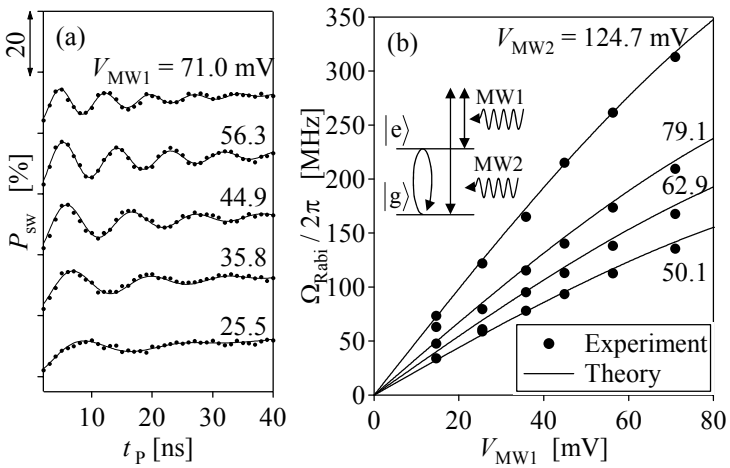


Fig. 2. (a) Rabi oscillations observed in the flux qubit. (b) Microwave amplitude dependence of Rabi frequency. Inset is schematic of parametric control.

Trapping Atoms with a Superconducting Atom Chip

Tetsuya Mukai[1], Alexander Kasper[1] and Fujio Shimizu[2]
[1]Physical Science Laboratory
[2]University of Electro-Communications/NTT Research Professor

Neutral atoms have specific features suitable for realizing quantum computers/gates, e.g. quantized internal states, indistinguishability, controllability of the atom-atom and atom-photon interactions, and very small influence from the environment. A promising approach is using a pair of internal states of the atom as a unit of quantum computation (qubit). To realize this "internal-state-qubit", making confinement of single atoms in 2- or 3-dimensional arrays will be a key technique. In the world of atom optics experiments, making single atom traps is a challenging job because of the influence from a surface and current noise.

We are trying to achieve the atomic arrays with two different approaches: using lasers to form an optical lattice (3D) and employing magnetic micro traps formed by wires, i.e. atom chip (2D). With the optical lattice approach, we have two original schemes: (i) double optical lattices [1], which is using two different atomic species trapped in independent optical lattices with the same lattice constant, and (ii) an all optically controlled "lattice-in-cavity", which uses a cavity mode as a bus for all qubits. With these methods we will be able to achieve a universal set of gates with more than 1,000 qubits.

The atom chip approach is using our fine processing technique for making a 2-dimensional array of atoms. An advantage of the atom chip, which is not possible with optical lattices, is that we can control and address specific lattice sites, which is essential for future applications. Our approach in addition allows us to overcome for example current noise problem by using superconducting materials. We have constructed an apparatus combining two functions: a flux cryostat to cool a superconducting atom chip (Fig.1) and a laser/magnetic trap system to pre cool and trap atoms. With this apparatus we have for the first time demonstrated the trapping of atoms with magnetic potential generated by a superconducting current. Figure 2 represents the absorption images of atoms (a) before and (b) after trapping with a magnetic potential (the brighter represents the higher atomic density). With this superconducting atom chip technique we are going to make single atom traps in the vicinity of a surface as a resource for quantum computations.

[1] F. Shimizu, Jpn. J. Appl. Phys. **43** (2004) 8376.

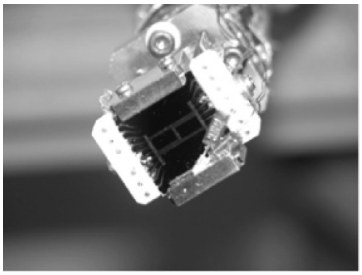


Fig.1. MgB_2 atom chip.

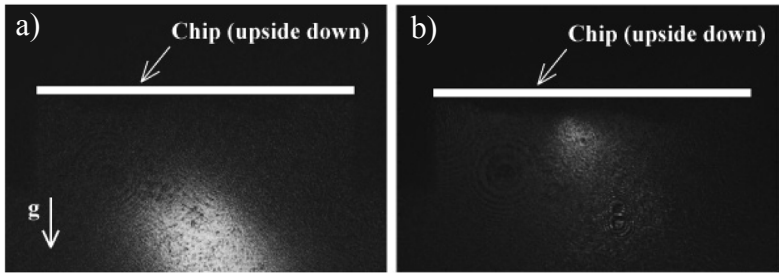


Fig.2. Images (a) before and (b) after loading atoms on chip.

Measurements of Magnetic-Domain-Wall Velocity Using Local Hall Effect

Yoshiaki Sekine[1] and Junsaku Nitta[2,3]
Device Physics Laboratory[1], Tohoku University[2], CREST JST[3]

The velocity of a magnetic domain wall (DW) in a NiFe wire has been obtained measuring the time dependence of the stray fields from both ends of the wire. Logic devices utilizing the motion of a DW were recently demonstrated and intensive investigations on the dynamics of a DW have been carried out. In this study, we focus on the local Hall effect (LHE) to deduce the velocity of a DW because the LHE method has the advantages of large signal, independency of the shapes of magnet, and flexibility of changing temperature. Using this LHE method, the DW velocity of 250 m/s at 77 K has been obtained and these results are useful for DW devices.

In the magnetization reversal process of a NiFe wire, a DW nucleates at one end of the wire and displaces to the other end. Then, the DW and annihilates at the other end. The nucleation and annihilation of the DW result in the reverse of the direction of the stray field. Therefore, time in which the DW passes through the wire corresponds to a period between times when the directions of the stray fields from both ends of the wire change. Figures 1(a) and (b) shows a schematic cross-view and an optical microscopy image of the sample, respectively. The stray fields from both ends of the wires with different length were detected by the local Hall probes. We used an InGaAs two-dimensional electron gas and an external field was applied parallel both to the wire and the 2DEG. Figure 2(a) shows the time dependence of the Hall voltages, V_H1 and $-V_H2$, at 77 K. The rapid increase of V_H corresponds to the reverse of the stray field direction caused by the nucleation and annihilation of the DW. With increasing the length of the wire, the period between the nucleation and annihilation times increases. The period (Δt) as a function of the wire length (L) is plotted in Fig. 2(b). The dotted line represents the velocity of 250 m/s. From this relation between Δt and L, the DW velocity of 250 m/s is deduced. These results show the LHE method is attractive for investigating the DW dynamics that is a key to DW devices.

[1] Y. Sekine and J. Nitta, in *Narrow Gap Semiconductors*, Inst. Phys. Conf. Ser. No 187, edited by J. Kono and J. Léotin (Taylor & Francis, New York, 2006), p. 461.

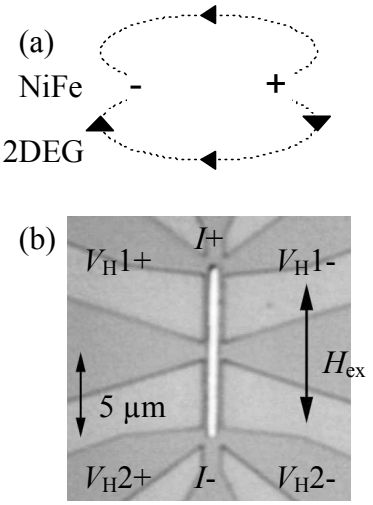


Fig. 1(a) a schematic cross-view (b) an optical microscopy image of the sample. The stray field is detected with the InGaAs local Hall probe.

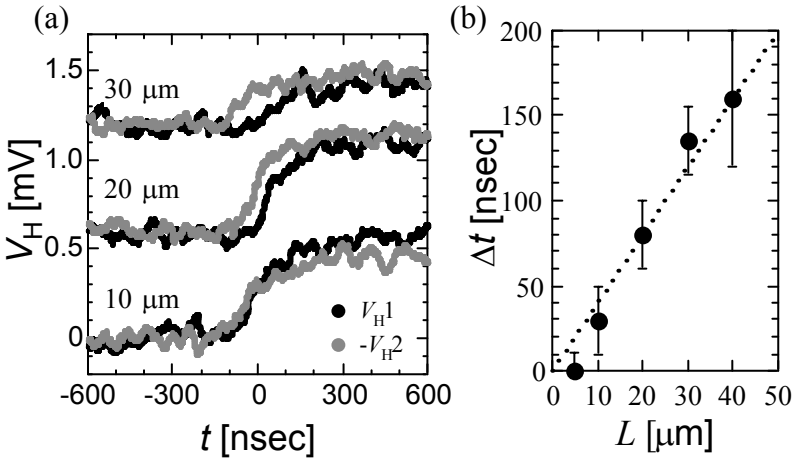


Fig. 2(a) the time dependence of V_H. Rapid increases of V_H correspond to the nucleation and annihilation of the DW. With increasing L, Δt increases. (b) Δt as a function of L. The dotted line represents the velocity of 250 m/s. From these results, the velocity of 250 m/s on NiFe is obtained.

Gate control of Electron Density and Electric Field in GaAs Quantum Well

Masumi Yamaguchi
Physical Science Laboratory

Producing an artificial crystal based on gate-confined semiconductor quantum dots requires the ability to control the electron density and electric field. The electron density of the two-dimensional electron system (2DES) formed at a semiconductor hetero-interface can be changed by applying a front- or back-gate bias [1]. The change in the electron density is accompanied by a change of the effective electric field since 2DES has a finite width along the confinement direction. Although the transport properties are usually sensitive only to the electron density, optical properties, such as the photoluminescence (PL), are sensitive to the electric field as well as to the electron density. It is expected that the electron density and electric fields of a semiconductor quantum well (QW) can be controlled independently by applying front- and back-gate biases.

In this research, PL from an acceptor-delta-doped GaAs QW was measured while the gate electric field was changed by applying front- and back-gate biases [2]. The sample structure is shown in Fig. 1. The open circles in the left panel of Fig. 1 denote the radiation energy of the PL peak in changing the front-gate bias. The panels A, B, and C on the right show the simulated conduction band profiles of the QW and the electron density. The front-gate bias dependence of the radiation energy has three regimes, which reflect the situation of A, B, and C. A: The conduction electrons accumulate at both sides of the QW when positive high biases are applied to both the front and back gates. In this case, the electric field in the middle part of the QW is screened by the accumulated electrons and thus the PL peak energy weakly depends on the gate biases. B: When the front-gate bias becomes small, the front-side electrons disappear and electrons exist only at the rear side. In this case, the effective electric field changes with changing the front-gate bias and the PL energy shifts largely. C: When the front gate bias is decreased further, the QW becomes empty. The simulated energy shift (solid curve in the left panel) is in good agreement with the experimental results. In addition, we found that the electric field can be changed by keeping the electron density constant in the B regime.

[1] M. Yamaguchi, et al., Suf. Sci. **583** (2005) 94.
[2] M. Yamaguchi, et al., J. Appl. Phys. (to be published).

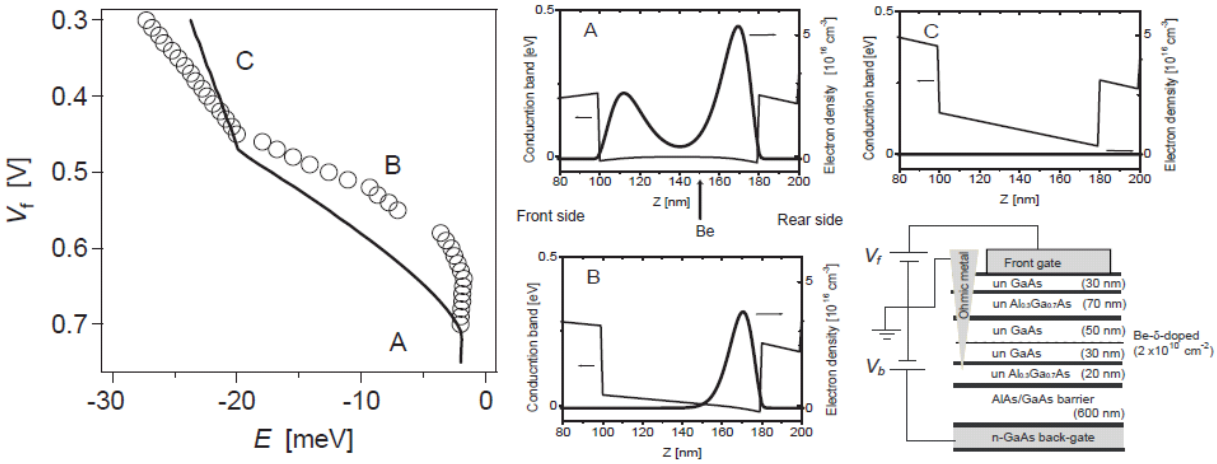


Fig. 1. PL energy shift and simulated results.

Fast and Long-Distance Quantum Key Distribution Using Up-Conversion Detectors

Hiroki Takesue[1], Toshimori Honjo[1] and Kyo Inoue[2]
[1]Optical Science Laboratory, [2]Osaka University/NTT Research Professor

The differential phase shift quantum key distribution (DPS-QKD) protocol has been attracting attention in recent years because of its robustness against strong attacks including a photon number splitting attack [1]. Here we report a fast and long-distance DPS-QKD experiment using single photon counters based on frequency up-conversion in periodically poled lithium niobate (PPLN) waveguides [2].

Fig. 1 (a) shows the experimental setup. A continuous lightwave from a laser is modulated into pulses with a width of 100 ps and a 1-GHz repetition frequency using an intensity modulator. Each pulse is randomly phase-modulated by {0,π} with a phase modulator, and attenuated by an optical attenuator to give an average photon number per pulse of around 0.2. The pulse train is then transmitted over fiber spools and input into a 1-bit delayed Mach-Zehnder interferometer based on planar lightwave circuit technology, whose two output ports are connected to up-conversion detectors. The configuration of the up-conversion detector is shown in Fig. 1 (b). A 1.5-μm photon is combined with a 1.3-μm pump lightwave and then input into a PPLN waveguide, where the 1.5-μm photon is converted into a 0.7-μm photon. The converted photon are transmitted through an optical filter system to suppress noise photons, and received by a silicon avalanche photodiode (Si-APD). Since an Si-APD can be operated in a non-gated mode, we can significantly increase the key generation rate by employing the up-conversion detectors in a fast clock QKD system.

We first set the quantum efficiency (QE) and the combined dark count rate (DC) at 9% and 26 kHz, respectively. The obtained secure key rates as function of fiber length are shown by squares in Fig. 2. We have generated secure keys at a rate of 455 kbit/s over 20 km of fiber, and also achieved 1-Mbit/s sifted key rate over 30 km of fiber. We then reduced the QE and DC to 2% and 2.7 kHz, respectively, to improve signal to noise ratio. As a result, we have successfully generated secure keys at a rate of 209 bit/s over 105 km fiber (the circle). The triangles show the secure key rate of a BB84 QKD system reported in [3]. Thus, we have significantly increased both secure key rate and distribution distance.

This result is an important step toward realization of long-distance QKD systems.

[1] K. Inoue et al., Phys. Rev. Lett. **89** (2002) 037902.
[2] H. Takesue et al., New J. Phys. **7** (2005) 232.
[3] C. Gobby et al., Electron Lett. **40** (2004) 25.

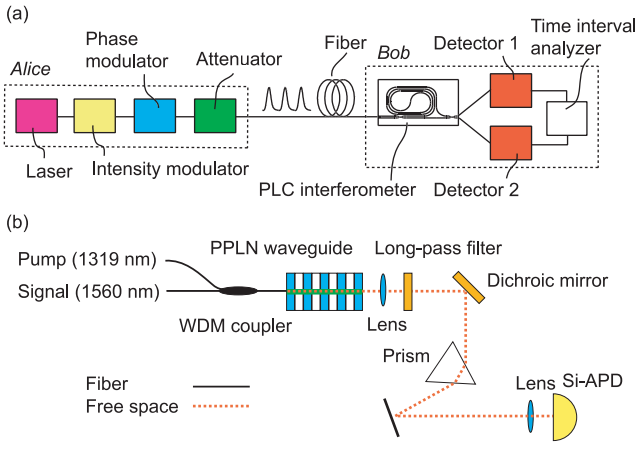


Fig. 1. Experimental setup.

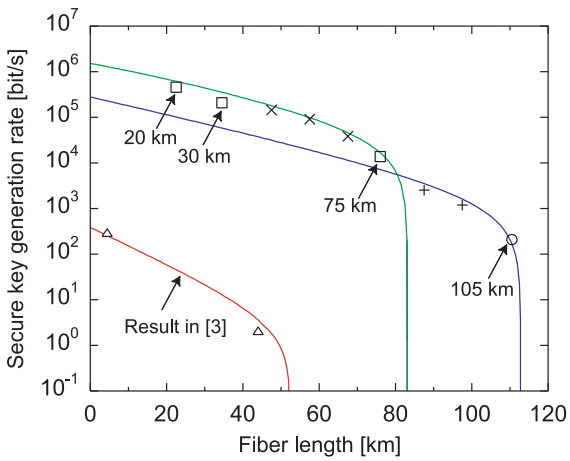


Fig.2. Secure key rate.

Generation of Energy-Time Entangled Photon Pairs in 1.5-μm Band

Toshimori Honjo[1], Hiroki Takesue[1] and Kyo Inoue[2]
[1]Optical Science Laboratory, [2]Osaka University/NTT Research Professor

The generation of entangled photon pairs in the 1.5-μm telecom band is essential for quantum communication over optical fiber networks[1, 2]. In this paper, we report the generation of 1.5-μm band energy-time entanglement using a periodically poled lithium niobate (PPLN) waveguide and a two-photon interference experiment using a planar lightwave circuit (PLC) [3].

Figure 1 shows the experimental setup. A continuous wave light from a laser diode with a wavelength of 780 nm was used as a pump light. The light was polarization controlled and then launched into a PPLN waveguide. Frequency degenerated photon pairs were generated in the PPLN at around 1560 nm by the spontaneous parametric down conversion process. After the PPLN, the light was filtered to suppress the 780-nm pump light and was also filtered by a 1560-nm band pass filter to reduce the dispersion in the PLC interferometer. The entangled photon pairs were launched into a 3-dB fiber coupler, which separated the signal and idler with 50% probability. The signal and idler photons were launched into a planar lightwave circuit (PLC) Mach-Zehnder interferometer. The phase difference between the two paths was precisely adjusted by controlling the temperature of the interferometer and stable operation was possible. Photon detectors based on an InGaAs APD were set at each output of the Mach-Zehnder interferometer. The output signals of the photon detectors were input into a time interval analyzer (TIA) to measure the coincidence. We used this setup to perform a two-photon interference experiment. In this experiment, we fixed the temperature of the PLC interferometer for the signal and changed that for the idler, and measured the coincidence.

Figure 2 shows the experimental results. The triangles indicate the experimentally obtained coincidence rate per detected signal photon for each temperature. The count rate of each detector was ~1700 cps throughout the measurement. Although the count rates remained, we observed a deep modulation of the coincidence rate as we changed the temperature. We obtained coincidence fringes with 77.3% visibilities without subtracting the accidental coincidences. Considering both the estimated average number of photon pairs per gate of 0.12 and their Poisson distribution, the visibility of the setup was theoretically estimated to be 77.4%, which means energy-time entanglement was confirmed and very few noise photons were generated by the pump light.

[1] I. Marcikic et al., Phys. Rev. Lett. **82** (1999) 2594.
[2] H. Takesue et al., Phys. Rev. A **72** (2005) 041804(R).
[3] T. Honjo et al., CLEO/QELS 2006 (2006) JTuA5.

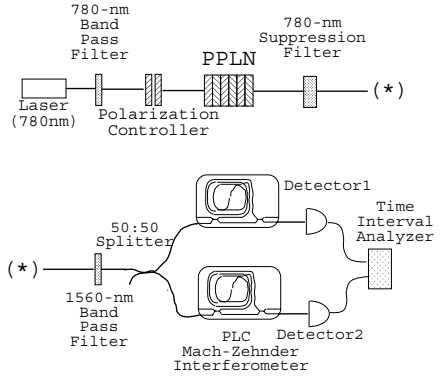


Fig. 1. Experimental setup.

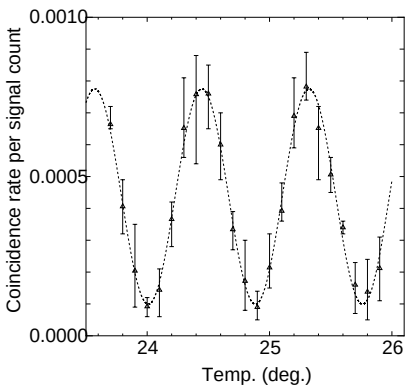


Fig.2. Coincidence fringe.

Coherent Single Electron Spin Control in a Slanting Zeeman Field

Yasuhiro Tokura
Optical Science Laboratory

Stimulated by electron-spin-based proposals for quantum computation, a growing interest has emerged in realizing the coherent manipulation of a single electron spin in a solid-state environment. The application of the electron's spin—rather than its charge—as a quantum bit (qubit) is motivated by its potentially long coherence time in solids and the fact that it comprises a natural two-level system. Single electron spin resonance (SESR) plays a key role in realizing electron-spin-qubit rotation, however had not been detected in semiconductor quantum dots (QDs) so far, because of the necessary high-frequency (10 GHz) selective magnetic field in a cryogenic (100 mK) setup. Waveguides and microwave cavities as used in conventional ESR cause serious heating, limiting the operation temperature to 1 K.

We propose a new SESR scheme that eliminates the need for an externally applied ac magnetic field, and with the potential of very high and tunable quality factors. An ac voltage is applied to let an electron in a QD oscillate under a static slanting Zeeman field. This effectively provides the electron spin with the necessary time-dependent magnetic field. Note the analogy with the Stern-Gerlach experiment, where the spin and orbital degrees of freedom are coupled by employing an inhomogenous magnetic field. The spatial oscillation of the electron within the QD involves the hybridization of orbital states.

We estimated expected coherence time of this qubit and demonstrated that single-qubit rotation and the controlled-NOT operation are possible. This qubit is easier to manipulate than a spin qubit and has a better quality factor than a charge qubit. The concept is general and can be applied to a range of systems, such as single wall carbon nanotubes, GaAs, and SiGe QDs. This scheme also allows for the measurement ofthe intrinsic single electron spin coherence time.

[1] Y. Tokura et al., Phys. Rev. Lett. **96** (2006) 047202.

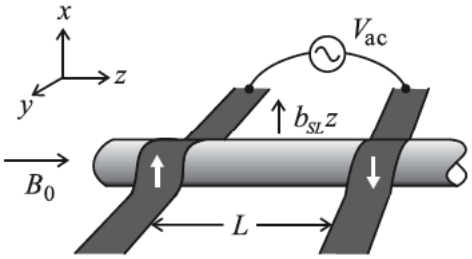


Fig. 1. Model: Ferromagnetic gate electrodes are located at either end of the dot and are magnetically polarized in the plus or minus x direction, creating a magnetic field gradient b_{SL}. A uniform magnetic field B_0 is applied in the z direction. The spin in the dot is controlled by applying an oscillating voltage V_{ac} between the two gates.

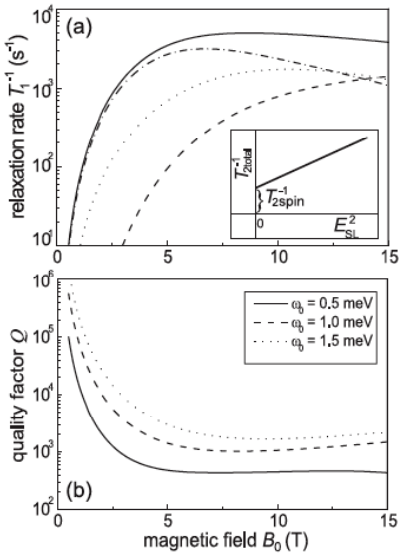


Fig. 2. (a) Relaxation rate $1/T_1$ in a GaAs QD as function of external magnetic field B_0 due to different phonon scattering mechanisms: deformation potential (dashed line), longitudinal (dotted line) and transversal (dash-dotted line) piezoelectric. The solid line is the total. (b) B_0 dependence of the quality factor Q for a single-qubit operation.

Optical Nonlinearity by Exciton-Biexciton Coherent Effects in Quantum Dots

Hideki Gotoh and Hidehiko Kamada
Optical Science Laboratory

Quantum dots have been attracting much attention because of their distinctive exciton-biexciton physics and important contribution to quantum information processes. In quantum dots, excitons and biexcitons (combined two excitons) stably exist due to the confinement effects in nanometer-scale structures. The stable excitons can induce coherent interactions with biexcitons. These coherent interactions provide quantum correlation effects as well as strong nonlinear optical effects like electromagnetically induced transparency (EIT), which are very useful in quantum information processing and conventional optical devices.

We found the strong optical nonlinearity in exciton absorption in zero-dimensional InGaAs quantum dots by using single-dot photoluminescence excitation (PLE) spectroscopy. This nonlinearity was caused by a coherent interaction between an exciton (X) and a biexciton (XX) [1, 2].

Figure 1 shows PLE spectra of X and XX for different excitation intensities. PLEs correspond to absorption spectra. With a low excitation, peak-shaped spectra can be seen in X and XX. With a high excitation, XX PLE spectrum exhibits usual peak-shaped with a broadened linewidth. In contrast, the X PLE has an unusual spectral shape with dip-shaped structure. The PLE almost disappears at the exciton resonance. A large coherent effect between X and XX yielded this unusual PLE. These coherent effects can be interpreted in terms of EIT. To examine the coherent effects for optical nonlinearities, we performed a pump and probe measurement. PL signals from an X and a XX were detected with two beams through an interferometer. Figure 2 shows the X and XX PL intensities as a function of excitation intensity. The XX PL increases with pump power and saturates above 300 μW. In contrast, the X PL increases up to 100 μW and decreases with pump power. This decreasing region reflects large coherent effects between the X and XX states. Our results reveal that an EIT-like optical nonlinearity is achieved by the coherent interaction.

Our results constitute an important milestone for the quantum computing and will assist the development of novel optical device functions.

[1] H. Gotoh et al., Phys. Rev. B71 (2005) 195334.
[2] H. Gotoh et al., Appl. Phys. Lett. **87** (2005) 102101.

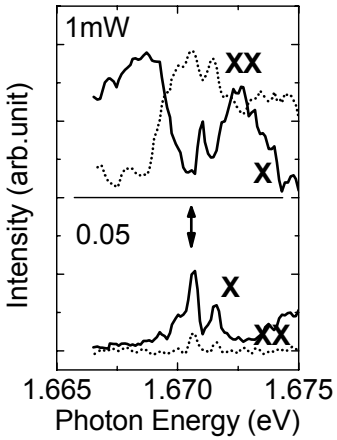


Fig. 1. PLE spectra for two excitation powers.

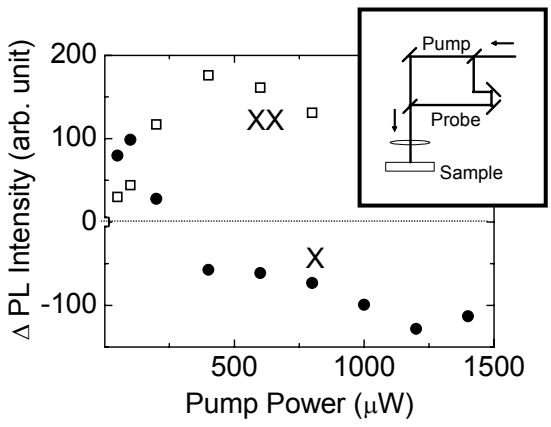


Fig. 2. Nonlinear PL intensity.

Nanoholes Formed by Reverse VLS Mechanism

Kouta Tateno, Hideki Gotoh and Hidetoshi Nakano
Optical Science Research Laboratory

There are several kinds of nanohole fabrication techniques suitable for nano-scale devices. Anodic oxidation of aluminum produces an elegant array of highly ordered nanoholes with a high aspect ratio. For semiconductors in nanohole fabrication, electron beam lithography and reactive ion etching (RIE) have been researched, especially for silicon-on-insulator (SOI) substrates for two-dimensional photonic crystals. Here, we report a new nanohole fabrication method using Au particles. This method is based on the reverse VLS (vapor-liquid-solid) mechanism.

The VLS mechanism is well known as the growth mechanism for free-standing semiconductor nanowires. The point of the VLS growth is to use the liquid-state metal alloy particles as catalysts at low temperature around 400 - 500˚ C. In the case of GaAs using Au particles as catalysts, the liquid Au particles maintain constant Ga and As concentrations in a thermodynamically balanced vapor-liquid-solid system so that the growth occurs when Ga and As are supplied and super-saturation occurs in the Au alloy particles. The concept of the reverse VLS process (etching) as follows: Ga and As are removed from the particles by supplying an etching source gas, at the boundary between the Au particle and the substrate, Ga and As dissolve continuously from the substrate to maintain their concentrations in the particle, and it turns out that Au particles dig into the substrate to make holes. We were able to successfully demonstrate smooth holes in GaAs and InP substrates by the reverse VLS mechanism for the first time [1].

The etching was carried out in a low-pressure (76 Torr) horizontal MOVPE reactor. Carbon tetrabromide (CBr_4) was the etching source (5×10^{-6} mol/min). AsH_3 and PH_3 were the group-V sources (2×10^{-3} mol/min) and were supplied around the etching temperature. Au-deposited GaAs and InP substrates were used for etching. For the InP samples, PH_3 was also supplied during the etching to reduce the etching rate.

The nanohole formation tends to proceed in the [111]B direction. For GaAs, straight holes sometimes appear in the [011] (as shown in Fig. 1) and [211]B directions. This is due to the stable {111}B facets, which block the etching. For InP, many straight holes are seen in the [111]B direction as shown in Fig. 2. For both materials, direct etching of the surface also occurs. It is therefore necessary to find the optimum etching conditions for high selectivity to fabricate nanoholes. This hole-fabrication method is very promising for application to various types of nano-devices and is expected to contribute to nano-science and -technology.

[1] K. Tateno et al., Jpn. J. Appl. Phys. **44** (2005) L428.

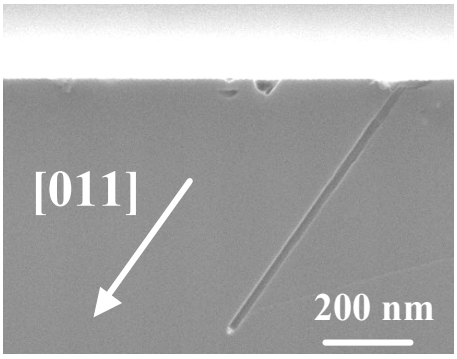


Fig. 1. Cross-sectional SEM images of [011] oriented hole in GaAs (111)A.

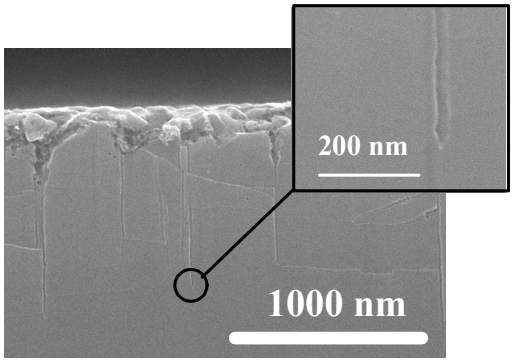


Fig. 2. Cross-sectional SEM images of [111]B oriented hole in InP (111)A.

Direct Measurement of the Carrier-Envelope Phase of a Few-Cycle Laser Pulse by Interference between Surface Harmonics

Atsushi Ishizawa and Hidetoshi Nakano
Optical Science Laboratory

The carrier-envelope phase (CEP) is the phase of the carrier wave at the maximum of the envelope. The timing of the oscillation cycles within a light pulse plays a role in the interaction of light with matter when the duration of the pulse becomes comparable to the light oscillation period. Therefore, it is necessary to control the CEP of few-cycle laser pulses in order to apply nonlinear spectroscopy.

To date, it has been observed that high-order harmonic generation [1] and above-threshold ionization are sensitive to the CEP. Almost all previous direct measurements of the CEP have relied on strong-field processes using 100-μJ amplified laser pulses, which are available only at low repetition rates in a vacuum chamber equipped with a specialized detector. Therefore, only a few laboratories have been able to measure the CEP.

We demonstrated a measurement that provides direct information about the CEP of a few-cycle laser pulse. In any f -to-2f or 2 f -to-3f spectrum interferogram method using a nonlinear crystal, there is a certain unknown phase shift in the measured value because of the linear dispersion in the SHG crystal. We have devised a way of directly measuring the CEP using the interference between the second and third harmonics from the surface of a solid. Both harmonics have a π/2 phase shift relative to the fundamental optical field when they are generated from the surface of a solid. This means the interference signals do not include a constant offset phase component and can therefore be used to measure the CEP directly. This method uses pulses with a low energy of less than 1 μJ, and it's very easy to set up the equipment and perform the measurement in air. The spectrum of the laser pulse is shown in Fig. 1. In this experiment, a 5-fs 1-μJ laser pulse was focused on a glass target at the incident angle of 45° . Even and odd harmonics were generated due to the broken symmetry of an interface. The second and third harmonic spectrums overlap in the ultra-violet region. Figure 2 shows a series of interference signals of different phases. The signals cyclically move up and down with the CEP, which has a period of 2 π rad. We will be able to achieve stabilization of the CEP of a few-cycle amplified laser pulse by detecting it using this method.

[1] A. Baltuška, et al., Nature. **421** (2003) 611.
[2] A. Ishizawa and H. Nakano, Jpn. J. Appl. Phys. **45** (2006) 4087.

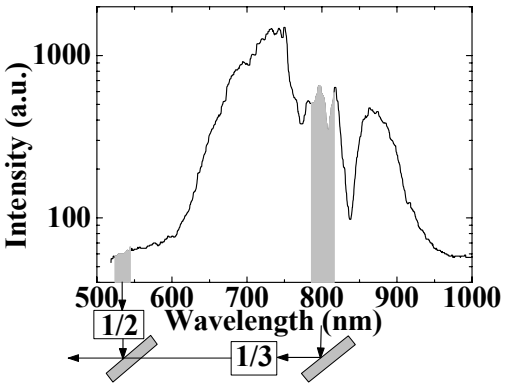


Fig. 1 Measured spectrum of a few-cycle laser pulse.

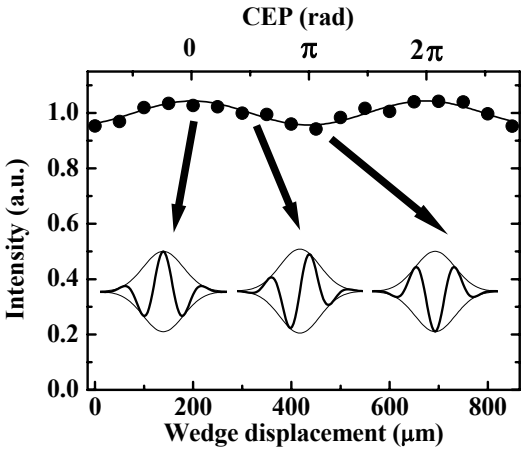


Fig. 2 Dependence of the CEP on the interference intensity.

Ultrahigh-Q Photonic Crystal Nanocavity Realized with Locally Modulated Line Defect

Eiichi Kuramochi, Takasumi Tanabe, Akihiko Shinya and Masaya Notomi
Optical Science Laboratory

An advantage of photonic crystal (PC) nanocavities is compatibility of a high quality factor (Q) with an ultra-small mode volume (V) [1].. A higher Q has been demanded in order to enhance device performance [2,3] and decrease the device insertion loss resulting from the reduction in transmittance caused by cavity-waveguide coupling. Although intensive studies have raised the theoretical Q value to 10^6 [1], a further increase will be difficult to achieve using conventional approaches.

A new scheme for realizing a higher Q PC nanocavity involves a Fabry-Perot cavity composed of a loss-less line-defect mode and two mode-gap mirrors [4]. The use of a mode-gap mirror instead of a photonic bandgap (PC) mirror greatly reduces the out-of-plane loss from the cavity because of the smooth and gradual decay of the electromagnetic field in the mode-gap barrier region. We have found that such a mode-gap can be generated by modulating the line-defect width [1]. In this study, we designed a nanocavity in which holes around the cavity center were shifted away from a line defect. In addition, we employed a tapered shift structure (this 3-stage structure is shown in Fig. 1) in which a gradual change of line-defect width enhanced the advantage of the mode-gap mirror. Numerical studies with the 3D finite difference time domain method revealed that the 3-stage structure can achieve an ultrahigh-Q (10^8) with an ultrasmall V (1.7 $(\lambda/n)^3$). Next, we fabricated this structure in a Si PC slab by using electron beam lithography [5]. The intensity spectrum of the cavity resonant mode is shown in Fig. 2. The ultranarrow linewidth (1.5 pm) corresponded to a Q of 1.0×10^6.

In summary, our newly designed cavity has increased the theoretical Q value by two orders of magnitude and we achieved an experimental Q of one million for the first time as a PC-based nanocavity [6]. The Q achieved here is sufficiently high for many device applications and this report is a first step towards adding new functions (optical buffering and optical delay) to PC-based devices.

[1] M. Notomi et al., Opt. Express **12** (2004) 1551.
[2] M. Notomi et al., Opt. Express **13** (2005) 2678.
[3] T. Tanabe et al., Opt. Lett. **30** (2005) 2575.
[4] E. Kuramochi et al., Appl. Phys. Lett. **88** (2006) 041112.
[5] E. Kuramochi et al., Phys. Rev. **B72** (2005) 161318(R).
[6] E. Kuramochi et al., LEOS2005, PD1.1 (2005).

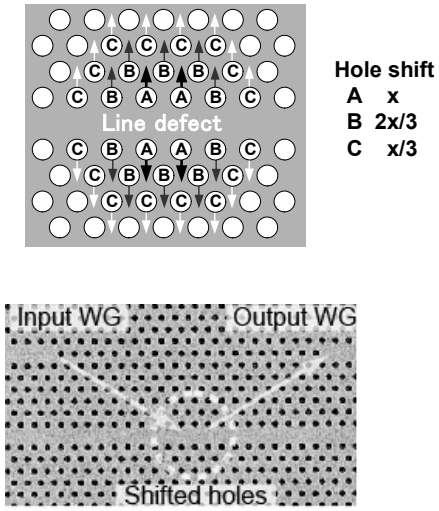


Fig. 1. Schematic and SEM image.

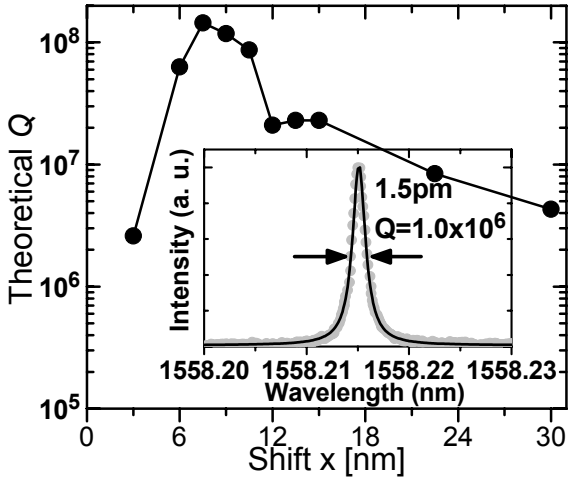


Fig. 2. Theoretical Q and resonant spectrum.

All-Optical Flip-Flop Circuit Using Photonic Crystal Resonators

Akihiko Shinya, Takasumi Tanabe, Eiichi Kuramochi, Satoki Kawanishi and Masaya Notomi
Optical Science Laboratory

An all-optical flip-flop circuit will be needed in future all-optical high-speed signal circuits. A flip-flop circuit is a digital circuit that temporarily memorizes past input/output information, and processes it with present input signals. These functions are indispensable in terms of achieving all-optical regeneration functions. One of the most important functions is to synchronize the output pulses with the system clock. Although several successful all-optical circuits have already been proposed, their operating speed is not very fast due to their large circuit size.

To overcome this problem, we used a two-dimensional photonic crystal (PhC), which has attracted attention as a platform on which to construct devices with dimensions of a few wavelengths of light. Figure 1 shows the schematic structure of our flip-flop circuit based on a 2D-PhC with a triangular air-hole lattice [1]. The lattice constant a is 400 nm, and the air-hole diameter is 0.55a. The two resonators (C1, C2) have one identical resonant wavelength ($\lambda 2$) and two different resonant wavelengths ($\lambda 1$ and $\lambda 3$ for C1 and C2, respectively). The waveguides (WG1, WG2) are tuned so that the $\lambda 1$ and $\lambda 3$ lights can propagate in both WG1 and WG2, and the $\lambda 2$ light can propagate only in WG1.

Here, we consider a situation where the input data (DATA: $\lambda 2$ = 1548 nm) with a non-return-to-zero (NRZ) format deviates from the internal system clock. In order to synchronize the data and the clock, we set all the input powers of the $\lambda 1$, $\lambda 2$ and $\lambda 3$ lights at 60 mW to employ the bistable operation of C1 and C2, and used two signals as internal system clocks (CLOCK : $\lambda 3$ = 1463 nm, $\overline{\text{CLOCK}}$: $\lambda 1$ = 1493 nm). We simulated our system with the 2D-FDTD method taking account of the Kerr effect of the PhC material (AlGaAs).

Figure 2 shows the calculated time charts of our system. This figure shows that our system outputs the AND signal between the ideal DATA (dotted line) and the CLOCK. That is, this system can synchronize the DATA with the CLOCK and regenerate the ideal DATA with a return-to-zero format. The system response time is about 10 ps, which means our system can operate with a 50 GHz clock.

The result is the first step towards all-optical digital processing.

[1] A. Shinya, S. Mitsugi, T. Tanabe, M. Notomi, I. Yokohama, H. Takara, and S. Kawanishi, Optics Express 14 (2006) 1230

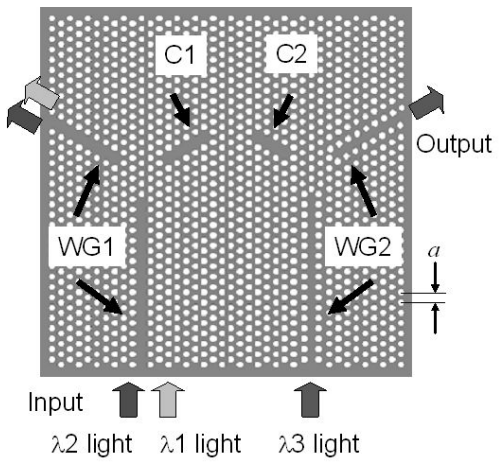


Fig. 1. Schematic structure of flip-flop circuit.

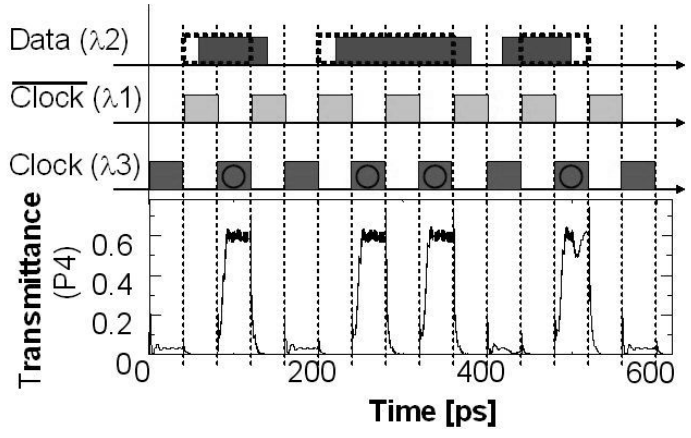


Fig. 2. Time chart of our system.

Adiabatic Wavelength Conversion via Dynamic Tuning of a Cavity

Masaya Notomi
Optical Physics Laboratory

"Wavelength" is one of the most important characteristics of light, which has been employed in various optical technology, such as wavelength-demultiplexing communication. Though it is not so difficult to generate light with a particular wavelength using a tunable laser, it is not easy to change the wavelength after generated. Usually, we make use of high-order optically-induced electronic polarization in some special crystals to convert the wavelength. However, this nonlinear process requires high optical intensity. Very recently, we found that we can linearly convert the wavelength of light by a fundamentally different mechanism.

This novel conversion process is described as follows: First, we prepare a light pulse in a high-Q cavity, and then we dynamically change the resonant wavelength of the cavity within a time scale shorter than the photon lifetime of the cavity. As a result of the dynamic parameter tuning process, the wavelength of light in the cavity follows the changed resonant wavelength of the cavity. We have confirmed this phenomenon by numerical experiments for realistic Si photonic crystal high-Q cavities, as shown in Fig. 1. This phenomenon is purely linear, thus it does not depend on the optical intensity of the signal light, and 100% conversion efficiency is possible regardless of the intensity, which are quite different from conventional nonlinear wavelength conversion. In fact, this process is equivalent to a parameter tuning process in a classical oscillator, such as a guitar (suppose that plucking a guitar code and then screwing a peg before the sound is dying out). Although the process is very simple, it has been difficult to realize in the optical regime because the light velocity is generally too fast and the decay time is too short. And only recently this becomes meaningful after the recent rapid technical advance in high-Q microcavities. We have also confirmed that so-called adiabatic invariant (the energy divided by the frequency) is preserved all through this process, proving that it is a adiabatic tuning process.

In future, we plan to experimentally demonstrate some of important characteristics of this wavelength conversion process, such as wavelength conversion of few photons.

[1] M. Notomi and S. Mitsugi, Phys. Rev. A**73** (2006) 051803(R).

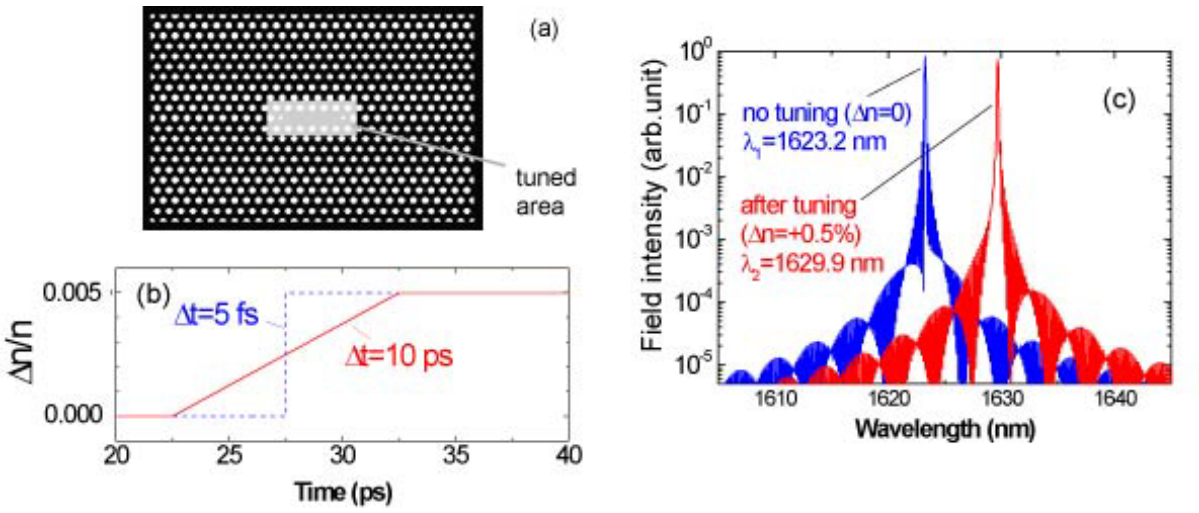


Fig. 1. (a) Schematic of Si photonic crystal cavity assumed for the calculation. (b) Dynamic change of the refractive index as a function of time. (c) Calculated wavelength spectra with and without dynamic tuning.

Ⅱ. Data

Science Plaza 2005Fall

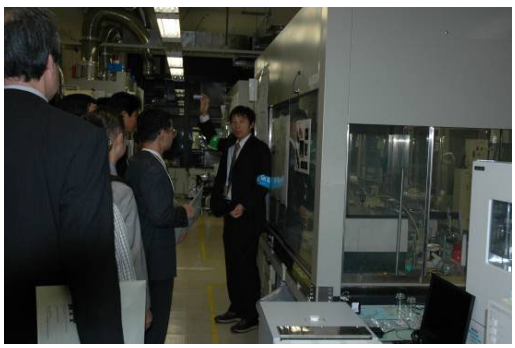
"Science Plaza 2005Fall" was held at NTT Atsugi R&D Center on Friday, October 28th, 2005. Entitled "Nanoscience Opens Up the Quantum World", the Science Plaza symposiums have been implemented with the aim of bringing together various people from inside and outside of NTT while gathering diverse opinions through discussions on our latest research accomplishments.

At Science Plaza 2005Fall, following an opening address from the laboratory chief, Dr. Takayanagi, brief summaries of each exhibited poster were given in the form of short presentations. After lunch, symposium lectures were given by three distinguished technical members of NTT Basic Research Laboratories. The lecture topics and respective presenters were "Current status and outlook for diamond FETs as high-frequency power devises" by Makoto Kasu, "Micro/nanotechnology and quantum effects" by Koji Yamaguchi, and "Single-electron dynamics" by Toshimasa Fujisawa. Each lecture was well-attended and was followed by enthusiastic question-and-answer sessions.

As regards the poster exhibits, 27 posters presenting our latest research accomplishments were displayed. While explaining the originality and impact—as well as the future prospects—of our research accomplishments in detail, these poster sessions generated pretty intense discussions on the research topics, and many meaningful opinions were received. At the video screening, promotion videos summarizing some typical research topics were shown in a short, easy-to-understand manner along with footage from some previously hosted international symposiums. This year's "Lab tour"—an inspection of the research facilities at NTT BRL that has been highly appraised over the years—took in four destinations and was repeated a total of five times during the day. Care was taken to ensure that anybody wishing to attend the tour could do so. After all the lectures, presentations, and exhibitions were completed, a banquet was held in the research center's dining room, becoming a place for the meaningful discussions during which the various guests could deep their mutual relations.

More than 200 people from research institutes, universities, and general industries, as well as from NTT Group, attended Science Plaza 2005Fall, and thanks to the efforts of all those who attended, the conference could end on a high note. We would thus like sincerely express our gratitude to all the attendees.






3rd NTT-BRL School

The third NTT-Basic Research Laboratories (BRL) school was held during the period of October 31-November 4, 2005, at the NTT Atsugi R&D Center. The aim of the NTT-BRL school is to foster young researchers in the field of physics field and to promote the international visibility of NTT BRL. This year the theme selected was "Noise and Decoherence in Quantum Systems", which is closely related to the research on quantum information processing that NTT BRL is now conducting intensively. Seven prestigious professors were invited to the school as lecturers. Thirty-four participants, mainly Ph. D students, gathered from seventeen countries.

On the first day, after the director and the managers of NTT BRL presented an overview of NTT BRL, Prof. Boris Altshuler (Columbia University, USA) gave a lecture entitled "Introduction to Theory of Mesoscopic Systems". On the second day, there were two lectures, "Quantum Transport and Electron Dephasing in Diffusive Metal Wires" by Prof. Norman Birge (Michigan State University, USA) and "Decoherence in the Josephson Charge Qubits" by Dr. Oleg Astafiev (NEC, Japan), both including the recent topic of the experimental research. Following them, Prof. Yuri Galperin (University of Oslo, Norway) gave a talk on "Decoherence in Metallic Conductors and Mesoscopic Devices (theory)". In the morning of the third day, a laboratory tour was conducted so that the students could enjoy looking at the research facilities and activities at NTT BRL. After the afternoon lecture by Prof. Leonid Levitov (MIT, USA) "Quantum Noise and Counting Statistics", the poster session was held in the evening, where each student gave a presentation about his/her research at university.

On the last two days, we had three lectures: "Quantum Shot Noise Probing Interactions and Magic Properties of the Fermi Sea" by Prof. Christian Glattli (ENS, France), "Mesoscopics in Quantum Dots" by Prof. Charles Marcus (Harvard University, USA), and "Transport in Arrays of Quantum Dots" by Prof. Valerii Vinokur (Argonne National Laboratories, USA). In the final talk, the director of NTT-BRL, Hideaki Takaynagi talked about "Readout of Superconducting flux quits". At the farewell party, best poster prizes were awarded to the students who gave prominent presentations. The students were able to network and build friendships while exchanging their contact addresses. NTT BRL will continue to provide these kinds of occasions to foster young researchers and build human networks in the field of physics.

International Symposium on "Mesoscopic Superconductivity and Spintronics 2006"

From February 27 to March 2, NTT Basic Research Laboratories (NTT BRL) and CREST-JST held an international symposium on physics entitled "Mesoscopic Superconductivity and Spintronics" (MS+S2006) at NTT Atsugi R&D Center. These fields have recently been attracting considerable attention from scientific researchers and engineers because they are fundamental areas that may lead to the physical realization of quantum information processing and computation. Many distinguished researchers in these fields from all over the world have joined every event of this series of symposium and given important presentations. It is now recognized as an important international symposium on mesoscopic. MS+S2006 included 46 oral presentations and approximately 80 poster presentations.

At the symposium this year, we were impressed by the fact that mesoscopic superconductivity is attracting attention in terms of applications in addition to the academic interest. Professor J. Martinis, Professor F. W. J. Hekking, Professor D. Esteve, Professor J. Clark, Professor C. J. P. M. Harmans, Dr. K. Semba, Dr. Y. Nakamura, Dr. Wallraff, and Professor A. Ustinov gave talks on new results in their superconducting qubits(SQubits) experiments. These people represent almost all the research groups throughout the world that actually have SQubits in operation. In particular, Professor J. Martinis's group in UCSB has had a greatest success. They observed two-quantum-bit entanglement and provided the quantum tomography charts of their system. On the other hand, the Yale Univ. group showed the entanglement between their SQubit and a transmission line resonator, and the NTT BRL group demonstrated entanglement manipulation of their SQubit and a sub-millimeter LC resonance circuit coupled system, which is known as "vacuum Rabi oscillation". These two studies are the first clear demonstrations of entanglement in macroscopic quantum objects.

We also found that rapid progress is being made in spintronics. In particular, electrical ways of manipulating spins in semiconductor systems generated great interest in this symposium. A talk on the generation and detection of spin entanglement in double quantum dots was presented by Professor C. Marcus of Harvard University. Dr. S. Sasaki of NTT BRL described a gate-controlled RKKY interaction in a double quantum dot-quantum wire coupled system. Much attention has focused on the spin-orbit interaction in semiconductors. Professor D. Awschalom of UCSB demonstrated optical detection of the spin Hall effect in GaAs and InGaAs. Gate control of spin precession in InGaAs 2DEGs (two-dimensional electron gases) was reported by Professor J. Nitta of Tohoku University. Professor H. Ohno of Tohoku Univ. observed current-induced domain wall motion in GaMnAs.

Midway through the symposium, a special lecture on entanglement manipulations with trapped ions was given by Dr. H. Haffner of Innsbruck. Most participants were surprised by the admirable skill shown in manipulating ions although they were not very familiar with the system.

The symposium welcomed approximately 200 participants, of whom a quarter were from overseas. They have now returned home with the dream of fruitful interaction between fundamental physics and information sciences, which will become common in the near future.

Award Winners' List (Fiscal 2005)

International Symposium on Photonic and Electromagnetic Crystal Structures (PECS-VI) Best Paper Award	E. Kuramochi M. Notomi S. Hughes G. Kira L. Ramunno A. Shinya T. Watanabe	"Optical Properties of Photonic Crystal Slab Components: Role of Disorder"	Jun. 24, 2005
Young Scientist Award for the Presentation of Excellent Paper	K. Oguri	"For Time-resolved EXAFS Measurement of Ultrafast Laser-melted Si Using a Sub-10-ps Soft-x-ray Pulse"	Sep. 7, 2005
Medal with purple Ribbon	Y. Yamamoto	"Quantum Optioncs"	Nov. 3, 2005
The Surface Science Society of Japan The Best Poster Prize ISSS-4(International Symposium on Surface Science and Nanotechnology)	K. Uchida	"First-Principles Study of Field-Effect Doping in Nano-Scale Systems by the Enforced Fermi-Energy Difference Method"	Nov. 15, 2005
The Surface Science Society of Japan SSSJ Review Paper Award	T. Ogino Y. Homma K. Sumitomo H. Omi D. Bottomley Z. Zhang	"Nanostructure Self-Organization by Controlling Surface and Interface Strain"	Nov. 17, 2005

In-house Award Winners' List (Fiscal 2005)

NTT Technical Review Selected Papers	Y. Hirayama H. Takayanagi K. Inoue K. Shimizu H. Kamada T. Fujisawa	"Toward Quantum Information Technology"	Dec.14, 2005
NTT R&D Award	M. Notomi E. Kuramochi A. Shinya T. Tanabe K. Yamada	"Realization of Ultrasmall Photonic-Crystal Optical Components"	Dec.14, 2005
NTT R&D Award	K. Kumakura M. Hiroki T. Makimoto H. Yokoyama T. Kobayashi	"Substrate for nitride semiconductor growth"	Dec.14, 2005
NTT R&D Award	T. Honjo H. Takesue Y. Tokura A. Sahara H. Takahashi	"Quantum cryptography"	Dec.14, 2005
Award for Achievements by Director of Basic Research Laboratories	S. Suzuki D. Takagi K. Kanzaki Y. Homma Y. Kobayashi	"Suspended architecture formation and functionalization by low-energy electron irradiation of carbon nanotubes"	Mar. 16, 2006
Award for Achievements by Director of Basic Research Laboratories	W. Hu H. Nakashima Y. Kashimura K. Furukawa	"Fabrication and characterization of conductive polymer based molecular device combined with nano-gap electrodes"	Mar. 16, 2006
Award for Achievements by Director of Basic Research Laboratories	K. Yamazaki H. Namatsu	"Three-dimensional electron beam lithography"	Mar. 16, 2006
Award for Achievements by Director of Basic Research Laboratories	K. Oguri Y. Okano T. Nishikawa H. Nakano	"Development of ultrafast absorption spectroscopy using femtosecond-laser-based ultrashot x-ray source"	Mar. 16, 2006

Award for Excellent Papers by Director of Basic Research Laboratories	G. Yusa K. Muraki	"Controlled multiple quantum coherences of nuclear spins in a nanometre-scale device" Nature Vol. 434, 1001 (2005)	Mar. 16, 2006
Special Award by Director of Basic Research Laboratories	T. Fujisawa K. Suzuki H. Tamura M. Kumagai	"Significant cost reduction and improved management for the helium liquefier and the recovery system"	Mar. 16, 2006

List of Visitors' Talks (Fiscal 2005)

I. Materials Science

Date	Speaker	Affiliation "Topic"
May 25	Prof. Tom Lemberger	Ohio State University, USA "Pairing symmetry of electron- and hole-doped cuprates from the magnetic penetration depth measurements"
July 21	Dr. Krishna G. Nath	INRS-EMT, Univ. of Quebec, Canada "Supramolecule-Nanopattering for Future Medical and Biological Application"
Aug. 4	Prof. Shigeya Naritsuka	Meijo University "Beam Induced Lateral Epitaxy of GaAs on GaAs substrates"
Sep. 29	Prof. Yung Joon Jung	Northeastern University, USA "Tailoring Carbon Nanotube Structure and Building Nanotube based system"
Jan. 17	Dr. Kazuhiko Omote	Rigaku Corp. "Small Angle X-ray Scattering for Nano-strucure Analysis"
Jan. 23	Prof. Erhard Kohn	Universität Ulm, Germany "Liquid Junctions to Wide Bandgap Semiconductors"

II. Physical Science

Date	Speaker	Affiliation "Topic"
Apr. 6	Prof. David Haviland	Kungliga Tekniska Högskolan, Sweden "Spin Transport and Superconducting Nano-Circuits"

Apr. 15	Dr. Stefan Fölsch	Paul-Drude-Institut, Germany "Assembly and spectroscopy of atomic-scale surface structures by low-temperature STM: From monatomic chains to single-molecule/quantum wire contacts"
May 27	Dr. Tetsuo Kishimoto	PRESTO, JST, The University of Tokyo "Electric trapping of Neutral atoms and its on-chip application"
June 2	Dr. Yosuke Takasu	Kyoto University "Quantum Degenerate Gases of Ytterbium Atoms"
June 16	Ms. Irina Stefana Ionica	Institut de Microelectronique, France "Coulomb Blockade and Field Effect for Silicon Nanostructures Fabricated by Atomic Force Microscope on Ultrathin SOI Substrates"
June 28	Prof. A. R. Hamilton	University of New South Wales, Australia "Quantum Interference and Interaction Effects in 2D Quantum Wells and 1D Quantum Wires"
July 8	Dr. Tom Stace	University of Cambridge, UK "Population inversion in driven quantum dots with an unstructured phonon bath"
July 15	Prof. Richard A. Kiehl	University of Minnesota, USA "Information Processing by Assemblies of Molecules: Directed Self-Assembly, Nonlinear Behavior, Array Architectures"
July 28	Ms. Claire Marrache-Kikuchi	Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, France "Dimensionality effects in NbSi thin films"
Aug. 1	Prof. Rui-Rui Du	Rice University, USA "New aspects of microwave-induced zero-resistance states in high-mobility 2DEG"
Aug. 1	Dr. K.-J. Friedland	Paul-Drude-Institut, Germany "Intrinsic planar Hall effect in Fe and Fe3Si films on GaAs(001) and GaAs(113) substrates"
Aug. 3	Prof. Daniel E. Prober	Yale University, USA "Quantum Shot Noise of a Tunnel Junction and a Diffusive Wire: Third Moment and Driven Response"
Aug. 9	Dr. Lieven Vandersypen	Delft University of Technology, Netherlands "Single-shot read-out, relaxation and decoherence of single spins in GaAs quantum dots"

Sep. 6	Prof. Andrew Briggs	University of Oxford, UK "Carbon nanomaterials for quantum information processing"
Sep. 28	Dr. Guy Austing	National Research Council Canada, Canada "Recent research topics on vertical quantum dot structures and carbon nanotubes"
Sep. 30	Dr. Adam Micolich	University of New South Wales, Australia "Fractal Conductance Fluctuations in Semiconductor Billiards" and "Superconductivity in Metal-mixed Ion-implanted Polymer Films"
Oct. 7	Prof. Jonathan Finley	Walter Schottky Institut, Germany "Semiconductor quantum dots, molecules and their coupling to light"
Oct. 24	Mr. Daisuke Akamatsu	Tokyo Institute of Technology "Preserving squeezed vacuum with electromagnetically induced transparency (EIT)"
Oct. 26	Prof. Amnon Aharony	Tel Aviv University, Israel "Old and new results on phase measurements in Aharonov-Bohm interferometers"
Oct. 26	Prof. Ora Entin-Wohlman	Tel Aviv University, Israel "Spin-Hall effect of localized electrons"
Nov. 7	Dr. Alexandre Blais	Yale University, USA "Quantum optics and quantum information processing with superconducting circuits"
Nov. 22	Prof. Giuseppe Iannaccone	Universita' di Pisa, Italy "Modeling of Nanoelectronic Devices as a Strategic Tool in Semiconductor Technology"
Dec. 19	Dr. Yasuhiro Utsumi	RIKEN "Full Counting Statistics in Quantum Dots"
Jan. 12	Dr. Pawel Hawrylak	National Research Council Canada, Canada "Electronic Correlations in Quantum Degenerate Systems"
Jan. 16	Dr. Kazuhito Tsukagoshi	RIKEN "Nano-scale fabrication and materials transport"
Jan. 23	Dr. Masaya Kataoka	University of Cambridge, UK "Charge Transport using Surface Acoustic Wave"
Feb. 15	Prof. Mikio Nakahara	Kinki University "Artificial generation and suppression of decoherence in NMR quantum computer"
Feb. 16	Prof. Mats Jonson	Chalmers/Goteborg University "Mechanically assisted single electronics"

Feb. 17	Prof. Eleanor E.B. Campbell	Gothenburg University, Sweden "Taming Carbon Nanotubes for Use as Nanoelectronics and NEMS Devices"
Feb. 20	Dr. Andrew Watt	Oxford University, UK "Spin Active Fullerene Superlattices"
Feb. 22	Prof. Christopher Bäuerle	Centre de Recherches sur les Très Basses Températures, France "Dimensional crossover in quantum networks: from macroscopic to mesoscopic"
Feb. 22	Mr. Yuji Kurotani	Tokyo Institute of Technology "Theoretical circuit analysis of quantum measurement processes"
Mar. 20	Prof. Wilfred G. van der Wiel	Universiteit Twente, Nederlands "NanoElectronics: More than Moore"

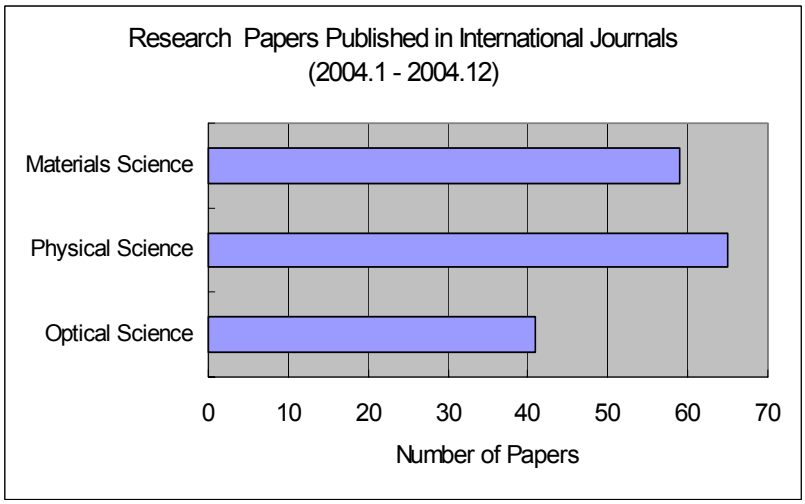
III. Optical Science

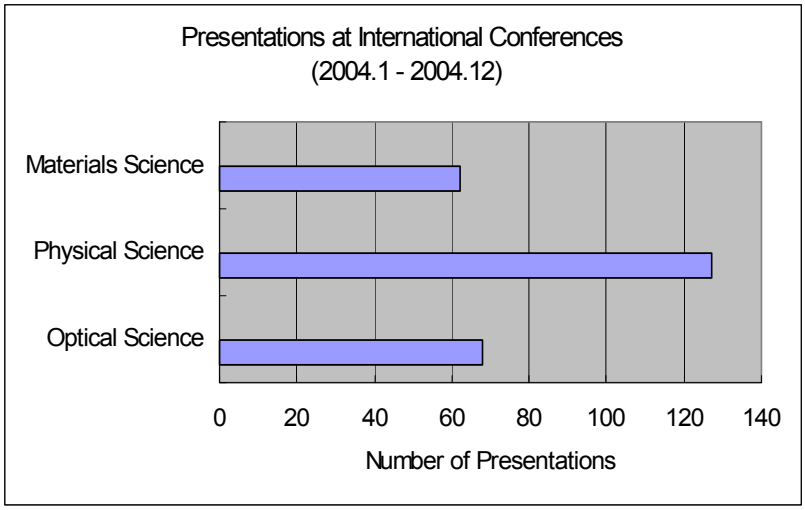
Date	Speaker	Affiliation "Topic"
Apr. 21	Dr. Yuki Kawaguchi	Tokyo Institute of Technology "Splitting process of a quadruply charged vortex in a Bose-Einstein condensate with alkali-metal atoms"
Apr. 27	Dr. Shiro Kawabata	Nanotechnology Research Institute AIST "Macroscopic Quantum Tunneling in High-Tc Superconductor Josephson Junctions: Theory and Experiment"
July 27	Mr. Wouter Wetzels	Delft University of Technology, Netherlands "Non-collinear single electron spin-valve transistors"
Aug. 10	Dr. Ulrich Zuelick	Massey University, New Zealand "Spin interferometry and entanglement generation with Rashba spin splitting"
Sep. 1	Dr. David Poulin	The University of Queensland, Australia "Robust quantum key distribution: Putting quantum error correction theory to work on small systems"

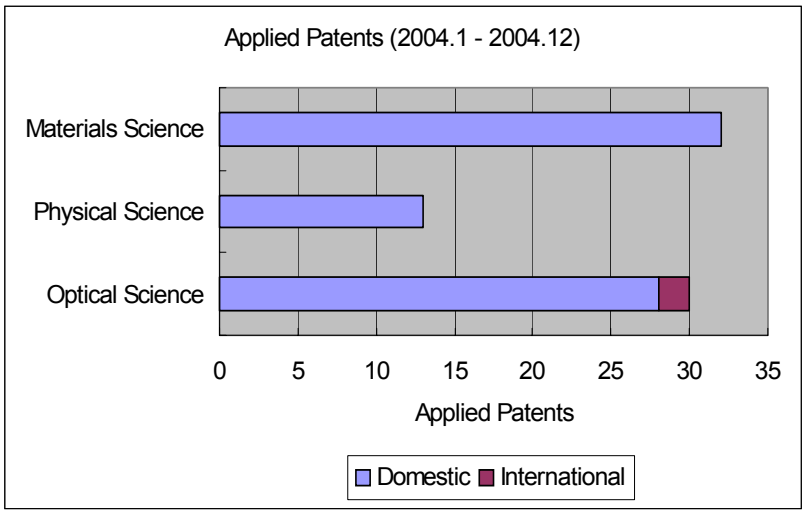
Nov. 11	Mr. Brig Elliott	BBN Technologies, USA "Introduction of BBN and BBN's Quantum Network test bed"
Dec. 8	Dr. Alessandro Pioda	Eidgenössische Technische Hochschule Zürich, Switzerland "Local spectroscopy on quantum dots"
Dec. 22	Dr. Parisa Fallahi	Harvard University, USA "Coulomb Blockade Imaging of electrons in Few-Electron Quantum Dots"
Jan. 6	Prof. Shun Lien Chuang	University of Illinois, USA "Slow Light Using Quantum Devices"
Jan. 19	Prof. Yong-Hang Zhang	Arizona State University, USA "Electroluminescence refrigeration in Semiconductors"
Feb. 16	Dr. Koji Hatanaka	Tohoku Univ. "Interaction between intense laser and solutions: Pulsed x-ray emission from aq. solutions when irradiated by femtosecond laser"
Mar. 3	Prof. Vlatko Vedral	University of Leeds, UK "Entanglement in the Solid State"
Mar. 16	Dr. Wataru Izumida	Tohoku University "Phonon-assisted tunneling in interacting suspended single wall carbon nanotubes"

Research Activities of Basic Research Laboratories in 2005

The numbers of research papers, presentations at the international conferences and applied patents amounted to 165, 257, and 75 in Basic Research Laboratories as a whole. All numbers according their research areas are as follows.







The major journals and the number of published papers are shown below.

General Science Journals

name	(IF2003)*	numbers
Nature	(30.979)	1

Specialized Journals

name	(IF2003)*	numbers
Japanese Journal of Applied Physics	1.171	34
Applied Physics Letter	4.049	18
Physical Review B	2.962	14
Physical Review Letter	7.035	11
Physical Review A	2.589	9
Journal of Applied Physics	2.171	6
Physica E	0.93	5
Optics Letter	3.395	4
Surface Science	2.063	4
Physica C	1.192	4
Optics Express	3.219	3
Journal of the Physical Society of Japan	1.903	3
Molecular Cell	16.835	1
Journal of the American Chemical Society	6.516	2
The Journal of Biological Chemistry	6.482	1
Nano Letters	6.144	1

*IF2003: Impact factor 2003（Journal Citation Reports, 2003）

The average impact factor for individual research papers from all NTT Basic Research Laboratories is 2.79.

The major international conferences and their number of presentation are shown below.

Conferences	numbers
International Conference on Nanoelectronics, Nanostructures and Carrier Interactions (NNCI2005)	32
IQEC and CLEO-PR	21
International Conference on Solic State Devices and Materials (SSDM)	16
Electronic Properties of Two-Dimensional Systems and Modulated Semiconductor Structures (EP2DS)	12
CLEO/QELS	9
Annual APS Meetiong	9
International Symposium on Surface Science and Nanotechnology	8
International Conference on Low Temperature Physics	7
International Conference on Nitride Semiconductors (ICNS)	5
International Symposium on Superconductivity	5
LEOS	5
Seventh International Conference on New Phenomena in Mesoscopic Structures / Fifth International Conference on Surfaces and Interfaces of Mesoscopic Devices (NPMS-7 / SIMD-5)	5
International Conference on Defects in Semiconductors	4
International Conference on Si Epitaxy and Heterostructures	4
Silicon nanoelectronics workshop	4
International School and Conference on Semiconductor Spintronics and Quantum Information Technology	4
Materials Research Society meetings (MRS)	3
International Symposium on Compound Semiconductors (ISCS)	2
ACS National Meeting	1
International Conference on Electron, Ion, Photon Beam Technology and Nanofabrication (EIPBN)	1
Gordon Research Conference	2
International Workshop of Photonic and Electromagnetic Crystal Structures (PECS)	1

List of Invited Talks at International Conferences (2005)

I. Materials Science Laboratory

(1) T. Matsuoka, H. Okamoto, M. Nakao, and, T. Makimoto, "Temperature Dependence of Optical Bandgap of Wurtzite InN", Air Force Office of Scientific Research (AFOSR) Indiumu Nitride Workshop, Hawaii, USA (Jan. 2005).

(2) K. Torimitsu, "Effect of magnesium on neural activities and its analysis using micro-electrode array-based measurement", 9th Gordon Research Conference on Magnesium in Biochemical Processes and Medicine, Gordon Research Conference, Ventura, USA (Feb. 2005).

(3) H. Omi and Y. Homma, "Stiffness of step bunches on Si(111)", Crystalization and electrocrystalization: Fundamentals and applications (CEFA), Varna, Bulugaria (Mar. 2005).

(4) K. Torimitsu, "Information processing in neuron and molecular function", 3rd Sweden/Japan Workshop on Nanobiotechnology, Lund, Sweden (Mar. 2005).

(5) A. Shimada and K. Torimitsu, "Nano-Bio Science: Neuronal Functions and Nano-Bio Devices", The 20th UK-Japan High Technology Industry Forum, LIFE SCIENCES, Kyoto, Japan (May 2005).

(6) K. Torimitsu, N. Kasai, A. Shimada, Y. Furukawa, C. Han, T. Nyberg, "Functional analysis of neuron and its application to nanobio device", Workshop on Neural Networks: Measurement and Adaptive Properties, Newcastle, UK (May 2005).

(7) N. Kasai, C. Han, A. Shimada, T. Nyberg, K. Torimitsu, "Multichannel electrochemical measurement for neurotransmitter distribution in a rat hippocampal slice", Workshop on Neural Networks: Measurement and Adaptive Properties, Newcastle, UK (May 2005).

(8) T. Nyberg, N. Kasai, A. Shimada, Y. Furukawa,K. Torimitsu, "Conducting polymer electrodes for interfacing to neural networks", Workshop on Neural Networks: Measurement and Adaptive Properties, Newcastle, UK (May 2005).

(9) T. Makimoto and K. Kumakura, "Npn-type Nitirde Heterojunction Bipolar Transistor", 3rd International Conference on Materials for Advanced Technologies (ICMAT-2005), J-6-IN13, Singapore (Jul. 2005).

(10) K. Torimitsu, Y. Furukawa, N. Kasai, A. Shimada, Distinguished Lecturer, International

Conference on Composites/Nano Engineering, ICCE/12, Tenerife, Spain (Aug. 2005).

(11) H. Sato, M. Naito, and A. Tsukada, "Difference in Tc for La-214 strained thin films grown by molecular beam epitaxy: assessment on the factors determining Tc", 18th International Symposium on Superconductivity (ISS2005), PC-12-INV, Tsukuba, Japan (Oct. 2005).

(12) M. Kasu, K. Ueda, H. Ye, Y. Yamauchi, S. Sasaki, and T. Makimoto, "Diamond field-effect transistors for RF power application", 1st International Diamond Conference, D-1, Barcelona, Spain (Oct. 2005).

(13) K. Torimitsu, K. Furukawa, H. Nakashima, Y. Kashimura, N. Kasai, A. Shimada and Y. Furukawa, "Neural Functions and Nanobio-interface", Japan-UK Symposium on Promotion of Regional Partnerships on Nanotechnology Development, Sapporo , Japan (Oct. 2005).

II. Physical Science Laboratory

(1) N. M. Zimmerman, A. Fujiwara, Y. Ono, H. Inokawa, Y. Takahashi, and E. Hourdakis, "The physics of Coulomb blockade in tunable barrier Si wires", International Conference on Nanoelectronics, Nanostructures, and Carrier Interaction (NNCI2005), Atsugi, Japan (Jan. 2005).

(2) T. Fujisawa, "Dynamics of single-electron charge and spin in semiconductor quantum dots", Nanometer-Scale Quantum Physics(nanoPhys'05), Tokyo, Japan (Jan. 2005).

(3) K. Semba, "Coherent control of superconducting flux qubits", 10th International Vortex Workshop, TIFR-Mumbai, India (Jan. 2005).

(4) H. Takayanagi, "Control and detection of electron and hole states in double-gated quantum wells", 2005 RCIQE International Seminar for 21C COE Program, Hokkaido, Japan (Feb. 2005).

(5) H. Takayanagi, "Advances in Science and Technology for Quantum Computing", 3rd International Symposium on Nanotechnology (JAPAN NANO 2005), Tokyo, Japan (Feb. 2005).

(6) H. Yamaguchi, S. Miyashita, and Y. Hirayama, "Low-dimensional Micro/Nanomechanical Systems", The International Conference on Nanotechnology: Science and Application (Nano Tech Insight 2005), Luxor, Egypt (Feb. 2005).

(7) Y. Hirayama, "Coherent control in semiconductor nanostructures", JSPS Japan-Germany Colloquium, Dresden, Germany (Feb. 2005).

(8) Y. Ono, A. Fujiwara, Y. Takahashi, and H. Inokawa (invited), "Silicon single-electron pump and turnstile; Interplay with crystalline imperfection", Material Research Society Spring Meeting (2005 MRS Spring meeting), San Francisco, USA (Mar. 2005).

(9) G. Yusa, K. Muraki, K. Takashina, T. Saku, K. Hashimoto, and Y. Hirayama "Self-sustaining resistance oscillations: Electron-nuclear spin coupling in mesoscopic quantum Hall devices", The American Physical Society Meeting, Los Angels, USA (Mar. 2005).

(10) T. Fujisawa, "Dynamics of single-electron charge and spin in semiconductor quantum dots", ESF-JSPS Frontier Science Conference Series (Quantum Information and Quantum Physics), Shonan, Japan. (Mar. 2005).

(11) G. Yusa, K. Muraki, K. Takashina, T. Saku, K. Hashimoto, and Y. Hirayama "Self-sustaining resistance oscillations: Electron-nuclear spin coupling in mesoscopic quantum Hall devices", The American Physical Society, Los Angels, USA (Mar. 2005).

(12) H. Takayanagi, "Readout of flux qubits", Workshop "Physics of Superconducting Phase shift Devices", Ischia, Italy (Apr. 2005).

(13) H. Takayanagi, "Japanese Policy", NSIT(Forward look in nanosciences and the long-term evolution of information technology), Paris, France (Apr. 2005).

(14) M. Uematsu, H. Kageshima, S. Fukatsu, K. M. Itoh, and K. Shiraishi, "Enhanced Si and B Diffusion in Semiconductor-Grade SiO_2 and the Effect of Strain on Diffusion", The Fourth International Conference on Silicon Epitaxy and Heterostructures (ICSI-4), Awaji, Japan (May 2005).

(15) Y. Takahashi, Y. Ono, A. Fujiwara, K. Nishiguchi, and H. Inokawa, "Silicon-based single-electron devices", Fourth International Conference on Silicon Epitaxy and Heterostructures (ICSI-4), Awaji Island, Japan (May 2005).

(16) S. Nomura, M. Yamaguchi, T. Akazaki, H. Tamura, H. Takayanagi and Y. Hirayama, "Eectron-Hole complexes in a back-gated quantum well in the fractional quantum Hall regime", 351-WE-Heraeus-Seaminar, Electron-Exciton Interaction in Semiconductor Nanostructure, Bad Honnef, Germany (May 2005).

(17) H. Takayanagi, "Nanotechnology Research Activities at NTT BRL", Conference on nanotechnology and new materials (NANOMAT), Trondheim, Norway (June 2005)

(18) H. Takayanagi, "Readout of flux qubits (Beijing)", "Recent progress in mesoscopic superconductivity"(Nanjing), 5th ICQS(International Center for Quantum Structures) Annual Workshop, Beijing & Nanjing, China (June 2005).

(19) Y. Hirayama, "Quantum information technology", Spin and Qubits 2005, Copenhagen, Denmark (June, 2005).

(20) T. Fujisawa, "Counting statistics of single-electron transport" Spin&Qubit-2005, Copenhagen, Denmark (June 2005)

(21) T. Hayashi, "Decoherence and energy relaxation in a double quantum dot", RIKEN International Nanoscience and Technology Conference, Nagano, Japan (June 2005).

(22) K. Takashina, Y. Ono, A. Fujiwara, Y. Takahashi and Y. Hirayama, "Control of valley and spatial subbands in double-gate SOI MOSFETs", Asia-Pacific Workshop on Fundamental and Application of Advanced Semiconductor Devices (AWAD 2005), Seoul, Korea (June 2005).

(23) H. Tanaka, "Superconducting flux qubits", Spin and Qubit 2005, Symposium at the Niels Bohr Institute, Copenhagen, Denmark (June 2005).

(24) M. Uematsu, "Self-diffusion and impurity diffusion in silicon dioxide", 1st International Conference on Diffusion in Solids and Liquids (DSL-2005), Aveiro, Portugal (July 2005).

(25) H. Yamaguchi, "InAs/GaAs (111)A Heterostructures", 3rd Vacuum and Surface Sciences Conference of Asia and Australia (VASSCAA-3), Singapore (July 2005).

(26) S. Hosoi, K. Nakajima, M. Suzuki, K. Kimura, Y. Shimizu1, S. Fukatsu, K. M. Itoh, M. Uematsu, H. Kageshima, and K. Shiraishi, "Oxidation of Si(001) studied by high-resolution RBS in combination with stable isotope tracing", The 17th International Conference on Ion-Surface Interactions (ISI-2005), Zvenigorod, Russia (Aug. 2005).

(27) Y. Hirayama, G. Yusa and K. Muraki, "Coherent control of nuclear spins in a mesoscopic fractional-quantum-Hall device", Awaji-island, Japan (Aug. 2005).

(28) H. Takayanagi, "Readout of flux qubits", ESF Research Conferences - Fundamental Problems of Mesoscopic Physics, Entanglement and Coherence in Nanoelectronics-, Maratea, Italy (Sep. 2005).

(29) H. Takayanagi, "Readout of supercondcuting flux qubits", VORTEX IV (VORTEX MATTER IN NANOSTRUCTURED SUPERCONDUCTORS), Crete, Greece (Sep. 2005).

(30) Y. Hirayama, "Qubits and nuclear spin polarization", 32nd Int. Symp. on Compound Semiconductors (ISCS2005), Rust, Germany (Sep. 2005).

(31) H. Nakano, "Superconducting qubits and their interaction", in International Symposium "Quantum computing 2005 Algorithms, Physical Realizations and Beyond", Higashi-Osaka, Japan (Sep. 2005).

(32) H. Takayanagi, "A Flux Qubit coupled with an external LC-Cavity", 2005 Deutschland in Japan -Tokyo Workshop Frontier Sciences-, Tokyo, Japan (Oct. 2005).

(33) H. Inokawa, Y. Ono, A. Fujiwara, K. Nishiguchi, and Y. Takahashi, " Single-Electron Devices and Circuits Based on MOS Processes," 2005 Tera-level NanoDevices (TND) Technical Forum, Seoul, Korea (Oct. 2005).

(34) Y. Ono, A. Fujiwara, Y. Takahashi, and H. Inokawa, "Single-electron manipulation Interplay with crystalline imperfection", 2nd International Symposium on Point Defect and Nonstoichiometry (ISPN-2), Kaoshiung, TaiwanSession (Oct. 2005).

(35) G. Yusa, K. Muraki, K. Takashina, K. Hashimoto, and Y. Hirayama, "Controlled multiple quantum coherences of nuclear spins in a nanometer-scale Device", 50th Magnetism and Magnetic Materials Conference (MMM2005), San Jose, USA (Oct. 2005).

(36) G. Yusa, K. Muraki, K. Takashina, K. Hashimoto, and Y. Hirayama, "Controlled multiple quantum coherences of nuclear spins in a nanometer-scale Device", 50th Magnetism and Magnetic Materials Conference, San Jose, USA (Oct. 2005).

(37) H. Tamura, "RKKY interaction and Kondo effect in double quantum-dot devices", International Workshop on Spins and Quantum Transport, Sendai, Japan (Oct. 2005).

(38) Y. Ono, "Single-electron manipulation in silicon; Towards single-dopant electronics", 7th International Conference on New Phenomena in Mesoscopic Structures and 5th International Conference on Surfaces and Interfaces of Mesoscopic Devices (NPMS-7/SIMD-5), Maui, USA (Nov. 2005).

(39) H. Yamaguchi, "Micro/Nanomechanical Quantum Electron Transport", Second Joint International Conference on New Phenomena in Mesoscopic Systemsand Surfaces and Interfaces of Mesoscopic Devices (NPMS7/SIMD5), Maui, USA (Nov. 2005).

(40) Y. Ono, A. Fujiwara, Y. Takahashi, and H. Inokawa, "Single-electron transfer in silicon", International Workshop on the Physics semiconductor devices (IWPSD 2005), Delhi, India (Dec. 2005).

(41) T. Fujisawa, "Counting statistics of single-electron transport through quantum dots",

International Semiconductor Device Research Symposium (ISDRS2005), Washinton DC, USA (Dec. 2005).

III. Optical Science Laboratory

(1) H. Nakano, K. Oguri, and T. Nishikawa, "Time-resolved measurements using ultrafast soft x-ray sources based on femtosecond laser", International Symposium on Atoms, Molecules, and Clusters in Intense Laser Fields 2 (ISAMCILS2), Tokyo, Japan (Jan. 2005).

(2) M. Notomi, A. Shinya, E. Kuramochi, S. Mitsugi, T. Tanabe, "PBG Resonator-Waveguide Coupled Systems for Optical Integration", SPIE Photonics West 2005, San Jose, USA (Jan. 2005).

(3) A. Shinya, S. Mitsugi, E. Kuramochi, T. Tanabe, G. Kim, G. Kira, S. Kondo, K. Yamada, T. Watanabe, T. Tsuchizawa, and M. Notomi, "Ultrasmall resonant tunneling/dropping devices in 2D photonic crystal slabs", SPIE Photonics West 2005, San Jose, USA (Jan. 2005).

(4) H. Nakano, K. Oguri, and T. Nishikawa, "High-order harmonic pulse characterization by femtosecond ionization dynamics of singly charged ions from rare gas", The First Asian Workshop on Generation and Applications of High-Order Harmonics, Daejeon, Korea (Feb. 2005).

(5) H. Gotoh and H. Kamada, "Exciton and Biexciton Coherent Optical Properties in Semiconductor Nanostructures", The 1st International Symposium on Nanovision Science, Hamamatsu, Japan (Feb. 2005).

(6) H. Nakano, K. Oguri, and T. Nishikawa, "Picosecond time-resolved XAFS measurements using femtosecond laser-produced plasma soft x-rays", COAST Symposium on Laser Based Ultrashort VUV and X-ray Sources and Their Applications, Tokyo, Japan (Mar. 2005).

(7) Y. Tokura, "Scattering and manipulation of electron spins in one dimensional structures", 2nd International Workshop on Spin-FET Based Quantum Information Processing (Spin_FET-QIP), Julich, Germany (Mar. 2005).

(8) A. Yokoo, "Nanoimprint technology and organic material", Third International Conference on Molecular Electronics and Bioelectronics (M&BE3), Tokyo, Japan (Mar. 2005).

(9) M. Notomi, "Dynamic Nonlinear Control of Resonator-Waveguide Coupled System in Photonic Crystal Slabs", CIPS Annual Meeting 2005, Cambridge, USA (May 2005).

(10) T. Tawara, "InGaN Cavity Polaritons", The Fifth International Conference on the Physics of Light Matter Coupling in Nanostructures," (PLMCN5), Glasgow, Scotland (June 2005).

(11) M. Notomi, T. Tanabe, A. Shinya, E. Kuramochi, S. Mitsugi, "Dynamic Nonlinear Control of Photonic Crystal Resonator-Waveguide Coupled System", International Symposium on Photonic Electromagnetic Structures (PECS-VI), Crete, Greece (June 2005).

(12) M. Notomi, T. Tanabe, A. Shinya, E. Kuramochi, S. Mitsugi, "Dynamic Nonlinear Control of Resonator-Waveguide Coupled System in Photonic Crystal Slabs", CLEO Pacific Rim 2005, Tokyo, Japan (July 2005).

(13) M. Notomi, H. Suzuki, T. Tamamura, K. Edagawa, "Organic Photonic Quasicrystal lasers: lasing action due to quasiperiodicity", SPIE Optics & Photonics 2005, San Diego, USA (July 2005).

(14) M. Yamashita and M. W. Jack, "Decoherence of spin-one bosonic atoms via linear loss", International Laser Physics Workshop (LPHYS'05), Kyoto, Japan (July 2005).

(15) H. Nakano, K. Oguri, and T. Nishikawa, "Picosecond time-resolved XAFS measurements of optically excited silicon by using femtosecond-laser-plasma soft x-rays", 14th International Laser Physics Workshop (LPHYS'05), Kyoto, Japan (July 2005).

(16) A. Yokoo, "Photonic crystal with organic functional material", The 5th International Symposium on Advanced Organic Photonics (ISAOP-5), Jena, Germany (Oct. 2005).

(17) M. Notomi, A. Shinya, E. Kuramochi, S. Mitsugi, T. Tanabe, M. Morita, "Dynamic Nonlinear Control of Resonator-Waveguide Coupled Systems in Photonic Crystals", The 18th annual meeting of the IEEE Lasers and Electro-Optics Society (LEOS 2005), Sydney, Australia (Oct. 2005).

(18) A. Shinya, S. Mitsugi, T. Tanabe, K. Kuramochi, S. Kondo, M. Notomi, I. Yokohama, H. Takara, S. Kawanishi, "All-Optical Digital Circuits using Coupled Resonator-Waveguide System in 2D Photonic Crystal Slab", The 18th annual meeting of the IEEE Lasers and Electro-Optics Society (LEOS2005), Sydney, Australia (Oct. 2005).

(19) Y. Tokura, "Electron spin resonance and two qubit operation in a slanting Zeeman field", International Argonne Fall Workshop on Nanophysics V: Nanoscale Superconductivity and Magnetism, Argonne, USA (Nov. 2005).

(20) M. Notomi, A. Shinya, E. Kuramochi, S. Mitsugi, T. Tanabe, M. Morita, "Dynamic Nonlinear Control of Resonator-Waveguide Coupled Systems in Photonic Crystals", Workshop on Photonic Crystals and Nano-Photonics, Taipei, Taiwan (Nov. 2005).

(21) H. Nakano, K. Oguri, and T. Nishikawa, "Picosecond time-resolved XAFS measurements using femtosecond laser-produced plasma soft x-rays", 2005 International Chemical Congress of Pacific Basin Society (PACIFICHEM 2005), Honolulu, USA (Dec. 2005).

List of Research Papers Published in International Journals

Materials Science Laboratory

Thin-Film Materials Research Group

1. T. Akasaka and T. Makimoto, "BGaN micro-islands as novel buffers for GaN hetero-epitaxy",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (50-52), L1506-L1508 (2005).

2. T. Akasaka, H. Gotoh, H. Nakano, and T. Makimoto, "Blue-purplish InGaN quantum wells with shallow depth of exciton localization",
Appl. Phys. Lett. **86** (19), 191902 (2005).

3. M. Kasu, K. Ueda, H. Ye, Y. Yamauchi, S. Sasaki, and T. Makimoto, "2W/mm output power density at 1 GHz for diamond FETs",
Electron. Lett. **41** (22), 1249-1250 (2005).

4. K. Kumakura and T. Makimoto, "High-voltage operation with high current gain of pnp AlGaN/GaN heterojunction bipolar transistors with thin n-type GaN base",
Appl. Phys. Lett. **86** (2), 023506 (2005).

5. K. Kumakura, T. Makimoto, N. Kobayashi, T. Hashizume, T. Fukui, and H. Hasegawa, "Minority carrier diffusion length in GaN- Dislocation density and dopoing concentration dependence",
Appl. Phys. Lett. **86** (5), 052105 (2005).

6. K. Kumakura, Y. Yamauchi, and T. Makimoto, "High power operation of Pnp AlGaN/GaN heterojunction bipolar transistors",
Phys. Stat. Sol. (c), **2** (7), 2589-2592 (2005).

7. J. Kurian, H. Sato, T. Makimoto, and M. Naito, "Silver-assisted growth of $NdBa_2Cu_3O_7$-delta thin films: An approach for the growth of superior quality ceramic oxide films",
Appl. Phys. Lett. **87** (2), 022501 (2005).

8. J. Kurian and M. Naito, "MBE growth of large area RE-123 superconductor thin films for microwave applications",
IEEE Trans. Appl. Supercond. **15** (2), 2966-2969 (2005).

9. H. S. Lee, H. J. Kim, H. J. Kim, M. H. Jung, Y. Jo, S. I. Lee, A. Tsukada, and M. Naito, "Three-dimensional superconductivity of the structurally two-dimensional superconductor $La_{1.87}Y_{0.13}CuO_4$: study of an angle-dependent critical current density",
Supercond. Sci. Technol. **18** (7), 944-947 (2005).

10. N. Maeda, T. Makimura, T. Maruyama, C. X. Wang, M. Hiroki, H. Yokoyama, T. Makimoto, T. Kobayashi, and T. Enoki, "DC and RF characteristics in Al_2O_3/Si_3N_4 insulated-gate AlGaN/GaN heterostructure field-effect transistors",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (20-23), L646-L648 (2005).

11. N. Maeda, T. Makimura, C. X. Wang, M. Hiroki, T. Makimoto, T. Kobayashi, and T. Enoki, "Al_2O_3/Si_3N_4 Insulated Gate Channel-doped AlGaN/GaN Heterostructure Field-Effect Transistors with Regrown Ohmic Structure: Low Gate Leakage Current with High Transconductance",
Jpn. J. Appl. Phys. Part 1 – Regul. Pap. Short Notes Rev. Pap. **44** (4B), 2747-2750, (2005).

12. N. Maeda, C. X. Wang, T. Enoki, T. Makimoto, and T. Tawara, "High drain current density and reduced gate leakage current in channel-doped AlGaN/GaN heterostructure field-effect transistors with Al_2O_3/Si_3N_4 gate insulator",
Appl. Phys. Lett., **87** (7), 073504 (2005).

13. T. Makimoto, Y. Yamauchi, T. Kido, K. Kumakura, Y. Taniyasu, M. Kasu, and N. Matsumoto, "Strained Thick p-InGaN Layers for GaN/InGaN Heterojunction Bipolar Transistors on Sapphire Substrates",
Jpn. J. Appl. Phys. Part 1 – Regul. Pap. Short Notes Rev. Pap. **44** (4B), 2722-2725 (2005).

14. T. Matsuoka, "Progress in nitride semiconductors from GaN to InN - MOVPE growth and characteristics",
Superlattices Microstruct. **37** (1), 19-32 (2005).

15. T. Mitate, S. Mizuno, H. Takahata, R. Kakegawa, T. Matsuoka, and N. Kuwano, "InN polarity determination by convergent-beam electron diffraction",
Appl. Phys. Lett. **86** (13), 134103 (2005).

16. A. Nishikawa, K. Kumakura, T. Akasaka, and T. Makimoto, "Current-voltage characteristics of p-InGaN/n-GaN vertical conducting diodes on n^+-SiC substrates",
Appl. Phys. Lett. **87** (23), 233505 (2005).

17. M. Noda, A. Tsukada, H. Yamamoto, and M. Naito, "Origin of superconducting carriers in "non-doped" T'-(La,RE)(2)CuO_4 (RE = Sm, Eu, Gd, Tb, Lu, and Y) prepared by molecular beam epitaxy",
Physica C **426**, 220-224 (2005).

18. H. Oyanagi, N. L. Saini, A. Tsukada, and M. Naito, "Lattice anomalies in (La,Sr)(2)CuO_4 under epitaxial strain probed by polarized X-ray absorption spectroscopy",
J. Supercond. **18** (5-6), 731-735 (2005).

19. H. Sato and J. Kurian, "Superconducting bandpass filters on thin films of $NdBa_2Cu_3O_7$",
Physica C **426**, 1616-1621 (2005).

20. A. Tsukada, H. Yamamoto, and M. Naito, "Ce doping in T-La_2CuO_4 films: Broken electron-hole symmetry for high-T-c superconductivity",
Physica C **426**, 454-458 (2005).

21. A. Tsukada, M. Noda, H. Yamamoto, and M. Naito, "Role of impurity oxygen in superconductivity of "non-doped" T '-(La, RE)(2)CuO_4",
Physica C **426**, 459-463 (2005).

22. A. Tsukada, Y. Krockenberger, M. Noda, H. Yamarnoto, D. Manske, L. Alff, and M. Naito, "New class of T '-structure cuprate superconductors",
Solid State Commun. **133** (7), 427-431 (2005).

23. K. Ueda, S. Saito, K. Semba, T. Makimoto, and M. Naito, "All-MgB_2 Josephson tunnel junctions", Appl. Phys. Lett. **86** (17), 172502 (2005).

24. C. X. Wang, N. Maeda, M. Hiroki, T. Tawara, T. Makimoto, T. Kobayashi, and T. Enoki, "Comparison of AlGaN/GaN insulated gate heterostructure field-effect transistors with ultrathin Al_2O_3/Si_3N_4 bilayer and Si_3N_4 single layer",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Short Notes Rev. Pap. **44** (4B), 2735-2738 (2005).

25. H. T. Ye, H. X. Yan, and R. B. Jackman, "Dielectric properties of single crystal diamond",
Semicond. Sci. Technol. **20** (3), 296-298 (2005).

Low-Dimensional Nanomaterials Research Group

1. P. Finnie, Y. Homma, and J. Lefebvre, "Band-gap shift transition in the photoluminescence of single-walled carbon nanotubes",
Phys. Rev. Lett. **94** (24), 247401 (2005).

2. S. Fujikawa, T. Kawamura, S. Bhunia, Y. Watanabe, K. Tokushima, Y. Tsusaka, Y. Kagoshima, and J. I. Matsui, "Real-time observation of fractional-order x-ray reflection profiles of InP(001) during step-flow growth",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (1-7), L144-L146 (2005).

3. H. Hibino, Y. Watanabe, C. W. Hu, and I. S. T. Tsong, "Thermal decay of superheated 7 x 7 islands and supercooled "1 x 1" vacancy islands on Si(111) ",
Phys. Rev. B **72** (24), 245424 (2005).

4. H. Hibino and Y. Watanabe, "Arrangement of Au-Si alloy islands at atomic steps",

Surf. Sci. **588** (1-3), L233-L238 (2005).

5. H. Hibino and Y. Watanabe, "Growth of twinned epitaxial layers on Si(111)root 3x root 3-B studied by low-energy electron microscopy",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Short Notes Rev. Pap. **44** (1A), 358-364 (2005).

6. Y. Homma, D. Takagi, S. Suzuki, K. Kanzaki, and Y. Kobayashi, "Electron-microscopic imaging of single-walled carbon nanotubes grown on silicon and silicon oxide substrates",
J. Electron Microsc. **54**, I3-I7 (2005).

7. Y. Homma, "Summary of ISO/TC 201 standard: X ISO 17560: 2002 - Surface chemical analysis - Secondary ion mass spectrometry - Method for depth profiling of boron in silicon",
Surf. Interface Anal. **37** (1), 90-91 (2005).

8. G. H. Jeong, S. Suzuki, Y. Kobayashi, A. Yamazaki, H. Yoshimura, and Y. Homma, "Effect of nanoparticle density on narrow diameter distribution of carbon nanotubes and particle evolution during chemical vapor deposition growth",
J. Appl. Phys. **98** (12), 124311 (2005).

9. G. H. Jeong, A. Yamazaki, S. Suzuki, H. Yoshimura, Y. Kobayashi, and Y. Homma, "Cobalt-filled apoferritin for suspended single-walled carbon nanotube growth with narrow diameter distribution",
J. Am. Chem. Soc. **127** (23), 8238-8239 (2005).

10. A. Kaneko, Y. Homma, H. Hibino, and T. Ogino, "Ultrahigh vacuum scanning electron microscope system combined with wide-movable scanning tunneling microscope",
Rev. Sci. Instrum. **76** (8), 083709 (2005).

11. T. Kawamura, S. Bhunia, Y. Watanabe, S. Fujikawa, J. Matsui, Y. Kagoshima, and Y. Tsusaka, "High-resolution x-ray diffraction analysis of epitaxially grown indium phosphide nanowires",
J. Appl. Phys. **97** (8), 084318 (2005).

12. T. Matsumoto, Y. Homma, and Y. Kobayashi, "Bridging growth of single-walled carbon nanotubes on nanostructures by low-pressure hot-filament chemical vapor deposition",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (10), 7709-7712 (2005).

13. H. Omi and Y. Homma, "Self-ordering on vicinal Si(111) during molecular beam epitaxy",
Phys. Rev. B **72** (19), 195322 (2005).

14. H. Omi, Y. Homma, V. Tonchev, and A. Pimpinelli, "New types of unstable step-flow growth on Si(111)-(7 x 7) during molecular beam epitaxy: Scaling and universality", Phys. Rev. Lett. **95** (21), 216101 (2005).

15. H. Omi, T. Kawamura, S. Fujikawa, Y. Tsusaka, Y. Kagoshima, and J. Matsui, "In-plane strain distribution in the surface region of thin silicon overlayers on insulator", Appl. Phys. Lett. **86** (26), 263112 (2005).

16. V. Peano, M. Thorwart, A. Kasper, and R. Egger, "Nanoscale atomic waveguides with suspended carbon nanotubes", Appl. Phys. B-Lasers Opt. **81** (8), 1075-1080 (2005).

17. S. Suzuki and Y. Kobayashi, "Conductivity decrease in carbon nanotubes caused by low-acceleration-voltage electron irradiation", Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (46-49), L1498-L1501 (2005).

18. S. Suzuki, Y. Watanabe, Y. Homma, S. Y. Fukuba, A. Locatelli, and S. Heun, "Photoemission electron microscopy of individual single-walled carbon nanotubes", J. Electron Spectrosc. Relat. Phenom. **144**, 357-360 (2005).

19. S. Suzuki, H. Yamamoto, F. Maeda, Y. Watanabe, K. Yamada, and T. Kiyokura, "Beamline for angle-resolved photoemission spectroscopy at low-temperature constructed at NTT Atsugi R&D Center", J. Electron Spectrosc. Relat. Phenom. **144**, 1109-1112 (2005).

20. S. Suzuki, D. Takagi, Y. Homma, and Y. Kobayashi, "Selective removal of carbon nanotubes utilizing low-acceleration-voltage electron irradiation damage", Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (1-7), L133-L135 (2005).

21. D. Takagi, Y. Homma, S. Suzuki, and Y. Kobayashi, "Vertical growth of individual single-walled carbon nanotubes on silicon and SiO2 substrates", Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Short Notes Rev. Pap. **44** (4A), 1564-1568 (2005).

22. A. Vijayaraghavan, K. Kanzaki, S. Suzuki, Y. Kobayashi, H. Inokawa, Y. Ono, S. Kar, and P. M. Ajayan, "Metal-semiconductor transition in single-walled carbon nanotubes induced by low-energy electron irradiation", Nano Lett. **5** (8), 1575-1579 (2005).

23. T. Yamazaki, S. Ohmi, S. Morita, H. Ohri, J. Murota, M. Sakuraba, H. Omi, and T. Sakai, "Separation by bonding Si islands (SBSI) for advanced CMOS LSI applications", IEICE Trans. Electron. **E88C** (4), 656-661 (2005).

24. T. Yamazaki, S. Ohmi, S. Morita, H. Ohri, J. Murota, M. Sakuraba, H. Omi, Y. Takahashi, and T. Sakai, "Separation by bonding Si islands (SBST) for LSI applications",
Mater. Sci. Semicond. Process **8** (1-3), 59-63 (2005).

Molecular and Bio Science Research Group

1. I. Bosanac, H. Yamazaki, T. Matsu-ura, T. Michikawa, K. Mikoshiba, and M. Ikura, "Crystal structure of the ligand binding suppressor domain of type 1 inositol 1,4,5-trisphosphate receptor",
Mol. Cell **17** (2), 193-203 (2005).

2. A. Fontes, K. Ajito, A. A. R. Neves, W. L. Moreira, A. A. de Thomaz, L. C. Barbosa, A. M. de Paula, and C. L. Cesar, "Raman, hyper-Raman, hyper-Rayleigh, two-photon luminescence and morphology-dependent resonance modes in a single optical tweezers system",
Phys. Rev. E **72** (1), 012903 (2005).

3. C. X. Han, N. Kasai, and K. Torimitsu, "Apoptosis induced by bicuculline involves the P/Q-type voltage-dependent calcium channel in rat hippocampal slice cultures",
Epilepsia **46**, 11-11 (2005).

4. C. X. Han, N. Kasai, and K. Torimitsu, "CA2: the most vulnerable sector to bicuculline exposure in rat hippocampal slice cultures",
Neuroreport **16** (4), 333-336 (2005).

5. W. P. Hu, H. Nakashima, K. Furukawa, Y. Kashimura, K. Ajito, Y. Q. Liu, D. B. Zhu, and K. Torimitsu, "A self-assembled nano optical switch and transistor based on a rigid conjugated polymer, thioacetyl-end-functionalized poly(para-phenylene ethynylene)",
J. Am. Chem. Soc. **127** (9), 2804-2805 (2005).

6. M. Iwai, Y. Tateishi, M. Hattori, A. Mizutani, T. Nakamura, A. Futatsugi, T. Inoue, T. Furuichi, T. Michikawa, and K. Mikoshiba, "Molecular cloning of mouse type 2 and type 3 inositol 1,4,5-trisphosphate receptors and identification of a novel type 2 receptor splice variant",
J. Biol. Chem. **280** (11), 10305-10317 (2005).

7. N. Kasai, C. X. Han, and K. Torimitsu, "Hydrogen peroxide distribution and neuronal cell death in a rat hippocampal slice",
Sens. Actuator B-Chem. **108** (1-2), 746-750 (2005).

8. H. Nakashima, K. Furukawa, K. Ajito, Y. Kashimura, and K. Torimitsu, "Selective chemisorption of end-functionalized conjugated polymer on macro- and nanoscale-surfaces",

Langmuir **21** (2), 511-515 (2005).

9. Z. H. Zhang, K. Sumitomo, and F. Lin, "Observation of B segregation on Si(113) by scanning tunneling microscopy",
Ultramicroscopy **105** (1-4), 16-21 (2005).

10. Z. H. Zhang and K. Sumitomo, "Boronizing structures of Si(113) surfaces",
Surf. Sci. **576** (1-3), 83-88 (2005).

Physical ScienceLaboratory

Nanodevices Research Group

1. T. Akiyama, H. Kageshima, M. Uematsu, and T. Ito, "Theoretical investigation of oxygen diffusion in compressively strained high-density alpha-quartz",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (10), 7427-7429 (2005).

2. T. Akiyama and H. Kageshima, "Reaction mechanisms of oxygen at SiO_2/Si(100) interface",
Surf. Sci. **576** (1-3), L65-L70 (2005).

3. Z. A. Burhanudin, R. Nuryadi, Y. Ishikawa, M. Tabe, and Y. Ono, "Thermally-induced formation of Si wire array on an ultrathin (111) silicon-on-insulator substrate",
Appl. Phys. Lett. **87** (12), 121905 (2005).

4. N. Clement and H. Inokawa, "Foundry metal-oxide-semiconductor field-effect-transistor electrometer for single-electron detection",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (7A), 4855-4858 (2005).

5. Y. Ono, K. Nishiguchi, H. Inokawa, S. Horiguchi, and Y. Takahashi, "Charge-state control of phosphorus donors in silicon-on-insulator metal-oxide-semiconductor field-effect transistor",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Short Notes Rev. Pap. **44** (4B), 2588-2591 (2005).

6. Y. Ono, A. Fujiwara, K. Nishiguchi, H. Inokawa, and Y. Takahashi, "Manipulation and detection of single electrons for future information processing",
J. Appl. Phys. **97** (3), 031101 (2005).

7. M. Tsuda, H. Arai, M. Takahashi, H. Ohtsuka, Y. Sakurai, K. Sumitomo, and H. Kageshima, "Electrode performance of layered $LiNi_{0.5}Ti_{0.5}O_2$ prepared by ion exchange",

J. Power Sources **144** (1), 183-190 (2005).

8. K. Uchida, H. Kageshima, and H. Inokawa, "Charge-injection effects in a single 4,4 "-terphenyldithiol molecule",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (12), 8759-8763 (2005).

9. M. Uematsu, H. Kageshima, and K. Shiraishi, "Effect of nitrogen on diffusion in silicon oxynitride",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (11), 7756-7759 (2005).

10. M. Uematsu, "Self-diffusion and impurity diffusion in silicon dioxide",
J. Phase Equilib. Diffus. **26** (5), 547-554 (2005).

11. M. Uematsu, "Unified simulation of diffusion in silicon and silicon dioxide", in *Diffusion In Materials: Dimat 2004, Pt 1and 2*, Defect And Diffusion Forum Vol. 237-240 (Trans Tech Publications Ltd, Zurich-Uetikon, 2005), pp. 38-49.

Nanostructure Technology Research Group

1. Y. Furukawa, K. Hoshina, K. Yamanouchi, and H. Nakano, "Ejection of triatomic hydrogen molecular ion from methanol in intense laser fields",
Chem. Phys. Lett. **414** (1-3), 117-121 (2005).

2. M. Nagase, K. Nakamatsu, S. Matsui, and H. Namatsu, "Carbon multiprobes with nanosprings integrated on Si cantilever using focused-ion-beam technology",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (7B), 5409-5412 (2005).

3. K. Nakamatsu, M. Nagase, J. Y. Igaki, H. Namatsu, and S. Matsui, "Mechanical characteristics and its annealing effect of diamondlike-carbon nanosprings fabricated by focused-ion-beam chemical vapor deposition",
J. Vac. Sci. Technol. B **23** (6), 2801-2805 (2005).

4. K. Nakamatsu, M. Nagase, H. Namatsu, and S. Matsui, "Mechanical characteristics of diamond-like-carbon nanosprings fabricated by focused-ion-beam chemical vapor deposition",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (37-41), L1228-L1230 (2005).

5. K. Nakamatsu, K. Watanabe, K. Tone, H. Namatsu, and S. Matsui, "Nanoimprint and nanocontact technologies using hydrogen silsesquioxane",
J. Vac. Sci. Technol. B **23** (2), 507-512 (2005).

6. H. Namatsu and M. Sato, "Supercritical improvement of resist patterns by introducing

functional molecules",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (1-7), L227-L229 (2005).

7. K. Nishiguchi, O. Crauste, H. Namatsu, S. Horiguchi, Y. Ono, A. Fujiwara, Y. Takahashi, and H. Inokawa, "Back-gate effect on Coulomb blockade in silicon-on-insulator trench wires",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (10), 7717-7719 (2005).

8. Y. Ohminami, S. Suzuki, N. Matsudaira, T. Nomura, W. J. Chun, K. Ijima, M. Nakamura, K. Mukasa, M. Nagase, and K. Asakura, "Preparation and characterization of a microfabricated oxide-on-oxide catalyst of alpha-Sb_2O_4/$VSbO_4$",
Bull. Chem. Soc. Jpn. **78** (3), 435-442 (2005).

9. H. Okamoto, T. Yamada, H. Miyazaki, T. Nakanishi, K. Takeda, K. Usui, I. Obataya, H. Mihara, H. Azehara, W. Mizutani, K. Hashimoto, H. Yamaguchi, and Y. Hirayama, "Difference in self-assembling morphology of peptide nanorings",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (11), 8240-8248 (2005).

10. H. Okamoto, T. Akazaki, M. Ueki, and H. Yamaguchi, "Strongly enhanced sensitivity of piezoresistive cantilevers by utilizing the superconducting proximity effect",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (28-32), L893-L895 (2005).

11. T. Sakata, H. Ishii, Y. Okabe, M. Nagase, T. Kamei, K. Kudou, M. Yano, and K. Machida, "Anti-sticking effect of organic dielectric formed by electrodeposition in microelectromechanical-system structures",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (7B), 5732-5735 (2005).

12. T. Shimura, K. Yasutake, M. Umeno, and M. Nagase, "X-ray diffraction measurements of internal strain in Si nanowires fabricated using a self-limiting oxidation process",
Appl. Phys. Lett. **86** (7), 071903 (2005).

13. H. Yamaguchi, A. K. Das, A. Ney, T. Hesjedal, C. Pampuch, D. M. Schaadt, and R. Koch, "From ferro- to antiferromagnetism via exchange-striction of MnAs/GaAs(001)",
Europhys. Lett. **72** (3), 479-485 (2005).

14. H. Yamaguchi, S. Miyashita, and Y. Hirayama, "Force/displacement detection using quantum effects in InAs/$Al_{0.5}Ga_{0.5}Sb$ two-dimensional electron systems", in *Compound Semiconductors 2004, Proceedings*, Institute Of Physics Conference Series Vol. 184 (Iop Publishing Ltd, Bristol, 2005), pp. 187-192.

15. H. Yamaguchi, Y. Hirayama, S. Miyashita, and S. Ishihara, "Force/displacement detection using quantum transport in InAs/AlGaSb two-dimensional heterostructures",

Appl. Phys. Lett. **86** (5), 052106 (2005).

16. T. Yamaguchi and H. Namatsu, "Graphoepitaxy of diblock copolymer on micropatterned substrates",
J. Photopolym Sci. Technol. **18** (3), 421-423 (2005).

Quantum Solid State Physics Research Group

1. D. G. Austing, R. J. A. Hill, A. Patane, P. C. Main, M. Henini, L. Eaves, and S. Tarucha, "Transport properties of gated sub-micron mesas incorporating InAs self-assembled quantum dots that conduct near zero bias",
Physica E **26** (1-4), 482-485 (2005).

2. W. R. Clarke, A. P. Micolich, A. R. Hamilton, M. Y. Simmons, K. Muraki, and Y. Hirayama, "Fabrication and characterization of a 2D hole system a in novel (311)A GaAsSISFET",
Microelectron. J. **36** (3-6), 327-330 (2005).

3. N. Goel, J. Graham, J. C. Keay, K. Suzuki, S. Miyashita, M. B. Santos, and Y. Hirayama, "Ballistic transport in InSb mesoscopic structures",
Physica E **26** (1-4), 455-459 (2005).

4. K. Hashimoto, K. Muraki, N. Kumada, T. Saku, and Y. Hirayama, "Effects of inversion asymmetry on electron-nuclear spin coupling in semiconductor heterostructures: Possible role of spin-orbit interactions",
Phys. Rev. Lett. **94** (14), 146601 (2005).

5. H. Ishizaki, T. Akiyama, K. Nakamura, K. Shiraishi, A. Taguchi, and T. Ito, "Theoretical investigation of phase transition on GaAs(001)-c(4 x 4) surface",
Appl. Surf. Sci. **244** (1-4), 186-189 (2005).

6. T. Ito, K. Asano, T. Akiyama, K. Nakamura, K. Shiraishi, and A. Taguchi, "An ab initio-based approach to Ga adatom migration on GaAs(n 1 1)A-(001) non-planar surfaces",
Appl. Surf. Sci. **244** (1-4), 178-181 (2005).

7. K. Iwata, M. Morino, M. Suzuki, A. Fukuda, A. Sawada, Z. F. Ezawa, N. Kumada, and Y. Hirayama, "Anisotropic magnetotransport around the v=1 bilayer quantum Hall state",
J. Phys. Chem. Solids **66** (8-9), 1556-1559 (2005).

8. N. Kumada, K. Muraki, K. Hashimoto, and Y. Hirayama, "Spin degree of freedom in the nu=1 bilayer electron system investigated by nuclear spin relaxation",
Phys. Rev. Lett. **94** (9), 096802 (2005).

9. H. W. Liu, T. Fujisawa, T. Hayashi, and Y. Hirayama, "Pauli spin blockade in cotunneling transport through a double quantum dot",
Phys. Rev. B **72** (16), 161305 (2005).

10. K. Onomitsu, H. Fukui, T. Maeda, Y. Hirayama, and Y. Horikoshi, "Spatially separated Mn and Be doping for high hole concentration in GaMnAs by using MEE",
J. Cryst. Growth **278** (1-4), 699-703 (2005).

11. S. Sasaki, T. Fujisawa, T. Hayashi, and Y. Hirayama, "Electrical pump-and-probe study of spin singlet-triplet relaxation in a quantum dot",
Phys. Rev. Lett. **95** (5), 056803 (2005).

12. S. Sasaki and S. Tarucha, "The Kondo effect enhanced by state degeneracy",
J. Phys. Soc. Jpn. **74** (1), 88-94 (2005).

13. A. Taguchi, "First-principles investigations of Ga and As adsorption properties on a GaAs(110) surface", in *Compound Semiconductors 2004, Proceedings*, Institute Of Physics Conference Series Vol. 184 (Iop Publishing Ltd, Bristol, 2005), pp. 345-348.

14. A. Taguchi, "First-principles investigations of surface reconstructions of an InAs(111)B surface",
J. Cryst. Growth **278** (1-4), 468-472 (2005).

15. A. Taguchi, H. Kageshima, and K. Wada, "First-principles investigations of nitrogen-doping effects on defect aggregation processes in Czochralski Si",
J. Appl. Phys. **97** (5), 053514 (2005).

16. A. Taguchi and K. Shiraishi, "Surface reconstructions and stabilizing mechanism of the GaAs(311)A surface",
Phys. Rev. B **71** (3), 035349 (2005).

17. D. Terasawa, S. Kozumi, A. Fukuda, A. Sawada, Z. F. Ezawa, N. Kumada, and Y. Hirayama, "Pseudospin domain of v=1 double-layer quantum Hall state near commensurate-incommensurate transition",
J. Phys. Chem. Solids **66** (8-9), 1560-1562 (2005).

18. G. Yusa, K. Hashimoto, K. Muraki, T. Saku, and Y. Hirayama, "Resistance oscillations by electron-nuclear spin coupling in microscopic quantum Hall devices",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Short Notes Rev. Pap. **44** (4B), 2669-2671 (2005).

19. G. Yusa, K. Muraki, K. Takashina, K. Hashimoto, and Y. Hirayama, "Controlled multiple quantum coherences of nuclear spins in a nanometre-scale device,"
Nature **434** (7036), 1001-1005 (2005).

Superconducting Quantum Physics Research Group

1. P. Bertet, I. Chiorescu, G. Burkard, K. Semba, Cjpm Harmans, D. P. DiVincenzo, and J. E. Mooij, "Dephasing of a superconducting qubit induced by photon noise", Phys. Rev. Lett. **95** (25), 257002 (2005).

2. B. Chesca, M. Seifried, T. Dahm, N. Schopohl, D. Koelle, R. Kleiner, and A. Tsukada, "Observation of Andreev bound states in bicrystal grain-boundary Josephson junctions of the electron-doped superconductor $La_{2-x}Ce_xCuO_{4-y}$", Phys. Rev. B **71** (10), 104504 (2005).

3. T. Kutsuzawa, H. Tanaka, S. Saito, H. Nakano, K. Semba, and H. Takayanagi, "Coherent control of a flux qubit by phase-shifted resonant microwave pulses", Appl. Phys. Lett. **87** (7), 073501 (2005).

Spintronics Research Group

1. T. Akazaki, H. Nakano, J. Nitta, and H. Takayanagi, "Observation of enhanced thermal noise due to multiple Andreev reflection in ballistic InGaAs-based superconducting weak links", Appl. Phys. Lett. **86** (13), 132505 (2005).

2. Y. Asari, K. Takeda, and H. Tamura, "New shell structures and their ground electronic states in spherical quantum dots (II) under magnetic field", Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Short Notes Rev. Pap. **44** (4A), 2043-2052 (2005).

3. T. Bauch, E. Hurfeld, V. M. Krasnov, R. Delsing, H. Takayanagi, and T. Akazaki, "Correlated quantization of supercurrent and conductance in a superconducting quantum point contact", Phys. Rev. B **71** (17), 174502 (2005).

4. B. R. Choi, A. E. Hansen, T. Kontos, C. Hoffmann, S. Oberholzer, W. Belzig, C. Schonenberger, T. Akazaki, and H. Takayanagi, "Shot-noise and conductance measurements of transparent superconductor/two-dimensional electron gas junctions", Phys. Rev. B **72** (2), 024501 (2005).

5. M. Kawamura, H. Yaguchi, N. Kikugawa, Y. Maeno, and H. Takayanagi, "Tunneling properties at the interface between superconducting Sr_2RuO_4 and a Ru microinclusion", J. Phys. Soc. Jpn. **74** (2), 531-534 (2005).

6. V. M. Krasnov, T. Bauch, S. Intiso, E. Hurfeld, T. Akazaki, H. Takayanagi, and P. Delsing, "Collapse of thermal activation in moderately damped Josephson junctions", Phys. Rev. Lett. **95** (15), 157002 (2005).

7. Y. P. Lin, T. Koga, and J. Nitta, "Effect of an InP/$In_{0.53}Ga_{0.47}As$ interface on spin-orbit interaction in $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ heterostructures",
Phys. Rev. B **71** (4), 045328 (2005).

8. F. E. Meijer, A. F. Morpurgo, T. M. Klapwijk, and J. Nitta, "Universal spin-induced time reversal symmetry breaking in two-dimensional electron gases with Rashba spin-orbit interaction",
Phys. Rev. Lett. **94** (18), 186805 (2005).

9. A. K. M. Newaz, W. Song, E. E. Mendez, Y. Lin, and J. Nitta, "Shot-noise characteristics of triple-barrier resonant-tunneling diodes",
Phys. Rev. B **71** (19), 195303 (2005).

10. J. Nitta and M. Steiner, "Magnetization properties of microstructured NiFe rings investigated using semiconductor/ferromagnet hybrid structures",
J. Supercond. **18** (3), 331-334 (2005).

11. J. Nitta and M. Steiner, "Semiconductor/ferromagnet hybrid devices to probe magnetisation states in microstructured NiFe rings",
IEE Proc.-Circuit Device Syst. **152** (4), 297-300 (2005).

12. J. Ohe, M. Yamamoto, T. Ohtsuki, and J. Nitta, "Mesoscopic Stern-Gerlach spin filter by nonuniform spin-orbit interaction",
Phys. Rev. B **72** (4), 041308 (2005).

13. A. Richter, K. Matsuda, T. Akazaki, T. Saku, H. Tamura, Y. Hirayama, and H. Takayanagi, "Transport properties of a lateral semiconductor quantum dot defined by a single connected metallic front-gate",
Physica E **25** (4), 472-478 (2005).

14. H. Tamura and L. Glazman, "Tunable Kondo screening in a quantum dot device",
Phys. Rev. B **72** (12), 121308 (2005).

15. M. Yamaguchi, S. Nomura, D. Sato, T. Akazaki, H. Tamura, and H. Takayanagi, "Photoluminescence measurements in Be-delta-doped back-gated quantum well",
Surf. Sci. **583** (1), 94-99 (2005).

16. M. Yamamoto, J. Ohea, T. Ohtsuki, J. Nitta, and B. Kramer, "Spin-polarization in a 3-terminal conductor induced by Rashba spin-orbit coupling",
Physica E **29** (3-4), 490-494 (2005).

Optical Science Laboratory

Quantum Optical State Control Research Group

1. E. Diamanti, H. Takesue, T. Honjo, K. Inoue, and Y. Yamamoto, "Performance of various quantum-key-distribution systems using 1.55-mu m up-conversion single-photon detectors",
Phys. Rev. A **72** (5), 052311 (2005).

2. T. Honjo and K. Inoue, "Plug & play quantum key distribution using modulation sidebands for shifting frequency",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (9A), 6550-6552 (2005).

3. K. Inoue and T. Honjo, "Robustness of differential-phase-shift quantum key distribution against photon-number-splitting attack",
Phys. Rev. A **71** (4), 042305 (2005).

4. K. Inoue, "Quantum key distribution using a series of quantum correlated photon pairs",
Phys. Rev. A **71** (3), 032301 (2005).

5. A. Ishizawa and H. Nakano, "Fluctuation of the carrier-envelope phase of a few-cycle laser pulse from a chirped-pulse amplification system with the gas pressure in a hollow fiber",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (8), 6039-6041 (2005).

6. Y. Katagiri, H. Takesue, and E. Hashimoto, "Wavelength-scanning optical bandpass filters based on optomechatronics for optical-frequency sweepers",
IEEE Trans. Ind. Electron. **52** (4), 992-1004 (2005).

7. T. Kubo and Y. Tokura, "Electron transport in magnetic-field-induced quasi-one-dimensional electron systems in semiconductor nanowhiskers",
Physica E **29** (3-4), 525-529 (2005).

8. T. Kubo and Y. Tokura, "Many-body effects on tunneling of electrons in magnetic-field-induced quasi-one-dimensional electron systems in semiconductor nanowhiskers",
J. Phys. Soc. Jpn. **74** (2), 519-522 (2005).

9. M. W. Jack and M. Yamashita, "Maximal entanglement of two spinor Bose-Einstein condensates",
Phys. Rev. A **71** (3), 033619 (2005).

10. M. W. Jack and M. Yamashita, "Bose-Hubbard model with attractive interactions", Phys. Rev. A **71** (2), 023610 (2005).

11. C. Langrock, E. Diamanti, R. V. Roussev, Y. Yamamoto, M. M. Fejer, and H. Takesue, "Highly efficient single-photon detection at communication wavelengths by use of upconversion in reverse-proton-exchanged periodically poled LiNbO3 waveguides", Opt. Lett. **30** (13), 1725-1727 (2005).

12. K. Maruyama, F. Morikoshi, and V. Vedral, "Thermodynamical detection of entanglement by Maxwell's demons", Phys. Rev. A **71** (1), 012108 (2005).

13. H. Oberst, Y. Tashiro, K. Shimizu, and F. Shimizu, "Quantum reflection of H* on silicon", Phys. Rev. A **71** (5), 052901 (2005).

14. H. Oberst, D. Kouznetsov, K. Shimizu, J. Fujita, and F. Shimizu, "Fresnel diffraction mirror for an atomic wave", Phys. Rev. Lett. **94** (1), 013203 (2005).

15. H. Takesue, E. Diamanti, T. Honjo, C. Langrock, M. M. Fejer, K. Inoue, and Y. Yamamoto, "Differential phase shift quantum key distribution experiment over 105km fibre", New J. Phys. **7**, 232 (2005).

16. H. Takesue and K. Inoue, "Generation of 1.5-mu m band time-bin entanglement using spontaneous fiber four-wave mixing and planar light-wave circuit interferometers", Phys. Rev. A **72** (4), 041804 (2005).

17. H. Takesue and K. Inoue, "1.5-mu m band quantum-correlated photon pair generation in dispersion-shifted fiber: suppression of noise photons by cooling fiber", Opt. Express **13** (20), 7832-7839 (2005).

18. H. Takesue, K. Inoue, O. Tadanaga, Y. Nishida, and M. I. Asobe, "Generation of pulsed polarization-entangled photon pairs in a 1.55-mu m band with a periodically poled lithium niobate waveguide and an orthog onal polarization delay circuit", Opt. Lett. **30** (3), 293-295 (2005).

19. Y. Tokunaga, T. Yamamoto, M. Koashi, and N. Imoto, "Simple experimental scheme of preparing a four-photon entangled state for the teleportation-based realization of a linear optical controlled-NOT gate", Phys. Rev. A **71** (3), 030301 (2005).

20. B. Y. Zhang, G. S. Solomon, M. Pelton, J. Plant, C. Santori, J. Vuckovic, and Y. Yamamoto, "Fabrication of InAs quantum dots in AlAs/GaAs DBR pillar

microcavities for single photon sources",
J. Appl. Phys. **97** (7), 073507 (2005).

Quantum Optical Physics Research Group

1. N. I. Cade, H. Gotoh, H. Kamada, T. Tawara, T. Sogawa, H. Nakano, and H. Okamoto, "Charged exciton emission at 1.3 μm from single InAs quantum dots grown by metalorganic chemical vapor deposition",
Appl. Phys. Lett. **87** (17), 172101 (2005).

2. H. Gotoh, T. Akasaka, T. Tawara, Y. Kobayashi, T. Makimoto, and H. Nakano, "Efficient observation of narrow isolated photoluminescence spectra from spatially localized excitons in InGaN quantum wells",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (42-45), L1381-L1384 (2005).

3. H. Gotoh, H. Kamada, H. Nakano, T. Saitoh, H. Ando, and J. Temmyo, "Optical nonlinearity induced by exciton-biexciton coherent effects in InGaAs quantum dots",
Appl. Phys. Lett. **87** (10), 102101 (2005).

4. H. Gotoh, H. Kamada, T. Saitoh, H. Ando, and J. Temmyo, "Exciton absorption properties of coherently coupled exciton-biexciton systems in quantum dots",
Phys. Rev. B **71** (19), 195334 (2005).

5. T. Hattori, T. Yogi, Y. Hama, N. Watanabe, and R. Yano, "Chirp control of free carrier injection in GaAs using femtosecond optical pulses",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (8), 6101-6104 (2005).

6. S. Hughes, "Modified spontaneous emission and qubit entanglement from dipole-coupled quantum dots in a photonic crystal nanocavity",
Phys. Rev. Lett. **94** (22), 227402 (2005).

7. S. Hughes, "Quantum emission dynamics from a single quantum dot in a planar photonic crystal nanocavity",
Opt. Lett. **30** (11), 1393-1395 (2005).

8. S. Hughes, L. Ramunno, J. F. Young, and J. E. Sipe, "Extrinsic optical scattering loss in photonic crystal waveguides: Role of fabrication disorder and photon group velocity",
Phys. Rev. Lett. **94** (3), 033903 (2005).

9. A. Nakamura, J. Ishihara, S. Shigemori, K. Yamamoto, T. Aoki, H. Gotoh, and J. Temmyo, "$Zn_{1-x}Cd_xO/ZnO$ heterostructures for visible light emitting devices",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (1-7), L4-L6 (2005).

10. K. Oguri, Y. Okano, T. Nishikawa, and H. Nakano, "Transient observation of extended x-ray absorption fine structure in laser-melted Si by using femtosecond laser-produced-plasma soft x-ray",
Appl. Phys. Lett. **87** (1), 011503 (2005).

11. K. Tateno, H. Gotoh, and H. Nakano, "Nanoholes formed by Au particles digging into GaAs and InP substrates by reverse vapor-liquid-solid mechanism",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (50-52), L1553-L1555 (2005).

12. K. Tateno, H. Gotoh, and Y. Watanabe, "Nanoholes in InP and C-60 layers on GaAs substrates by using AlGaAs nanowire templates",
Jpn. J. Appl. Phys. Part 2 - Lett. Express Lett. **44** (12-15), L428-L431 (2005).

13. R. Yano and H. Gotoh, "Tunable terahertz electromagnetic wave generation using birefringent crystal and grating pair",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Brief Commun. Rev. Pap. **44** (12), 8470-8473 (2005).

14. R. Yano, H. Gotoh, Y. Hirayama, S. Miyashita, Y. Kadoya, and T. Hattori, "Terahertz wave detection performance of photoconductive antennas: Role of antenna structure and gate pulse intensity",
J. Appl. Phys. **97** (10), 103103 (2005).

Photonic Nano-Structure Research Group

1. E. Kuramochi, M. Notomi, S. Hughes, A. Shinya, T. Watanabe, and L. Ramunno, "Disorder-induced scattering loss of line-defect waveguides in photonic crystal slabs",
Phys. Rev. B **72** (16), 161318 (R)(2005).

2. M. Notomi, A. Shinya, S. Mitsugi, G. Kira, E. Kuramochi, and T. Tanabe, "Optical bistable switching action of Si high-Q photonic-crystal nanocavities",
Opt. Express **13** (7), 2678-2687 (2005).

3. A. Shinya, S. Mitsugi, E. Kuramochi, and M. Notomi, "Ultrasmall multi-channel resonant-tunneling filter using mode gap of width-tuned photonic-crystal waveguide",
Opt. Express **13** (11), 4202-4209 (2005).

4. T. Tanabe, M. Notomi, S. Mitsugi, A. Shinya, and E. Kuramochi, "All-optical switches on a silicon chip realized using photonic crystal nanocavities",
Appl. Phys. Lett. **87** (15), 151112 (2005).

5. T. Tanabe, M. Notomi, S. Mitsugi, A. Shinya, and E. Kuramochi, "Fast bistable all-optical switch and memory on a silicon photonic crystal on-chip",
Opt. Lett. **30** (19), 2575-2577 (2005).

6. H. Taniyama, M. Notomi, and Y. Yoshikuni, "Propagation characteristics of one-dimensional photonic crystal slab waveguides and radiation loss",
Phys. Rev. B **71** (15), 153103 (2005).

7. A. Yokoo and S. Sasaki, "Oxidation patterning of GaAs by nanoelectrode lithography",
Jpn. J. Appl. Phys. Part 1 - Regul. Pap. Short Notes Rev. Pap. **44** (2), 1119-1122 (2005).

NTT Basic Research Laboratories
3-1 Morinosato Wakamiya, Atsugi-shi
Kanagawa 243-0198 Japan
Phone: +81-46-240-3312
URL: http://www.brl.ntt.co.jp/
E-mail: katsudou-mail@will.brl.ntt.co.jp