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研究成果報告書

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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 30 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.

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 and 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.

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, 2016

Takamaro Kikkawa
Director
Research Insitute for Nanodevice and Bio Systems
Hiroshima University

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）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プロジェクト、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。

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。

2016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　　　　　吉川公麿

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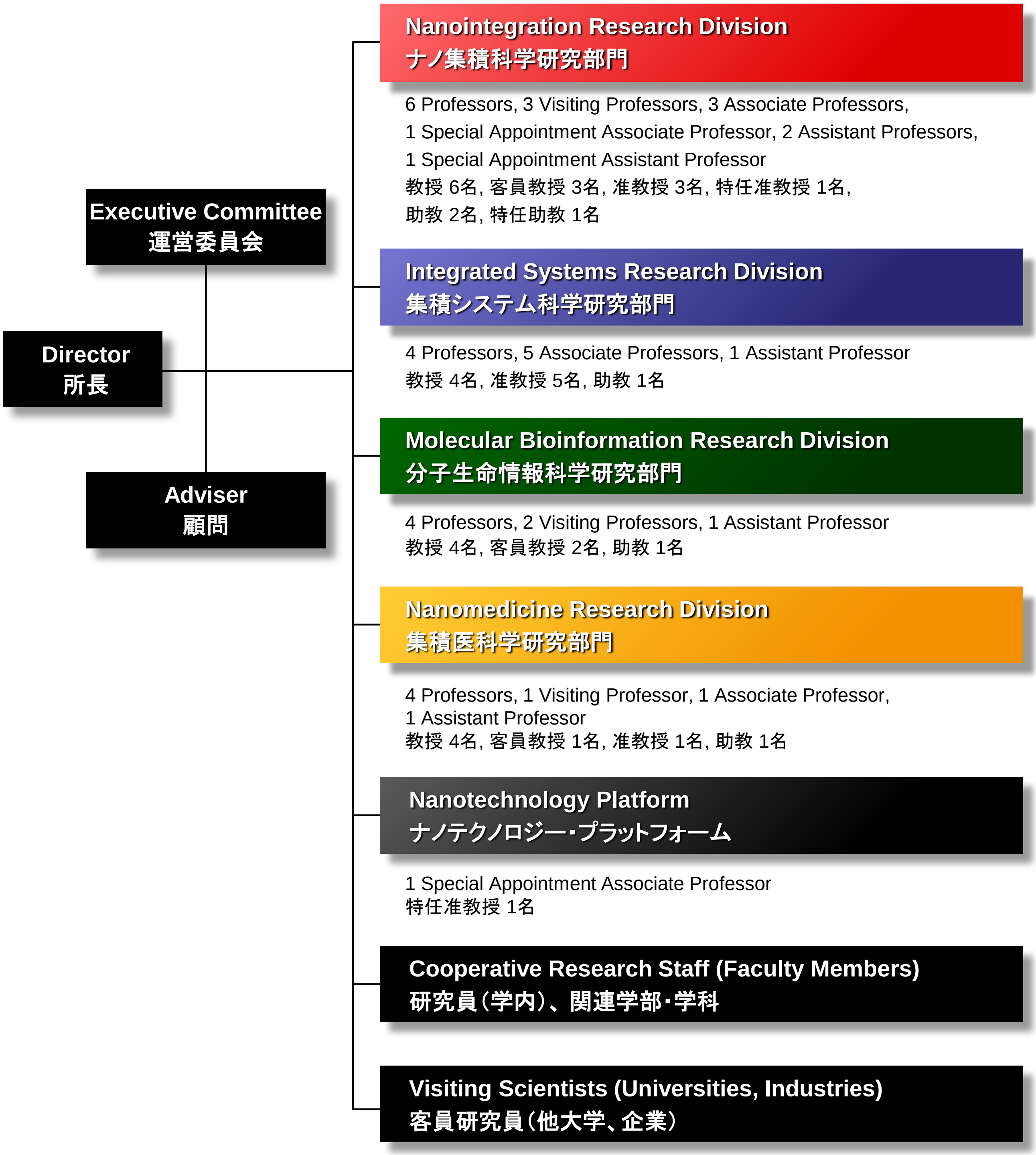

2. Staff of Research Institute for Nanodevice and Bio Systems (RNBS)

ナノデバイス・バイオ融合科学研究所構成員
(2015年10月1日時点)

Nanointegration Research Division

ナノ集積科学研究部門

Takamaro Kikkawa 吉川　公麿	Director of RNBS and Professor 研究所長，教授
Shin Yokoyama 横山　新	Associate Director and Professor 副研究所長，教授
Seiichirou Higashi 東 清一郎	Professor 教授
Johji Ohshita 大下 浄治	Professor 教授
Kazuo Takimiya 瀧宮 和男	Professor 教授
Manabu Shimada 島田 学	Professor 教授
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
Tetsuo Tabei 田部井 哲夫	Associate Professor (Special Appointment) 特任准教授
Hideki Murakami 村上 秀樹	Assistant Professor 助教
Hiroaki Hanafusa 花房　宏明	Assistant Professor 助教
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
Idaku Ishii 石井　抱	Professor 教授
Kazufumi Kaneda 金田　和文	Professor 教授
Tetsushi Koide 小出　哲士	Associate Professor 准教授
Mamoru Sasaki 佐々木　守	Associate Professor 准教授
Tsuyoshi Yoshida 吉田　毅	Associate Professor 准教授
Toru Tamaki 玉木　徹	Associate Professor 准教授
Takeshi Takaki 高木　健	Associate Professor 准教授
Tadayoshi Aoyama 青山　忠義	Assistant Professor 助教

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
Takashi Yamada 山田　隆	Professor 教授

Seiji Kawamoto | Professor
河本 正次 | 教授

Takeshi Ikeda | Assistant Professor
池田 丈 | 助教

Nanomedicine Research Division

集積医科学研究部門

Kazuaki Chayama | Professor
茶山 一彰 | 教授

Michihiro Hide | Associate Director and Professor
秀 道広 | 副研究所長，教授

Hiroki Nikawa | Professor
二川 浩樹 | 教授

Koichi Kato | Professor
加藤 功一 | 教授

Kazuhiro Tsuga | Associate Professor
津賀 一弘 | 准教授

Yuhki Yanase | Assistant Professor
柳瀬 雄輝 | 助教

Nanotechnology Platform

ナノテクノロジープラットフォーム

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

Visiting Professor

客員教授

Yuji Miyahara | Visiting Professor
宮原 裕二 | 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

Researchers

研究員

Azhari Afreen アズハリ　アフリーン	Post Doctoral Researcher 機関研究員　(2010.5～)
Hoang Anh Tuan ホアン　アイン　トゥワン	Post Doctoral Researcher 機関研究員　(2012.11～)
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　(2011.7～)
Yutaka Furubayashi 古林　寛	Researcher, NEDO "Thermal Management Materials and Technology Research Association (TherMAT)" NEDO研究員　(2014.5～) （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　(2015.4～)
Shinji Yamada 山田　真司	Research Associate 教育研究補助職員　(2015.10～)

Advisory Board

顧問

Masataka Hirose 廣瀬　全孝	Professor Emeritus, Hiroshima University 広島大学名誉教授

Visiting Staff

客員スタッフ

Hirofumi Fukumoto 福本　博文	Visiting Scientist, Asahi Kasei Corporation 客員研究員，旭化成(株) (2007.12～)
Tomonori Maeda 前田　知徳	Visiting Scientist, Phenitec Semiconductor Corporation 客員研究員，フェニテックセミコンダクター(株) (2009.11～)
Seiji Ishikawa 石川　誠治	Visiting Scientist, Phenitec Semiconductor Corporation 客員研究員，フェニテックセミコンダクター(株) (2011.4～)
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Hirofumi Tanaka 田中　博文	Visiting Scientist, Mitsui Chemicals Incorporated 客員研究員，三井化学(株)
Shoko Ono 小野　昇子	Visiting Scientist, Mitsui Chemicals Incorporated 客員研究員，三井化学(株)
Yasuhisa Kayaba 茅場　靖剛	Visiting Scientist, Mitsui Chemicals Incorporated 客員研究員，三井化学(株)
Takeshi Kumaki 熊木　武志	Visiting Scientist, Department of VLSI System Design, College of Science & Enginnering, Ritsumeikan University 客員研究員，立命館大学理工学部電子情報デザイン学科
Shozo Takada 高田　省三	Visiting Scientist, Asahi Kasei E-materials Corporation 客員研究員，旭化成イーマテリアルズ(株)
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Akihiro Toya 外谷　昭洋	Visiting Scientist, Kure National College of Technology 客員研究員，呉工業高等専門学校
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Takuo Hirano 平野　拓男	Visiting Scientist, MAZDA Motor Corporation 客員研究員，マツダ(株)
Toshihiko Ohta 太田　年彦	Visiting Scientist, Sharp Takaya Electronic Industry Corporation 客員研究員，シャープタカヤ電子工業(株)
Hiromasa Watanabe 渡邉　礼方	Visiting Scientist, Sharp Takaya Electronic Industry Corporation 客員研究員，シャープタカヤ電子工業(株)
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Jyunichi Somei 染井　潤一	Visiting Scientist, Sharp Corporation 客員研究員，シャープ(株)
Eiji Suematsu 末松　英治	Visiting Scientist, Sharp Corporation 客員研究員，シャープ(株)
Keisuke Satou 佐藤　啓介	Visiting Scientist, Sharp Corporation 客員研究員，シャープ(株)
Yuichi Watarai 渡来　友一	Visiting Scientist, Sharp Corporation 客員研究員，シャープ(株)

Supporting Staff

支援スタッフ

Naofumi Yamamoto 山本　尚史	Finance Affairs 財務担当
Noriko Ishioka 石岡　紀子	General Affairs 総務担当
Fumitaka Nishiyama 西山　文隆	Technical Assistant 技術補佐員

Chikahisa Machida 町田　親久	Office Assistant 事務補佐員
Chiaki Ashihara 葦原　千秋	Office Assistant 事務補佐員
Naoko Nakatani 中谷　尚子	Office Assistant 事務補佐員
Mayumi Fujioka 藤岡　真由美	Office Assistant 事務補佐員

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

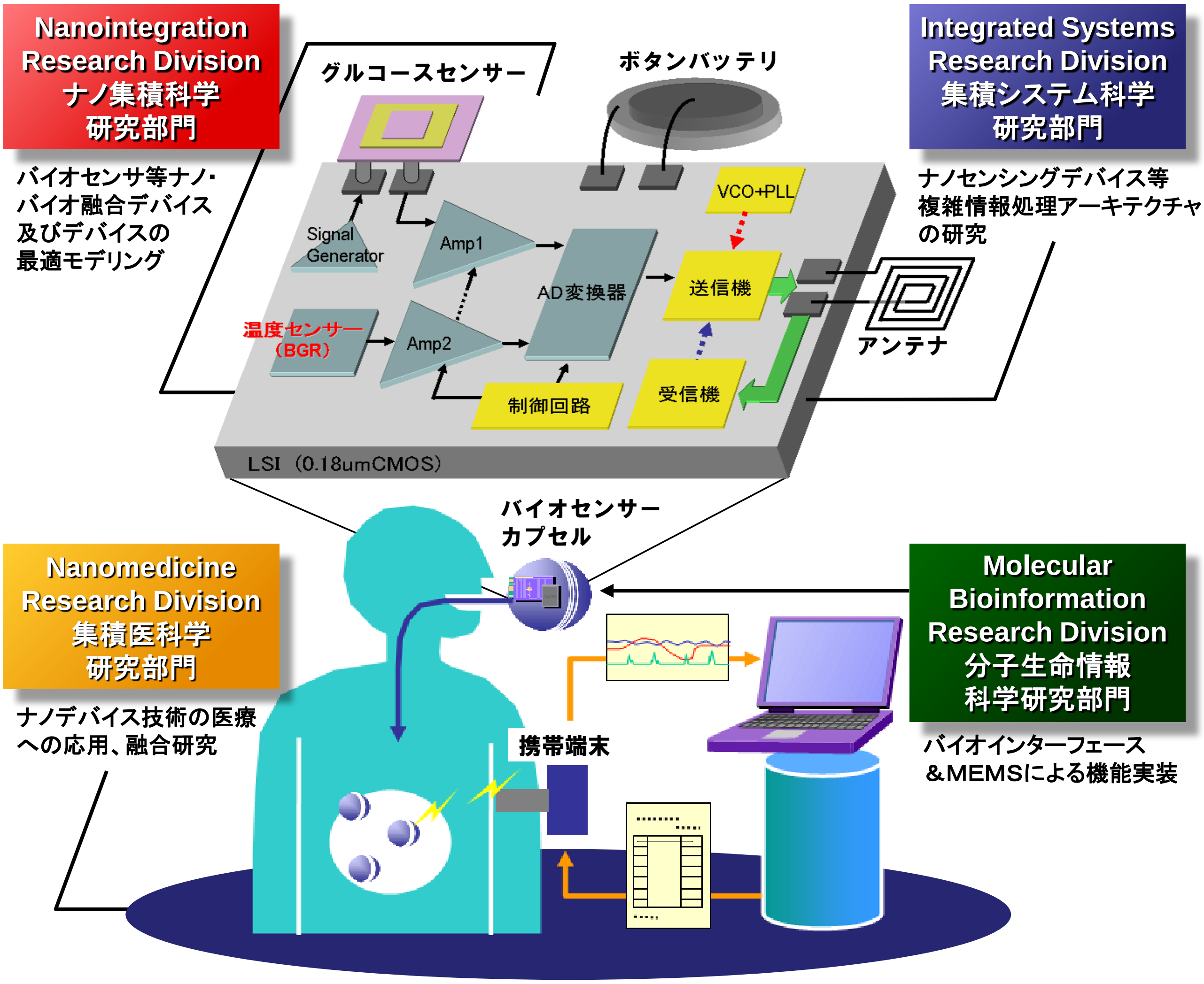
Takamaro Kikkawa 吉川 公磨	Director and Professor 研究所長・教授	RNBS ナノデバイス・バイオ融合科学研究所
Shin Yokoyama 横山 新	Associate Director and Professor 副研究所長・教授	RNBS ナノデバイス・バイオ融合科学研究所
Michihiro Hide 秀 道広	Associate Director and Professor 副研究所長・教授	Graduate School of Biomedical Sciences 医歯薬保健学総合研究院(医)
Hans Jürgen Mattausch マタウシュ 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
Seiichirou Higashi 東 清一郎	Professor 教授	Graduate School of Advanced Sciences of Matter 先端物質科学研究科
Toshikazu 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
Hiroki Nikawa 二川 浩樹	Professor 教授	Graduate School of Biomedical Sciences 医歯薬保健学総合研究院(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.

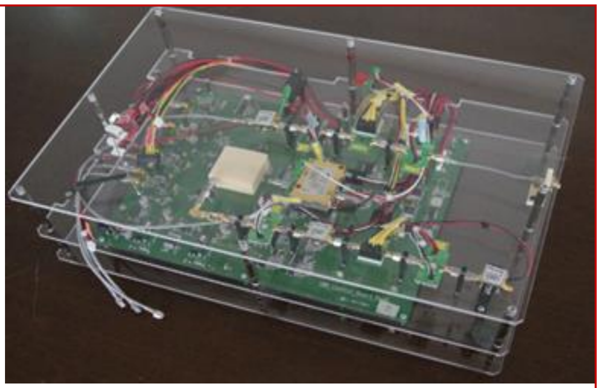
ナノ集積科学研究部門では、ナノデバイス、プロセス、ナノインテグレーション、ナノバイオ融合デバイス、フォトニックデバイス、ナノ量子デバイス、薄膜デバイス、ナノデバイスモデリング、機能性材料等に関する研究を行っている。ナノ集積科学研究部門における研究の主なものの概要を紹介する。

乳がん検出システムの開発
Breast Cancer Detection System

教授　吉川　公麿
Prof. Takamaro Kikkawa

インパルス超広帯域電波（UWB)を使った乳がん検出システムプロトタイプを開発し、乳がんファントムの共焦点画像に成功した。これにより、大きさ 1cm の乳がん組織は検出可能であることが示されました。この研究の成果は IEEE ACCESS に掲載された。

A prototype of a breast cancer detection system using impulse-radio ultra-wide-band (IR-UWB) was developed. A beast cancer phantom was detected by confocal algorithm. It is confirmed that a 1cm-size breast cancer tissue could be detected by this system.
(IEEE ACCESS, 2015)



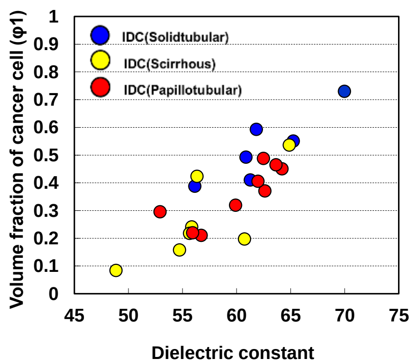
インパルス電波を用いる乳がん検出システムのプロトタイプ
A photograph of a prototype of IR-UWB-based breast cancer detection system.

乳がん組織の誘電特性
Dielectric Properties of Breast Cancers

教授　吉川　公麿
Prof. Takamaro Kikkawa

乳がん組織の誘電率は正常組織の誘電率より高いことが知られている。本研究では乳がんのサブタイプについて、マイクロ波領域で測定した複素誘電率について調べた結果、誘電率分布は病理組織学的顕微鏡写真から計算される癌細胞の体積分率と相関があることがわかった。

It has been reported that the dielectric constants of breast tumor tissues are higher than those of normal breast tissues. In this study, the microwave properties of the breast cancer subtypes obtained from cancer surgeries are characterized for classification. (IEEE Engineering in Medicine and Biology Society : EMBC 2015)



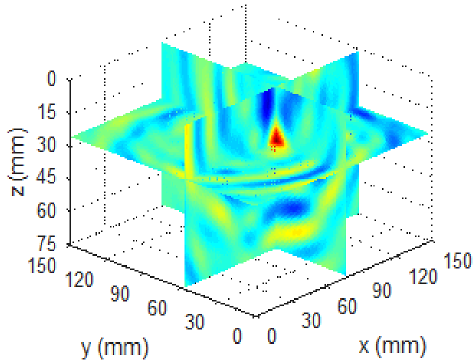
浸潤性乳管がんの誘電率と病理組織学的顕微鏡観察における乳がん細胞の間質に対する体積分率の相関
Correlation between the dielectric constants of invasive ductal carcinomas and volume fraction of cancer cells in histopathological observation.

乳がんの共焦点画像
Confocal Imaging of A Breast Cancer

教授　吉川　公麿
Prof. Takamaro Kikkawa

超広帯域インパルス電波を用いたドーム型アンテナアレイを有する乳がん検出装置を使って、半球状構造の乳房ファントム中に置かれた 1cm 大の乳がんファントムの共焦点画像化に成功した。

The performance of a prototype of a breast cancer detection system with a dome-shape antenna array using impulse-radio ultra-wide-band (IR-UWB) was demonstrated. A beast cancer phantom with the size of 1 cm which was placed in a hemispherical breast phantom was detected by confocal algorithm.
(Solid-State Devices and Materials SSDM 2015)



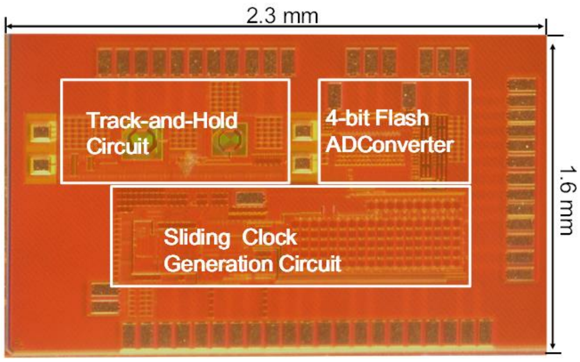
乳がんファントムの共焦点画像（XY, ZY, XY 断面）
Confocal imaging of a breast cancer phantom
(XY-, ZX-, ZY-planes)

IR-UWB-CMOS サンプリング回路
IR-UWB-CMOS Sampling Circuits

教授　吉川　公麿
Prof. Takamaro Kikkawa

超広帯域インパルス(IR-UWB)電波を用いた乳がん検出用 65nmCMOS サンプリング回路を設計試作した。同一の回路を2つの異なるデバイス特性を有する会社で試作した結果、トランジスタ特性の違いにより、インピーダンスマッチング等の回路特性に強く影響が現れることがわかった。

65 nm CMOS impulse-radio ultra-wide-band (IR-UWB) integrated circuits were designed and fabricated by two different foundries. It was found that impedance matching characteristics were significantly influenced by the their transistor characteristics. (STARC FORUM2015)



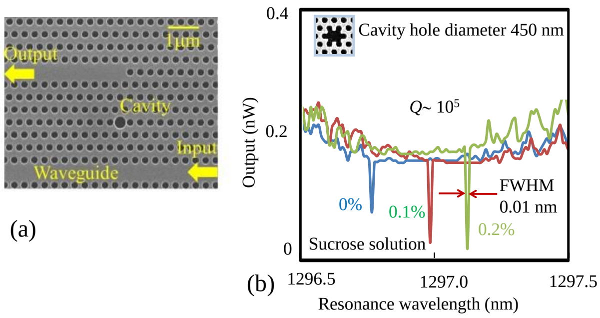
乳がん検出用 IR-UWB-CMOS サンプリング回路チップ写真
A photograph of IR-UWB-CMOS sampling integrated circuit.

シリコン光共振器バイオセンサー
Biosensors using silicon optical resonators

教授　横山　新
Prof. Shin Yokoyama

家庭で手軽に利用できる安価なバイオセンサーの開発を目的として、シリコンリング及びフォトニック結晶光共振器を用いたバイオセンサーの研究を行っている。非常に急峻な共振特性をもつフォトニック結晶光共振器を製作した。ショ糖溶液を用いその有用性を示した。

We are studying Si ring and photonic-crystal (PhC) optical-resonator biosensors in order to develop compact biosensors with low price and easily handled at home. The PhC crystal resonators with very sharp resonance characteristics were fabricated and their usefulness was demonstrated by using sucrose solution.



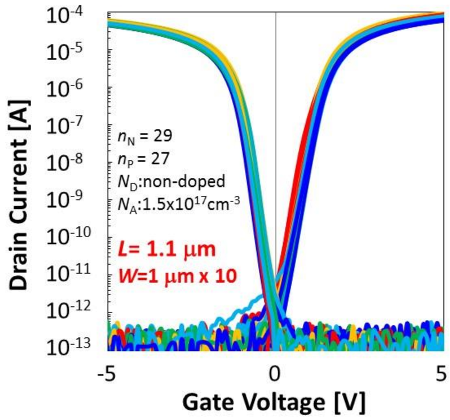
(a)　電子ビームリソグラフィーにより作製したシリコンフォトニック結晶共振器の走査電子顕微鏡写真、(b) 種々のショ糖濃度に対する共振スペクトルの例
(a) Scanning electron microscope image of the photonic crystal resonator fabricated by using electron beam lithography, (b) resonance spectra for various sucrose concentrations

熱プラズマジェットによる高性能 CMOS 薄膜トランジスタ作製
High-performance CMOS Thin-Film Transistors Fabrication by Thermal Plasma Jet Crsytallization

教授　東　清一郎（併任）
Prof. Seiichiro Higashi

大気圧プラズマジェット照射急速熱処理により非晶質基板上のアモルファスシリコン細線を溶融・結晶化することによりランダム粒界を抑制した擬似単結晶成長を実現し、n チャネル移動度 503 $cm^2V^{-1}s^{-1}$、p チャネル移動度 355 $cm^2V^{-1}s^{-1}$の高性能 CMOS 薄膜トランジスタ作製に成功した。

Atmospheric pressure thermal plasma jet irradiation to amorphous silicon strips suppresses generation of random grain boundaries and realizes pseudo-single-crystalline growth. Thin-film transistors fabricated on the crystals showed high n-channel mobility of 503 $cm^2V^{-1}s^{-1}$ and p-channel mobility of 355 $cm^2V^{-1}s^{-1}$, respectively.



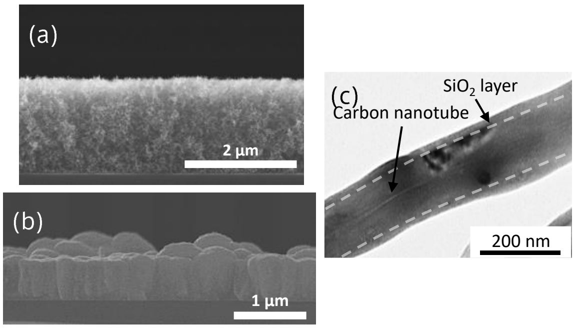
大気圧プラズマジェット結晶化シリコン膜を用いて作製した薄膜トランジスタの I_d–V_g 特性
I_d-V_g characteristics of thin-film transistors fabricated by atmospheric pressure plasma jet crystallized silicon films.

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.



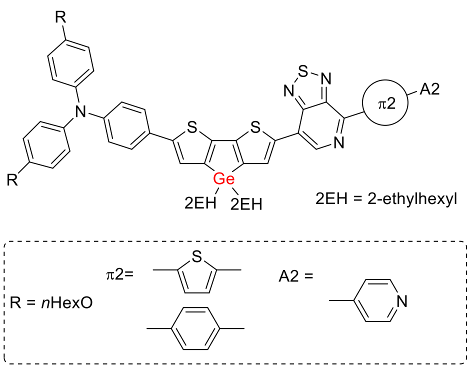
(a) ナノ粒子の気相堆積で作成した一様空隙薄膜; (b) 分子状物質とナノ粒子の同時析出／堆積で生じた複合物と異常成長; (c) 浮遊状態のナノチューブに気相合成した稠密被覆膜
(a) Uniformly-porous thin film fabricated by gas phase deposition of nanoparticles; (b) composite material and abnormal growth formed by simultaneous deposition of molecular and nanoparticulate substances; (c) dense coating layer synthesized in gas phase on the surface of gasborne nanotubes

14 族元素をベースとした有機電子デバイス材料の設計と合成
Design and Synthesis of Organic Electronic Device Materials Based on Group 14 Elements

教授　大下浄治（併任）Prof. Joji Ohshita

有機電子デバイスの材料の開発を目指して、14 族元素を有する新規な色素を合成し、それらの物性・機能を検討している。

Aiming at developing new materials for organic electronic devices, organic deys with group 14 elements prepared and their properties and functionalities are investigated.



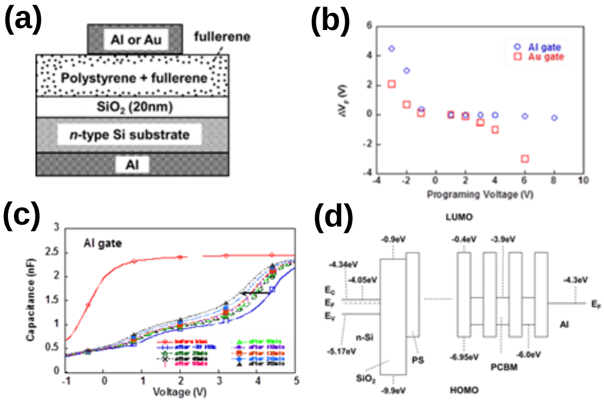
DSSC 用増感色素
Sensitizing Dye for DSSCs

フラーレン混合有機ポリマーメモリの研究
Research of Organic Polymer Containing Fullerene

准教授　中島安理
Assoc. Prof. Anri Nakajima

フラーレンをフローティングドットとして有機ポリマーに混合したメモリの研究開発を行っている。柔軟で軽量・安価なメモリの実現のために動作機構の詳細を調べている。

Research and development are carried our about fullerene-containing organic polymer memory in which fullerenes act as floating dots. The memory operation mechanism is investigated in detail for realizations of a memory with mechanical flexibility, low weight, and cost effectiveness.



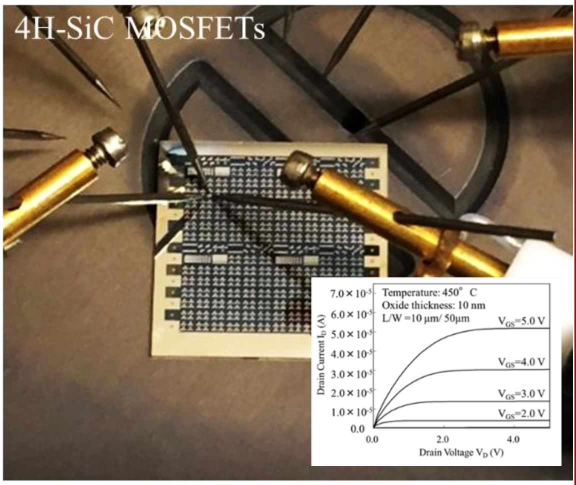
(a) 作製したキャパシターの図. (b) フラットバンドシフト ΔV_F とプログラミング電圧の関係. (c) C-V 保持特性. (d) バンド図.
(a) Schematic diagram of fabricated capacitor. (b) Relation between flatband voltage shift ΔV_F and programming voltage. (c) C-V retention characteristics. (d) Band diagram.

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 Electronics

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。極限環境集積回路用の 4H-SiC MOSFETs を試作し、113 Mrad (1.13MGy)の高ガンマ線曝露後動作および450℃の極高温動作の実証を行った。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 nMOSFETs were fabricated for the electronics, and were demonstrated under high gamma-ray radiation up to over 100 Mrad and 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.



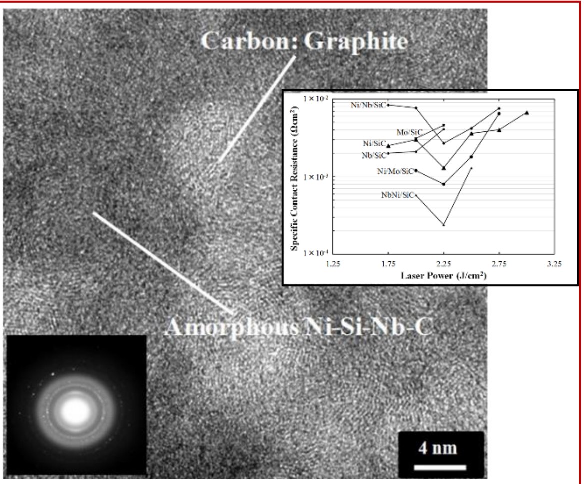
4H-SiC MOSFEts と450℃での超高温動作
4H-SiC MOSFETs and its high-temperature characteristics at 450°C

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。1kV 級パワーデバイスの設計・開発を進めるとともに、特に低抵抗化の要となる金属/SiC 間接触において、アモルファスNb-C-Ni-Si 電極を形成し、高効率パワー半導体デバイスを実現した。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。

1kV SiC power devices had been developed and research on ohmic contact between silicide and SiC, which was critical element for low resistance, was carried out. This research has been carried out under the collaboration with Phenitec Semiconductor Co. Ltd., and Sumitomo Heavy Industries Ltd, Japan.



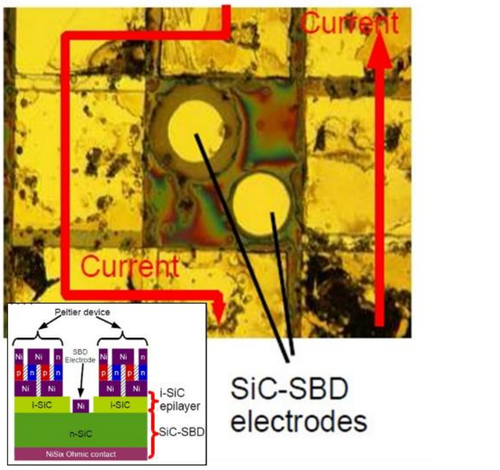
4H-SiC 上の低抵抗アモルファス Nb-C-Ni-Si 電極
Low-resistance amorphous Nb-C-Ni-Si on 4H-SiC

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.



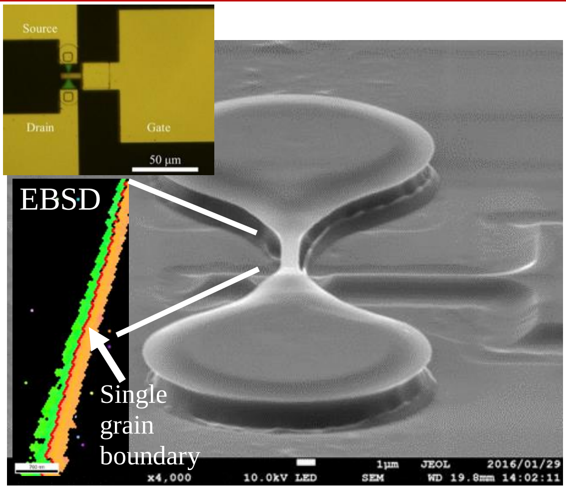
半導体吸熱構造と SiC パワーデバイスの 3 次元集積デバイス
3D integrated device with heat transfer and power devices

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を提案し、3 軸方向に結晶面方位を制御した多結晶シリコン薄膜を形成し、560cm^2/Vs の高電子移動度 TFT を実現した。結晶グレインが直線状である特徴を生かし、単一結晶および単一グレインバウンダリ TFT を作製し研究を進めた。この成果の一部は国際学会 iMiD2015 などで、招待講演として発表した。

Poly-Si thin films with large crystal grains of over 100 μm were fabricated by continuous-wave laser lateral crystallization with double-line beam, and its high-performance TFT with electron mobility of 560 cm^2/Vs was also fabricated. Single-grain boundary TFTs were fabricated and their characteristics showed Σ3 grain boundary had low electrical activity.



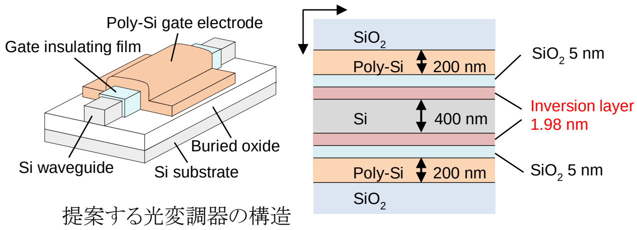
単一グレインバウンダリ　Si TFT
Single-grain-boundary Si TFT

MOS 構造を用いた表面プラズモン共鳴による光変調
Optical modulation based on surface plasmon resonance using MOS structure

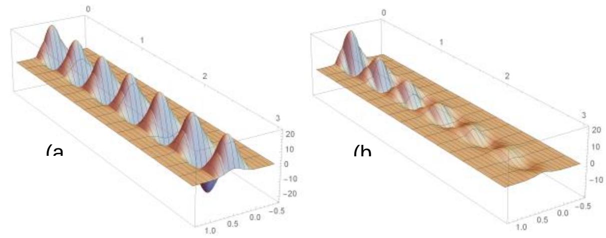
准教授　田部井哲夫(特任)
Assoc. Prof. Tetsuo Tabei

表面プラズモン共鳴を利用したシリコン光変調器について、導波モードの数値解析を行なった。MOS 構造において、電圧を印可した際に形成される反転層により、導波路内を伝搬する TM 偏光波の強度が変化することを数値的に確認した。

Guided modes for silicon optical modulator based on surface plasmon resonance were investigated numerically. It was confirmed numerically that the intensity of TM polarized propagation light changed by the inversion layer formed within MOS structure when applying gate voltage.



提案する光変調器の構造
Schematic structure of the proposed optical modulator.



TM 偏光波の H_y 成分の分布。(a)ゲート電圧 $V_G = 0$ V, (b) $V_G = 6.1$ V
Distribution of H_y component for TM polarized wave. (a) Gate voltage $V_G = 0$ V, (b)Gate voltage $V_G = 6.1$ V.

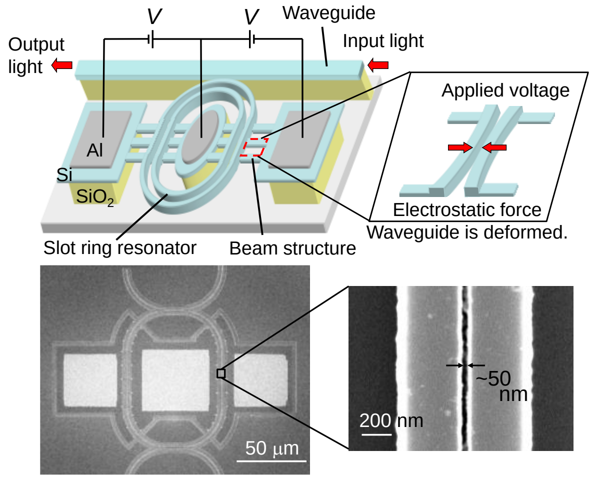
シリコンフォトニクス技術を用いたMEMS 光変調素子の研究

MEMS optical modulator using silicon photonics technology

助教　雨宮嘉照（特任）
Assist. Prof. Yoshiteru Amemiya

チップ内光配線やバイオセンサーチップへの応用を目的として、シリコンフォトニクス技術を用いた小型で低電圧動作が可能なマイクロ電子機械システム(MEMS）型の光変調素子の研究を行っている。

For applications of optical interconnection and biosensor chips, we study the small-size Micro-Electro-Mechanical-Systems (MEMS) optical modulator with low-voltage operation using silicon photonics technology.



提案している光変調素子の概略図とSEM像
Schematic figure of the proposed optical modulator and SEM images

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。

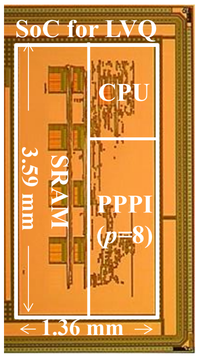
機能メモリの設計及び応用
Functional Memories and their Application

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.

Technology	180 nm
Chip area	4.88 mm²
Power supply	1.8 V
Power dissipation	214 mW
Frequency	25 MHz
Bit precision	16-bit
Dimension of input vectors	1-1024
Number of neurons	1-512
Minimal recognition speed (μs)	0.32
Minimal learning speed (μs)	20.9



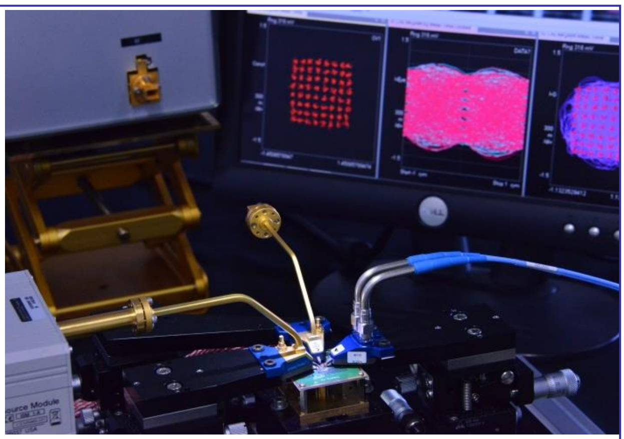
任意の学習ベクトル量子化（LVQ）アルゴリズムを使用するインテリジェントアプリケーションを実行できる 180nm CMOS の VLSI チップ
VLSI chip in 180nm CMOS capable of executing any intelligent application using the learning-vector-quantization (LVQ) algorithm.

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
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 CMOS 送信器を用いた無線通信デモ
Demonstration of 300GHz wireless transmitter.

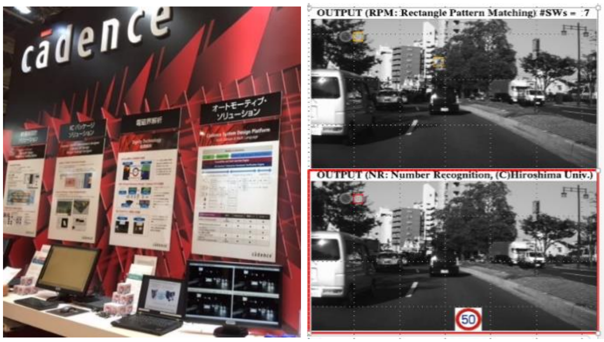
先進運転支援システム ADAS のための道路交通標識認識システムのプロトタイプ実装

A Prototype Speed Limit Sign Recognition System Implementation on Rapid Prototyping Platform for ADAS

准教授　小出哲士　　Assoc.Prof. Tetsushi Koide

近年、自動車普及台数の増加により交通事故件数の増加が深刻化している。交通事故の主な原因として、発見の遅れ、判断ミス、及び操作ミス等の運転手によるものがある。交通事故を未然に防ぐために、自動車で環境を認識して状況を判断し、運転手の操作をアシストすることで、運転手の操作ミスや判断ミスを未然に防ぐ先進運転支援システム（ADAS）が注目されている。本研究では，車両前方に取り付けた単眼カメラからの画像から速度標識を検出して、標識の速度をリアルタイム（15 ～ 30fps 以内）に読み取る組込みシステムの開発をした。

This study introduces our prototype speed limit traffic sign recognition system implementation on Rapid Prototyping Platform. The system utilizes simple image feature such as area luminosity difference of grayscale image to detect traffic sign candidates and block histogram feature in binary image to recognize the speed. Combination of those simple traffic sign features helps our algorithm to achieve 100% of accuracy in recognizing speed limit traffic signs in daytime and over 90% in hard lightning condition such as rainy night. Simplicity in computation enables real-time processing (> 30ps) and relatively small hardware occupied.



ラピッドプロトタイピングプラットフォーム Protium への実装例

A Prototype Speed Limit Sign Recognition System Implementation on Rapid Prototyping Platform: Protium

This paper shows our novel algorithm and prototype system for speed limit traffic sign recognition on Rapid Prototyping Platform Protium. Advantage of the integrated software of the Proium helps to reduce prototype system development time by hardware/software development in parallel as well as separately develop the hardware/software interface and our own algorithm.

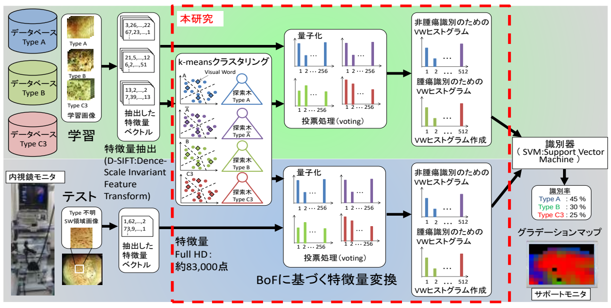
大腸内視鏡診断支援のための高速 Visual Word 特徴量変換の FPGA 実装

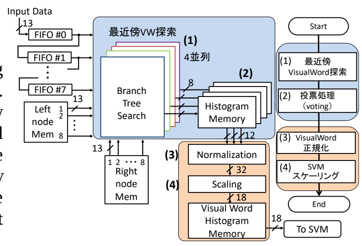
FPGA Implementation of High-Speed Visual Word Feature Transformation for CAD of Colorectal Endoscopic Images

准教授　小出哲士　　Assoc.Prof. Tetsushi Koide

本研究では Full HD（1920×1080 pixel）の大腸 NBI（Narrow Band Imaging）拡大内視鏡画像に対して局所的特徴量から病理タイプを識別し、医師に提示する大腸 NBI 拡大内視鏡画像診断支援システム eCAD における、内視鏡画像から得られた特徴量を Visual-Word（VW）ヒストグラムに変換する特徴量変換処理のハードウェア実装について述べる。限られた FPGA ハードウェアリソースで実装を行うため低リソースでの実装と，医師からの要求性能を満たすための高速処理を実現する。このためマンハッタン距離の使用、正規化処理省略等による高速処理を提案する。これらの結果、Full HD の約 83,000 点の特徴量変換を約 60 msec で処理することを可能とした。

This study describes a hardware implementation of feature transformation processing which transforms features of colorectal endoscopic images to Visual Word (VW) histogram. This processing is used in our eCAD system for colorectal endoscopic images with narrow band imaging (NBI) magnification, which is used to identify pathology types from local feature in the NBI endoscopic image. We propose a high speed and low cost feature transformation for CAD system by using Manhattan distance calculation and on-the-fly normalization method. The proposed high speed feature transformation can complete the transformation in real time (60 msec) for Full HD NBI endoscopic image, which has about 83,000 key-points of 64-dimention vector.





大腸 NBI 拡大内視鏡画像診断支援システム eCAD の識別アルゴリズムと特徴量変換アーキテクチャのブロック

The Overview of the Proposed CAD of Colorectal Endoscopic Images and Architecture of High-Speed Visual Word Feature Transformation.

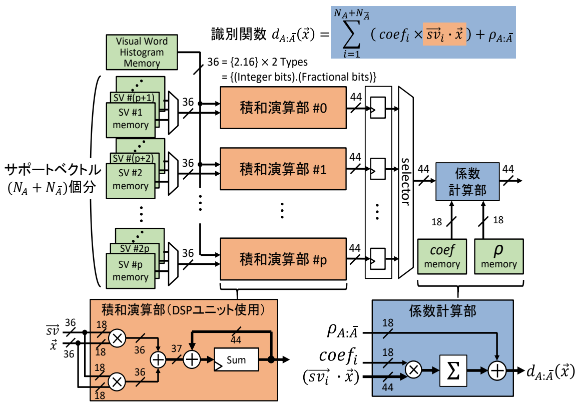
大腸内視鏡画像のタイプ識別に適した SVM の FPGA 実装

Effective Implementation of SVM in the FPGA for Type Identification with Colorectal Endoscopic Images

准教授　小出哲士　　Assoc.Prof. Tetsushi Koide

近年の大腸ガン患者数の増加に伴い、病状を定量的に評価し医師の診断を支援するComputer-Aided Diagnosis（CAD）システムの要求が高まっている。本研究では、大腸 Narrow Band Imaging（NBI）拡大内視鏡 Full HD（1920×1080 pixel）画像に対して、局所特徴量から病理タイプを識別しその情報を医師に提示する大腸 NBI 拡大内視鏡診断支援システム（eCAD）のハードウェア実現を目指している。本研究では，システムコンポーネントのひとつであるタイプ識別部で用いる Support Vector Machine（SVM）の FPGA 実装について報告する。更に、目標性能達成のため，SVM を階層的に構成することで識別精度向上が可能な手法として提案した、階層的タイプ識別手法の各階層の演算並列度の調整を行い、リアルタイム Full HD 全画面識別が可能であることを示した。

With the increase of colorectal cancer patients in recent years, the needs of quantitative evaluation of colorectal cancer are increased, and the Computer-Aided Diagnosis (CAD) system which supports doctor's diagnosis is essential. In this study, we introduce a SVM hardware architecture for CAD system for colorectal endoscopic images with NBI magnification findings. Additionally, we also introduce a consideration of parallel degree which can compute a pyramid style SVM with multi-SVMs for effective diagnosis image segmentation in parallel.



SVM 識別関数計算アーキテクチャ

An Architecture of the proposed Support Vector Machine based Type Identification for CAD with Colorectal Endoscopic Images.

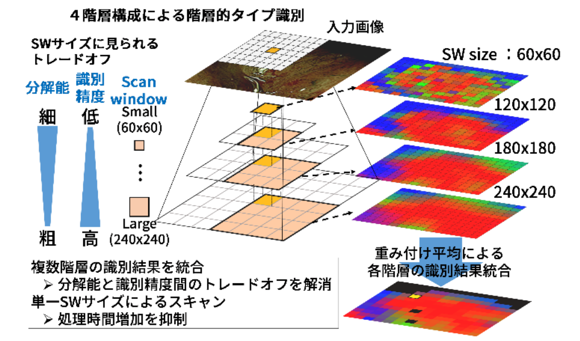
大腸内視鏡画像診断支援のための SVM を用いた階層的タイプ識別手法

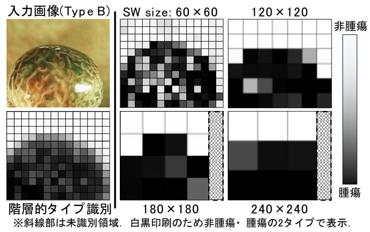
A Hierarchical Type Identification Method Based on Support Vector Machine in Computer Aided Diagnosis for Colorectal Endoscopic Images

准教授　小出哲士　　Assoc.Prof. Tetsushi Koide

本研究では Full HD（1920×1080 pixel）の大腸 NBI（Narrow Band Imaging）拡大内視鏡画像診断支援システム eCAD の階層的タイプ識別手法を開発した．Full HD 全画面識別結果を医師に分かり易く診断支援として提示するために、異なる Scan Window（SW）サイズでラスタスキャンを行い、各 SW サイズの識別結果を階層的に組合せて全画面識別を得る必要がある。その際には、局所的に見ると異なるタイプに識別されてしまい易い画像が存在する。これに対し、システムオフラインで行う学習フェーズの段階で学習画像データセットに含まれるこれらの画像を取り除くことで識別性能の向上を図った。シミュレーションの結果、識別性能の向上を確認した。

This study describes a type identification processing in our eCAD system for colorectal endoscopic Full HD images with Narrow Band Imaging (NBI) magnification findings. In order to make a clear presentation of an identified result of Full HD to clinical doctors by raster scanning, it is necessary to develop a computation method with hierarchical combination of multi Scan Window (SW) sizes. For these images that are easily miss-identified due to the local information, we suggest that they should be removed from the learning dataset as avoid the images. As a result the software simulation, verifies the increase identification performance.





階層的タイプ識別手法コンセプトと階層的タイプ識別手法適用例
A Concept of Hierar- chical Type Identification Method and An Example of Results of the Proposed Method for 4-layer Hierarchical Type Identification.

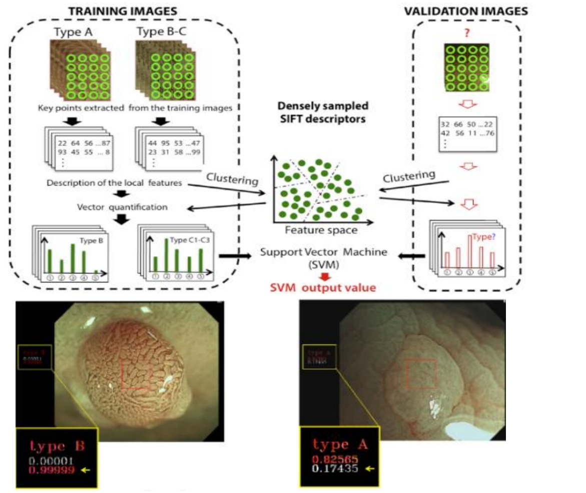
リアルタイム大腸 NBI 拡大内視鏡診断支援による大腸ポリープ病理組織に関する研究

Computer-aided diagnosis of colorectal polyp histology by using a real-time image recognition system and narrow-band imaging magnifying colonoscopy

准教授　小出哲士　　Assoc.Prof. Tetsushi Koide

大腸癌は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。大腸癌では治療リスク、治療後のサーベイランス間隔などを加味したがん予防に効果的な、費用対効果の高い検査法や治療方法の確立が望まれている。本研究では、開発している内視鏡診断支援のための CAD（Computer-Aided Diagnosis）システムを用いることで、高度な知識や経験を要せずに簡便に診断の正確性を向上させ、さらに米国消化器内視鏡学会で提唱されている PIVI statement を満たすことを示唆することができた。

Concordance between the endoscopic diagnosis and diagnosis by a real-time image recognition system with a support vector machine output value was 97.5% (115/118). Accuracy between the histologic findings of diminutive colorectal lesions (polyps) and diagnosis by a real-time image recognition system with a support vector machine output value was 93.2% (sensitivity, 93.0%; specificity, 93.3%; positive predictive value (PPV), 93.0%; and negative predictive value, 93.3%). Gastrointest Endosc. 2016 Mar;83(3):643-9. doi: 10.1016/j.gie.2015.08.004. Epub 2015 Aug 8.



リアルタイム大腸 NBI 拡大内視鏡診断支援の方法と診断支援結果の例
Computer-aided diagnosis of colorectal polyp histology by using a real-time image recognition system and narrow-band imaging magnifying colonoscopy

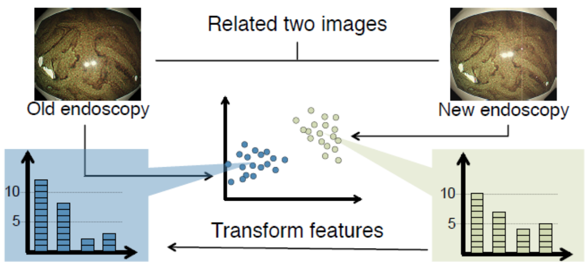
大腸内視鏡画像認識のための転移学習手法

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。しかし、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。具体的には、最新の内視鏡画像と旧内視鏡画像の違いを画像より抽出される特徴量分布の違いとして捉え、特徴量分布の変換をすることで旧内視鏡の学習画像データベースの再利用を行うことが可能となった。

In this study we propose a method for transfer learning of endoscopic images. For transferring between features obtained from images taken by different (old and new) endoscopes, we extend the Max–Margin Domain Transfer (MMDT) proposed by Hoffman et al. in order to use L2 distance constraints as regularization, called Max–Margin Domain Transfer with L2 Distance Constraints (MMDTL2). Furthermore, we develop thedual formulation of the optimization problem in order to reduce the computation cost. Experimental results demonstrate that the proposed MMDTL2 outperforms MMDT for real data sets taken by different endoscopes.



The Idea of transfer learning in our study.

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 [17]). (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 [18]).

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。

魚のバイオリフレクター（生体反射板）でつくるフォトニクス技術
Photonics technique utilizing bio-reflectors of fish

教授　岩坂正和 Prof. Masakazu Iwasaka

海のさまざまな生物は，人類がまだ活用していない光学機能をもつ材料（新しい光学デバイス）を持っている。瀬戸内海、太平洋、南西諸島近辺の魚から特異な光学材料を探し、近未来の表示デバイスや医療用チップを目指している。

Various kinds of living creatures in sea are using biogenic photonic devices which have not yet been utilized by human. We are exploring novel photonic materials in fishes of Setouchi sea, pacific ocean and south-west sea of Japan, and developing a new method for the next generation photonics.

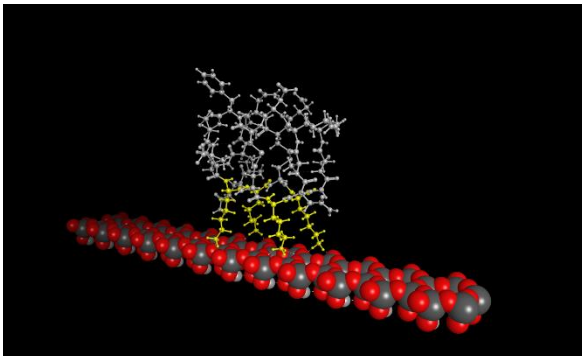
魚のバイオリフレクター（生体反射板）
Bio-reflector in fish skin

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
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.

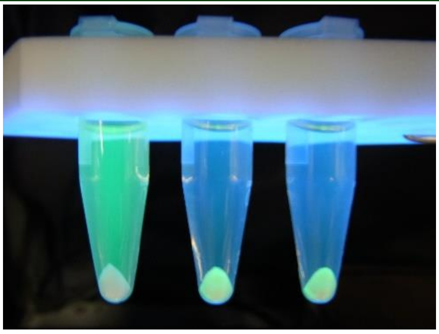
Si 結合ペプチドの発見とタンパク質固定化への利用

Application of Si-binding peptides for protein immobilization on Si materials

助教　池田　丈　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.



Si 結合ペプチドを利用した緑色蛍光タンパク質 GFP の固定化。GFP を単独で Si 粒子と混合しても Si に結合しないため、上清に GFP の蛍光が見られる(左)。シリカ結合ペプチドを GFP に融合すると、GFP は Si 粒子表面に結合する(中・右)。
Immobilization of green fluorescent protein on Si particles using the Si-binding peptide.

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.

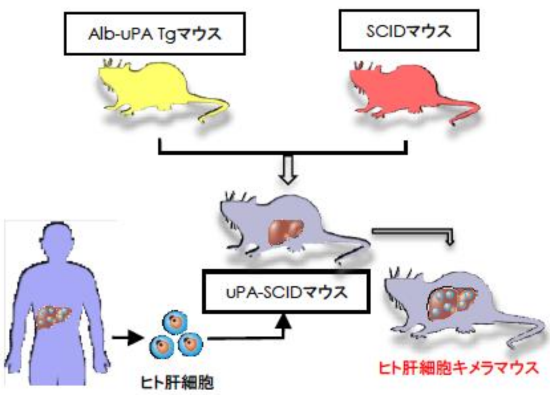
集積医科学研究部門では、ナノメディシン、ナノデンティストリー、ナノファーマシー等、医療とナノ技術の融合研究を行っている。現在行われている集積医科学研究部門における研究の主なものの概要を紹介する。

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

B 型あるいは C 型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に関する SNPs や肝癌のゲノム解析も行っている。

We are currently investigating hepatitis B and C 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 also analyzing SNPs and cancer genomes associated with viral hepatitis.



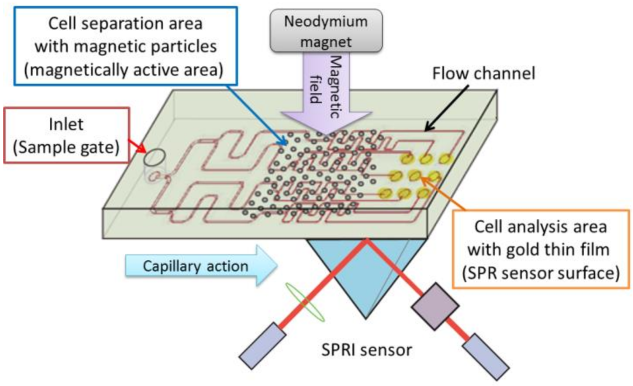
ヒト肝細胞キメラマウス
Humna hepatocyte chimeric mouse

SPRI イメージング解析のための好塩基球分離チップの開発
Development of basophil isolation chip for SPR imaging

教授　秀　道広
Prof. Michihiro Hide

末梢血から好塩基球を分離、SPRI 測定部位に搬送、SPRI 解析の工程を 1 枚のチップ上で行うためのマイクロ流体デバイスを開発した。好塩基球分離チップは、投入口、細胞分離部、SPR イメージング部で構成され、好塩基球以外の細胞は磁力によって細胞分離部で捕捉される。

We have developed a basophil isolation chip for SPR imaging. The chip is composed of three parts: inlet (sample gate), cell separation area with magnetic particles (magnetically active area), and SPR imaging analysis area containing a gold film (SPR sensor surface).



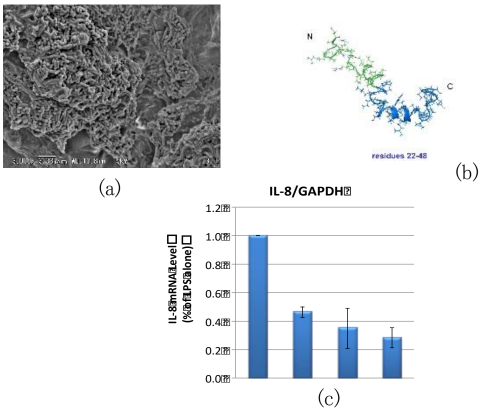
SPR イメージング解析用好塩基球分離チップ
Structure of the basophil separation chip for SPR imaging.

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

教授　二川浩樹
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.



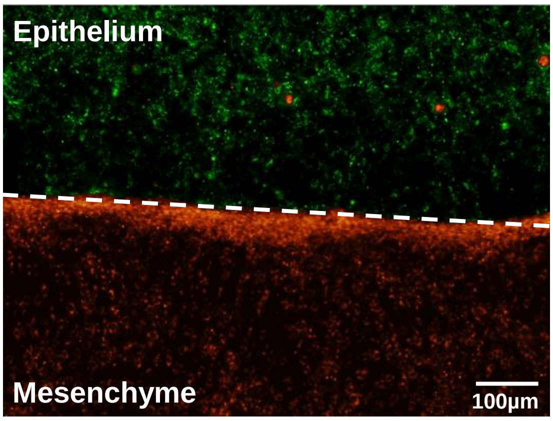
L8020 乳酸菌(a)のバクテリオシン Kog1(b)は、歯周病菌の内毒素 LPS を不活性化させる作用がある(c)。
Kog1(b), a bacteriocin produced by *L. rhamunosus* L8020 (a) inactivate the LPS produced by periodontal burdens (c).

上皮間葉相互作用解析プラットフォーム
Cell culture platforms for analyzing epithelial-mesenchymal interactions

教授　加藤 功一
Prof. Koichi Kato

複雑な構造をもつ組織や器官の発生機序を理解するには、上皮間葉相互作用に基づく形態形成過程について深く理解することが重要である。我々は、抗体の 2 次元ディスプレイ法を確立し、異種細胞の相対位置を制御しながら共培養することを可能にした。この方法を用いて、歯の発生過程の再現を試みている。

A microfabrication method has been utilized to establish co-culture of epithelial and mesenchymal cells in a spatially-controlled manner on a single substrate. This co-culture system is used to duplicate *in vitro* an early step toward tooth development.



上皮細胞（緑）と間葉細胞（赤）の境界部に，歯の発生初期にみられる細胞凝集と類似した構造形成が観察された
The formation of cell aggregates observed at the epithelial-mesenchymal border (dotted line) seem to mimic the “condensation” process seen in tooth development.

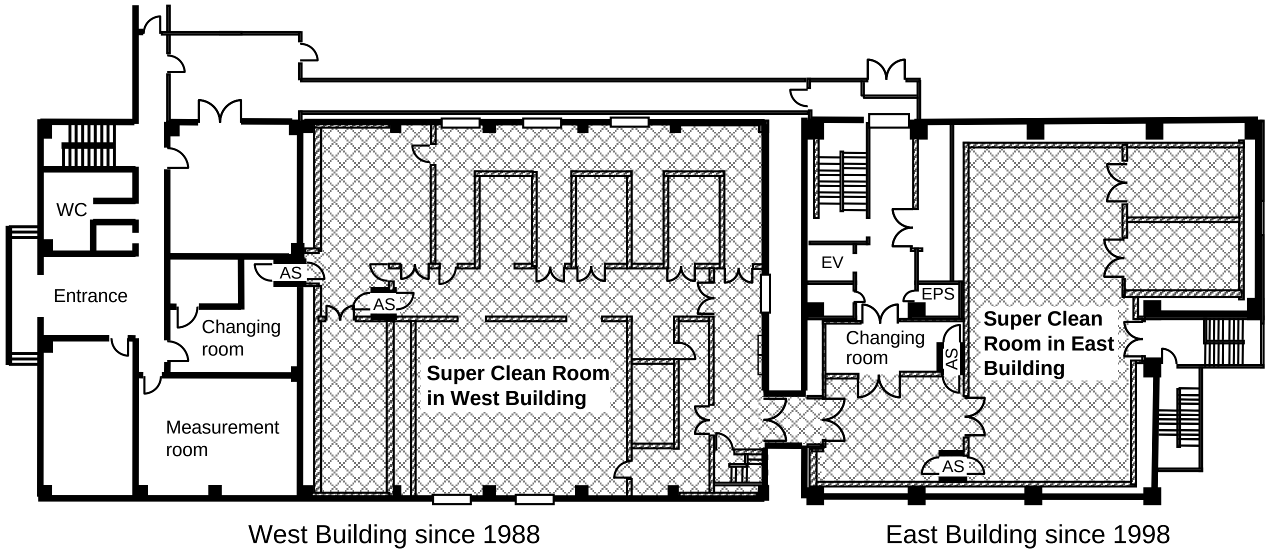
5. Research Facilities of RNBS

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）最小線幅 50nm

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

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

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

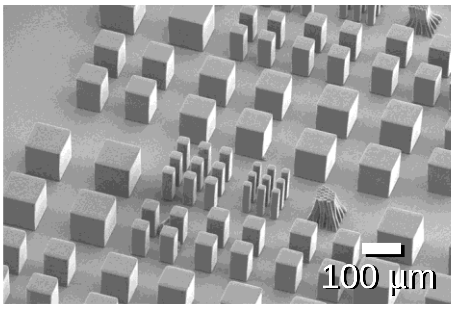
ポイントビーム型電子ビーム描画装置
（エリオニクス ELS-G100）最小線幅 6nm

◆ i-line optical stepper (Nikon NSR i8a)

i-線ステッパー
（ニコン NSR i8a）最小線幅 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） 最小描画サイズ 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

酸化・拡散炉キャリア搬送風景

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) 最高使用温度 1150℃


◆ Ion implanter
(ULVAC)

イオン注入装置
(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) 昇温速度最大 200℃/s

◆ Phosphorus diffusion furnaces
(SHINKO SEIKI)

リン拡散炉
(神港精機) 最高使用温度 900℃

◆ Annealing furnaces for general purpose
(Koyo Thermo System)

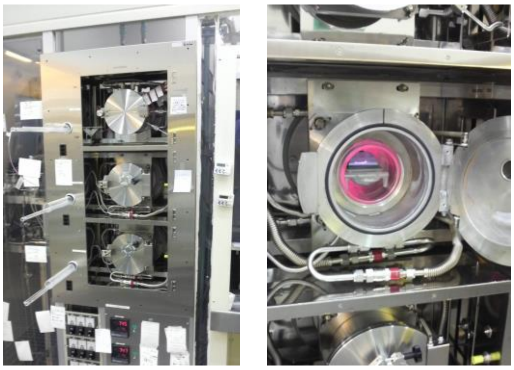
汎用熱処理装置
(光洋サーモシステム) 最高使用温度 1000℃

酸化炉講習風景

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
(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 (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 (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 (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
(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

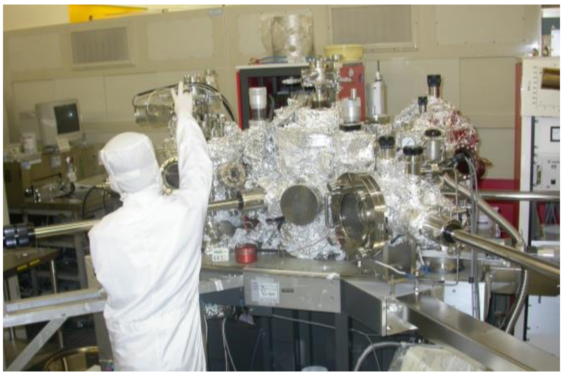
5.2.5 Metal deposition
金属薄膜堆積

◆ Metal/dielectrics sputtering system (ULVAC)

金属/絶縁膜スパッタリング装置 (アルバック)
BST 等堆積可能

◆ Sputtering machine for metal interconnects (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 (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 (EIKO)

汎用スパッタ装置
(エイコー) 広範な材料堆積

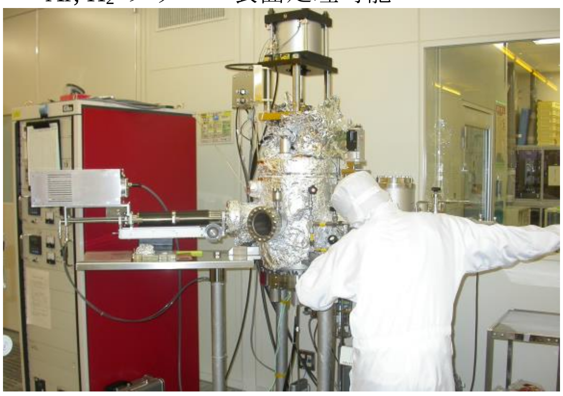
◆ Vacuum evaporation system (Donated: RICOH)

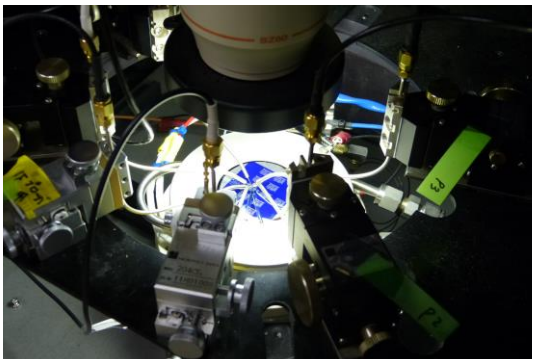
真空蒸着装置
(寄贈:リコー) Al 等堆積可能

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 プラズマ表面処理可能



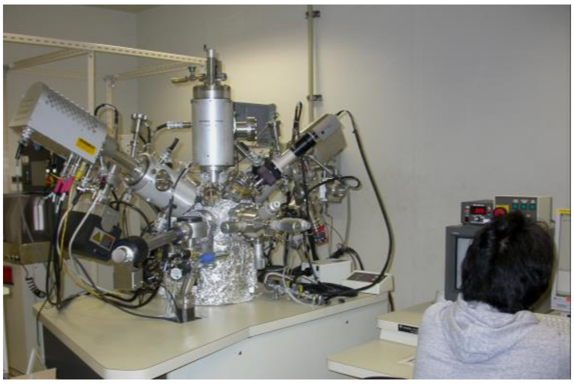


マニュアルプローバーによる電気特性測定

5.3 Characterization and diagnostics equipment
評価･分析装置

◆ Secondary ion mass spectroscopy (SIMS) system (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）分解能 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）分解能 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) 角度分解能 0.0002度

◆ 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）
最小測定膜厚 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）最小測定膜厚 10nm

◆ Hall effect measurement system
(ACCENT HL5500PC)

ホール効果測定装置 (ACCENT HL5500PC)
入力インピーダンス $10^{10}\,\Omega$

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

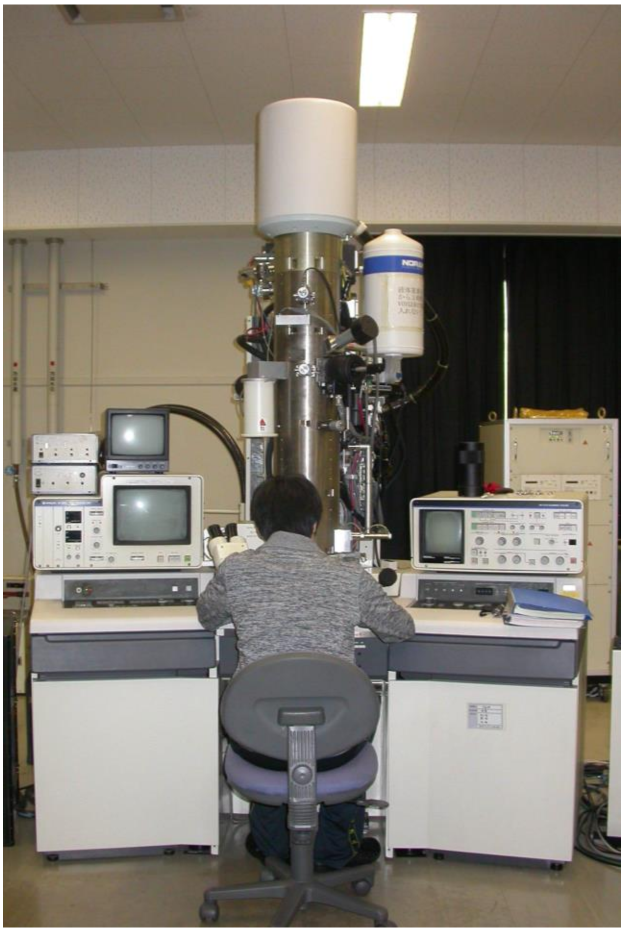
X線光電子分光分析装置
(KRATOS ESCA-3400) X線源：Mg, Ka

◆ 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) 分光器半径：300mm, X線パワー：4kW

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

透過電子顕微鏡
(日立 HF-2100) 格子分解能 0.102nm

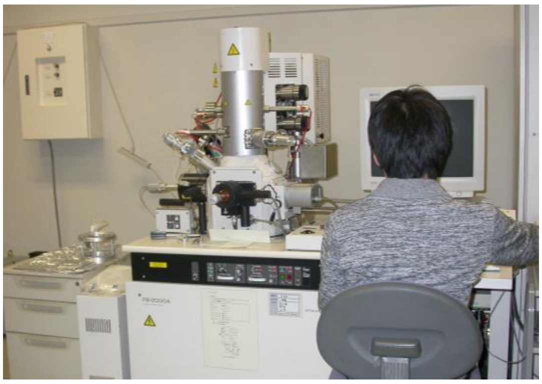


◆ Field emission scanning electron microscope (FE-SEM) (Hitachi S4700)

電界放出型走査電子顕微鏡
（日立 S4700）最高分解能 1.5nm

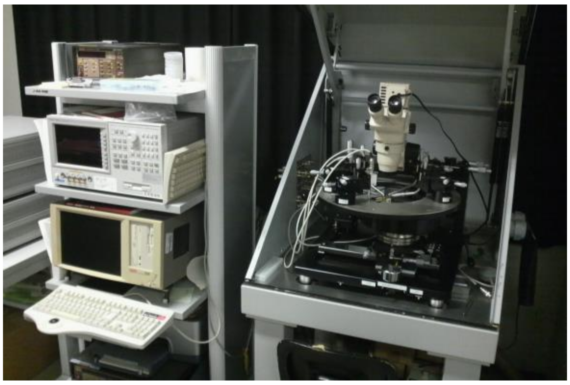
◆ Focused ion beam (FIB) system (Hitachi FB-2000)

集束イオンビーム加工装置
（日立 FB-2000）最小ビーム径 10nm



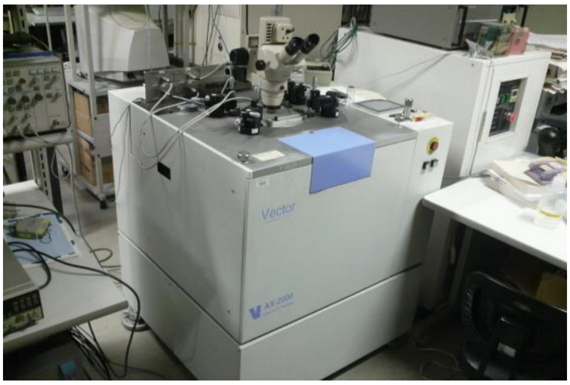
◆ Manual wafer prober (Vector Semiconductor) and semiconductor parameter analyzer (Keithley)

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 scaled MOS devices and TFTs

[1] S-I. Kuroki, H. Nagatsuma, M. De Silva, S. Ishikawa, T. Maeda, H. Sezaki, T. Kikkawa, T. Makino, T. Ohshima, M. Östling, and C.-M. Zetterling, “Characterization of 4H-SiC nMOSFETs in Harsh Environments, High-Temperature and High Gamma-Ray Radiation,” Mat. Sci. Forum, **858**, pp. 864-867, 2016.

[2] M. D. Silva, S. Ishikawa, T. Kikkawa, and S-I. Kuroki, “Low resistance ohmic contact formation on 4H-SiC c-face with NbNi silicidation using nano-second laser annealing,” Mat. Sci. Forum, **858**, pp. 549-552, 2016.

[3] H. Nagatsuma, S-I. Kuroki, M. De Silva, S. Ishikawa, T. Maeda, H. Sezaki, T. Kikkawa, M. Östling, and C.-M. Zetterling, “4H-SiC nMOSFETs with As-doped S/D and NbNi Silicide ohmic contacts,” Mat. Sci. Forum, **858**, pp. 573-576, 2016.

[4] Y. Furubayashi, T. Tanehira, K. Yonemori, N. Seo, and S-I. Kuroki, “3D Integration of Si-based Peltier device onto 4H-SiC power device,” Mat. Sci. Forum, **858**, pp. 1107-1111, 2016.

[5] S-I. Kuroki, T. Hirata, N. T. Thi, K. Kotani, and T. Kikkawa, “Poly-Si TFTs with One-dimensionally Long Silicon Crystal Grains Using DLB Continuous-wave Laser Lateral Crystallization,” iMiD 2015: The 15th International Meeting on Information Display, ISSN 1738-1558, Daegu, Korea, 55-1, p. 250, 2015 (Invited).

[6] S-I. Kuroki, H. Nagatsuma, M. De Silva, S. Ishikawa, T. Maeda, H. Sezaki, T. Kikkawa, T. Makino, T. Ohshima, M. Östling, and C.-M. Zetterling, “Characterization of 4H-SiC nMOSFETs in Harsh Environments; High Temperature and High Gamma-Ray Radiation,” The International Conference on Silicon Carbide and Related Materials 2015(ICSCRM2015), Giardini Naxos, Italy, We-P-60, 2015.

[7] H. Nagatsuma, S-I. Kuroki, M. De Silva, S. Ishikawa, T. Maeda, H. Sezaki, T. Kikkawa, M. Östling, and C.-M. Zetterling, “4H-SiC nMOSFETs with As-doped S/D and NbNi silicide ohmic contacts,” The International Conference on Silicon Carbide and Related Materials 2015 (ICSCRM2015), Giardini Naxos, Italy, Mo-P-26, 2015.

[8] M. D. Silva, S. Ishikawa, T. Kikkawa, and S-I. Kuroki, “Low resistance ohmic contact formation on 4H-SiC c-face with NbNi silicidation using nano-second laser annealing,” The International Conference on Silicon Carbide and Related Materials 2015 (ICSCRM2015), Giardini Naxos, Italy, Mo-P-21, 2015.

[9] Y. Furubayashi, T. Tanehira, K. Yonemori, N. Seo, and S-I. Kuroki, “3D Integration of Si-based Peltier device onto 4H-SiC power device,” The International Conference on Silicon Carbide and Related Materials 2015 (ICSCRM2015), Giardini Naxos, Italy, Mo-P-32, 2015.

[10] H. Nagatsuma, S-I. Kuroki, M. De Silva, S. Ishikawa, T. Maeda, H. Sezaki, T, Kikkawa, M. Östling, and C.-M. Zetterling, “Characterization of 4H-SiC nMOSFETs with As-doped S/D and NbNi Silicide Contacts After

High Gamma-Ray Radiation," Proceedings of The 11th International Workshop on Radiation Effects on Semiconductor Devices for Space Applications (RASEDA2015), Kiryu, Japan, P5-9, pp. 117-118, 2015.

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[12] N. Matsuo, T. Takada, A. Heya, K. Yamana, T. Sato, S. Yokoyama, and Y. Omura, "Blockade and Staircase Phenomena of Holes in Mesoscopic Scale -Deoxyribonucleic Acid (DNA) / SiO2/ Si Structure," IEEE Electron Device Letters 37, pp.224-227, 2016.

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[14] M. Akazawa, K. Sakaike, and S. Higashi, "Formation of silicon-on-insulator layer with midair cavity for meniscus force-mediated layer transfer and high-performance transistor fabrication on glass," Jpn. J. Appl. Phys., **54**, pp. 086503-1 - 086503-7, 2015.

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[18] R. Ishimaru, H. Hanafusa, K. Maruyama, S. Higashi, "Atmospheric Pressure Thermal-Plasma-Jet Oxidation of 4H-SiC," 68th Annual Gaseous Electronics Conference/9th International Conference on Reactive Plasmas/33rd Symposium on Plasma Processing (ICRP-9/GEC-68/SPP-33), Honolulu, Hawaii, 2015.

[19] S. Morisaki, T. Nakatani, R. Shin, S. Higashi, "Atmospheric Pressure Micro-Thermal-Plasma-Jet Crystallization of Amorphous Silicon Strips for High-Performance Thin Film Transistor Fabrication," 68th Annual Gaseous Electronics Conference/9th International Conference on Reactive Plasmas/33rd Symposium on Plasma Processing (ICRP-9/GEC-68/SPP-33), Honolulu, Hawaii, 2015.

[20] H. Hanafusa, K. Maruyama, R. Ishimaru, S. Higashi, "High Efficiency Activation of Phosphorus Atoms in 4H‐SiC by Atmospheric PressureThermal Plasma Jet Annealing," 16th International Conference on Silicon Carbide and Related Materials (ICSCRM 2015), Giardini, Naxos, Italy, 2015.

[21] M. Akazawa, S. Takeshima, A. Nakagawa, K. Hiramatsu and S. Higashi, "Formation of Single Crystalline Silicon with Midair Cavity for Meniscus Force-Mediated Local Layer Transfer and Fabrication of High-

Performance MOSFETs on Insulator," Ext. Abs. 2015 Int. Conf. Solid State Dev. Mat. (SSDM2015), Sapporo, Japan, pp. 36-37, PS-1-15, 2015.

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6.1.5 CVD and contamination/particle control

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