戦略的国際共同研究プログラム(SICORP)

日本－V4 共同研究

終了報告書　概要

1. 研究課題名：「金属 - IV 族半導体ナノ複合体のナノフォトニクス：単一ナノ粒子から機能性集合体まで」
2. 研究期間：2015 年 11 月～2019 年 3 月
3. 主な参加研究者名：

日本側チーム

	氏名	役職	所属	研究分担
研究代表者	藤井　稔	教授	神戸大学	総括
主たる 共同研究者	杉本　泰	助教	神戸大学	シリコンナノ結晶形成・評価
主たる 共同研究者	加納　伸也	助教	神戸大学(～２０１９年３月)	電子デバイス形成・評価
研究参加者	今北　健二	准教授	神戸大学（～２０１６）	シリコンナノ結晶評価
研究参加者	管野　天	学生	神戸大学(～２０１７年３月)	シリコンナノ結晶評価
研究参加者	井上　飛鳥	学生	神戸大学(～２０１９年３月)	バイオ応用
研究期間中の全参加研究者数　　６名				

チェコ側チーム

	氏名	役職	所属	研究分担
研究代表者	Jan Valenta	Professor	Charles University in Prague	Supervision, management, Single dot spectroscopy
主たる 共同研究者	Marie Hubalek-Kalbacova	Associate Professor	Charles University in Prague	Bio-imaging
主たる 共同研究者	Anna Fucikova	Assistant Professor	Charles University in Prague	Surface functionalization
研究参加者	Lucie Ostrovská	PhD student	Charles University in Prague	Bio-imaging
研究参加者	Tereza Belinova	PhD student	Charles University in Prague	Bio-imaging
研究参加者	Ondřej Pavelka	PhD student	Charles University in Prague	Composite formation
研究期間中の全参加研究者数　　６名				

ハンガリー側チーム

	氏名	役職	所属	研究分担
研究代表者	Ádám Gali	Research group leader	Wigner Research Centre for Physics, Hungarian Academy of Sciences	Supervision, management
主たる 共同研究者	Bálint Somogy,	PhD student	Wigner Research Centre for Physics, Hungarian Academy	DFT calculations

			of Sciences	
主たる 共同研究者	David Beke	PhD student	Wigner Research Centre for Physics, Hungarian Academy of Sciences	SiC nanoparticle formation
研究参加者				
研究参加者				
研究参加者				
研究期間中の全参加研究者数　　３名				

スロバキア側チーム

	氏名	役職	所属	研究分担
研究代表者	Ivan Štich	Professor	Institute of Physics, Slovak Academy of Sciences	Supervision, management
主たる 共同研究者	René Derian	Post doc researcher	Institute of Physics, Slovak Academy of Sciences	Quantum Monte Carlo simulation
主たる 共同研究者	Kamil Tokár	Post doc researcher	Institute of Physics, Slovak Academy of Sciences	Quantum Monte Carlo simulation
研究参加者				
研究参加者				
研究参加者				
研究期間中の全参加研究者数　　３名				

ポーランド側チーム

	氏名	役職	所属	研究分担
研究代表者	Romuald Bartlomiej Beck	Professor	Warsaw University of Technology	Supervision, management
主たる 共同研究者	Robert Mroczynski	Associate Professor	Warsaw University of Technology	Device formation
主たる 共同研究者	Andrzej Mazurak	Researcher	Warsaw University of Technology	Device modeling
研究参加者				
研究参加者				
研究参加者				
研究期間中の全参加研究者数　　３名				

4．国際共同研究の概要

本研究は、代表的な低環境負荷半導体材料であるシリコンのナノ結晶と金属ナノ構造からなる新複合ナノ材料を創成し、その光・電子デバイス応用とバイオ・医療応用の可能性を検証することを目的とする。本研究の中心となる材料は，研究代表者のグループが開発したホウ素とリンを同時にドーピングした全無機極性溶媒分散性シリコンナノ結晶であり，本材料の基礎物性解明，電子状態の理論計算，光・電子デバイス応用の検討，細胞毒性検証，バイオイメージング応用実証，バイオセンサ応用検討，及び本材料を用いた新複合ナノ材料の開発を行う。

本国際共同研究には、日本、チェコ、ハンガリー、スロバキア、ポーランドの５カ国の研究グループが参画する。各国チームの役割は以下の通りである。日本グループがシリコ

ンナノ結晶の開発（ドーピング、表面修飾、複合ナノ構造形成等）を行う。チェコグループは単一ナノ粒子レベルの高精度な物性評価とバイオ応用研究を実施する。ハンガリーグループとスロバキアグループは、それぞれ密度汎関数理論と量子モンテカルロ法による電子状態計算を行う。ポーランドグループは、電子デバイスのモデリングと形成を行う。

各国の研究グループの研究資産を持ちよった共同研究により、優れた特性を有するシリコンベース新複合ナノ材料を開発し，低環境負荷社会の実現に貢献する。

5. 国際共同研究の成果

5-1 国際共同研究の学術成果および実施内容

本国際共同研究では、ホウ素とリンを同時ドーピングした全無機水分散性シリコンナノ結晶を中心材料として、基礎物性の解明、複合機能性材料の開発、バイオ応用実証、電子デバイス応用実証等について、以下の項目について研究を行った。①構造評価、②高品質化，高性能化、③電子状態解析、④表面修飾技術開発、⑤吸着分子間の電子授受及び光触媒作用、⑥蛍光バイオイメージングと細胞毒性検証、⑦多層膜形成技術開発、⑧複合ナノ構造形成と発光増強、⑨電子デバイス応用。それぞれの項目について、目標以上の成果を得、多数の論文を発表した。

5-2 国際共同研究による相乗効果

本国際共同研究には、専門が大きく異なる５カ国のグループが参画するため、大きな相乗効果を生み出すためにはスムーズな意思疎通が可能な体制を構築することが非常に重要である。スムーズな意思疎通を実現するために、face to face で議論をする機会を可能な限り多く設定した。具体的には、採択直後に神戸大学でキックオフミーティングを実施した。さらに、各グループ持ち回りで年次ミーティングを開催した。さらに、若手研究者が互いを訪問し協力して研究する機会を多く設けた。

5-3 国際共同研究成果の波及効果と今後の展望

本国際共同研究は、新しいナノ材料の開発に関わる基礎研究であるため、基本的には学術論文の発表により社会に貢献すべきだと考えている。それについては、高インパクトファクター誌に多くの論文を発表しており、十分な成果を挙げることができたと考えている。また、大部分の論文で大学院学生か若手研究者が筆頭著者であり、本プロジェクトを通して若手研究者の育成に大きく貢献できた。

Strategic International Collaborative Research Program (SICORP)
Japan－V4 Joint Research Program
Executive Summary of Final Report

1. Project title:「Nanophotonics with metal – group-IV-semiconductor nanocomposites: From single nanoobjects to functional ensembles」
2. Research period：November 2015 ～ March 2019
3. Main participants：

Japan-side

	Name	Title	Affiliation	Role in the research project
PI	Minoru Fujii	Professor	Kobe University	Supervision, management
Co-PI	Hiroshi Sugimoto	Assistant Professor	Kobe University	Si nanocrystal formation, characterization
Co-PI	Shinya Kano	Assistant Professor	Kobe University (~March 2019)	Electronic device
Collaborator	Kenji Imakita	Associate Professor	Kobe University (~March 2016)	Characterization
Collaborator	Takashi Kanno	PhD student	Kobe University (~March 2017)	Characterization
Collaborator	Asuka Inoue	PhD student	Kobe University (~March 2019)	Bio- imaging
Total number of participants throughout the research period: 6				

Czech-side

	Name	Title	Affiliation	Role in the research project
PI	Jan Valenta	Professor	Charles University in Prague	Supervision, management, Single dot spectroscopy
Co-PI	Marie Hubalek-Kalbacova	Associate Professor	Charles University in Prague	Bio-imaging
Co-PI	Anna Fucikova	Assistant Professor	Charles University in Prague	Surface functionalization
Collaborator	Lucie Ostrovská	PhD student	Charles University in Prague	Bio-imaging
Collaborator	Tereza Belinova	PhD student	Charles University in Prague	Bio-imaging
Collaborator	Ondřej Pavelka	PhD student	Charles University in Prague	Composite formation
Total number of participants throughout the research period: 6				

Hungary-side

	Name	Title	Affiliation	Role in the research project
PI	Ádám Gali	Research group leader	Wigner Research Centre for Physics, Hungarian Academy of Sciences	Supervision, management

Co-PI	Bálint Somogy,	PhD student	Wigner Research Centre for Physics, Hungarian Academy of Sciences	DFT calculations
Co-PI	David Beke	PhD student	Wigner Research Centre for Physics, Hungarian Academy of Sciences	SiC nanoparticle formation
Collaborator				
Collaborator				
Collaborator				
Total number of participants throughout the research period: 3				

Slovakia-side

	Name	Title	Affiliation	Role in the research project
PI	Ivan Štich	Professor	Institute of Physics, Slovak Academy of Sciences	Supervision, management
Co-PI	René Derian	Post doc researcher	Institute of Physics, Slovak Academy of Sciences	Quantum Monte Carlo simulation
Co-PI	Kamil Tokár	Post doc researcher	Institute of Physics, Slovak Academy of Sciences	Quantum Monte Carlo simulation
Collaborator				
Collaborator				
Collaborator				
Total number of participants throughout the research period: 3				

Poland-side

	Name	Title	Affiliation	Role in the research project
PI	Romuald Bartlomiej Beck	Professor	Warsaw University of Technology	Supervision, management
Co-PI	Robert Mroczynski	Associate Professor	Warsaw University of Technology	Device formation
Co-PI	Andrzej Mazurak	Researcher	Warsaw University of Technology	Device modeling
Collaborator				
Collaborator				
Collaborator				
Total number of participants throughout the research period: 3				

4. Summary of the international joint research

The purpose of the project is to develop new environmentally-friendly composite nanomaterials composed of silicon nanocrystals and metal nanostructures and demonstrate their potential for optoelectronic device and biomedical applications. Silicon nanocrystals are known to be environmentally friendly and biocompatible and thus potentially suitable for biomedical applications. Furthermore, they have high compatibility with the silicon-based microelectronics industry. A core

material in this project is a newly-developed all-inorganic polar-solvent-dispersible silicon nanocrystal, in which boron and phosphorus are simultaneously doped. Because of the boron and phosphorus codoping, the property of the Si nanocrystals is very much different from conventional ones and they have many superior properties. In this project, we perform comprehensive experimental and theoretical studies to understand fundamental physics of the codoped Si nanocrystals, and develop composite nanostructures based on the codoped Si nanocrystals. We also study the cytotoxicity to investigate the potential for bioimaging and biosensing applications. Furthermore, we explore the applications in electronic devices.

This international joint research involves research groups from five countries: Japan, Czech Republic, Hungary, Slovakia, and Poland. The role of each team is as follows. The Japan group will develop boron and phosphorus codoped silicon nanocrystals (doping, surface modification, composite nanostructure formation, etc.). The Czech group will conduct the physical property evaluation at the single nanoparticle level and the bio-application research. The Hungarian group and the Slovak group perform electronic structure calculation by a density functional theory and a quantum Monte Carlo method, respectively. The Polish group perform modeling and production of electronic devices.

5. Outcomes of the international joint research

5-1 Scientific outputs and implemented activities of the joint research

In this international joint research project on boron and phosphorus codoped silicon nanocrystals, the following researches were performed; 1 evaluation of the structure, especially distribution of dopants, 2 improvement of the quality of silicon nanocrystals (e.g., size distribution, luminescence quantum yield, etc.), 3 analysis of the energy level structures, 4 development of the technology for surface modification, 5 analysis of the photocatalytic activity, 6 evaluation of the cytotoxicity and demonstration of the bioimaging application, 7 formation of multilayer films made from different size silicon nanocrystals, 8 formation of composite nanostructures and achievement of the luminescence enhancement, and 9 development of electronic devices such as thin film transistor, resistive memory, respiration sensor, etc. The results obtained in this projects were published in prestigious scientific journals.

5-2 Synergistic effects of the joint research

In this international joint research project, groups of five countries with very different specialties participate, so establishment of a firm communication routs was crucial to generate the synergy effect. We set up many opportunities for face-to-face discussions to make smooth communication possible. Specifically, kick-off meetings were held at Kobe University immediately after the acceptance of the application, and annual meetings, in which members of all groups participate, were held in each group annually. In addition, we prepared many opportunities for young researchers to visit each other and collaborate on research. As a result of research exchange in various forms, the synergetic effect of this international joint research has yielded many important results.

5-3 Scientific, industrial or societal impacts/effects of the outputs

As this international joint research is a basic research related to the development of new nanomaterials, it contributes to society through the publication of academic papers. As for that, we have published many articles in high impact factor journals, and we believe that we have achieved satisfactory results. In addition, graduate students and young researchers are the leading authors in most of the papers, and thus this project has greatly contributed for the carrier development of young researchers.

国際共同研究における主要な研究成果リスト

1．論文発表等

＊原著論文（相手側研究チームとの共著論文）
・査読有り：発表件数：計 4 件

1. Lucie Ostrovska, Antonin Broz, Anna Fucikova, Tereza Belinova, Hiroshi Sugimoto, Takashi Kanno, Minoru Fujii, Jan Valenta, and Marie Hubalek Kalbacova , "The Impact of Doped Silicon Quantum Dots on Human Osteoblasts", RSC Advances, Vol. 6, 63403-63413 (2016) DOI: 10.1039/C6RA14430F
2. Takashi Kanno, Hiroshi Sugimoto, Anna Fucikova, Jan Valenta, and Minoru Fujii, "Single-Dot Spectroscopy of Boron and Phosphorus Codoped Silicon Quantum dots", Journal of Applied Physics, Vol. 120, pp. 164307-1-6 (2016) DOI: 10.1063/1.4965986
3. A. Mazurak, R. Mroczyński, J. Jasiński, D. Tanous, B. Majkusiak, S. Kano, H. Sugimoto, M. Fujii, J. Valent,"Technology and Characterization of MIS Structures with Co-Doped Silicon Nanocrystals (Si-NCs) Embedded in Hafnium Oxide (HfOx) Ultra-Thin Layers", Microelectronic Engineering, Vol. 178, No. 25, pp. 298–303 (2017) DOI: 10.1016/j.mee.2017.05.050
4. Tereza Belinova, Lucie Vrabcova, Iva Machova, Anna Fucikova, Jan Valenta, Hiroshi Sugimoto, Minoru Fujii, Marie Hubalek Kalbacova, "Silicon Quantum Dots and Their Impact on Different Human Cells", Physica Status Solidi (b), 255, 1700597, pp. 1-5 (2018) DOI: 10.1002/pssb.201700597

・査読無し：発表件数：計 0 件

＊原著論文（相手側研究チームを含まない日本側研究チームの論文）：発表件数：計 41 件
・査読有り：発表件数：計 36 件

1. Masato Sasaki, Shinya Kano, Hiroshi Sugimoto, Kenji Imakita, and Minoru Fujii, "Surface Structure and Current Transport Property of Boron and Phosphorous Co-doped Silicon Nanocrystals", The Journal of Physical Chemistry C, Vol. 120, No. 1, pp. 195-200 (2016) DOI: 10.1021/acs.jpcc.5b05604
2. Yusuke Hori, Shinya Kano, Hiroshi Sugimoto, Kenji Imakita, and Minoru Fujii, "Size-Dependence of Acceptor and Donor Levels of Boron and Phosphorus Codoped Colloidal Silicon Nanocrystals", Nano Letters, Vol. 16, Issue 4, pp. 2615-2620 (2016) DOI: 10.1021/acs.nanolett.6b00225
3. Hiroshi Sugimoto, Kenji Imakita, and Minoru Fujii, "Silicon Nanocrystal-Noble Metal Hybrid Nanoparticles", Nanoscale, Vol. 8, Issue 21, pp. 10956-10962 (2016) DOI: 10.1039/C6NR01747A
4. Minoru Fujii, Hiroshi Sugimoto, and Kenji Imakita, "All-Inorganic Colloidal Silicon Nanocrystals-Surface Modification by Boron and Phosphorus Co-Doping", Nanotechnology, Vol. 27, Issue 26, pp. 262001-1-20 (2016) DOI: 10.1088/0957-4484/27/26/262001
5. Shinya Kano, Masato Sasaki, and Minoru Fujii, "Combined Analysis of Energy Band Diagram and Equivalent Circuit on Nanocrystal Solid", Journal of Applied Physics, Vol. 119, Issue 21, pp. 215304-1-6 (2016) DOI: 10.1063/1.4953216
6. Hiroshi Sugimoto, Shiho Yashima, Kenta Furuta, Asuka Inoue, and Minoru Fujii, "Probing Purcell Enhancement in Plasmonic Nanoantennas by Broadband Luminescent Si Quantum Dots", Applied Physics Letters, Vol. 108, pp. 241103-1-4 (2016) DOI: 10.1063/1.4953829
7. Asuka Inoue, Hiroshi Sugimoto, Hidenobu Yaku, and Minoru Fujii, "DNA Assembly of Silicon Quantum Dots / Gold Nanoparticle Nanocomposites", RSC Advances, Vol. 6, pp. 63933-63939 (2016) DOI: 10.1039/C6RA13565J
8. Keita Nomoto, Hiroshi Sugimoto, Andrew Breen, Anna Ceguerra, Takashi Kanno, Simon Ringer,Ivan Wurfl,Gavin Conibeer, and Minoru Fujii, "Atom Probe Tomography Analysis of Boron and/or Phosphorus Distribution in Doped Silicon Nanocrystals", The Journal of Physical Chemistry C, Vol. 120, pp. 17845–17852 (2016) DOI: 10.1021/acs.jpcc.6b06197

9. Hiroshi Sugimoto, Kenta Furuta, and Minoru Fujii, "Controlling Energy Transfer in Silicon Quantum Dot Assemblies Made from All-Inorganic Colloidal Silicon Quantum Dots", The Journal of Physical Chemistry C, Vol.120, pp. 24469-24475 (2016) DOI: 10.1021/acs.jpcc.6b08423
10. Takashi Kanno, Shinya Kano, Hiroshi Sugimoto, Yasuhiro Tada, and Minoru Fujii, "Water-Dispersible Near-Infrared Luminescent Silicon Nanocrystals–Immobilization on Substrate", MRS Communications, Vol. 6, Issue 4, pp. 429-436 (2016) DOI: 10.1557/mrc.2016.51
11. Yasuhiro Higashikawa, Yasuo Azuma, Yutaka Majima, Shinya Kano, and Minoru Fujii, "Integration of Colloidal Silicon Nanocrystals on Metal Electrodes in Single-Electron Transistor", Applied Physics Letters, Vol. 109, 213104, pp. 1-5 (2016) DOI: 10.1063/1.4968583
12. Shiho Yashima, Hiroshi Sugimoto, Hiroyuki Takashina, and Minoru Fujii, "Fluorescence Enhancement and Spectral Shaping of Silicon Quantum Dot Mono-Layer by Plasmonic Gap Resonances", The Journal of Physical Chemistry C, Vol. 120, pp. 28795-28801 (2016) DOI: 10.1021/acs.jpcc.6b09124
13. Shinya Kano, and Minoru Fujii, "Conversion Efficiency of an Energy Harvester Based on Resonant Tunneling Through Quantum Dots with Heat Leakage", Nanotechnology, Vol. 28, No. 9, pp. 095403-1–7 (2017) DOI: 10.1088/1361-6528/aa5939
14. Keita Nomoto, Sebastian Gutsch, Anna Ceguerra, Andrew Breen, Hiroshi Sugimoto, Minoru Fujii, Ivan Perez-Wurfl, Simon Ringer, Gavin Conibeer, "Atom Probe Tomography of Phosphorus- and Boron-Doped Silicon Nanocrystals of Various Composition of Silicon Rich Oxide", MRS Communications, Vol. 6, Issue 3, pp. 283-288 (2016) DOI: 10.1557/mrc.2016.37
15. Hiroshi Sugimoto, Yusuke Hori, Yusuke Imura, and Minoru Fujii, "Charge Transfer Induced Photoluminescence Enhancement in Colloidal Silicon Quantum Dots", The Journal of Physical Chemistry C, Vol. 121, Issue. 21, pp. 11962–11967 (2017) DOI: 10.1021/acs.jpcc.7b03451
16. Asuka Inoue, Hiroshi Sugimoto, and Minoru Fujii, "Photoluminescence Enhancement of Silicon Quantum Dot Monolayer by Double Resonance Plasmonic Substrate", The Journal of Physical Chemistry C, Vol. 121, Issue. 21, pp. 11609–11615 (2017) DOI: 10.1021/acs.jpcc.7b00717
17. Hiroshi Sugimoto, Yusuke Ozaki, and Minoru Fujii "Silicon Quantum Dots in Dielectric Scattering Media-Broadband Enhancement of Effective Absorption Cross Section by Light Trapping", ACS Applied Materials & Interfaces, Vol. 9, Issue. 22, pp. 19135–19142 (2017) DOI: 10.1021/acsami.7b04292
18. Hiroshi Sugimoto, and Minoru Fujii "Colloidal Dispersion of Sub-Quarter Micron Silicon Spheres for Low-Loss Antenna in Visible Regime", Advanced Optical Materials, Vol. 5,Issue 17, 1700332, pp. 1–8 (2017) DOI: 10.1002/adom.201700332
19. Shinya Kano, Kwangsoo Kim, and Minoru Fujii "Fast-Response and Flexible Nanocrystal-Based Humidity Sensor for Monitoring Human Respiration and Water Evaporation on Skin", ACS Sensors, Vol. 2, Issue. 6, pp. 828–833 (2017) DOI: 10.1021/acssensors.7b00199
20. Or Ashkenazi, Doron Azulay, Isaac Balberg, Shinya Kano, Hiroshi Sugimoto, Minoru Fujii, and Oded Millo,"Size-Dependent Donor and Acceptor States in Codoped Si Nanocrystals Studied by Scanning Tunneling Spectroscopy", Nanoscale, Vol. 9, pp. 17884-17892 (2017) DOI: 10.1039/C7NR06257E
21. Hiroto Yanagawa, Asuka Inoue, Hiroshi Sugimoto, Masahiko Shioi, and Minoru Fujii, "Photoluminescence Enhancement of Silicon Quantum Dot Monolayer by Plasmonic Substrate Fabricated by Nano-Imprint Lithography", Journal of Applied Physics, Vol. 122, Issue 22, pp. 223101-1-6 (2017) DOI: 10.1063/1.5001106
22. Shinya Kano, Yuya Dobashi, and Minoru Fujii, "Silica Nanoparticle-Based Portable Respiration Sensor for Analysis of Respiration Rate, Pattern, and Phase during Exercise", IEEE Sensors Letters, Vol. 2, No 1, 2000104, pp. 1-4 (2018) DOI: 10.1109/LSENS.2017.2787099

23. Takuya Kojima, Hiroshi Sugimoto, and Minoru Fujii, "Size-Dependent Photocatalytic Activity of Colloidal Silicon Quantum Dot", The Journal of Physical Chemistry C, Vol. 122, Issue 3, pp. 1874–1880 (2018) DOI: 10.1021/acs.jpcc.7b10967
24. Yuki Ohata, Hiroshi Sugimoto, and Minoru Fujii, "Assembling Silicon Quantum Dots into Wires, Networks and Rods via Metal Ion Bridge ", Nanoscale, Vol. 10, Issue 16, pp. 7597-7604 (2018) DOI: 10.1039/C8NR00631H
25. Hiroshi Sugimoto, Masataka Yamamura, Makoto Sakiyama, and Minoru Fujii, "Visualizing Core-Shell Structure of Heavily Doped Silicon Quantum Dots by Electron Microscope using Atomically Thin Support Film", Nanoscale, Vol. 10, Issue 16, pp. 7357-7362 (2018) DOI: 10.1039/C7NR09474D
26. Hiroshi Sugimoto, and Minoru Fujii, "Broadband Dielectric-Metal Hybrid Nanoantenna -Silicon Nanoparticle on Mirror", ACS Photonics, Vol. 5, Issue 5, pp. 1986–1993 (2018) DOI: 10.1021/acsphotonics.7b01461
27. Minoru Fujii, Hiroshi Sugimoto, and Shinya Kano, "Silicon Quantum Dot with heavily Boron and Phosphorus Codoped Shell", Chemical Communications, Vol. 54, Issue 35, pp. 4375-4389 (2018) DOI: 10.1039/C8CC01612G
28. Shinya Kano, Yasuhiro Tada, Satoshi Matsuda, and Minoru Fujii, "Solution Processing of Hydrogen-Terminated Silicon Nanocrystal for Flexible Electronic Device", ACS Applied Materials & Interfaces, Vol. 10, Issue 24, pp 20672–20678 (2018) DOI: 10.1021/acsami.8b04072
29. Hiroshi Sugimoto, Shiho Yashima, and Minoru Fujii, "Hybridized Plasmonic Gap Mode of Gold Nanorod on Mirror Nanoantenna for Spectrally Tailored Fluorescence Enhancement", ACS Photonics, Vol. 5, Issue 8, pp 3421–3427 (2018) DOI: 10.1021/acsphotonics.8b00693
30. Makoto Sakiyama, Hiroshi Sugimoto, and Minoru Fujii, "Long-Lived Luminescence of Colloidal Silicon Quantum Dots for Time-Gated Fluorescence Imaging in the Second Near Infrared Window in Biological Tissue", Nanoscale, Vol. 10, Issue 29, pp. 13902-139007 (2018) DOI: 10.1039/C8NR03571G"
31. Takeshi Kawauchi, Shinya Kano, and Minoru Fujii, "Forming-Free Resistive Switching in Solution-Processed Silicon Nanocrystal Thin Film", Journal of Applied Physics, Vol. 124, 085113, pp. 1-6 (2018) DOI: 10.1063/1.5032244
32. Shinya Kano, and Minoru Fujii, "All-Painting Process To Produce Respiration Sensor Using Humidity-Sensitive Nanoparticle Film and Graphite Trace", ACS Sustainable Chemistry & Engineering, Vol. 6, Issue 9, pp. 12217–12223 (2018) DOI: 10.1021/acssuschemeng.8b02550
33. Akiko Minami, Hiroshi Sugimoto, Iain Crowe, and Minoru Fujii, "Growth of Core-Shell Silicon Quantum Dots in Borophosphosilicate Glass Matrix -Raman and Transmission Electron Microscopic Studies", The Journal of Physical Chemistry C, Vol. 122, Issue 36, pp. 21069-21075 (2018) DOI: 10.1021/acs.jpcc.8b07316
34. Rens Limpens, Hiroshi Sugimoto, Nathan R Neale, and Minoru Fujii, "Critical Size for Carrier Delocalization in Doped Silicon Nanocrystals: A Study by Ultrafast Spectroscopy", ACS Photonics, Vol. 5, Issue 10, pp. 4037–4045 (2018) DOI: 10.1021/acsphotonics.8b00671
35. Hiroshi Sugimoto, Masataka Yamamura, Riku Fujii, and Minoru Fujii, "Donor−Acceptor Pair Recombination in Size-Purified Silicon Quantum Dots", Nano Letters, Vol. 18, Issue 11, pp. 7282-7288 (2018) DOI: 10.1021/acs.nanolett.8b03489
36. Kosuke Inoue, Takuya Kojima, Hiroshi Sugimoto, and Minoru Fujii, "Charge Transfer-Induced Photobrightening of Silicon Quantum Dots in Water Containing a Molecular Reductant", The Journal of Physical Chemistry C, Vol. 123, Issue 2, pp. 1512-1519 (2019). DOI: 10.1021/acs.jpcc.8b11359

・査読無し：発表件数：計 0 件
該当なし

＊その他の著作物（相手側研究チームとの共著総説、書籍など）：発表件数：計 0 件
該当なし

＊その他の著作物（相手側研究チームを含まない日本側研究チームの総説、書籍など）：発

表件数：計 5 件

1. Minoru Fujii, "All-Inorganic Colloidal Silicon Nanocrystals" in "Silicon Nanophotonics - Basic Principles, Present Status, and Perspectives (Second Edition)", Ed. Leonid Khriachtchev (University of Helsinki, Finland), Pan Stanford Publishing (September 30, 2016) DOI: 10.4032/9789814669771
2. Hiroshi Sugimoto and Minoru Fujii, Part One, From Research to Application, Chapter 10, "Silicon Quantum Dot Composites for Nanophotonics" in "Micro- and Nanophotonic Technologies", Ed. Patrick Meyrueis, Kazuaki Sakoda, Marcel Van de Voorde, Wiley (March 6, 2017) DOI: 10.1002/9783527699940.ch10
3. 杉本　泰，藤井　稔, 第４章　第５節，「Si 量子ドット」、"量子ドット材料の技術と応用展開", 情報機構 (2017 年 6 月 27 日)
4. Hiroshi Sugimoto, and Minoru Fujii, Chapter 17. "Near-Infrared Luminescent Colloidal Silicon Nanocrystals" in Silicon Nanomaterials Sourcebook, Low-Dimensional Structures Nanopowders, Nanowires", Edited by Klaus D. Sattler, CRC Press (August 9, 2017) DOI: 10.1201/9781315153544-20
5. 杉本　泰、藤井　稔，第 5 章. シリコンナノ結晶, "量子ドット・マイクロ LED ディスプレイと関連材料の技術開発 (Technical Development of Quantum-dot・Micro LED Display and their Material)", ㈱シーエムシー・リサーチ (2018 年月 3 日 9 日) ISBN: 978-4-904482-44-5

2．学会発表

＊口頭発表（相手側研究チームとの連名発表）

発表件数：計 3 件（うち招待講演：0 件）

＊口頭発表（相手側研究チームを含まない日本側研究チームの発表）

発表件数：計 55 件（うち招待講演：9 件）

＊ポスター発表（相手側研究チームとの連名発表）

発表件数：計 1 件

＊ポスター発表（相手側研究チームを含まない日本側研究チームの発表）

発表件数：計 10 件

3．主催したワークショップ・セミナー・シンポジウム等の開催

1. 2017 Europe Materials Research Society Fall Meeting (Warsaw, September 18-21) Symposium T “Silicon, Germanium, Diamond and Carbon nanostructures and their nanocomposites with other materials”, Organizers: Jan Valenta, Minoru Fujii, Adam Gali, Milos Nesladek, Number of submitted abstracts: 56

4．研究交流の実績（主要な実績）

【合同ミーティング】

1. 2015 年 11 月： キックオフミーティング，神戸大学，参加者：Jan Valenta, Marie Hubalek-Kalbacova, Anna Fucikova, Lucie Ostrovská (Czech Republic)， Minoru Fujii, Kenji Imakita, Shinya Kano, Hui Lin, Hiroshi Sugimoto（Japan）, Adam Gali (Hungary), René Derian (Slovakia), Robert Mroczyński (Poland)
2. 2016 年 5 月 2-6 日：Intermediate meeting，リール，E-MRS Spring meeting 期間中），参加者：Jan Valenta, Anna Fucikova, Lucie Ostrovská (Czech Republic)， Minoru Fujii, Hiroshi Sugimoto, Takashi Kanno（Japan）, Robert Mroczyński, Andrzej Mazurak (Poland)

3. 2016 年 10 月 17-18 日：First annual meeting，ブラチスラバ，ブダペスト，
参加者：Jan Valenta, Marie Hubalek-Kalbacova, Anna Fucikova (Czech Republic)，Minoru Fujii（Japan), Adam Gali, Bálint Somogy, David Beke (Hungary), Ivan Stich,René Derian (Slovakia), Andrzej Mazurak (Poland)
4. 2017 年 9 月 21 日：2nd annual meeting，ワルシャワ，参加者：Jan Valenta, Marie Hubalek-Kalbacova, Anna Fucikova, Tereza Belinova (Czech Republic)，Minoru Fujii, Hiroshi Sugimoto（Japan), Bálint Somogy, David Beke (Hungary), Ivan Stich,René Derian (Slovakia), Robert Mroczyński , Andrzej Mazurak (Poland)
5. 2018 年 10 月 4-5 日：3rd (final) annual meeting，プラハ，参加者：Jan Valenta, Marie Hubalek-Kalbacova, Anna Fucikova, Ondřej Pavelka, Mikel Greben (Czech Republic)，Minoru Fujii, Hiroshi Sugimoto（Japan), Adam Gali, Bálint Somogy, David Beke (Hungary), Ivan Stich (Slovakia), Robert Mroczyński , Andrzej Mazurak (Poland)）

【学生・研究者の派遣、受入】

1. 日本→チェコ
   - ① Takashi Kanno（ph.D 学生） April 6 - July 1st, 2016
   - ② Hiroshi Sugimoto（若手研究者） October 3-10, 2018
2. チェコ→日本
   - ③ Jan Valenta November 15-22, 2017
   - ④ Tereza Belinova（ph.D 学生） November 15-22, 2017
   - ⑤ Ondřej Pavelka（ph.D 学生） November 15-22, 2017
   - ⑥ Ondřej Pavelka（ph.D 学生） October 29 – Nov. 11, 2018

5．特許出願

研究期間累積出願件数：0 件

6．受賞・新聞報道等

該当なし

7．その他

1. SPIE (The International Society for Optics and Photonics)の Newsroom において、本プロジェクトの成果の一部を紹介。