金沢工業大学附置研究所

光電相互変換デバイスシステム研究開発センター

研究所年報

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ANNUAL RESEARCH REPORT

OPTOELECTRONIC DEVICE SYSTEM R&D CENTER

KANAZAWA INSTITUTE OF TECHNOLOGY

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研究成果報告書刊行にあたって

光電相互変換デバイスシステム研究開発センター

所長　山口　敦史

金沢工業大学「光電相互変換デバイスシステム研究開発センター」での令和２年度（令和２年４月－令和３年３月）における研究成果を、ここに報告書として取りまとめましたので、謹んでお届け申し上げます。

当研究開発センターは、平成１２年度の文部省（現文部科学省）の私立大学ハイテク･リサーチ･センター整備事業（研究期間５年）に選定され、金沢工業大学の附置研究所として設立されました。当センターは、エレクトロニクス分野のインテグレーション技術が生み出すデバイスシステムの研究開発を目的として、昭和５９年に開設した電子デバイスシステム研究所を母体として、開設以来１５年の間に最重点研究領域として成長した光電相互変換デバイスシステム開発に集中・特化し、組織の再編と施設の強化を図り革新的に発展させたものであります。専用研究棟（４０号館）を金沢工業大学野々市キャンパス内に新築し、既設設備の移設や新規設備の搬入を終え、平成１３年３月から［酸化物半導体の価電子制御と高導電率化およびデバイスへの応用］及び［次世代電子ディスプレイシステムの開発］２つの研究プロジェクトが本格的に活動を開始しました。平成１６年３月に両プロジェクトの成果を報告書としてまとめて報告し終了しました。引き続き、平成１７年度の私立大学学術研究高度化促進事業（研究期間３年）に選定され、「環境調和型光電相互変換デバイス技術の確立とその応用」並びに「環境調和型電子ディスプレイシステムの開発」の２つのプロジェクトを実施し、平成２０年３月に両プロジェクトの成果を報告書としてまとめて報告し終了しました。また，平成２３年度の「私立大学戦略的研究基盤形成支援事業」に選定され、設立された電気・光・エネルギー応用研究センターに所属して光・電子デバイスシステムの開発研究を実施しています。平成２９年３月末に、研究所設立時より長期に渡り所長を務めてこられた南教授が所長を退任され、平成２９年４月より山口敦史が所長の職を引き継いでおります。

本報告をご覧くださる諸賢のご忠告やご助言をお願いする次第であります。今後とも皆様方のご理解とご支援を心からお願い申し上げます。

終わりにあたり、本センターの研究に対し、種々のご支援・ご協力を頂いた関係機関、並びに委託研究や奨学寄付金を提供して頂いた多くの民間企業各社に対し、深く感謝申し上げます。

令和３年３月

FORWARD

This research report is issued annually to summarize the research activities in the Optoelectronic Device System Research and Development (OEDS R&D) Center, Kanazawa Institute of Technology (KIT). This report, which covers the activities in the OEDS R&D Center from April 2020 to March 2021, is distributed to researchers engaged in the study of materials, devices and systems in the field of electronics, especially optoelectronics, in order to stimulate mutual exchange of scientific information. We believe that this report represents our continuing commitment toward achieving and maintaining research excellence in the area of materials, devices and systems for optoelectronics.

Historically, the Electron Device System (EDS) Research Laboratory was established at KIT in June 1984. Professor Ichiro Fukuda was installed as the first director of the EDS Research Laboratory. Since the establishment of the EDS Research Laboratory, research has centered on fundamental studies of materials, devices and systems as well as on technology to integrate them into electronic devices. In the past 15 years, optoelectronic device system research has grown into a major research field. For the purpose of focusing on the development of optoelectronic device systems, the EDS Research Laboratory was transformed into the OEDS R&D Center attached to KIT in May 2000 with a regrouping of the staff and construction of a new building (building 40). The OEDS R&D Center was financially supported in part by a High-Tech Research Center Project Grant from the Ministry of Education, Culture, Sports, Science and Technology of Japan, and Professor Tadatsugu Minami was appointed the first director of the OEDS R&D Center. There are two important research projects in the OEDS R&D Center: the development of 1) Oxide Electronics and 2) Next Generation Electronic Display Systems. We are extensively investigating new n- and p-type oxide semiconductors for optoelectronic devices, new oxide phosphors for emissive displays, new optoelectronic devices and new display systems. These research projects were successfully finished in March 2008.

After that, we have jointed a new research project in the Center for Electric, Optic and Energy Applications attached to KIT and started in April 2011: Research and development of optoelectronic device systems. A part of our works was financially supported by a Program for the Strategic Research Foundation at Private Universities from the Ministry of Education, Culture, Sports, Science and Technology of Japan. In 2017, Professor Minami, who served as director for a long term since the establishment of the center, retired from the position of director, and Professor Atsushi A. Yamaguchi has taken over the position.

All of us at the OEDS R&D Center are grateful for the generosity and continuing support of the organizations and companies which have been providing research funds.

Atsushi A. Yamaguchi, Director
Optoelectronic Device System R & D Center
March 2021

研究スタッフ

　光電相互変換デバイスシステム研究開発センターは、新しい光電相互変換デバイスの開発を目的として、7 名の研究員体制で平成 12 年度から研究開発を開始した。これまでに、石井 恂 教授、得永嘉昭 教授、福田一郎 教授、南 内嗣 教授、坂本康正 教授が退職された一方、平成 23 年度に山口敦史 教授を、平成 30 年度には平間淳司 教授、柳橋秀幸 講師を新たに迎え、所長を含む以下の計 5 名の所員ならびに 1 名の客員教授が研究テーマを分担して研究開発を行っている。

令和 2 年度研究所組織

・研究所員

所長	山口敦史	教授・理学博士
所員	宮田俊弘	教授・博士（工学）
所員	平間淳司	教授・工学博士
所員	深田晴己	准教授・博士（工学）
所員	柳橋秀幸	講師・博士（工学）

・客員教授

坂本康正	工学博士

各研究テーマの概要

山口研究室 (Yamaguchi Laboratory)

Optical Properties of III-nitride materials and devices are investigated both experimentally and theoretically. The following two topics are intensively being studied at present.

[1] Optical Gain Characteristics of InGaN Green-Emitting Laser Diodes

We theoretically predicted in 2006 that the utilization of semi polar GaN substrates is beneficial to realize high-performance and low-cost green laser diodes. Now, we are performing more realistic calculation of optical gain characteristics to design the device structure in detail. In addition, experimental studies have just been launched to measure the anisotropic optical gain characteristics of semipolar-oriented InGaN quantum wells.

[2] Optical Characterization of GaN Substrates for High-Efficient White LEDs

High quality GaN substrates with low defect density and small residual strain are required for high-efficient white LEDs. We are measuring time-resolved photoluminescence spectra to elucidate defect density and to investigate carrier dynamics. 2D-strain mapping measurements by low-temperature micro-reflectance are also being carried out to understand the strain relaxation mechanism and to reduce the residual strain in the substrates.

宮田研究室 (Miyata Laboratories)

We are extensively investigating new n- and p-type oxide semiconductors for optoelectronic devices, new oxide phosphors for emissive displays, new optoelectronic devices and new display systems. A new research project was started in May 2007: Development of indium substitute materials for a transparent conducting electrode. This research was financially supported in part by the Rare Metal Substitute Materials Development Project initiated by the Ministry of Economy, Trade and Industry of Japan and transferred to the New Energy Development Organization from April 2008; the research project was completed successfully in March 2009. A new research project was started in August 2010: Development of low cost and high quality transparent conducting oxide (TCO) films by sputtering deposition. The research was financially supported in part by the New Energy and Industrial Technology Development Organization (NEDO), Japan, via the Photovoltaic Power Generation Technology Research Association (PVTEC), Japan; the research project was finished successfully in March 2013.

[1] Preparation and device application of intelligent oxide thin films.

Highly conductive and transparent thin films have many applications such as transparent electrodes for optoelectronic devices and transparent heat mirrors for solar energy utilization.

Although indium tin oxide (ITO) films are in practical use, ITO is a relatively expensive material because indium is in rather limited supply. We have proposed use of new transparent conducting oxide (TCO) materials, consisting of ZnO and multicomponent oxide. Especially, the following subjects are in progress:

1) Development of new TCO materials and its deposition techniques.

2) Development of new p-type oxide semiconductors and its deposition technique.

3) Development of optoelectronic devices using new oxide semiconductors.

4) Development of sensor and MEMS using new oxide semiconductors.

[2] Photovoltaic application of oxide semiconductors.

We have proposed new p–n heterojunction solar cells have been fabricated using cuprous oxide (Cu_2O), a semiconductor with a direct energy gap of 2.1 eV. The significantly enhanced efficiencies could be achieved in Al-doped ZnO (AZO)/n-type semiconductor/p-type Cu_2O heterojunction solar cells fabricated by preparing an oxide semiconductor thin film on a thermally oxidized p-Cu_2O sheet using low-damage and low-temperature deposition techniques. The following subjects are in progress:

1) Development of new oxide semiconductor thin films materials as an n-type layer and its deposition techniques.

2) The Cu_2O homojunction was formed by epitaxially growing an impurity-doped Cu_2O thin film on thermally oxidized polycrystalline p-type sodium-doped Cu_2O sheets by electrochemical deposition (ECD) method.

平間研究室 (Hirama Laboratory)

［1］New SPA based (wasabi) plant factory with optimally controlled cultivation environment utilizing the leaf electric potential

For plants that are considered difficult to grow in plant factories (wasabi), a controlled cultivation environment that was created with IoT based sensor and actuator networks and cloud management was implemented early on.

By analyzing the weak leaf electric potentials from the wasabi when exposed to external environmental stimuli, a “health check” on the wasabi is performed. In addition to growth environmental control based on other biometric SPA (Speaking Plant Approach) measurement techniques, continuous health monitoring of the wasabi using the leaf electric potential data is also obtained in order to further optimize the cultivation environmental control.

[2] Small scale low magnetic field MRI device development

In this laboratory, a low magnetic field small scale MRI device is under development. It is intended to be used for medical diagnostics immediately after brain surgery. This high quality light weight MRI system is being implemented in collaboration with the Applied Electronics laboratory (AEL) using technology and techniques developed at KIT.

In addition, a low magnetic field 52mT MRI system is also being developed mainly to analyze the internal makeup of food by measuring the relaxation time from MR images.

[3] Small scale high sensitivity FGM development

A small sized magnetic sensor (Fluxgate Magnetometer: FGM) with highly sensitive magnetic saturation characteristics that can operate at room temperature was developed. Up until now, an ultra-high sensitivity of 30pT/√Hz was achieved. The focus of the research from now is to rebuild and reduce the size of the sensor body while simplifying the magnetic detection circuit.

深田研究室 (Fukada Laboratory)

[1] Development of thin film phosphor materials

Our objective is the development of thin film phosphors with high efficiency and chemical stability for inorganic thin-film electroluminescence devices and white light-emitting diodes. Various phosphor thin films are prepared by a sol-gel dip coating followed by post annealing at a high temperature. In addition, we will conduct studies on inorganic-organic hybrid phosphors and luminescent devices utilizing these phosphors.

[2] First-principles molecular-dynamics calculations

The first-principles molecular-dynamics simulation is an effective method of explaining and predicting various properties of semiconductors and metals though electron-state calculations based on quantum dynamics. Aiming at the improvement of the experimental conditions in the preparation of inorganic or organic semiconductors and/or the development of new optoelectronic devices, we will conduct exploring and predicting physical phenomena on the atomic and electronic levels.

柳橋研究室 (Yanagibashi Laboratory)

[1] Development of SPA typed mushroom factory

The final goal of our study is actual operation of SPA (Speaking Plant Approach) typed mushroom factory. SPA means environmental control using some biological information as index. In this study, bioelectric potential responses of mushrooms to various environmental factors have been measured and associated with their morphogenetic properties. Mushroom growth promotion by bioelectric potential activation has also been tried and it is gradually becoming clear that bioelectric potential is effective as an index of growth control.

[2] Contactless measurement of plant physiological activity using magnetic fluid

This study is the world's first trial aiming to realize a quite new method to measure plant physiological activity without physical contact of sensors. It is considered that nano particle sized magnetic fluid is absorbed into the plant body and its movement by solution transport related to plant physiological activity will result in extremely weak magnetic fluctuations that seems to be detectable without contact by FGM. In the future, we will also work on the application of this measurement technology on medical scene.

坂本研究室 (Sakamoto Laboratory)

[1] Three-dimensional Display Using Light Emitting Diode

The purpose of this research is to develop a system to make display with a three-dimensional image that was overflowed in the sensation of reality. We arranged Light Emitting Diode (LED) three-dimensionally for this purpose.

Our goal is to make a big screen and then attempt to reduce the cost.

[2] The Driving Circuits of LED-light

With the developments of luminous efficiency of LED, popularization of LED lamps is to be expected. Therefore, as well as luminous efficiency, increasing efficiency of lighting circuit is important from the point of view of consideration the efficiency of an entire of the lighting system. In response to this requirement, the following studies are being conducted.

1) Development of the new rush current suppressor which uses a solid state relay
2) Development of the high efficiency lighting circuit of LED lamp.

予 算

（非公開）

委員会活動等

機　関	委員会等の名称	参加者	備　考
日本学術振興会	産学協力研究委員会（ワイドギャップ半導体光･電子デバイス第１６２委員会）	山口	研究会企画幹事
応用物理学会 応用電子物性分科会		山口	企画幹事
応用物理学会 論文誌企画・編集委員会		山口	JJAP 編集委員
電子情報通信学会 レーザ・量子エレクトロニクス研究専門委員会		山口	専門委員
2020 年度応用物理学会 論文賞委員会		山口	委員
2020 年度応用物理学会 化合物半導体エレクトロニクス業績賞（赤﨑勇賞）表彰委員会		山口	委員
The 14th International Conference on Nitride Semiconductors (ICNS-14), Program Committee		山口	副委員長
半導体レーザ国際会議(ISLC 2021) Technical Program Committee		山口	委員
International Workshop on Nitride Semiconductors (IWN 2020) Program Committee		山口	委員
国立大学法人北陸先端科学技術大学院大学		山口	教育連携アドバイザー
日本学術振興会	産学協力研究委員会（光電相互第１２５委員会）	宮田	委員
日本学術振興会	産学協力研究委員会（透明酸化物光･電子材料第１６６委員会）	宮田	委員

機　関	委員会等の名称	参加者	備　考
日本生物環境工学会	本会	平間	会長補佐
日本生物環境工学会	本会	平間	理事
日本生物環境工学会	本会	平間	監事
日本生物環境工学会	全自動植物工場部会	平間	部会長
日本生物環境工学会	北信越支部	平間	支部長
株式会社　イーグルテクノロジー		平間	技術顧問
日本生物環境工学会	本会	柳橋	理事
日本生物環境工学会	本会	柳橋	和文誌編集委員
日本生物環境工学会	北信越支部	柳橋	役員

教育活動

（非公開）

研究活動

1. 発表論文＜査読あり＞

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2) 柳橋秀幸、阿部航也、平間淳司、小山大介、八田純一：“超低磁場 NMR 装置の開発と非破壊での食品類の状態分析”，植物環境工学, Vol.33 No.1, pp.12-19, (2021).

2. 国際学会・シンポジウム講演

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2) 森恵人、高橋佑知、坂井繁太、森本悠也、山口敦史、草薙進、蟹谷裕也、工藤喜弘、冨谷茂隆、“光音響・発光同時計測法と積分球法による InGaN 量子井戸の内部・外部量子効率推定”，電子情報通信学会レーザ・量子エレクトロニクス研究会（LQE）, online, (2020).

3) 山口拓海、有賀恭介、森恵人、山口敦史、“InGaN 量子井戸の発光温度消光の励起波長依存性”，電子情報通信学会レーザ・量子エレクトロニクス研究会（LQE）, online, (2020).

4) 山口敦史: （招待講演）“光学的評価の基礎と実践”, 応用物理学会結晶工学分科会主催第26回結晶工学スクール, online, (2020).

3. 出願特許リスト

1) 発明者：南 内嗣、宮田俊弘
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