Sixth Photonics Center Symposium

Nanophotonics in Asia 2011

Sep 20th (Tue) — 21st (Wed), 2011

Shima Kanko Hotel THE CLASSIC

Organized by Photonics Center, Osaka University

Funded by JSPS Asian Core Program, MEXT, MOST and NSC

Organizer | Photonics Center, Osaka University

Sponsoring Organizations | The Japan Society for the Promotion of Science, Asian CORE Program, Advanced Nanophotonics Research and Education Center in Asia, Japan
Project for Developing Innovation Systems, Creation of innovation centers for advanced interdisciplinary research areas Program, MEXT, Japan
Ministry of Science and Technology (MOST), China
National Science Council (NSC), Taiwan

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September 20th-21st, 2011

Shima Kanko Hotel THE CLASSIC, Kashikojima, Japan

Committee

Conference Chair

Satoshi Kawata (The executive director of Photonics Center, Osaka University)

Co-chairpersons

Din Ping Tsai (The executive director of Instrument Technology Research Center, National Applied Research Laboratories)

Xuan-Ming Duan (Professor, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences)

Executive Committee Chair

Junichi Takahara (The deputy director of Photonics Center, Osaka University)

Sponsoring Organizations

The Japan Society for the Promotion of Science Asian CORE Program

Japan Project for Developing Innovation Systems
Creation of innovation centers for advanced interdisciplinary research areas Program, MEXT, Japan

Ministry of Science and Technology(MOST), China

National Science Council (NSC), Taiwan

Symposium Venue

Shima Kanko Hotel THE CLASSIC

731 Shinmyo, Ago-cho, Shima-shi

Mie 517-0502 JAPAN

TEL:+81-599-43-1211 FAX :+81-599-43-3538

General Information

Registration
The registration desk will be open from 9:30 on Sep 20th.
You can leave your luggage at the registration desk. Your luggage will be delivered by hotel staff to your room by 3:55pm on Sep 20th.

For domestic participants:
Please make one of the following payments at the symposium registration desk on Sep 20th.
Students : JPY 1,000
Employees of Osaka University, Kobe University, The University of Tokushima and RIKEN : JPY 3,000
Others : JPY 5,000

Symposium Office
The Symposium office will be open during the following times :
Sep 20th, 2011 9:00am-11:00pm
Sep 21st, 2011 8:00am-01:00pm

Breakfast and Lunch
Lunch (Sep 20th) and Breakfast (Sep 21st) will be provided.
Breakfast : Restaurant La mer Classic (6:30-9:30am) .
Lunch: Banquet Halls "Zen" and "Bi".

Banquet
Your dinner will be served in the banquet halls "Zen" and "Bi" from 7:05pm on Sep 20th.
The dinner is free of charge, as it is already included as a part of the symposium.

Poster Sessions
Poster session venue: Banquet halls "Bi" and "Zen" (next to the symposium venue "Shin")
Please attach your posters to the panel in the banquet halls by 1:00pm on Sep 20th.
If your poster number is an odd number, you are required to attend your poster for 30 minutes following the banquet.
If your poster number is an even number, you are required to attend your poster for 30 minutes following the presentations by the odd numbered posters.

Internet Access
Internet access will not be available in your room. However, you have internet access via wireless LAN all the times in the hotel lobby. You can also use wireless at the symposium.

Awards
Best Poster Presentations will be awarded after the final talk on Sep 21st.

Check Out
Check out time is 11:00am. Please check out before the symposium starts, or during the break (10:45-11:05am). We will prepare the space for your luggage in the symposium room. However, please keep valuable things with you.

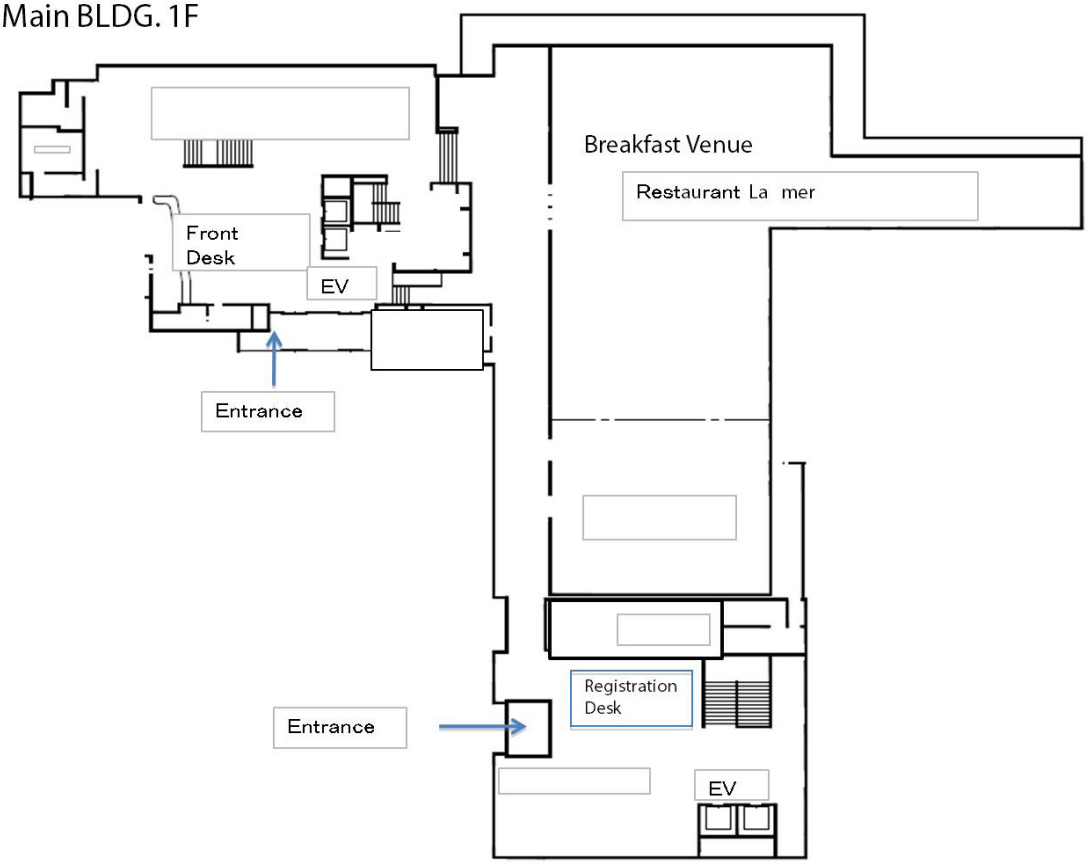
Maps


Ise Shima Map
Meiwa-cho
Ise Bay
Ise Azuchi-Momoyama Bunka Mura (amusement park)
Hinjitsukan (historic building)
Futami Okitama Jinja (shrine)
Meotoiwa (wedded rocks)
Kawasaki Area
Information Center
Futami Plaza Futami Sea Paradise
Ukishima Nature Aquarium
Minwa-no-eki Somin (local food & souvenir shop)
Information Center
Mikimoto Pearl Island
Sugashima Todai (lighthouse)
Toba Aquarium
Geku
Information Center
Tamaki-cho
Mount Asama View Point
Oharaimachi Okage Yokocho
Naiku
Ise City
Anrakujima Beach
Toba Sea-Folk Museum
Shirahama Beach
Asourahashi Bridge
Toba City
Toba View Point
Sato-no-megumi Furin (local food & souvenir store)
Ama-no-iwato (folklore site)
Chidorigahama Beach
Watarai-cho
Izawanomiya (shrine)
Ama (women diver) Museum
Osatu Ishigami Jinja (shrine)
Ama (women divers) Rest House
Shima Spain Village (amusement park)
Minamiise-cho
Information Center
Michi-no-eki Iseshima (local food & souvenir store)
Anorisaki Todai (light house)
Ukishima Park
Nantou
Shima City
Kofu Shirahama Beach
Mount Yokoyama View Point
Yokoyama Ishigami Jinja (shrine)
Information Center
Shima Manneland (aquarium)
Nishiyama Bojogaoka (view point)
Nemu-no-sato Hotel & Resort
Umi Nozuki (nature facility)
Goza Shirahma Beach
Daiosaki Todai (lighthouse)
Ama (women diver) Rest House
Azunhama Beach
Mugisaki Toda (lighthouse)
Shima Kanko Hotel THE CLASSIC (Symposium Venue)

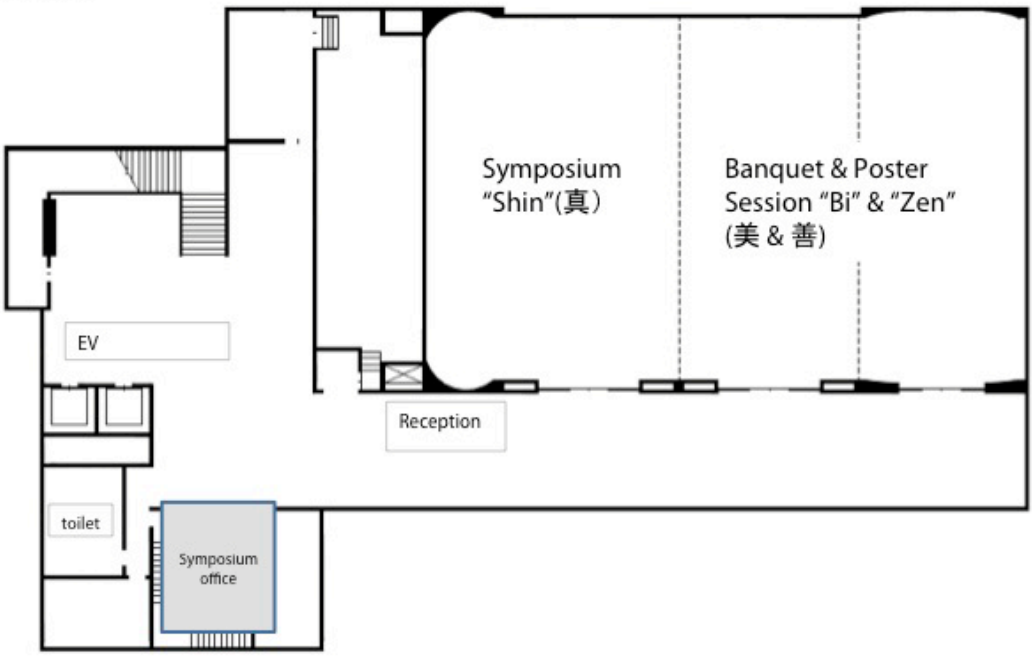

賢島大橋
KASHIKOJIMA BRIDGE
志摩マリンランド
SHIMA MARINE LAND
志摩観光ホテル
SHIMA KANKO HOTEL
賢島
KASHIKOJIMA
賢島スポーツガーデン
KASHIKOJIMA SPORTS GARDEN
遊覧船のりば
SIGHTSEEING BORT PIER
賢 島
KASHIKOJIMA
賢島宝生苑
KASHIKOJIMA HOJOEN
英虞湾
AGO BAY

Floor Plan

Main BLDG. 1F



Symposium Hall
Annex BLDG. B2F



Program

Sep 19th (Mon)

18:30-20:00	**Get-Together**	

Sep 20th (Tue)

	-----HALL "Shin" 真-----	
10:15-10:20	**Opening Remarks**	
10:20-10:35	**Activity of the Program in Taiwan** Din-Ping Tsai 蔡定平 (Instrument Technology Research Center) / Chair : Masanobu Haraguchi 原口雅宣	14
10:35-10:50	**Brief Introduction of the Technical Institute of Physics and Chemistry, Chinese Academy of Sciences** Zhen-Sheng Zhao 赵震声 (Technical Institute of Physics and Chemistry, CAS) / Chair : Masanobu Haraguchi 原口雅宣	16
10:50-11:05	**PARC: An Innovative Photonics Program in Japan** Satoshi Kawata 河田聡 (Osaka University) / Chair : Masanobu Haraguchi 原口雅宣	18
11:05-11:40	**Near-Field Enhancement Caused by Nonmetallic Nanostructures** Shinji Hayashi 林真至 (Kobe University) / Chair: Masanori Ozaki 尾崎雅則	20
11:40-13:00	Lunch Break	
13:00-13:30	**Optical Response and Coloration of Natural Photonic Structures without Long-Range Order** Jian Zi 资剑 (Fudan University) / Chair : Chih-I Wu 吳志毅	22
13:30-14:00	**Functional Crystals for and by Photonics** Yusuke Mori 森勇介 (Osaka University) / Chair : Chih-I Wu 吳志毅	24
14:00-14:25	Coffee Break	
14:25-14:55	**Si-based Nano-Structures for Photovoltaic and Photonics** Ching-Fuh Lin 林清富 (National Taiwan University)/ Chair : Zhanggui Hu 胡章贵	26
14:55-15:25	**Waveguide Quantum Photonic Devices** Toshiaki Suhara 栖原敏明 (Osaka University) / Chair : Zhanggui Hu 胡章贵	28
15:25-15:55	**Ultracompact and Ultrafast Plasmonic Devices Based on SPPs** Qihuang Gong 龚旗煌 (Peking University) / Chair : Zhanggui Hu 胡章贵	30
15:55-18:45	Break	
	------HALL"Zen&Bi" 善&美------	
18:45-19:05	**From Scientists, For Scientists** Rinto Nakahara 中原林人 (Nanophoton Corp.) / Chair : Eiichi Tamiya 民谷栄一	32
19:05-22:00	Banquet & Poster Session	

Sep 21st (Wed)

-----HALL "Shin"真-----

08:30-09:00	**Exploiting Plasmonics in Active Photonic Device Applications: In the Point of View of Surface Plasmon Heat Dissipation** Chih-Ming Wang 王智明 (National Dong Hwa University) / Chair : Prabhat Verma	34
09:00-09:30	**New Regimes of Surface Plasmon Resonance Control in Metal Nanoparticles** Zhi-Yuan Li 李志远 (Institute of Physics, CAS) / Chair : Prabhat Verma	36
09:30-09:55	**Bulk Hetero-Junction Solar Cells Utilizing Liquid Crystalline Phthalocyanine and Fullerene** Akihiko Fujii 藤井彰彦 (Osaka University) / Chair : Susumu Kuwabata 桑畑進	38
09:55-10:20	**Numerical Study on Nanophotonics and Their Some Applications** Yuan-Fong Chau 周趙遠鳳 (Ching Yun University) / Chair : Susumu Kuwabata 桑畑進	40
10:20-10:45	**Development of UV Plasmonics and Microscopic Techniques** Yuika Saito 斎藤結花 (Osaka University) / Chair : Susumu Kuwabata 桑畑進	42
10:45-11:05	Coffee Break	
11:05-11:35	**Developments and Prospects of the Nano-Optics Measurements and Characterizations** Jia Wang 王佳 (Tsinghua University) / Chair : Ryoichi Nakatani 中谷亮一	44
11:35-12:05	**Resonant Microwave Sensing of Virus** Chi-Kuang Sun 孫啟光 (National Taiwan University) / Chair : Ryoichi Nakatani 中谷亮一	46
12:05-12:15	Poster Award	
12:15-12:25	Closing Remarks	

Poster Titles

P-1 **Fabrication and Characterization of Three Dimensional Erected U-shape Metamaterials by Stress-driven Assembly Method /** Che Chin Chen, Chih Ting Hsio, Yu Hsiang Tang, Ming Hua Shio and Din Ping Tsai / *Instrument Technology Research Center, National Applied Research Laboratory and Department of Physics, National Taiwan University*

P-2 **Ambipolar, Light-Emitting Transistors Utilizing Liquid-Crystalline Semiconducting Polymers** / Hirotake Kajii, Yusuke Kusumoto, Daiki Terashima and Yutaka Ohmori / *Graduate School of Engineering, Osaka University*

P-3 **Fast Protein Labeling with Designed Fluorogenic Probes and Application to Real-Time Pulse-Chase Analysis** / Mitsuru Ueda, Shin Mizukami, Shuji Watanabe, Yuri Akimoto and Kazuya Kikuchi / *Graduate School of Engineering, Photonics Advanced Research Center, and Immunology Frontier Research Center, Osaka University*

P-4 **Detection of Chemical Reactions Using Emission Quenching of Semiconductor Nanoparticles** / Taro Uematsu, Akihisa Doko, Yusuke Kaji, Tsukasa Torimoto and Susumu Kuwabata / *Graduate School of Engineering, Osaka University, Japan Science and Technology Agency, CREST, and Graduate School of Engineering, Nagoya University*

P-5 **UV Photoresponse of Single-Walled Carbon Nanotubes Decorated with ZnO Layer** / Kenta Itabashi, Kazutoshi Matsushita, Shinji Minami, Hitoshi Kubo, Hiroshi Tabata and Mitsuhiro Katayama / *Graduate School of Engineering, Osaka University*

P-6 **A Resolution of λ/22 Achieved in Two-photon Polymerization Nanofabrications** / Xian-Zi Dong, Zhen-Sheng Zhao and Xuan-Ming Duan / *Technical Institute of Physics and Chemistry, Chinese Academy of Sciences*

P-7 **Photo-induced Inactivation of Metallic SWNTs in H_2O_2 Aqueous Solution** / Kenta Imakoga, Hiroshi Tabata and Mitsuhiro Katayama / *Graduate School of Engineering, Osaka University*

P-8 **Simulation Study of Magnetic Quantum Dots Cellular Automata Shift Register** / Soichiro Miura, Atsushi Sugihara, Hikaru Nomura and Ryoichi Nakatani / *Graduate School of Engineering, Osaka University*

P-9 **THz Radiation from Antiferromagnetic Magnons** / Junichi Nishitani, Takeshi Nagashima and Masanori Hangyo / *Institute of Laser Engineering, Osaka University*

P-10 **Transport Properties of Free Carriers in High Quality n-type GaN Wafers Studied by THz Time-domain Magneto-optical Ellipsometry** / Kenichi Yatsugi, Naoki Matsumoto, Takeshi Nagashima and Masanori Hangyo / *Institute of Laser Engineering, Osaka University and Murata Manufacturing Co. Ltd.*

P-11 **CdSe-Au Hybrid Nanocrystals: Shape-controlled Synthesis and Photovoltaic Application** / Feng Jin, Mei-Lin Zhang, Mei-Ling Zheng, Zhen-Sheng Zhao and Xuan-Ming Duan / *Technical Institute of Physics and Chemistry, Chinese Academy of Sciences and Graduate University of Chinese Academy of Sciences*

P-12 **Design of Visible Light Sensitive TiO_2 Based Materials via Formation of Surface Complexes and Their Photocatalytic Activities** / Takashi Kamegawa, Hiroki Seto, Daiki Yamahana, Kohsuke Mori and Hiromi Yamashita / *Graduate School of Engineering, Osaka University*

P-13 **Solution Processable Organic Solar Cell Based on Bulk Heterojunction Utilizing Phthalocyanine and Fullerene** / Junki Sakamoto, Shota Tominaga, Tetsuro Hori, Dao Quang Duy, Tetsuya Masuda, Kaoru Fukumura, Takeshi Hayashi, Hiroyuki Yoshida, Akihiko Fujii, Yo Shimizu and Masanori Ozaki / *Graduate School of Engineering, Osaka University and Research Institute for Ubiquitous Energy Devices, National Institute of Advanced Industrial Science and Technology (AIST)*

P-14 **Thermal and Electronic Properties of Octahexylphthalocyanine / PCBM Binary Systems for Efficient Solar Cell** / Fabien Nekelson, Yasuo Miyake, Tetsuro Hori, Kouji Miyamoto, Yo Shimizu, Akihiko Fujii and Masanori Ozaki / *Graduate School of Engineering, Osaka University and Research Institute for Ubiquitous Energy Devices, National Institute of Advanced Industrial Science and Technology (AIST)*

P-15 **Spectral and Polarization Characteristics of Terahertz Radiation from Metaatom-loaded Photoconductive Antennas** / Hirofumi Sasaki, Keisuke Takano and Masanori Hangyo / *Institute of Laser Engineering, Osaka University*

P-16 **Femtosecond Laser Direct Writing of Gold Nanostructures by Ionic Liquid Assisted Multiphoton Induced Photoreduction** / Wei-Er Lu, Mei-Ling Zheng, Xian-Zi Dong, Zhen-Sheng Zhao and Xuan-Ming Duan / *Technical Institute of Physics and Chemistry, Chinese Academy of Sciences and Graduate University of Chinese Academy of Sciences*

P-17 **Strong Exciton-Plasmon Coupling in MIM Structures** / Yuta Ishigaki, Minoru Fujii and Shinji Hayashi / *Graduate School of Engineering, Kobe University*

P-18 **Fluorescence Enhancement Caused by GaP Particles: Dependence on Excitation Wavelength** / Chiaki Yoshikawa, Mioru Fujii and Shinji Hayashi / *Graduate School of Engineering, Kobe University*

P-19 **Multi-Color Cathodoluminescence Microscopy for Biological Imaging** / Taichi Furukawa, Hirohiko Niioka, Masayoshi Ichimiya, Masaaki Ashida and Mamoru Hashimoto / *Graduate School of Engineering Science, Osaka University, Institute for NanoScience Design, and Department of Physics, Osaka Dental University*

P-20 **Saturated Excitation (SAX) Microscopy for Biological Imaging beyond the Diffraction Limit** / Yasuo Yonemaru, Masahito Yamanaka, Satoshi Kawata and Katsumasa Fujita / *Graduate School of Engineering, Osaka University, RIKEN and Japan Science and Technology Agency*

P-21 **Interfacial Engineering of Organic Optoelectronic Devices /** Chih-I Wu / *Graduate Institute of Photonics and Optoelectronics, National Taiwan University*

P-22 **Monitoring of CPT-11 in Living Cells with CARS Microscopy and Fluorescence Microscopy** / Harsono Cahyadi, Hirohiko Niioka, Tsutomu Araki and Mamoru Hashimoto / *Graduate School of Engineering Science, Osaka University and Institute for NanoScience Design, Osaka University*

P-23 **DNA-templated Gold Nanoparticle Trimer Ring** / Ryoko Watanabe-Tamaki and Takuo Tanaka / *RIKEN and Hokkaido University*

P-24 **Gold Nanofin Array for Far-infrared Enhancement** / Wakana Kubo and Takuo Tanaka / *RIKEN*

P-25 **Design of Localized Plasmon Mode at a Gold Nano Dimer for SHG** / Hiroto Hashiguchi, Toshihiro Okamoto, Yohei Kurata and Masanobu Haraguchi / *The University of Tokushima*

P-26 **Alternating Growth of ZnO Nanowire Array for Quantum Dot Sensitized Solar Cell /** Mei-Lin Zhang, Feng Jin, Mei-Ling Zheng, Zhen-Sheng Zhao and Xuan-Ming Duan / *Technical Institute of Physics and Chemistry, Chinese Academy of Sciences and Graduate University of Chinese Academy of Sciences*

P-27 **Stub Structures in Gap Plasmon Waveguide** / Masanobu Haraguchi, Naohiro Kamon, Hiroaki Suzuki, Shimpei Tanabe, Hidenori Sokabe and Toshihiro Okamoto / *The University of Tokushima*

P-28 **Tip-enhanced Raman Imaging and Analysis of Crossed Nanotube Junctions/** Yoshihiro Okuno, Shota Kuwahara, Kazumasa Uetsuki, Takaaki Yano, Prabhat Verma and Satoshi Kawata / *Graduate School of Engineering, Osaka University, Chuo University, RIKEN and Japan Science and Technology Agency*

P-29 **Development of a Plasmonic Biosensing System Using Au Nano-particle Pairs /** Hiroyuki Morimura, Shin-ichi Tanaka, Hidekazu Ishitobi and Yasushi Inouye / *Graduate School of Frontier Biosciences, Osaka University*

P-30 **Origin of Bulk Third Harmonic Generation** / Tung-Yu Su, Chien-Sheng Liao, Chih-Yuan Yang, Zong-Yan Zhuo, Szu-Yu Chen and Shi-Wei Chu / *Department of Physics, National Taiwan University and Department of Optics and Photonics, National Central University*

P-31 **Electromagnetic Response of Asymmetric Double Fishnet Metamaterials** / Yong-liang Zhang, Xian-Zi Dong, Zhen-sheng Zhao and Xuan-Ming Duan / *Technical Institute of Physics and Chemistry, Chinese Academy of Sciences*

P-32 **Microstructure Formation of Au Nanorods /Methyl Methacrylate Composite Assisted by Two-photon Polymerization** / Kyoko Masui, Satoru Shoji, Kenji Asaba, Xuan-Ming Duan and Satoshi Kawata / *Graduate School of Engineering, Osaka University, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences and RIKEN*

P-33 **Advanced Medical Design by Photonics** / Kazuo Kawasaki and the PiD Lab / *Graduate School of Engineering, Osaka University*

P-34 **Plasmonic Devices in the Visible-Terahertz Region** / Masashi Miyata, Yosuke Ueba, Hiroto Yada and Junichi Takahara / *Graduate School of Engineering, Osaka University*

P-35 **Optical Biosensing by a Laser Deposition of Silver Nanoparticles** / Takayuki Hironaka, Hiroyuki Yoshikawa, Masato Saito and Eiichi Tamiya / *Graduate School of Engineering, Osaka University*

P-36 **Nonlinear Optical Properties of DAST Crystals at Nanometric Scale** / Mei-Lin Zheng, Katsumasa Fujita, Wei-Qiang Chen, Xuan-Ming Duan and Satoshi Kawata / *Technical Institute of Physics and Chemistry, Chinese Academy of Science and Graduate School of Engineering, Osaka University*

P-37 **Transforming of the Nano-Pillar from the Porous Alumina Mold Using Nanoimprinting Technology and Application to the Plasmonic Biosensor** / Akito Kitamura, Masato Saito, Keiichiro Yamanaka, Yoshinori Yamaguchi and Eiichi Tamiya / *Graduate School of Engineering, Osaka University*

P-38 **Quantitative Imaging Analysis and Micro-chip Platform for Drug Diagnosis on Cardiomyocyte Derived from Mouse Embryonic Stem Cell /** Yoshinori Yamaguchi, Eiichi Shimizu, Maha A. El-Hagrasy, Courtney Peterson and Eiichi Tamiya / *Photonics Advanced Research Center and Graduate School of Engineering, Osaka University*

P-39 **Development of stimulated Raman scattering microscopy system for label-free cell imaging /** Yasuyuki OZEKI, Wataru UMEMURA, and Kazuyoshi ITOH / *Graduate School of Engineering, Osaka University, PRESTO-JST*

Presenter’s Profiles and Abstracts

Din Ping TSAI

Department of Physics, National Taiwan University
National Instrument Technology Research Center, NARL
Research Center for Applied Sciences, Academia Sinica

Education

1990 Ph.D, University of Cincinnati, Ohio, U.S.A.

Experience

1990-1991, Research Staff, Micro Lithography Inc., Sunnyvale, California, U.S.A.
1991-1994, Postdoctoral Fellow, Ontario Laser & Lightwave Research Center, Canada
1994-1999, Associate Professor, Dept. of Physics, National Chung Cheng University, Taiwan
2001-, Professor, , Dept. of Physics, National Taiwan University, Taiwan
2006-, Distinguished Professor, Dept. of Physics, National Taiwan University, Taiwan
2008-, Director General, National Instrument Technology Research Center, NARL, Taiwan

Scientific Interests:

My current research interests in general are nanophotonics, near-field optics, plasmonics, metamaterials and bio-photonics. My R&D are focused on energy, environment and better life with the applications of plasmonic nanophotonics, nanolithography, nano optical imaging, near-field optical storage, plasmonic metamaterials, plasmonic integrated optical circuits, nano antennas, nano optical sensors, bio-nano-photonics, and plasmonic photo-catalytic chemical reactors, etc.

Recent Papers :

1. J. J. Chen, C. S. Wu, P. C. Wu, **D. P. Tsai**, “Plasmonic Photocatalyst for H2 Evolution in Photocatalytic Water Splitting,” J. Phys. Chem. C 115, 210-216 (2011).
2. W. M. Zhu, A. Q. Liu, X. M. Zhang, **D. P. Tsai**, T. Bourouina, J. H. Teng, X. H. Zhang, H. C. Guo, H. Tanoto, T. Mei, G. Q. Lo, D. L. Kwong, "Switchable Magnetic Metamaterials Using Micromachining Processes," Advanced Materials 23, 1792-1796 (2011)
3. W. T. Chen, C. J. Chen, P. C. Wu, S. Sun, L. Zhou, G. Y. Guo, C. T. Hsiao, K. Y. Yang, N. I. Zheludev, **D. P. Tsai**, "Optical magnetic response in three-dimensional metamaterial of upright plasmonic meta-molecules," Optics Express **19**(13), 12837 (2011).
4. W. T. Chen, P. C. Wu, C. J. Chen, C. J. Weng, H. C. Lee, T. J. Yen, C. H. Kuan, M. Mansuripur, **D. P. Tsai**, "Manipulation of multidimensional plasmonic spectra for information storage" Appl. Phys. Lett. 98, 171106 (2011).
5. C. H. Chu, M. L. Tseng, C. D. Shiue, S. W. Chen, H. P. Chiang, M. Mansuripur, **D. P. Tsai**, "Fabrication of phase-change Ge2Sb2Te5 nano-rings," Optics Express **19**(13), 12652 (2011).

Activity of the program in Taiwan

Din Ping TSAI

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1, Sec.4, Roosevelt Road, Taipei 10617, Taiwan
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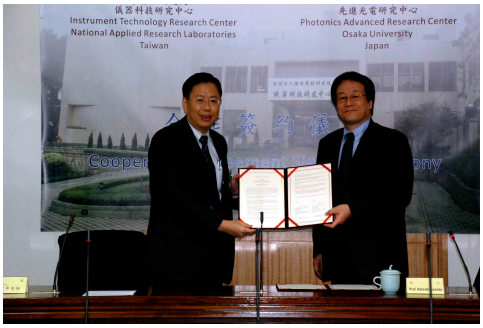
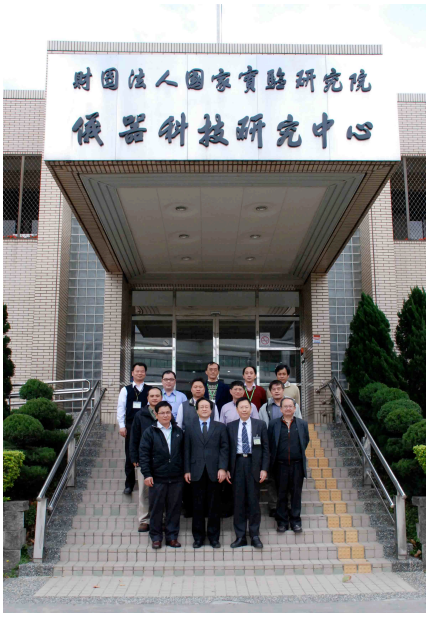
The corresponding collaborators of Photonics Advanced Research Center of Osaka University in Taiwan are professors and researchers of National Taiwan University (NTU) and National Instrument Technology Research Center (ITRC) in Taiwan. Professor Satoshi Kawata was invited to give a plenary lecture at National Instrument Technology Research Center on January 27, 2011. Professor Kawata and Director General Din Ping Tsai have signed the cooperation agreement for the long term research collaboration on the same day. Under the agreement, joint activities will be established to enhance the exchange of scientific knowledge and cultural traditions at the global level. Subsequently, Professor Satoshi Kawata was also invited to give a plenary key-note talk at the International Nanophotonics Symposium held in National Taiwan University on March 15, 2011. President of NTU, Professor Si-Chen Lee and Chairman of Institute of Photonics, NTU, Professor Ching Fuh Lin signed the MOU with Professor Kawata for the research collaboration with NTU. NTU agreed to host a Bilateral Conference on Nano-Photonics and Nano-Materials from January 10 to 14 in 2012. Many other activities of nanophotonics in Taiwan in last one year will be reported as well. (Research collaboration of this project is funded by National Science Council and NTU.)





Zhensheng ZHAO

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Education

B.S. 1976, Zhejiang University;
Advanced Study, 1978-1979, University of Science and Technology of China;
Ph.D. 1991, Karl-Franzens University of Graz, Austria;
EMBA, 2002, University Wiskonsion and Chinese Academy of Sciences.
Visiting schlolar, 1982-1984, Max-Planck-Institute of Quantum-Optics, Munich, Germany;
Visiting schlolar, 1989-1992, Karl-Franzens University of Graz, Austria;
Visiting schlolar, 2006, Osaka University, Japan;
Associate Professor, 1991-1998 ; Professor, 1999-2000, Anhui Institute of Optics and Fine Mechanics (AIOFM), Chinese Academy of Sciences;
Professor, Vice President, 2000-2006, the Graduate University of Chinese Academy of Sciences (GUCAS) ;
Professor, Vice Director, 2006- , Technical Institute of Physics and Chemistry, Chinese Academy of Sciences (TIPC, CAS).

Scientific Interests:

Laser technology and application: nanophotonics of micro/nono-scale and 3D microstructure fabrication and micro-imaging using femo- / pico-second lasers, excimer lasers.

Recent Papers :

1. W.-K. Wang, M.-L. Zheng*, W.-Q. Chen, F. Jin, Y.-Y. Cao, Z.-S. Zhao, and X.-M. Duan*, "Microscale golden candock leaves self-aggregated on a polymer surface: Raman scattering enhancement and superhydrophobicity", *Langmuir* **2011**, 27, 3249-3253.
2. L.-T. Shi, F. Jin*, M.-L. Zheng, X.-Z. Dong, W.-Q. Chen, Z.-S. Zhao, and X.-M. Duan*, "Threshold optimization of polymeric opal photonic crystal cavity as organic solid-state dye-doped laser", *Appl. Phys. Lett.* **2011**, 98, 093304.
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Brief Introduction of the Technical Institute of Physics and Chemistry, Chinese Academy of Sciences

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Technical Institute of Physics and Chemistry (TIPC), Chinese Academy of Sciences (CAS) was founded in June, 1999. The maxim is self-discipline, realitic approach, harmonic envionment and creative spirit. There are 430 of staff, 4 of CAS fellows, 2 CAES fellows, 71 of full professors, and 400 of Master and doctor students. The TIPC focuses on the innovation, development, and transfer of technologies based on physics, chemistry, and engineering sciences. CAS is very international and has organized many conferences and exchange programs to communicate with the scientists all over the world.

There are 5 key laboratories of CAS, such as key laboratory of functional crystals and laser technology, key laboratory of photochemical conversion and optoelectronic materials, key laboratory of cryogenics engineering and key laboratory of space energy conversion technologies, national engineering research center for engineering plastics. The key laboratory of functional crystals and laser technology as one of the key laboratories, has been gained much attention. It not only focuses on the development of crystals, the world famous crystals of BBO, LBO and KBBF, but also the laser technology, such as 3D micro/nano fabrication, micro-imaging using femo- / pico-second lasers and excimer lasers.

The cooperation between TIPC, CAS and Osaka University has been established since Nov. 24, 2007 when the agreement of joint training for graduate students was signed. Up to date, two students have benefited from this project. A lot of staffs in TIPC have studied or awarded doctor degree in Osaka Universty. We have carried out cooperated projects, e.g. to build China-Japan Joint Laboratory of Advance Photonics, we shall try this modern field together hard and learn from each other. Besides, we have involved honorary professor project, for example, professor Satoshi Kawata in Osaka University is the honorary professor of CAS. These would open up more opportunity for the cooperation between China and Japan and benefit us more in future.

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Education:

B.S.c in Applied Physics 1974, Osaka University
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Ph.D. in Applied Physics 1979, Osaka University
Postdoctoral Fellow, 1979, Japan Society for the Promotion of Science
Research Associate, 1979-1981, University of California, Irvine
Assistant Professor, 1981, Osaka University
Associate Professor, 1992, Osaka University
Professor, 1993-, Osaka University
Chief Scientist, 2002-, RIKEN

Scientific Interests:

Nanophotonics, Plasmonics, Nano-fabrication and Spetroscopy.

Recent Papers :

Miyu Ozaki, Jun-ichi Kato and Satoshi Kawata
“Surface-Plasmon Holography with White-Light Illumination”
Science, Vol.332, pp. 218-220 (2011).

Prabhat Verma, Taro Ichimura, Taka-aki Yano, Yuika Saito, and Satoshi Kawata,
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Yao-Yu Cao, Nobuyuki Takeyasu, Takuo Tanaka, Xuan-Ming Duan, and Satoshi Kawata,
"3D Metallic Nano-Structure Fabrication By Surfactant-Assisted Multi-Photon-Induced Reduction,"
Small, Vol. 5, pp. 1144-1148 (2009).

PARC: An innovative photonics program in Japan

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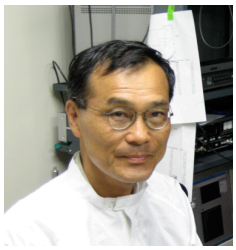
Following in the footsteps of 20th century electronics, the field of photonics is attracting increasing attention as one of the key technologies that will underpin the science, industry, and society of the 21st century. Together with collaborating organizations in industry, Osaka University established the Photonics Advanced Research Center (PARC) in 2007, one of the 10-year projects for the “Creation of Innovation Centers for Advanced Interdisciplinary Research Areas” that are financed through Special Coordination Funds for Promoting Science and Technology by Ministry of Education, Culture, Sports, Science and Technology (MEXT) Japan.

The research covers a range of disciplines encompassing biology, chemistry, physics, mathematics, mechanical and electrical engineering. Participating members have carefully discussed the meaning and promise of photonics to Japan in the 21st century, and are developing solutions to the challenges of industrial application. The most promising result of these discussions is a new research direction to develop innovative methods and devices using the fusion of nanomaterials and photonic technology. From this, the research of nanophotonics and especially plasmonics must now begin to advance. The driving force of this research is to seek the application of plasmonics to the medical care, information technology, and renewable energy industries. The “mutual interactive scheme” of the Photonics Center in Osaka University is noteworthy in that it has proven to be very effective. Under this system both universities and collaborating companies have committed laboratories to develop new technology together and integrate basic researches with industrial applications. Some of the fruits of first few years of study at PARC are tip-enhanced Raman imaging at a resolution of a few nanometers (visualize objects by light at nm-scale), multiple label-free detection of antigen-antibody reaction by using surface plasmon resonance and world's fastest (10 times) Raman microscopic imaging.

One of the important goals of this center is to develop young researchers who are capable of conducting internationally viable, pioneering photonics research for future generations. To launch advanced nanophotonics research ahead of the rest of the world and develop researchers in this pioneering subject, Osaka University's Photonics Center has set up Advanced Nano Photonics Research and Education Center in Asia (2011-2015) an Asian CORE program financed by JSPS, MOST and NSC with the Technical Institute of Physics and Chemistry, Chinese Academy of Science and the Instrument Technology Research Center of Taiwan's National Applied Research Laboratories, both of which are leading research institutes in their respective country/area.

Shinji HAYASHI



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Scientific Interests:

Nanophotonics : Synthesis and Optical Properties of Nanomaterials
Carbon Nanomaterials : Synthesis and Optical Properties of Carbon Onions and Polyynes
Plasmonics : Fluorescence enhancement, MIM structures, Anisotropic SPP propagation

Recent Papers :

Yohei Takeichi, Yasuo Kimoto, Minoru Fujii and Shinji Hayashi, “Anisotropic propagation of surface plasmon polaritons induced by para-sexyphenyl nanowire films”, accepted for publication in Physical Review B.

Kenji Hanamura, Minoru Fujii, Tomonari Wakabayashi, and Shinji Hayashi, “Surface-enhanced Raman Scattering of Size-selected Polyynes (C_8H_2) Adsorbed on Silver Colloidal Nanoparticles”, Chemical Physics Letters, Vol. 503, No. 1-3, pp. 118-123 (2011) .

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Shinji Hayashi, Yohei Takeuchi, Shinichi Hayashi, and Minoru Fujii, “Quenching-free Fluorescence Enhancement on Nonmetallic Particle Layers: Rhodamine B on GaP Particle Layers”, Chemical Physics Letters, Vol. 480, pp. 100-104 (2009).

NEAR-FIELD ENHANCEMENT CAUSED BY NONMETALLIC NANOSTRUCTURES

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Surface plasmon reonances in metallic nanostructures are commonly used to achieve near field enhancement and generate enhanced signals in various optical processes, such as Raman scattering, fluorescence and second-harmonic generation. However, the use of metallic nanostructures is not always convinient because of the energy dissipation in metals. The quenching of fluorescence signals caused by metals is one of the problems to be overcome. In this contribution, I would like to demonstrate both theoretically and experimentally the possibility of the near-field enhancement and the optical signal enhancement brought by nonmetallic nanostructures.

For simplicy, let us consider a single spherical particle embedded in a medium. Mie theory allows us to calculate the efficiencies of extinction, scattering and absorption for the sphere of arbitrary radius. As introduced by Messinger et al. [1], the Mie theory can be modified to calculate the near-field efficiency Q_{NF}, which is the average of the square of electric field over the sphere surface. Figure 1 compares Q_{NF} calculated for 100 nm-radius Ag and Si spheres embedded in air. We see several peaks in Q_{NF} for both the Ag and Si spheres. For the Ag sphere, the peaks labeled as TM_1 and TM_2 correspond to the excitation of the dipolar and quadrapolar surface plasmons. For the Si sphere, we see the peaks corresponding to the TM modes as well as the TE modes. They are low order *Whispering-gallery modes* in a Si sphere. It should be stressed that the 100 nm-radius Si particle can give rise to the near-field enhancement comparable to (or even larger than) that of the 100 nm-radius Ag particle in the visible wavelength region.

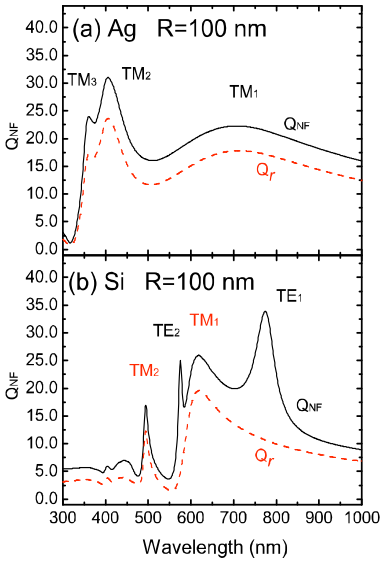

Fig.1 Comparison between Q_{NF} for Ag and Si spheres.

In my talk, Raman and fluorescence enhancement observed by using GaP particles [2] are presented. The field enhancement in nonmetallic multilayer systems [3] is also discussed.

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Scientific Interests:

Photonic crystals & metamaterials
Natural photonic structures & structural coloration
Plasmonic structures
Liquid surface waves propagating in periodic structures

Recent Papers :

1. X. H. Hu, C. T. Chan, K. M. Ho, and J. Zi, *Negative Effective Gravity in Water Waves by Periodic Resonator Arrays*, Phys. Rev. Lett. **106**, **174501** (2011).
2. B. Q. Dong, X. H. Liu, T. R. Zhan, L. P. Jiang, H. W. Yin, F. Liu, and J. Zi, *Structural coloration and photonic pseudogap in natural random close-packing photonic structures*, Opt. Express **18**, 14430 (2010).
3. D. Z. Han, F. Q. Wu, X. Li, C. Xu, X. H. Liu, and J. Zi, *Transmission and absorption of metallic films coated with corrugated dielectric layers*, Appl. Phys. Lett. **89**, 091104 (2006).
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5. J. Zi, X. D. Yu, Y. Z. Li, X. H. Hu, C. Xu, X. J. Wang, X. H. Liu, and R. T. Fu, *Coloration strategies in peacock feathers*, PNAS **100**, 12576 (2003).

OPTICAL RESPONSE AND COLORATION OF NATURAL PHOTONIC STRUCTURES WITHOUT LONG-RANGE ORDER

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Photonic structures have been exploited in the biological world to produce coloration since the Cambrian explosion. Interesting photonic structures have been found including multilayers and two- and three-dimensional photonic crystals. These photonic structures possess both short- and long-range order and can produce structural coloration with iridescence. On the other hand, there exist also amorphous photonic structures in the biological world, namely, those photonic structures without long-range order and possessing only short-range order. These photonic structures display non-iridescent structural coloration. To our knowledge, the optical properties of amorphous photonic structures have been less studied and understood. In this presentation, we will talk about two types of amorphous photonic structures found in the biological world: one is a random-close-packing structure of nanoparticles [1] and the other is a phase-separated structure via spinodal decomposition [2]. Their optical response and mechanisms of non-iridescent structural coloration will be discussed, based on structural characterizations, optical measurements, and numerical simulations.

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Education

B.S. 1989, Osaka University
Ph.D. 1996, Osaka Uniersity
Assistant Professor, 1993-2000, Osaka University
Associate Professor, 2000-2007, Osaka University
Professor, 2007-, Osaka University

Scientific Interests:

Crystal growth: I have interested in controlling the nucleation and growth processes that are important for growing high-quality, large crystals of oxide, nitride, and protein from solution.

Recent Papers :

Y. Mori, Y. Kitaoka, M. Imade, N. Miyoshi, M. Yoshimura, and T. Sasaki. Growth of bulk GaN crystals by Na flux method. Physica Status Solidi, C8, No.5, pp1445-1449 (2011)

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M. Imade, Y. Hirabayashi, Y. Konishi, H. Ukegawa, N. Miyoshi, M. Yoshimura, T. Sasaki, Y. Kitaoka, and Y. Mori. Growth of Large GaN Single Crystals on High-Quality GaN Seed by Carbon-Added Na Flux Method. Applied Physics Express 3, 075501-1-3, (2010).

N. Shimizu, S. Sugiyama, M. Maruyama, Y. Takahashi, M. Adachi, T. Tamada, K. Hidaka, T. Kimura, Y. Kiso, H. Adachi, K. Takano, S. Murakami, T. Inoue, R. Kuroki, Y. Mori and H. Matsumura. Crystal growth procedure of HIV-1 protease-inhibitor KNI-272 complex for neutron structural analysis at 1.9 A resolution. Crystal Growth Des., Vol.10, pp.2990-2994, (2010)

M. Adachi, T. Ohhara, K. Kurihara, T. Tamada, E. Honjo, N. Okazaki, S. Arai, Y. Shoyama, K. Kimura, H. Matsumura, S. Sugiyama, H. Adachi, K. Takano, Y. Mori, K. Hidaka, T. Kimura, Y. Hayashi, Y. Kiso, R. Kuroki. Structure of HIV-1 protease in complex with potent inhibitor KNI-272 determined by high-resolution X-ray and neutron crystallography. Proc. Natl. Acad. Sci. USA, 106 (12), 4641-4646 (2009)

Functional Crystals for and by Photonics

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Functional crystals, such as nonlinear optical (NLO) materials and semiconductors, are important for generation of photons. In 1990's, the blue LED and LD have been realized by group III nitride semiconductors. Researches on the growth of high-quality bulk GaN crystals are accelerated in order to improve the performance of blue LED and LD devices. For the generation of shorter wavelength like ultraviolet (UV) laser light, frequency conversion process is indispensable because of difficulty in electrical doping for wide-bandgap semiconductors. NLO borate crystals are found to be promising for UV generation because of their wide-bandgap and adequate optical non-linearity. Barium borate (BBO), lithium triborate (LBO) have been developed by Chen's group in China in 1980's. In 1993, another new borate crystal, $CsLiB_6O_{10}$ (CLBO), has been discovered and developed by the author's group. CLBO crystals can generate the shorter wavelength below 200 nm with high efficiency. Recently, vacuum UV laser light (>200 nm) became important in the field of lithography mask inspection technology. Therefore, high-quality CLBO crystal is requested to realize high power VUV light source.

Recently, author's group found that photons can induce crystallization of protein molecules. Protein crystallization can be induced by using the femto-second laser irradiation. This method is useful for producing high quality protein crystals in short nucleation times. The forced nucleation in a low supersaturation solution followed with crystal growth in stirred solution is very effective to produce crystals with high X-ray diffraction (XRD) resolution. The precise structural information of membrane proteins is important for designing and developing novel drugs. With this new technology, we have succeeded to crystallize various proteins with high XRD resolution, such as, membrane protein AcrB, orotidine 5'-monophosphate decarboxylase, the translocon-associated membrane protein (SecDF), the tRNA thiolation enzyme MnmA from Escherichia coli complexed with tRNA Glu, SHPS-1(receptor-type transmembrane protein). Based on this technology, we have established protein crystallization company SOSHO Inc..

In this report, I will present the solution growth of CLBO, GaN and protein crystals and show the following results: (1) high quality CLBO crystals for high power VUV generation, (2) high quality bulk GaN crystal by Na flux method for high efficient LED, and (3) high quality protein crystal growth by means of forced nucleation induced by laser irradiation and solution stirring method.

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Education

B.S. 1983, National Taiwan University
M.S., 1989, Cornell University
Ph.D. 1993, Cornell University
Associate Professor, 1993-1998, National Taiwan University
Professor, 1998-, National Taiwan University
Chairman of IPO, 2010-, National Taiwan University

Scientific Interests:

Si-Photonics: Design, fabricate Si photonics on regular (100) Si wafer for integration of Si-photonics and electronics
Si-nanostructured photovoltaics, Fabricate nano-structures on SI wafer for low-cost photovoltaic devices.
Organic-inorganic hybrid solar cells: Combine inorganic nano-size inorganic materials with organic materials for low-cost and highly reliable solar cells.

Recent Papers :

- Yu-Hong Lin, Po-Ching Yang, Jing-Shun Huang, Guo-Dong Huang, Ing-Jye Wang, Wen-Hao Wu, Ming-Yi Lin, Wei-Fang Su, and Ching-Fuh Lin, "High-Efficiency Inverted Polymer Solar Cells with Solution-Processed Metal Oxides," *Solar Energy Materials & Solar Cells*, 95 pp. 2511-2515, 2011.
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- Jing-Shun Huang, Chen-Yu Chou, and Ching-Fuh Lin, "Efficient and air-stable polymer photovoltaic devices with WO_3-V_2O_5 mixed oxides as anodic modification," IEEE Electron Device Letters, Volume 31, Issue 4 , pp. 332-334, April 2010.
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Si-based Nano-Structures for Photovoltaic and Photonics

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The foreseeable depletion of fossil fuel and the global warming caused by the carbon dioxide had led to the increasing attention of alternative renewable energy and energy saving. Therefore, crystalline Si-PV devices are quickly spreading. Therefore, one of the issues in this talk is the use of Si-based nanostructures for photovoltaic applications. Here we will discuss two major parts for the photovoltaics: the combination of the Si nanowires with the organic materials to form p-n junction and the technique to form single crystalline Si thin film to lower the material cost. The fabrication of Si-nanowire/PEDOT solar cells is simple in terms of process steps. The device so far demonstrates a power conversion efficiency of 8.4%. On the other hand, the single crystalline Si thin-film is fabricated using two-step etching techniques. The film thickness could be from around 5 um to 15 um. For the film of 15 um, the absorption is 99% in the wavelength range from below 400 nm to 800 nm, then decreases to about 90% at the wavelength 912 nm. The film has very good crystal orientation, almost identical to Si wafer.

The second issue is the use of Si technology for photonics. Because Si is the most mature material for electronics, it is highly desired to use it for photonics and fully integrate electronics and photonics in a single chip. Here we will present the fabrication of nearly cylindrical waveguides on regular (100) wafers using laser reformation technique. Because the possibly selective exposure at designed areas under laser pulses, this technique provides the promising possibility of integration with electronics. The details will be discussed.

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Education

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Guest Research Scientist, 1980, Technical Research Centre of Finland
Guest Research Fellow, 1986-1987, Glasgow University
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Associate Professor, 1991-2002, Osaka University
Guest Professor, 1997, Chalmers University of Technology
Professor, 2002-, Osaka University

Scientific Interests:

Integrated Optics, Waveguide Nonlinear Optic Devices, Optical Waveguides, Quantum Optics, Integrated Semiconductor Lasers, Optical Memories, Applications of Electron Beam

Recent Papers :

T.Suhara and M.Ohno, “Quantum theory analysis of counterpropagating twin photon generation by parametric downconversion,” IEEE J. Quantum Electron., vol.46, No.12, pp.1739-1745, 2010.

T.Suhara, G.Nakaya, J.Kawashima and M.Fujimura, “Quasi-phase matched waveguide devices for generation of postselection-free polarization-entangled twin photons,” IEEE Photon. Tech. Lett., vol.21, No.15, pp.1096-1098, 2009.

T.Suhara, “Generation of quantum-entangled twin photons by waveguide nonlinear optic devices,” (Invited review paper) Laser & Photon. Rev., DOI 10.1002/lpor.200810054, vol.3, No.4, pp.370-393, 2009.

T.Suhara, H.Okabe and M.Fujimura, “Generation of polarization-entangled twin photons by type-II quasi-phase matched waveguide nonlinear-optic device,” IEEE Photon. Tech. Lett., vol.19, No.14, pp.1093-1095, 2007.

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WAVEGUIDE QUANTUM PHOTONIC DEVICES

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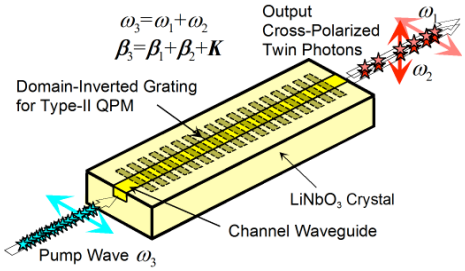
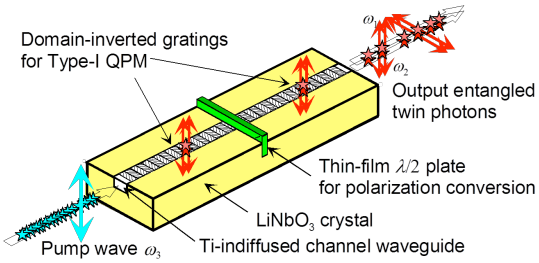
An important and challenging research area of modern photonics is quantum information technology (QIT) which utilizes the quantum nature of photons for transmitting and processing information. It is expected that the quantum photonic approaches will implement innovative technologies, such as quantum cryptography, teleportation and computing, beyond the limitations of the conventional methods. This presentation reviews the work of the author's group on the quasi-phase matched (QPM) nonlinear-optic (NLO) waveguide quantum photonic device technologies for QIT. After brief introduction to the concept of quantum states of light and quantum entanglement, the technique of quantum theory analysis on NLO interactions of photons is outlined, to discuss the device design procedure and the theoretical performances of waveguide QPM quantum photonic devices. Then, the device configurations and experimental demonstrations are presented on the proposed quantum photonic devices:

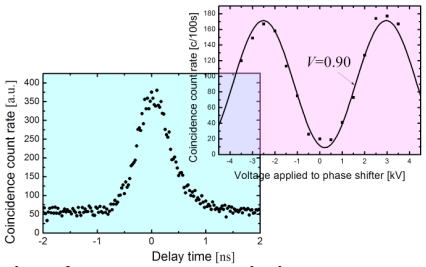
a frequency up-converter (sum frequency generation converter) for single-photon detection,
parallel- and cross-polarized twin photon generation devices using type-I and type-II QPM,
a highly-nondegenerate twin photon generation device for heralded single photon source,
polarization entangled twin photon generation devices using type-I and type-II QPM, and
integrated QPM devices for postselection-free polarization entangled twin photon generation.



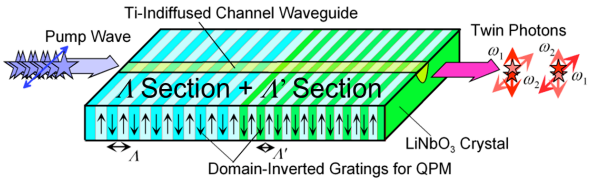
Cross-polarized twin-photon generation device



Type-I QPM polarization-entangled twin photon generation device



Results of quantum correlation measurement and quantum interference measurement



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Ultracompact and ultrafast plasmonic devices based on SPPs

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An asymmetric single-nanoslit composed of a conventional nanoslit with a nanogroove next to it in a metallic film is proposed to generate unidirectional surface plasmon polaritons (SPPs) efficiently with back-side illumination [1]. An extinction ratio of about 30:1 for SPPs to opposite directions and a generation efficiency of about 1.8 times that of the symmetrical case are experimentally demonstrated at wavelength of 830 nm with the lateral dimension of the asymmetric single-nanoslit of only 370 nm.

By coating the metal with a finite-thickness dielectric film, evident differences in the wave-vector magnitude between SPPs and quasicylindrical waves emerge [2]. This brings modulation patterns to the total field on the metal surface near the electromagnetic source. Based on such an effect, an ultracompact SPP splitter with a lateral dimension of only 800 nm is experimentally demonstrated at wavelengths of 740 nm and 832 nm in a dielectric-film-coated asymmetric single nanoslit.

By coating a compact asymmetric single slit with a photorefractive polymer, SPP generation was efficiently controlled by a pump beam [3]. In this structure, the length of light–matter interactions is twice that of its lateral dimension because of the cavity effect, which considerably increases the sensitivity of SPPs to the surrounding dielectric. Experimentally, a large modulation depth of 60% and phase modulation of more than π were observed. Moreover, the SPP generation and modulation processes are integrated in the same asymmetric single slit, which makes the device ultracompact with a lateral dimension of only about 2 μm.

By exciting a plasmonic lens with femtosecond laser and utilizing the optical nonlinearity of the gold, an ultrasmall and ultrafast all-optical modulation spot was successfully achieved inside a thin gold film. Near-field pump–probe measurements [4] indicated a modulation spot size of about 600 nm, and a response time of about 1.5 ps. Moreover, the optical nonlinearity and the modulation depth were increased by one order of magnitude at the focus compared to that at positions without structures [5].

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Nanophoton is a nanotechnology small enterprise found by Professor Satoshi Kawata, Osaka University in 2003, providing the state-of-the-art scientific instruments by utilizing light, mainly Raman microscope system for worldwide laboratories and manufacturers. Nanophoton is developing the completely new products that exist nowhere in the world, and always stands at the frontier of the time and continuously contributes to scientists in research and industrial applications. Now, Nanophoton attaches great importance to the fast-growing Asian market, and looks for opportunities to contribute to the scientists in Asia, with novel nano-technology and innovative nano-photonics products.

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Recent Papers :

[1] C. M. Wang, Y. L. Tsai, S. H. Tu, C. C. Lee, C. H. Kuo, and J. Y. Chang, "Optical properties of light emitting diodes with a cascading plasmonic grating," Opt. Express, **18**, pp. 25608-25614 (2010)

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Exploiting plasmonics in active photonic device applications: in the point of view of surface plasmon heat dissipation

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In the point of view of heat dissipation, we discuss the plasmonics applied in active photonic device, such as thermal emitter, solar cell and LED. In plasmonic LED, we investigate the polarization dependent optical properties of InGaN/GaN multi-quantum wells (MQWs) LED with cascading plasmonic gratings using angle-resolved photoluminescence (ARPL) spectrometer. The ARPL spectrum of the TE-TM state presents a broadband emission with resonance dips coincident with the SP dispersion which contributes to the nonradiative heat dissipation. For solar cell light harvesting, we shows that the absorption enhancement due to the SP coupling usually accompanies with heat dissipation which cannot contribute to the electron-hole generation. For thermal emitter, the corresponding emission properties mainly depend on the heat dissipation of SP which can be easily manipulating through modifying the geometric parameter of the plasmonic structure. Multi-resonance wavelength and/or sigle resonance wavelength can be acheived. In addition, according to the Kirchhoff's law of thermal radiation: he absorption eventually contributed to the emission. These natures make that the SP is very useful for thermal emitter applications.

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Scientific Interests:

Photonic Crystal: Silicon Photonic Crystal for Integrated Optical Devices and High-Q Cavities, Magneto-optical Photonic Crystal with Time-Reversal Symmetry Breaking
Nonlinear Optics: Nonlinear Photonic Crystal for High-Efficiency Frequency Conversion, Ultrafast Optical Switching and Logic Gates
Plasmonics: Metal Nanoparticles for Surface Plasmon Resonance Control and Applications, Metal Thin Film Nanostructures for Surface Plasmon Polariton Transport Control and Applications

Recent Papers :

1. Fei Zhou, Ye Liu, and **Zhi-Yuan Li**, "Surface plasmon assisted dipole-dipole interaction near metal surface", Optics Letters **36**, 1969 (2011).

2. Si-Yun Liu, Jia-Fang Li, Fei Zhou, Lin Gan, and **Zhi-Yuan Li**, "Efficient surface plasmon amplification from gain-assisted gold nanorods", Optics Letters **36**, 1296 (2011).

3. Shu-Ya Du and **Zhi-Yuan Li**, "Enhanced light absorption of TiO_2 in near-UV band by Au Nanoparticles", Optics Letters **35**, 3402-3404 (2010).

4. Jiafang Li, Siyun Liu, Ye Liu, Fei Zhou, and **Zhi-Yuan Li, "**Anisotropic and enhanced absorptive nonlinearities in a macroscopic film induced by aligned gold nanorods, Appl. Phys. Lett. **96**, 260103 (2010).

5. **Zhi-Yuan Li** and Younan Xia, "Metal nanoparticles with gain towards single-molecule detect via surface-enhanced Raman scattering", Nano Letters **10**, 243-249 (2010).

New Regimes of Surface Plasmon Resonance Control in Metal Nanoparticles

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Metal nanoparticles have attracted extensive interest of research in the past decades due to their unique physical, chemical, and optical properties on catalysis, photonics, plasmonics, optical sensing and detection, biomedical diagnosis and therapy, and surface-enhanced Raman scattering. Many of these properties are closely related with surface plasmon resonance (SPR) that occurs when light illuminates metal nanoparticles. In this talk, we will report our recent theoretical and experimental progress on exploring new regimes of SPR.

We first discuss the new opportunities of manipulating SPR brought by introducing gain into metal nanoparticles. It is found that the key obstacle towards a high enhancement of local field is that SPR will quickly decay once it is excited because energy is dissipated by metal absorption, leading to a very bad quality factor of resonance. A gain medium can well compensate the dissipation and maintain SPR to a much longer lifetime. Gain media can greatly sharpen SPR, reduce the bandwidth, lead to two orders of magnitude higher quality factor of the resonance peak, and ultimately result in giant enhancement of local field intensity to a level that is far above the single-molecule detection level via SERS [1]. Our study indicates that the threshold of gain coefficient strongly depends on the geometric shape of metal nanoparticles. For instance, SPR can be amplified much more easily in a gold nanorod than in a gold nanosphere [2,3]. Our study also shows that the reduction of SPR linewidth brought about by gain media can significantly improve the performance of metallic nanoparticle nonlinear optical bistability structures, such as low threshold power and high signal contrast [4]. We have observed spontaneous emission amplification of surface plasmon polaritons in a conventional prism setup with gain molecules introduced and pumped [5].

We will also report on our recent theoretical study of utilizing gold metal nanoparticles to enhance the near-ultraviolet (near-UV) absorption cross section of TiO_2 nanoparticles, which can help to improve the catalytic efficiency of TiO_2 nanoparticles in the UV band. Our analysis shows that gold nanoparticle dimers can strongly focus the incident near-UV light onto the tiny TiO_2 nanoparticle placed at the gap of the dimer. As a result of this light harvesting effect, the effective absorption cross section of the TiO_2 particle increases a lot. This suggests a promising way to boost the photocatalytic activity of TiO_2 [6]. Finally, we reported the behavior of surface plasmon polariton assisted and mediated dipole-dipole interaction [7].

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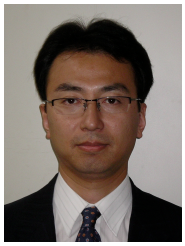

Education

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Research Associate, 1998-2006, Osaka University
Associate Professor, 2006-, Osaka University

Scientific Interests:

Optical and electrical devices utilizing organic materials including dye molecules and conducting polymers

Recent Papers :

1. T. Hori, Y. Miyake, N. Yamasaki, H. Yoshida, A. Fujii, Y. Shimizu and M. Ozaki
"Solution processable organic solar cell based on bulk heterojunction utilizing phthalocyanine derivative"
Appl. Phys. Express 3 (2010) 101602.
2. N. Yamasaki, K. Masuyama, A. Fujii and M. Ozaki
"Spectral Modulation of Microcapillary Laser Based on Emissive π-Conjugated Polymers by Poor Solvent Injection"
Thin Solid Films 519 (2010) 995-997.
3. Y. Miyake, Y. Shiraiwa, K. Okada, H. Monobe, T. Hori, N. Yamasaki, H. Yoshida, M. J. Cook, A. Fujii, M. Ozaki and Y. Shimizu
"High Carrier Mobility up to 1.4 $cm^2 \cdot V^{-1} \cdot s^{-1}$ in Non-Peripheral Octahexyl Phthalocyanine"
Appl. Phys. Express 4 (2011) 021604.
4. T. Hori, N. Fukuoka, T. Masuda, Y. Miyake, H.Yoshida, A. Fujii, Y. Shimizu and M. Ozaki
"Bulk Heterojunction Organic Solar Cells Utilizing 1,4,8,11,15,18,22,25-Octahexylphthalocyanine"
Solar Energy Materials and Solar Cells, in press.
5. T. Higashi, N. Yamasaki, H. Utsumi, H.Yoshida, A. Fujii and M. Ozaki
"Anisotropic Properties of Aligned π-Conjugated Polymer Films Fabricated by Capillary Action and Their Post-Annealing Effects"
Appl. Phys. Express, in press.

BULK HETERO-JUNCTION SOLAR CELLS UTILIZING LIQUID CRYSTALLINE PHTHALOCYANINE AND FULLERENE

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Organic thin-film solar cells based on a bulk hetero-junction utilizing a non-peripherally alkyl-substituted phthalocyanine, such as, 1,4,8,11,15,18,22,25-octahexylphthalocyanine ($C6PcH_2$), have been studied. $C6PcH_2$ is a low-molecular-weight organic semiconductor and has high solubility for typical organic solvents due to the long substituents. $C6PcH_2$ exhibits liquid crystalline phase, such as, hexagonal disordered columnar mesophase between 161 and 170 °C. In the time-of flight measurement, the high drift mobilities, for example, 1.4 and 0.5 cm^2/Vs for hole and electron at -15 °C, were observed in the crystal phase as well as liquid crystal phase [1].

The blend uniform thin film with the $C6PcH_2$ and 1-(3-methoxy-carbonyl)-propyl-1-1-phenyl-(6,6)C61 (PCBM) could be fabricated by a spin-coating method. Solar cells with $C6PcH_2$:PCBM bulk hetero-junction active layer have demonstrated a high external quantum efficiency above 70% in the Q-band absorption region of $C6PcH_2$ and a high energy conversion efficiency of 3.1% [2].

The photovoltaic properties of the solar cell with bulk heterojunction of $C6PcH_2$ and PCBM demonstrated the strong dependence of active layer thickness, and the optimized active layer thickness was clarified to be 120 nm. By inserting MoO_3 hole transport buffer layer between the positive electrode and active layer, the FF and energy conversion efficiency were improved to be 0.50 and 3.2%, respectively. The tandem organic thin-film solar cell has also been studied by utilizing active layer materials of $C6PcH_2$ and poly(3-hexylthiophene) and the interlayer of LiF/Al/MoO_3 structure, and a high V_{oc} of 1.27 V has been achieved [3].

$C6PcH_2$ is available as a dopant for conventional organic thin-film solar cells with an bulk hetero-junction active layer composed of poly(3-hexylthiophene) (P3HT) and PCBM. The improvement of long-wavelength sensitivity in P3HT:PCBM bulk hetero-junction solar cells by doping $C6PcH_2$ has been succeeded.

[1] Y. Miyake *et al.*, *Appl. Phys. Express*, **2011**, 4, 021604.

[2] T. Hori *et al.*, *Appl. Phys. Express*, **2010**, 3, 101602.

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Recent Papers :

1.Yuan-Fong Chau*, Fong-Lin Wu, Zheng-Hong Jiang, and Huang-Yi Li, "Evolution of the complete photonic bandgap of two-dimensional photonic crystal," Opt. Express 19, 4862-4867 (2011)

2.Yuan-Fong Chau*, Han-Hsuan Yeh, Din Ping Tsai," A new type of optical antenna: plasmonics nanoshell bowtie antenna with dielectric holes", J. of Electromagn. Waves and appli., 24, 1621-1632(2010)

3.Yuan-Fong Chau* , Yi-Ju Lin and Din Ping Tsai, "Enhanced surface plasmon resonance based on the silver nanoshells connected by the nanobars", Optics Express 18, 3510-3518 (2010)

4.Yuan-Fong Chau*"Surface Plasmon Effects excited by the Dielectric Hole in a silver-shell nanospherical pair", **Plasmonics, 4, 253-259** (2009)

5.Yuan-Fong Chau*, Han-Hsuan Yeh ," A comparative study of solid-silver and silver-shell nanodimers on surface plasmon resonances"' J nanopart. Res. 23:637-644 **(2011)**

Numerical study on nanophotonics and their some applications

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Numerical study on nanophotonics and their some applications of our recent works are introduced in this talk. Two topics are investigated, which include photonic crystal and plasmonics effects on nanometal. In the topic of photonic crystal, the photonic crystal bandgap, photonic crystal fibers and photonic crystal waveguide are explored numerically by use of the finited different time domain method and plane wave expansion. In the topic of plasmonics effects on nanometal, the optical properties of silver nanorods and plasmonic waveguides are investigated by use of finite element method. Some meaningful results and their applications are also disscussed in this talk.

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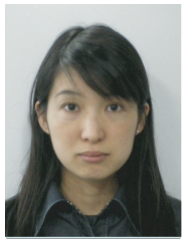

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Molecular science : Near-field Microscopy, Raman Spectroscopy, Instrumentation, Optical properties of nano-materials, Optical Imaging, *in Vivo* Imaging

Recent Papers

Honda M, Saito Y. Smith NI, Fujita K, Kawata S
Nanoscale heating of laser irradiated single gold nanoparticles in liquid
Optics Express, in press

Saito Y, Honda M, Moriguchi Y, Verma P
Temporally dynamic photopolymerization of C60 molecules encapsulated in single-walled carbon nanotubes
Physical Review B, 81, 245461-7 (2010)

Yano T, Verma P, Saito Y, Ichimura T, Kawata S
Pressure-assisted tip-enhanced Raman imaging at the resolution of a few nanometres
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Saito Y, Verma P, Masui K, Inouye Y, Kawata S
Nano-scale Analysis of Graphene Layers by Tip-enhanced Near-field Raman Spectroscopy
J.Raman Spectrosc., 40, p1434-1440 (2009)

Saito Y, Verma P,
Imaging and Spectroscopy Through Plasmonic Nano-Probe
European Physical Journal- Applied Physics, 46, 20101-15 (2009)

Development of UV Plasmonics and Microscopic Techniques

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The research field “Plasmonics” has been rapidly growing in these decades. Under the plasmonic effect, the optical field is enhanced 10^3-10^{10} times due to the surface plasmon oscillations in a metal nanostructure that couple with an incident phonon [1]. The advantage of the effect is enormous and variety of applications has been developed such as surface enhanced Raman spectroscopy (SERS) [2], Tip-enhanced Raman spectroscopy [3,4] and imaging marker [5] etc . The optical wavelength range of plasmonis is now limited only in visible to near-infrared range.

One of the reasons for the limitation is that the metals that have been used for plasmonics were mainly silver and gold, which shows plasmon resonance in visible range. In this study, we employed aluminum as a new candidate for the UV plasmonics. Since it is difficult to chemically synthesize nano particles from aluminum, we employed lithographic techniques to make nanostructures for plasmonic coupling. With downsizing the polystyrene masks by microwave heating, we have achieved surface plasmon resonance at peak ~270 nm that is the shortest record of the plasmon peak wavelength that has been reported so far. If the wavelength range of the plasmonics extend to UV, we will find even more versatile applications such as photo-catalytic effects, solar cells and sensors for bio materials that have the absorption peaks in deep-UV wavelength etc.

Another reason that the UV plasmonics is still under developing is that the optical microscopy is not easily available in UV wavelength range compared to visible. We have been developing a white light scattering microscopy in UV region for instant evaluation of the plasmonic nanostructures in the wavelength under 300nm. White light scattering microscopy has been widely used to investigate the optical properties of the nano-materials, again only in visible range [6,7]. We can access the electronic states of molecules through the refractive index parameter obtained by the scattering spectra. For evaluation of structured sample, the microscopic technique is necessary therefore, the conventional UV-VIS absorption spectrometer is not enough for the evaluation of UV plasmonic nano-materials. Besides plasmonic materials, the method will be a powerful tool for studying the optical properties of small structures under UV light .

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Scientific Interests:

Theoretical research and simulation on nano-optics and near field optics; principle and system of scanning near field optical microscopy (SNOM); single molecule detection with SNOM; near field spectroscopy and Tip Enhanced Raman Spectroscopy (TERS); Plasmonics device and SPP device; measurement and characterization of optical features in nanometer scale with SNOM.

Recent Papers :

1. Fenghuan Hao, Rui Wang, Jia Wang, A Design Method for a Micron-Focusing Plasmonic Lens Based on Phase Modulation, Plasmonics, 5(4): 405-409, 2010

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3. Rui Wang, Jia Wang, Fenghuan Hao, Tian Qian, Tip-enhanced Raman spectroscopy with silver-coated optical fiber probe in reflection mode for investigating multi-wall carbon nanotubes, Applied Optics, Vol.49, No.10, pp1845-1848, 2010

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Developments and Prospects of the Nano-Optics Measurements and Characterizations

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The Scanning Near-field optical Microscope (SNOM) is the most ideal experimental measuring system. Its performances include imaging beyond the diffraction limits, localized spectroscopy with nanometer resolution and other novel properties. They have become indispensable in the nano-optics and nano-photonics.

Near-field optic measuring system has been developed for more than two decades. It has being going through the four phases of development in the past years and in the future.

The first stage, the arising of the near-field optics. The diffraction limit was surpassed and the optical super-resolution obtained in the microscopic imaging. The near-field optical imaging and measuring systems are rapidly developed and widely used in various fields as the well-known method and system, the Scanning Near-field Optical Microscopy (SNOM).

The second stage, near-field spectroscopy as a new highlight followed the super-resolution imaging in the near-field optics. TERS has become a powerful tool and will be widely used in many fields, physics, chemistry, biomedical science, materials science, plasmonic devices, nano-metrology and so on, especially in the fields of nano-optics and nano-spectroscopy.

The third stage, measurement and characterization of nano-optical field parameters have become the new research hotspot. The novel method used to measure the amplitude and the phase distribution in optical field was proposed. This method combined laser heterodyne interferometry and near-field optics and is developed as the tip heterodyne interferometry. Based on the technology and the Faraday's effect, a slip metal probe has been used to visualize with subwavelength resolution the magnetic- and electric-field distribution of propagating light. The conversion mechanism and conditions of magnetic- and electric-field will be measured in the future.

The fourth stage, research and detection on the interaction between light and matter and nano-structures will be the most important aim in the coming decade. For example, undisturbed detection method, "split probe", optical dipole antennas, controllable polarization field vector measurement and optical field phased analysis method will be employed. Scientists will reveal that the essence of nanophotonics and will develop the new fundamental theory and methods for the design and fabrication of nanophotonics devices and systems. It will promote the developments of nano-photonics systems, metamaterial devices and circuitry, single molecule detection, localized chemical information extraction and characterization.

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Education

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Scientific Interests:

Molecular Imaging, Femtosecond Optics, Ultrafast Phenomena, Quantum Devices, Ultrahigh Bandwidth Electronics, THz Optoelectronics, Biophotonics, Nano Acoustics.

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Resonant Microwave Sensing of Virus

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For a free nanosphere, originally free-propagating acoustic waves will be confined and results in quantized eigenmodes [1]. When the mechanical vibration of the confined acoustic modes modifies the dipole moments of the nanosphere, incoming electromagnetic waves should be able to be resonantly coupled with the nanosphere's confined acoustic phonons. By treating a spherical virus as one free nanoshpere, the frequency of the dipolar active (l=1) confined acoustic mode [2] should fall in the microwave range [3]. This microwave resonant effect is very different from previously-reported molecule-induced microwave resonant absorption (MRA) in a cell and is highly size and shape sensitive. Exploiting this characteristic absorption, here we report a non-contact method to rapidly characterize the geometrical and mechanical properties of viruses. Using a standard network analyzer system and a coplanar waveguide circuit, we measured the MRA spectra of *Perina Nuda* virus (PnV), White Spot Syndrome virus (WSSV), Entrovirus type 71 (EV71), and Influenza A virus. The negatively charged genome (DNA or RNA) and the capsid protein (sometimes with extra envelope) of a virus provide the inherent charge separation required for the activation of the MRA. As predicted by elastic continuum theory [1-3], we found that the resonant absorption frequencies and the absorption selection rules are sensitive to and depend on the dimension and shape of viruses [4,5]. Compared with transmission electron microscope (TEM) or atomic force microscope (AFM), our method has joint advantages of rapid characterization, staining free, non-contact, and in *vivo* capability. Combined with mature microwave technology, we anticipate our method to be a starting point from which to develop a rapid bio-chip for the identification, quantification, and manipulation of viruses. Also, it reveals a new physical mechanism for microwave to resonantly interact with biological system, which might cause biological and medical effects at radiation level lower than the regulations.

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Abstracts for Poster Presentations

Fabrication and Characterization of three dimensional erected U-shape metamaterials by stress-driven assembly method

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The artificial metamaterials such as split ring resonaotrs (SRRs) recently have attracted much interests due to its unique optical properties. The U-shape matematerials both in planar and three dimensional (3D) types have been demonstrated to show a series of resonance modes excited by an incident light with electric field perpendicular to the arms of the U-shape matematerial or with magnetic field oscillating through the gap of the U-shape matematerial. In this study, we fabricated arrays of three dimensional U-shape SRRs through a simple self-assembly strategy. This strategy is combining with an electron beam lithography and a reactive ion etch. The 3D structures is achieved through an intrinsic stress force while the arms of the U-shape SRR are released from the substrate. The fabrication procedures are described as follows. Firstly, the planar templates consisting of two long arms with length of 2 μm and width of 125 nm and a gap part with length of 300 nm and width of 250 nm were defined by an electron beam lithography through a lift-off process with metal multilayer deopisition of Al (10nm)/ Au (35nm)/ Al(10nm) on a quartz substrate. Notice that the gap part with larger width was designed to prevent the gap part from the release during dry etching process. Second, the dry etching process with C_4F_8 plasma was applied to the sample to etch the quartz substrate and release the metal arms from the underneath quartz substrate. While the metal arms were release from the substrate, the intrinsic compressive stress of Au film was effective in pulling up the arms vertically and resulted in 3D U-shape SRRs. Details of optical properties will be presented later.

Ambipolar, Light-Emitting Transistors Utilizing Liquid-Crystalline Semiconducting Polymers

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Recently, organic field effect transistors (OFETs) have been extensively studied in view of their applications to low-cost, large-area, flexible electronics. In organic semiconductors, π-conjugated polymers, being quasi-one-dimensional macromolecular electronic systems, offer a number of unique properties. Poly(9,9-dioctylfluorene) (F8), which is one of liquid-crystalline semiconducting polymers, exhibits blue emission and various morphological behaviors. Liquid-crystalline semiconducting polymers were self-organized due to both the reorientation of molecules and the growth of size of crystalline regions during thermal annealing process. Fluorene-type polymers have emerged as an important class of conducting polymers due to their efficient emission, high stabilities and relatively high mobility. Fluorene-type polymers also have the potential for full color emission via energy transfer to longer wavelength emitters in blends with other emissive materials. Then, in this work, we investigated the fabrication and characteristics of top-gate type orgnic light-emitting transistors (OLETs) with ITO drain/source electrodes utilizing fluorene-type polymers as ambipolar organic materials. An OFET with F8 as an active layer, which contains only a fluorene backbone, exhibited ambipolar characteristics with hole and electron field-effect mobilities of approximately 10^{-3} cm^2 V^{-1} s^{-1}. All OFETs with fluorene-type polymers exhibited ambipolar characteristics because the value of the work function of the ITO electrodes is approximately in the middle between the highest occupied molecular orbital and lowest unoccupied molecular orbital levels of fluorene-type polymers. In ambipolar OFETs, simultaneous electron and hole injection can be achieved by applying the gate voltages. An OLET based on F8 emitted blue light owing to the ambipolar transport (Fig. 1). Ambipolar OLETs with fluorene copolymers F8BT and F8T2 exhibited yellow-green and yellow EL emissions, respectively, with varying gate voltage, as shown in Fig. 2.

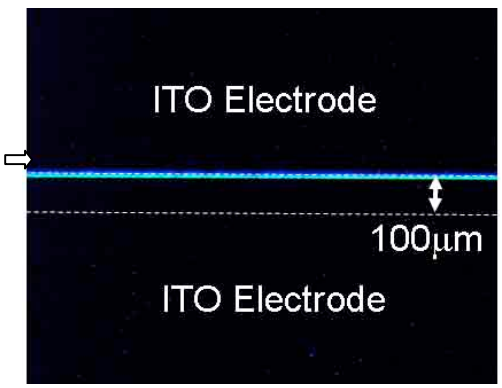

Fig.1 Camera image of light emission from an OLET with F8 (channel length : 100μm)

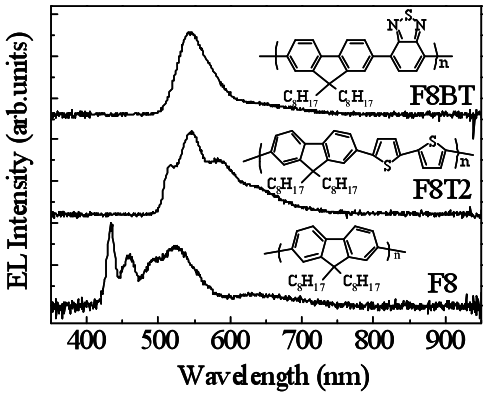

Fig.2 EL spectra of various OLETs.

Fast Protein Labeling with Designed Fluorogenic Probes and Application to Real-Time Pulse-Chase Analysis

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Protein labeling technology has attracted a great deal of attention from researchers in life sciences because protein labeling methods hold promise for overcoming the various limitations of fluorescent proteins in live cell imaging. This technology enables the various functionalization of proteins with small molecules and is expected to lead to the development of various protein assay methods. Fluorescence labeling techniques have contributed to several biological advances including characterization of the protein-protein interactions of the G protein-coupled receptor, trafficking of myoblasts, and cell cycle-regulated processes. Fluorescent protein such as GFP is used widely in the field of medicine and biology as fluorescent labeling reagent. However, because the fluorescent protein is a big molecule of about 30kDa, the function of a target protein that is imaging might be damaged and aggregation be caused by uniting the fluorescent protein.

We recently developed a fluorogenic protein labeling system exploiting a genetically modified β-lactamase and the synthesized β-lactam probes. This technology is quite versatile, and its various applications such as multicolor fluorescence imaging and pulse-chase experiment with luminescent quantum dots via specific biotinylation were demonstrated. Use of FRET-based labeling probes in this system conferred both specificity and turn-on fluorescence property. The labeling mechanism involves two steps: initial non-catalytic enzyme reaction and subsequent quencher elimination via self-immolative reaction.

Moreover, we developed a no-wash fluorogenic labeling system by utilizing fluorescence resonance energy transfer (FRET)-based fluorescein (fluorescent agent) - cephalosporin (β-lactam) - azopyridinium (quencher) probes and a mutant β-lactamase tag. Fast quencher elimination, hydrophilicity, and high resistance against autodegradation were achieved by rational refinement of the structure. By applying the probe to real-time pulse-chase analysis, the trafficking of epidermal growth factor receptors between cell surface and intracellular region was imaged. In addition, membrane-permeable derivatization of the probe enabled no-wash fluorogenic labeling of intracellular proteins. That is to say, through chemistry-based rational design, we developed a novel fluorogenic labeling probe that does not require the washing procedure in live cell imaging. This system provided an innovative protein analytical method by real-time pulse-chase analysis.

Detection of chemical reactions using emission quenching of semiconductor nanoparticles

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Semiconductor nanoparticles (quantum dots) with their size of ca. 10 nm have some special properties which are different from those of bulk semiconductors. Confinement of excitons into particles smaller than their Bohr radii cause quantum size effect, which increase the band gap of semiconductors, and contribute to the photoluminescence under UV exposure even at room temperature. With the spread of their use for fluorescent marker in biochemistry, nanoparticles those are free of toxic elements, such as cadmium, mercury, and phoshorus, have been desired. Our gourp have developed ZnS-$AgInS_2$ solid solution (ZAIS) semiconductor nanoparticles having bright fluorescence from green to near-infrared according to their composition (ZnS/$AgInS_2$). Low toxcitiy of these I-III-VI semicondcutror nanoparticles have potential applicability to general use, such as wavelength conversion of light emittinig devices, and chemical sensors using fluorescence as a probe.

In the present study, we report on the emission quenching of the ZAIS nanoparticles that occurs in the presence of some redox species (Fig. 1) by the electron transfer from the nanoparticles to the quenchers in oxidized state. Besides the basic studies on emission quenching using steady-state and time-dependent fluorescecne spectroscopy, a concept of chemical sensing based on the controlled emission quenching is presented (Fig. 2).

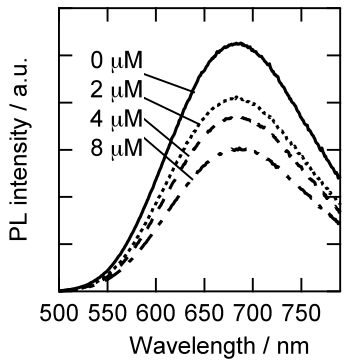

Fig. 1. Emission quenching of the ZAIS nanoparticles aqueous solution in the presence of 9-aminoacridine.

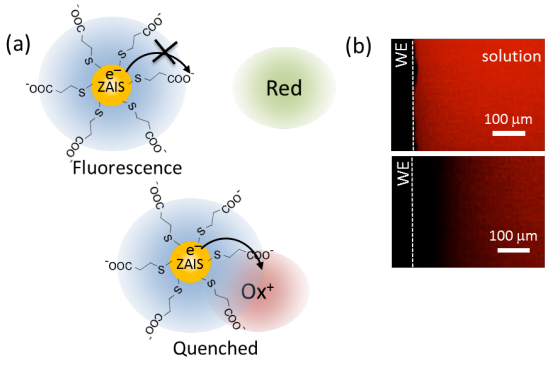

Fig. 2. Image of redox-dependent variation of emission quenching (a), and detection of electrochemical reactions using fluorescence as a probe (b).

UV Photoresponse of Single-Walled Carbon Nanotubes Decorated with ZnO Layer

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Single-walled carbon nanotubes (SWNTs) decorated with nanomaterials can possess a function, such as an enhanced responsivity for specified gas molecules, which pristine SWNTs do not have. Recently, it is reported that SWNTs can be given the response for UV light by decorating ZnO nanoperticles on them [1]. However, the effect of the parameters of the decorating ZnO nanoparticles such as the size, crysatallinity and surface morphology on the photoresponse for the ZnO decorated SWNTs have not yet been fully understood. In this study, to reveal the effect, we investigated the UV photoresponses of SWNTs decorated with thickness-controlled ZnO layers.

SWNTs were directly grown on a conventional sensor platform by thermal chemical vapor deposition (CVD) method. The SWNTs were then decorated with ZnO layer (ZnO-SWNTs) by pulsed laser deposition (PLD). Figure 1 shows transmission electron microscopy (TEM) image of a ZnO-SWNT. The ZnO layer was found to be wholly wrapped around a SWNT. The thickness of ZnO layer can be controlled by PLD duration. Figure 2 shows a series of UV photoresponses for the ZnO-SWNTs prepared by various PLD durations from 3 to 45 min, which are plotted in terms of photocurrent as a function of measuring time. The ZnO-SWNTs exhibited a significant decrease in current upon a UV illumination. After the UV light was turned off, the current in ZnO-SWNTs was gradually recovered. ZnO-SWNTs (PLD 15 min) exhibited the most excellent photoresponse property, i.e., the largest photocurrent and the fastest recovery time. This result indicates that the photoresponse property of ZnO-SWNTs strongly depends on the thickness of the ZnO layer coating them.

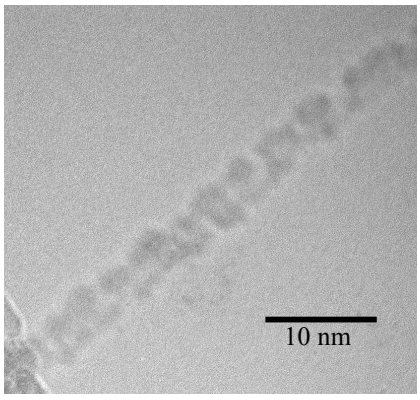

Fig.1 TEM image of ZnO-SWNT (PLD 15 min)

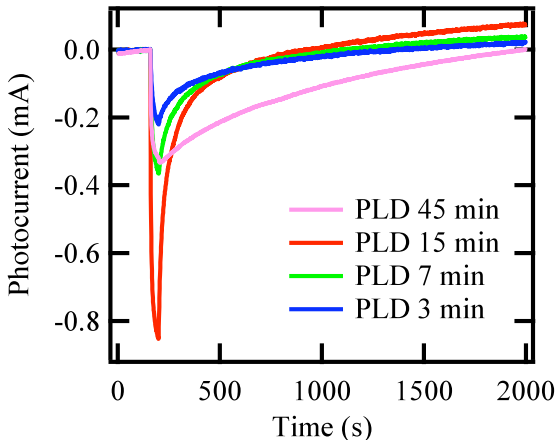

Fig.2 UV Photorenponses of ZnO-SWNTs depending on thickness of decorated ZnO layer

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A resolution of λ/22 achieved in two-photon polymerization nanofabrications

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Two-photon process is one kind of nonlinear phenomenon. It can only happen in the center of laser focus in which the number of photons is big enough. Theoretically, polymer voxel can be infinitesimal in two-photon polymerization. Therefore, better line width resolution is one of the most important targets for two-photon fabrication technique[1-4].
A mode-locked Ti:sapphire laser with a center wavelength of 780 nm, pulse width of 100 fs and repetition rate of 80 MHz was employed as a light source . A commercially available photocurable resin (SCR500) was used as resolution test material. A three-dimensional piezostage and a neutral density filter were used in two-photon fabrication systems for controlling the exposure time and excitation power with the precision as high as 0.02 ms and 7 pW, respectively. By precisely controlling the exposure time and the laser power approaching to the polymerization threshold, 35 nm and 45 nm polymer lines on cover glass were achieved, respectively, which were only 1/22 and 1/17 of the laser wavelength used for fabrication. These are the highest line width resolution obtained by two-photon fabrication on cover glass until now. It is revealed that the resolution of line width can be efficiently improved with ultra-small reduction of the exposure time or exposure power near the polymerization threshold. This study would provide good prospects for improving the resolution in two photon polymerization process.

Keywords: femtosecond laser; two-photon fabrication; line width resolution; polymerization threshold.

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Photo-induced inactivation of metallic SWNTs in H_2O_2 aqueous solution

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Single walled carbon nanotubes (SWNTs) have been regarded as a promissing candidate for applications in nanoelectronic devices due to their high mobilities and high current-carrying capacities. In order to realize high-performance carbon nanotube field effect transistor (CNT-FETs), simple, reliable and scalable approaches to remove metallic carbon nanotubes from as-grown SWNTs are desired. One possible approach is a selective inactivation of metallic SWNTs induced by UV irradiation in air enviroment[1,2]. However, this process is quiet slow and time-consuming. More efficient process to inactivate metallic CNTs is required. In this work, we investigated the photo-induced inactivation of metallic SWNTs caused by UV irradiation in H_2O_2 aqueous solution, which is known to work as an effective oxidant for degradation of organic compunds in water.

CNT-FETs used for this study were back-gated devices with horizontally arraigned multiple SWNTs as a channel. The channel length and width were set 10 and 100 μm, respectively. A fabricated substrate with the CNT-FETs was immersed in H_2O_2 aqueous solution and was subjected to the light from a Hg-Xe lamp (1 W/cm^2). The electrical transport properties were measured by a semiconductor parameter analyzer with a probe station in air at room temperature.

Figure 1(a) shows the transfer characteristics for a typical device before and after 90 min of UV irradiation in H_2O_2 aqueous solution. A remarkable increase in the channel current on/off ratio (I_{on}/I_{off}) was observed from 3 before irradiation to 220 after irradiation, indicating inactivation of mettallic nanotubes in the channel of the device. Figure 1(b) shows the on-state current (I_{on}) and the off-state current (I_{off}) plotted as a function of UV irradiation duration. As seen in Fig.1(b), the I_{on} and the I_{off} remained for the first 60 min and a siginificant decrease in the I_{off} was observed after 60min of irradiation. The times to start decreasing in the I_{off} were different from device to device. However, they tended to be shorter than those in the case of UV irradiation in air.

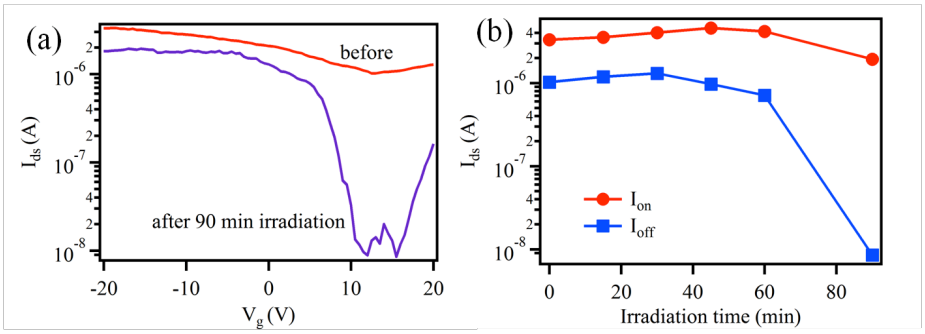

Fig. 1 (a) The transfer characteristics of CNT-FET before irradiation and after 90 min of irradiation. (b) I_{on} and I_{off} for the same device plotted as a function of UV irradiation duration.

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Simulation study of magnetic quantum dots cellular automata shift register

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Magnetic Quantum dots Cellular Automata (MQCA)[1] consists of elliptic nano-magnets which is small enough to take a single domain state. Digital information of “0” and “1” are stored as a magnetization direction. The MQCA can translate and calculate[2,3] Boolean information via magneto-static interactions between the nano-magnets with external magnetic clock field.

In general, the nano-magnets are set to be parallel to each other. Thus the magnetization of the nano-magnet shows same behavior to the external magnetic clock field. Thus, in arrayed MLG structure, it is necessary to apply a local magnetic clock field to control a data flow direction between the MQCA gates. In this study, we develop a MQCA shift register which can define the data flow direction with uniform magnetic field.

Figure 1 shows schematic diagram of 8-bit shift register. D_n and B_n are data bits and buffer bits, respectively. When the clock field direction is set to be parallel to the easy axis of the D_n or B_n, the data are copied from D_i to B_i. While the clock field direction is set to be parallel to the easy axis of the B_n, the data are copied form B_i to D_{i+1}. By repeating above process, the data can be shifted.

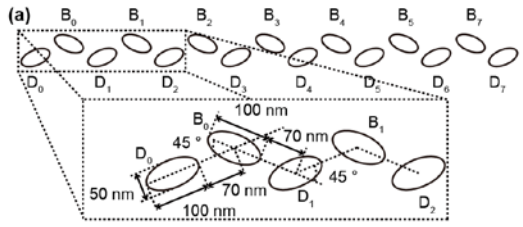

Fig. 1. Schematic of 8-bit shift register.

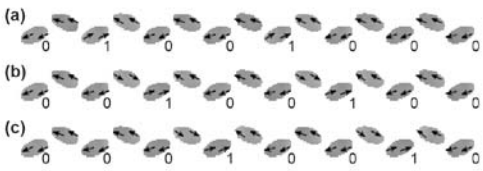

Fig. 2. Simulation results of 8-bit MQCA shift register. (a) initial states and (b, c) operation results.

In numerical simulation, OOMMF was used to calculate the behavior of 8-bit shift register. The material parameters used for the numerical calculations are those for Permalloy which contained in the OOMMF, and amplitude of the external magnetic field is 70 mT. Figure 2 shows simulation results of the 8-bit shift register. Fig. 2 (a) shows initial states of the 8-bit shift register D = (01001000). By applying the clock field, the 8-bit shift register shows shifted data D = (00100100) [Fig. 2(b)] and (00010010) [Fig.2 (c)]. With this method we can define the data flow direction, without creating a complex system for applying the local magnetic clock field to arrayed MLG structures.

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THz radiation from antiferromagnetic magnons

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Terahertz (THz) wave is the electromagnetic wave (0.1 THz ~ 10 THz) in the frequency region between microwave and infrared. One of the most important applications of THz technology is the spectroscopy for characterizing various materials. The observation of time-domain waveforms of THz radiation from materials excited by optical laser pulses allows us to investigate the ultrafast dynamics of the microscopic properties of various materials. In this study, we use this powerful technique called "THz emission spectroscopy" to investigate the ultrafast spin dynamics in magnetic materials. Studies on the detection and manipulation of ultrafast electron spins in magnetic materials are important for spintronics. The knowledge of the ultrafast spin dynamics leads to the development of ultrafast spintronics devices such as MRAM and spin FET.

So far, we have observed THz pulses radiated from antiferromagnetic (AFM) single-crystal NiO(110) irradiated with femtosecond laser pulses [1]. Figure 1 shows that the waveform of THz radiation from NiO has a main pulse and characteristic oscillations (~1 THz at R.T.). The spectrum (Fig. 2) obtained from the Fourier transform of the waveform clearly shows that the oscillations are the electromagnetic wave radiation with a frequency of ~1 THz. This oscillating radiation at R.T. has the same frequency as that of AFM resonance [2]. In addition, we confirmed that the temperature dependence of the radiation frequency almost corresponds with that of the AFM resonance absorption at which AFM magnons with a wave number k ~ 0 are excited. Therefore, we conclude that the characteristic oscillations are radiated from coherent AFM magnons excited by optical laser pulses. Inverse Faraday effect is a possible mechanism of the coherent AFM magnon excitation by the laser pulses. The excited coherent AFM magnons in NiO produce the THz radiation via magnetic dipole radiation that is an inverse process of AFM resonance absorption of the terahertz wave.

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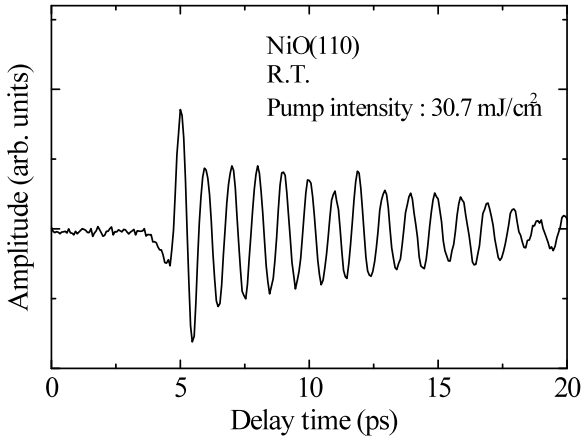

Fig.1 Time-domain waveform of THz radiation from NiO(110).

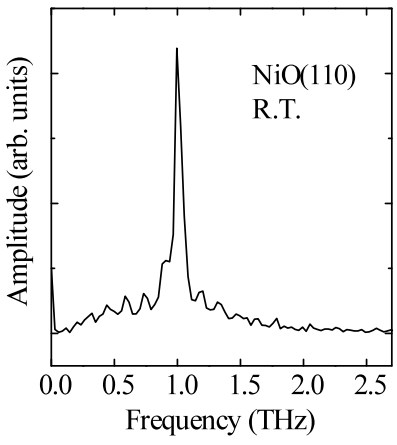

Fig.2 Frequency-domain spectrum of THz wave radiated from NiO(110).

Transport Properties of Free Carriers in High Quality n-type GaN Wafers Studied by THz Time-domain Magneto-optical Ellipsometry

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GaN is one of promising materials for high-power and high-frequency electric devices because of its high break down voltage and high-field saturation drift velocity. The carrier density and mobility are critical parameters since those dominate the device properties. Furthermore, the dependence of the transport properties on the carrier density is needed for clarifying details for free carrier conduction mechanism in GaN. However, systematic studies on the transport properties in GaN with a wide range of the carrier density in non-contact fashion are scarce up to now. We have developed a scheme for THz time-domain magneto-optical ellipsometry (THz-TDMOE) to investigate the transport properties of the free carriers in semiconductors through measurement of the magneto-optical Kerr effect.[1] In this study, using THz-TDMOE, we have measured the dependence of the effective mass and electron mobility of high quality n-type (0001) GaN wafers on the carrier density in the range from 7.9×10^{15} to 7.8×10^{17} cm^{-3}.

A schematic diagram of of the experimental set up for THz-TDMOE is shown in Fig. 1. THz pulses are radiated from a biased dipole-type photoconductive antenna excited by a mode-locked Ti:sapphire laser. The THz pulses are collimated and focused onto a sample by off-axis parabolic mirrors. The incident angle is 45.3°. Figure 2(a) shows the carrier density dependence of effective mass. The obtained values show no systematic carrier density dependence. This behavior agrees well with calculated value m_p taking into account nonparabolicity of the conduction band and polaron effect. Figure 2(b) shows the carrier density dependence of mobility. In high carrier density region (>10^{17} cm^{-3}), the mobility decreases with carrier density, which is consistent with well established fact that ionized impurity scatering is dominant at high carrier densities in GaN. In contrast, the mobility in low carrier density region is almost independent of carrier density. This behavior can be explained by a theory taking into account carrier scattering caused by charged dislocations in GaN. [2] The theory predicts that the mobility of samples with low dislocation density (<10^{7}~10^{8} cm^{-2}) is nearly constant because the polar optical phonon scattering becomes more dominant than the dislocation scattering, which is consistent with our results for the samples with dislocation densities of $0.2\sim2.0\times10^{6}$ cm^{-2}.[3]

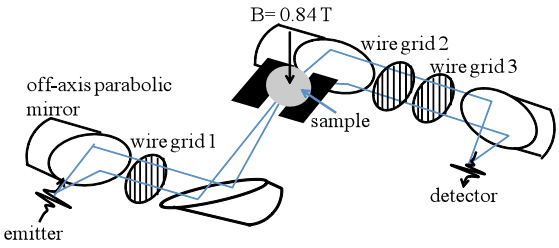

FIG. 1. Schematic diagram of setup for the terahertz time-domain magneto-optical ellipsometry.

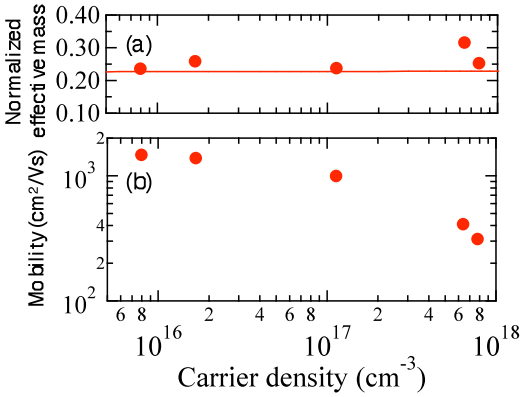

FIG. 2. Carrier density dependence of effective mass (a) and mobility (b) of n-type GaN. Solid circles indicate the values obtained from our measurements. The solid curve show the calculated values of m^*_p.

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CdSe-Au hybrid nanocrystals: shape-controlled synthesis and photovoltaic application

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CdSe NC is a kind of widely investigated semiconductor nanomaterial for its academic and practical applications.[1] Size quantization effect of CdSe NCs is regarded as the most attractive feature for attaining organic solar cell application by utilizing different particle sizes and shape.[2] In addition, CdSe NC is also likely to exploit hot electrons or generate multiple carriers with a single photon.[3] Nevertheless, one significant challenge of CdSe NC is to extract the light-induced charge carriers before they decay via competing pathways, including exciton cooling, surface trapping, radiative recombination, and Auger process.[4] Metal-semiconductor hybrid nanostructures are promising for solving this problem, in which the subgap states emerge and facilitate exciton dissociation and charge transport.[5] Although numerous CdSe-Au hybrid NCs have been studied,[6] the synthesis of CdSe-Au hybrid NCs with extended order and hierarchy is still a challenging task.

Here, we present the shape-controlled synthesis of highly symmetrical CdSe-Au hybrid NCs with Zinc-Blende CdSe NCs as seeds. The synthesized CdSe-Au hybrid NCs were constructed by selective deposition of gold clusters on the apexes of both cubic and tetrahedral Zinc-Blende CdSe NCs for the different reactivity of crystal facets. In addition, the isolated CdSe-Au hybrid NCs can further self-assemble into hierarchical CdSe-Au nanostructures of greater complexity. The as-prepared CdSe-Au hybrid NCs exhibited broadened absorption spectra, strong fluorescence quenching, and good photoinduced exciton dissociation and charge transfer properties. The photovoltaic application of the CdSe-Au hybrid NCs was also demonstrated. This study would provide high opportunities for improving the properties of photoelectric devices, such as solar cells, photocatalysts, quantum computing and sensors.

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Design of Visible Light Sensitive TiO_2 Based Materials via Formation of Surface Complexes and Their Photocatalytic Activities

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In several decades, TiO_2 based photocatalysts have attracted much attention because of their technological importance for variety of applications. The purification of air/water as well as production of important chemicalas have been intensively studied by many researchers.[1-3] The development of efficient photocatalytic systems, which work not only under UV but also visible light, has also been great concern regarding the need to address energy problems.

In this work, visible light sensitive TiO_2 based photoctalysts were designed by composites of platinized TiO_2 (Pt-TiO_2) and naphthalene derivatives via formation of surface complexes. Naphthalene derivatives with different number and substituted position of hydroxyl group were adopted as surface-attached ligands. The application of them for organic syntheses such as reduction of nitrobenzene (NB) to aminobenzene (AB) was investigated under irradiation of visible light ($\lambda > 420$ nm).

Pt-TiO_2 was prepared by the photodeposition method from deaerated aqueous methanol solution of $H_2PtCl_6 \cdot 6H_2O$ under UV light. The average diameter of Pt nanoparticles was about 3.7 nm, which were homogeneously dispersed on TiO_2. Pt-TiO_2 showed the absorption band below 380 nm corresponding to the band-gap energy of anatase type of TiO_2. After treatment of Pt-TiO_2 with an acetone solution of naphthalene derivatives, especially 2,3-dihydroxynaphthalene (2,3-DN), the powder color changed to yellowish gray, whereas the original 2,3-DN solution exhibited no absorption in the visible light region. This visible light absorption is assigned to the ligand-to-metal charge transfer of surface complexes formed by the coordination of phenolic compounds on surface Ti atoms.

The photocatalytic reduction of NB to AB was occured on Pt-TiO_2 modified with 2,3-DN upon excitation of absorption band in the visible light region, while this reaction hardly proceeded on pure Pt-TiO_2. It was also found that the loading of Pt on TiO_2 surface play an important role for enhancement of this reaction with relatively high AB selectivity. The detailed characterizations and the catalytic performances of these composits will be presented.

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Solution processable organic solar cell based on bulk heterojunction utilizing phthalocyanine and fullerene

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Organic thin-film solar cells based on a bulk heterojunction utilizing the phthalocyanine derivative, 1,4,8,11,15,18,22,25-octahexylphthalocyanine ($C6PcH_2$) have been studied. Some of low-weighted molecular semiconductors have a high crystallinity and charge mobility, but it is difficult to apply wet process fabrication due to their poor solubiltity in typical organic solvents. $C6PcH_2$ is soluble in organic solvents[1] such as chloroform and the blend uniform thin film with the fullerene derivative, 1-(3-methoxy-carbonyl)-propyl-1-1-phenyl-(6,6)C61 (PCBM), could be fabricated by a spin-coating method. Solar cells with an indium-tin-oxide/$C6PcH_2$:PCBM/Al structure, the active layer of which was prepared by a wet process using a low-weighted molecular system, were fabricated.

The composite ratios of $C6PcH_2$:PCBM in these solutions were 2 : 1 , 1 : 1 , and 1 : 2 by weight ratio. The $C6PcH_2$:PCBM composite ratio dependence of external quantum efficiency (EQE) and current–voltage characteristics of the solar cells were investigated. The EQE of the solar cell with the $C6PcH_2$:PCBM composite layer at a weight ratio of 2 : 1 reached more than 70% in Q-band absorption region of $C6PcH_2$ (Fig. 1) and the energy conversion efficiency of that reached 3.1% (Fig. 2)[2]. We will also report the active layer thickness dependence, hole transport buffer layer dependence and tandem structured solar cell[3]

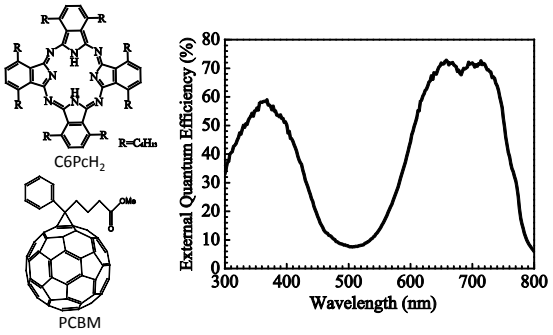

Fig. 1 Molecular structures of $CuPcH_2$ and PCBM and EQE spectrum of the solar cell, the composite ratio of $C6PcH_2$:PCBM is 2 :1 in weight.

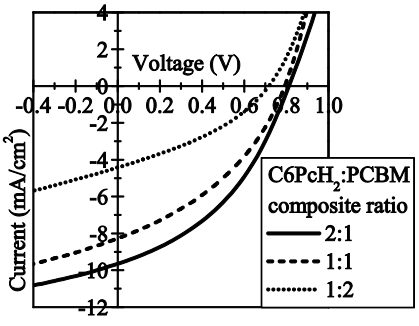

Fig. 2 $C6PcH_2$:PCBM composite ratio dependence of current–voltage characteristics of the solar cells

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Thermal and Electronic Properties of Octahexylphthalocyanine / PCBM Binary Systems for Efficient Solar Cell

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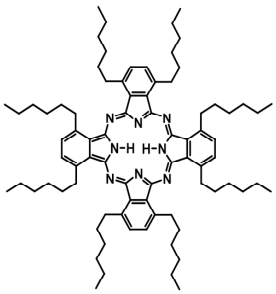
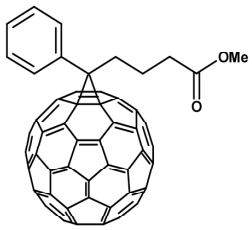
Non-peripherally octaalkylated phthalocyanines are promising new molecular semiconductors used as donor material in solution processed organic solar cells. Indeed, the substitution of long aliphatic chains onto the rigid core of these materials allows their preparation as thin films by wet processes. Moreover, control of the molecular orientation within the film can be achieved thermally. These compounds exhibit ambipolar carrier mobilities identical to that of amorphous silicon (~10^{-1} cm^2 V^{-1} s^{-1}) in their liquid crystal phase. [1,2] We have also recently reported drift mobility for holes as fast as 1.4 cm^2 V^{-1} s^{-1} in the crystalline phase of the octahexylphthalocyanine metal-free derivatives (C_6PcH2).[2] Bulk heterojunction solar cells using a 2:1 weight ratio of the binary system C_6PcH_2 and 1-(3-methoxy-carbonyl)-propyl-1-1-phenyl-(6,6)C_{61} (PCBM) as active layer demonstrated high energy conversion efficiency of 3.1% with external quantum yield exceeding 70%.[3]

We will present our recent results on the thermal behaviors and phase separations of 1:1, 2:1, and 3:1 wt. ratios of C_6PcH_2/PCBM binary mixtures studied by Differential Scanning Calorimetry (DSC), Polarized Optical Microscopy (POM) and X-ray diffraction (XRD). Carrier transport in thin films of these mixtures studied by Time of Flight technique will also be presented.

Unlike the phthalocyanine single material which shows a liquid crystal phase, only crystallization is observed for the binary mixtures. Phase separation of the PCBM within C_6PcH_2 domain could be obtained by repetitive heating and cooling cycles.



C_6PcH_2



PCBM

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Spectral and Polarization Characteristics of Terahertz Radiation from Metaatom-loaded Photoconductive Antennas

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Photoconductive antennas (PCAs) are important devices for electromagnetic waves at terahertz frequencies (terahertz waves). Various antenna patterns such as a dipole, bowtie, spiral, and stripline type PCAs and their arrays are being developed for improving efficiency and controlling the direction and polarization of the radiation. The terahertz emission characteristics of the antenna are governed by the resonance frequencies of the antenna structure.

A split-ring resonator (SRR) is one of the most popular “metaatom” to design effective optical parameters of metamaterials. The resonance wavelength of the SRR is more than ten times of the size of the SRR. It has been demonstrated by O’Hara *et al.*[1] that loading SRRs to the PCAs is effective to enhance the efficiency at specific frequencies. In this work, we investigate the terahertz radiation characteristics from the dipole-type PCAs loaded with the metaatoms which are located with some configurations.The polarization characteristics must be affected by the shape and orientation of the SRRs.

The PCAs were fabricated by super-fine ink-jet (SIJ) printing technology on semi-insulating gallium arsenide (SI-GaAs) substrates[2-4]. The antenna patterns were formed with silver nanopaste (Harima Chemicals Inc.). Figure 1 shows a schematic of a dipole PCA with the SRR (D-SRR) and the microscopic photographs of the antenna patterns. The two D-SRRs and a dipole antenna loaded with a closed-ring resonator (D-CRR) were fabricated. The orientations of the SRRs are mutually perpendicular for the D-SRR1 and D-SRR2.

The amplitude spectra of the antennas were obtained by the terahertz time-domain spectroscopy. The emission spectrum of the D-SRR1 shows the resonant peak at 0.3 THz, which is the resonant frequency of the SRR. The spectra of the D-SRR2 and the PCA loaded with the CRR (D-CRR) are similar to each other and show a peak at 0.5 THz. The radiation of the D-SRR1 is elliptic and the polarization angle is tilted from the direction of the bias voltage. In contrast, the *y*-polarized components of the D-SRR2 and D-CRR are small and the polarizations of them are almost linear. The characteristics of the emission spectrum and polarization of the samples are explained by the resonant excitation of the *LC* resonance mode of the SRR. In the D-SRR1, the electric field generated by exciting the gap of the dipole antenna by femtosecond laser pulses excites the *LC* resonance mode of the SRR. The *LC* resonance can be excited in the D-SRR1 but cannot in the D-SRR2 in the fashion similar to the transmission spectra of the SRR array with incident plane waves[4]. The present result demonstrates that the spectrum and polarization of the radiation can be controlled by loading the metaatoms to the PCAs.

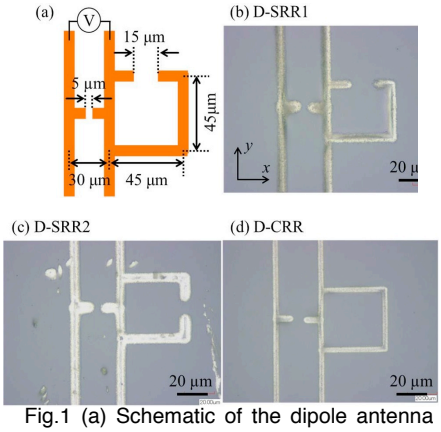

Fig.1 (a) Schematic of the dipole antenna with the SRR and (b) – (d) microscopic photographs of the samples

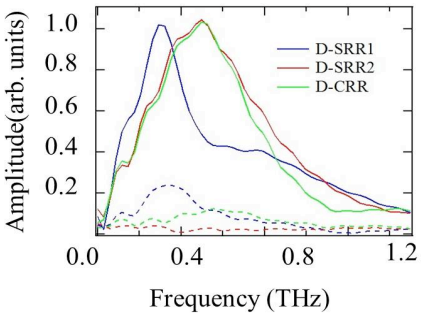

Fig.2 Terahertz emission spectra of the three PCAs. The solid and dash lines in the figure indicate the polarization components parallel to the *x*- and *y*-axes, respectively. The amplitude spectra are normalized with the peak values of each sample.

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Femtosecond laser direct writing of gold nanostructures by ionic liquid assisted multiphoton induced photoreduction

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During the past decade, multiphoton photoreduction (MPR) of conductive metallic microstructures have been received great interest because of their potential application in microelectronics, plasmonics and so on.[1] The media for the process mainly included polymeric films and the aqueous solutions.[2-5] The bottle-neck for the polymer system was the lower metal loading which resulted in the metallic structures that aggregated by the isolated metal particles with bad conductivities.[2] The formation of three-dimensional (3D) silver microstructures through MPR of aqueous solution of silver ions were achieved with smooth surface and high resolution.[3,4] However, it was important to note that oxidization and sulfurization of silver microstructures were liable to happen, which greatly affected their conductivity. The ability to fabricate gold nanostructures without the encapsulation of macromolecular polymers was less explored.[2,5]

In this study, we presented the fabrication of gold nanostructures by femtosecond laser direct writing technique from an aqueous solution of gold ions with the assistance of a glyciate ionic liquid (IL), 2-hydroxyethyl)trimethylammonium 5-aminopentanoic [HETMA][AP]. The results of ^{1}HNMR and UV-Vis absorption indicated that gold were generated by MPR of [AP]-$AuCl_4^-$ complex. The IL acted as gold growth inhibitor and a photoreducing agent, which resulted in the photoreduction threshold power as lower as 1.47 mW and a resolution of 200 nm. The gold lines were composed of closely connected smaller gold nanoparticles with the sizes smaller than 5 nm, which contributed to high conductivity that just several times lower than that of bulk gold. Furthermore, functional gold nanostructures such as chiral diffraction grating and spiral were fabricated. We demonstrate a simple way to achieve designable gold nanostructures, which would provide a good prospect for wide applications of IL assisted aqueous solution of metal ions in the realization of arbitrary 2D and 3D metallic nanostructures.

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Strong Exciton-Plasmon Coupling in MIM Structures

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It is known that a MIM structure with a thin insulator layer can support a symmetric and an anti-symmetric surface plasmon polariton (SPP) mode and a TE waveguide mode [1]. Strong coupling between MIM modes and excitons is expected to bring about interesting optical properties that are attractive for device applications. However, such a strong coupling between in MIM structures has not been reported yet. In this study, we demonstrate that the strong coupling in the MIM structure can clearly be observed.

We used J-aggregated cyanine dye (TDBC) that exhibits strong exciton absorption at 2.1 eV. The samples consist of Ag (35nm) / TDBC in PVA matrix / Ag (35nm) layers. The metal layers were fabricated by vacuum evaporation technique. The TDBC+PVA layer were deposited by spin coating on the metal layer. We measured reflection and transmission spectra for the *p*- or *s*-polarized incident light. To calculate dispersion curve of the MIM modes, we used the CPS theory [2].

Figure 1 shows *p*- and *s*-polarized transmission spectra recorded for different incident angles. We see that two peaks are present in each spectrum. The peak shifts to higher energies as the incident angle increases. The appearance of the two peaks is thought to be the signature of the strong coupling between the TDBC exciton and the symmetric SPP or TE waveguide mode.

Figure 2 shows the energies of the transmission peaks as a function of the in-plane wave vector (square: p-pol and circle: s-pol) and the calculated dispersion curves (gray scale map). The horizontal dotted line is the TDBC exciton energy. The only one fitting parameter of the calculation is the thickness of the insulator layer. Experimental results agree fairly well with calculated dispersion curves of MIM modes.

We have demonstrated that the strong coupling between the organic exciton and the symmetric SPP or TE mode occurs in the MIM structure. The behavior of the exciton-plasmon coupling and the exciton-TE mode coupling are different. The calculation could reproduce experimental results. The strongly coupled modes in MIM structures may be employed in new applications of coherent light-matter excitations.

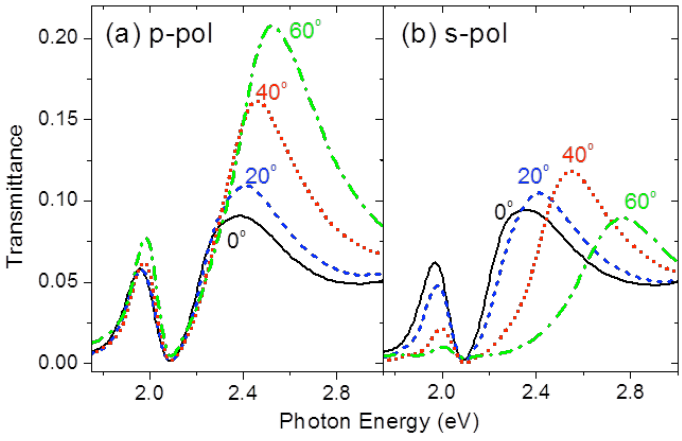

Fig. 1 (a) p- (b) s-polarized transmission spectra.

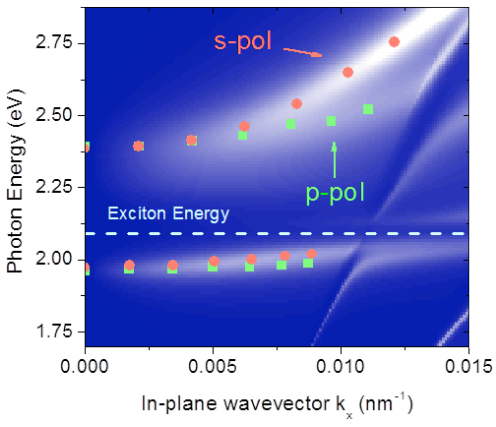

Fig. 2 MIM dispersion curves.

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Fluorescence Enhancement Caused by GaP particles: Dependence on Excitation Wavelength

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A drawback of the metal-enhanced fluorescence is the quenching of fluorescence caused by the energy transfer from excited molecules to the metal. It is desirable to develop a method of fluorescence enhacement free from quenching. In our previous work [1], we demonstrated the quenching free fluorescence enhancement from Rhodamine B molecules deposited on GaP particles. It is suggested that the enhanced electric fields at the surface of GaP particles associated with the excitation of electromagnetic modes are responsible for the observed enhancement.

In order to further clarify the mechanism of observed fluorescence enhancement on the nonmetallic particles, we measured fluorescence excitation spectra. GaP particles layers were deposited on glass substrates by gas-evaporation method. Then fluorescence excitation spectra of DCM layers deposited on GaP particles layers were measured. Figure 1 shows the dependence of enhancement factor (EF) on the excitation wavelength. We can clearly see that the EF exhibits different excitation spectra depending on the gas pressure used for gas-evaporation. Since the average size of GaP particles increases as the gas pressure increases, this result suggests that the enhancement in excitation process differs depending on the particle size. Figure 2 shows calculated near field intensities at the surface (Q_{NF}) of GaP particles for two different average sizes. Q_{NF} for the larger average size shows a resonance behavior around 460~480 nm in qualitative agreement with the experimental result of 120 Torr. Q_{NF} for the smaller average size and the experimental result of 60 Torr do not exhibit resonance behavior. The qualitative agreement between experiment and calculation suggests that strong electric fields near the surface of GaP particles enhance fluorescence of dye molecules in excitation process.

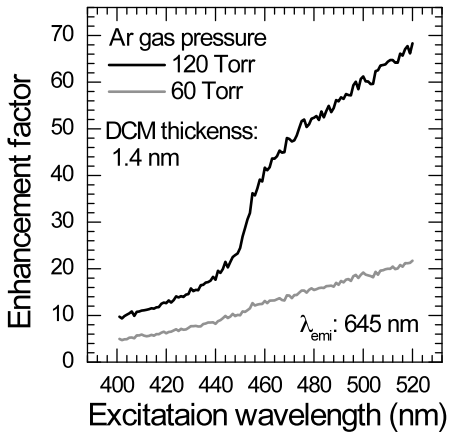

Fig.1 Dependence of EF on the excitation wavelength

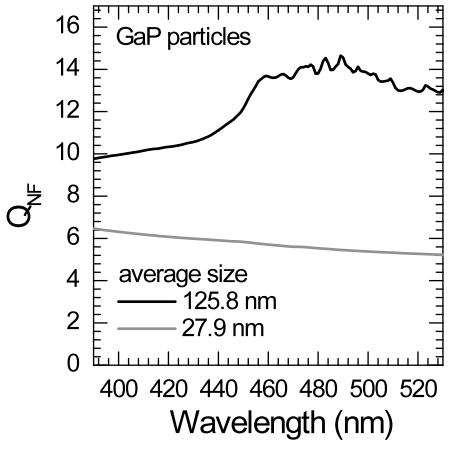

Fig.2 Calculated near field intensities at the surface of GaP particles

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Multi-Color Cathodoluminescence Microscopy for Biological Imaging

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We report the first demonstration of multi-color high spatial resolution imaging technique for observation of biological cells with using cathodoluminescence (CL) from nano phosphors. Three kinds of rare earth doped nano phosphors were injected into macrophage cells and the spatial distribution of nano phosphors were visualized by using scanning electron microscopy cathodoluminescence (SEM-CL) system.

To confirm the spatial resolution of the CL imaging technique, Y_2O_3:Eu NPs dispersed on Si substrate was observed. An SEM image of aggregated Y_2O_3:Eu NPs is shown in Fig. 1 (a), and a CL image of the same Y_2O_3:Eu NPs is shown in Fig. 1 (b). Line profiles (A-B) of the two images were plotted to compare the resolution of each image (Fig. 1 (c)). The resolution of the CL imaging technique reached a few tens of nanometers or less.

Three kinds of nano phosphors (Y_2O_3:Tm, Y_2O_3:Tb and Y_2O_3:Eu) were injected into macrophage cells via endocytosis to obtain multi-color images of the specimens using the CL imaging system. Specimens were prepared with using standard biological sample preparation protocols for TEM observation, such as fixation, dehydration, and embedding in epoxy resin. Thin sections of the cells sliced to a thickness of 500 nm were placed on glass substrates, and the epoxy resin was etched away with saturated KOH / ethanol solution. To decrease the effect of charging, a 10 nm Au was sputtered on the sliced cells.

SEM images and the CL images of the aggregated NPs in a macrophage cell are shown in Fig. 2. Fig. 2 (a) is an SEM image of the NPs-contained macrophage cell. It was not possible to discriminate the three kinds of NPs from the SEM images. Fig. 2 (b)–(d) shows CL images observed at wavelengths of 462 nm, 550 nm, and 614 nm, which correspond to the distributions of Y_2O_3:Tm, Y_2O_3:Tb and Y_2O_3:Eu, respectively. Different distributions of NPs inside the macrophage cells were observed. This result indicates the ability to acquire multi-color images of particular molecules via multiple labeling technique with nano phosphors.

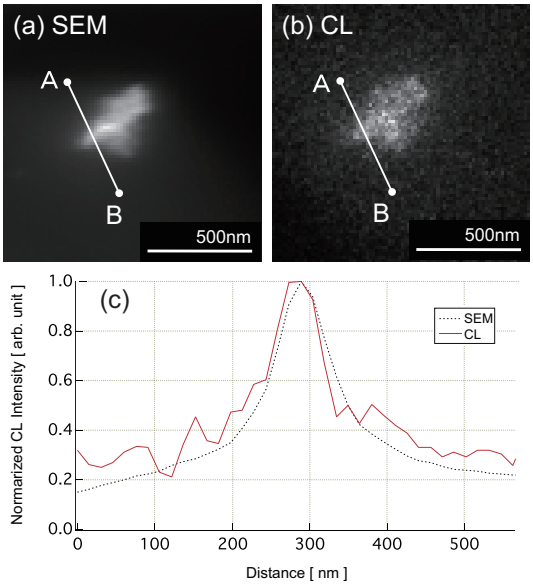

Fig. 1. SEM image and CL image of Y_2O_3:Eu, and the profiles of intensity.

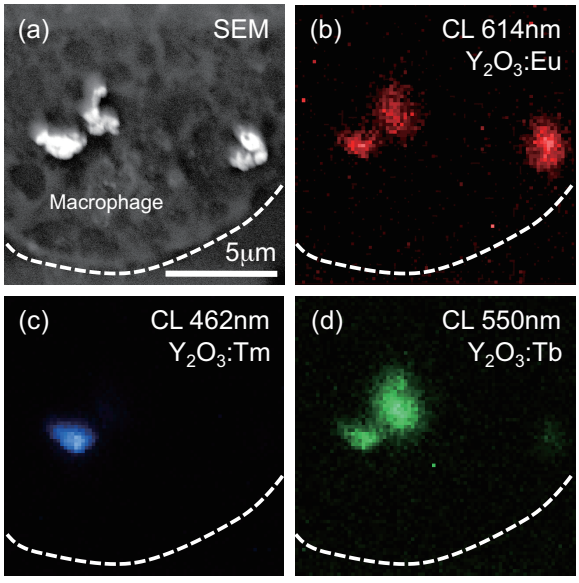

Fig. 2. SEM image and CL image of rare earth doped nanoparticles in macrophage.

Saturated excitation (SAX) microscopy for biological imaging beyond the diffraction limit

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The spatial resolution of optical microscopy is restricted by the diffraction limit of light. Recently we have demonstrated that saturated excitation (SAX) can be used for improving three-dimensional spatial resolution of confocal laser-scanning microscopy [1, 2]. The technique called SAX microscopy exploits nonlinear fluorescence response under the saturation phenomena of fluorescence molecules at the excited state, which appear predominantly at the center of the laser focus. To extract the nonlinear signals in the emitted fluorescence, we used temporal modulation of the excitation intensity at a single frequency and demodulation of the fluorescence signals at the higher-order harmonic frequencies. In SAX microscopy, higher harmonics demodulation gives higher-order nonlinear fluorescence, which emerges at a region smaller than the excitation point spread function (PSF), where the resolution improvement is theoretically unlimited. In addition, out-of-focus signals are suppressed significantly in a similar manner as two-photon excitation fluorescence microscopy, because the induction of the nonlinear response is limited in the laser focus.

In SAX microscopy, the improvement of the spatial resolution is achieved just by modulation of the excitation intensity of light from a single laser and demodulation of the fluorescence signals. An optical setup for a SAX microscope is realized only by adding laser intensity modulators and lock-in amplifier to a typical confocal laser-scanning microscope.

We observed actin filaments in a HeLa cell stained ATTO Rho6G phalloidin. The figures show fluorescence images obtained by conventional confocal (Fig. a)) and SAX (Fig. b)) microscopy. In the experiments, the dye was excited with a CW laser (532 nm of wavelength) and an oil immersion objective lens (1.49 of N.A.). Comparing Fig. a) and b), we confirmed that SAX microscopy achieved higher spatial resolution in three dimensions by the demodulation of fluorescence signals at second-order harmonic frequency than conventional confocal microscopy. From this experiment, we confirmed significant improvement of the spatial resolution and the effective removal of fluorescence from the out-of-focus plane.

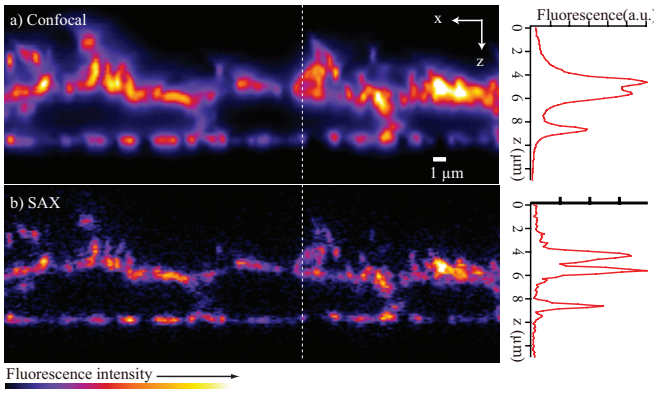

Fig. Fluorescence images of actin filaments of a HeLa cell. Both lateral and axial resolution can be enhanced by SAX microscopy.

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Interfacial Engineering of Organic Optoelectronic Devices

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One of the important factors determining the performance of organic optoelectronic devices is the current efficiency of devices. We will present a systematic study on the relations between the device performance and interactions at the metal-organic and organic-organic interfaces. The effects of gap states and energy level alignments on the carrier injection mechanisms in the organic light emitting devices are investigated. The performances of devices with various combinations of anode and cathode structures are compared to find out effects of interfacial band alignments on turn-on voltages of OLEDs. To find out the key factors affecting carrier injection efficiency, the interfacial electronic structures and chemical properties were then studied with using X-ray and ultra violet photoemission spectroscopy (XPS and UPS). XPS and UPS data indicate that although energy alignments are still the keys to the efficient carrier injections, the gap states, in these cases, play more important roles to help the carriers move over the barriers and inject into the organic materials. The origins of the gap states will also be discussed.

On the other hand, while the current density versus voltage (J-V) characteristics can only evaluate the performance of OLEDs after they start to conduct current, the impedance versus voltage (Z-V) characteristic can be used to explore more electrical properties of devices even before they were turned on. It has been demonstrated that the accumulation charges at organic interfaces in OLED devices can be observed by Z-V characteristics measurement. We carried out Z-V experiments on devices with several combinations of hole transport layers (HTLs) and electron transport layers (ETLs). We found that the accumulation charges are caused by the extremely different mobility of hole and electron in HTL and ETL, respectively.

MONITORING OF CPT-11 IN LIVING CELLS WITH CARS MICROSCOPY AND FLUORESCENCE MICROSCOPY

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A recent issue in drug development process is the necessity to monitor and visualize the drug action in living cells, in order to understand the drug metabolism and the response of the cells. CPT-11 is known as an effective anticancer drug for its broadest application and less toxicity in treatment of various tumors and carcinomas. As a prodrug, CPT-11 has a very complex pharmacological profile in biological process. However, CPT-11 is generally hydrolyzed by carboxylesterase to its active metabolite, SN-38.

Some previous studies reported that CPT-11 and SN-38 emitted strong fluorescence by excitation around near UV and violet region. This fact provides an advantage to perform detection of CPT-11 using fluorescence microscopy. However, our study showed that CPT-11 and SN-38 had similar excitation-emission spectra. Thus, it is difficult to distinguish the presence of CPT-11 and SN-38 in living cells.

Raman spectroscopy is a reliable tool for chemical detection and analysis. Raman band of particular molecule provides specific information about its chemical structure and properties. To enhance the application of Raman spectroscopy, some researchers observe the possibility of employing chemical tagging that has characteristic of Raman band in biological silent region (1800 – 2800 cm^{-1}). Due to this fact, we use CPT-11 that has deuterated structure in order to distinguish from SN-38. Deuterated structure of CPT-11 enables the detection of carbon-deuterium (C-D) bond around 2100 cm^{-1} inspite of its related carbon-hydrogen (C-H) bond.

Conventional Raman spectroscopy can not satisfy the need of real-time imaging in biological events, because of long acquisition time and low signal efficiency. CARS microscopy is introduced to solve this problem and recently it has been developed with various techniques for better applications in biomedical imaging. CARS microscopy enables us to perform label-free, fast, high spatial imaging. CARS signal can be detected if the difference of the laser sources in CARS system (ω_1, ω_2) coincides with a specific molecular vibration.

For better and more complete imaging, we have developed a multimodal imaging system that combines the CARS microscopy and fluorescence microscopy to detect CPT-11 in living cells. Using fluorescence microscopy, we can detect the indistinguishable presence of CPT-11 and SN-38 in incubated living cells with the CPT-11. To identify the presence of the CPT-11 in the living cells, we employ CARS microscopy at Raman band of C-D bond. The difference between CARS image from C-D bond and fluorescence image describes the metabolism of CPT-11 to SN-38 in living cells.

DNA-templated gold nanoparticle trimer ring

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Metal nanostructure that may induce a magnetic response to the visible light have gathered a lot of attention because it has an important role as metamaterial elements. We employed programmable DNA-templating, which is one of the promising bottom-up techniques to form well-defined metal nanoparticle (NP) structures, to mass-productively obtain metamaterial elements. By applying a facile method to prepare cyclic assemblies of gold NPs using only DNAs and gold NPs,[1] 2-dimensional gold trimer rings as the simplest ring resonator structure[2] were fabricated on quartz substrates for the investigation of its optical properties.

Figure 1 shows the assembly process of a gold trimer ring. Three kinds of DNA mono-conjugated gold NP building blocks were prepared separately by mixing aqueous colloid solution of gold NPs with 20-nm diameter, "Ligand DNA," "Template DNA," and "Supporting DNA" at the optimal molar ratio and concentration.[1] The resulting three building blocks were mixed together to form a trimer ring by means of hybridization of a Template DNA with a Ligand DNA of another building block. Quartz substrates modified with 3-aminopropyltrimethoxysilane, providing positive charges, adsorbed negatively charged gold trimer rings in the solutions.

Typical tapping mode atomic force microscope (AFM) images of gold timer rings on a quartz substrate are shown in Fig. 2. The number of particles composing an assembly was clearly confirmed by checking both the height (Fig. 2a) and phase (Fig. 2b) images. The presence probability of gold trimer rings was estimated to be ~45% by counting 100~200 particles. The AFM observation visualized the neighboring particles in a trimer were connected each other because the tip radius was too large to trace the gaps between the particles. Monomers, dimers, linear trimers, and oligomers were formed due to the imperfect hybridization and destruction during adsorption-desorption process at the surface. In the poster presentation, the optical properties of gold trimer rings dispersed on quartz substrates are also reported.

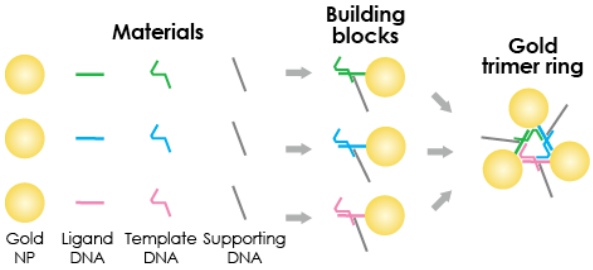

Fig. 1 Schematic illustration of assembly process of gold trimer ring by DNA-templating.

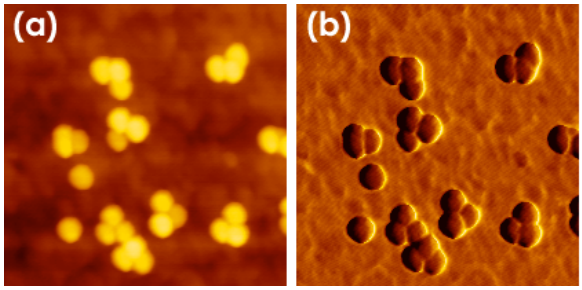

Fig. 2 Tapping mode AFM images of gold trimer rings on a quartz substrate. Image size is 1 μm x 1 μm. (a) Height image with z range of 24 nm. (b) Phase image.

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Gold nanofin array for far-infrared enhancement

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When surface plasmons are excited on the metal surface, electromagnetic field density is dramatically increased. By introducing this field enhancement characteristic to the far-infrared spectroscopy, high sensitive detection and characterization of the fingerprint of materials can be expected. However, surface plasmons are unfortunately not supported in the far-infrared spectral region because of the dispersion properties of the metals. To overcome this limitation, many ideas on artificial modification of the surface of metal such as forming an array of holes are proposed. In this paper, we will propose another route to fabricate artificial structures that can accumulate infrared light energy with wafer-scale fabrication area.

As a metal structure that can support surface plasmon-like wave, we propose an Au nanofin array. Au nanofin arrays on Cr film were prepared using "sidewall lithography" technique [1]. At the first setout, a Cr film with 100-nm in thickness was formed on a Si substrate. A resist template with line pattern was photolithographically formed on the Cr film. Au thin film with 80-nm in thickness was sputtered on the sample surface. The sample was subjected to Ar plasma to remove the top layer of Au films and only the Au films on the sidewall of the resist template were remained. Finally, the resist was removed by O_2 plasma gas and vertically self-standing Au nanofins were formed (Fig. 1(a)).

The reflection spectra of the Au nanofin arrays were characterized using an FT-IR with various incident angles, incident directions to the fin structure (parallel and vertical), and polarization directions (p- and s-pol.) shown in Fig. 1 (b). Figure 2 shows reflection spectra of Au nanofin array of four possible combinations of polarizations and incident directions (p-parallel, p-vertical, s-parallel, and s-vertical). As shown in Fig. 2, only under the condition of p-vertical, resonant absorption peaks are observed. Figure 3 shows reflection spectrum change according to the incident angles.

Figure 3(a) shows an experimental result taken by FT-IR and Fig. (b) shows a calculation result done by Rigorous Coupled Wave Analysis (RCWA). These two results show good agreement and dispersion properties of absorption peaks are clearly observed.

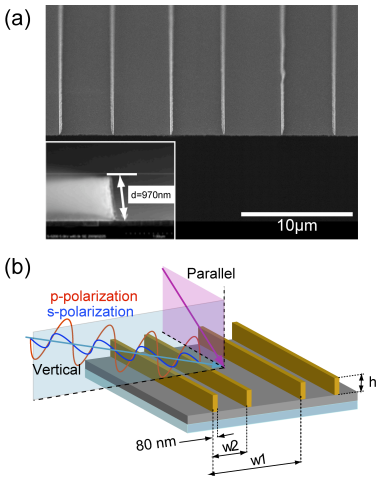

Figure 1. (a) Scanning electron micrograph of Au nanofin arrays. The inset is the enlarged cross-sectional image. (b) Schematic image of Au nanofin arrays and spectral measurement of them.

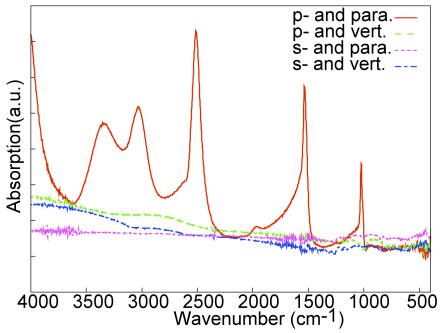

Figure 2. Reflection spectra of Au nanofin according to p- and s-, and vertical and horizontal incident conditions.

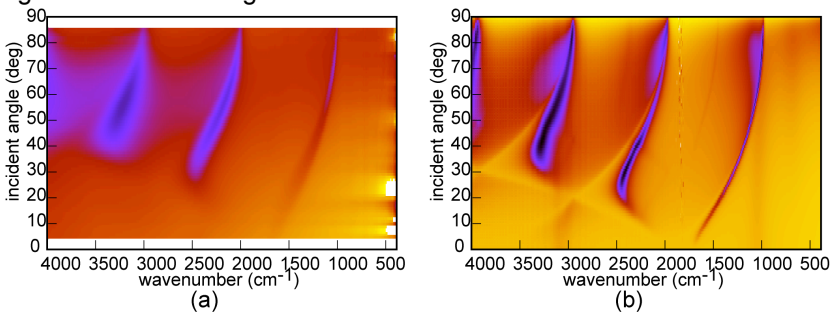

Figure 3. (a) Experimental result of reflection spectra of Au nano-fin array according to the incident angle change. (b) Numerical calculation result by RCWA.

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Design of Localized plasmon mode at a gold nano dimer for SHG

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As well known, localized surface plasmon (LSP) of a nano metal particle will provide the electric field enhancement of light on resonance. By using such the enhancement, it is expected to develop a nano size nonlinear optical device with low pumping power. For a pair of the particles with the same size, i.e., a dimer, the resonance frequency can be controlled by the geometric configuration keeping the strong field enhancement. When we tune the frequencies of a LSP mode to that of the pumping light, the intensity of SHG will be expected to enhance extremely compared with that for the detuned case. In this paper, we analyze the characteristics of the localized plasmon mode at a gold nano dimer and make clear the potential for a nano-size SHG light source.

We illustrate our numerical configuration in Fig. 1. On a dielectric substrate (n = 1.72) with the second order optical nonlinearity, two gold nano particles were placed with a nano gap (6 nm) to form a dimer. The shape of the particle was a pillar of a square base with rounded corner (R = 3 nm). The size of base was L nm and the height of the pillar is 32 nm. The dimer was illuminated by light from the normal direction on the substrate surface. To detect resonance of plasmon modes, the observation point O_1 of the electric field intensity was set at the center of the gap. We employed the FDTD method to solve the electromagnetic response of the dimer.

For L = 200 nm, the intensity of localized field at O_1 take peaks at 688 nm, 875 nm and 1339 nm. In order to make the origin of these peaks clear, we calculated the field distributions under the linear intensity regime at these wavelengths. Figures 2(a), (b) and (c) are shown the distributions at 688 nm, 875 nm and 1339 nm. We also show the direction of the electric field by small triangles and the positions of positive and negative charges. Judging from the field direction and the positions of charges, Fig. 2 (a), (b) and (c) correspond to the dipole, quadruple pole and hexagonal pole modes of the dimer.

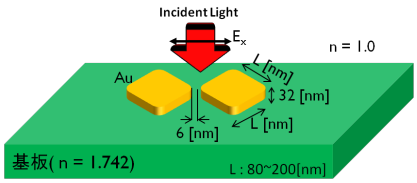

Fig. 1 Numerical configuration

(a) λ_0 = 1339 nm (b) λ_0 = 875 nm (c) λ_0 = 688 nm

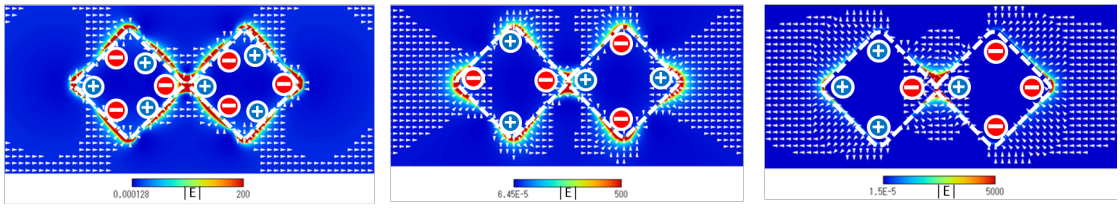

Fig. 2 Field distribution on resonances

Alternating growth of ZnO nanowire array for quantum dot sensitized solar cell

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Nowadays, a series of nano-photovoltaic devices based on one-dimensional nanostructure, including nanowires and nanotubes[1-2], has been widely studied. One-dimensional nanostructure arrays are beneficial for photovoltaic applications due to their geometrical structure which provides a direct pathway for charge transport. Quantum dots (QDs) sensitized nanowires solar cells attract many attentions since QDs can absorb light in the visible region and transfer electrons to large band gap semiconductors. Recently, depleted-heterojunction QD solar cells[3] offer new opportunity to achieve high efficient solar cell. Compared to the conventional QDs sensitization solar cells, the new architecture could significantly increase the short circuit current density.

Herein, we present the alternating growth of ZnO nanowire array for QDs sensitized solar cell. Firstly, the ZnO nanowire array was grown on ITO glass using an alternating growth method. It led to ZnO nanowire array of good qualities, such as the high ratio of length to diameter, good crystallization and orientation capability. The ZnO nanowire array with a diameter of 50-100nm and a length of 8μm has been obtained. Then, the ZnO/CdS core/shell heterojunction nanowire array was fabricated by depositing CdS nanocrystals on the ZnO nanowires to offer an interlay to reduce the charge recombination on the ZnO nanowires[4]. A thin and integrated CdS layer with a thickness of about 10nm has been deposited on the ZnO nanowire array. Additionly, the PbS QDs were deposited on the surface of the ZnO/CdS nanowires to absorb photons and transfer charge carriers to ZnO nanowires. PbS QDs has been covered on the ZnO/CdS nanowire array completely. Finally, a solar cell was constructed using Na_2S solution as electrolyte and Pt as counter electrode. The as-prepared ZnO/CdS/PbS heterojuction nanowire array would open up good prospects for the application in high efficient solar cells.

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Stub structures in Gap plasmon waveguide

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Recently, channel plasmon waveguides (CPW) are attracted attention because they are expected to realize high-density optical integrated circuits and interface between a nano-optical device and a conventional optical waveguide. Various types of CPW were proposed already. Among them, we have noticed the gap plasmon waveguide because of its advantages for future applications: a simple structure to fabricate with ease and strong electromagnetic field confinement in gap compared with other CPW. For functional devices in plasmon circuits, a compact structure is required to take merit of the gap plasmon considering the propagation length of plasmon. We have already reported that stub structures are compact and useful for compact resonator [1,2]. In this study, we will demonstrate applications of stub structures for other devices.

Figure 1 shows typical applications for stub structures: Fig. 1(a), (b) and (c) are the loss-free 90 degrees sharp bend, selective wavelength T branch and the multiple branch. The function of the stub can be understood easily considering that it is similar to that of the short stub in a microwave circuit. We can predict and design the characterization of above structures by using 3D numerical simulation. Numerical results show that three structures work well with a size and a shape tolerances of which values allow to employ current fabrication process to fabricate structures.

We also fabricated the structures in Fig.1 and a Fabry-Perot resonator with two stubs in gap plasmon waveguides in a 1.5 μm-thick silver film on a dielectric substrate by using FIB direct processing techniques [2]. The width of the waveguide was about 150 nm. From the intensity measurement of light scattered at observation point of the gap plasmon excited by a polarized NIR laser, we found that intensity depends on both the wavelength of light and the length of the stub. And works of the stub agree well with the numerical prediction of these structures.

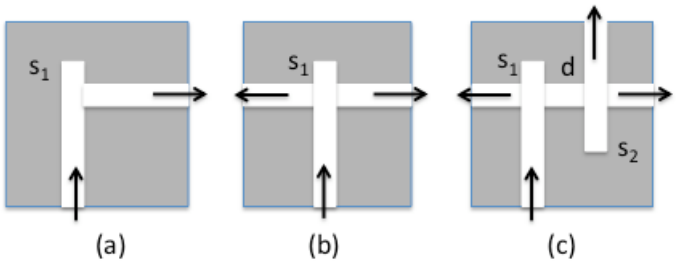

Fig. 1 Examples of stub structures

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Tip-enhanced Raman imaging and analysis of crossed nanotube junctions

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Tip-enhanced Raman spectroscopy (TERS) has been recognized as a powerful tool to optically analyze carbon nanotubes (SWCNTs) on a nanometer scale [1]. TERS has been so far utilized to characterize localized defects and change of chirality in nanotube, and even to measure local distribution of molecules encapsulated in nanotube [2]. Here in this time, we show TERS imaging and analysis of SWCNTs including a junction of two SWCNTs crossing with each other on own structure. The crossed CNTs were formed in the process of dispersing alcohol-diluted solution of SWCNT onto a glass substrate, which was confirmed by the topographic image shown in Fig. 1(a). Tip-enhanced Raman spectroscopy image was performed on around cross part of SWCNTs with a silver-coated tip and excitation wavelength of 488 nm. Figure 1(b) shows the TERS image of the G-band intensity, revealing local intensity change at the junction and also other bundle parts of SWCNTs which is arrowed. This was due to local change of the resonant Raman condition caused by local deformation of SWCNTs at the junction and bundle parts. And in our presentation, we will discuss deformation-induced frequency shift of the Raman bands (the radial breathing mode, the D-band and the G-band) as well.

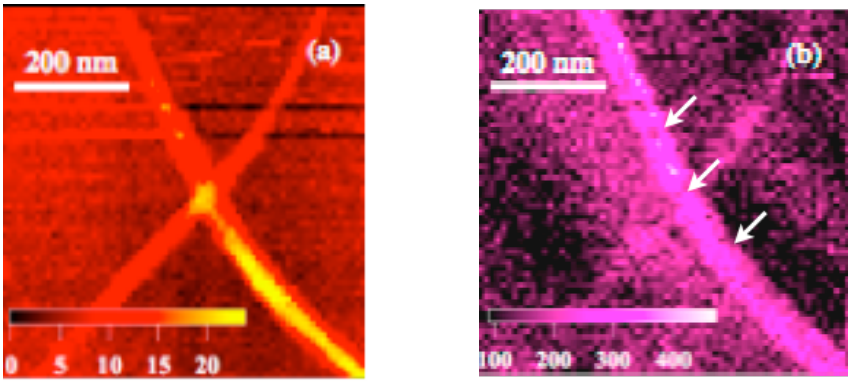

Fig.1 (a)AFM image of the crossed SWCNTs
(b) simultaneously-obtained TERS image

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Development of a Plasmonic Biosensing System using Au Nano-particle Pairs

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Plasmonics have been attracting increasing attention because of their potential application in biomedical research. In particular, plasmon nano-rulers, whose light scattering properties are strongly dependent on inter-particle distance and particle size, have the potential to investigate dynamic distance changes ranging 1- to 100-nm. In this presentation, we report a novel plasmonic biosensing system that uses gold (Au)-nanoparticle pairs to investigate the molecular dynamics of DNA bending caused by SOX2, a transcription factor essential for maintaining the self-renewal of undifferentiated embryonic stem cells. A finite difference time-domain (FDTD) simulation suggested SOX2 binding generates the largest spectral shift in a plasmon nano-ruler consisting of 50 nm Au-nanoparticles and 50 base-pair DNA (Figure 1). To prepare Au-nanoparticle pairs, the 50 nm Au particles were split into two separate batches for fictionalization with complementary 50 base-pair, single-strand oligonucleotides (ssDNA). The complementary DNA modified Au-particles were then hybridized with each other. Dark-field microscopy showed that before SOX2 binding, the scatter spectrum has a 570 nm peak wavelength (Figure 2), but after SOX2 binding, the peak wavelength shifts to 607 nm due to DNA conformational changes that lead to changes in the inter-particle distance. These results indicate that our plasmon nano-ruler can be used to measure dynamical distance changes in single-molecule biophysical experiments.

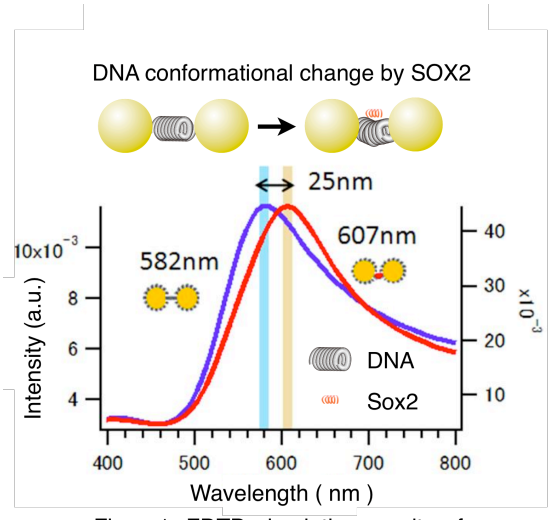

Figure1: FDTD simulation results of Au dimer's plasmon resonance shift caused by adding SOX2

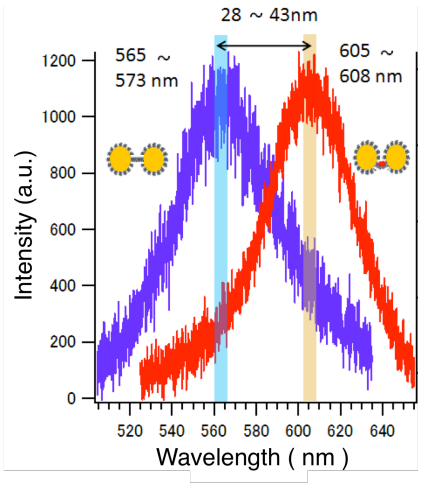

Figure2:Scattering spectra of Au dimer before/after adding SOX2
(Blue/Red: Before/After Binding SOX2)

ORIGIN OF BULK THIRD HARMONIC GENERATION

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Recently, third harmonic generation (THG) microscopy has been applied for deep-tissue observations due to its advantages including optical sectioning, high penetration depth, and intrinsic contrast mechanism. Conventionally, THG was found at interfaces of cellular organisms, such as plasma membrane and lipid bodies. But a recent study of THG on human skin showed bulk THG in cytoplasm of melanocyte and suggested that melanin concentration plays an important role in THG.

Our current work is focused on characterizing THG of melanin. Since melanin is insoluble in water, we studied two kinds of melanin samples: one is sonicated hydrocolloid, and the other is solution in NaOH. As expected from theoretically formulation including Gouy phase shift, THG is only observed at the glass/solution interface for the solution sample. Nevertheless, significant bulk contribution was found for the hydrocolloid sample. In Figure 1, different THG z-profiles are observed with different melanin concentrations. Obvious bulk

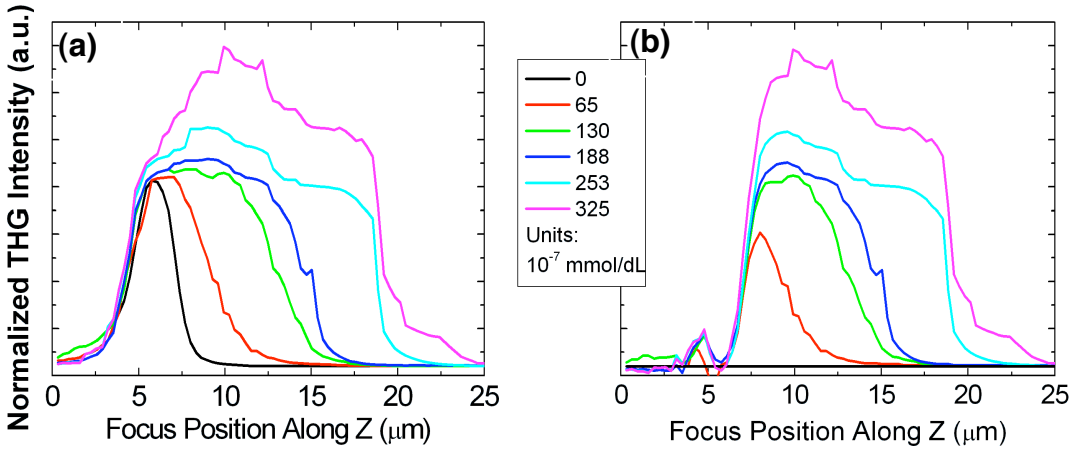

Figure 1. THG z-axis profiles of melanin hydrocolloid with different concentration. Interface between glass substrate and hydrocolloid samples locates at 5.2 μm.

THG signals in Fig.1 (b) were observed after removing the interface-induced THG signal, which is the black curve in Fig.1(a).

By analyzing the THG-concentration dependency in these two samples respectively, distinct features were revealed. For the solution sample, a minimal interface THG exists at a specific melanin concentration, indicating the matching of linear and nonlinear susceptibilities. This result implies not only that THG at plasma membrane would become diminishing at certain solvent concentration in cytoplasm, but also the $\chi^{(3)}$ of melanin can be deduced from the THG-concentration curve. On the other hand, for the hydrocolloid sample, THG linearly increases with melanin concentration, suggesting incoherent signal accumulation of THG. The broken coherence of THG is consistent with the observation of bulk THG in hydrocolloid melanin. Since melanin should exist in the form of colloids in skin cells, our results satisfactorily explain the observation of bulk THG in melanocytes. Our methods will be useful for other colloids in cytoplasm and can be extended to the study of nanoparticles.

Electromagnetic response of asymmetric double fishnet metamaterials

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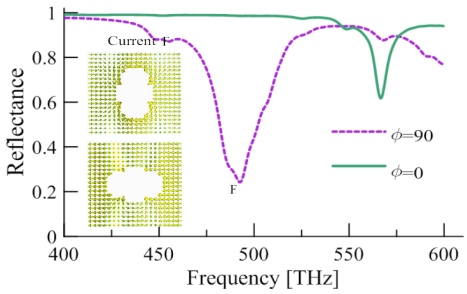
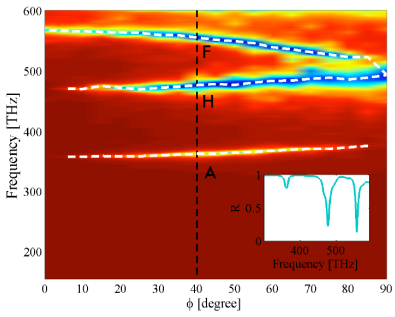
Electromagnetic metamaterials (MM) are artificially engineering composite materials with nanoscale inclusions and unconventional electromagnetic (EM) functionality that can't find in naturally occurring materials. Among the various designs of MM, the double fishnet structures [1], which is the combination of pair of metal slabs and continuous wires, have demonstrate superior performance in the frequency region ranging from infrared regime to the visible. It has been shown that the localized surface plasmons (LSPRs) play an important role for the specific EM response [2]. For two dimensional arrays of air hole in a single metal film, there is a resonance in the spectrum with nearly unity transmission due to the excitation of LSPRs. When a further layer is added, the LSPRs will couple with each other when the layers spacing is compared with the decaying length of LSPRs. The magnetic resonance of the double fishnet MM is result from the anti-symmetric mode of the LSPRs.

In this paper we consider a modification of the well-known fishnet structure. We proposed and numerically investigate a design of MM with 2D elliptical air holes milled in the silver film. We found the EM response is strongly influenced by the orientation of the ellipse in the layers. An ultra-broad band frequency region with negative permittivity and permeability is found when the angle between the major axis of the ellipses is 90 degree. We also study the frequency dependent of the resonances with the angle, spacing and the aspect ratio of the ellipses. We interpret the characteristics of the EM behavior with the mode coupling between the LSPRs supported by 2D array of elliptical air hole milled in a single silver film. It's interesting that there are two distinct resonances driven by the electric and magnetic field, respectively. Our findings may be useful to understanding the underlying physics of the fishnet MM and the potential photonics and plasmonics applications.





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Microstructure formation of Au nanorods /methyl methacrylate composite assisted by two-photon polymerization

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We present a micro structure fabrication method of Au nanorods/ methyl methacrylate (MMA) composite assisted by two-photon polymerization (TPP). Femtosecond laser light excited TPP on the surface of Au nanorods dominantly and the micro structure was formed by the aggregation of Au nanorods wrapped by PMMA. Au nanorods were synthesized by seed-mediated growth method in aqueous solution. In order to disperse into photo-polymerizable resin which contains MMA monomer and photo-initiator, the Au nanorods surface was modified by polyethylene glycol. The shape of Au nanorods was tuned around 20 nm width and 65 nm length. The absorption spectrum of the compound showed clear peaks at 520 nm and 780 nm, corresponding to the transverse and longitudinal local surface plasmon resonance mode (LSPR) of isolated individual Au nanorods, respectively. The compounds were dropped on a glass substrate. Near infrared femtosecond laser light (780 nm) was focused into the Au nanorods/MMA compound by a microscope objective lens and scanned according to the trace of pre-programed structure with TPP lithography technique. After rinsing of non-polymerized resin by ethanol, micro structure remained on the glass substrate. By SEM observation, we found that the micro structure was formed by Au nanorods aggregation and each nanorods were wrapped by PMMA. By controlling the intensity and the exposure time of the laser light, we found an optimal condition to induce dominant polymerization of MMA without causing thermal damage. The mechanism of this method is based on the LSPR-induced TPP only at the surface of Au nanorods and laser-induced aggregates of Au nanorods. By continuous irradiation of laser light, the PMMA-wrapped Au nanorods were aggregated at the focus spot and the polymerized resin was used as glue to adhere each Au nanorods, resulting in a unique mechanism of Au nanorods aggregated microstructure formation.

ADVANCED MEDICAL DESIGN BY PHOTONICS

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Design, medicine, and photonics are closely related. Since mid 1990s rapid prototyping system using laser lithography has been used for simulating surgeries before actual operations. Prof. Kazuo Kawasaki of the PiD lab., Osaka University, focused on designing a completely new form of an artificial organ: heart. He studied topology theorem and its application on geometry modeling. and is known as the first person to succeed producing Klein bottle (a 4-D version of Möbius strip) by using laser lithography. His advanced model of total artificial heart has been archived in Science Museum of Montreal and also under process of in-vivo experiments in goats at University of Tokyo.

In recent years Prof. Kawasaki and members of the PiD lab. have developed many advanced designs for medicine based on photonics technologies, including Photonics Drug Dosing, Advanced Mammography, Remote Heart Monitor, Photonics Lumber Corset, Photonics Throat Cleaner, Pain Remover, Photonics Hand Sterilizer, and Photon Shower. These advanced designs are categorized in two groups: passive devices and active devices.

Remote Heart Sensor, for an example in the passive device category, monitors infant's heart without attaching sensors to the body of the infant. Instead, it beams near infrared photons to the heart by penetrating the skin, and detects reflectance of the photons from blood. By Doppler effect the device is able to track the blood flow point by point. As imaging the whole heart it will be possible to compute the whole blood flow per a unit time.

Photonics Hand Sterilizer, for an example in the active device category, is another highly demanded device. It kills bacteria on the skin by ultraviolette ray when the user just hover his/her hands over the device. Dynamic beam forming technology enables pin-point focusing on the skin, and makes possible to scan the whole hands of which the device detects the shape in real time by using far infrared imager.

As the photonics technology has enabled new era of designing by introducing laser lithography, we have been tackling enormous problems on design especially in medical field. And as the photonics technology has making many dreams come reality, it is our mission to design highly demanded devices (especially in medical field) in advance based on the photonics technology. The photonics design would be the place where the engineering and the design meet together at very high level.

Future works include photonics design for total disaster like 3-11 Great Earthquake in Japan and many problems in developing areas/countries. One obvious application of photonics is computer networking, however, it is quite possible to design photon/electron hybrid grid for distributing information/power simultaneously. Other photonics technologies will be used for rescuing human, detects and visualize radioactive parts, and also figuring out inflammable liquids from water.

Plasmonic Devices in the Visible-Terahertz Region

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Surface plasmon polariton (SPP) offers unique prospects for the design of advanced nanophotonic devices beyond the diffraction limit in the visible and near infrared region [1]. Moreover, by introducing the spoof surface plasmon (spoof SP), which shows plasmonic behaviour by a metal artificial structure, the concept of SPP can be expanded into the mid-infrared and terahertz region. In this paper, we present plasmonic slow light (PSL) [2] and thermal radiation from a plasmonic structure [3], as unique plasmonic devices in various frequency regions. The devices reported here show the new functions based on plasmonics, and have the potential for operating in the visible, infrared and terahertz region, by using real or spoof SP.

Plasmonic Slow Light (visible)

PSL is SPP with a remarkably low group velocity, inducing field enhancement. Figure 1 shows the finite-difference time-domain (FDTD) analysis of field enhancement by PSL. SPP pulses are longitudinally compressed due to the abrupt slow-down of propagation between PSL and long-range SPP (LR-SPP), resulting in large field enhancement. This new approach for field enhancement will offer benefits in nonlinear optical effects, sensors and nanoimaging.

Thermal Radiation from Plasmonic Structure (terahertz)

Thermal radiation can be controlled by means of various mode on the surface structure. We found that effective surface wave called spoof SP on the metal microcavity array selectively enhanced the vertical thermal radiation at terahertz or mid-infrared region, without limitations of material properties. The thermal radiation source is a good candidate as a new terahertz emitter for spectroscopy or medical and environmental applications.

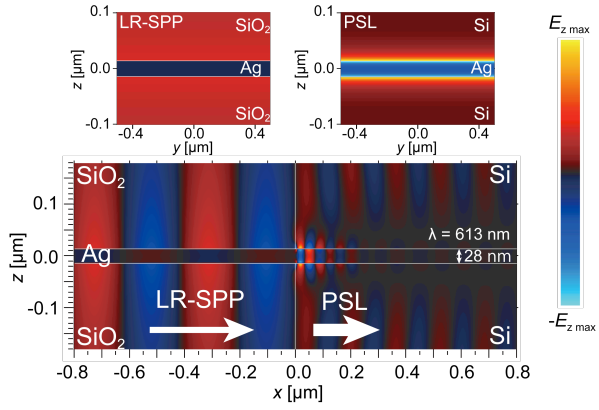

Fig. 1. Feld enhancement by PSL.

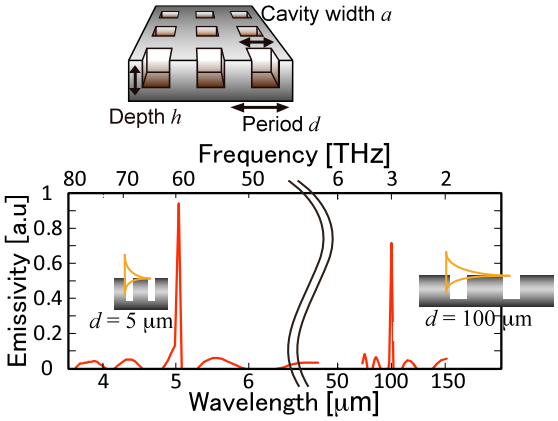

Fig. 2. Thermal radiation control by spoof SP.

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OPTICAL BIOSENSING BY A LASER DEPOSITION OF SILVER NANOPARTICLES

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Label-free biosensing is of great importance for both fundamental studies in biochemistry and applications in point-of-care diagnostics. Noble metal nanostructures are useful in development of label-free optical biosensors. Receptor biomolecules such as peptides, antibodies, and DNAs can be immobilized on the metal surface according to an easy protocol. Photons and molecules can strongly interact via localized surface plasmon resonance (LSPR) in the vicinity of metal nanostructures. These characteristics of metal nanostructures can be used in biosensing applications. We introduce novel bioanalysis methods using plasmonic metal nanostructures being developed in our group.

Silver nanoparticles (AgNPs) are deposited by focusing a visible laser beam in the silver nitrate solution including a reducing agent. Laser irradiation time necessary for AgNP deposition depends on the species and concentration of reducing reagent. This AgNP deposition by a focused laser beam can be applicable to the optical biosensing because some biomolecules or products due to biochemical reaction act on the reduction of silver ions. By using an enzymatic reaction of glucose oxidase and peroxidase, the detection of glucose concentration is demonstrated. Growth of the nanoparticle under the laser focus can be monitored by the intensity change of the backscattered laser light. In addition, we succeeded in fabricating Ag nanostructures in a glass micropipette tip and measuring surface enhanced Raman scattering (SERS) spectra of molecules sucked in the micropipette (Fig. 1). This SERS micropipette could be used for the single cell analysis of intercellular and intracellular signaling molecules.

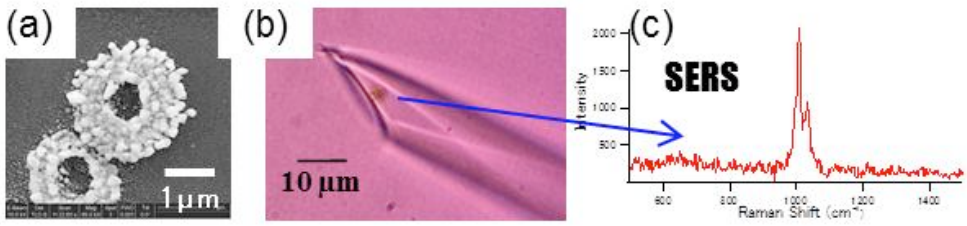

Figure 1. (a) Ag nanoparticles deposited on a glass substrate. (b) Ag nanoparticles deposited in the end of a glass micropipette. (c) A SERS spectrum from a pyridine solution sucked in the micropipette.

Nonlinear optical properties of DAST crystals at nanometric scale

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Development of organic materials with excellent nonlinear optical (NLO) properties has been a highly active area of researches for a wide variety of promising applications, including optical limiting, up-converted lasing, 3D optical data storage and microfabrication, bioimaging, and photodynamic therapy. We succeeded to achieve nanoscale organic nanocrystals (ONCs) by using carbosiloxane dendrimer to control the growth process of *trans*-4-[4-(dimethylamino)-*N*-methylstilbazolium] *p*-tosylate (DAST) DAST crystal, which would provide the suitable material of high quality for investigating the optical nonlinearity of ONCs. The NLO properties of the size-controlled DAST ONCs have been investigated. The size and monoclinic crystal structure have been demonstrated by the scanning electron microscope, transmission electron microscope, and X-ray diffraction measurement. The DAST ONCs exhibited 6-fold enhanced fluorescence quantum yield and prolonged fluorescence lifetime compared to DAST molecular solution. The evaluations of two-photon excited fluorescence (TPEF) and second-harmonic generation (SHG) microscopes have been implemented for investigating the optical nonlinearities of DAST nanocrystals. The TPEF intensity of DAST ONCs was improved by a factor of 37.3 compared to DAST molecular solution. The extraordinary large two-photon absorption cross section up to 1.72×10^{6} GM was observed. DAST ONC was demonstrated as a single crystal from the four-lobe polarization response in the SHG microscope. These results would provide DAST ONCs the opportunity for the potential application in photonics and bioimaging as nonlinear optical materials.

TRANSFORMING OF THE NANO-PILLAR FROM THE POROUS ALUMINA MOLD USING NANOIMPRINTING TECHNOLOGY AND APPLICATION TO THE PLASMONIC BIOSENSOR

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Nanoimprinting technology has been remarked in the area of micro-nano-fabrication technology because the nanostructure can be formed in the large area with exceptionally high reproducibility. The porous alumina which has the honeycombed nanostructure, also has been attractive in the nano devices field. Therefore, we think that this substrate is applicable to use as the nanoimprint mold. On the other hand, the plasmonic biosensor has highly applicability to the life science based on its ability of the label free detection. Taking into account all the above mentioned points, we had fabricated the gold-capped nano structures in different sizes by applying the alumina porous substrate as a nano-mold for the nanoimprinting technology, and then applied to the plasmon biosensing. The nano-porous mold was formed by the alumina anodizing processes. The size of porous structures was successfully controlled by varying the applying voltages and anodizing time. Next, these nano-porous structures were transferred to the Cyclo olefin polymer (COP) film surface from the porous mold by the thermal nanoimprinting process. A plasmonic substrate was fabricated by sputtering thin layer of gold on this nano-villus polymer structure and evaluated the response of the refractive index in a variety of solutions. Finally, we carried out the measurement of avidin-biotin reactions as a biosensing model on this plasmonic substrate and successfully detected the molecular specific reactions.

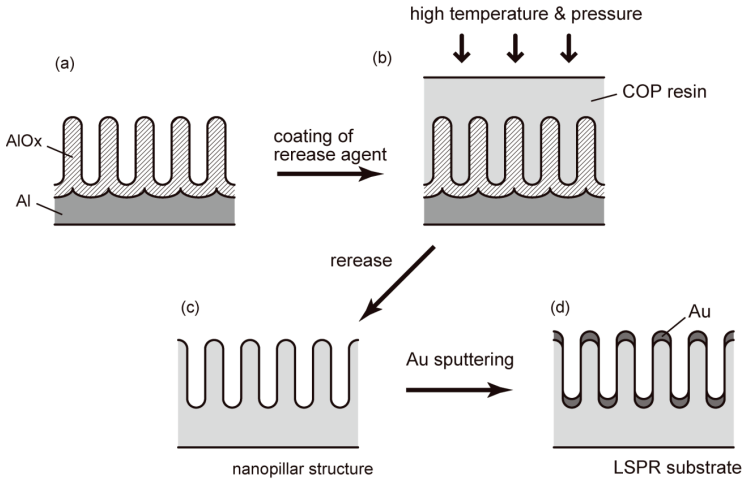

Figure 1. The schematic illustration of the experimental steps for the fabrication of LSPR substrate by nanoimprinting.

Quantitative imaging analysis and micro-chip platform for drug diagnosis on cardiomyocyte derived from mouse Embryonic Stem cell

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The interest on cardiomyocyte derived from differentiation of Embryonic Stem (ES) cells or induced pluripotent stem (iPS) cells is increasing due to their potential for regenerative therapeutics and as a pharmaceutical model of microbiological toxicity or drug screening. Characterization of ES or iPS derived cardiomyocyte is challenging, time and resource consuming while inevitable for the intended usage of such cells. We discuss a novel, non-invasive method for evaluating in vitro beating properties of mouse embryonic stem cell derived cardiomyocytes and micro chip drug testing platform for the cardiomyocyte. The method was based on progressive video recording and the derivative of successive frames. The derivative intensity of two successive frame was binarized into time dependent intensity variation by accumulation of the total pixel intensities in every frame, and the consecutive systolic and diastolic of cardiomyocyte was well corresponding with the intensity variation in derivative images, and the strength of the cardiomyocyte beating acceleration was obtained as the magnitude of intensity. We have successfully applied our quantitative imaging analysis for monitoring mESC derived cardiac muscle cells to determine the initiation of beating, organization and maturation of beating tissue, calculating the beating rhythms in terms of beating interval and the strength of beating. The beating rhythms and fluctuations of beating rhythms were gradually signed and narrowed as the progress of the maturation of cardiomyocyte. We also applied our method for drug diagnosis. Beating rhythms, fluctuation of the intervals and strength was stimulated on the caffeine administration. And there was no beating variations when the acetaminophen was applied on the cardiomyocyte. Our approach will be useful to monitor the differentiation and organization of cardiomyocytes from mES, hES or iPS cells in vitro to determine their attainment of maturity for their subsequent utilization for clinical or drug screening purposes.

Development of stimulated Raman scattering microscopy system for label-free cell imaging

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Raman microscopy is a powerful technique for label-free biological imaging because it provides chemical specificity based on vibrational spectroscopy. In particular, stimulated Raman scattering (SRS) microscopy, which was introduced recently [1-5], has several advantages such as (i) high-sensitivity, (ii) high-contrast, (iii) easy access to vibrational spectrum, etc.

In SRS microscopy, two-color laser pulses, one of which is intensity-modulated beforehand, are focused on a sample, and the modulation transfer due to SRS is detected by the lock-in technique. It is crucial that the lock-in frequency is sufficiently high that the effect of low-frequency laser noise is mitigated. We proposed that the lock-in frequency can be easily increased by using subharmonically synchronized laser pulses, and clearly demonstrated the nearly shot-noise-limited sensitivity [4]. However, the spectral resolution was low therein because subpicosecond pulses were used. Also the imaging speed was limited by the speed of the sample stage and by the integration time of the lock-in amplifier.

Here we report our recent development of SRS microscopy system, which is schematically shown in Fig. 1. We replaced the subpicosecond lasers by picosecond Ti:sapphire and Yb fiber lasers to improve the spectral resolution down to <5 cm^{-1}. The lasers are synchronized by using two-photon photodetector and an intracavity electro-optic modulator in the Yb fiber laser [4]. In order to improve the imaging speed, we introduced a laser scanner and a home-made lock-in amplifier. Fig. 2(a) shows the SRS spectrum of a polystyrene bead, which was taken by scanning the wavelength of Ti:sapphire laser. The SRS spectrum (open circle) matches well with the spontaneous Raman spectrum (broken line), demonstrating the improved spectral resolution. Fig. 2(b) shows an SRS image of a HeLa cell, which was taken with a pixel dwell time of 50 µs. The Raman shift was set to 2850 cm^{-1} (red) and 2950 cm^{-1} (green), which correspond to CH_2 stretching (lipids) and CH_3 stretching (proteins) modes, respectively. We could clearly visualize the lipid distribution and the cell morphology with high contrast.

References: [1] C. W. Freudiger *et al.*, Science **322**, 1857 (2008). [2] Y. Ozeki *et al.*, Opt. Express **17**, 3651 (2009). [3] P. Nandakumar *et al.*, New J. Phys. **11**, 033026 (2009). [4] Y. Ozeki *et al.*, Opt. Express **18**, 13708 (P-2010). [5] B. G. Saar *et al.*, Science **330**, 1368 (2010).

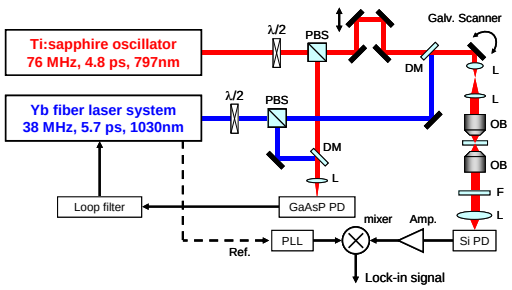
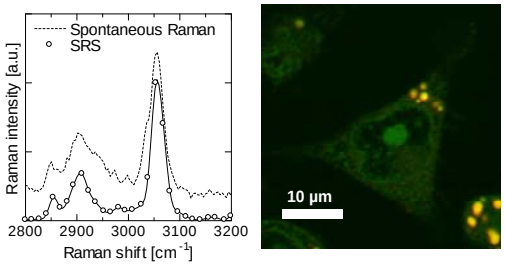


Fig. 1. Experimental setup. PBS: polarization beam splitter. DM: dichroic mirror. L: lens. OB: objective lens. PLL: phase-locked loop. Amp: electric amplifier.



(a) (b)

Fig. 2. Experimental results. (a) SRS spectrum (open circle) and spontaneous Raman spectrum (broken line) of polystyrene. (b) SRS image of HeLa cell. Red: 2850 cm^{-1}. Green: 2950 cm^{-1}. Pixel size: 401 x 401.

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