III. 大学院学位論文

DISSERTATIONS

A. 大学院博士課程論文梗概

Doctor's Dissertations

電気系工学専攻

A1. 励起子共振器ポラリトンの実現に向けた空隙/III 族窒化物半導体分布ブラッグ反射型微小共振器の作製と評価に関する研究

陶 仁春

Fabrication and Characterization of Air/III-Nitride Distributed Bragg Reflector Microcavity for Exciton Cavity Polariton

By Tao Renchun

Strong coupling between photons and excitons can generate new quasi-particles, i.e., exciton-polaritons. Exciton-polaritons have many interesting applications such as in Bose Einstein condensation, polariton lasers with ultralow threshold, parametric amplification, bistability, superfluidity and so on.

III-nitrides have special interests for strong coupling researches, namely, their high exciton binding energy and strong exciton oscillator strength (or large Rabi splitting). These properties allow for exciton polaritons that survive at room temperature (RT). However, in III-nitrides, the refractive index contrast is relatively low.

Air-gap structures are one promising option to overcome the low refractive index contrast in III-nitride DBRs. Previously, many different wet etching and dry etching methods have been tried to fabricate air-gap nitride DBRs. But each of these methods has certain drawbacks of its own. Consequently, no complete air/nitride DBR MCs have been reported to date. Here, we employed a newly developed technology utilizing the thermal decomposition of GaN to fabricate III-nitride air-gap nano-structures. This technique, based on a dry process, is easier and faster, allowing the fabrication of complicated multilayer structures.

On the other hand, for polaritons in III-nitrides, non-polar nitride MCs would be a better option, since the absence of built-in electric fields would lead to an enhancement of the electron/hole wave-function overlap, consequently resulting in a higher exciton binding energy and a large Rabi splitting in polariton devices. However, there are very few works published on non-polar nitride DBR MCs due to the still challenging growth and fabrication techniques.

This thesis presents the original research work on the MOCVD growth of non-polar m-plane III-nitride structures, the fabrication of air/III-nitride DBR MCs using thermal decomposition technique and the demonstration of cavity modes with high quality (Q) factors and strong coupling phenomenon. A record Rabi-splitting of 84 meV is estimated at room temperature. In addition, due to the thickness fluctuations in the cavity layers, we also observed the emission from trapped photons and trapped polaritons. This is actually the first demonstration of such trapped states in III-nitride DBR MCs. At the same time, we observe a quantized energy of 6 meV for exciton-polaritons, which is also the largest value reported to date in a solid cavity system. These results show that our air-gap DBR MCs are versatile for many interesting researches in the future.

The structure of this thesis and the content in each chapter are shown as follows.

Chapter 1 gives the introduction to this thesis, including basic concepts and application of exciton polariton, the advantages, disadvantages and current research status of III-nitride DBR MCs to exciton polariton applications. As for the disadvantages, we come up with the idea of non-polar air-gap/III-nitride DBR MCs.

Chapter 2 presents some very basic but very important design issues for air-gap cavities. Transfer matrix method is used to simulate air-gap DBR cavity structures. By simulation, it is found that 2 cavity should be avoided since there are no anti-nodes inside the cavity. Besides, the high efficiency of air/III-nitride DBR MCs and their difference from conventional DBR MCs are revealed: for the realization of strong coupling in III-nitrides, two period DBRs at the bottom and on the top are enough for the observation of strong coupling.

Chapter 3 contains the growth techniques for multilayer structures on m-plane free-standing GaN substrates. The normal direction tilt of the substrate surface and the growth temperature are found to be the key parameters that affect the surface morphology of epitaxial multiple GaN/AlGaN layers. We used the

substrates with their normal directions tilted toward -c axis by 1° and the optimal growth temperature was between 930 °C and 970 °C. On the other hand, we also find that the InGaN single quantum well with its AlGaN barriers grown at the same temperature as other DBR AlGaN layers could still have a strong enough PL emission intensity. At the end of Chapter 3, complete cavity samples were grown and some special considerations in design and detailed parameters were given.

Chapter 4 describes the development of the fabrication process for non-polar nitride air-gap DBR MCs by using thermal decomposition of GaN. First of all, during GaN decomposition, it is found that the decomposition rate is asymmetric depending on crystal facets and ammonia flow rate. At lower ammonia flow rate, the decomposition rate along -c direction is fast and the difference between -c direction and a direction was large. We could utilize this feature to fabricate air-gap layers. Finally two types of DBR cavities have been grown and fabricated. The parameters used in each fabrication step were given. Images of the fabricated structures taken by scanning electron microscope and atomic force microscope revealed their good structure quality.

Chapter 5 presents optical characterization for the fabricated non-polar air/III-nitride MCs by micro photoluminescence measurements at room temperature. In the cavity center, a single InGaN QW is used as the active layer. A Q factor of 1600 was estimated and anisotropic optical properties have been investigated. Especially, to analyze the optical anisotropy, k•p method based theoretical calculation is performed, whose results are in good agreement with experimental measurements.

Chapter 6 contains the experimental demonstration of strong exciton-photon coupling in air-gap/III-nitride DBR MCs. Three 34-nm-thick GaN layers are used as active layers. A Rabi-splitting of 84 meV is estimated. This is actually the largest Rabi-splitting reported to date. We believe that the key to the realization of such a large $¥Omega$ is both the use of air/AlGaN DBRs and the use of three thick GaN layers at the cavity anti-nodes. An even larger Rabi splitting can be expected by further optimizing the fabrication process or simply incorporating more active layers in the cavity region. As expected to exhibit both a large and a high Q, air-gap DBR MCs are potential candidates for realizing highsystems (where is the cavity loss, $\propto$ 1/Q), and thus for realizing polariton lasers with ultra-low threshold. In addition, anisotropic coupling strength is revealed by the phenomenon that strong coupling regime is reached for light with polarization E//a while weak coupling regime is often observed for E//c.

Chapter 7 presents the first observation of emission from trapped photon states and trapped exciton-polariton states in III-nitride cavity systems. The photonic traps here are formed by the cavity thickness fluctuations. Due to the anisotropic coupling conditions in non-polar nitride cavities, trapped photons and trapped polaritons are demonstrated for E//c and E//a respectively. In the observation, it is found that a spatial pinhole can be employed to intentionally select particular sates, which could provide a very useful tool for spectroscopy of lower dimension structures. These observations are also confirmed by our theoretical calculations based on a linear Hamiltonian. These observations are also confirmed by our theoretical calculations based on a linear Hamiltonian. Another very interesting thing is that a quantized energy up to 6 meV is demonstrated for trapped polaritons, which is also the largest value ever reported so far.

Finally, Chapter 8 makes conclusions to this thesis, indicating possible prospective researches based on the results presented in this thesis. The demonstrated high Q and largest Rabi splitting could be further enhanced by simply increasing the DBR period numbers and cavity thickness, and thus air-gap/III-nitride DBR cavities with high could be expected, which could be helpful to further reduce the threshold of BEC or polariton lasing, and could also give rise to new physics. The observed polaritons in a trap contains many interesting topics. For example, the polariton-polariton interactions in such traps could be large and can be further enhanced by Feshbach resonance effect, laying the foundation for single photon emitters based on polariton blockade effects. The large quantized energy of trapped polaritons demonstrated in our cavities could also contribute to polariton BEC with lower thresholds, polariton Josephson junction with faster photon pulse generations, stable multi-component BEC and ultrafast mode-locked polariton lasing, etc.

A2. ディジタルインターフェースを用いた PLL の周波数特性の測定手法に関する研究

吉川 俊之

A Study on Measurement Method of PLL Frequency Characteristics through Digital Interface

By Toshiyuki Kikkawa

This thesis proposes a measurement method of PLL frequency characteristics not through analog measurement but through digital interface in order to reduce the test cost.

Chapter 1 introduces the background and objective of this study. These days, much-higher frequency should be synthesized by a PLL in order to realize higher-speed communication systems or more efficient utilization of the frequency bands. On the supply chain, testing measurements should be carried out to confirm the correct operation of the PLL before shipping. We challenge to integrate the measurement macros on the chip in order to reduce the test cost. Furthermore, we aim at the realization of the measurement through only digital interface.

Chapter 2 forms the foundation of the PLL and its frequency characteristics. First of all, the closed loop transfer function and related characteristics are introduced with mathematical expressions. Then several analysis methods of the transfer function are discussed. Sinusoidal phase modulation is conventionally used in the frequency-domain analysis, we propose to use triangular phase modulation. We theoretically compare these analysis methods using MATLAB, and show that the triangular phase modulation is easy to implement and accurate after some mathematical operations. We also explain about the lock range

of the PLL.

Chapter 3 describes the circuit components to realize our proposed method. The proposed method utilizes Digital-to-Time Converter (DTC) as an integrated stimulus source generator, and its architecture, operation and design constraint of the DTC is explained. Then, the triangular phase modulation carried out by the DTC is described. At the same time our proposed method employs Time-to-Digital Converter (TDC) as an integrated response analyzer, and its architecture and operation of the Vernier TDC is described in addition to the flash TDC. Dynamic range of the TDC required for the proposed method is also explained.
Finally, the Process, Voltage, and Temperature (PVT) effects on the DTC and TDC are discussed. Since both the DTC and the TDC are composed of the same delay cells in our proposed method, the measurement result is robust against the PVT variations. The robustness of our proposed method is demonstrated by HSPICE simulations.

Chapter 4 introduces a flow of the proposed measurement method. Design of the circuit components suitable for our measurement method are also summarized in this chapter. The 2nd-order PLL is constructed by Simulink for MATLAB demonstration. Furthermore, a the 3rd-order PLL with the DTC and the TDC, which are manually designed, as well as the control circuit of the DTC and the Thermometer-to-Binary Converter (TBC), which are designed in standard digital circuit design flow in 180 nm CMOS process for HSPICE simulation. As a summary of this chapter, the circuit area is compared and the result shows that the circuit area occupied by the additional components for the measurement is less than quarter of the total area. Since the additional components have a high scalability, the overhead of the additional components will be reduced as the process scaling is advanced.

Chapter 5 demonstrates the proposed measurement method using MATLAB and HSPICE simulations. Since only the divisor of the reference frequency can be the modulation frequency in our method, we shift the reference frequency so as to increase the calculated frequency points on the transfer function and it is demonstrated by MATLAB simulation. Additionally, from the transfer function with increased frequency points, we discuss the error caused by the harmonic components of the triangular phase modulated stimulus. HSPICE simulations confirm that our proposed method can be applicable to real PLLs which are composed of non-linear circuits. Here, the time-domain method using an impulse response is also carried out on the same DTC and TDC, and the comparison results show that our proposed triangular modulation method has better accuracy than the time-domain method.
The lock range measurement is also discussed in this chapter.

Chapter 6 introduces a PLL bandwidth control as an application of the proposed measurement method. Our method easily measures the magnitude of the transfer function at a specified modulation frequency. The bandwidth is feedback controlled by changing the charge pump current of the PLL such that the magnitude transfer function at the specified frequency becomes -3dB. The proposed bandwidth control is demonstrated by MATLAB.

Through the analysis and the demonstration of the PLL measurement method presented in this thesis, it is shown that the integration of the DTC which carries out the triangular phase modulation at the input and the TDC which digitalizes the output response effectively reduces the PLL measurement cost. Furthermore, the robustness against the PVT variations with the high process scalability, as well as the ease of use through the digital interface make our proposed method more attractive.

A3. プラズモニックナノワイヤ量子ドットレーザの設計と評価に関する研究

ホ ジンファ

Design and Characterization of Plasmonic Nanowire Quantum Dot Lasers

By Ho Jinfa

Plasmonics is the study of the coherent oscillation of electrons at the interface between a metal and a dielectric, known as surface plasmons as they resemble the electronic oscillations in a plasma gas. The term “plasmonics” was first coined in Caltech in the early 2000s, for a new device technology that exploits the unique optical properties of nanoscale metallic structures to route and manipulate light at the nanoscale. Surface plasmons are electromagnetic waves and thus travel at the speed of light, but with subwavelength confinement due to exponential decay from the metal-dielectric interface. This property has since been widely employed to miniaturize optical devices to spatial dimensions comparable to that of their electrical device counterparts, which is below the diffraction limit of light and thus cannot be achieved with conventional optics, for the purpose of monolithic, high density integration of electrical and optical components.

The replacement of electrons with photons as information carriers provides many advantages such as higher bandwidths and operation speed, and this is one of the main motivations for opto- electronic integration. A key ingredient for the realization of such hybrid circuitry is the nanolaser: a coherent source of photons at the nanoscale. The past decade has seen huge research efforts in reducing the size of conventional lasers below the diffraction limit. Various approaches using photonic crystals, metallic cavities, and plasmonic structures have been explored. Despite the drawback of higher losses, plasmonic nanolasers, particularly those based on nanowires, has been a hot research topic as they are promising for achieving enhanced light-matter interactions and enhanced spontaneous emission coupling factors. Recent advances in plasmonic nanowire lasers have made significant progress towards the point where practical applications are becoming viable, but there exists several avenues for further improvement. In particular, nanowire plasmonic lasers to date are based on semiconductor materials that emit in the visible range, but emission in the near infrared range of ~800 nm to 1100 nm is desirable for high-speed short reach interconnects. For improved device performance, the use of quantum wells or quantum dots embedded within the nanowires is also desirable

due to better carrier confinement. The current plasmonic nanowire design based on the hybrid plasmonic-waveguide mode supported in a dielectric layer between the nanowire and the metal layer exhibits poor mode confinement within the nanowire core region, and coupling to quantum structures in the nanowire is expected to be poor.

In this thesis, the problems raised above are addressed, and original research on the fabrication and optical properties of plasmonic AlGaAs-GaAs core-shell nanowire lasers are presented. The feasibility of achieving sufficient gain for plasmonic lasing with InGaAs quantum dots embedded in GaAs nanowires was also demonstrated experimentally.

A4. ウェハ融着法によるシリコン基板上量子ドットレーザの作製とその評価に関する研究

張 芫瑄

Fabrication and Characterization of Wafer-Bonded Quantum Dot Lasers on Silicon

By Jhang Yuan-Hsuan

In the current information explosion era, the conventional electrical interconnection cannot meet the demand of high data transmission rate, and the optical interconnection is introduced for both longer- and shorter-distance transmission. However, the relatively high cost makes it inapplicable to the data center application. Silicon photonics, an ideal candidate for the electrical-to-optical interconnection transition, is thus a promising technology for the industrial-scale photonic-integrated circuits (PICs). Although the passive photonic devices on Si have been systematically studied, the realization of the active Si photonic devices, the efficient light sources, is still a challenge due to the indirect-bandgap nature of Si. III-V semiconductor lasers, which have been deeply studied for long time, are extremely suitable as the light sources for Si. In particular, semiconductor quantum dot (QD) lasers, with advantages of low threshold condition and temperature stability, are thus preferable to the PIC applications. For the integration of III-V light sources on Si, the wafer bonding technology provides a simple and effective way, which is not subject to the materials' limitations. Moreover, the performances of bonded devices are comparable to the as-grown devices. Due to these merits, we utilize the wafer bonding technology for jointing QD lasers on Si and realize the active Si photonic devices in this study.

This dissertation mainly focuses on the fabrication and characterization of high-performance InAs/GaAs QD lasers wafer-bonded onto Si. The main conclusions of this study are briefly described as follows.

In order to integrate QD lasers on Si, we first made a series of bonding tests to determine the bonding conditions for GaAs on Si. We mainly utilized two bonding schemes: the direct bonding method and the metal-mediated bonding method. According to the properties of the bonded GaAs/Si pairs, the bonding temperature at 300 oC for direct bonding and metal-metal bonding have best properties of the GaAs/Si bonding interface, and this condition is thus applicable to the integration of lasers on Si. We also made an improvement on the bonding strength for the direct bonding by ultraviolet (UV) surface activation, where the UV-activated bonding strength is ten times stronger than that of our original bonding.

The determined bonding conditions were then applied to the integration of InAs/GaAs QD lasers on Si. We firstly established the fabrication process and demonstrated the QD lasers on Si with comparable lasing performances as for that of the as-grown lasers. The metal-bonded and direct-bonded QD lasers on Si operate with threshold currents of 140 mA and 100 mA under pulse pumping, respectively, and both of them exhibit room-temperature lasing wavelengths at 1.3 μm.

The modulation properties in the bonded lasers was next presented, which is one of the important issues for the communication system. The 600-μm-long bonded laser was performed under continuous-wave pumping, with a threshold current of 130 mA and a maximum output power of around 15 mW (single facet). The first direct modulation experiment in QD lasers on Si was then demonstrated with a bit rate up to 6 Gbps, and the extinction ratio according to the eye pattern is 5 dB. We also estimated the modulation bandwidth f_3dB of 8 GHz according to the eye diagram at different modulation speeds. Noted that we did not introduce any grating structure into the lasers, and there is no coating on the as-cleaved facets, which would improve the modulation properties of the bonded lasers.

On the other hand, we also aim for a realization of the hybrid evanescent lasers. The metal-stripe bonding scheme was adapted here for the QD lasers on Si-ribbed silicon-on-insulator (SOI) substrates with the light emission from the III-V region. Here the Si rib structure was introduced for imitating the Si waveguide, and the metal stripe was installed as the bonding metal as well as the electrodes. In this study, we have successfully demonstrated the broad-area type laser with a threshold current density of 520 Acm-2, and the ridge-type bonded laser with a threshold current of 110 mA. To our best knowledge, this is the first demonstration of InAs/GaAs QD lasers on SOI substrate by directly bonding metal and semiconductor materials. Note that our bonded lasers were all performed without any coating on the as-cleaved facets. After the fabrication part, we further designed the hybrid QD/Si evanescent lasers. According to the simulation, the hybrid laser could be designed with a fixed 150-nm-thick AlGaAs lower clad layer, and the Si waveguide with widths of 0.8 μm and 1.5 μm could be adapted to the design with the adiabatic taper for light manipulation with a compact waveguide design.

With simple device structure and fabrication, our result shows an encouraging demonstration for III-V QD lasers on Si, which benefits the silicon photonic integrated circuits for high-speed and low-cost applications.

A5. IoT ノード向け低消費電力無線通信回路と高効率無線給電の研究

井口 俊太

Research on Low Power RF Circuits and Highly Efficient Wireless Power Transmission for IoT Nodes

By Shunta Iguchi

Internet of things (IoT) applications are a prospective technology driver for a low power design in a very large scale integration (VLSI) system. A low power operation for a large number of IoT nodes is a fundamental requirement because the energy cost is the most significant concern to realize the IoT application. In IoT applications, “things” are sensing the information relating to a human activity and environment as data. The IoT nodes send the sensed data to high performance computers through an internet. Using the data, the system improves our productivity and quality of life after some transactions at the computer. For this application, the cost of the IoT nodes limits the performance of the whole of the system because the quality of available data depends on the number of IoT nodes. To enhance the system performance, inexpensive sensing and communication techniques are required. In accordance with these backgrounds, a low power circuit design is a key technology to reduce a cost because the cost corresponds to the power consumption in IoT nodes. Specifically, the power consumption in a wireless communication and power management circuit needs to be reduced because the power of these blocks dominates the large portion of the total power in IoT nodes. A purpose of this dissertation is to reduce the cost of IoT nodes by reducing the power consumption in wireless communication and power management circuits. This dissertation is organized with five chapters. The first chapter describes an introduction for IoT applications and target of this dissertation. A wireless transceiver is a fundamental circuit block to connect “things” through an internet. The power consumption to communicate with other devices is a dominant source for a total power in IoT nodes. To reduce the power consumption for the wireless communication, low-power crystal oscillators and wireless transmitter are developed in the chapter 2 and 3, respectively. Additionally, a highly efficient wireless power transmission circuit is developed to reduce the wiring cost for IoT nodes in chapter 4. The misalignment tolerant wireless power transmission circuit realizes an inexpensive and robust wireless power charging for IoT nodes. A summary of this dissertation is given in chapter 5. New findings and discussions introduced in this dissertation are summarized in the chapter. Finally, several discussion for upcoming IoT applications is given for future works.

In the Chapter 2, three energy efficient crystal oscillators are developed to reduce the power consumption during the start-up and steady state in IoT nodes. At first, a quick start-up crystal oscillator reduces the start-up time of IoT nodes by introducing a new variation-torelant chirp injector and negative resistance booster. The developed crystal oscillator reduces the start-up time by 92 % from 2.1 ms to 158 μs at a temperature of 25 °C and supply voltage of 1.5 V. The variation-tolerant quick start-up technique reduces the power consumption in the whole system because the short start-up time in a crystal oscillator significantly reduces a wasted power loss in other active circuits (e.g., low noise amplifier and power amplifier) for RF communications. This is the first report to achieve the variation-tolerant quick start-up in a crystal oscillator design. Next, a dual mode crystal oscillator with a new snooze mode is developed for an intermittent operation in IoT nodes. The new crystal oscillator varies the operation mode depending on the state in IoT nodes. A new snooze mode with a proposed automatic self-power gating (ASPG) and multistage CMOS inverter reduces the power consumption by 93 % from a conventional Pierce crystal oscillator with a single-stage CMOS inverter. The crystal oscillator achieves a low power operation at the oscillation frequency of 39.25 MHz with the power consumption of 69 μW in an active mode and 9.2 μW in a snooze mode. Finally, a stacked-amplifier crystal oscillator is developed for an ultra-low power operation in the steady state. A 3.3 V, 39.25 MHz stacked-amplifier crystal oscillator fabricated in a 65 nm CMOS consumes 19 μW and achieves the phase noise of -139 dBc/Hz at 1 kHz offset frequency. The corresponding figure of merit (FoM) of -248 dBc/Hz is the lowest in published crystal oscillators. The low-power and low-noise crystal oscillator enhances the performance (e.g., minimum sensitivity and power consumption) of wireless transceivers in IoT nodes.

In the Chapter 3, a new highly energy-efficient wireless transmitter is developed to achieve the low-energy wireless communication for IoT applications. To develop a highly efficient power amplifier for IoT nodes, a new design method of a dual supply voltage scheme is introduced in this chapter. A wireless transmitter fabricated in a 40 nm CMOS process achieves the highest drain efficiency of 42 % and the highest global efficiency of 28 % at a output power of -20 dBm, thereby achieving the lowest energy of 36 pJ/bit among the reported wireless transmitters.

In the Chapter 4, a misalignment tolerant magnetically resonant wireless power transmission is introduced to achieve a low cost and robust power charging for a large number of IoT nodes. The wireless power transmission system with a new control algorism of zero-phase-difference capacitance control (ZPDCC) achieves an adaptive capacitance control to maximize the transmission efficiency depending on the transmission distance. The measured total efficiency is increased by 1.7 times from 16 % to 27 % at a transmission distance of 2.5 mm by introducing the new ZPDCC fabricated in a 180 nm CMOS process.

Chapter 5 gives a summary about the developments shown in this dissertation. Short summaries corresponding to each chapter are given in this chapter. The technical progresses for developing IoT nodes are briefly described. Finally, a discussion for future works is given in this chapter.

A6. 非言語情報の違いに頑健な特徴量表現に着目したニューラルネットワーク音声認識に

関する研究

柏木 陽佑

A research of neural network based speech recognition based on a feature representation of robustness of the nonlingusitc information

By Yosuke Kashiwagi

A speech recognition system becomes one of the major interface with spread of smart phones and evolution of computational power. The performance of the speech recognition system has become enough for the use as the simple interface, however the accuracy of the system is still poor than that of human. To use for further application, more improvement is required. In our speech sound, a variety of information is inherent: linguistic information, paralinguistic information and nonlinguistic information. The speech recognition can be considered as a task of extracting linguistic information from the speech. The paralinguistic information is eliminated in the process of speech analysis. However nonlinguistic information become noise of acoustic features, so that to control nonlinguistic information is a long-standing problem in speech recognition.

In recent years, statistical machine learning has reached a turning point; the evolution of the deep neural networks. They also affect to speech recognition area, the neural networks based system become major stream in speech recognition. However, the neural networks have different properties from traditional Gaussian based models. Therefore, it is difficult to directly use the elemental technologies related to conventional Gaussian based approach, so that the trends of the current speech recognition research is based on trial and error. It is required to control nonlinguistic information based on theoretical background.

In this paper, a several neural networks based approach is proposed in the feature domain and the acoustic model domain to realize robustness of the nonlinguistic information. As mentioned above, the neural networks and Gaussian based model have different properties, so that the knowledge of the Gaussian based approach is used in this paper. Thus, the efficient control of the nonlinguistic information can be achieved.

A7. オンチップ集積高電圧太陽電池の高安定化と遠隔光駆動型 MEMS の高速動作応用に関する研究

森 功

A Robust On-Chip-Integrated High-Voltage Photovoltaic Cell Array and Application to High-Speed Remote Optical Operation of MEMS Actuators

By Isao Mori

A microdevice working in a remote place has been widely investigated for various applications. For operation of these remote microdevices, power feed and signal transmission are two important issues. As a remote microdevice is desirable as small as possible, a power source which can transmit signals simultaneously is preferable. A photovoltaic (PV) cell, which converts light into electricity, is a solution for power feed and signal transmission by light. However, an electrostatic actuator, which is used for microdevices, generally requires high voltage, while voltage generated by a PV cell is quite low due to their material properties. Therefore, a method for obtaining high voltage from a PV cell is required, and thus series connection of PV cells is often employed. There are several conventional series-connected PV cell array. However, they modifed a standard CMOS process and they are difficult for foundries to accept to fabricate.

We have proposed an on-chip high-voltage silicon PV cell array. This array consists of PV cells connected in series, and they are made with a standard CMOS process and mesa-isolated by a post-process. Because this technology is based on standard CMOS technologies, it ensures high reliability and quality of the cells. In addition, it does not require modifications of a standard CMOS process.

This paper firstly confirmed that the output voltage is proportional to the number of series-connected cells, and the current is also confirmed to be proportional to the area of a p-n junction of a cell. In this paper, the area required for certain voltage and current is also discussed, and found that the length of gaps between PV cells and the thickness of a device layer of an SOI wafer should be carefully considered when a PV cell array is small. It is also discussed that the efficiency of this PV cell array.

Series-connected PV cell array has the feature that the amount of its current is limited to that of the least-illuminated cell, thus a serious degradation of PV output power is caused even by a small dust on only one PV cell. To avoid this degradation, bypass diodes are commonly used for a large-scale PV cell module. However, unlike a large-scale PV cell module, the PV cell array concerned in this paper is based on standard CMOS technologies, and thus PV cells and bypass diodes are on the same plane. Therefore, bypass diodes reduce the area of PV cells. In this paper, a trade-off between the areas of a PV cell and a bypass diode are discussed. To examine whether bypass diodes work in a microscale PV cell module and to experimentally extract the parameters of a bypass diode, bypass diode test structures are proposed. The experiments using the test structures proved a successful operation of bypass diodes even in a microscale PV module. It also revealed that the gap between cells and bypass diodes should be taken into consideration when the optimum area of a bypass diode in a microscale PV module is calculated. In addition, the area of a bypass diode must be enlarged to reduce the effect of Joule heating.

This paper also demonstrates that the PV cell array concerned in this paper has the ability to drive a MEMS actuator in a remote manner. In this experiment, 125-cell PV cell array and a MEMS comb drive actuator was employed. A laser beam which was emitted from the distance of 1.5 m successfully actuated the

MEMS actuator, and it is proved that the PV cell array has the ability of driving a MEMS comb drive actuator. However, this experiment also showed that the PV cell array can only charge the actuator and cannot discharge it.

There are some methods for fast driving of the MEMS comb drive actuator such as a high-voltage CMOS switch, self-oscillation and reversely-connected photodiodes. Reversely-connected photodiodes are the easiest method for implementation. However, it doubles the area of the PV cell array system. To reduce the area of the system, this paper reports a PV cell array with discharging phototransistors instead of photodiodes. In the circuit, a PV cell array and phototransistors are both connected to an electrostatic MEMS actuator in parallel. On the PV cell array and the phototransistors are green and red filters respectively. By changing the color of light, it can charge and discharge the MEMS actuator. Because the phototransistors are used instead of photodiodes, this discharge circuit has an advantage in compactness. In this paper, the experiments of demonstrating the system were conducted, and it is found that the proposed system can charge and discharge the actuator. The optimum area of the system is also discussed.

In this paper, a high-voltage CMOS switch which can be used in a standard CMOS process was also proposed. The experiments demonstrated switching successfully.

A8. 走行中電気自動車への給電をめざしたワイヤレス電力伝送

コー キム エン

Wireless power transfer for moving electric vehicles

By Koh Kim Ean

This thesis focuses on designing and evaluating various wireless power transfer design for charging while moving of electric vehicles. Vehicle electrification has become a recognized solution to oil shortage and pollution problems from engines-driven vehicle. Electric vehicles are also cleaner, quiet and more energy efficient. Renewable energy sources can be used especially with the development of distributed energy system. However, electricity storage is a bottleneck for rapid development and wide adoption of electric vehicles. Batteries for supporting the same or close to the driving range of vehicle users used to enjoy are costly, heavy and with long charging time.

Wireless power transfer alleviates above mentioned problems by providing a safer and more convenient charging method compared to plug-in charging. For charging while parking, the wireless charging facility is more durable, space saving and does not pollute the city view with overhead electricity grid. Current development of wireless power transfer technology furthers allows dynamic charging possible on highways and roads. The wireless power transfer system is constructed to support certain distance and vehicles pick up power while moving along the road. The challenges of constructing the system include complexity of the wireless powering network underneath the ground, cost, transfer gap, efficiency and power levels.

In this work, wireless power transfer configurations which consist of combination of multi-receiver and repeaters are proposed for dynamic charging. Power division method between receivers with different amount of coupling to the transmitters is proposed. On the other hand, repeaters are also used in a system to extend the effective range. New methods for power division and impedance matching are derived and then generalized for arbitrary number of receivers and repeaters including cross coupling consideration. Impedance inverter representation is used to simplify the analysis and calculation. Additionally, a special case where the existence of repeaters causes dead zone is analyzed. The simplicity of using impedance inverter representation compared to only solving conventional equivalent circuit equations is further demonstrated in the analysis of this special case. All the methods proposed are validated using simulations and experiments.

Above mentioned work generalized the analysis of wireless power transfer using impedance inverter representations of coupling for arbitrary combinations of receiver and repeaters. Using this theory as basis, a dynamic charging system using two transmitters simultaneously powering a receiver to achieve even magnetic field and therefore constant power level during running is proposed. Mutual inductance is calculated using Neumann formula. Maximum efficiency depends on the ratio of mutual inductance to the coil resistance. When using long transmitters, the mutual inductance is similar to using short transmitters but the coil resistance is larger. Therefore multiple short transmitters are connected in parallel to the power source via impedance inverter circuit are proposed. The coupling design which depends on the size and turns of the transmitters, and receiver size determines the power level. Spacing between transmitters is also designed to achieve even magnetic field. Additionally, cross coupling between the transmitters also affects the constant power level. Cross coupling cancellation method is also proposed by absorbing the additional cross coupling impedance into the coil inductance and resonant capacitance. The hardware setup for this even magnetic field system including the transmitter module, the receiver module and the magnetic sensors for sensing the position of the receiver is shown in the last chapter.

In the next chapter, the steady state and transient analysis of one-to-one wireless power transfer are discussed. In series-series compensated wireless power transfer, the maximum efficiency depends on both the receiver and transmitter. However the maximum power depends dominantly on the transmitter. This characteristic is exploited to achieve a flatter efficiency curve across different power levels as different power is required when the vehicle is at different moving speeds. A design flow is then proposed using efficiency vs. power level curve. The design method is discussed using round spiral coils and the AC resistance is approximated using extended Dowell formula. However the method can be applied to other coils once the AC resistance calculation method is developed. The transient of the wireless power transfer is then studied using general state space averaging (GSSA).

A9. Fe ベース新規強磁性半導体およびそのヘテロ構造の物性とデバイス応用

レ デゥック アイン

Properties and device applications of new Fe-based ferromagnetic semiconductors and heterostructures

By Le Duc Anh

Spintronics is the field of science and technology that aims to utilize both the charge and spin degree of freedom of electrons in device applications. One central challenge of spintronics is to integrate spin-dependent phenomena into semiconductors, the platform of almost all present electronic devices. So far, the most straightforward way is to create ferromagnetic semiconductors (FMSs), which is usually done by doping a large amount of transition metal elements (Mn, Fe, Cr…) into conventional semiconductors. While many efforts in searching for an ideal FMS have been concentrated on wide-gap diluted magnetic semiconductors such as oxides, nitrides, carbides, our early works on Fe-based III-V FMS (In,Fe)As have shown many positive results. (In,Fe)As was proved to be the first n-type electron-induced III-V FMS with strong s-d exchange interaction. These results indicate that the narrow-gap FMSs also possess a very high potential.

This thesis presents the magnetic properties and device applications of new Fe-based III-V FMSs and their heterostructures. A large part of the study focuses on the n-type FMS (In,Fe)As. The magnetic properties of ultrathin (In,Fe)As samples, where the quantization of electron energy is observed, were studied. By controlling the two-dimensional electron wave function using field-effect-transistor structures, electrical modulation of the ferromagnetism of these (In,Fe)As quantum wells was demonstrated. Then the band structure and magnetic properties of bulk-like thick (In,Fe)As layers were studied in the context of spin Esaki diode structures. Next, we discuss on the mechanism of ferromagnetism of (In,Fe)As and propose a new material design strategy for high-Curie temperature FMSs. Finally, as a demonstration for this strategy, study on another Fe-based FMS (Al,Fe)Sb was also conducted and the results of (Al,Fe)Sb are presented.

In Chapter 2 the magnetic properties of ultrathin InAs/(In,Fe)As/InAs trilayer, where the quantization of electron energy is observed, are studied. The results indicate that electron carriers of (In,Fe)As possess a long coherence length (>40 nm) and the their wavefunctions extend into the neighboring InAs layers. When gradually etching the top InAs layer of a (In,Fe)As trilayer quantum well (QW), we observed a large decrease of Curie temperature of the QW by 42% without modifying the (In,Fe)As magnetic layer. These results were successfully explained by the decrease of the overlap of the electron wavefunctions and the (In,Fe)As magnetic layer in the QW. A large N0α value of 4.5 eV was estimated for (In,Fe)As.

In Chapter 3, we demonstrate the electrical control of the magnetic properties of InAs/(In,Fe)As/InAs trilayer quantum wells (QWs) by manipulating the overlap of the two-dimensional wavefunctions and the (In,Fe)As layer, using a gate voltage VG in field-effect transistor structures. Unlike conventional experiments, by controlling the carrier wavefunction instead of the carrier density, we reduced the power consumption to only 10^-4 ~ 10^-6 of that of the conventional method. At the end, we discuss on the mechanism of ferromagnetism of (In,Fe)As and propose a new material design strategy for high-Curie temperature FMSs.

In chapter 4 we studied the band structure of n-type ferromagnetic semiconductor (In,Fe)As, using tunneling spectroscopy in n-(In,Fe)As/p-InAs spin Esaki diodes. (In,Fe)As samples with Curie temperature (Tc) of 45 - 65 K show spontaneous spin splitting energy of 40 - 50 meV in the conduction band, whose magnitude depends on the Fe concentration, electron density, temperature and external magnetic field. When rotating the magnetization in the film plane, tunneling anisotropic magnetoresistance (TAMR) reveals different symmetries of the (In,Fe)As band structure components. Finally, origin of strong electron-induced ferromagnetism in (In,Fe)As, and chemical trend of Fe-based FMSs were discussed, which suggests that the relative position of the Fe-related IB to the CB or VB of the host materials is important for the realization of ferromagnetism in Fe-based FMSs.

In Chapter 5, we investigate the crystal structure, transport and magnetic properties of Fe-doped (Al,Fe)Sb thin films with the Fe concentration x up to 14% grown by molecular beam epitaxy. All the samples show p-type conduction at room temperature and insulating behavior at low temperature. The (Al,Fe)Sb thin film with x = 10% shows intrinsic ferromagnetism with a Curie temperature of 40 K. In the (Al,Fe)Sb thin film with x = 14%, a sudden drop of mobility and Curie temperature was observed, which may be due to microscopic phase separation. The observation of ferromagnetism in (Al,Fe)Sb paves the way to realize a spin-filtering tunnel barrier that is compatible with well-established III-V semiconductor devices.

In Chapter 6, we give the conclusions and further outlook of the work on Fe-based FMSs. With new perspectives, the Fe-based FMSs have high potential to be the principle spintronics material in the future.

A10. 小型衛星搭載の合成開口レーダー用の集中型送受信システムを有する２偏波対応進行波型アンテナ

ラビンドラ ビネー

Dual Polarization Travelling-Wave Antenna with Centralized Radio-Frequency Transmitting/Receiving System for Synthetic Aperture Radar in Small Satellites

By Ravindra Vinay

Active radar sensors have certain advantages over passive optical sensors for space-based remote sensing. They however are difficult to accommodate on a small satellite bus primarily due to large mass, size of antenna system. To make the system compact and lightweight, a dual-polarization traveling-wave antenna with centralized high power Radio Frequency (RF) source is proposed as antenna system candidate. The advantage of this type of antenna is that orthogonal polarizations can be radiated by the same aperture, provided some constraints are met. These constraints do not allow application of traditional antenna pattern synthesis algorithms. A multi-objective evolutionary algorithm is selected to synthesize optimal excitation coefficients. The optimization objectives are chosen to enhance quality of end (processed) SAR image. A computer model is developed of a traveling-wave antenna panel made of parallel aluminum plates separated by honeycomb dielectric with orthogonal radiating slot-pair. The simulated panel is fabricated and measurements are conducted. Aperture efficiency of 50.1% and 49.2% at 9.65 GHz for right-hand-circularly-polarized and left-hand-circularly-polarized beams respectively is achieved.

To realize centralized feeding, a high power RF source is required, which is possible by either using Traveling-Wave-Tube-Amplifiers (TWTAs) or Solid-State-Power-Amplifiers (SSPAs). Although SSPAs exhibit better reliability as compared to TWTAs they are poor in terms of the power output capability. The power output capacity can be increased by coherently combining output of several SSPAs. Different power combining techniques are discussed and a novel low-loss, compact power combiner is proposed. The proposed combiner is resonant in nature with cylindrical TM0m0 cavity. A novel way of directly interfacing the cavity and microstrip line of SSPA with no intermediate adapters is presented. A novel method to improve graceful degradation by fixing the relative position of input unit amplifiers is presented.

This design of the dual-polarization traveling-wave antenna with centralized high-power RF source is proven to be compact and efficient. It also demonstrates the successful application of modern heuristic multi-objective optimization techniques in antenna design and realization of a resonant cavity power-combiner directly interfaced to modern solid-state technology.

A11. 惑星探査ローバの画像航法誘導における知能化に関する研究

大津 恭平

Study on Robotic Intelligence for Vision-based Planetary Surface Navigation

By Kyohei Otsu

Robotic probes on remote planetary surfaces have been the recent focus of major space agencies and private companies. These robotic intelligence has established landmark studies in planetary science, as well as demonstrating the state-of-the-art technologies of extraterrestrial surface mobility. To accommodate the requirements of challenging future missions, mobile robots should acquire advanced mobility that enables longer distance traversal in complex terrain with lesser human intervention. Since every stride brings a robot into a place where no one has ever been, the robotic pioneer must handle difficult and usually unpredictable challenges raised by unknown environments. This the- sis focuses on the onboard decision-making systems to accomplish fully autonomous navigation in substantial distance on challenging planetary surfaces, while maintaining the safety of precious robots with intelligent perception, planning, and localization capabilities.

An important requirement for future exploration robots is accurate traversability assessment in natural terrain. Unordered planetary terrain puts high-level complexity on the perception problem, requiring a capability to sense not only the geometric topology but also the non-geometric properties of extraterrestrial terrain surfaces. A current limitation on autonomous perception is the inability to detect non-geometric terrain hazards, such as sandy ripples which reduces the wheel traction, and pointy pebbles which may damage the wheels. This thesis proposes two learning-based perception methods which extract non-geometric terrain properties using multimodal sensors. A key common idea is to employ a self-learning scheme which enables a robotic system to learn physical experience of distant terrain from exteroceptive and proprioceptive sensing. In the first method, semantic terrain types are estimated using a vision-based machine learning classifier which is trained in collaboration with mechanical measurements. In the second method, energy consumption in the mobility system is accurately predicted with a model-based estimator that learns complex wheel-terrain interactions. The proposed techniques could interpret measured data as qualitative and quantitative forms. The validity of the proposed methods are shown through real-world experiments with test-bed robots in Mars-analogous fields.

After perceiving the environment, the robot is required to determine the next motion while considering various hazardous factors arose from the environment and system's kinematic constraints. Future missions will require autonomous exploration in challenging complex sites where the surface is covered with an abundance of obstacles to avoid. Such environments pose difficulty in a simple conservative planning strategy which tries to generate a detour path around the obstacles. This thesis proposes a robust and efficient algorithm for motion planning in obstacle-abundant terrain, which navigates the robot onto the destination while avoiding obstacles with straddling motions. The developed method has two components: kinematics-based state estimator and receding horizon trajectory planner. These components are organically coupled to provide an optimal path which is safe and robust to various uncertainty with less computational expense. The proposed planner is analyzed with synthetic terrain simulating Martian rock distributions and showed a high success rate up to 15% rock abundance.

Finally, a robust and efficient localization method is developed to accurately guide the robot to the target coordinate. Recently, visual odometry has gathered substantial attention as a robust localization method in natural terrain, whereas its computational

cost is challenging for limited onboard computers. One of the computationally expensive operations is the robust estimation of pose parameters with a sampling-based outlier rejection scheme. The sampling efficiency can be drastically improved by reducing the minimal number of data points for relative pose estimation, which is theoretically three for a stereo camera system. This thesis presents a novel formulation which reduced the minimal number to two, by employing a common reference direction derived from a distant point measurement. A field test in volcanic terrain shows that the proposed method can successfully estimate robot trajectories with increased computational efficiency.

A12. La2O3/InGaAs MOS 界面と MOSFET への応用に関する研究

張 志宇

Study on La2O3/InGaAs MOS interfaces and the application to InGaAs MOSFETs

By Chih-Yu Chang

InGaAs has been seen as one of promising III-V semiconductor material for fabricating high performance nMOSFET in the upcoming 5 nm node CMOS technology because of its light electron mass (0.0411 m0) and high electron mobility (13800 cm2/V-s). However, unlike conventional channel material Si, which can be easily passivated by SiO2 to have good interface between channel and gate insulator, the sp3 hybrid electron orbital of InGaAs make InGaAs difficult to be passivated such that there is always a large amount of interface states between InGaAs and gate insulator, which may degrade the subthreshold slope (S. S.) and the mobility in InGaAs MOSFET. The interface state density (Dit) of InGaAs MOS structures is usually larger than 1012 cm-2-eV-1, over an order larger than Si. Therefore, to reduce the interface state density is a critical issue to improve InGaAs MOSFET performance.

In this thesis, the improvement of InGaAs MOS interfaces by atomic-layer-deposited (ALD) La2O3 was studied. It is found that the La2O3 can have good passivation on InGaAs not only because it is a trivalent oxide, which has the same electron count with InGaAs, but the intermixing layer of As2O3 is formed between La2O3 and InGaAs, which further reduces the Dit. The recorded-low Dit value on InGaAs of 3 × 1011 cm-2-eV-1 was obtained in Au/ La2O3/InGaAs MOS capacitors.

In addition, in order to make use of the good interface of La2O3/InGaAs to fabricate InGaAs MOSFET, the impact of gate metal on La2O3/InGaAs MOS interfaces was also investigated. It is found that thinner capacitance equivalent thickness (CET) and less slow traps can be obtained by using W as gate metal on La2O3/InGaAs. The reaction of W on La2O3/InGaAs was analyzed by X-ray photoelectron spectroscopy (XPS). We found that the interfacial layer of As2O3 between La2O3 and InGaAs was reduced during PMA such that the CET was decreased but Dit was increased. The reaction is similar to the scavenging effect on high-k/Si MOS interfaces. For those advantages and process compatibility of W gate to La2O3/InGaAs, W can be seen as a good candidate for gate metal to fabricate La2O3/InGaAs MOSFET.

The energy distributions of slow traps density at W/La2O3/InGaAs MOS interfaces were also evaluated. By mearsuring the hysteresis with elaborately changing the range of Vg sweep in C-V measurement, we characterized the distributions of slow traps at W/La2O3/InGaAs MOS interfaces that more slow traps distributed from the midgap toward valence band and less distributed around conduction band edge in the InGaAs MOS band diagram. The distributions allow the performance of W/La2O3/InGaAs nMOSFET being less influenced by the slow traps because nMOSFET turns on while the position of Fermi lever is around conduction band edge.

Then the W/La2O3/InGaAs MOSFETs has been successfully fabricated. High-k/InGaAs MOSFET with small S. S. was realized by La2O3/InGaAs MOS interfaces due to its low Dit. Also, by the low Dit in La2O3/InGaAs MOS interfaces, the carriers transporting through the channel of La2O3/InGaAs MOSFET is more immune from the carrier trapping, providing higher reliability of positive bias temperature instability (PBTI). The scattering effect on mobility of La2O3/InGaAs MOSFET was also elaborately analyzed by Hall mobility measurement. The overview of the applications of La2O3/InGaAs MOS interfaces to InGaAs MOSFET was given in this thesis.

In the end, we firstly found the ferroelectric-like characteristic in W/La2O3/InGaAs MOS structures. The ferroelectricity in W/La2O3/InGaAs MOS structures was examined by electrical analysis on the hysteresis in C-V measurement and P-E hysteresis loop. Due to the ferroelectric-like characteristic in W/La2O3/InGaAs MOS structures, W/La2O3/InGaAs MOSFET was found to be having negative capacitance FET (NCFET) properties. The prospects of utilizing W/La2O3/InGaAs MOSFET to realize steep slope transistor with subthreshold slope (S. S.) lower than 60 mV/dec were also discussed.

In this thesis, we clarified the physical origin of interface state on InGaAs and obtained the recorded-low Dit on InGaAs by ALD-La2O3. The InGaAs MOSFET with La2O3 as gate insulator has been successfully fabricated with elaborate analysis on the mobility, reliability and the slow traps distribution. On the other hand, a new functionality of ferroelectricity in W/La2O3/InGaAs MOS structures was firstly demonstrated. This research provides an insight into gate stacks technology on InGaAs for further improving the performance of InGaAs MOSFETs, and proposes a feasibility of realizing steep slope transistors by W/La2O3/InGaAs gate stacks we developed.

A13. Study on monolithic integration of InGaAsP optical modulator and InGaAs driver MOSFET on III-V CMOS photonics platform

朴 珍權

III-V CMOS フォトニクス・プラットフォーム

上における InGaAsP 光変調器および InGaAs 駆動用 MOSFET のモノリシック集積に関する研究

By Jin-Kwon Park

Si electro-photonic integrated circuit (EPIC) has been enabled to realize ultra-small EPIC using strong optical confinement by large refractive index differences between Si and buried oxide layer (BOX) and monolithically integrated Si MOSFET based on mature Si CMOS technology serve high compatibility of electronic-photonic integration. However, the Si which has indirect bandgap structure, is not a suitable for monolithic integration of active optical component such as optical source. The conventional InP based photonics has been widely used for optical communication and it was very proper to realize active component. Therefore, various EPIC based on III-V photonics have demonstrated in early 1980's even technological difficulties. But, the weak optical confinement was not a CMOS compatible and poor MOS interface of III-V material prohibit the monolithic integration of III-V MOS devices. To overcome these problems, the III-V CMOS photonics platform has been suggested. The III-V CMOS platform is realized by III-V on insulator (III-VOI) wafer by direct wafer bonding (DWB) method. This III-VOI wafer serve the strong optical confinement by large refractive index contrast between III-V and SiO2 same as Si photonics. Moreover, the improved MOS interface of III-V material enable to realize MOSFET. Thus, the III-V CMOS photonics platform give the potential of monolithic integration of ultra-small III-V photonic components and III-V electronics. Recently, there are several photonic and electronic device such as ultra-small array waveguide grating (AWG), sharp-bend waveguide (WG) and InGaAs-OI MOSFET have been reported on III-V CMOS photonics platform. Nevertheless, the monolithic integrated active photonic component such as optical modulator and electronic device are not reported yet on III-V CMOS photonics platform because of several issues. One is the large propagation loss of WG, another one is the thermal budget control for monolithic integration. The high resistance of lateral P-I-N junction also one of issue.

In this thesis, we demonstrated the monolithically integrated InGaAsP optical modulator with InGaAs driver MOSFET on III-V CMOS photonics platform with solving above problems.

Firstly, the effect of pre-bonding annealing on III-VOI wafer was investigated. The micro-void generation while post annealing process prohibit the optical propagation of waveguide. By applying pre-bonding annealing process, we successfully suppressed void generation. The void density was highly reduced from 106 to 103 after post annealing process at 600°C. Then propagation loss by sidewall roughness was reduced by optimization of process condition. By electron-beam (EB) lithography and controlling etching condition, the roughness of sidewall of waveguide was reduces from 11 nm to 4 nm.

Secondly, low resistive lateral P-I-N junction was formed by Zn diffusion and Ni-InGaAsP alloy junction. The conventional ion implantation process which is needed high temperature activation process, was replaced to Zn diffusion and Ni-InGaAsP alloy method. By Zn diffusion method, the sheet and contact resistance of p+ region was highly reduced compare to Be ion implantation method. Moreover, the Ni-InGaAsP alloy was firstly demonstrate to form the n+ junction of InGaAsP. The Ni-InGaAsP alloy enable to form a low resistive n+ junction with low temperature under 350°C. Although the total process temperature was suppressed to 500°C, the access resistance of lateral P-I-N junction was reduced from 2.4 Ω·cm to 0.4 Ω·cm. Using these result, we demonstrate the InGaAsP optical modulator using optical absorption. The InGaAsP modulator shows almost -40dB/mm attenuation at 40mA/mm current injection which is almost 2 times larger than Si modulator. By numerical analysis, we investigated that this large attenuation comes from the inter-valence band absorption of InGaAsP.

Finally, we firstly demonstrated monolithically integrated InGaAsP asymmetric mach-zhender interferometer (MZI) modulator and InGaAs driver MOSFET. The InGaAsP modulator shows shift of free-spectrum range (FSR) by current injection and it needs almost 2.2 mA for phi shift. While modulator operation via InGaAs driver MOSFET, we obtained the phase shift of InGaAsP modulator by gate bias change.

A14. 低電圧 SRAM における特性ばらつきの書き込み安定性への影響

チュウ ハオ

The Effects of Variability on Write Stability in SRAM at Low Supply Voltage

By Hao Qiu

Static random access memory (SRAM) acts as the buffer role in pyramid-like memory hierarchy to compensate the speed gap between processors and bottom-level memories. Targeting a larger capacity of SRAM arrays with higher performance and lower cost, both designers and manufacturers are driving efforts to minimize the footprint of SRAM cells. Also, both active energy and leakage power considerations make operating voltage scaling significantly compelling for SRAM. However, continued increase in variability consisting of time-zero and time-dependent variability is perceived to be a major roadblock for future operating voltage scaling. Thus, variability analysis in SRAM becomes critical for both gaining a deeper understanding of the sources of variability and for developing more robust circuits.

By adopting the intrinsic channel, silicon-on-Thin-BOX (SOTB) – in other words, fully-depleted (FD) silicon-on-insulator (SOI) – technology eliminates large time-zero variability from random dopant fluctuations (RDF) in CMOS bulk one. The immunity to RDF also helps suppress the impact of random telegraph noise (RTN). The big innovation facilitates the experimental demonstration of low-power SOTB SRAM cells operable down to sub-0.4 V regime. Considering the limited data to date, this work presents a comprehensive variability

analysis on write stability in SRAM at low VDD based on SOTB technology platform.

Firstly, four commonly used write stability metrics – including write static noise margin (WSNM) from write butterfly curve, IW from write N-curve, bit-line margin (BLM) from bit-line method and combined word-line margin (CWLM) from word-line method – are compared in order to select the good candidate for write yield estimation at low VDD. The core standard is that the selected one follows good normality and can correctly predict write failure. Bit-line method and word-line method are concluded as good candidates for write yield estimation at low VDD. On the other hand, the non-normality of WSNM and IW is clarified and ascribed to sub-Vth operation of cell transistors at low VDD. HSPICE simulation results help extend our conclusions up to ±6 sigma.

Besides, a new write stability metric is proposed for write yield estimation. The extended write butterfly curve extends the voltage sweeping range of conventional write butterfly curve. Due to the clearer emergence of failure mode, the extended write noise margin (E-WSNM) shows good normality and is demonstrated as a good metric for write yield estimation. More evidence is also given to support the newly proposed one.

Lastly, a statistical model is developed to evaluate the impact of time-dependent RTN in SRAM at low VDD. IW from write N-curve is selected as the write stability metric due to its being current-based one. Based on the distribution fitting of both IW and RTN-induced fluctuation (δIW), the degradation due to RTN on fail bit rate (FBR) is discussed. It is found that RTN degrades Vmin – the minimum voltage which guarantees stability of the whole capacity of SRAM arrays – over 10 % in sub-0.4 V regime, thus emphasizing the importance of RTN for low-power SRAM design.

Overall, our conclusions are not limited to SOTB technology but are applicable to other technologies such as FinFET SRAM, and give implications to SRAM design at low VDD.

電子情報学専攻

A15. 薄膜物体の形状と光学パラメータの推定に関する研究

小林 由枝

Shape and Optical Parameters Determination of Thin Film Objects

By Yoshie Kobayashi

Modeling the shape and appearance of real world objects is one of the important research in computer graphics and computer vision fields. Such modeling results are widely used to games, movies and cultural heritage digitization to name a few. Appearances of many objects include several complex reflectance properties such as scattering, absorption, diffraction, refraction and interference. These properties make it difficult to model the shapes and appearances of such objects.

Interference is one of the most intractable effects since its color varies iridescence along the viewing and lighting directions. Various objects have interference optical properties, such as laminated materials, soap bubbles and oil films. Yet, modeling shapes and appearances of these objects with interference effects would be useful for diverse applications in industry, biology, archeology and medicine. For example, realizing the digitization of thin film objects, we can obtain more realistic appearance of new coating products in digital space. Several Japanese art crafts such as Tamamushi Shrine were made of wings of green buprestids with interference.

The interference effects are due to interactions between incoming and reflected lights, and depend mainly on geometric parameters such as film thickness and refractive indexes. Once we can establish a method to estimate those geometric parameters, we can generate appearances of such objects relatively easily using a rendering program.

For appearance modeling, it is necessary to estimate those geometric parameters from a non-planar surface. For example, appearance modeling of a heritage object requires a nondestructive measurement method. We cannot peal out a part of the surface from a priceless heritage asset for modeling purposes. Such objects often have a complicated shape with non-planar surfaces. Thus, we have to establish a method to measure those geometric parameters without destroying or deforming original non-planar objects.

In this thesis, we propose a novel method to model thin film objects. We have three contributions as follows. First, we introduce a method to estimate refractive index and film thickness of thin film with planar surface using hyper-spectral images. Second, we explain how to reconstruct shapes and appearances of thin film with non-planar surfaces using hyper-spectral images and RGB images. Finally, we develop an equipment to measure reflectance images of thin film at ones.

A16. 協力中継ネットワークのための高秘匿データ伝送に関する研究

牛 瀬

Study on Secrecy-Enhanced Data Transmission for Cooperative Relay Networks

By Niu Hao

Recent years have witnessed an explosive increase in the research works on cooperative relaying to improve the data transmission reliability and efficiency of wireless communications at the physical layer. Different from these works, this thesis focuses on secrecy-enhanced data transmission for cooperative relay networks (CRN) based on the concept of physical layer security (PLS). There are generally two kinds of eavesdropping attacks for CRN: external eavesdropping attack from pure eavesdroppers and internal eavesdropping attack from untrusted relays. The thesis is thus divided into two parts by considering these two kinds of attacks.

In the first part of the thesis, the cooperative relaying to protect

from the external eavesdropping attack, also named cooperative security, is studied. 1) We first investigate the cooperative security in the typical two-user cooperation scenario under the framework of game theory. Based on the fact that the conventional cooperation may deteriorate the secrecy performance compared to the direct transmission (DT), an opportunistic user cooperation scheme (OUCS) is proposed. The OUCS activates the cooperation only when it is regarded to be worthwhile according to the channel fading. It is proved that the OUCS consistently have a better secrecy performance than the DT, which motivates the users to cooperate with each other. 2) Then, we extend the OUCS to multi-user cooperation scenarios by jointly solving the questions of whether to cooperate and with whom to cooperate under the eavesdropping attack. It is derived that the full secrecy diversity performance is achieved by the OUCS, which outperforms existing alternatives in the literature. 3) Moreover, we consider the application of cooperation security in a kind of specific sensor networks - wireless body area networks (WBAN). Based on the channel characteristics of WBAN, the secrecy outage probabilities for the DT and cooperative relaying are derived respectively. It is confirmed that the cooperative security is also feasible in WBAN.

In the second part of the thesis, the code assisted security to protect from the internal eavesdropping attack is studied. Because the cooperative relays themselves are the eavesdroppers in this case, the cooperative security is no longer workable. Therefore, the code assisted security is introduced. 1) We first design a scheme of fountain-code assisted security (FCAS) for protecting from the internal eavesdropping. Because for fountain-code based transmission the receivers need a sufficient number of fountain packets to recover the original data, the security can be achieved if the destination receives fountain packets faster than the eavesdropper (/untrusted relay). The channel fading itself and transmit power control are exploited by us to make a higher packet reception rate at the destination. From the analysis of FCAS in the cooperative relay networks with an untrusted relay, it is observed that the FCAS can realize an arbitrarily small intercept probability by simply increasing the number of source packets. 2) We further propose a revised information self-encrypted coding scheme based on fountain codes, and apply it to resist multiple untrusted relays. Because the randomness characteristics of fountain codes still results in a small quantity of data leakage, we are motivated to design the new information self-encrypted coding scheme with a better secrecy performance. Based on the new coding scheme, the intercept probability of the cooperative networks with multiple untrusted relays is analyzed. It is observed that the new coding scheme maintains the superiority of FCAS that the intercept probability is decreased to zero exponentially as the number of source packets increases. In addition, the destination based jamming strategy is also considered to accelerate the rate of decrease.

Overall, based on the concept of PLS this thesis comprehensively studies how to enhance the secrecy of data transmission for the cooperative relay networks. Both of the external and internal eavesdropping attacks are considered. The contributions herein can be also applied in the conventional multi-hop networks to improve the data transmission security.

A17. 複雑さに関連した特徴を用いた主観的印象予測

孫 理天

Subjective Impression Prediction by Complexity Related Features

By Litian Sun

As the amount of multimedia content shared and consumed online is growing exponentially, it is becoming more and more important to develop a system that is capable to understand and interpret these content in a way that is consistent with human beings. In addition, from the perspective that the best way to understand ourselves is to build a machine that could think similar with us, predicting users' impression towards such content is of great meaning in both psychology and computer science. Our aim in this thesis is to predict human impressions towards photographs and videos through analysing both the content and the viewer under the inspiration of psychological works.

Complexity is considered as an important indicator in cognitive process. And a stimulus with a moderate complexity level leads to the most positive cognitive experience. In this work we predict the viewers' impression towards photographs by analyzing the complexity of the content. In addition, the level of cognitive load caught by the complexity of a stimulus could be measured through the viewer's eye movement. Thus, we predict individual impression towards video lectures using gaze information. However, psychological theories concerning complexity are only verified on limited situations, and the relationship between complexity and viewer's experience on extensive scope of application is not yet clear. To these end, we propose a series of complexity related features, verify the relationship between complexity and viewer impression, predict the subjective impression for both photographs and video lectures.

Firstly, we evaluate the role of complexity played in aesthetic assessment and verify the relationship between complexity and aesthetics on large-scale photographs through computational methods. We designed an experiment to collect human ratings on the complexity of various photos. We proposed a set of visual complexity operators taking reference of the factors used in psychological experiments and extract visual complexity properties of the photograph from the aspects of composition, shape and distribution. We extract a set of visual complexity features using these operators from various perception cues (VCPC). And we applied gradient boost trees regression on these features to set up the complexity model and showed that the complexity level calculated from the proposed features have a near-monotonic relationship with human beings' beauty expectation on thousands of photos. After that we calculated complexity levels for large-scale photo database, and analysed the relationship between public aesthetics ratings and complexity

level.

Secondly, we built up a hierarchical framework to extract structures of different size and intensity contrast, and applied the visual complexity operators to extract the visual complexity features from hierarchical structure (VCHA). We then applied the VCHA features to estimate the aesthetic quality for photographs. There is no standard training and testing protocol for the public aesthetics dataset, so we conducted various experiments under different conditions in order to ensure fair comparisons with state-of-the-art methods. The experimental results demonstrated that the proposed visual complexity features could outperform existing manually prepared features and even better than deep features for balanced training samples. In addition, the proposed features can be extracted directly from samples without tedious learning stage required by deep features.

Thirdly, we use features extracted from gaze information to predict individual rating for video talks. We constructed a dataset of eye movements during video lecture watching together with viewer's rating. Then we proposed a set of gaze features, which not only include the conventional distribution features but also include the analysis of the relationship between visual saliency and gaze point in both static and dynamic aspects. By doing so, we set up a baseline for researches in personal rating prediction for video lectures using gaze.

A18. SIMD 命令の効率的な活用による非数値計算アプリケーションの高速化

井上 拓

Efficient Exploitation of SIMD Instructions in Non-Numerical Applications

By Hiroshi Inoue

To achieve high performance on today's systems, it is critically important to exploit different types of parallelisms available in algorithms by mapping them onto hardware parallelisms. For example, multiple cores and multiple SMT threads in a core can accelerate applications by executing multiple threads simultaneously. Another important processor feature to accelerate compute-intensive workloads is Single Instruction Multiple Data (SIMD) instructions, which can operate on multiple data in one instruction, to exploit data parallelism. Many high-performance processors support the SIMD instructions, such as the SSE and AVX instruction set of the x86 processors or the VMX and VSX instruction set of the PowerPC processors. To fully utilize the huge computing capability of today's processors, the programmers need to identify the thread-level and data parallelism available in the algorithms. Hence, there are many existing research projects to enhance important algorithms for parallelizing with multiple threads or vectorizing with SIMD instructions. The SIMD instructions have been widely used in many scientific computing workloads (such as matrix computations), image processing workloads (such as movie encoding and decoding), and basic string operations since it is mostly straightforward to vectorize these algorithms. However, there are still many important algorithms and workloads we cannot efficiently exploit SIMD instructions.

In this dissertation, we present new high-performance algorithms for efficiently exploiting SIMD instructions on the following three key operations: sorting for integer values, sorting for structures, and sorted set intersection. These algorithms are important building blocks of many non-numerical applications, such as database management systems and search engines. We showed that our proposed algorithms improve the performance over scalar algorithms and existing SIMD algorithms by efficiently exploiting SIMD instructions.

In these three new algorithms, the key to achieve high performance is 1) to exploit data parallelism available in the algorithm and 2) to reduce the number of conditional branches 3) while avoiding non-contiguous memory accesses, which increases the memory access overhead. Although the data parallelism available in one instruction is an obvious and straightforward advantage of the SIMD instructions, the reduced branch misprediction overhead also gives non-negligible performance gain; and hence the advantage of the SIMD instructions can surpass the data parallelism of the SIMD instruction. For example, we demonstrated 8.0x to 11.9x performance improvements using 4-wide SIMD instruction (SSE for 32-bit integers) in various sorting algorithms that are suitable for vectorizing with SIMD instructions.

To reduce the number of branch mispredictions, we take two different approaches for the sorting and the set intersection. For the set intersection, we aggregate multiple conditional branches into one since the direction of most of the conditional branches is same. For sorting, on the other hands, we replace conditional branches by SIMD minimum and maximum instructions. In sorting, especially for random numbers, the directions of conditional branches are mostly unpredictable and the branch directions are divergent; hence it is not effective to aggregate multiple branches. By replacing control flow of the unpredictable conditional branches into a data flow by arithmetic instructions avoid the huge overhead of branch mispredictions and hence very effective to improve the performance. Although we take different approaches for handling conditional branches, some of the optimization techniques are common among our proposed algorithms. For example, using a smaller data type instead of a larger type to increase the data parallelism in one instruction is an important technique to get larger performance gain in sorting of structures and set intersection. Typically, using a small data type does not improve the computation performance with scalar processing, and hence it is unique to SIMD processing.

In addition to the superior performances with SIMD instructions, we have demonstrated that we can improve the energy efficiency (performance per Watt) using SIMD instructions efficiently. The energy efficiency is critically important for computing systems today ranging from super computers to mobile devices. We observed only small increase in energy consumption in trade for huge performance boost for both sorting and set intersection. Using SIMD increases energy consumption in vector ALUs, but it also reduces the execution time. In total, we observed significant improvement in the energy efficiency.

Hence, our results show that our new algorithms can contribute wide range of applications and systems.

A19. 高機能公開鍵暗号技術と経験的なセキュリティプロトコルの証明可能安全性

大畑 幸矢

Provable Security of Applied Public Key Cryptosystems and Heuristically Secure Protocols

By Satsuya Ohata

The information on the internet is always exposed the threat of eavesdropping and falsification. Even in these conditions, we can ensure the confidentiality and integrity of information by using cryptosystems. In the research of cryptosystems, especially in public key cryptosystems, it is strongly required that we should rigorously prove its security. When we prove the security of cryptosystems, we usually reduce its security to the difficulty of mathematical problems. In this framework, we can objectively judge the security. Although not all the cryptosystems without security proof are insecure, the concept of provable security is useful in many aspects. In this thesis, we show two types of results related to the provable security.

First, we denote the results of provably secure applied cryptosystems in Chapters 3-5. In general, it often appears many entities, keys, and ciphertexts in applied cryptosystems. Therefore, we have to consider a complex model to deal with various attacks. If we fail this modeling, it is meaningless to prove the security. In these chapters, we show the results about threshold public key encryption and proxy re-encryption under the extended models and security definitions. In Chapter 3, we show three new constructions of threshold public key encryption schemes with key re-splittability. In Chapter 4, we show a generic construction of a proxy re-encryption scheme with new functionality called re-encryption verifiability. In Chapter 5, we show a construction of a multi-hop and uni-directional proxy re-encryption scheme based on a cryptographic obfuscator. In this thesis, we discuss the practical / theoretical meaning of new models and security definitions.

Next, in Chapter 6, we extend the provable security to the security protocols other than cryptosystems. More concretely, this is a result about a protocol that we call “password reset protocol”. We define models and security definitions, propose generic constructions, prove its security, and implement a prototype to evaluate its efficiency. This result can improve the security of real world protocols. Moreover, we can expect progress of theoretical analysis for password reset protocol based on this result.

A20. 一人称視点映像からの手操作解析に関する研究

蔡 敏捷

Understanding Hand Manipulation from First-Person View Videos

By Minjie Cai

Understanding the ways how human hands interact with objects (hand manipulation) automatically from daily tasks is important for domains such as robotics, human grasp understanding, and motor skill analysis.

To promote the study of daily hand manipulation, I present a recognition framework for hand manipulation under first-person vision paradigm with a wearable camera, which overcomes the constraints of tactile sensors and calibrated cameras used in traditional approaches. However, the tasks of recognizing different types of hand manipulation from first-person view video are challenging due to rapidly changing background, ambiguous hand appearance and mutual hand-object occlusions. To tackle the challenges, I propose approaches to reason about semantic information of hands and objects which are considered critical in understanding hand manipulation.

The thesis work is composed by three components which address different aspects of understanding hand manipulation from first-person view videos: (1) An image-based approach for hand grasp analysis from image appearance is presented, which plays a central role in understanding hand manipulation; (2) A sequence-based method is proposed for hand grasp analysis from a different perspective of hand dynamics rather than static appearance; (3) An unified framework for recognizing grasp types, object attributes and manipulation actions is proposed, in which semantic relationship between hands, objects, and actions is modeled.

The study of hand grasp plays a central role in understanding hand manipulation since hand grasp characterizes the ways how hand hold an object and implies attribute information of the manipulated object. Therefore, an appearance-based approach for hand grasp analysis under first-person vision (FPV) paradigm is first presented. The proposed approach recognizes the types of hand grasp from image appearance and analyzes visual similarity among different grasp types (visual structures of hand grasp). Experiment results demonstrate the potential of automatic grasp recognition in unstructured environments. Analysis of real-world video shows that it is possible to automatically learn intuitive visual grasp structures that are consistent with expert-designed grasp taxonomies.

Appearance-based method is insufficient to discriminate between different grasp types which are ambiguous from a single image, and is sensitive to unreliable hand detection. To address this problem, I propose a sequence-based method to study hand grasp from perspective of hand dynamics. In particular, a feature representation which encodes dynamical information of hand appearance and motion is proposed based on hand-guided feature tracking from image sequences. In addition, I propose a

metric for comparing hierarchical clusters in order to quantitatively evaluate the consistency between different visual structures of hand grasp. Through extensive experiments, effectiveness of the proposed method is verified that hand dynamics can help improve grasp recognition and learn more consistent grasp structures.

Building on the work of hand grasp analysis, a further step is taken to study hand manipulation in a broader scale. I believe that grasp types together with object attributes provide complementary information for characterizing different manipulation actions. Thus, I propose an unified model for recognizing hand grasp types, object attributes and manipulation actions from a single image. Experiments strongly support the hypothesis that: (1) Attribute information of the manipulated object can be extracted without any specific object detectors by exploring spatial hand-object configuration; (2) Contextual information between grasp types and object attributes is important in dealing with mutual hand-object occlusions; (3) Action models that address the semantic relationship with grasp types and object attributes outperform traditional appearance-based models which are not designed to take into account semantic constraints and are overfitting to image appearance.

A21. 漫画の検索と描画支援

松井 勇佑

Retrieval and Drawing Assistance for Manga
By Yusuke Matsui

Manga are Japanese style comics. In Japan, the manga industry serves an extremely large market, and e-manga are also becoming popular. In the face of the massive quantities concerned, can we create amazing applications like those for naturalistic images? To answer the question, we propose a fundamental component (sketch-based retrieval architecture), a theoretical improvement (efficient search using hash tables), and a data-driven application (drawing assistance). We expect that this thesis will provide a promising future direction for research into manga image processing.

A22. 励起子ポラリトン凝縮からレーザー発振へのクロスオーバー

松尾 康弘

Crossover from Exciton Polariton Condensation to Photon Lasing
By Yasuhiro Matsuo

A semiconductor laser is a ubiquitous device used throughout industry particularly for optical communication and data storage. As the name suggests, a laser (Light Amplification by Stimulated Emission of Radiation) emits and amplifies light by stimulated emission with population inversion. In recent years, a new device, the polariton laser has been suggested and demonstrated. A polariton laser emits coherent light similar to a semiconductor laser but the mechanism of light emission is different. A polariton laser uses exciton-polariton condensation and emits coherent light by leakage of photonic component of exciton-polaritons without population inversion. Exciton-polaritons, composite particles made of excitons and cavity photons, form a condensate via stimulated cooling at sufficiently low temperatures. Its main attractive feature is that the polariton laser threshold is lower than that of a semiconductor laser and the coherence properties of emitted light is inherited from the exciton-polariton condensate. One of the open questions about the physical aspect of a polariton laser is a high density state of exciton-polariton condensate. In low density regime, an exciton-polariton behaves as a composite boson. On the other hand, in the high density regime, exciton-polaritons overlap with each other and the fermionic character of electrons and holes becomes apparent. The bosonic exciton-polariton and fermionic electron-hole-photon pictures are overlap continuously by changing the carrier density. The crossover physics is an important subject not only for applications but also for understanding fundamental physics. In this thesis, we create a high density state of exciton-polaritons of this system, beyond that which is necessary to form a condensate and characterize the crossover from exciton-polariton condensation to photon lasing by a time- and spatial-resolved measurement. A high density state of exciton-polariton condensate is photoexcited by a pulsed laser. The highest density reaches about seven hundred times as high as that of the exciton-polariton condensation threshold. By measuring the first-order coherence, above the second threshold, we observed the plateaued spatial coherence indicating the single mode photon lasing.

A23. バイナリ局所特徴による画像検索のための拡張転置インデックスおよびフィッシャーカーネル

内田 祐介

Extended Inverted Index and Fisher Kernel Approaches for Binary Local Feature-based Image Retrieval
By Yusuke Uchida

With an increasingly wide-spread use of mobile devices such as Android phones or iPhones, mobile visual search (MVS) has become one of the major applications of image retrieval and recognition technology. With MVS, we can recognize the surrounding world with mobile devices using its built-in camera as an input to image recognition or retrieval systems. The recognition or retrieval results might be effectively shown using augmented reality technology on mobile devices for instance. Thus, mobile devices are now one of the best platforms for image retrieval systems.

While some research focuses on server-client systems in the context of MVS, we assume the situation that visual search is performed directly on the mobile device. We call the latter type

of MVS "local MVS". Local MVS does not require any server and it works without a network, realizing faster recognition. In this thesis, we aim at developing a practical MVS system focusing on recent binary local features for efficiency. Although the performance of mobile devices has been improved, it is not sufficient to use non-binary features that requires a heavy processing load. Surprisingly, there are few studies focusing on the image retrieval using binary features. In many studies, binary features are used for feature-level matching between image pairs, not for image retrieval. One reason why binary feature-based image retrieval is not well-studied is that binary features are considered to be not enough robust to apply them to an image retrieval problem. However, we believe that binary features are very important for image retrieval on mobile devices and that there is a large room for improvement in the accuracy of binary feature-based image retrieval if we consider the recent significant advances in image representations for non-binary features.
Thus, in this thesis, we explore the potential of binary features in the area of image retrieval and establish the basis of binary feature-based image retrieval that can be used to real applications. To this end, we propose and evaluate three approaches in order to achieve a practical binary feature-based image retrieval system.

First, we propose the application of the Fisher vector representation to binary features aiming at improving the accuracy of binary feature-based image retrieval by considering underlying distribution of binary features. Main contribution of this approach is to model binary features using the Bernoulli mixture model (BMM) and derive the closed-form approximation of the Fisher vector of BMM. To the best of my knowledge, this is the first time to model binary features with BMM and apply the Fisher vector approach. We show that, by modeling binary features with BMM, it becomes possible to evaluate how informative different binary features are. Experimental results show that the proposed Fisher vector outperforms the BoVW method on various types of objects.

Second, we propose a substring extraction method that extracts informative bits from original binary vector and stores in the inverted index in order to improve the bag-of-visual words framework. These substrings are used to refine visual word-based matching. This is the first time to bring the idea of the Hamming embedding method to binary features. The advantage of this approach is its practicability. The developed system is very simple but effective, achieving good trade-offs between search precision, memory requirement, and speed. In addition, a modified version of the local naive Bayes nearest neighbor scoring method is proposed in the context of image retrieval, which considers the density of binary features in scoring each feature matching. The proposed system can retrieve the database with one million images in 87 [ms] and its accuracy significantly outperforms that of the state-of-the-art local MVS system.

Finally, we propose to integrate the advantages of the above two approaches. Starting with general match kernel, we show that the Fisher kernel-based similarity measurement can be implemented using the extended inverted index structure. Using the assumption that posterior probability is peaky, the Fisher kernel is linked with the BoVW framework, resulting in two proposed method, namely BMM-VW and BMM-FK. BMM-VW is a variant of BoVW, where VWs are defined by the BMM components. BMM-FK is the modified version of the second approach, where more appropriate similarity measurement is used. In order to ensure real-time applications, the method called randomized BMM trees is also proposed, which significantly accelerates the calculation of the quantization in BMM-VW and BMM-FK. In experiments, it is shown that the BMM-FK significantly outperforms the two previous approaches and the conventional state-of-the-art system in terms of the image retrieval accuracy.

We have developed real applications based on the above approaches, where a stand-alone system, a server-client system, and a hybrid system are used as a backend. Through these practical applications, it has been proven that our developed systems have sufficient potential for practical usages.

B. 大学院修士課程論文リスト
Masters' Dissertations

電子情報学専攻

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山部 芳朗	分散タスク並列アプリケーション向けプロファイラ	Yoshiro Yamabe	A Profiler for Task Parallel Apprications on Distributed Memory Machines
吉田 夏子	褒める効果音ボタンを用いたブレインストーミング支援システムの実践的研究	Natsuko Yoshida	Practical Study on Brainstorming Support System using Positive-feedback Button with Interjection Sound Effects
金 洪善	マイクロブログにおける言語横断的な影響力を持つ情報カスケードの検出に関する研究	Jin Hongshan	Detecting Influential Cross-lingual Information Cascades on Microblogs

電気系工学専攻

名前	タイトル	Name	Title
鈴木 健太郎	InGaAlAs/InAlAs 多重量子井戸を用いたモノリシック集積可能な偏波制御器の設計と作製	Kentaro Suzuki	Design and fabrication of monolithic polarization controller with InGaAlAs/InAlAs multiple quantum well
金 仁基	フォノニック結晶共振器を用いた光弾性変調器に関する研究	Kim Ingi	Study on Photo-Elastic Modulator Using Phononic Crystal Cavity
權 泰五	FPGA スパイキング神経ネットワーク間の通信プロトコル	Taeoh Kwon	Communication Protocol for FPGA-based Spiking Neural Networks
井上 智之	集光型システムへの応用に向けた薄膜多重量子井戸太陽電池の作製と特性評価	Tomoyuki Inoue	Fabrication and Characterization of Thin-film Multiple Quantum Well Solar Cells for Concentrator Photovoltaics
梅田 翔	電動スカイカーにおけるラダー・プロペラ・駆動輪を用いた走行安定化制御に関する研究	Sho Umeda	Study on Motion Stabilization Control of Electric Skycars by Using Rudder, Propeller and Driving Wheels in Driving Mode
白畑 卓磨	ディスクリートモデルによる OCT 用分散チューニングレーザの特性解析	Takuma Shirahata	Numerical Simulation of a Dispersion Tuning Laser using Discrete Model for OCT
峠 仁人	周波数同期性能を改善した高速起動クロックデータ再生回路	Norihito Tohge	A Quick-Lock Clock and Data Recovery Circuit with Improved Frequency Tracking Performance
東出 紀之	分割ゲート構造における単一架橋カーボンナノチューブのエレクトロルミネッセンス及びフォトルミネッセンス	Noriyuki Higashide	Electroluminescence and photoluminescence from individual air-suspended carbon nanotubes within split-gate structures
森 一倫	反応拡散モデルによる NBTI シミュレーションの高速化	Kazunori Mori	Acceleration of NBTI simulation by Reaction-Diffusion model
津吹 優太	X 線光電子分光法における SiO2/Si の帯電補償現象に関する研究	Yuta Tsubuki	Research on the charge compensation phenomenon of SiO2 / Si in X-ray photoelectron spectroscopy
メノン ヴィヴェーク	DNA 結合金ナノ粒子のハイブリダイゼーション現象のリアルタイム観察に向けたヒーター集積リキッド TEM セル	Menon Vivek	Toward Real Time Visualization of DNA and Gold Nanoparticle Hybridization Events using Heater-Integrated Liquid Cells in TEM
サルマン アーメド	リニア搬送システム用の位置センサレスでエネルギー効率の良い電磁吸引浮上制御 -- 高周波スイッチング雑音の賢い利用--	Salman Ahmed	Position Sensorless and Energy-efficient Electromagnetic Levitation for Translational Motion Conveyor System -- Smart use of high frequency switching noise --
カツカルト グラント アレクサンドル	薄膜トランジスタゲートアレイを用いた in-vitro 培養細胞の実時間インピーダ ンス計測に関する研究	Grant Alexander Cathcart	A Study on Real-Time In-vitro Impedance Spectroscopy of Cell Cultures via Thin Film Transistor Gated Electrode Arrays
顧 剣	フレキシブル光学センサアレイを用いた脈波モニタリングシステムの開発	Gu Jian	Pulse wave monitoring system using flexible optical sensor array
居 艷陽	高解像度イメージセンサマトリクスに向けた有機フォトダイオードと有機整流ダイオードの積層型光検出器	Yanyang Ju	A vertically stacked organic photodiode and organic rectifier diode for high-resolution image sensor matrix
フロリアン レル	GaN 界面揺らぎ量子ドットにおける単一光子発生に関する研究	Florian Le Roux	Study on Single Photon Emission from GaN Interface Fluctuation Quantum Dots

盧毅	メッシュ構造再構成可能プロセッサのための通信遅延を考慮したコンパイラ	Lu Yi	Communication Aware Compiler for Mesh-Structured Reconfigurable Processors
ムーア コンラッド ジンヨン	多重縮退故障用テストパターン自動生成手法	Conrad Jinyong Moore	Automatic Test Pattern Generation Method for Multiple Stuck-At Faults
ダワージャルガル オリギル	多様なロードバランサーを提供可能なLBaaS(Load Balancer as a Service)の検討	Davaajargal Orgil	Study of LBaaS(Load Balancer as a Service) which can provide various Load Balancer
淺見 周佑	シリコン神経デバイスと培養神経系の接続	Shusuke Asami	Connection between Silicon Neural Device and Cultured Nervous System
芦原 渉	半導体からのキャリア注入による強磁性量子井戸のスピン分極率変調に関する研究	Wataru Ashihara	Study on the Modulation of the Spin Polarization in a Ferromagnetic Quantum Well by the Carrier Injection from a Semiconductor
阿部 圭佑	真空ギャップにおける微小粒子による絶縁破壊現象	Keisuke Abe	Micro particle triggered breakdown in vacuum gap
池川 晶貴	ドレスト光子を用いた光増幅機能を持つ 405nm 帯シリコン光検出器	Masaki Ikegawa	Si photodetector for 405nm light with optical gain due to dressed photon
石川 涼一	移動型プラットフォームを用いた三次元計測システムのための Line-to-Surface 位置合わせ手法	Ryoichi Ishikawa	Line-to-Surface Alignment for 3D Scanning Systems with a Mobile Platform
石橋 祐太	連続パルスストリーマ放電中 OH ラジカルの挙動観測	Ishibashi Yuta	Observation of OH radical behavior in repetitive pulsed streamer discharge
井上 周	高選択性ガスセンサーに向けたゼオライト埋め込み型 CMOS 歪みゲージ MEMS 集積カンチレバーの研究	Shu Inoue	Research on Zeolite-trench-embedded MEMS cantilevers with CMOS strain-gauge for high selectivity gas sensors
上原 大典	スマートイメージセンサを用いたテクスチャマッピング向け高速三次元形状計測	Daisuke Uehara	High-speed range finding for texture mapping using smart image sensor
宇佐美 尚人	偏波状態の入射角依存性に着目した偏波合成開口レーダによる積雪マッピング	Naoto Usami	Wet Snow Mapping With Focus on Incident Angle Influential to Polarization State
小澤 悠平	ターマン法を用いた二硫化モリブデン MOS 界面特性評価	Yuhei Ozawa	Evaluation of MoS2 MOS interface properties by the Terman method
堅山 耀太郎	免疫細胞の多様性データの解析法の提案と T 細胞生成における遺伝子構造の役割の解明	Yotaro Katayama	New analysis methods for immune repertoire sequence data and the role of genome structure in T cell generation process
勝間田 優樹	同時送信フラッディングを用いたユーザ指向型無線センサネットワークに関する研究	Yuki Katsumata	A Study on User-oriented Wireless Sensor Networks using Concurrent Transmission Flooding
川尾 太郎	FPGA を利用した科学技術計算の高速化	Taro Kawao	Acceleration of Scientific Computation with FPGA
川上 裕生	Arimaa 評価関数における比較学習	Yusei Kawakami	Comparison Training of Arimaa Evaluation Functions
川田 和周	小天体における着地を考慮した正四面体型跳躍探査ロボットに関する研究	Kazunari Kawata	Study on Tetrahedron Hopping Robot with Landing Control for Small Body Exploration
川端 祐斗	InP モノリシック集積偏波アナライザの設計と試作	Yuto Kawabata	Design and Fabrication of Monolithically Integrated InP Polarization Analyzer
車 一宏	量子ドット-フォトニック結晶ナノ共振器結合系における結合状態の量子ドット位置依存性に関する研究	Kazuhiro Kuruma	Study on Quantum Dot Position Dependence of the Coupling in Quantum Dot-Photonic Crystal Nanocavity Coupled Systems
古賀 丈尚	オフセットパルスを用いたパルス縮小型時間デジタル変換器	Takehisa Koga	A Pulse-Shrinking Time-to-Digital Converter Utilizing Offset Pulse
小松　里紗	光熱モード原子間力顕微鏡による Cu(In,Ga)Se2 系太陽電池材料の非発光再結合特性評価	Risa Komatsu	Investigation of Non-radiative Recombination Property in Cu(In,Ga)Se2 Solar Cell Materials by Means of Photothermal Mode Atomic Force Microscopy
近藤 健一	PFC コンバータによる無効電力制御を用いた配電系統電圧逸脱抑制の検討	Ken-ichi Kondo	Suppression of Voltage Violation in Distribution Network by Use of PFC Converter Reactive Power Control

坂本 弘明	大気安定かつ高電流密度を有する有機ショットキーダイオードの作製と回路応用	Hiroaki Sakamoto	Air-stable and high current density organic schottky diodes for circuit applications
坂本 直之	マイクロ電磁界共鳴電力伝送回路の設計論構築と電流型･電圧型 MEMS デバイスの非接触駆動応用	Naoyuki Sakamoto	A Design Methodology of Micro-Scale Magnetic Resonance Coupling Power Transmission Circuit and Applications to Wireless Drive of Voltage/Current Controlled MEMS Devices
佐々木 和哉	光変調器応用に向けたスラブ付きグラフェンスロット導波路の設計及び導波特性評価	Kazuya Sasaki	Design and transmission spectrum evaluation of the graphene slot waveguide with slab for optical modulator application
下村 北斗	InAs 量子ドット太陽電池の高効率化及び低コスト化技術の研究	Hokuto Shimomura	Research of methods of enhancing efficiency and reducing cost for InAs/GaAs quantum dot solar cells
甚野 裕明	大気安定な極薄基板上有機発光ダイオードの作製に関する研究	Hiroaki Jinno	Air-Stable Organic Light Emitting Diodes Fabricated on Ultrathin Films
鈴木 健太郎	InGaAlAs/InAlAs 多重量子井戸を用いたモノリシック集積可能な偏波制御器の設計と作製	Kentaro Suzuki	Design and fabrication of monolithic polarization controller with InGaAlAs/InAlAs MQW.
鈴木 颯	テンソル分解に基づく音声表現とその言語識別・話者識別への応用	So Suzuki	Tensor-based Speech Representation and its Application to Identification of Languages and Speakers
高山 真一	再生可能エネルギー大量連系を考慮した需給制御システムの設計と評価	Shinichi Takayama	Design and Evaluation of Supply and Demand Control System in Power Systems Integrating Large-scale Renewable Energy
竪山 智博	CF3I 混合ガスを用いた管路気中送電線の概念設計	Chihiro Tateyama	Conceptual design of gas insulated transmission lines using CF3I gas mixture
田中 克久	高耐圧パワーデバイスにおける浅いガードリング終端構造の設計指針	Katsuhisa Tanaka	Device Design Guideline of Shallow Guard Ring Structure in High-Voltage Power Devices
田村 雅人	楕円曲線デジタル署名ハードウェアの設計	Masato Tamura	Hardware Implementation of ECDSA
千枝 航	InP 光導波路と結合した金属クラッド共振器構造の設計と作製	Koh Chieda	Design and Fabrication of Metallic Cavity Integrated on InP-based Waveguide
坪井 宏至	基幹系統における太陽光発電システムの仮想同期発電機制御による系統安定化効果	Hiroshi Tsuboi	Stabilization Effect of Virtual Synchronous Generator Model Based Control of PVs in Power System with a Massive Integration of PVs
都井 敬	パルス幅位相同期ループ回路の製造ばらつき耐性向上手法	Takashi Toi	Improvement of Process-Variation Tolerance for Pulse-Width Controlled Phase Locked Loop
徳永 京也	利得スイッチング駆動半導体レーザを用いた誘導ラマンイメージング	Kyoya Tokunaga	Stimulated Raman Imaging with a Gain-Switched Laser Diode
中川 純貴	単結晶 Si とアモルファス SiGe フォノニック結晶ナノ構造における熱伝導	Junki Nakagawa	Thermal Conduction in Single-crystalline Si and Amorphous SiGe Phononic Crystal Nanostructures
中須賀 謙吾	要約抽出文の解析結果を用いた教師付き学習による学術論文要約	Kengo Nakasuka	Supervised scientific paper summarization using sentence extraction analysis
永田 翼	ディジタルコヒーレント受信技術による FMCW-LiDAR における信号補正の研究	Tsubasa Nagata	The signal compensation for FMCW-LiDAR with Digital Coherent
中張 遼太郎	作業支援のための電気的筋肉刺激による重量知覚制御	Ryotaro Nakahari	Weight Perception Control using Electrical Muscle Stimulation for Assisting Physical Work
中村 達也	生体応用に向けたフレキシブル温度センサの測定温度領域の拡大	Tatsuya Nakamura	Development of Flexible and Wide-Range Polymer-Based Temperature Sensor for Human Bodies
那須 英和	スピン波デバイス応用に向けたパルスレーザー蒸着法による Nd3Fe5O12 薄膜の作製とその磁気特性	Hidekazu Nasu	Formation of Nd3Fe5O12 thin films grown by a pulsed laser deposition and their magnetic properties for spinwave device application
名波 拓哉	皮質及び視床の神経細胞のデジタル演算回路向けモデルとその実装	Takuya Nanami	Cortical and thalamic neuron model for digital arithmetic circuit and its implementation
成田 大輝	複数送電コイルを有する走行中非接触給電システムの特性解析と送電側電圧電流情報による効率最大化制御	Hiroki Narita	Characteristic Analysis and Efficiency Maximization by using Transmitter-side Voltage/Current Information for Multiple-Transmitter Dynamic Wireless Power

			Transfer
西山 万里	月着陸機の着陸地点選定および探査ローバの経路計画に関する多目的最適化研究	Mari Nishiyama	Study on Selecting Landing Sites for Moon Exploration and Path Planning for Exploration Rovers using Multi-Objective Optimization
野間 健太郎	過渡的ヌル点におけるトーラス放電機構の検証	Kentaro Noma	Verification of torus discharge mechanism at transient null point
濱松 昌宗	リコンフィギュラブルム無線回路向け CMOS コンパレータの高精度化の研究	Masamune Hamamatsu	A Research on High-Precision CMOS Comparator for Reconfigurable RF Circuits
百武 恭汰	絵本読み聞かせ風音声合成のためのコーパス構築とコンテキストラベルの設計	Kyota Hyakutake	Construction of a speech corpus and design of contextual labels for infant-directed storytelling speech synthesis
福田 将治	ウェットプロセスによる InP 垂直結合型 1 次元光フェーズドアレイスキャニング素子の研究	Masaharu Fukuda	Research on InP vertically coupled 1-D optical phased array scanning device by wet process
福山 佳佑	CFRP 製模擬航空機燃料タンクにおける電荷挙動	Keisuke Fukuyama	Electrostatic-Charge Behavior in Mock Fuel Tank Made of CFRP
渕田 紳平	デルタ線による SRAM ソフトエラーのスケーリング効果	Shimpei Fuchida	Scaling effect on delta-ray-induced soft errors in SRAMs
本田 雅宣	電源コード外皮と筋電位からのエネルギーハーベスティング	Masanobu Honda	Research on energy harvesting from insulating cover of AC power cable and myoelectric potential
松井 遼平	水中での高分解能 STEM 観察を目指す MEMS リキッドセルと生体分子観察への応用	Ryohei Matsui	MEMS liquid TEM cell for nano-scale in-situ observation in liquid toward visualization of biomolecules
丸山　富士之介	ブリルアン光相関領域リフレクトメトリにおける性能向上手法の融合による測定レンジの拡大	Fujinosuke Maruyama	Enlargement of Measurement Range in Brillouin Optical Correlation Domain Reflectometry with Combining Performance Improvement Schemes
三浦 信一	平面光波回路内のブリルアン周波数シフトの分布測定に関する研究	Shinichi Miura	Distributed Measurement of Brillouin Frequency Shift in Planar Lightwave Circuit
水原 悠	ハンディキャップのあるボードゲームに関するレーティング手法の研究	Yuu Mizuhara	A Study on a Rating Method for Board Games with Handicaps
森 瑞希	光干渉を考慮した薄膜中間バンド型太陽電池のデバイスシミュレーション	Mizuki Mori	Device simulation of thin-film intermediate-band solar cell considering optical interference effect
森 健太郎	静電駆動型 MEMS ロールアップ可変光学アパチャに関する研究	Kentaro Mori	A Study on Electrostatic MEMS Roll-up Variable Optical Apertures
盛本 真史	X-band 小型衛星 通信用の GaN と GaAs 増幅器における非線形位相歪みの評価と多値変調への影響	Masafumi Morimoto	Evaluation of Nonlinear Phase Distortion in X-band GaAs and GaN Power Amplifiers for Small Satellite Communication and its Effect to Multi-level Modulations
矢野 智比古	プロセスばらつきに強い時間領域アナログアキュムレータ	Tomohiko Yano	A Process Variation Tolerant Time-Mode Analog Accumulator
山内 善高	CMOS DC-DC コンバータの外部受動部品を含めた小型化・高効率化を実現する集積回路設計の研究	Yoshitaka Yamauchi	Research on Integrated Circuit Design for Small and Highly Efficient CMOS DC-DC Converters Including Off-Chip Passive Components
山下 大之	多接合太陽電池の高効率化に向けた表面活性化ウエハ接合界面の評価	Daiji Yamashita	Evaluation of surface activated bonding interface for high efficiency multi-junction solar cell
山本啓太	在宅経頭蓋磁気刺激治療のための高効率広範囲刺激コイルの設計・作成	Keita Yamamoto	Development of Wide Focus and High Efficiency Coil for TMS Therapy at Home
山本　彬依	スピンポンピングを用いたトポロジカル結晶絶縁体 SnTe へのスピン注入の研究	Akiyori Yamamoto	Investigation of the spin injection into the topological crystalline insulator SnTe using spin pumping
山本 有途	既存電源および電気自動車の活用を考慮した周波数調整市場の設計とその経済性評価	Yuto Yamamoto	Design and Economic Evaluation of a novel Frequency Regulation Market Taking Use of Existing Power Generations and Electric Vehicles into Consideration
安大煥	Zn 拡散ソースプレーナ型 InGaAS トンネル FET の性能向上に関する研究	Ahn Daehwan	Study on performance improvement of Planar-type InGaAs Tunnel FETs with Zn-diffused source
陳昆韓	側壁電極リソグラフィによるナノパターンの一括転写	Chen Kunhan	Nano Pattern Collective Transcription by Thin-film Edge Electrode Lithography

崔 伝琪	ダイナミック回路を用いたゲートレベルハンドシェイク型非同期システムの SEU 耐性評価	Cui Chuanqi	Evaluation on SEU Tolerance of Asynchronous System Based on Gate-level Handshake Using Dynamic Circuits
カク ズイケン	リニア波力発電機電気出力最大化に必要なエネルギー蓄積システム設計と制御	Guo Ruijuan	Design and Control of Energy Storage System for a linear Generator to Maximize Electric Output Power for Ocean Power Plant
モハンマド マルフ ホサイン	統計的コンパレータによるアナログ-ディジタル変換回路の最適設計手法	Md. Maruf Hossain	Optimal Design Method of Analog-to-Digital Converters based on Stochastic Comparator
陳ハンビッ	電子布地応用のための高伸縮性プリンタブル伸縮性導体	Hanbit Jin	Highly stretchable, printable conductors for electronic textile applications
羅 丹	高感度 RF エネルギーハーベスティング回路の設計	Luo Dan	Design of High-Sensitivity RF Energy Harvesting Circuit
朴主言	フォトニック結晶導波路型電流注入単一光子源の実現に向けた素子の設計と作製に関する研究	Jueon Park	Study on device design and fabrication for realization of electrically-driven photonic crystal waveguide single photon sources
朴燦鎬	ユーザの状況を考慮した携帯端末の内蔵センサを用いた把持姿勢認識手法	Chanho Park	A Grasp Recognition Method Using Built-in Sensors of Smartphones with Considering Users' Situations and Postures
宋炫根	生物に学ぶアクチュエーションシステムの制御器設計をめざした 筋肉活性度の逆推定に関する研究		Inverse Muscle Activity Estimation Toward Controller Design Generalized for Biologically Inspired Actuation Systems
ヴォ クオック フイ	分子線エピタキシー法による少数 InAs/GaAs 量子ドットの形成とその制御に関する研究	Vo Quoc Huy	Research on Controlling the Formation of a Few InAs/GaAs Quantum Dot System by MBE
ブランデンバーグ フィーリックス ユリアン	ダイヤモンド窒素欠陥に対する近接場光エッチング関する研究	Felix Julian Brandenburg	A Study on Dressed-Photon Phonon Etching on Diamond Nitrogen-Vacancy Center
グリーン イーサン ジョセフ	サブスレショルド MOSFET アナログシリコンニューロンの温度依存特性補償	Ethan Joseph Green	Compensating Temperature Dependent Characteristics of a Subthreshold-MOSFET Analog Silicon Neuron
イザディ ラド ホセイン	近似アルゴリズムを用いた最大共通部分回路の抽出	Hossein Izadi Rad	Approximation Methods for Identifying Maximum Common Subcircuit
ゲイ イケン	受動モード同期ファイバレーザ用新規ナノカーボン系可飽和吸収体に関する研究	Ni Weijian	Research on New Type Nano-carbon-based Saturable Absorbers for Passively Mode-locked Fiber Lasers
喜楽楽	人間の意図抽出に基づく車椅子のフォースセンサレスパワーアシスト制御	Lele Xi	Force Sensorless Power Assist Control for Wheelchairs Based on Human Intention Extraction
セン ブンケイ	低コスト波長多重パッシブ光ネットワーク応用に向けたセルフシーデッド反射型半導体光増幅器の最適化設計	Zhan Wenhui	Optimal Design of Self-seeded Reflective Semiconductor Optical Amplifier for Low-cost Wavelength Division Multiplexed Passive Optical Network Applications
須田 涼介	GIS 絶縁スペーサの直流帯電機構	Ryosuke Suda	Charge accumulation process in GIS under dc field