# ANNUAL RESEARCH REPORT

## Vol. 11

April 2018 - March 2019

# 研究成果報告書

## 第 11 巻

平成 30 年 4 月—平成 31 年 3 月

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 33 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, 2019

Seiichiro Higashi
Director
Research Institute for Nanodevice and Bio Systems
Hiroshima University, Japan

# 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。

2019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　　　　　　東　清一郎

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**Director**
**所長**

**Executive Committee**
**運営委員会**

**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,
2 Special Appointment Assistant Professors
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 2名

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

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

### 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
# (2018年12月1日時点)

## Nanointegration Research Division

### ナノ集積科学研究部門

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

## Integrated Systems Research Division

## 集積システム科学研究部門

| | |
|---|---|
| Minoru Fujishima<br>藤島 実 | Professor<br>教授(併任) |
| Idaku Ishii<br>石井 抱 | Professor<br>教授(併任) |
| Kazufumi Kaneda<br>金田 和文 | Professor<br>教授(併任) |
| Tetsushi Koide<br>小出 哲士 | Associate Professor<br>准教授 |
| Tsuyoshi Yoshida<br>吉田 毅 | Associate Professor<br>准教授(併任) |
| Toru Tamaki<br>玉木 徹 | Associate Professor<br>准教授(併任) |
| Takeshi Takaki<br>高木 健 | Associate Professor<br>准教授(併任) |

## Molecular Bio-information Research Division

## 分子生命情報科学研究部門

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

## Nanomedicine Research Division

## 集積医科学研究部門

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

## Nanotechnology Platform

## ナノテクノロジープラットフォーム

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

## Visiting Professor

## 客員教授

| | |
|---|---|
| Yuji Miyahara<br>宮原　裕二 | Visiting Professor<br>客員教授 |
| Takashi Ito<br>伊藤　隆司 | Visiting Professor<br>客員教授 |
| Hiroshi Ohki<br>大木　博 | Visiting Professor<br>客員教授 |
| Seiichi Miyazaki<br>宮崎　誠一 | Visiting Professor<br>客員教授 |

| | |
|---|---|
| Ryo Miyake<br>三宅　亮 | Visiting Professor<br>客員教授 |
| Shigeto Yoshida<br>吉田　成人 | Visiting Professor<br>客員教授 |
| Koichi Ito<br>伊藤　公一 | Visiting Professor<br>客員教授 |
| Takeshi Tanaka<br>田中　武 | Visiting Professor<br>客員教授 |
| Katia Zheleva Vutora | Visiting Professor<br>客員教授 |
| Hideki Murakami<br>村上　秀樹 | Visiting Associate Professor<br>客員准教授 |

## Researchers

## 研究員

| | |
|---|---|
| Tadashi Sato<br>佐藤　旦 | Researcher, Nanotechnology Platform<br>ナノテクノロジープラットフォーム研究員 |
| Tatsuya Meguro<br>目黒　達也 | Researcher<br>研究員 |
| Azhari Afreen<br>アズハリ　アフリーン | Researcher<br>研究員 |
| Shinji Yamada<br>山田　真司 | Research Associate<br>教育研究補助職員 |
| Kazushi Okada<br>岡田　和志 | Research Associate<br>教育研究補助職員 |

## Advisory Board

## 顧問

| | |
|---|---|
| Masataka Hirose<br>廣瀬　全孝 | Professor Emeritus, Hiroshima University<br>広島大学名誉教授 |

## Visiting Staff

## 客員スタッフ

| | |
|---|---|
| Hirofumi Fukumoto<br>福本　博文 | Visiting Scientist, Asahi Kasei Corporation<br>客員研究員，旭化成(株) |
| Tomonori Maeda<br>前田　知徳 | Visiting Scientist, Phenitec Semiconductor Corporation<br>客員研究員，フェニテックセミコンダクター(株) |
| Seiji Ishikawa<br>石川　誠治 | Visiting Scientist, Phenitec Semiconductor Corporation<br>客員研究員，フェニテックセミコンダクター(株) |
| Hiroshi Sezaki<br>瀬崎　洋 | Visiting Scientist, Phenitec Semiconductor Corporation<br>客員研究員，フェニテックセミコンダクター(株) |
| Hirofumi Tanaka<br>田中　博文 | Visiting Scientist, Mitsui Chemicals Incorporated<br>客員研究員，三井化学(株) |
| Jun Kamata<br>鎌田　潤 | Visiting Scientist, Mitsui Chemicals Incorporated<br>客員研究員，三井化学(株) |
| Yasuhisa Kayaba<br>茅場　靖剛 | Visiting Scientist, Mitsui Chemicals Incorporated<br>客員研究員，三井化学(株) |
| Takeshi Kumaki<br>熊木　武志 | Visiting Scientist, Department of VLSI System Design, College of Science & Enginnering, Ritsumeikan University<br>客員研究員，立命館大学理工学部電子情報デザイン学科 |
| Kenji Sakamoto<br>坂本　憲児 | Visiting Scientist, Center for Microelectronic System, Kyusyu Institute of Technology<br>客員研究員，九州工業大学マイクロ化総合技術センター |
| Akihiro Toya<br>外谷　昭洋 | Visiting Scientist, Kure National College of Technology<br>客員研究員，呉工業高等専門学校 |
| Toshihiko Ohta<br>太田　年彦 | Visiting Scientist, Sharp Takaya Electronic Industry Corporation<br>客員研究員，シャープタカヤ電子工業(株) |
| Hiromasa Watanabe<br>渡邉　礼方 | Visiting Scientist, Sharp Takaya Electronic Industry Corporation<br>客員研究員，シャープタカヤ電子工業(株) |
| Jyunichi Sunada<br>砂田　潤一 | Visiting Scientist, Sharp Takaya Electronic Industry Corporation<br>客員研究員，シャープタカヤ電子工業(株) |
| Eiji Suematsu<br>末松　英治 | Visiting Scientist, Sharp Corporation<br>客員研究員，シャープ(株) |
| Atsushi Iwata<br>岩田　穆 | Visiting Scientist, Sharp Corporation<br>客員研究員, (株)エイアールテック |

| | |
|---|---|
| Yositaka Murasaka<br>村坂　佳隆 | Visiting Scientist, Sharp Corporation<br>客員研究員, (株)エイアールテック |
| Takafumi Ohmoto<br>大本　貴文 | Visiting Scientist, Sharp Corporation<br>客員研究員, (株)エイアールテック |
| Toshifumi Imamura<br>今村　俊文 | Visiting Scientist, Sharp Corporation<br>客員研究員, (株)エイアールテック |
| Tomoaki Maeda<br>前田　智晃 | Visiting Scientist, Sharp Corporation<br>客員研究員, (株)エイアールテック |
| Masahiro Ono<br>小野　将寛 | Visiting Scientist, Sharp Corporation<br>客員研究員, (株)エイアールテック |
| Yoshihiro Masui<br>升井　義博 | Visiting Scientist, Hiroshima Institute of Technology<br>客員研究員, 広島工業大学 |
| Kazuyoshi Nishino<br>西野　和義 | Visiting Scientist, Shimadzu Corporation<br>客員研究員, (株)島津製作所 |
| Hang Song<br>宗　航 | Visiting Scientist<br>客員研究員 |

## Supporting Staff
## 支援スタッフ

| | |
|---|---|
| Shusaku Mohri<br>毛利　周作 | Finance Affairs<br>財務担当 |
| Masahide Sasaki<br>佐々木　雅英 | General Affairs<br>総務担当 |
| Chikahisa Machida<br>町田　親久 | Office Assistant<br>事務補佐員 |
| Chiaki Ashihara<br>葦原　千秋 | Office Assistant<br>事務補佐員 |
| Naoko Nakatani<br>中谷　尚子 | Office Assistant<br>事務補佐員 |
| Junko Hinohara<br>樋原　純子 | Office Assistant<br>事務補佐員 |
| Izuko Kushida<br>串田　何子 | Office Assistant<br>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

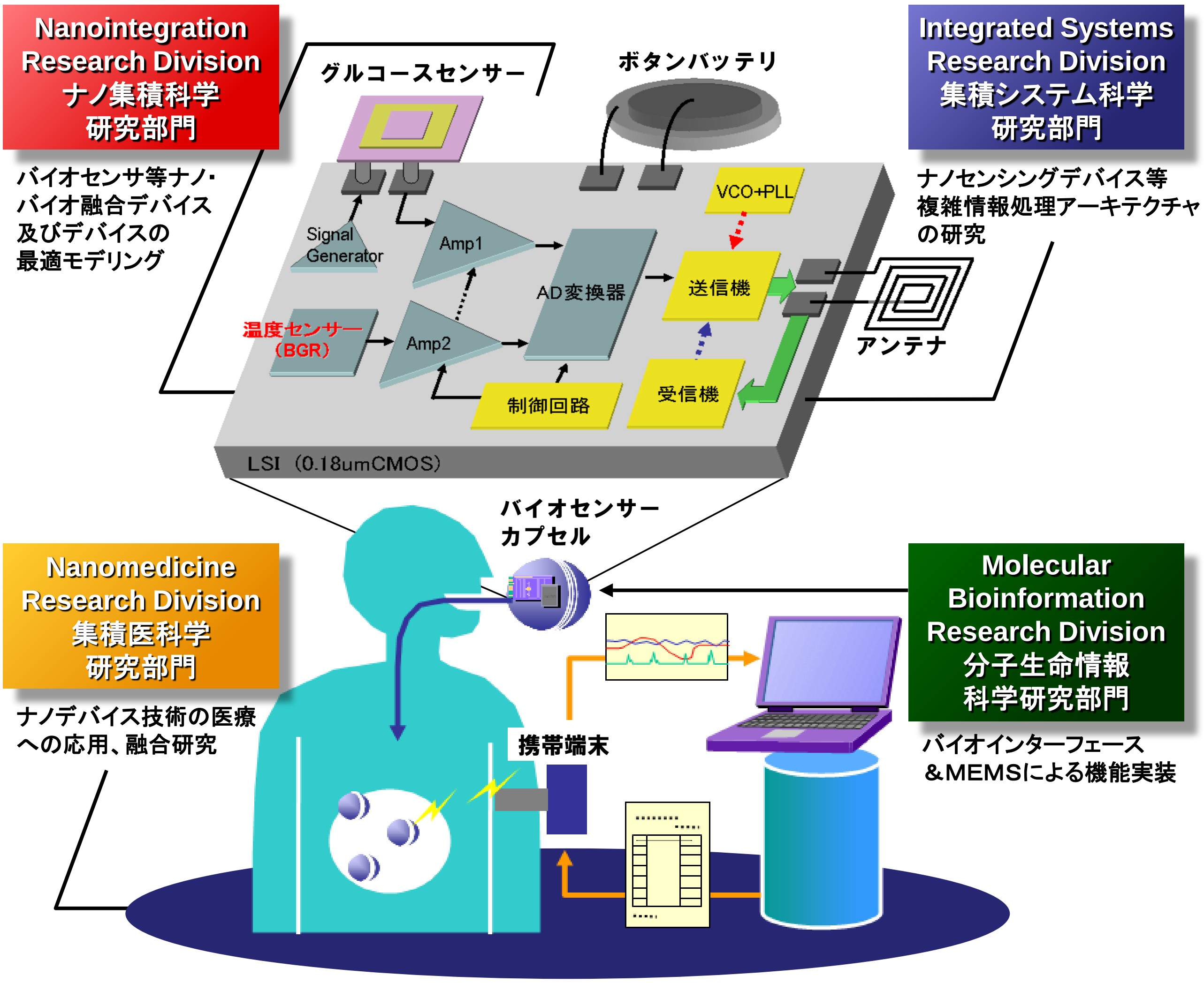
| | | |
|---|---|---|
| Shin Yokoyama<br>横山　新 | Director and Professor<br>研究所長・教授 | RNBS<br>ナノデバイス・バイオ融合科学研究所 |
| Seiichiro Higashi<br>東　清一郎 | Associate Director and Professor<br>副研究所長・教授 | Graduate School of Advanced Sciences of Matter<br>先端物質科学研究科 |
| Hiroki Nikawa<br>二川　浩樹 | Associate Director and Professor<br>副研究所長・教授 | Graduate School of Biomedical Sciences<br>医歯薬保健学総合研究科（歯） |
| Masakazu Iwasaka<br>岩坂　正和 | Professor<br>教授 | RNBS<br>ナノデバイス・バイオ融合科学研究所 |
| Yutaka Kadoya<br>角屋　豊 | Professor<br>教授 | Graduate School of Advanced Sciences of Matter<br>先端物質科学研究科 |
| Minoru Fujishima<br>藤島　実 | Professor<br>教授 | Graduate School of Advanced Sciences of Matter<br>先端物質科学研究科 |
| Yositake Takane<br>高根　美武 | Professor<br>教授 | Graduate School of Advanced Sciences of Matter<br>先端物質科学研究科 |
| Toshikazu Ekino<br>浴野　稔一 | Professor<br>教授 | Graduate School of Integrated Arts and Sciences<br>総合科学研究科 |
| Yoshihiro Kuroiwa<br>黒岩　芳弘 | Professor<br>教授 | Graduate School of Science<br>理学研究科 |
| Toshio Tsuji<br>辻　敏夫 | Professor<br>教授 | Institute of Engineering<br>工学研究院 |
| Yoshihiro Sanbongi<br>三本木　至宏 | Professor<br>教授 | Graduate School of Biosphere Sciences<br>生物圏科学研究科 |
| Michihiro Hide<br>秀　道広 | Professor<br>教授 | Graduate School of Biomedical Sciences<br>医歯薬保健学総合研究科（医） |
| Koichi Kato<br>加藤　功一 | Professor<br>教授 | Graduate School of Biomedical Sciences<br>医歯薬保健学総合研究科（歯） |
| Anri Nakajima<br>中島 安理 | Associate Professor<br>准教授 | RNBS<br>ナノデバイス・バイオ融合科学研究所 |
| Tetsushi Koide<br>小出 哲士 | Associate Professor<br>准教授 | RNBS<br>ナノデバイス・バイオ融合科学研究所 |
| Shin-Ichiro Kuroki<br>黒木 伸一郎 | Associate Professor<br>准教授 | RNBS<br>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.

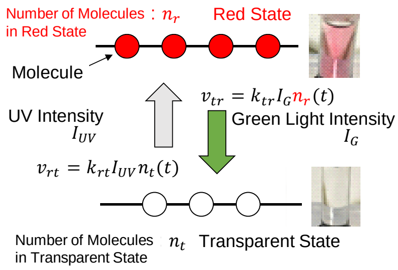
ナノ集積科学研究部門では、ナノデバイス、プロセス、ナノインテグレーション、ナノバイオ融合デバイス、フォトニックデバイス、ナノ量子デバイス、薄膜デバイス、ナノデバイスモデリング、機能性材料等に関する研究を行っている。ナノ集積科学研究部門における研究の主なものの概要を紹介する。

### フォトクロミック材料の光応答のモデル化
### Modeling of Photoresponse of Photochromic Material

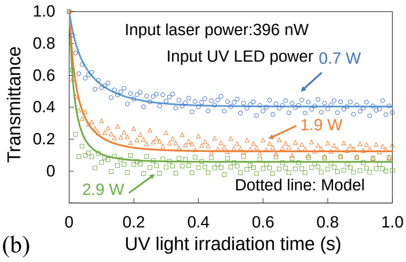
**教授　横山　新**
**Prof. Shin Yokoyama**

光ニューラルネットワーク構築を目的とし、フォトクロミック材料を用いてシナプスを模倣する研究を行った。ジアリールエテンとよばれる、紫外線によって赤色に変色し、緑色光によって透明にもどる材料を導波路に添加し、シナプス同様、通過緑色光量が増すほど光透過率が増加する特性を確認した。その光応答特性をモデル化し、応用に適した条件を決定することが可能になった。

We are conducting research on imitating synapses using photochromic materials with the aim of constructing optical neural networks. A material called diarylethene, which changes color to red by ultraviolet light and returns to transparent by green light, was added to the waveguide, and as in the case of synapses, it was confirmed that the light transmittance increased as increasing the amount of transmitted green light. By modeling the optical response, it became possible to determine the conditions suitable for the application.



(a)



(b)

(a) 光応答モデル、(b) 実験結果とモデルの比較

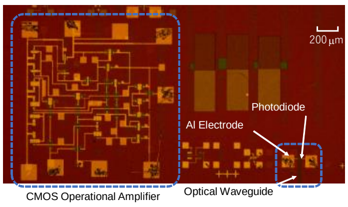
(a) Photoresponse model, (b) comparison between experiment and model.

### CMOS アンプ内蔵光電子集積回路の研究
### Study of Optoelectronic Integrated Circuits with CMOS Amplifier

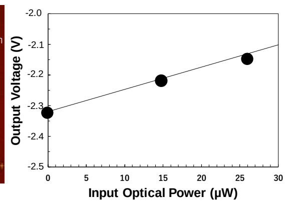
**教授　横山　新**
**Prof. Shin Yokoyama**

光電子集積回路(OEIC)は、高速・高機能な次世代の集積回路として注目されている。OEICをモノリシックに集積する技術を開発した。チップは、本研究所のクリーンルームにおいて製作された。入力した光パワーとCMOS 演算増幅器の出力は良好な線形関係を示した。この技術は、光バイオセンサーや光ニューラルネットワークへの応用が期待される。

Optoelectronic integrated circuit (OEIC) has attracted attention as a next-generation high-speed, high-performance integrated circuit. We developed a technology to monolithically integrate an OEIC on a single chip. The chips were fabricated in the clean room of our laboratory. The optical power input versus output of the CMOS operational amplifier showed a good linear relationship. This technology is expected to be applied to optical biosensors and optical neural networks.



(a)



(b)

(a) 製作した CMOS 演算増幅器、光導波路、フォトダイオードをモノリシックに集積した光電子集積回路
(b) 光入力とアンプ出力の関係

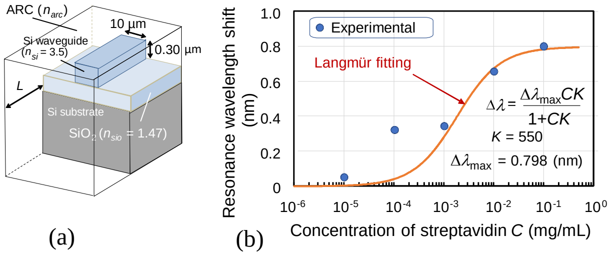
(a) Optical micrograph of fabricated monolithic optoelectronic integrated circuits with CMOS operation amplifier, waveguide and photodiode.
(b) Relation between optical input and amplifier output.

## 反射防止膜を付与した光バイオセンサー
## Optical Biosensor with Antireflection Coating


教授　横山　新
Prof. Shin Yokoyama


Si リング光共振器バイオセンサーにおいて、光入出力を行う導波路端面の光反射を防止することは、ファブリペロー光共振の抑制及び光強度増大によるノイズ低減に有効であり、バイオセンサーの感度向上に繋がる。SiN 反射防止膜(ARC)を付与し、ビオチン-ストレプトアビジン反応の検出を試みた結果、従来に比べ 10 倍感度が向上した。

In Si ring optical resonator biosensors, preventing light reflection at the waveguide edge for optical input/output is effective in suppressing Fabry-Perot optical resonance and reducing noise due to increased light intensity. This leads to improved sensitivity. As a result of applying a SiN anti-reflection coating (ARC), detection sensitivity of the biotin-streptavidin reaction was 10 times improved compared to the conventional method.



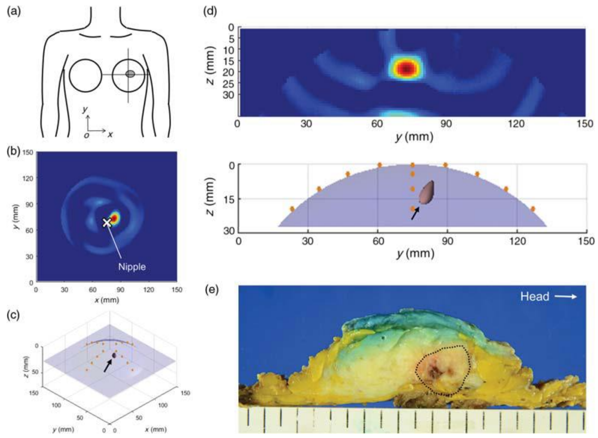

(a) 反射防止膜を付与したバイオセンサー端部の構造
(b) ビオチンーストレプトアビジン反応検出結果
(a) Structure at the antireflection coating/ waveguide edge.
(b) Detection result of biotin-streptavidin reaction.

## 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（特任）
Prof. Takamaro Kikkawa


携帯型インパルス超広帯域電波を使った乳がん検出レーダー装置を開発し、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ました。

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. (Journal of Medical Imaging, 2018)



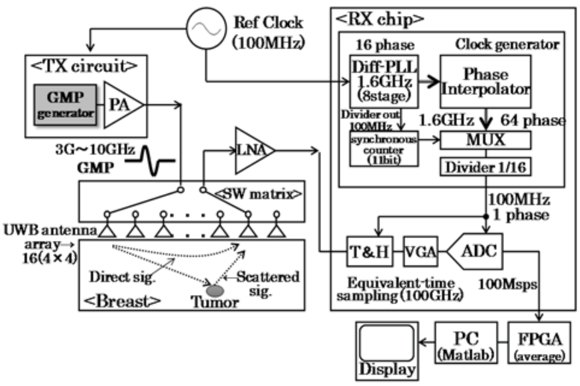

パイロット臨床試験
Comparison between images acquired by the prototype and the resected specimen.

## シングルチップレーダーCMOS-LSI
## Single-Chip Radar CMOS-LSI


教授　吉川公麿（特任）
Prof. Takamaro Kikkawa


超広帯域ガウシアンモノサイクルインパルス電波を用いた乳がん検出用レーダーCMOS－LSI を 65nm テクノロジーで設計試作した。 内部には送信回路、受信回路、トラックアンドホールド回路、8bit-ADC 回路を有している。

A single-chip CMOS-LSI for radar-based breast cancer detection was developed by the use of 65 nm silicon technology and ultra-wide-band Gaussian monocycle pulse. (BioCAS 2018)



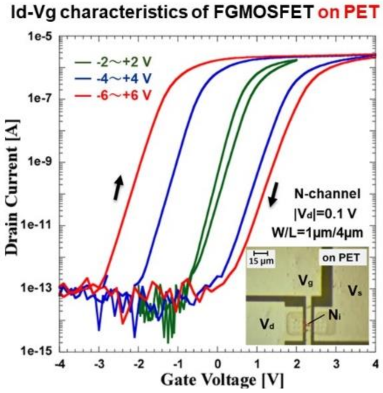

シングルチップレーダー用 CMOS-LSI 回路ブロック図
A single-chip radar CMOS-LSI circuit block.

## プラスチック上のフローティングゲート MOSFET メモリ動作
## Memory Operation of Floating Gate MOSFETs on Plastic Substrate


教授　東　清一郎（併任）
Prof. Seiichiro Higashi


水のメニスカス力を利用して SOI ウエハ上の単結晶シリコン層をプラスチック（PET）基板に転写する技術において、PET 表面の洗浄法改善と濡れ性制御によって 99.97%の転写歩留まりを達成した。転写したシリコン層をチャネルとした MOSFET 構造中に Ni フローティングゲートを導入し、130℃の低温でデバイス作製プロセスを構築し、メモリ動作に成功した。

A high transfer yield of 99.97% has been achieved by meniscus force mediated layer transfer of SOI to plastic (PET) substrate based on improved surface cleaning and wettability control. By introducing Ni floating gate layer into gate dielectric of MOSFET, clear memory operation of the device fabricated at 130ºC on PET has been observed.




PET 基板上に 130℃プロセスで作製したフローティングゲート MOSFET の $I_d$–$V_g$ 特性. ゲート電圧掃引による明瞭なメモリ動作を確認した

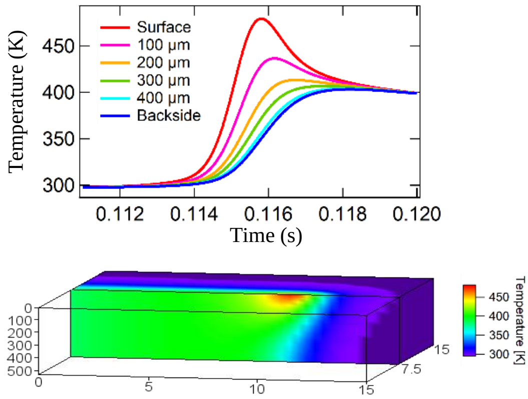
$I_d$-$V_g$ characteristics of floating gate MOSFET fabricated at 130ºC on PET. Clear memory operation during the gate voltage sweep is observed.

## プラズマプロセス中のシリコンウエハ温度の精密非接触測定
## Precise Non-contact Measurement of Silicon Wafer Temperature during Plasma Processing


教授　東　清一郎（併任）
Prof. Seiichiro Higashi


大気圧熱プラズマジェット（TPJ）照射中のシリコンウエハ内温度分布を非接触で精密測定するために、熱光学係数（TOC）の精密測定および過渡熱伝導解析モデルの三次元化をおこなった。熱電対（TC）との比較から、ミリ秒時間分解で±2℃以下の精度で温度測定可能であることが明らかになった。

Temperature distribution inside silicon wafer during rapid plasma processing has been precisely observed by a Optical Interference Contactless Thermometer (OICT). Improvements in thermo-optic coefficient (TOC) and three-dimensional heat diffusion and optical simulation model achieved +/-2ºC accuracy on the basis of comparison with thermos couple (TC) measurements.




大気圧熱プラズマジェット（TPJ）照射急速熱処理中のシリコンウエハ内部温度の時間変化（上）と、ウエハ内部の三次元温度分布（下）

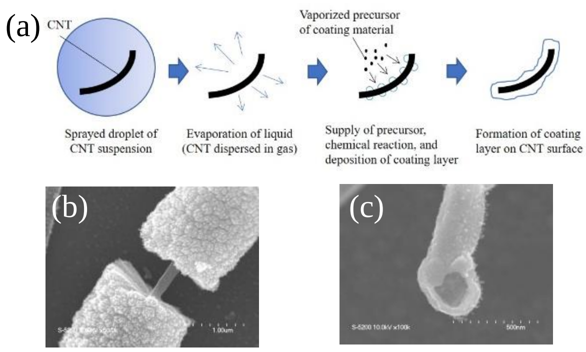
Transient temperature variation inside silicon wafer during atmospheric pressure thermal plasma jet (TPJ) irradiation and three-dimensional temperature distribution.

## 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)気相浮遊コーティング法による多層カーボンナノチューブ（MWCNT）複合体の作製の概念；(b)作製された酸化チタン被覆 MWCNT；(c)酸化チタン被覆と MWCNT の焼成除去で得られた中空酸化チタンナノチューブ

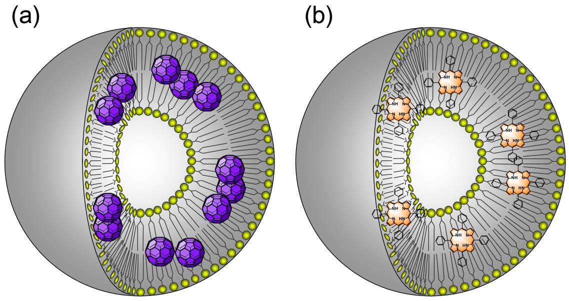
Concept of preparation of multi-walled carbon nanotube (MWCNT) composite by the ‘in-flight’ coating technique; (b) MWCNT coated with titanium dioxide; (c) hollow titanium dioxide nanotube obtained by coating and removal of MWCNT.

## 可溶化剤で水溶化した光増感剤を用いる光線力学治療薬の開発
## Development of Photosensitizers 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.



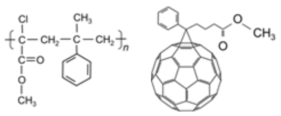

可溶化剤としてリポソームを用いた(a)フラーレンまたは(b)リポソーム含有脂質膜
Lipid-membrane-incorporated (a) fullerenes and (b) porphyrins using liposomes as a solubilizing agent.

## 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

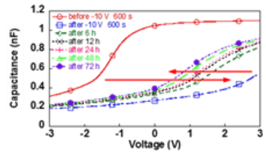
准教授　中島安理
Assoc. Prof. Anri Nakajima

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ます。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。

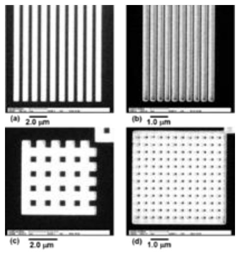
Fullerene-incorporated electron beam (EB) organic resists are developed to realize high integration of nanometer lateral-scale organic electronic devices. The structures of nanoscale dots and nanowires having electrical conductivity are able to be fabricated with a simple fabrication process of only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



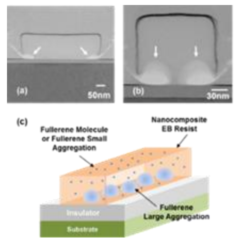
ZEP520a と PCBM
ZEP520a and PCBM.




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.



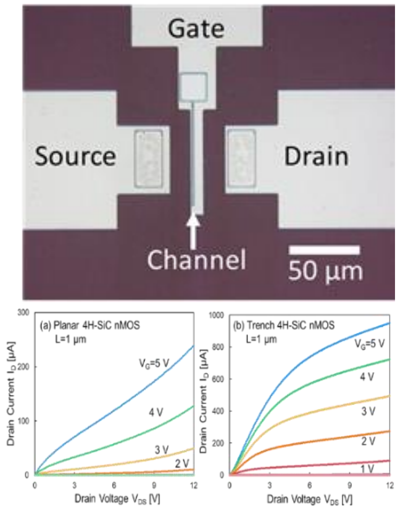
ナノワイヤ構造の透過電子顕微鏡像とフラーレンの分布
TEM of micrograph of nanowire and PCBM distribution.

## 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 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。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、さらに短チャネル効果抑制を実証した。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. By this structure, short-channel effects are suppressed. This research is carried out under the collaboration with KTH Royal Institute of Technology, Sweden, QST and Phenitec Semiconductor Co. Ltd., Japan.



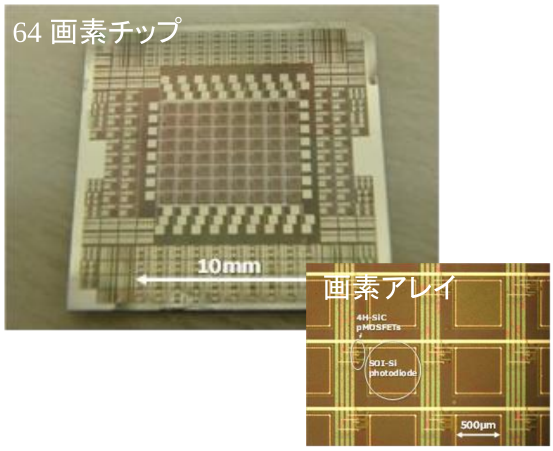

SiC 短チャネル MOSFETs
SiC short channel MOSFETs.

## SiC 半導体と SOI 基板による耐放射線イメージセンサの研究
### SiC 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 1 画素とし、64 画素を同一基板上に集積しその動作を実証した。これらの成果は ICSCRM2019 などで発表しました。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 64-pixel devices with SOI wafer and 4H-SiC had been developed. These results were reported at ICSCRM2019. This research has been carried out under the collaboration with AIST and QST, Japan.



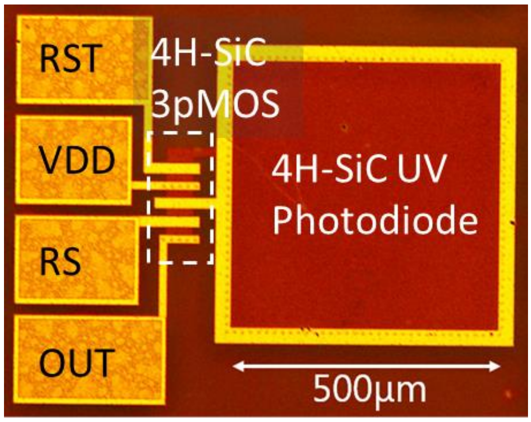

4H-SiC/ SOI-Si 耐放射線ハイブリッド画素デバイス
4H-SiC/ SOI-Si hybrid pixel device for Rad-Hardened image sensor.

## フル SiC 耐放射線 UV イメージセンサの研究
### Radiation-Hardened Full-SiC UV Pixel Devices

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

今後のデブリ取り出しなどを見据え、フォトダイオードも SiC で作製したフル SiC UV（紫外光）イメージセンサを提案し、実証研究を進め、3 MGy 以上のガンマ線照射後も駆動可能であることを示しました、これらの成果は ICSCRM2019 などで発表しました。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。

Full SiC pixel devices for a radiation hardened UV image sensors had been demonstrated. These results were reported at ICSCRM2019. This research has been carried out under the collaboration with AIST and QST, Japan.



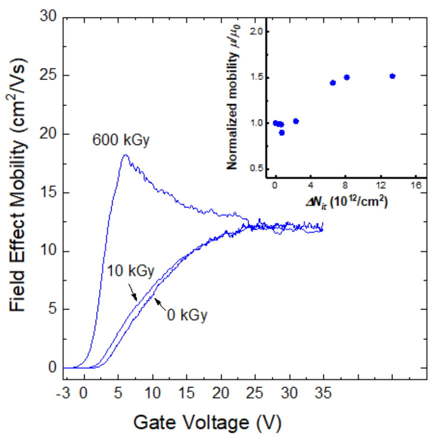

フル 4H-SiC UV ピクセルデバイス（1 画素デバイス）
Full 4H-SiC pixel device for Rad-Hardened UV image sensor.

## 4H-SiC MOSFETs へのガンマ線照射効果
### Gamma-Ray Exposure Effects on 4H-SiC MOSFETs

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

シリコンカーバイド（SiC）MOSFETs の反転層移動度向上技術として MOS 界面への BaO 導入の研究を進めた。ガンマ線照射効果の実験を進め、照射による移動度向上などを実験的に示した。本成果は Jpn. Jour. Appl. Phys.誌などに掲載された。この研究はフェニテックセミコンダクター社、量研機構などとの共同研究である。

BaO thin films are introduced to 4H-SiC MOS interface for enhancing carrier mobility. Gamma-ray radiation effects are also investigated. This research has been carried out under the collaboration with Phenitec Semiconductor Co. Ltd., and QST, Japan.



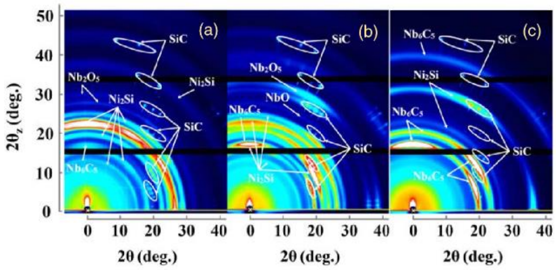

ガンマ線照射前後の BaO を界面に有する 4H-SiC MOSFET の電界効果移動度
Field effect mobility of the 4H-SiC NMOSFET with BaO before and after irradiation.

## 4H-SiC 上のオーミック電極の高温信頼性評価
## High-Temperature Reliability of Ni/Nb Ohmic Matals on 4H-SiC

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

4H-SiC 上のオーミック電極の高温信頼性評価を進めています。400℃で 100 時間の信頼性評価をシリサイド膜の組成比を変え、評価いたしました。これらの成果は ICSCRM2019 や Jpn. Jour. Appl. Phys.などで発表しました。本研究はフェニテックセミコンダクター社、SPring8、東北大学などとの共同研究である。

400℃ High temperature reliability of ohmic contacts on 4H-SiC at has been investigated. The results were reported at ICSCRM2019 and Jpn. Jour. Appl. Phys. This research has been carried out under the collaboration with Phenitec Semiconductor Co. Ltd., SPring8, and Tohoku University.



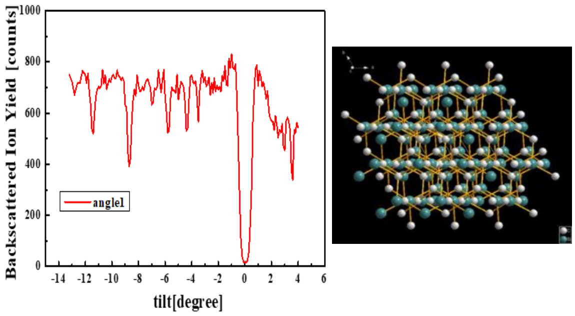

4H-SiC 上の NiNb シリサイド・オーミックコンタクトの 2 次元 XRD 像(膜厚依存性)
2D-XRD images of (a) Ni(75 nm)/Nb(25 nm)/4H-SiC, (b) Ni(50 nm)/Nb(50 nm)/4H-SiC and (c) Ni(25 nm)/Nb(75 nm)/4H-SiC contacts after annealing at 1000 °C for 3 min.

## 4H-SiC へのイオン注入における不純物制御
## Ion-Implantation on 4H-SiC

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

シリコンカーバイド(SiC)デバイスでのイオン注入高精度制御のために、イオン注入の研究を進めた。特にイオンビームによるチャネリング実験と実デバイスでの比較評価を進めることで、膜厚方向での不純物制御向上を行った。これらの成果は ICSCRM2019 などで発表しました。本研究は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。

Ion implantation on 4H-SiC has been investigated. By combining ion-channeling experiments and device fabrications, precise control of impurity in 4H-SiC substrate was achieved. The results were reported at ICSCRM2019. This research has been carried out under the collaboration with Phenitec Semiconductor Co. Ltd.



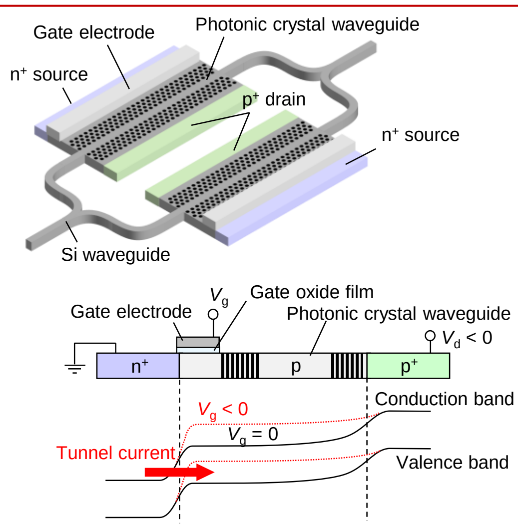

4H-SiC でのイオンチャネリング実験の結果(左図)とチャネリング抑制面での結晶モデル(右図)
Result of ion-channeling experiments (left hand side) and crystal model for ion-channeling suppression crystal face.

## 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

トンネル電界効果トランジスタ(TFET)を位相変調器として利用した、低電圧駆動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。現在、位相変調器用に構造を改善した TFET の電気的特性を検証している。

We study a low drive voltage Mach-Zehnder type silicon optical modulator using a tunnel field effect transistor (TFET) as a phase shifter. Currently, electrical characteristics of a TFET with an improved structure for a phase shifter are investigated.



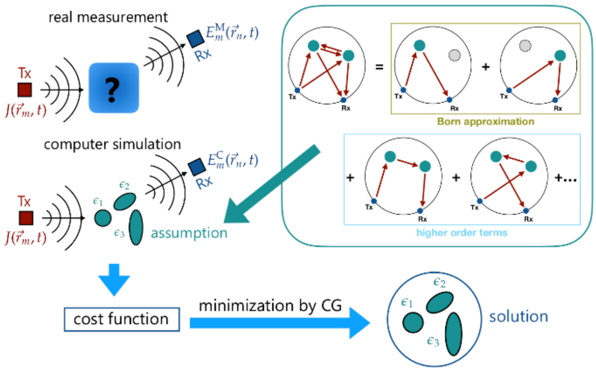

TFET 位相変調器の断面構造とバンド図
Cross-sectional structure and band diagram of TFET phase shifter.

## マイクロ波イメージングの研究
Microwave Imaging

助教　石川智己（特任）
Assist. Prof. Tomomi Ishikawa

マイクロ波を用いた撮像法(MWI)に関するアルゴリズムの研究を行なっている。MWI では電磁波を照射、対象物体で散乱、そして受信アンテナで得られたデータから物体の形状、電気的性質を得る。そこで必要となる計算アルゴリズムの開発、また計算の高速化等を行っている。

Microwave imaging and its computing algorithms are studied. The most desired strategy for the imaging is computed tomography (CT), which is time-consuming and sometimes ill-posed. Our research aims at code development of the imaging using the CT as well as the conventional confocal method.



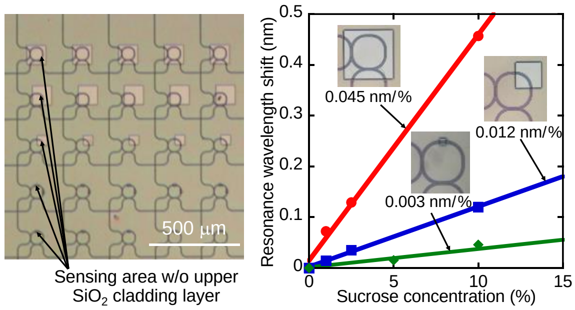

ボルン近似を用いたトモグラフィ技術の概念図
A sketch of the CT method using Born approximation. Measurements are carried out using an impulse-radar detector. The target dielectric properties are obtained by solving an inverse problem, where the iterative cost function minimization process is employed.

## 集積化シリコン光共振器バイオセンサー
Integrated Silicon Optical Resonator Biosensors

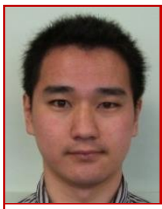
助教　雨宮嘉照（特任）
Assist. Prof. Yoshiteru Amemiya

シリコンフォトニクス技術を用いて、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。多項目や広範囲の濃度の検出が可能な光共振器を集積化させたチップを作製し、温度モニタやショ糖濃度検出について評価した。

We aim to realize biosensor chips for diagnosis of diseases and vital monitoring using silicon photonics technology. An optical biosensor chip with integrated optical resonators was fabricated, in which multiple-item and wide-range sensing are possible. Temperature monitoring and sucrose concentration sensing have been investigated.




集積化した光共振器の光学顕微鏡写真と共振波長シフト量のショ糖濃度依存性
Optical micrograph of integrated optical resonators and sucrose concentration dependence of resonance wavelength shift.

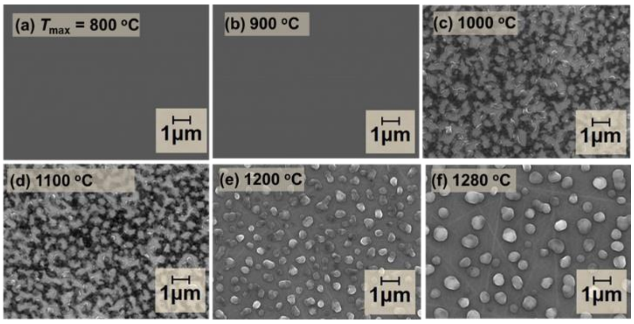


## Si/SiC ヘテロ接合によるバンドアライメント制御の研究
Band-Alignment Control by Si/SiC Hetero-Structure

助教　花房宏明（併任）
Assist. Prof. Hiroaki Hanafusa

Si と SiC のヘテロ接合とアニール処理を組み合わせることで Si の融点を大きく下回る温度で Si 層がドット化する現象とそれにより電極金属のシリサイド化を行わずに低抵抗コンタクトが形成される現象について研究を進めている。

We are studying mechanism of Si dots formation that caused by annealing of Si/SiC hetero structure at below the Si melting point. We also investigating low-resistive contacts using the Si-dots/SiC structure without metal silicidation process.




アニール温度に依存した SiC 上 Si の泳動とドット化を示す電子顕微鏡像
Scanning electron microscope images of Si migration and dots formation in accordance with the annealing temperature.

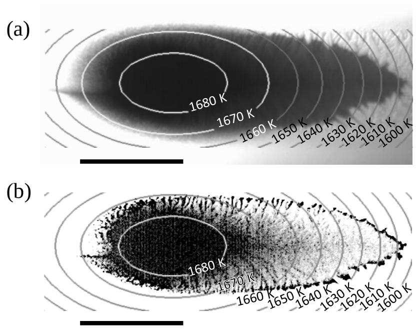
# 実時間観察・温度測定同時計測による シリコン融液の温度分布可視

## Visualization of a Temperature Distribution for Si Molten Region by Simultaneous Measurement


助教　水川友里（併任）
Assist. Prof. Yuri Mizukawa


液晶ディスプレイ等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、シリコン融液内の温度分布解析を行っている。基板表面温度の熱伝導シミュレーション解析と実時間観察を組み合わせて、シリコン融液内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 heat conductive simulation analysis of a substrate surface and the real-time observation.




シリコン固液混合領域とシリコン完全溶融領域内の2次元温度分布図 (a) 画像コントラスト調整無し(b) 調整有り

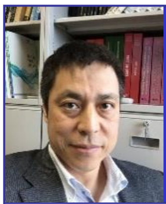
Two-dimensional temperature distribution image in solid-liquid mixture region and complete melting Si region (a) without and (b) with image processing. (Scale bar: 200 μm).

# 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。

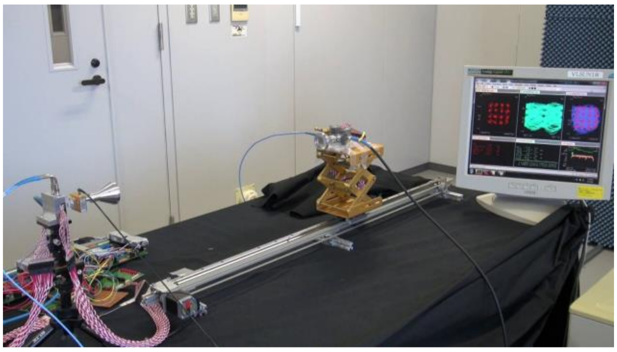


### テラヘルツ波デバイス基盤技術の研究
### Study on Fundamental Technologies for Terahertz-Wave Devices

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.



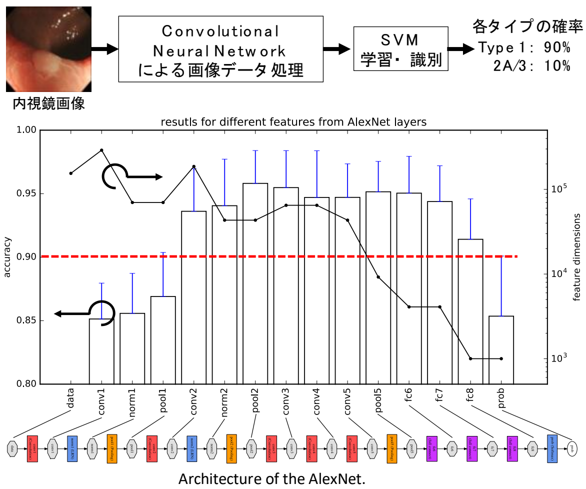
300GHz帯CMOSトランシーバを用いた伝送実験
Communication experiment with 300-GHz-band CMOS transmitter.

### CNN特徴を特徴抽出として利用した機械学習を用いた大腸がん診断支援アルゴリズム開発
### Development of Colorectal Tumor Diagnosis Support Algorithm Using Machine Learning Using CNN Features as Feature Extraction

准教授　小出哲士　Assoc. Prof. Tetsushi Koide

本研究では，大腸Narrow Band Imaging（NBI）拡大内視鏡がん診断支援実現のため、Convolutional Neural Network（CNN）の処理結果を特徴量と見做し、Support Vector Machine（SVM）による病理タイプ識別を行う手法を提案した。提案手法の組込みシステム化を考慮して識別精度の検証を行い、その結果非腫瘍･腫瘍の識別において医療現場からの要求性能である90% 以上の識別精度を確認した。

In this study, the processing results of the Convolutional Neural Network (CNN) are regarded as features, and pathological type discrimination by the Support Vector Machine (SVM) is performed in order to support the diagnosis of colonic narrow band imaging (NBI) endoscopic cancer. We proposed a method to perform Verification of the discrimination accuracy was performed in consideration of the systematization of the proposed method, and as a result, the discrimination accuracy of 90% or more, which is the required performance from medical sites, in non-tumor / tumor discrimination was confirmed.



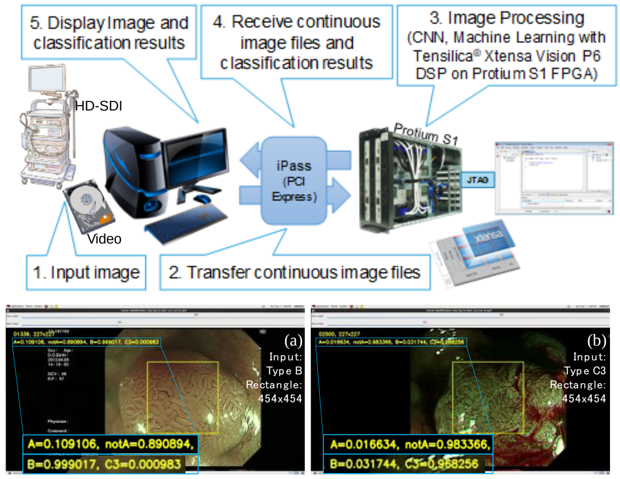

AlexNetを特徴抽出に用いた場合の精度と次元数のトレードオフ検証
Verification of tradeoff between accuracy and dimensionality when using AlexNet for feature. https://ieeexplore.ieee.org/document/8650331

## 機械学習を用いた大腸内視鏡画像がん診断支援システムのカスタマイザブル DSP コアへの実装
## Implementation of a Colonoscopy Imaging Tumor Diagnosis Support System Using Machine Learning on a Customizable DSP Core

准教授　小出哲士　Assoc. Prof. Tetsushi Koide

CNN 特徴と SVM 分類を適用した診断支援システムをカスタマイザブルな Digital Signal Processing (DSP) コアである、Cadence 社の Cadence Tensilica Vision P6 DSP コアに実装し評価を行った。その結果、コアアーキテクチャに適したアルゴリズム改良を行うことで CNN や SVM の主要処理が効率的に実行でき、改良前と比較して処理サイクル数が 1/30 に削減されリアルタイム処理(30 fps@100 MHz) が実現可能であることを示した。

A diagnostic support system using CNN features and SVM classification was implemented on a Cadence Tensilica Vision P6 DSP core from Cadence, a customizable Digital Signal Processing (DSP) core, and evaluated. As a result, by performing algorithm improvement suitable for the core architecture, the main processing of CNN and SVM can be executed efficiently, the number of processing cycles is reduced to 1/30 compared to before the improvement, and real-time processing (30 fps @ 100 MHz) is feasible.



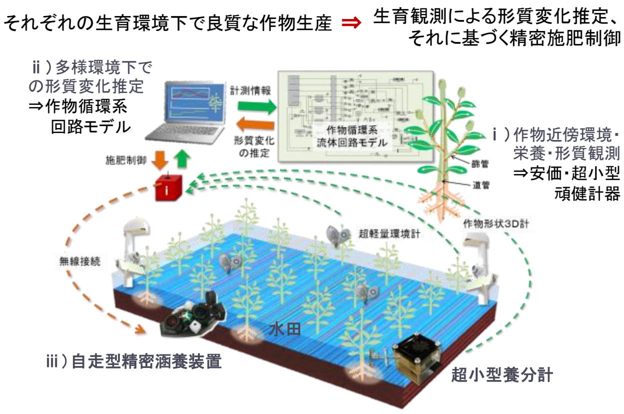

カスタマイザブル DSP コアへのプロトタイプシステムの実装
Implementation of a prototype system on a customizable DSP.
https://ieeexplore.ieee.org/document/8702379

## 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、CO2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を開発している。(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, CO2, 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)



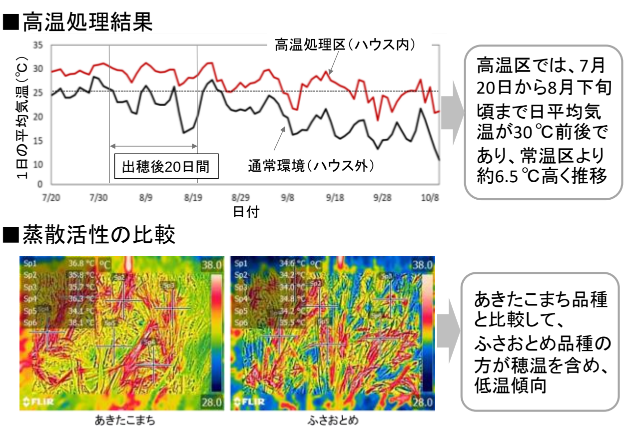

フィールド向け頑健計器と作物循環系流体回路モデルによる形質変化推定技術の概要
Overview of Development of plant growth estimation technologies combined with robust field monitors and micro-fluidic model simulating plant vascular system.
https://www.jst.go.jp/kisoken/crest/en/project/1111090/15666253.html

## スマート農業のための水稲の成長を顕著に示す画像由来の形質パラメータの探索と評価
## Search and Evaluation of Trait Parameters Derived from Images Showing Significant Changes in Rice Growth for Smart Agriculture

准教授　小出哲士　Assoc. Prof. Tetsushi Koide

水稲の成長を顕著に示す画像由来の形質パラメータの探索および、収量・外観品質との関係を調査した。全天候型ハウス内で、あきたこまちとふさおとめを栽培し、植物体周辺にサーモカメラを設置し、出穂期には高温灌漑処理を行った。出穂後 20 日間に高温が続くと白未熟粒の発生が増加する。本試験より、同条件下でふさおとめは穂温を低く保つことで白未熟粒の発生を抑制しており、その傾向はサーモカメラ画像で測定可能と考えられた。(JST CREST Project)

We searched for trait parameters derived from images that show remarkable rice growth, and investigated the relationship between yield and appearance quality. From this test, it was considered that the occurrence of white immature grains was suppressed by keeping the ear temperature low under the same conditions, and this tendency could be measured by thermometer camera images. (JST CREST Project)




全天候型ハウス内で、あきたこまちとふさおとめを栽培した検証結果
Verification results of cultivation of Akita Komachi and Fusaotome in an all-weather house.
https://ieeexplore.ieee.org/document/8650285

## 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.

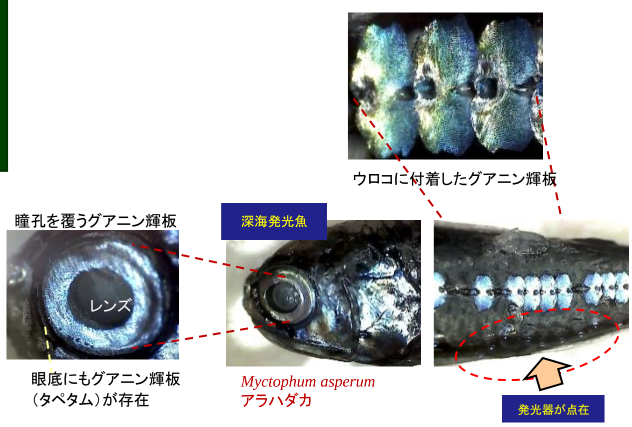
分子生命情報科学研究部門は、MEMS、バイオ分子固定、バイオセンシング、環境情報センシングに関する研究を行っている。分子生命情報科学研究部門における研究の主なものの概要を紹介する。

### 魚のバイオリフレクター
### Bioreflectors of Fish

教授　岩坂正和
Prof. Masakazu Iwasaka

魚のバイオリフレクターに関し、本学岩坂と、山口大、中部大での共同研究が行われた。図のような、深海魚の発光に関する研究もおこなわれた。
この研究プロジェクトに関連した話題が、日経サイエンス「深海発光魚」にも紹介された。

We investigated bio-reflectors of fish, etc. For example, new data on guanine platelets in luminous deep-sea fish was obtained.



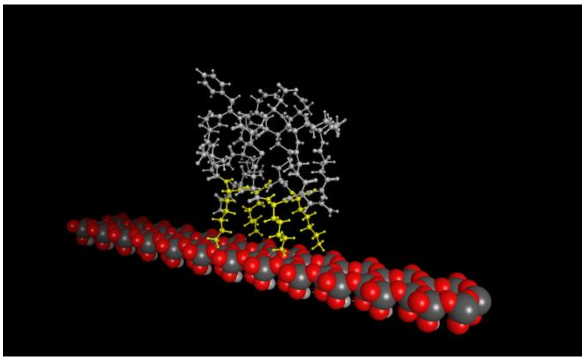

深海発光魚グアニン輝板
Guanine platelets in luminous deep-sea fish.

### 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.

## $SiO_2$結合ペプチドの発見とタンパク質固定化への応用

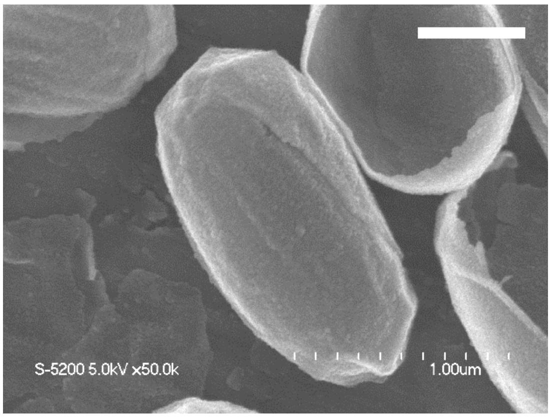
## Application of $SiO_2$-Binding Peptides for Protein Immobilization on Si-Based Materials


助教　池田　丈（併任）

Assist. Prof. Takeshi Ikeda


細胞内にてカプセル状の $SiO_2$ を形成するグラム陽性細菌 Bacillus cereus より、新規の $SiO_2$ 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 novel $SiO_2$-binding peptides from a Gram-positive bacterium *Bacillus cereus*, which forms a capsule-like structure of $SiO_2$ in the cell. Because of its high affinity for $SiO_2$, this peptide should be a powerful tool for developing Si-based biodevices.




*B. cereus* が形成したカプセル状 $SiO_2$ 構造体の SEM 像
スケールバー：500 nm

SEM image of capsule-shaped $SiO_2$ structures isolated from *B. cereus*. Scale bar: 500 nm.

# 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.

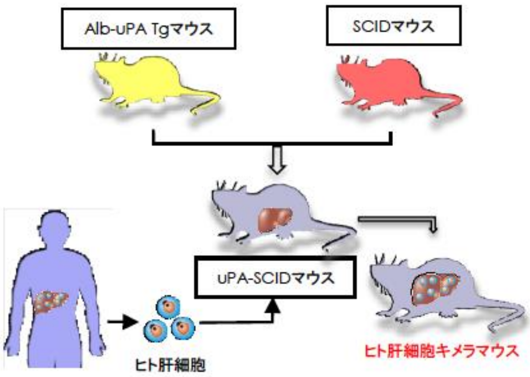
集積医科学研究部門では、ナノメディシン、ナノデンティストリー、ナノファーマシー等、医療とナノ技術の融合研究を行っている。現在行われている集積医科学研究部門における研究の主なものの概要を紹介する。

### 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

肝炎ウイルス感染モデルであるヒト肝細胞キメラマウスを用いて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。本モデルを用いて、NIH との共同研究により、シクロシクリジンのリード化合物の毒性、薬物動態、抗ウイルス効果を検討し、この化合物が、C 型肝炎に対する、安価な新規治療薬候補となることを示した（J Infect Dis 2018）。またロヨラ大学との共同研究により、B 型肝炎ウイルス感染後のマウス血中および肝臓内の HBV DNA を詳細に測定することにより、体内におけるウイルス動態を明らかにした（Hepatology 2018）。

We are currently investigating hepatitis viruses virology and developing treatment against these viruses using human hepatocyte chimeric mouse. In this year, we showed that antihistamine chlorcyclizine might be a new low cost treatment option for chronic hepatitis C by collaborating with NIH (J Infect Dis 2018). We also clarified the serum and intrahepatic HBV viral kinetics after infection using this animal model by collaborating with Loyola University (Hepatology 2018).



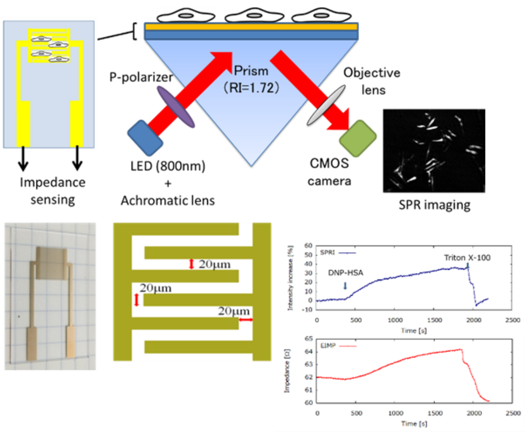

ヒト肝細胞キメラマウス
Humna hepatocyte chimeric mouse.

### SPR イメージングセンサとインピーダンスセンサを組み合わせたマルチセンサの開発
### Development of SPR Imaging-Impedance Sensor for Multi-Parametric Living Cell Analysis

教授　秀　道広（併任）
Prof. Michihiro Hide

センサチップ上の屈折率分布を可視化できる SPR イメージングセンサと、電極上のインピーダンス変化を高感度に測定できるインピーダンスセンサを組み合わせて、一枚の櫛型電極型のセンサチップ上で、細胞応答に基づく屈折率とインピーダンスの変化を同時に測定することに成功した。本成果は 2019 年の Sensors 誌に掲載された。

We developed a SPR-Impedance sensor in order to monitor both impedance and RI derived from living cells.



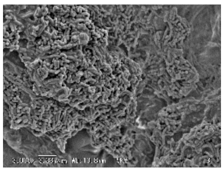

SPR イメージングセンサとインピーダンスセンサの組み合わせと、細胞応答計測
Schematics of surface plasmon resonance imaging-impedance sensor.

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

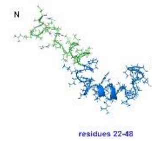
教授　二川浩樹（併任）
Prof. Hiroki Nikawa

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。

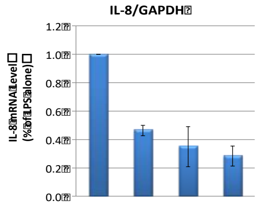
Kog1, a bacteriocin produced by *L. rhamunosus* L8020 which suppress both cariogenic bacteria and periodontal burdens in oral cavity, inactivate the LPS produced by periodontal burdens.



(a)




(b)




(c)

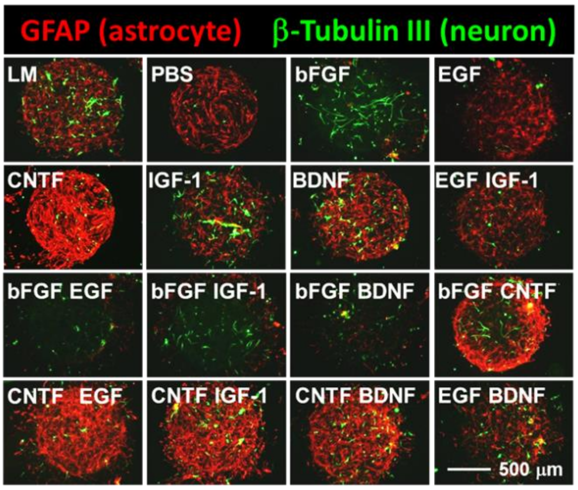
L8020 乳酸菌(a)のバクテリオシン Kog1(b)は、歯周病菌の内毒素 LPS を不活性化させる作用がある(c)
Kog1(b), a bacteriocin produced by *L. rhamunosus*　L8020 (a) inactivate the LPS produced by periodontal burdens (c).

## 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.

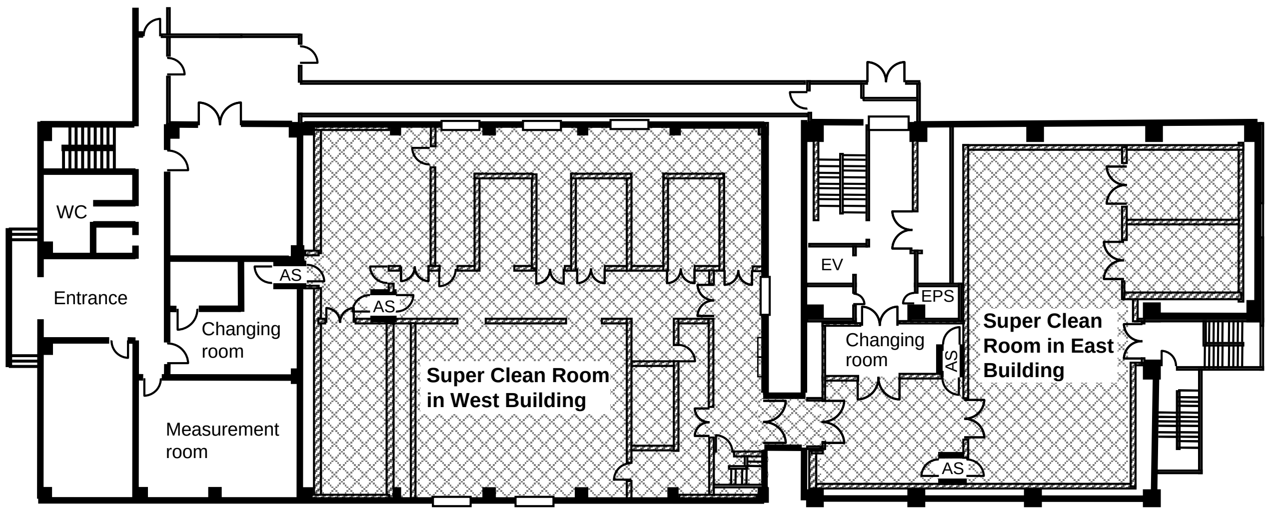



増殖因子アレイを用いた神経幹細胞の分化アッセイ
Assay for neural stem cell differentiation using a growth factor array.

# 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 830$m^2$。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)

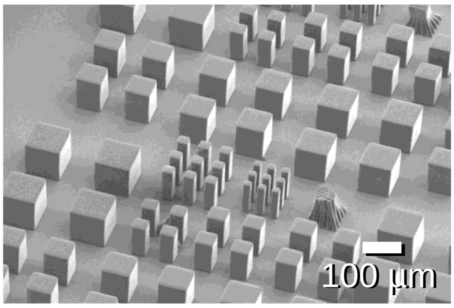
ポイントビーム型電子ビーム描画装置
（エリオニクス ELS-G100）Resolution 6nm

◆ 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)

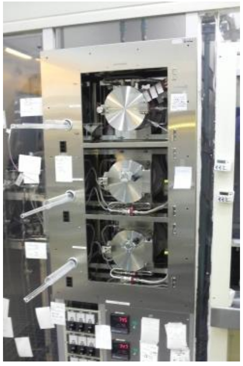
汎用熱処理装置 $H_2$, $N_2$, $O_2$, Low Pressure
(光洋サーモシステム) Max. Temp. 1000℃

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 $SiO_2$
Doing 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

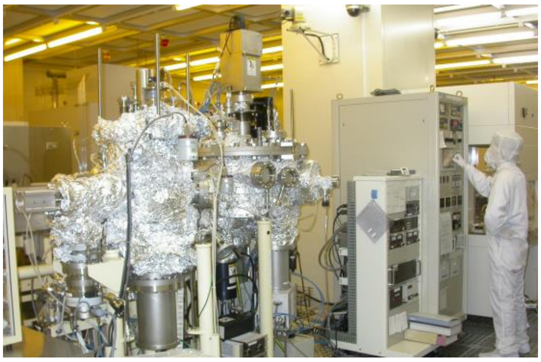
常圧CVDウェハセッティング風景

Wafer setting to atmospheric CVD reactor

## 5.2.5 Metal deposition
## 金属薄膜堆積

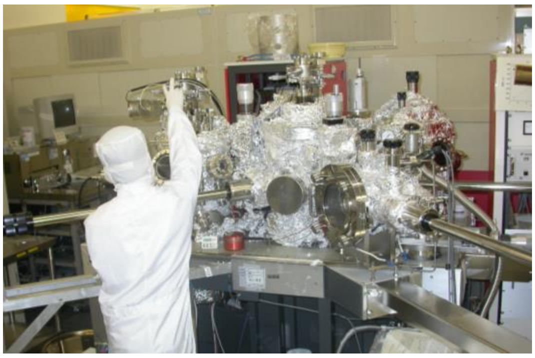
◆ Metal/dielectrics sputtering system for BiSrTiO compound etc. (ULVAC)

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

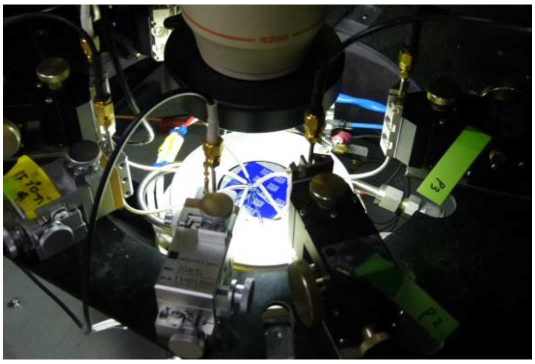
◆ Vacuum evaporation system for variety of metals (Donated: RICOH)

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



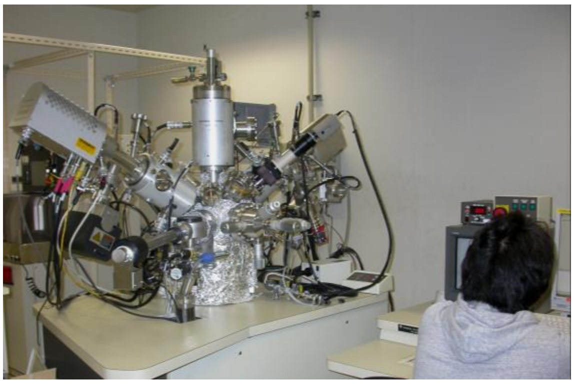
マニュアルプローバーによる電気特性測定

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)

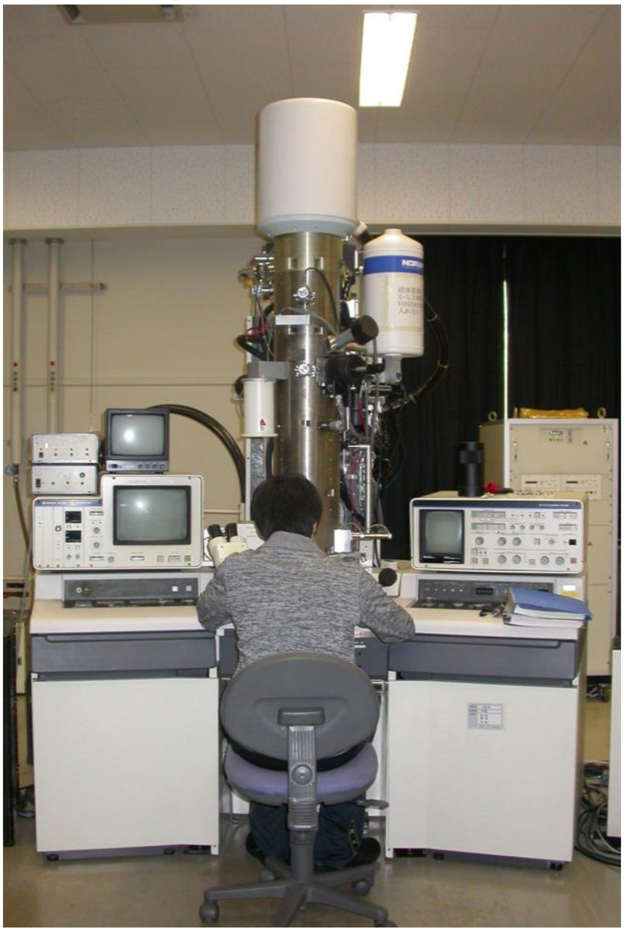
X線光電子分光分析装置
(KRATOS ESCA-3400) X ray source：Mg, Ka


◆ 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

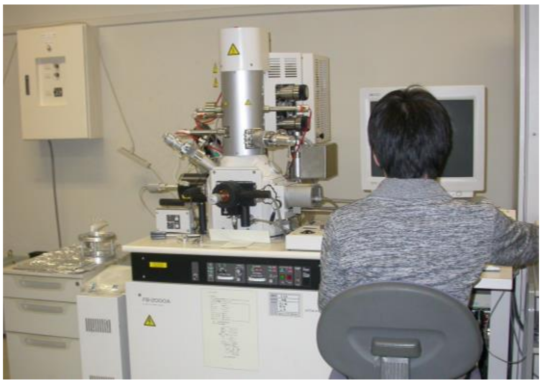


◆ Field emission scanning electron microscope (FE-SEM) (Hitachi S4700)

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

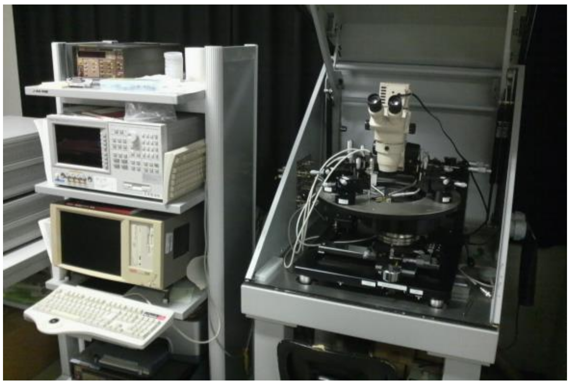
◆ Focused ion (Ga) beam (FIB) system (Hitachi FB-2000)

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



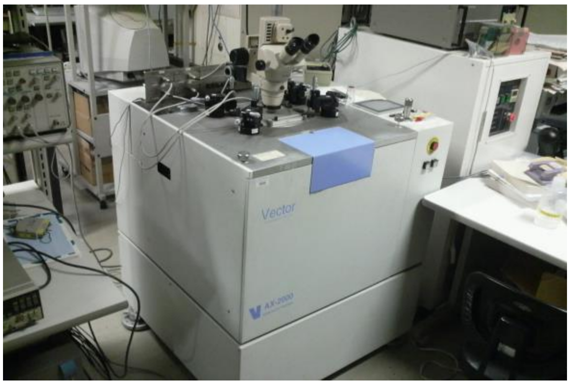
◆ Manual wafer prober (Vector Semiconductor) and semiconductor parameter analyzer (Keithley)

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, and S.-I. Kuroki, “Dependence of thin film transistor characteristics on low-angle grain boundaries of (100)-oriented polycrystalline silicon thin film,” Jpn. J. Appl. Phys. **58**, SBBJ08-1- SBBJ08-6, 2019.

[2] T. Kurose, S.-I. Kuroki, S. Ishikawa, T. Maeda, H. Sezaki, T. Makino, T. Ohshima, M. Ostling, and C.-M. Zetterling, “Low-parasitic-capacitance self-aligned 4H-SiC nMOSFETs for harsh environment electronics,” Mat. Sci. Forum, 9**24**, pp. 971-974, 2018.

[3] J. Kajihara, S.-I. Kuroki, S. Ishikawa, T. Maeda, H. Sezaki, T. Makino, T. Ohshima, M. Ostling, and C.-M. Zetterling, “4H-SiC pMOSFETs with Al-doped S/D and NbNi silicide ohmic contacts,” Mat. Sci. Forum, **924**, pp. 423-427, 2018.

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