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RNBS

RESEARCH INSTITUTE FOR NANODEVICE AND BIO SYSTEMS
HIROSHIMA UNIVERSITY

広島大学 ナノデバイス・バイオ融合科学研究所

Preface

The Research Institute for Nanodevice and Bio Systems (RNBS) was founded on May 1, 2008 with the faculty members of the Department of Semiconductor Electronics and Integration Science and the Department of Molecular Biotechnology at the Graduate School of Advanced Sciences of Matter as well as the Graduate School of Biomedical Sciences. RNBS consists of four research divisions; (1) Nanointegration Research Division, (2) Integrated Systems Research Division, (3) Molecular Bioinformation Research Division, and (4) Nanomedicine Research Division.

The forerunner of this institute was The Research Center for Integrated Systems (RCIS) which was founded in 1986 as a ministerial ordinance. The first center was reorganized after 10 years and The Research Center for Nanodevices and Systems (RCNS) was established in May, 1996.

It has been 32 years since the first RCIS was established by the first Director Dr. Masataka Hirose, Emeritus Advisor of National Institute of Advanced Industrial Science and Technology, Professor Emeritus of Hiroshima University. We also would like to thank the first Associate Director, Prof. Mitsumasa Koyanagi, Tohoku University, and Dr. Yasuhiro Horiike, Fellow Emeritus, National Institute for Materials Science, specially appointed Professor of University of Tsukuba.

The research at RNBS has been focused on silicon integrated circuits, devices, processes and materials so that the significant research results have been achieved as one of the prominent research institute among the national universities. The RNBS plays important roles not only as a research laboratory but also as an education institute, where graduate students and under graduate students as well as postdoctoral researchers have been studying on the most advanced leading-edge technologies to become independent leading researchers who conduct their researches by themselves in future semiconductor industries. The reputations of the graduates from the RNBS have been extremely high in the semiconductor industries.

The RNBS has achieved numerous projects supported by Japanese and local governments such as Nanotechnology Platform, Ministry of Education, Culture, Sports, Science and Technology, Strategic Basic Research Programs (CREST), Development of Systems and Technology for Advanced Measurement and Analysis, Japan Agency for Medical Research and Development, Grant-in-Aid for Scientific Research (A) by the Japan Society for the Promotion of Science (JSPS). The RNBS has also been selected as one of the members of the National University Research Institute and Research Center Council.
In April 2016, the Research Center of Biomedical Engineering (RCBE) was established in collaboration with the Institute of Biomaterials and Bioengineering at Tokyo Medical and Dental University, the Laboratory for Future Interdisciplinary Research of Science and Technology at Tokyo Institute of Technology, the Research Center for Nanodevice and Bio Systems at Hiroshima University, and the Research Institute of Electronics at Shizuoka University, with the support of the Minister of Education, Culture, Sports, Science and Technology (MEXT), Japan, The RCBE aims at promoting innovative researches in the field of biomedical engineering with strong network of these four institutes.

This annual report offers comprehensive information about the recent research activities and achievements at the RNBS to those who are engaged in the fields of advanced technologies. We hope this report will contribute to the mutual exchange of ideas and future progress of the researches on advanced integration of nanodevice and bio systems.

December 1, 2018

Shin Yokoyama
Director
Research Institute for Nanodevice and Bio Systems
Hiroshima University, Japan

Shin Yokoyama

巻頭言

広島大学ナノデバイス・バイオ融合科学研究所は2008年5月1日に大学院先端物質科学研究科半導体集積科学専攻の研究グループと分子生命機能科学専攻の研究グループおよび大学院医歯薬学総合研究科、歯学部の研究グループの協力を得て学内措置で設立されました。これまでの半導体研究の実績に加えて、医学・医療との融合をめざした基盤技術の研究を推進するため、研究領域はナノ集積科学、集積システム科学、分子生命情報科学、集積医科学の4つからなっています。

本研究所の前身は文部科学省の省令センターとして1986年に設立された集積化システム研究センターです。1996年5月にはナノデバイス・システム研究センターが新たな省令センターとして改組設立されました。 最初のセンター設立から22年目に本研究所を設立いたしました。

30年以上の実績を有するセンターは初代センター長の廣瀬全孝先生(現産業技術総合研究所研究顧問、広島大学名誉教授)をリーダーに、初代センター主任の小柳光正先生（元広島大学教授、現東北大学客員教授）、クリーンルーム立ち上げにご尽力いただいた堀池靖浩先生（元広島大学教授、現物質材料研究機構名誉フェロー、筑波大学数理物質系特命教授）をはじめとする諸先輩の努力の賜です。

広島大学ナノデバイス・バイオ融合科学研究所は我が国の大学の中でもユニークな存在です。30年間一貫して、シリコン集積回路、デバイス、プロセス、材料の研究を続けており、この分野では国内でも有数の研究機関としてその研究成果を着実にあげてきました。さらに、我が国の半導体産業の将来を担う、学部学生、大学院生、博士研究員らの人材育成にも力を入れてきました。最先端技術の研究を通して、世界に発信できる研究者を育成すべく、学生、研究員が自ら研究を企画し、自立して研究開発を進める能力を持つことができるよう教育指導しており、その実績は産業界から高く評価されております。

これまでの研究実績として、文部科学省ナノテクノロジープラットフォーム、戦略的創造研究推進事業(CREST)、日本医療研究開発機構(AMED)医療分野研究成果展開事業、科学研究費助成基盤研究費(A)などの大型プロジェクトに採択されて、研究を加速推進しております。
ナノデバイス・バイオ融合科学研究所は，2016年4月に、文部科学大臣から全国共同利用・共同研究拠点「生体医歯工学共同研究拠点」の認定（2016-2021年度）を受け、東京医科歯科大学生体材料工学研究所、東京工業大未来産業技術研究所、静岡大学電子工学研究所とともに共同研究ネットワークを構築して、本研究所の強み・特色であるナノバイオ・メディカル・エレクトロニクス分野における革新的医療技術創出の拠点を構築します。

アニュアルリサーチレポートはナノデバイス・バイオ融合科学研究所の最近1年間の研究活動と研究成果の一端をまとめて、先端技術の研究・教育に携わる方々に最新情報を共有していただくために発行しています。このレポートが今後ともこの分野での研究交流の一助になれば幸いです。

2018年12月1日

広島大学
ナノデバイス・バイオ融合科学研究所
所長　　　　　横山　新

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ナノデバイス・バイオ融合科学研究所組織

Executive Committee
運営委員会

Director
所長

Adviser
顧問

Nanointegration Research Division
ナノ集積科学研究部門

4 Professors, 1 Special Appointment Professor, 3 Visiting Professors,
3 Associate Professors,1 Special Appointment Associate Professor,
1 Visiting Associate Professor, 2 Assistant Professors,
1 Special Appointment Assistant Professor
教授 4名（専任: 1, 併任: 3）, 特任教授 1名, 客員教授 3名,
准教授 3名（専任: 2, 併任: 1）, 特任准教授 1名, 客員准教授 1名,
助教 2名（併任）, 特任助教 1名

Integrated Systems Research Division
集積システム科学研究部門

4 Professors, 2 Visiting Professors, 4 Associate Professors,
1 Assistant Professor
教授 4名（専任: 1, 併任: 3）, 客員教授 2名, 准教授 4名（専任: 1, 併任: 3）,
助教 1名（併任）

Molecular Bioinformation Research Division
分子生命情報科学研究部門

3 Professors, 4 Visiting Professors, 1 Assistant Professor
教授 3名（専任: 1, 併任: 2）, 客員教授 4名, 助教 1名（併任）

Nanomedicine Research Division
集積医科学研究部門

5 Professors, 1 Assistant Professor
教授 5名（併任）, 助教 1名（併任）

Nanotechnology Platform
ナノテクノロジー・プラットフォーム

1 Special Appointment Associate Professor
特任准教授 1名

Cooperative Research Staff (Faculty Members)
研究員（学内）、関連学部・学科

Visiting Scientists (Universities, Industries)
客員研究員（他大学、企業）

2. Staff of Research Institute for Nanodevice and Bio Systems (RNBS)

ナノデバイス・バイオ融合科学研究所構成員 (2017年12月1日時点)

Nanointegration Research Division

ナノ集積科学研究部門

Shin Yokoyama 横山　新	Director of RNBS and Professor 研究所長，教授
Takamaro Kikkawa 吉川　公麿	Professor (Special Appointment) 特任教授
Seiichiro Higashi 東　清一郎	Associate Director and Professor 副研究所長，教授(併任)
Atsushi Ikeda 池田　篤志	Professor 教授(併任)
Manabu Shimada 島田　学	Professor 教授(併任)
Anri Nakajima 中島　安理	Associate Professor 准教授
Shin-Ichiro Kuroki 黒木　伸一郎	Associate Professor 准教授
Shuhei Amakawa 天川　修平	Associate Professor 准教授(併任)
Tetsuo Tabei 田部井　哲夫	Associate Professor (Special Appointment) 特任准教授
Hiroaki Hanafusa 花房　宏明	Assistant Professor 助教(併任)
Yuri Mizukawa 水川　友里	Assistant Professor 助教(併任)
Yoshiteru Amemiya 雨宮　嘉照	Assistant Professor (Special Appointment) 特任助教

Integrated Systems Research Division

集積システム科学研究部門

Hans Jürgen Mattausch マタウシュ ハンス ユルゲン	Professor 教授
Minoru Fujishima 藤島　実	Professor 教授(併任)
Idaku Ishii 石井　抱	Professor 教授(併任)
Kazufumi Kaneda 金田　和文	Professor 教授(併任)
Tetsushi Koide 小出　哲士	Associate Professor 准教授
Tsuyoshi Yoshida 吉田　毅	Associate Professor 准教授(併任)
Toru Tamaki 玉木　徹	Associate Professor 准教授(併任)
Takeshi Takaki 高木　健	Associate Professor 准教授(併任)

Molecular Bio-information Research Division

分子生命情報科学研究部門

Masakazu Iwasaka 岩坂　正和	Professor 教授
Akio Kuroda 黒田　章夫	Professor 教授(併任)
Seiji Kawamoto 河本　正次	Professor 教授(併任)
Takeshi Ikeda 池田　丈	Assistant Professor 助教(併任)

Nanomedicine Research Division

集積医科学研究部門

Kazuaki Chayama 茶山　一彰	Professor 教授（併任）
Michihiro Hide 秀　道広	Professor 教授（併任）
Hiroki Nikawa 二川　浩樹	Associate Director and Professor 副研究所長，教授（併任）
Koichi Kato 加藤　功一	Professor 教授（併任）
Kazuhiro Tsuga 津賀　一弘	Professor 教授（併任）
Yuhki Yanase 柳瀬　雄輝	Assistant Professor 助教（併任）

Nanotechnology Platform

ナノテクノロジープラットフォーム

Tetsuo Tabei 田部井　哲夫	Chief and Associate Professor (Special Appointment) 主任，特任准教授

Visiting Professor

客員教授

Yuji Miyahara 宮原　裕二	Visiting Professor 客員教授
Takashi Ito 伊藤　隆司	Visiting Professor 客員教授
Hiroshi Ohki 大木　博	Visiting Professor 客員教授
Seiichi Miyazaki 宮崎　誠一	Visiting Professor 客員教授
Ryo Miyake 三宅　亮	Visiting Professor 客員教授

Shigeto Yoshida 吉田　成人	Visiting Professor 客員教授
Koichi Ito 伊藤　公一	Visiting Professor 客員教授
Takeshi Tanaka 田中　武	Visiting Professor 客員教授
Katia Zheleva Vutora	Visiting Professor 客員教授
Hideki Murakami 村上　秀樹	Visiting Associate Professor 客員准教授

Researchers

研究員

Hoang Anh Tuan ホアン アイン トゥワン	Post Doctoral Researcher 機関研究員
Tadashi Sato 佐藤　旦	Researcher, Nanotechnology Platform ナノテクノロジープラットフォーム研究員
Yutaka Furubayashi 古林　寛	Researcher, NEDO "Thermal Management Materials and Technology Research Association (TherMAT)" NEDO研究員 （未利用熱エネルギー革新的活用技術研究開発プロジェクト）
Tatsuya Meguro 目黒　達也	Researcher 研究員
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Kazushi Okada 岡田　和志	Research Associate 教育研究補助職員

Advisory Board

顧問

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Takuo Hirano 平野　拓男	Visiting Scientist, MAZDA Motor Corporation 客員研究員，マツダ(株)

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Yositaka Murasaka 村坂　佳隆	Visiting Scientist, Sharp Corporation 客員研究員, (株)エイアールテック
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Tomoaki Maeda 前田　智晃	Visiting Scientist, Sharp Corporation 客員研究員, (株)エイアールテック
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Masahide Sasaki 佐々木 雅英	General Affairs 総務担当
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Naoko Nakatani 中谷 尚子	Office Assistant 事務補佐員
Nao Michinaka 道中 奈緒	Office Assistant 事務補佐員
Junko Hinohara 樋原 純子	Office Assistant 事務補佐員
Aimi Yamano 山野 あいみ	Research Associate 研究補助職員
Dilipkumar Mootha Archana	Research Associate 研究補助職員

3. Executive Committee Members of Research Institute for Nanodevice and Bio Systems (RNBS)

ナノデバイス・バイオ融合科学研究所運営委員会委員

Shin Yokoyama 横山　新	Director and Professor 研究所長･教授	RNBS ナノデバイス･バイオ融合科学研究所
Seiichiro Higashi 東　清一郎	Associate Director and Professor 副研究所長･教授	Graduate School of Advanced Sciences of Matter 先端物質科学研究科
Hiroki Nikawa 二川　浩樹	Associate Director and Professor 副研究所長･教授	Graduate School of Biomedical Sciences 医歯薬保健学総合研究科（歯）
Hans Jürgen Mattausch マタウシュ ハンス ユルゲン	Professor 教授	RNBS ナノデバイス･バイオ融合科学研究所
Masakazu Iwasaka 岩坂　正和	Professor 教授	RNBS ナノデバイス･バイオ融合科学研究所
Yutaka Kadoya 角屋　豊	Professor 教授	Graduate School of Advanced Sciences of Matter 先端物質科学研究科
Minoru Fujishima 藤島　実	Professor 教授	Graduate School of Advanced Sciences of Matter 先端物質科学研究科
Yositake Takane 高根　美武	Professor 教授	Graduate School of Advanced Sciences of Matter 先端物質科学研究科
oshikazu Ekino 浴野　稔一	Professor 教授	Graduate School of Integrated Arts and Sciences 総合科学研究科
Yoshihiro Kuroiwa 黒岩　芳弘	Professor 教授	Graduate School of Science 理学研究科
Toshio Tsuji 辻　敏夫	Professor 教授	Institute of Engineering 工学研究院
Yoshihiro Sanbongi 三本木　至宏	Professor 教授	Graduate School of Biosphere Sciences 生物圏科学研究科
Michihiro Hide 秀　道広	Professor 教授	Graduate School of Biomedical Sciences 医歯薬保健学総合研究科（医）
Koichi Kato 加藤　功一	Professor 教授	Graduate School of Biomedical Sciences 医歯薬保健学総合研究科（歯）
Anri Nakajima 中島 安理	Associate Professor 准教授	RNBS ナノデバイス･バイオ融合科学研究所

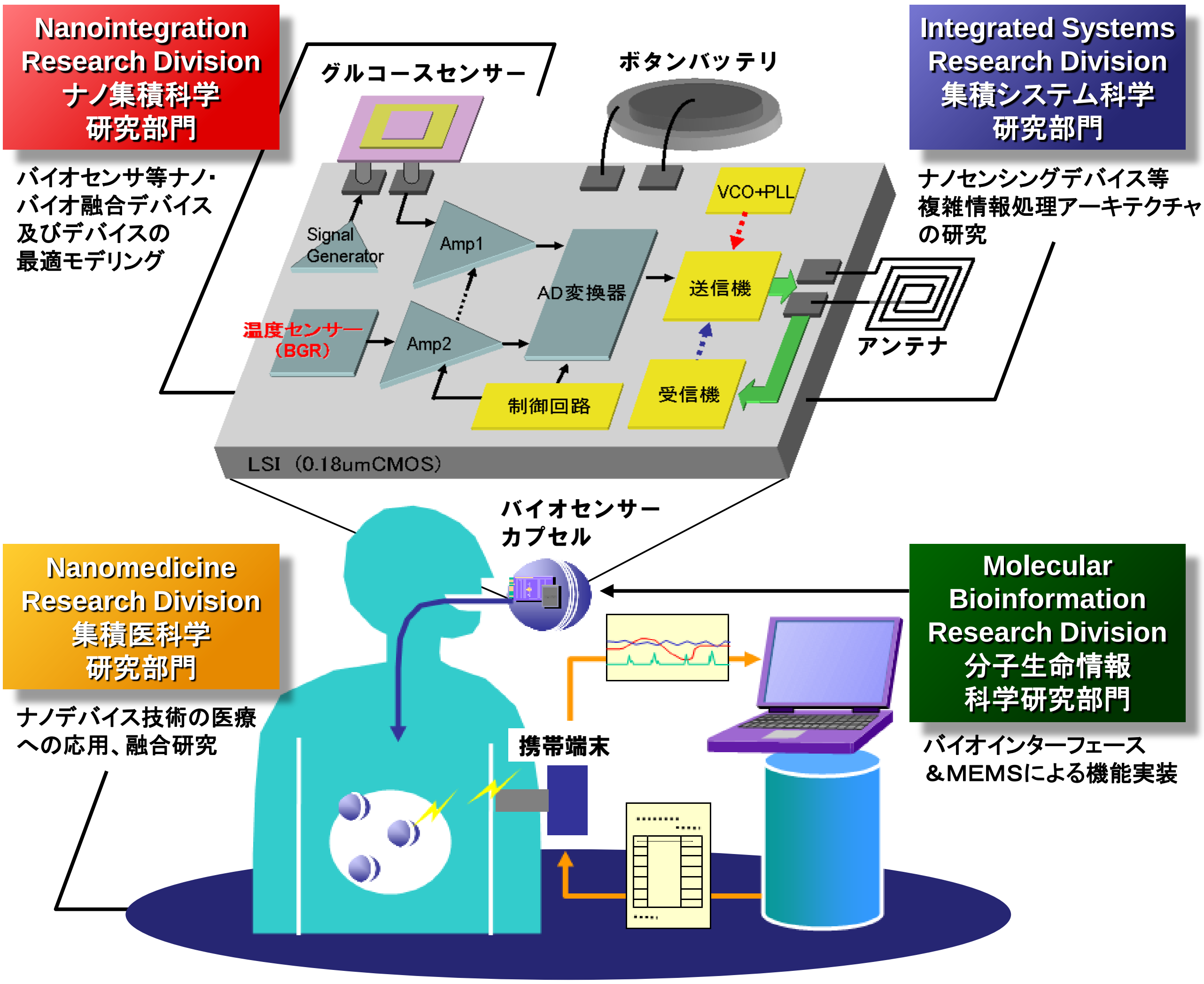
Tetsushi Koide 小出 哲士	Associate Professor 准教授	RNBS ナノデバイス・バイオ融合科学研究所
Shin-Ichiro Kuroki 黒木 伸一郎	Associate Professor 准教授	RNBS ナノデバイス・バイオ融合科学研究所

4. Research Divisions of Research Institute for Nanodevice and Bio Systems (RNBS)

ナノデバイス・バイオ融合科学研究所の研究領域

The Research Institute for Nanodevice and Bio Systems was founded on May 1, 2008, aiming to develop the fundamental technologies necessary to achieve global excellence in electronic and bio integrated sciences for preventive medicine and ubiquitous diagnoses on early stages of illnesses in the future advanced medical-care society beyond the present information society. The research field includes Nanointegration, Integrated Systems, Molecular Bioinformation and Nanomedicine.

ナノデバイス･バイオ融合科学研究所は情報化社会の先にある高度医療保障社会に向けた、予防医学やユビキタス病気早期診断を実現するためのエレクトロニクスとバイオテクノロジーの集積科学基盤技術を開発するグローバルな教育研究拠点を構築することを目的として設立された。研究領域はナノ集積科学、集積システム科学、分子生命情報科学、集積医科学の4つからなる。



Research Divisions
研究領域

4.1 Nanointegration Research Division

ナノ集積科学研究部門

At the Nanointegration Research Division we focus the research on nanodevices, fabrication processes, nanointegration, nano-bio integration devices, photonic devices, nano-quantum devices, thin film devices, nanodevice modeling and functional materials. The outlines of researches at the Nanointegration Research Division are as follows.

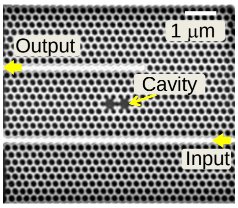
ナノ集積科学研究部門では、ナノデバイス、プロセス、ナノインテグレーション、ナノバイオ融合デバイス、フォトニックデバイス、ナノ量子デバイス、薄膜デバイス、ナノデバイスモデリング、機能性材料等に関する研究を行っている。ナノ集積科学研究部門における研究の主なものの概要を紹介する。

シリコン光共振器センサーの高感度化
Improvement of Sensitivity of Silicon Optical Resonator Sensors

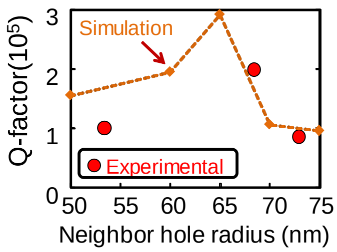
教授　横山　新
Prof. Shin Yokoyama

家庭で手軽に利用できる、シリコンフォトニック結晶光共振器によるバイオセンサーの研究を行っている。ダブルキャビティー型フォトニック結晶光共振器において、キャビティー周辺のホールサイズを変化させると共振の急峻性(Q 値)が極大値をとることを見出した。

We are studying Si photonic-crystal (PhC) optical-resonator biosensors applicable at home use. It was found that the sharpness of resonance (Q-value) takes a local maximum at the certain diameter of the neighbor holes around the double cavity.



(a)



(b)

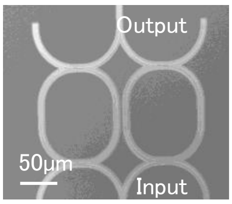
(a) 電子ビームリソグラフィーにより作製したシリコンフォトニック結晶ダブルキャビティー共振器の走査電子顕微鏡写真、(b) キャビティー周辺のホール半径と Q 値の関係
(a) Scanning electron microscope image of the photonic crystal double cavity resonator fabricated by using electron beam lithography, and (b) relation between Q-value and neighbor hole radius.

差動型シリコン光共振器センサーによる温度安定性の向上
Improvement of Thermal Stability of Si Optical Resonator Sensors by Differential

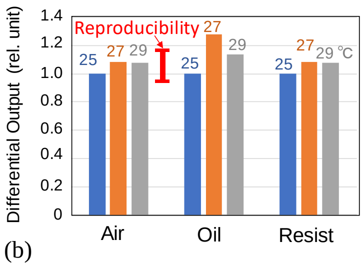
教授　横山　新
Prof. Shin Yokoyama

シリコン光共振器を屈折率センサーとして用いる場合、その大きな温度依存性が大きな問題となる。本研究では、近接した 2 つの共振器の差動出力を検出することによって、温度安定性が大きく改善できることを示した。

When a silicon optical resonator is used as a refractive index sensor, its large temperature dependence becomes a big problem. In this study, we showed that the temperature stability can be greatly improved by detecting the differential output of two closely placed resonators.



(a)

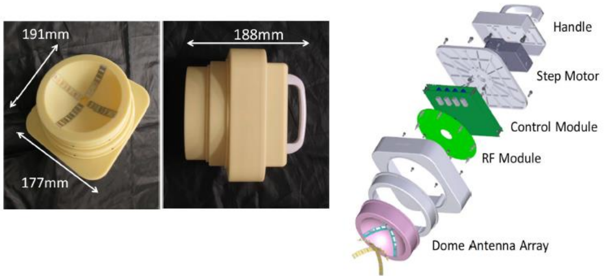


(b)

(a) 電子ビームリソグラフィーにより作製した差動型シリコンリング共振器バイオセンサーフ、(b) 種々のアッパークラッドに対する差動出力の温度依存性。差動でない場合はこの 10 倍以上の変化を示す。
(a) Scanning electron microscope image of the differential Si ring resonator biosensor and (b) temperature dependence of the differential output for different kind of upper clad. Non-differential type exhibits more than 10 times change.

乳がん検出レーダーシステムの開発
Breast Cancer Detection Radar System

教授　吉川　公麿
Prof. Takamaro Kikkawa



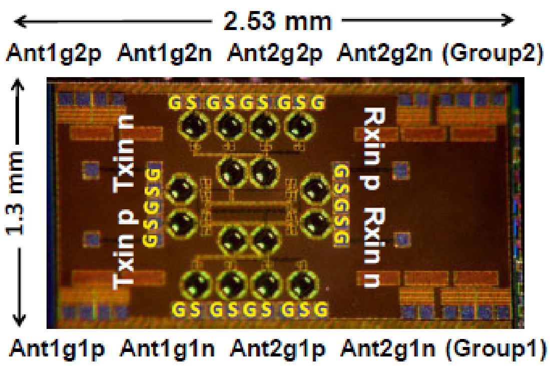
携帯型の乳がん検出装置のプロトタイプ
A photograph of a prototype-3 of hand-held impulse breast cancer detection system.

携帯型インパルス超広帯域電波を使った乳がん検出装置を開発し、広島大学病院においてパイロット臨床試験で乳がんの検出性能を実証した。

A hand-held impulse radar breast cancer detector is developed and the detectability of malignant breast tumors is demonstrated in the clinical test at Hiroshima University Hospital.　(Scientific Reports, 2017)

DP16T−CMOS スイッチングマトリクス
DP16T-CMOS Switching Matrix

教授　吉川　公麿
Prof. Takamaro Kikkawa



アンテナアレイ制御用 DP16TCMOS スイッチングマトリクス回路チップ写真
A photograph of CMOS double pole 16 throw switching matrix circuit.

超広帯域インパルス電波を用いた乳がん検出用 3-20 GHz，1.2 mW，DP16T のスイッチングマトリクス回路を 65nmCMOS で設計試作した。送受信の組み合わせは 224 通りを実現し、高解像度化に寄与できる。

A 3-20GHz transmit/receive double pole 16 throw (DP16T) switching matrix circuit has been developed on a printed circuit board to control sixteen antennas in a rada-based portable breast cancer detection system. (Japanese Journal of Applied Physics, 2017)

低温転写技術によるプラスチック上単結晶シリコン CMOS 回路動作
Single-Crystalline Silicon CMOS Circuit Operation on Plastic by Low Temperature Layer Transfer Technique

教授　東　清一郎（併任）
Prof. Seiichiro Higashi

水のメニスカス力を利用した転写技術（MLT）により、プラスチック（PET）上に歩留り 99.86%（5792/5800）で単結晶シリコンパターンの転写に成功した（Fig. 1）。CMOS トランジスタにより作製したリングオシレータは 14.6 MHz の周波数で発振し（Fig. 2）、プラスチック上で単結晶シリコン CMOS 回路の動作実証に成功した。

Single-crystalline silicon channel patterns are successfully transferred to PET substrate by meniscus force mediated layer transfer (MLT) technique (Fig. 1). CMOS ring oscillator fabricated on PET showed clear operation with a frequency of 14.6 MHz (Fig. 2). CMOS operation on plastic substrate has been demonstrated.

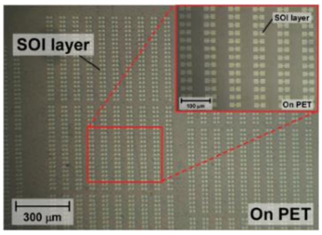


図 1. PET 基板上に転写した単結晶シリコンチャネルパターンの光学顕微鏡像
Fig. 1. Optical microscope image of transferred SOI islands on PET substrate.

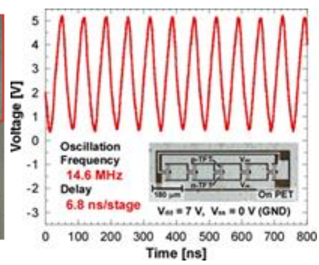


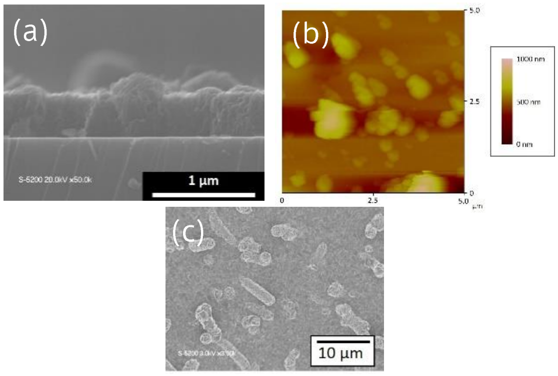
図 2. PET 基板上に作製したリングオシレータの動作波形
Fig. 2. Output signal of CMOS ring oscillator operated on PET.

ナノ物質の堆積による材料創製と表面汚染
Preparation of Materials and Surface Contamination by Deposition of Nanoobjects

教授　島田　学（併任）
Prof. Manabu Shimada

ナノサイズのクラスター・粒子状物質を合成し、ガス中に浮遊、堆積させて、有用な構造・組成をもつ薄膜、粒子、およびそれらの複合物を創製する研究を行っている。ナノサイズ物質が汚染物質として表面付着したときの影響も検討している。

Preparation of thin-films, particles, and their composites having useful structure and composition is being studied by synthesizing nano-sized clusters and particulate matter suspended in gases and depositing them in the gas phase. The effects of surface deposition of nanoobjects as contaminants are also being investigated.



プラズマ CVD と材料ナノ粒子の気相堆積の同時操作による複合薄膜の作製. (a) 直径 50 nm の酸化シリコン粒子を埋め込んだ酸化チタン薄膜の断面写真;(b) 同表面 AFM 像;(c) 多層カーボンナノチューブを埋め込んだ酸化チタン薄膜の表面写真

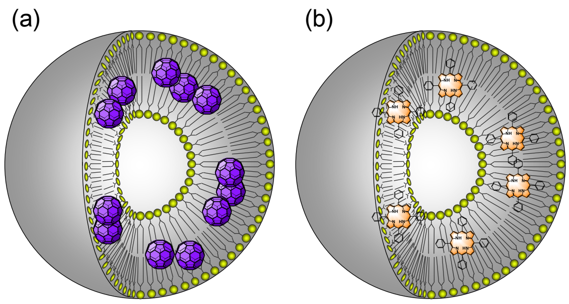
Preparation of composite thin films by simultaneous operation of plasma-enhanced CVD and gas-phase deposition of manufactured nanoparticles. (a) Cross-sectional view of titanium dioxide film with 50-nm silicon dioxide particles embedded inside; (b) AFM image of the surface of the film; (c) Surface view of titanium dioxide film with multi-walled carbon nanotubes embedded inside.

可溶化剤で水溶化したフラーレンまたはポルフィリンを用いる光線力学治療薬の開発
Development of Photosensitizer Using Fullerenes and Porphyrins Solubilized in Water by Solubilizing Agents

教授　池田篤志（併任） Prof. Atsushi Ikeda

がん治療の一つである光線力学治療に用いられる光増感剤を開発するために、種々の可溶化剤に包接することによって水溶性のフラーレンやポルフィリンを準備した。光線力学活性の向上を目指す。

To develop photosensitizers of photodynamic therapy for cancer treatments, we prepared the water-soluble fullerenes and porphyrins incorporated in various solubilizing agents. We aim for the improvement of the photodynamic activities.



可溶化剤としてリポソームを用いた(a)フラーレンまたは(b)リポソーム含有脂質膜

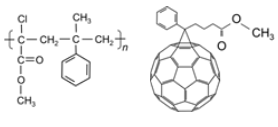
Lipid-membrane-incorporated (a) fullerenes and (b) porphyrins using liposomes as a solubilizing agent.

有機ナノデバイスのための電気伝導性フラーレン混合有機レジスト
Fullerene-Containing Electrically Conducting Electron Beam Resist for Organic Nanodevices

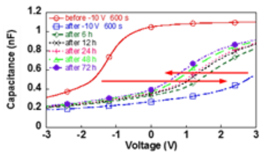
准教授　中島安理
Assoc. Prof. Anri Nakajima

簡便に高集積有機ナノサイズデバイスを作製するために、有機電子線レジストにフレーレンを混合した材料を開発している。電気伝導性の有機ナノドットや有機ナノワイヤ構造を電子線露光と現像のみのプロセスで作製できる。

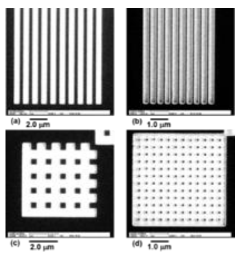
Fullerene-incorporated electron beam (EB) organic resists are developed to realize high integration of nanometer lateral-scale organic electronic devices. The structures of nanoscale dots and nanowires having electrical conductivity are able to be fabricated with a simple fabrication process of only EB exposure and development.



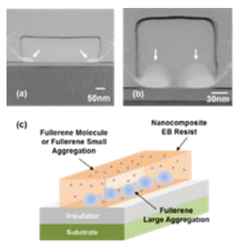
ZEP520a と PCBM
ZEP520a and PCBM.



C-V 特性
C-V characteristics.



ナノスケールドットとナノワイヤ構造の SEM 像
SEM micrographs of nanoscale dots and nanowires.



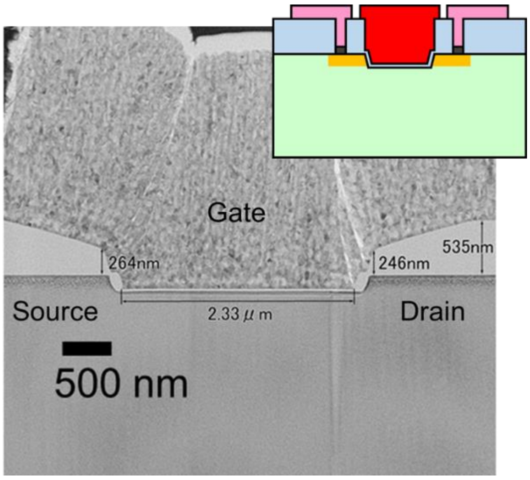
ナノワイヤ構造の透過電子顕微鏡像とフラーレンの分布
TEM of micrograph of nanowire and PCBM distribution.

シリコンカーバイド極限環境エレクトロニクス
Silicon Carbide Harsh Environment ElectronicsElectronics

准教授　黒木伸一郎
Assoc. Prof. Shin-Ichiro Kuroki

シリコンカーバイド(SiC)半導体を用いた極限環境用集積回路の研究を進めている。耐放射線、耐高温に加え、高周波動作のための低寄生容量 4H-SiC Trench MOSFETs を提案し実証した。本研究はスウェーデン王立工科大学、量研機構、およびフェニテックセミコンダクター(株)との共同研究として進めている。

Research on SiC harsh environment electronics has been carried out. 4H-SiC Trench nMOSFETs with low parasitic capacitance were suggested and demonstrated. And the trench nMOSFETs were operated under high-temperature up to 450°C. This research is carried out under the collaboration with KTH Royal Institute of Technology, Sweden, QST and Phenitec Semiconductor Co. Ltd., Japan.



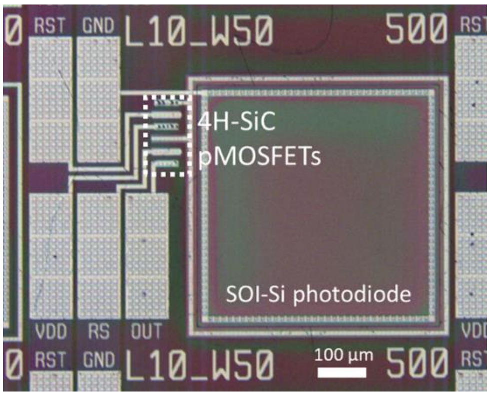
4H-SiC Trench nMOSFETs
4H-SiC Trench nMOSFETs

シリコンカーバイド・耐放射線イメージセンサの研究
Silicon Carbide Radiation-Hardened Image Sensors

准教授　黒木伸一郎
Assoc. Prof. Shin-Ichiro Kuroki

シリコンカーバイド(SiC)を用いた耐放射線イメージセンサの研究を進めた。3つの SiC MOSFETs と1つの Si フォトダイオードを同一基板上に集積し、画素デバイスを作製し、その動作を実証した。本研究は産総研、量研機構との共同研究として進めている。

SiC pixel devices with 3 4H-SiC MOSFETs and Si photodiode had been developed for radiation-hardened image sensors. This research has been carried out under the collaboration with AIST and QST, Japan.



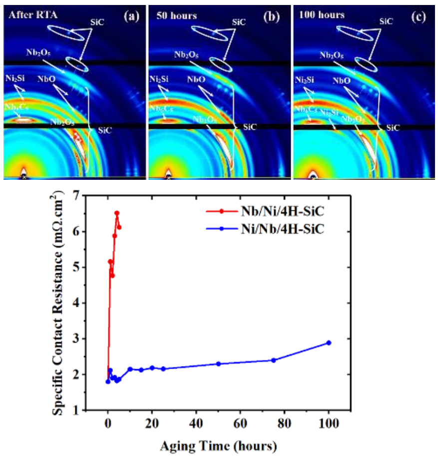
4H-SiC/ SOI-Si hybrid pixel device for Rad-Hardened image sensor
4H-SiC/ SOI-Si hybrid pixel device for Rad-Hardened image sensor

シリコンカーバイド・パワー半導体デバイス
Silicon Carbide Power Semiconductor Devices

准教授　黒木伸一郎
Assoc. Prof. Shin-Ichiro Kuroki

シリコンカーバイド(SiC)パワー半導体デバイスの研究・開発を進めた。特に SiC 上のオーミックコンタクトの研究を進め、400℃での 100 時間試験などの信頼性試験を実施し、NiNb シリサイドオーミックコンタクトの熱的安定性を実証した。本研究はフェニテックセミコンダクター(株)、および住友重機械工業(株)との共同研究として進めている。

SiC power devices had been developed. High temperature reliability at 400°C has been investigated. This research has been carried out under the collaboration with Phenitec Semiconductor Co. Ltd., and Sumitomo Heavy Industries Ltd, Japan.



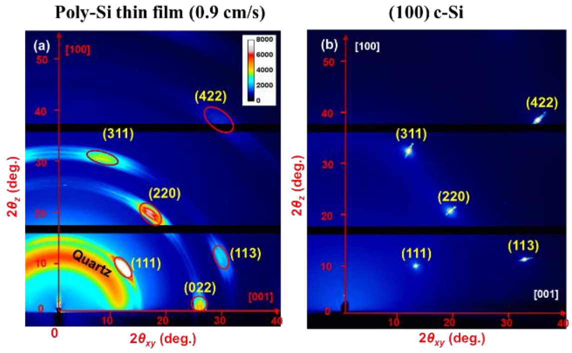
4H-SiC 上の NiNb シリサイド・オーミックコンタクトの 400℃、100 時間信頼性試験と 2 次元 XRD 像
400°C, 100hours reliability of NiNb ohmic contacts on 4H-SiC

連続発振レーザ結晶化による高性能薄膜トランジスタ
Multi-Line Beams CLC and Poly-Si TFTs

准教授　黒木伸一郎
Assoc. Prof. Shin-Ichiro Kuroki

マルチラインビーム連続発振レーザ結晶化により、(100)面方位に制御した多結晶シリコン薄膜を形成に成功した。このシリコン薄膜を用いて 1010 cm^2/Vs の高電子移動度 TFT を実現した。この結果は APEX 誌および JJAP 誌で発表した。また「応用物理」誌 2018 年 6 月号表紙を飾った。

Poly-Si thin films with (100) crystal grains were successfully fabricated by continuous-wave laser lateral crystallization with double-line beam, and its high-performance TFT with electron mobility of 1010 cm^2/Vs was also demonstrated.



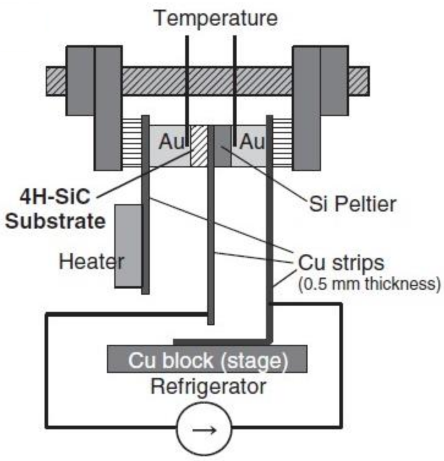
レーザ結晶化した poly-Si 膜の 2 次元 XRD 像
2D-XRD of the laser-crystallized poly-Si thin film

車載用パワーモジュールのための半導体吸熱素子の研究
Heat Transfer Module for Automobiles

准教授　黒木伸一郎
Assoc. Prof. Shin-Ichiro Kuroki

車載用の吸熱構造付き SiC パワー半導体デバイスと冷却モジュールの融合デバイスを実証し、その試作と通電試験から、熱移動効果の発現を確認し、 またパワーデバイス吸熱デバイスの技術コンセプトを構築した。この研究は NEDO 国立研究開発法人新エネルギー・産業技術総合開発機構の「未利用熱エネルギーの革新的活用技術研究開発プロジェクト」受託研究として進めている。

Heat transfer device with 3-D integration of 4H-SiC-based Schottky barrier diodes and Si-based film Peltier device, separated by intrinsic SiC layer, was realized by using conventional Si-based process flow. This research is carried out under TherMAT in New Energy and Industrial Technology Development Organization (NEDO) of Japan.



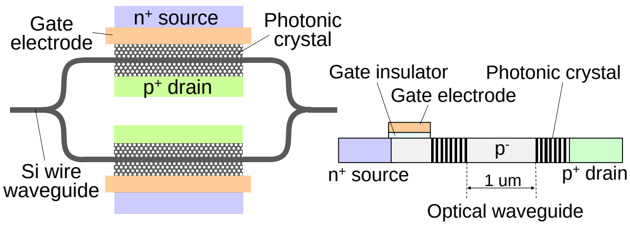
熱電効果の評価システムの概略図
Schematic of an apparatus for thermoelectric effects

トンネル電界効果トランジスタを用いた極低電圧シリコン光変調器の研究
Ultralow drive voltage Si optical modulator using tunnel field-effect transistor

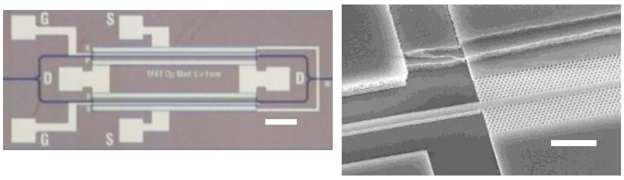
准教授　田部井哲夫(特任)
Assoc. Prof. Tetsuo Tabei

低電圧でのスイッチングが可能なバンド間トンネル型電界効果トランジスタを位相変調器として利用した、極低電圧で駆動するマッハツェンダ型シリコン光変調器の研究を行っている。

We study a Mach-Zehnder type silicon optical modulator driven by an extremely low voltage using a band-to-band tunneling field effect transistor that can switch at low voltage as a phase shifter.



提案する光変調器の上面及び断面構造
Schematic of top and cross-sectional structure of the proposed optical modulator.



試作した光変調器の光学顕微鏡写真及び SEM 像
Optical microscope image and SEM image of the fabricated optical modulator.

実時間観察・温度測定同時計測による シリコン融液温度分布の可視化

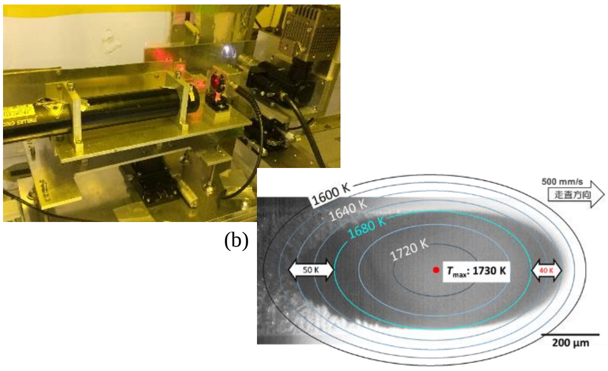
Visualization of a temperature distribution for Si molten region by simultaneous measurement

助教　水川友里（併任）

Assist. Prof. Yuri Mizukawa

ディスプレイなどの薄膜トランジスタ作製のため、大気圧熱プラズマジェット(Thermal Plasma Jet: TPJ)照射による急速熱処理時の実時間観察・温度測定の同時計測により、シリコン溶融域の温度分布解析を行っている．基板表面温度シミュレーション解析と実時間観察を組み合わせて、シリコン溶融域の温度分布を可視化した。

We're carrying out a temperature distribution analysis on Si molten region by simultaneous measurement of real-time observation and temperature measurement during the atmospheric pressure thermal plasma jet (TPJ) irradiation. We visualized the temperature distribution on Si molten region by combining the temperature analysis of a substrate surface and the real-time observation.



(a) TPJ 照射中の観察・温度測定同時計測ステージ
(b) シリコン融液温度分布可視化図像

(a) Image of the simultaneous measurement stage of real-time observation and temperature measurement during the irradiation of the atmospheric pressure thermal plasma jet, and (b) Visualization of temperature distribution on Si molten region.

バイオセンサー用光共振器と MEMS マイクロバルブの集積化

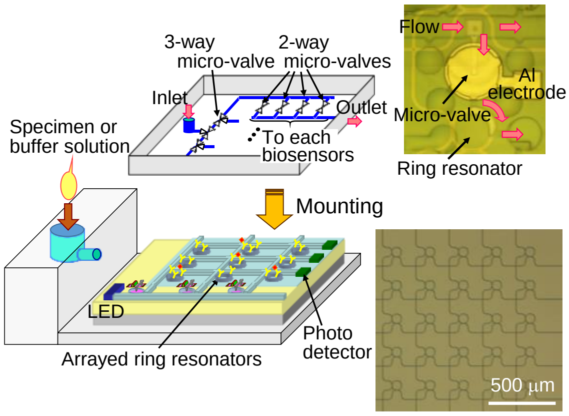
Integration of MEMS micro-valves and optical resonators for biosensors

助教　雨宮嘉照（特任）

Assist. Prof. Yoshiteru Amemiya

疾病検査や生体モニタリングを目的とした、バイオセンサーチップの実現を目指している。シリコンフォトニクス技術を用いた光共振器とマイクロ電子機械システム(MEMS) 型のバルブを付加させた流路を集積化させたチップを作製し、センシング動作について検討している。

We aim to realize biosensor chips for diagnosis of diseases and vital monitoring. An optical biosensor chip was fabricated, in which optical resonators using silicon photonics technology and fluid channel with Micro-Electro-Mechanical-Systems (MEMS) valves are integrated, and the performance of sensing operation has been investigated.



提案している光バイオセンサーチップの概略図とマイクロバルブとアレイ化した光共振器の光学顕微鏡写真

Schematic of the proposed optical biosensor chip and optical micrographs of micro-valve and arrayed optical resonators.

4.2 Integrated Systems Research Division

集積システム科学研究部門

The Integrated Systems Research Division focuses on basic research for terabit-capacity highly-functional memories, super-parallel processing, bio-sensing, wireless interconnection and 3-dimensional integration. With the obtained results we aim at the realization of artificial-brain technology exceeding humans in intelligent-processing speed, storage capacity and adaptive learning. The outlines of researches at the Integrated Systems Research Division are as follows.

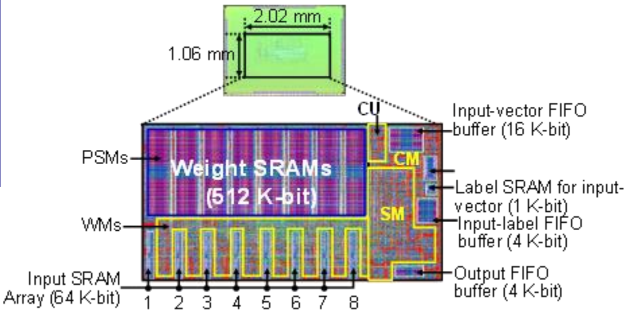
集積システム科学部門では、テラビット容量と高機能メモリ、超並列演算、バイオセンシング、無線インタフェース、3次元集積に関する基盤研究を推進している。そして、これらの基盤技術を用いて、人間の脳より速い認知処理、大規模な記憶容量、環境に適応する学習機能を有する集積ブレインの実現を目指す。集積システム科学部門における研究プロジェクトの主なものの概要を紹介する。

機能メモリの設計及び応用
Functional Memories and Their Application

教授　マタウシュ　ハンスユルゲン
Prof.　Hans Jürgen Mattausch

高速検索かつ超低消費電力を有するデジタル連想メモリ及び任意のアプリケーションを実装できる人工知能システムの研究開発。

Research and development on high-speed-searching digital associative memory with ultra-low power consumption and on artificial intelligence systems with capability to implement any arbitrary application.



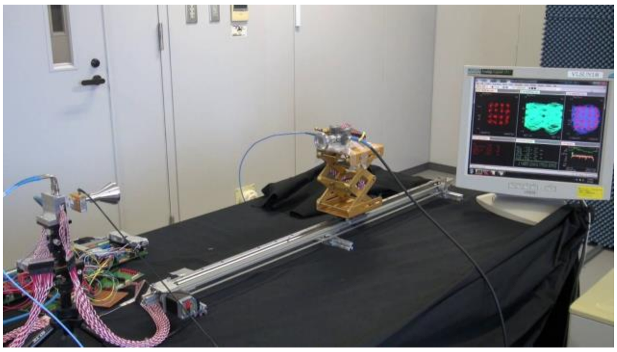
LVQ（学習ベクトル量子化）実現のために開発されたモジュラーで再構成可能なパイプラインアーキテクチャの 65nm CMOS 技術における試作チップの顕微鏡写真とレイアウト。
Micrograph and layout of a prototype chip in 65 nm CMOS technology which implements the developed modular and reconfigurable pipeline architecture for Learning Vector Quantization.

テラヘルツ波デバイス基盤技術の研究
Study on Fundamental Technologies for Terahertz-Wave Devices

教授　藤島　実（併任）
Prof. Minoru Fujishima

私たちは、ミリ波からテラヘルツ波まで含む超高周波 CMOS デバイスの研究を行っている。すでに実用化されている 79GHz 帯車載レーダーの CMOS 化や 100Gbps を超える通信速度を可能にする 300GHz 帯通信の研究を行っている。

We are studying ultra-high-frequency CMOS devices covering millimeter-wave to terahertz band. Current interests are CMOS devices for 79GHz-band automotive radars and 300GHz-band transceivers enabling near-fiber-optic speed wireless link.



300GHz 帯 CMOS トランシーバを用いた伝送実験
Communication experiment with 300-GHz-band CMOS transmitter

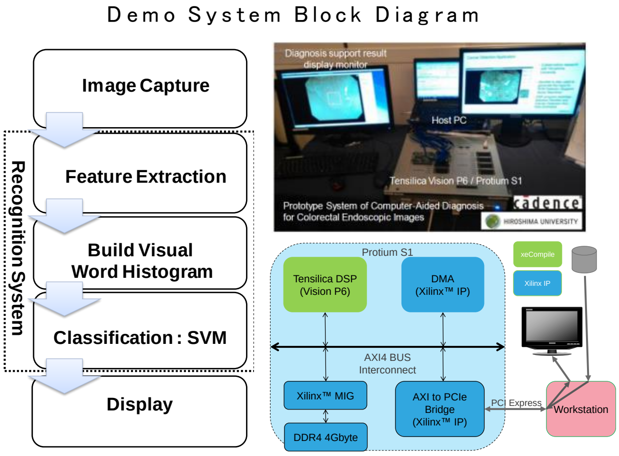
大腸 NBI 拡大内視鏡映像のリアルタイム診断支援プロトタイプシステムの構築

Development of a Real-Time Colorectal Tumor Classification System for Narrow-Band Imaging Zoom-Video-Endoscopy

准教授　小出哲士　Assoc. Prof. Tetsushi Koide

大腸癌は全世界的にも最もよく認められる癌の1つであり、日本でも年々増加傾向にあるが、大腸癌は、初期段階で発見し適切な治療を行うことで、完治が望める疾患であるため、内視鏡診断が非常に重要である。我々が開発している大腸癌の認識 CAD システムは、内視鏡から出力される映像を直接キャプチャし、大腸 NBI 拡大内視鏡画像をリアルタイムで診断支援することができる。実際に広島大学病院にて、臨床試験も行った。

Colorectal endoscopy is important for the early detection and treatment of colorectal cancer and is used worldwide. A computer-aided diagnosis (CAD) system that provides an objective measure to endoscopists during colorectal endoscopic examinations would be of great value. Our system captures the video stream from an endoscopic system and transfers it to a desktop computer. The captured video stream is then classified by a pretrained classifier and the results are displayed on a monitor. The experimental results show that our developed system works efficiently in actual endoscopic examinations and is medically significant.



大腸 NBI 拡大内視鏡映像のリアルタイム診断支援プロトタイプシステムの概要

Overview of the Development of a Real-time Colorectal Tumor Classification System for Narrow-band Imaging zoom-video-endoscopy. https://arxiv.org/abs/1612.05000v2.

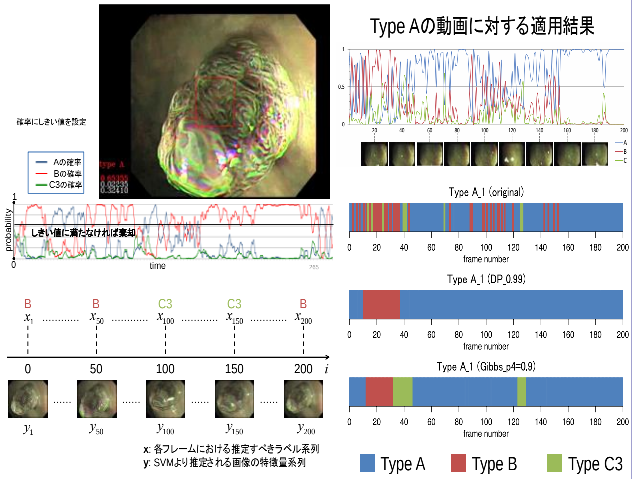
リアルタイム大腸 NBI 拡大内視鏡診断支援のための動画像の平滑化手法の開発

Development of Stable Endoscopic Video-Frame Recognition in Real-Time Computer-Aided Diagnosis for Narrow-Band Imaging of Magnifying Colonoscopy

准教授　小出哲士　Assoc. Prof. Tetsushi Koide

内視鏡による動画像のリアルタイム診断支援が必要不可欠である。そこで、我々が開発しているリアルタイム大腸 NBI(Narrow Band Imaging) 拡大内視鏡診断支援システムを、動画像に適用するために、各フレームにおける事後確率出力をパーティクルフィルタの尤度に用いることで、時系列データの平滑化を行う手法を提案し、実動画像を用いた実験により、安定した認識結果を得ることを確認した。

A real-time diagnosis support of endoscope video is indispensable. Therefore, in order to apply our real-time computer-aided diagnosis (CAD) support system to the videos, by using the posterior probability output in each frame as the likelihood of the particle filter. We proposed a method to smooth time series data and confirmed that stable recognition results are obtained by experiments using actual video data.



動画像の平滑化手法の適用例

Example of a Stable Endoscopic Video-frame Recognition.

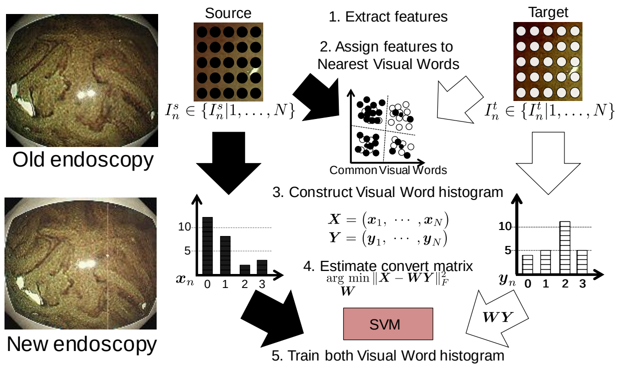
大腸内視鏡画像認識のための転移学習手法

Transfer Learning for Endoscopic Image Classification

准教授　小出哲士
Assoc. Prof. Tetsushi Koide

近年、大腸内視鏡の進歩はめざましく、最新の内視鏡と旧世代の内視鏡では視野、明るさ、コントラストなどの性能が向上している。この様なアップデートは機械学習をベースとしたコンピュータ診断支援システムにとって、学習画像データベースの再収集を必要とするため、診断支援システムの更新に高いコストを必要とする。そこで本研究では転移学習の枠組みを用い、旧世代の内視鏡で用いられた学習画像データベースを再利用することで最新の内視鏡の学習画像データベース構築のコストを低減する手法を提案した。

Recent advances in colonoscopy are remarkable, and performance of the latest endoscope and old generation endoscope is improved such as field of view, brightness, contrast, etc. Such an update requires a high cost for updating the computer-aided diagnosis (CAD) system because it requires re-collection of the learning image database for a computer diagnosis support system based on machine learning. In this research, we proposed a method to reduce the cost of building the latest endoscopic learning image database by reusing the learning image database used in the old generation endoscope using the framework of metastasis learning.



転移学習を用いた大腸 NBI 拡大内視鏡診断支援の概念

A Concept of Transfer Learning for Endoscopic Image Classification.

An example of appearance difference of different endoscope systems. (a) An image taken by an older system (video system center: Olympus EVIS LUCERA CV-260, endoscopy: Olympus OLYMPUS EVIS LUCERA CF-H260AZL/I). (b) An image of the same scene taken by an newer system (video system center: Olympus EVIS LUCERA ELITE CV-290, endoscope: OLYMPUS EVIS LUCERA ELITE CF-HQ290ZL/I).

大腸内視鏡診断支援のための動画像取得組込システムの開発

Development of Endoscopic Capturing Embedded System for Computer-Aided Diagnosis

准教授　小出哲士
Assoc. Prof. Tetsushi Koide

臨床データベースをユーザーフレンドリーな操作で拡張するために、内視鏡ビデオまたは静止画トリミングソフトウェアと内視鏡ビデオまたは静止画撮影組み込みシステムを開発した。 機械学習フレームワークを使用する CAD システムには、内視鏡画像やラベル付きビデオなどの臨床データベースが必要である。 したがって、内視鏡ビデオまたは画像トリミングソフトウェアを開発する。 開発されたソフトウェアは、医者にとって映画または画像からいくつかの点によって選択される注目領域（RoI）をトリミングして、抽出することができる。

We have developed the endoscopic video or still image trimming software and the endoscopic video or still image capturing embedded system for expanding the clinical database with user-friendly operation. The clinical database such as endoscopic images or videos with the labels are necessary for the CAD system using machine learning frameworks. Thus, we develop an endoscopic video or image trimming software. The developed software can trim and extract a region of interest (RoI) which is selected by several points from movie or image user-friendly for the doctors.

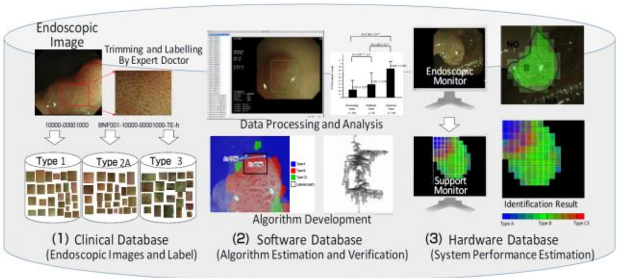


Figure 1. Database construction for Computer-Aided Diagnosis (CAD).

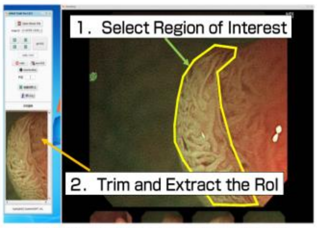


Figure 2. Endoscopic video / image trimming software.

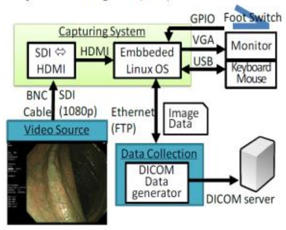


Figure 3. Endoscopic video / image capturing system.

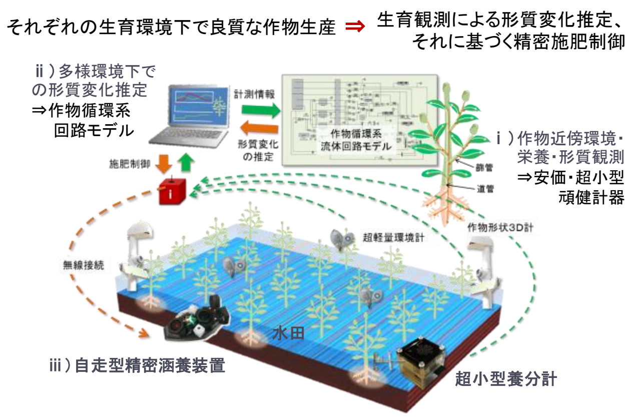
フィールド向け頑健計器と作物循環系流体回路モデルによる形質変化推定技術の研究

Development of Plant Growth Estimation Technologies Combined with Robust Field Monitors and Micro-Fluidic Model Simulating Plant Vascular System

准教授　小出哲士　Assoc.Prof. Tetsushi Koide

長期間、作物の近傍に設置して、作物の栄養の吸収や作物周辺の環境（光、温湿度、CO_2等）を逐次観測することのできる小型の計器類と、それと連動して動く、作物体内の水分や養分などの循環の状態を予測する作物体内循環系流体回路モデルを作成し、肥料添加や作物周辺環境が、その成長にどのように影響していくかを推定する技術の開発をしている。(JST CREST Project)

We are going to develop an ultra-small nutrients analyzer, a compact 3D-monitor (shape, color, etc.), and an ultra-light environment sensor (light intensity, temperature, humidity, CO_2, etc.), which can be installed near plants. Accordingly, plant growth estimation technologies based on micro-fluidic circuit model simulating plant vascular system are being developed. (JST CREST Project)



フィールド向け頑健計器と作物循環系流体回路モデルによる形質変化推定技術の概要
Overview of Development of plant growth estimation technologies combined with robust field monitors and micro-fluidic model simulating plant vascular system.
https://www.jst.go.jp/kisoken/crest/en/project/1111090/15666253.html

4.3 Molecular Bioinformation Research Division

分子生命情報科学研究部門

Molecular Bioinformation Research Division is specialized in the research for MEMS (Micro Electro Mechanical Systems), immobilization of bio molecule, bio-sensing technology, and environmental monitoring. The outlines of researches at the Molecular Bio-information Research Division are as follows.

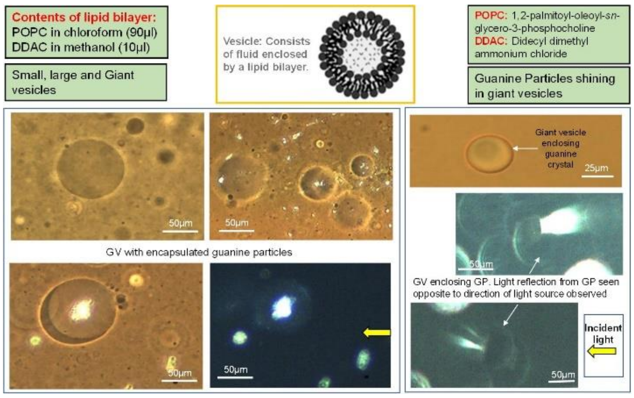
分子生命情報科学研究部門は、MEMS、バイオ分子固定、バイオセンシング、環境情報センシングに関する研究を行っている。分子生命情報科学研究部門における研究の主なものの概要を紹介する。

磁場応答性人工イリドソーム
Magnetic Field Responsive Synthetic Iridosome

教授　岩坂正和
Prof. Masakazu Iwasaka

バイオリフレクターとして光を高効率で制御すると期待されている魚のイリドソームのバイオミメティクスを行った。リン脂質内にてグアニン結晶を封入した人工イリドソームを開発した。

Biomimetics of fish iridosome which efficiently control light as a bio-reflector was carried out. An artificial iridosome which involved both phospholipid and guanine particles was developed.



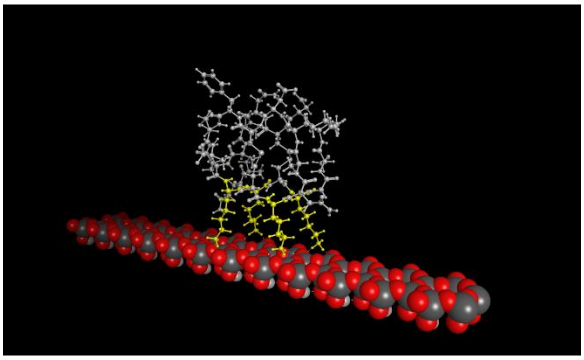
磁場応答性人工イリドソーム
Magnetic field responsive synthetic iridosome.

シリコンとバイオの界面制御の研究
Interface Technology between Silicon and Biomolecules

教授　黒田章夫（併任）
Prof. Akio Kuroda

Si デバイスの表面に、活性を保ったままバイオ分子を固定化する技術は新しい半導体バイオセンサーの開発に必要である。平坦な表面構造を有するタンパク質分子を改変して、Si との親和性が高いアミノ酸を平面状に配置することで、新規の Si 結合タンパク質の開発を進めている。

The ability to target proteins to specific sites on a Si device while preserving their functions is necessary for the development of new biosensors. We are developing a novel Si-binding protein by engineering a protein to display amino acids with affinity for Si on the flat surface.



作製した Si 結合タンパク質の結合モデル図
平面状に配置したアミノ酸(黄色)が Si 表面と相互作用する
Molecular model of the Si-binding protein.

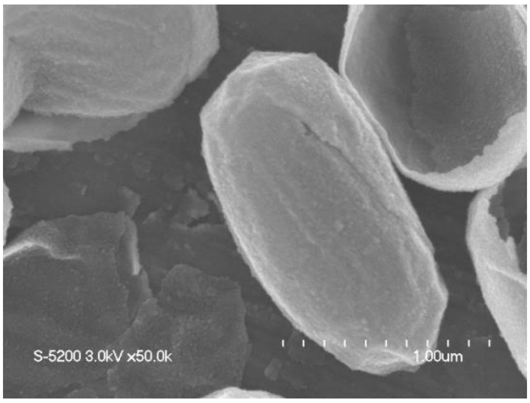
Si 結合ペプチドの発見とタンパク質固定化への利用

Application of Si-Binding Peptides for Protein Immobilization on Si Materials

助教　池田　丈（併任）
Assist. Prof. Takeshi Ikeda

細胞内に SiO_2 を蓄積する土壌細菌 *Bacillus cereus* より、14 残基のアミノ酸からなる新規の Si 結合ペプチドを取得した。本ペプチドを接着分子として利用することで Si 表面上に任意のタンパク質分子を固定化できるため、新たな半導体バイオ融合デバイスの開発が可能となると期待される。

We found a novel Si-binding peptide of 14 amino acids from a soil bacterium *Bacillus cereus*, which accumulates SiO_2 in the cell. Because of its small size and high affinity for Si, this peptide should be a powerful tool for developing Si-based biodevices.



B. cereus が形成した殻状 SiO_2 構造体の SEM 像
SEM image of a shell-shaped SiO_2 structure isolated from *B. cereus*.

4.4　Nanomedicine Research Division

集積医科学研究部門

Nanomedicine Research Division is specialized in the research for integration between medicine and nanotechnology, nanomedicine, nanodentistry, nano-pharmacy. The outlines of researches at the Nanomedicine Research Division are as follows.

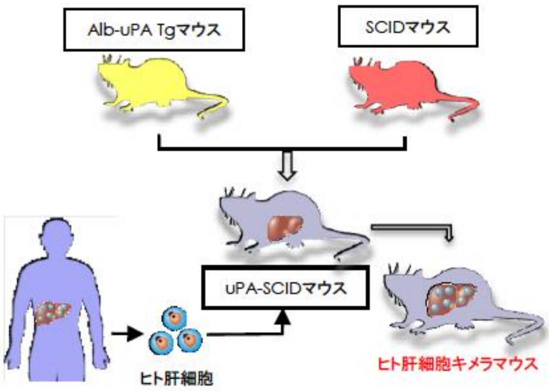
集積医科学研究部門では、ナノメディシン、ナノデンティストリー、ナノファーマシー等、医療とナノ技術の融合研究を行っている。現在行われている集積医科学研究部門における研究の主なものの概要を紹介する。

ウイルス性肝疾患に関する研究
Research on Hepatitis Viruses and Liver Disease

教授　茶山一彰（併任）
Prof. Kazuaki Chayama

肝炎ウイルスの増殖機構とその制御に関する研究を行っている。ヒト肝細胞キメラマウスは肝炎ウイルス感染モデルとして有用であり、培養細胞株を用いた reverse genetics による研究も可能である。またウイルス性肝炎の病態、治療効果に関与する SNPs および肝臓癌のゲノム解析も行っている。

We are currently investigating hepatitis viruses virology and developing treatment against these viruses using human hepatocyte chimeric mouse, which enables us to perform reverse genetics of hepatitis viruses.
We are analyzing SNPs associated with the pathogenesis of chronic viral hepatitis and response to anti-viral therapy and cancer genomes.



ヒト肝細胞キメラマウス
Humna hepatocyte chimeric mouse

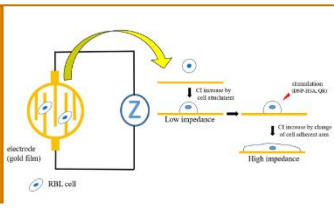
インピーダンスセンサを利用した即時型アレルギー診断法の開発
Impedance-Based Living Cell Analysis for Clinical Diagnosis of Type I

教授　秀　道広（併任）
Prof. Michihiro Hide

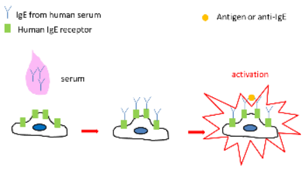
インピーダンスセンサの電極上にヒト IgE 受容体発現細胞（RBL-48）を患者血清存在下で培養し、抗原刺激に伴う細胞接着状態の変化をリアルタイムに評価可能な手法を開発した。また本手法を利用して、微量の患者血液（1項目に対して 6μL）を使って抗原に際する過敏性を評価することに成功した。

We established living cell reaction-based diagnostic test of type I allergy with small sample of conserved patient’s serum (6 μL per well) using an impedance sensor.

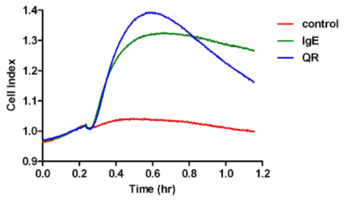
Reference: Irifuku R, Yanase Y, Kawaguchi T, Ishii K, Takahagi S, Hide M. (2017) Impedance-based living cell analysis for clinical diagnosis of type I allergy. Sensors. 17(11), 2503.

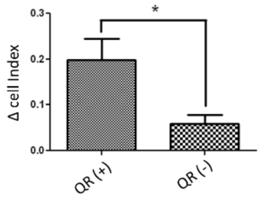


Schematic of impedance system for living cells.



Schematic of RBL-48 cells activation.





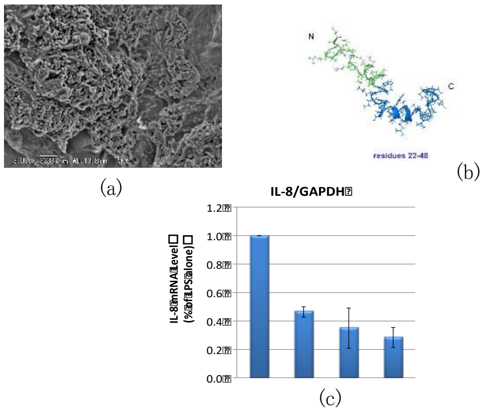
インピーダンスセンサによる即時型アレルギー診断
（汗抗原に対する過敏性評価）
Diagnosis of type I allergy by means of impedance sensor.

L8020乳酸菌のバクテリオシン
Bacteriocin Derived from *L. Rhamunosus* L8020

教授　二川浩樹（併任）
Prof. Hiroki Nikawa

虫歯・歯周病を抑制する L8020 乳酸菌のバクテリオシン Kog1 には、抗菌作用だけでなく、歯周病菌の内毒素 LPS を不活性化させる作用がある。

Kog1, a bacteriocin produced by *L. rhamunosus* L8020 which suppress both cariogenic bacteria and periodontal burdens in oral cavity, inactivate the LPS produced by periodontal burdens.



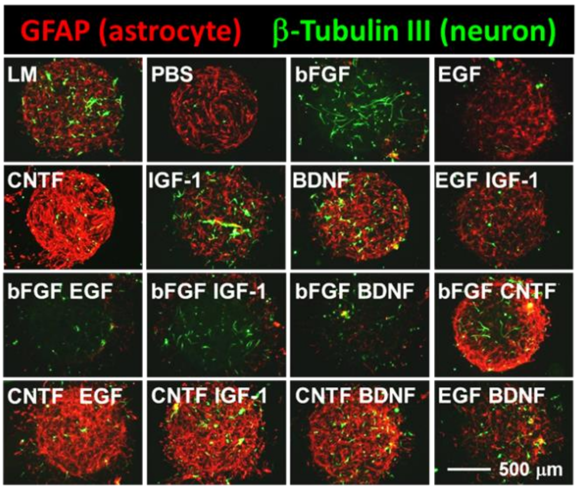
L8020 乳酸菌(a)のバクテリオシン Kog1(b)は、歯周病菌の内毒素 LPS を不活性化させる作用がある(c)
Kog1(b), a bacteriocin produced by *L. rhamunosus*　L8020 (a) inactivate the LPS produced by periodontal burdens (c).

幹細胞分析デバイスの設計
Bio-devices for Stem Cell Analyses

教授　加藤 功一（併任）
Prof. Koichi Kato

再生医療の早期実現に向けて、幹細胞分化に適した細胞外微小環境のスクリーニングや幹細胞の品質検査のためのバイオデバイスの設計に取り組んでいる。

Our goal is to develop bio-devices for the functional screening of extracellular microenvironments and the high-throughput analysis of surface markers expressed on stem cells for use in regenerative medicine.



増殖因子アレイを用いた神経幹細胞の分化アッセイ
Assay for neural stem cell differentiation using a growth factor array.

5. Research Facilities of RNBS

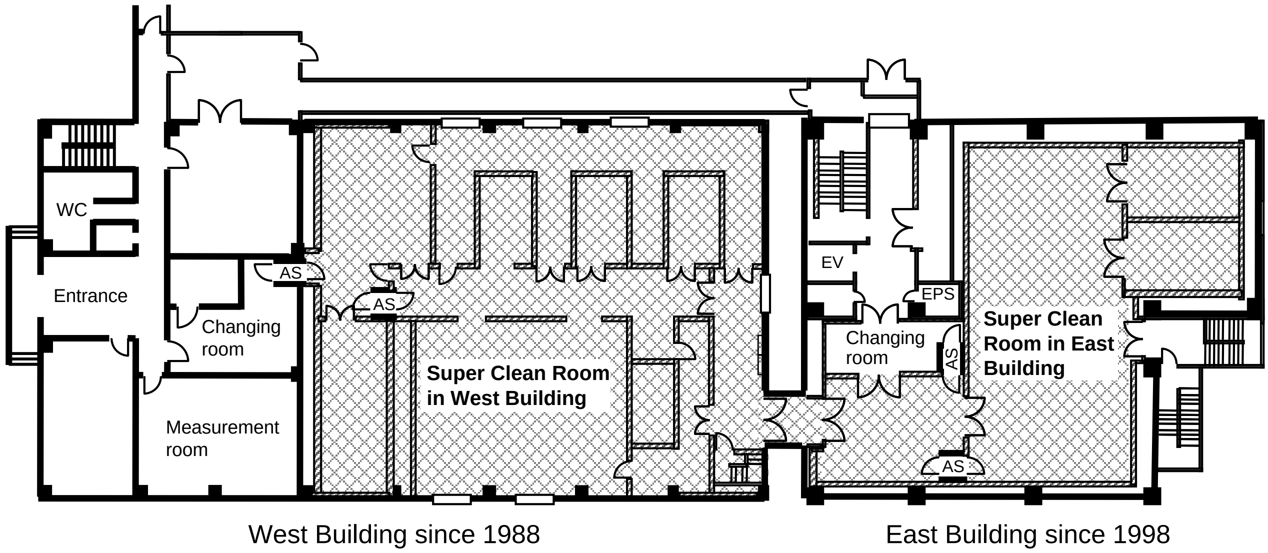
研究設備

5.1 Super clean rooms

スーパークリーンルーム

Super clean rooms, partly class 10 at 0.1-µm particles, are used for fabrication of advanced devices and LSI's.

先端デバイス及び LSI の製作はスーパークリーンルームで行われる。最も清浄度の高いセクションはクラス 10（1 立方フィート内に 0.1µm 以上の粒径の粒子が 10 個以下）である。



Plan view of clean rooms in west and east buildings. The total clean room area measures 830 m^2. Chemical filters are set in the east clean room to avoid hazardous gases.

西棟及び東棟クリーンルーム平面図。クリーンルーム総面積は 830m^2。東棟クリーンルームには危険ガス除去用のケミカルフィルターが設置されている。

Super clean room in west building.

西棟スーパークリーンルーム

Super clean room in east building.

東棟スーパークリーンルーム

5.2 Equipment for advanced devices and LSI fabrication

先端デバイス及びLSI作製のための設備

5.2.1 Lithography

リソグラフィー

◆ Variable rectangular-shaped electron beam lithography system (Hitachi HL700DII)

可変成形型電子ビーム描画装置
（日立 HL700DII） Resolution 50nm

◆ Point-beam type electron beam lithography system (JEOL JBX-5DII) Resolution 50 nm

ポイントビーム型電子ビーム描画装置
（日本電子 JBX-5DII）Resolution 50nm

◆ Point-beam type electron beam lithography system (ELIONIX ELS-G100)

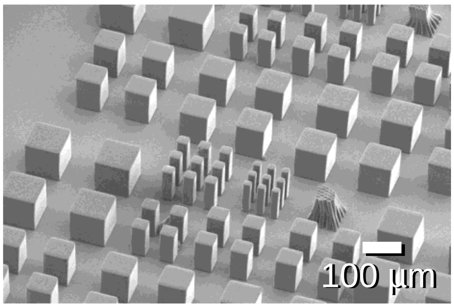
ポイントビーム型電子ビーム描画装置
（エリオニクス ELS-G100）Resolution 6nm

◆ i-line optical stepper (Nikon NSR i8a)

i-線ステッパー
（ニコン NSR i8a）Resolution 350nm

◆ Maskless photolithography system (Nanosystem Solutions D-light DL-1000)

マスクレス露光装置（ナノシステムソリューションズ D-light DL-1000） Resolution 1μm



Photoresist patterns by D-light DL-1000.
D-light DL-1000によるレジストパターン

5.2.2 Dry etching
ドライエッチング

◆ ICP (Inductively Coupled Plasma) etcher for Si (YOUTEC)

Si用ICP（誘導結合プラズマ）エッチング装置（ユーテック） Cl_2, HBr, N_2, O_2 使用可能

◆ ECR (Electron Cyclotron Resonance) etchers for Si (KOBELCO)

Si用ECR（電子サイクロトロン共鳴）エッチング装置（神戸製鋼） Cl_2, BCl_3, HBr, N_2, O_2 使用可能

◆ Si deep etching system (Sumitomo Precision Products)

Si用深堀りエッチング装置（住友精密工業） C_4F_6, SF_6, Ar 使用可能

◆ ICP etcher for highly selective etching of SiO_2 (AYUMI INDUSTRY)

SiO_2用ICPエッチング装置（アユミ工業） CF_4, H_2, O_2, Ar 使用可能

◆ ICP etcher for SiO_2 (SAMCO)

SiO_2用ICPエッチング装置(サムコ) CF_4, H_2, O_2, Ar 使用可能

◆ RIE (Reactive Ion Etching) system for SiO_2 (KOBELCO)

SiO_2用RIE(反応性イオンエッチング)装置（神戸製鋼） CF_4, H_2, O_2 使用可能

- ◆ ICP etcher for Al (YOUTEC)

Al用ICPエッチング装置
（ユーテック）Cl_2, BCl_3, N_2 使用可能

- ◆ Magnetron RIE system for Al (KOBELCO)

Al用マグネトロンRIE装置
（神戸製鋼）Cl_2, BCl_3, N_2 使用可能

- ◆ Chemical dry etching system for Si_3N_4 and poly-Si (KOBELCO)

Si_3N_4及びSiO_2用ケミカルドライエッチング装置
（神戸製鋼）CF_4, N_2, O_2 使用可能

- ◆ Plasma asher for removing photoresist (KOBELCO)

レジスト除去用プラズマアッシング装置
（神戸製鋼）N_2, O_2 使用可能

エッチング装置メンテナンス作業風景

During maintenance of dry etcher

酸化･拡散炉キャリア搬送風景

Wafer loading into furnace

5.2.3 Oxidation, annealing, and doping
酸化、アニール、不純物注入

◆ Oxidation and diffusion furnaces
(Tokyo Electron)

酸化・拡散炉
(東京エレクトロン) Max. Temp. 1150℃

◆ Ion implanter
(ULVAC)

イオン注入装置 Max 200 keV
(アルバック) B, As, P 等注入可能

◆ RTA (Rapid Thermal Annealing) system
(Samco HT-1000)

高速熱処理装置
(サムコ HT-1000) Max. Temp. raise rate 200℃/s

◆ Phosphorus diffusion furnaces
(SHINKO SEIKI)

リン拡散炉
(神港精機) Max. Temp. 900℃

◆ Annealing furnaces for general purpose
(Koyo Thermo System)

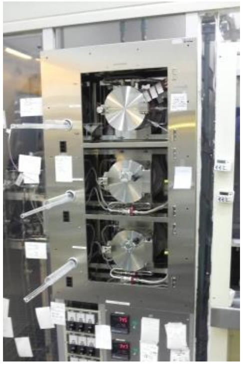
汎用熱処理装置 H_2, N_2, O_2, Low Pressure
(光洋サーモシステム) Max. Temp. 1000℃

酸化炉講習風景
Training of oxidation

5.2.4 Dielectric film deposition and epitaxial growth
絶縁膜堆積･エピタキシャル成長

- Low-pressure chemical vapor deposition (CVD) reactors for SiO_2, SiN, poly-Si (Tokyo Electron)

減圧CVD（化学気相成長）炉 （東京エレクトロン）
SiO_2, SiN, poly-Si堆積可能




- Atmospheric pressure CVD reactor for SiO_2 Doping of P and B possible (AMAYA)

SiO_2堆積用常圧CVD装置
(天谷製作所) PおよびBドープ可能

- Parallel plate type clean plasma CVD reactor for SiN, SiO_2, and amorphous Si (ULVAC)

平行平板型プラズマCVD装置 (アルバック)
SiN, SiO_2, アモルファスSi 堆積可能

- Molecular beam epitaxial growth system for GaAs and AlGaAs: Si, Be doping possible (EIKO)

分子線エピタキシャル成長装置
(エイコー) GaAs 等堆積可能

- Atomic layer CVD (ALCVD) reactor for SiN (Thermo Riko)

原子層CVD炉
(サーモ理工) SiN 堆積可能

常圧CVDウェハセッティング風景

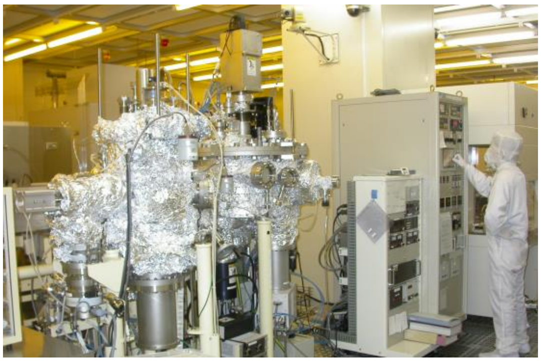
Wafer setting to atmospheric CVD reactor

5.2.5 Metal deposition

金属薄膜堆積

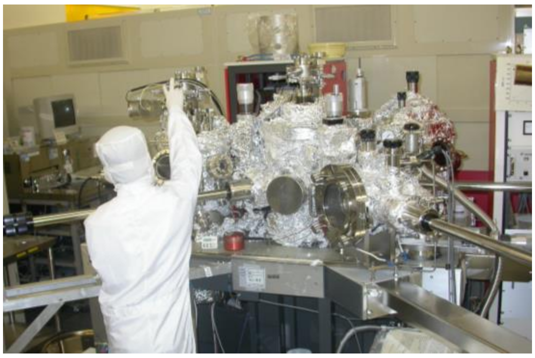
◆ Metal/dielectrics sputtering system for BiSrTiO compound etc. (ULVAC)

金属/絶縁膜スパッタリング装置 (アルバック)
BiSrTiO等堆積可能



◆ Sputtering machine for metal interconnects for Al, Ti, TiN (EIKO)

金属配線用スパッタリング装置 (エイコー)
Al, Ti, TiN 堆積可能



◆ Electron beam evaporation system for many kinds of metals (EIKO)

電子ビーム蒸着装置
(エイ コー) 多種材料堆積

◆ Sputtering system for general purpose for variety materials (EIKO)

汎用スパッタ装置
(エイコー) 広範な材料堆積

◆ Vacuum evaporation system for variety of metals (Donated: RICOH)

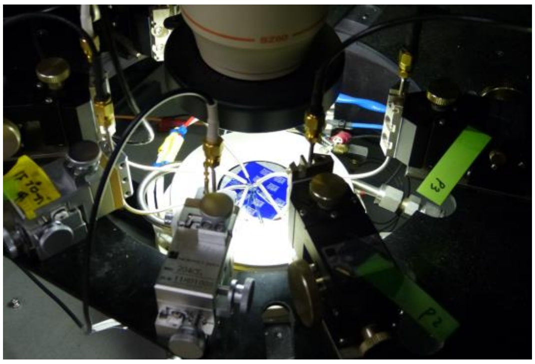
真空蒸着装置
(寄贈:リコー) Al 等堆積可能

5.2.6 Others

その他

◆ Surface-activated bonding system (EIKO)

表面活性化接合装置 (エイ コー)
Ar, H_2 Plasma treatment 可能



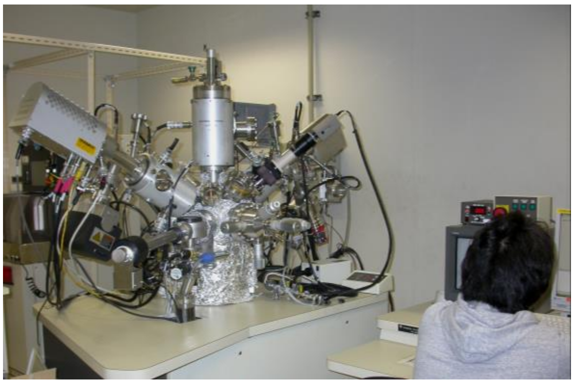
マニュアルプローバーによる電気特性測定

Measuring electrical properties using manual prober

5.3 Characterization and diagnostics equipment
評価・分析装置

◆ Secondary ion mass spectroscopy (SIMS) system with Cs and O ion gun (ULVAC-PHI PHI-6650)

2次イオン質量分析装置（アルバック-ファイ PHI-6650） Cs, Oガン装備



◆ Total reflection of X-ray fluorescence spectrometer (Technos TREX-610)

全反射蛍光X線分析装置 (Technos TREX-610)
感度(Cr-Zn)　10^{10} atom/cm^2

◆ Fourier-transform infrared spectrometer (FTIR) (JEOL)

フーリエ変換赤外分光光度計
（日本電子）Resolution 0.5cm^{-1}

◆ Atomic force microscope (AFM) (Seiko Instruments Inc. SPI3800)

原子間力顕微鏡（セイコーインスツルメンツ SPI3800）Resolution Z:0.01nm, X, Y：0.1nm

◆ High resolution X-ray diffractometer (Rigaku ATX-E)

高解像度X線回折装置
(リガク　ATX-E) Angle resolution 0.0002°

◆ X-ray diffractometer (Rigaku RINT2100)

X線回折装置
(リガク　RINT2100)

◆ Ellipsometer
（Rudolph Research Auto EL）

エリプソメーター （ルドルフリサーチ Auto EL）
Measurable thickness > 10nm

◆ Spectroscopic ellipsometer
(J.A.Woollam JAPAN M-2000D)

分光エリプソメーター （ジェー・エー・ウーラム・ジャパン M-2000D）Measurable thickness > 10nm

◆ Hall effect measurement system
(ACCENT HL5500PC)

ホール効果測定装置 (ACCENT HL5500PC)
Input impedance $10^{10}\,\Omega$

◆ High-resolution X-ray photoelectron spectroscopy (XPS) system (KRATOS ESCA-3400)

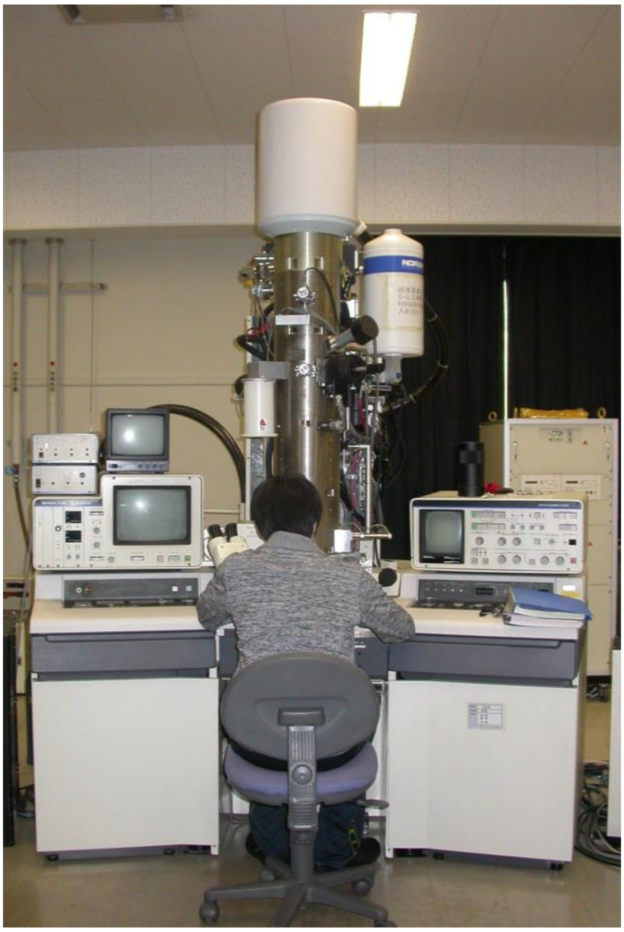
X線光電子分光分析装置
(KRATOS ESCA-3400) X ray source：Mg, Ka

◆ High-resolution X-ray photoelectron spectroscopy (XPS) system (VG Scienta ESCA-300)

X線光電子分光分析装置 (VGシエンタ ESCA-300） Radius of analyzer：300mm, X-ray source：4kW

◆ 200-kV field emission-transmission electron microscopy (FE-TEM) (Hitachi HF-2100)

透過電子顕微鏡
(日立 HF-2100) Lattice resolution 0.102nm

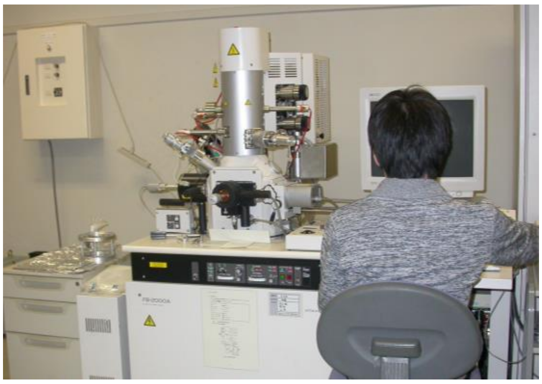


◆ Field emission scanning electron microscope (FE-SEM) (Hitachi S4700)

電界放出型走査電子顕微鏡
（日立 S4700）Resolution 1.5nm

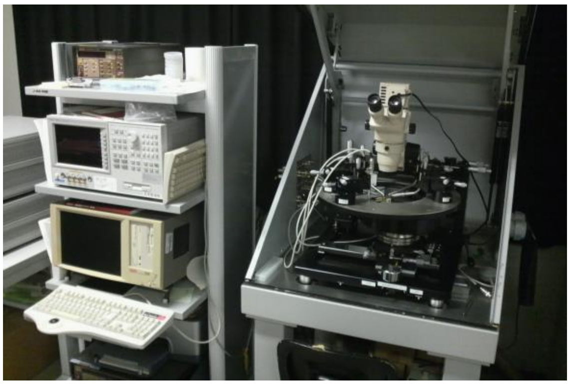
◆ Focused ion (Ga) beam (FIB) system (Hitachi FB-2000)

集束イオン(Ga)ビーム加工装置
（日立 FB-2000）Min. beam diameter 10nm



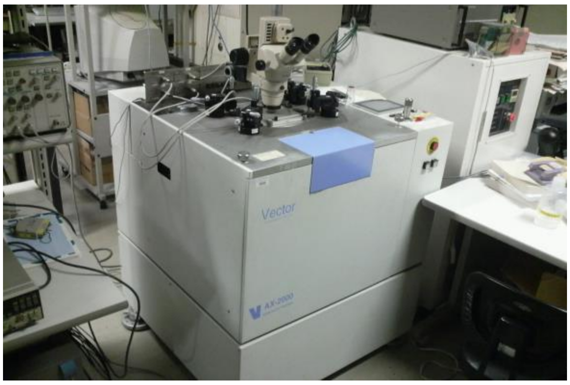
◆ Manual wafer prober (Vector Semiconductor) and semiconductor parameter analyzer (Keithley)

マニュアルプローバー(ベクターセミコン)及び
半導体パラメーターアナライザー(ケースレー)



◆ Semi-automatic wafer prober (Vector Semiconductor AX-2000)

セミオートプローバー
(ベクターセミコンAX-2000)



5.4 VLSI CAD environment

VLSI設計用CAD環境

5.4.1 Hardware

ハードウェア

Workstations

◆ SUN: 11 machines (SunFire X4600×1, SunFire V440×2, SunBlade2500×2, SunBlade2000×3, SunBlade1000×3)

◆ HP: 9 machines (ProLiant DL580G5×3, xw9300×1, xw8600×1, j6750×1, c8000×2, b2000×1)

Workstations for TCAD and LSI design
TCAD及びLSIデザイン用ワークステーション

5.4.2 Software

ソフトウェア

TCAD tools

◆ Process/Device Simulators: SYNOPSYS TSUPREM4/MEDICI, ISE TCAD, SYNOPSYS Sentaurus, Selete ENEXSS

Other simulators

◆ Electromagnetic Field Simulators: ANSOFT HFSS, CST Microwave Studio

◆ Optical Wave-guide Simulator: Apollo Photonics APSS

LSI design tools

◆ Layout Design: CADENCE Virtuoso*, JEDAT alpha-SX(ISMO), Silvaco Expert*

- ◆ Schematic Design: CADENCE Composer*, JEDAT alpha-SX(ASCA), Silvaco Gateway
- ◆ Functional Simulators: CADENCE SPW*, Mathworks MATLAB
- ◆ Circuit Simulators: CADENCE Artist*, Spectre*, Silvaco SmartSpice*, SYNOPSYS Star-HSPICE*, HSIM*, TimeMill/PowerMill*, NanoSim*
- ◆ Logic Simulators: CADENCE NC-Verilog*, VerilogXL*, MENTOR ModelSim*, SYNOPSYS VSS*
- ◆ Logic Synthesis: ALTERA QuartusII, CADENCE HDL Compiler*, SYNOPSYS Design Compiler*, FPGA Compiler*, XILINX ISE Foundation
- ◆ Automatic P&R: SYNOPSYS Milkyway*, Astro*, IC-Compiler*, CADENCE SoC-Encounter*
- ◆ Verification: CADENCE Diva*, Dracula*, Assura*, JEDAT Layver, MENTOR Calibre*, SYNOPSYS Hercules*

Notice that various kinds of popular CAD software (marked with "*") which support Verilog HDL/VHDL simulation, synthesis, layout design and verification for digital/analog VLSIs are provided by VLSI Design and Education Center (VDEC), the University of Tokyo.

6. List of Publications

6.1 Advanced device, process, and material technologies for ULSI

6.1.1 Fabrication techniques for MOS devices and TFTs

[1] T. T. Nguyen, M. Hiraiwa, T. Koganezawa, S. Yasuno, and S-I. Kuroki, "Formation of (100) Oriented Large Poly-Si Thin Films with Multi-Line Beam Continuous-Wave Laser Lateral Crystallization," Jpn. J. Appl. Phys. **57**, pp.031302-1 - 031302-6, 2018.

[2] T. Tanehira, Y. Furubayashi, A. Yamamoto, K. Yonemori, S. Miyoshi, and S-I. Kuroki, "Calculation of Seebeck Coefficients for Advanced Heat Transfer Modules," ECS Transaction **80** (5), pp. 57-62, 2017.

[3] Y. Furubayashi, T. Tanehira, A. Yamamoto, K. Yonemori, S. Miyoshi, and S-I. Kuroki, "Peltier Effect of Silicon for Cooling 4H-SiC-based Power Devices," ECS Transaction **80** (5), pp. 77-85, 2017.

[4] M. De Silva, T. Kawasaki, T. Miyazaki, T. Koganezawa, S. Yasuno, and S-I. Kuroki, "Formation of epitaxial Ti-Si-C Ohmic contact on 4H-SiC C face using pulsed-laser annealing," Appl. Phys. Lett. **110**, 252108-1 - 252108-5, 2017.

[5] T. T. Nguyen, M. Hiraiwa, and S-I. Kuroki, "Ultrahigh-performance (100)-oriented polycrystalline silicon thin-film transistors and their microscopic crystal structures," Appl. Phys. Express, **10**, 056501-1 -056501-4, 2017.

[6] S-I. Kuroki, T. Kurose, H. Nagatsuma, S. Ishikawa, T. Maeda, H. Sezaki, T. Kikkawa, T. Makino, T. Ohshima, M. Östling, and C.-M. Zetterling, "4H-SiC Pseudo-CMOS Logic Inverters for Harsh Environment Electronics," Mat. Sci. Forum, **897**, pp. 669-672, 2017.

[7] M. De Silva, T. Kawasaki, T. Kikkawa, and S-I. Kuroki, "Low Resistance Ti-Si-C Ohmic Contacts for 4H-SiC Power Devices Using Laser Annealing," Mat. Sci. Forum, **897**, pp. 399-402, 2017.

[8] K. Muraoka, H. Sezaki, S. Ishikawa, T. Maeda, T. Sato, T. Kikkawa, and S-I. Kuroki, "Enhanced-Oxidation and Interface Modification on 4H-SiC(0001) Substrate Using Alkaline Earth Metal," Mat. Sci. Forum, **897**, pp. 348-351, 2017.

[9] T. T. Nguyen, and S.-I. Kuroki, "Characterization of p-channel TFTs with (100)-oriented poly-Si thin film formed by multiline beam continuous-wave laser lateral crystallization," International Thin-Film Transistor Conference 2018 (ITC2018), Guangzhou, China, No.14, 2018.

[10] H. Oka, K. Inoue, T. Tomita, Y. Wada, T. T. Nguyen, S. Kuroki, T. Hosoi, T. Shimura, and H. Watanabe, “Back-side Illuminated GeSn Photodiode Array on Quartz Substrate Fabricated by Laser-induced Liquid-phase Crystallization for Monolithically-integrated NIR Imager Chip,” 2017 International Electron Devices Meeting (IEDM) Technical Digest, pp.393-396, 2017.

[11] S-I. Kuroki, “4H-SiC MOSFETs and Logic Inverters for Harsh Environment Electronics,” 19th Takayanagi Kenjiro Memorial Symposium, pp.15-17, 2017 (Invited).

[12] S-I. Kuroki, “4H-SiC Self-Aligned Gate MOSFETs and Logic Inverters for Harsh Environment Electronics,” The 2nd International Symposium on Biomedical Engineering, pp. 40-41, 2017.

[13] T. Tanehira, Y. Furubayashi, A. Yamamoto, K. Yonemori, S. Miyoshi, and S-I. Kuroki, “Calculation of Seebeck Coefficients for Advanced Heat Transfer Modules”, 232nd Electrochemical Society Meeting, National Harbor, MD, USA, #1177, 2017.

[14] Y. Furubayashi, T. Tanehira, K. Yonemori, S. Miyoshi, and S-I. Kuroki, “Peltier Effect of Silicon for cooling 4H-SiC-based power devices”, 232nd Electrochemical Society Meeting , National Harbor, MD, USA, #1186, 2017 (Invited).

[15] J. Kajihara, S-I. Kuroki, S. Ishikawa, T. Maeda, H. Sezaki, T. Makino, T. Ohshima, M. Östling, and C.-M. Zetterling, “4H-SiC pMOSFETs with Al-doped S/D and NbNi silicide ohmic contacts,” The International Conference on Silicon Carbide and Related Materials 2017 (ICSCRM2017), Washington, D.C., USA, WE.DP.4, 2017.

[16] T. Kurose, S.-I. Kuroki, S. Ishikawa, T. Maeda, H. Sezaki, T. Makino, T. Ohshima, M. Östling, and C.-M. Zetterling, “Low-parasitic-capacitance self-aligned 4H-SiC nMOSFETs for harsh environment electronics,” The International Conference on Silicon Carbide and Related Materials 2017 (ICSCRM2017), Washington, D.C., USA, TH.CP.3, 2017.

[17] K. Muraoka, S. Ishikawa, H. Sezaki, T. Maeda, and S.-I. Kuroki, “Correlation between field effect mobility and accumulation conductance at 4H-SiC MOS interface with barium,” The International Conference on Silicon Carbide and Related Materials 2017 (ICSCRM2017), Washington, D.C., USA, TH.CP.2, 2017.

[18] K. Kobayakawa, K. Muraoka, H. Sezaki, S. Ishikawa,T. Maeda, and S.-I. Kuroki, “Effects of CF4 surface etching on 4H-SiC MOS Capacitors,” The International Conference on Silicon Carbide and Related Materials 2017 (ICSCRM2017), Washington, D.C., USA, WE.CP.9, 2017.

[19] M. De Silva, T. Kawasaki, and S.-I. Kuroki, “Electrical properties of Ti-Si-C Ohmic contact on ion-implanted

n-type 4H-SiC C face," The International Conference on Silicon Carbide and Related Materials 2017 (ICSCRM2017), Washington, D.C., USA, TU.CP.7, 2017.

[20] S-I. Kuroki, T. T. Nguyen, and M. Hiraiwa, "(211) and (100) Surface Oriented Poly-Si Thin Film Transistors with Continuous-Wave Laser Lateral Crystallization," The 17th International Meeting on Information Display (iMID2017), Busan, Korea, C35-2, 157, 2017 (Invited).

[21] R. Nakashima, R. Shin, H. Hanafusa, and S. Higashi, "Generation of ultra high-power thermal plasma jet and its application to crystallization of amorphous silicon films," Jpn. J. Appl. Phys. **56** (6S2), 06HE05-1 - 06HE05-4, 2017.

[22] H. Hanafusa, R. Ishimaru, and S. Higashi, "High-temperature and high-speed oxidation of 4H-SiC by atmospheric pressure thermal plasma jet," Jpn. J. Appl. Phys. **56**, 040304-1 - 040304-3, 2017.

[23] H. Hanafusa, and S. Higashi, "Activation of High-temperature-implanted Phosphorus Atoms in 4H-SiC by Atmospheric Pressure Thermal Plasma Jet Annealing," Ext. Abs. 2018 18th Int. Workshop Junction Tech. (IWJT-2018), Shanghai, China, pp. 24-27, 2018 (Invited).

[24] S. Higashi, "Nitrogen-boosted Atmospheric Pressure Thermal-Plasma-Jet Generation and Its Application to Crystallization of Amorphous Silicon Films on Flexible Glass," Abs. 2018 Int. Thin-Film Transistor Conf. (ITC2018), Guangzhou, China, pp. 46, 2018 (Invited).

[25] R. Mizukami, T. Yamashita, and S. Higashi, "Single Crystalline Silicon CMOS Circuit Fabrication on Polyethylene Terephthalate Substrate by Meniscus Force Mediated Layer Transfer Technique," Abs. 2018 Int. Thin-Film Transistor Conf. (ITC2018), Guangzhou, China, pp. 44, 2018.

[26] S. Higashi, M. Wei, T. Kanamaru, "Low Temperature Formation of SiNx Encapsulation Films by Remote Plasma Enhanced Chemical Vapor Deposition," Proc. 24th Int. Display Workshops (IDW'17), Sapporo, Japan, pp. 687-689, 2017.

[27] R. Mizukami, T. Yamashita, S. Higashi, "Single Crystalline Silicon CMOS Circuit Fabrication on Plastic Substrate by Meniscus Force Mediated Layer Transfer Technique," Proc. 24th Int. Display Workshops (IDW'17), Sapporo, Japan, pp. 1525-1528, 2017.

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