Comprehensive studies on Shimura varieties, arithmetic geometry, Galois representations, and automorphic representations

Tetsushi Ito
(Kyoto University, Graduate School of Science, Assistant Professor)

【Outline of survey】

Shimura varieties are algebraic varieties (geometric objects defined by equations), which are generalizations of modular curves. Previously, several mathematical objects in arithmetic geometry, Galois representations, automorphic representations were studied from individual perspectives. However, these days, these are being studied from a unified viewpoint related to Shimura varieties, and many important applications are being obtained; examples are Fermat's last theorem proved by A. Wiles and the Sato-Tate conjecture proved in many cases by R. Taylor and his collaborators. In recent years, higher dimensional Shimura varieties are being studied extensively than before, and many essential applications of recently developed theories, such as rigid geometry, theory of p-adic uniformization, theory of (ϕ, Γ)-modules, are being obtained. In this project, we study Shimura varieties comprehensively with active young researchers including foreign ones, and we try to obtain new knowledge on arithmetic geometry, Galois representations, and automorphic representations.

【Expected results】

By studying integral models of Shimura varieties, we expect to understand the relation between p-adic uniformization of Shimura varieties and the etale cohomology of Rapoport-Zink spaces. We also expect to understand the geometric structures behind p-adic period maps, to understand the relation between the theory of (ϕ, Γ)-modules and the Langlands functoriality, to clarify the geometry behind the deformation theory of Galois representations, to obtain a new perspective on Shimura varieties, to obtain a new knowledge on the arithmetic geometry, Galois representations, and automorphic representations.

【References by the principal investigator】

・T. Ito, Weight-monodromy conjecture for p-adically uniformized varieties, Invent. Math. 159 (2005), no. 3, 607--656.
・T. Ito, Stringy Hodge numbers and p-adic Hodge theory, Compositio Math. 140 (2004), no. 6, 1499--1517.

【Term of project】 FY2008－2012	**【Budget allocation】** **29,400,000 yen** (direct cost)
【Homepage address】	None

Polarization Measurement aboard the Satellite and Solution of the Emission Mechanism of the Gamma-Ray Bursts

Daisuke YONETOKU
(Kanazawa University, School of Mathematics and Physics, Assistant Professor)

【Outline of survey】

Gamma-Ray Bursts (GRBs) are well known as the biggest explosions in the universe which release a huge amount of energy, 10^{52} ergs, as the gamma-ray emission during the short time interval of several 10 seconds. GRBs are very bright, so we can use them to explore the early universe. However we have little knowledge about the emission mechanism of GRBs, and it is an important open question. Theoretically, it is thought to be a synchrotron radiation. If so, the radiations have strong polarization degree, and their detection is a key to solve the mechanism.

In this program, we develop a polarization detector and install it in the small solar-powered-sail satellite scheduled to launch in May, 2010. We realize the GRB polarization measurement for the first time. Our detector has a capability to measure the angular distribution of scattered gamma-ray photons via Compton effect.

During this program, we cover the detector development, the satellite launch, observations and publications of results. The gamma-ray polarization measurement is now noticed as the future observation technique, so we hope to establish the base of the gamma-ray polarization astronomy.

【Expected results】

The detector is small about 3 kg in weight, but we can realize the GRB polarization measurement overwhelmingly in short term schedule. We expect to detect the polarization signals from 2-4 GRBs and the Crab nebula during 1 year observations. Both GRB phenomena and the observation technique of the gamma-ray polarization are noticed in the astrophysical communities. Therefore we expect to obtain the observation results with the strong impact.

【References by the principal researcher】

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- Possible observational evidence for the θ^{-2} angular distribution of the opening half-angle of GRB jet: Yonetoku et al., Monthly Notices of the Royal Astronomical Society, Vol.362, Issue.3, pp.1114 (2005)
- Spectral evolution of GRB 060904A observed with Swift and Suzaku: Yonetoku et al., Publications of the Astronomical Society of Japan, Vol.60, No.SP1, pp.S352 (2008)

【Term of project】 FY2008－2012	【Budget allocation】 49,900,000 yen (direct cost)

【Homepage address】 http://astro.s.kanazawa-u.ac.jp/~yonetoku/

Simulations of the Formation, Evolution, and Clustering of Early Cosmic Structure

Naoki Yoshida
(Nagoya University, Graduate School of Science , Assistant Professor)

【Outline of survey】

Large ground-based telescopes have discovered distant astronomical objects such as galaxies and quasars that were in place when the Universe was less than 1 billionyears old, corresponding to only about 5% of its current age. Moreover, these studies have shown that other luminous objects must have been present even earlier. Understanding how and when the first luminous objects were formed, and how they made the cosmic primordial gas to be in a plasma state is one of the major goals in modern cosmology and astronomy.

We study structure formation in the early universe using supercomputer simulations.

Our study will offer valuable inputs to future observations of the distant universe exploiting next-generation space-borne and ground-based telescopes.

【Expected results】

We use large three-dimensional cosmological simulations to reveal the following important properties of early cosmic structure.

1. The star-formation activities, gas metallicities of primeval galaxies
2. The evolution of chemical compositions in the inter-galactic medium
3. The effects of the nature of dark matter, dark energy, and models of inflaton field in the vry early universe on the above properties.

The results are extensively used to make proposals for surveys of the young Universe.

【References by the principal investigator】

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- N. Yoshida, S. Oh, T. Kitayama, L. Hernquist, “Early Cosmological HII/HeIII Regions and Their Impact on Second-Generation Star Formation”, Astrophysical Journal, 663, 687 (2007)
- V. Springel, S. White, C. Frenk, A. Jenkins, N. Yoshida et al. “Simulations of the formation, evolution and clustering of galaxies and quasars”, Nature, 435, 629

【Term of project】 FY2008− 2012	【Budget allocation】 **49,300,000 yen** (direct cost)

【Homepage address】 http://www.a.phys.nagoya-u.ac.jp/~nyoshida/cosmo.html

Study of Neutrino Mixing by using accelerator neutrino beams.

NAKAYA Tsuyoshi
(Kyoto University, Graduate School of Science, Associate Professor)

【Outline of survey】

In order to reveal neutrino mixing phenomena and to measure the mass square difference of neutrinos, we conduct the accelerator neutrino beam experiments: SciBooNE and T2K.

In SciBooNE, the Fermilab neutrino beam is used to measure the neutrino interaction cross sections in low energy. In SciBooNE, we concentrate to understand the inelastic reactions which are serious backgrounds in the neutrino oscillation signals in T2K. We also measure the anti-neutrino cross section around 1GeV.

In T2K, we use the high power and high quality neutrino beam from J-PARC and the Super-Kamiokande neutrino detector to study neutrino mixing. In T2K, the near neutrino detector installed in J-PARC plays a crucial role to understand the property of the neutrino beam and neutrino interactions. In T2K, we conduct the precise measurements of neutrino oscillation parameters and the high-sensitive search for the rare process $\nu_\mu \rightarrow \nu_e$ to determine θ_{13}.

【Expected results】

1. World-best precision measurements of neutrino cross-sections around 1 GeV.
2. Precise measurements of neutrino oscillation parameters: θ_{23} and Δm_{23}^2
3. Most-sensitive search for the unknown neutrino oscillation channel $\nu_\mu \rightarrow \nu_e$ and the determination of θ_{13}.
4. For a future neutrino CP violation experiment, compile of necessary information of neutrino and anti-neutrino cross sections and the neutrino beam properties.

【References by the principal investigator】

・”Measurement of neutrino oscillation by the K2K experiment”, M.H.Ahn, A.K.Ichikawa, T.Nakaya, M.Yokoyama et al., Phys. Rev. D74, 072003 (2006)
・”Improved Search for $\nu_\mu \rightarrow \nu_e$ Oscillation in a Long-Baseline Accelerator Experiment”, S.Yamamoto, T.Nakaya et al., Phys. Rev. Lett 96, 181801 (2006)
・”The JHF-Kamioka neutrino project”, Y.Itow, T.Nakaya et al., hep-ex/0106019

【Term of project】 FY2008－2012	【Budget allocation】 64,100,000 yen (direct cost)

【Homepage address】 http://www-he.scphys.kyoto-u.ac.jp/Neutrino/
http://www-he.scphys.kyoto-u.ac.jp/~nakaya

Correlation between magnetic and dielectric properties

Tsuyoshi Kimura
(Osaka University, Graduate school of Engineering Science, Professor)

【Outline of survey】

A magnetic field can be generated by the flow of an electrical current, which means intimate connection between an electric current and a magnetic field. In certain insulating materials, however, their magnetic properties can be changed by applying an electric field (not electric current). Such an unconventional coupling between magnetic and dielectric properties is termed *magnetoelectric* effect. The magnetoelectric effect defined as the generation of magnetization (electric polarization) by an electric (magnetic) field, has recently generated renewed attention since the effect can provide novel device design. In this research project, we investigate the following topics,

1. Development of materials with strong magnetoelectric coupling
2. Seeking novel magnetoelectric phenomena
3. Understanding of observed magnetoelectric phenomena
4. Proposal of novel measurements to study magnetism and/or dielectricity using magnetoelectric coupling.

Our goal is to construct a systematic research field concerning correlation between magnetism and dielectric property in solids.

【Expected results】

There have been no applications using magnetoelectric couplings developed to date, due mainly to materials limitations and the small magnitude of the effect. The success of the research project will be judged by the development of novel magnetoelectric materials and phenomena. The results will provide an important clue to device design for novel magnetoelectric memory elements or sensors.

【References by the principal investigator】

- "Cupric oxide as induced-multiferroic with high-T_C", T. Kimura, Y. Sekio, H. Nakamura, T. Siegrist, A. P. Ramirez, *Nature Mater.* **7**, 291-294 (2008).
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【Term of project】 FY2008－2012	【Budget allocation】 57,200,000 yen (direct cost)

【Homepage address】 http://www.crystal.mp.es.osaka-u.ac.jp/

Study of photo-spin science on the next-generation with multiple phase transition materials

Shin-ichi Ohkoshi
(The University of Tokyo, Graduate School of Science, Professor)

【Outline of survey】

A target of the research project is to create a novel phase transition in a chemically synthesized novel material which exhibits multiple phase transitions (ferromagnetism, ferroelectricity, spin transition, charge transfer transition, metal-insulator transition, spin reorientation, etc). Using these novel materials, we will also try to construct the next-generation photo-spin phenomena. In particular: (1) Development of novel multiple phase transition materials. (2) Creation of novel photo-spin phenomena such as photo-induced ferroelectric-ferromagnetism. (3) Establishment of "sub-terahertz magnetooptics" academic field by the first observation of the ferromagnetic resonance in 100-300 GHz range. (4) First observation of novel magnetization-induced nonlinear optical phenomena such as magnetization-induced nonlinear cascading process and magnetization-induced degenerated four-wave mixing.

【Expected results】

1. Development of novel multiple phase transition materials.
2. Creation of novel photo-spin phenomena such as photo-induced
3. ferroelectricity-ferromagnetism.
4. Establishment of the new magnetooptic field, sub-terahertz magnetooptics.
5. Proposal of new strategy for the next-generation opto-spinelectronic technology by first observation of the novel magnetization-induced nonlinear optic phenomena.

【References by the principal investigator】

・ "Coexistence of Ferroelectricity and Ferromagnetism in a Rubidium Manganese Hexacyanoferrate", S. Ohkoshi, H. Tokoro, T. Matsuda, H. Takahashi, H. Irie, and K. Hashimoto, ***Angew. Chem. Int. Ed.***, 46, 3238 (2007).
・ "Millimeter wave absorber based on gallium substituted ε-iron oxide nanomagnets", S. Ohkoshi, S. Kuroki, S. Sakurai, K. Matsumoto, K. Sato, and S. Sasaki, ***Angew. Chem. Int. Ed.***, 46, 8392 (2007).
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【Term of project】 FY2008－2012	【Budget allocation】 **81,200,000 yen** (direct cost)

【ホームページアドレス】http://www.chem.s.u-tokyo.ac.jp/users/ssphys/index.html

Development of Innovative Molecular Transformations via Cationic Rhodacycles as Active Species

Ken Tanaka
(Tokyo University of Agriculture and Technology, Institute of Symbiotic Science and Technology, Associate Professor)

【Outline of survey】

It is well known that metallacycles are efficient intermediates of cycloadditions for the synthesis of various cyclic compounds. Recently, we first discovered that cationic rhodium(I) complexes bearing BINAP-type bisphosphine ligands are highly effective catalysts for [2 + 2 + 2] cycloadditions via metallacycles. In this research, we investigate a variety of methods for the generation of highly reactive cationic rhodacycles and their reactivity toward novel catalytic molecular transformations. We also examine the mechanism of these catalyses and develop asymmetric variants of these catalyses. Finally, we apply these catalyses to the synthesis of novel chiral ligands, extended π-conjugated compounds, functional polymers, and biologically active compounds.

【Expected results】

The catalyses developed by this research enable the catalytic asymmetric synthesis of chiral functionalized aromatic compounds with ease. The present catalyses serve as a powerful tool for the synthesis of novel chiral ligands and extended π-conjugated compounds, which may contribute to the growth of the Japanese chemical industry. Furthermore, elucidation of the reaction mechanism provides a new principle for the catalyst design.

【References by the principal investigator】

- Asymmetric Assembly of Aromatic Rings To Produce Tetra-*Ortho*-Substituted Axially Chiral Biaryl Phosphorus Compounds. Nishida, G.; Noguchi, K.; Hirano, M.; Tanaka, K.* *Angew. Chem. Int. Ed.* **2007**, *46*, 3951–3954.
- Rh-Catalyzed Synthesis of Helically Chiral and Ladder-Type Molecules via [2 + 2 + 2] and Formal [2 + 1 + 2 + 1] Cycloadditions Involving C–C Triple Bond Cleavage. Tanaka, K.*; Kamisawa, A.; Suda, T.; Noguchi, K.; Hirano, M. *J. Am. Chem. Soc.* **2007**, *129*, 12078–12079.

【Term of project】 FY2008– 2012	【Budget allocation】 **65,400,000 yen** (direct cost)

【Homepage address】 http://www.tuat.ac.jp/~tanaka-k/

Development of New Synthetic Organic Reactions Based on the Universal Metals Catalysis

Masaharu NAKAMURA
(Kyoto University, Institute for Chemical Research, Professor)

【Outline of survey】

A number of precisely controlled organic reactions have been developed with catalysts of the 4d and 5d late transition metals such as Ru, Rh, Pd, Ir, Pt, and Au. It has been difficult to apply the well-established ligand-control strategies to the tuning of the catalytic reactivities of the much more universally abundant 3d late transition metals, which we call the universal metals. This is mainly due to the capricious intrinsic properties associated with these 3d metal elements, namely oxidation states, coordination modes, and spin states. This Research program aims at the development of new catalysts based on the universal metals for selective organic synthesis and production of functional molecules. In order to establish a general concept for the modulation of the 3d late transition metal catalysts, our initial focus is on iron as a representative universal metal. We will develop new iron-catalyzed reactions and apply them to the creation and industrial production of functional organic molecules such as organic electronic devices, liquid crystals, and pharmaceuticals.

【Expected results】

We expect the following results: 1) development of iron-catalyzed cross-coupling reactions between halo-alkanes or arenes, and organo-magnesium, zinc, aluminum, and boron reagents; 2) development of iron-catalyzed carbon-nitrogen bond forming reactions; 3) development of iron-catalyzed catalytic enantioselective C–C bond forming reactions; and 4) their demonstrative application to the industrial production of functional molecules.

【References by the principal investigator】

"Iron-Catalyzed Selective Biaryl Coupling: Remarkable Suppression of Homocoupling by the Fluoride Anion" Hatakeyama, T.; Nakamura, M. *J. Am. Chem. Soc.* **2007**, *129*, 9844-9845.

"Iron-Catalyzed Cross-Coupling of Primary and Secondary Alkyl halide with Aryl Grignard Reagents" Nakamura, M.; Matsuo, K.; Ito, S.; Nakamura E *J. Am. Chem. Soc.* **2004**, *126*, 3686–3687.

【Term of project】 FY2008− 2012	【Budget allocation】 80,500,000 yen (direct cost)

【Homepage address】 http://es.kuicr.kyoto-u.ac.jp/

Design, Synthesis and Biological Application of Chemical Probes for *in vivo* Imaging

Kazuya Kikuchi

(Osaka University, Graduate School of Engineering, Professor)

【Outline of survey】

One of the great challenges in the post-genome era is to clarify the biological significance of intracellular molecules directly in living animals. If we can visualize a molecule in action, it is possible to acquire biological information, which is unavailable if we deal with cell homogenates. One possible approach is to design and synthesize chemical probes that can convert biological information to chemical output.

Real-time imaging of enzyme activities *in vivo* offers valuable information in understanding living systems and in the possibility to develop medicine to treat various forms of diseases. Magnetic resonance imaging (MRI) is an imaging modality adequate for *in vivo* studies. Therefore, many scientists are interested in the development of MRI probes capable of detecting enzyme activities *in vivo*. However, in the case of ^{1}H-MRI probes, interference from the background signals intrinsic to ^{1}H becomes problematic. Because such a background signal is hardly detectable, ^{19}F-MRI probes are promising for *in vivo* imaging. Despite this potential, few principles exist for designing ^{19}F-MRI probes to detect enzyme activities.

【Expected results】

A novel design strategy for ^{19}F-MRI probes to detect protease activities is proposed. The design principle is based on the paramagnetic relaxation effect from Gd^{3+} to ^{19}F. A peptide was synthesized, Gd-DOTA-DEVD-Tfb, attached to a Gd^{3+} complex at the N-terminus and a ^{19}F-containing group at the C-terminus. The ^{19}F-NMR transverse relaxation time (T_2) of the compound was largely shortened by the paramagnetic effect of intramolecular Gd^{3+}. The peptide was designed to have a sequence cleaved by an apoptotic protease, caspase-3. When the peptide was incubated with caspase-3, the peptide was cleaved and subsequently the Gd^{3+} complex and the ^{19}F-containing group were separated from each other. T_2, after cleavage, was extended to cancel the intramolecular paramagnetic interaction. T_2 is a parameter that can be used to generate contrasts in MR images. Using this probe as a positive contrast agent, the probe could detect enzyme activity spatially from a phantom image using ^{19}F MRI.

【Reference by the principal investigator】

S. Mizukami, R. Takikawa, F. Sugihara, Y. Hori, H. Tochio, M. Wälchli, M. Shirakawa & K. Kikuchi: “Paramagnetic Relaxation-based ^{19}F MRI Probe to Detect Protease Activity”, *J. Am. Chem. Soc.*, **130,** 794-795 (2008).

【Term of project】 FY2008－2012	【Budget allocation】 81,500,000 yen (direct cost)

【Homepage address】

http://www-molpro.mls.eng.osaka-u.ac.jp/mlsmpwww/toppageenglish.html

Sensing Based on Nanomechanical systems coupled with stochastic resonance

Takahito Ono
(Tohoku University, Graduate School of Engineering, Associate Professor)

【Outline of survey】

This research aims at developing nonlinear mechanical micro/nano-sensors with an ability of signal processing on the basis of stochastic resonance under applying external noise. For this purpose, nonlinear mechanical silicon resonators will be developed, and its binary state with large or small vibration amplitude is used as digital signal for processing. External stimulus to the sensors causes the transition between the binary states, which can be applied to applications for sensing. The transition probability is also influenced by the external stimulus. Mechanical signal processing using the large array of mechanically- or electrically-coupled resonators will be studied. This mechanical circuit can perform logical operation at the sensor level, which reduces the excess load to LSI and realizes smart systems. Signal amplification can be performed by adding noise to the binary state. Developing devices consisted of coupled resonators with ability of advanced signal processing is our objective.

【Expected results】

A kind of sensory organs of creatures is known to use stochastic resonance for signal amplification. In this research, we propose micro-nanomechanical solid state sensors mimic to biological sensory systems. In addition, signal processing ability at the sensor can make the system smart, which reduces the load to LSI and may realize more complex signal processing. A highly-developed sensor system with advanced functions mimic to biological sensory systems is expected to open novel approach to realize sensory systems for robotics and artificial sensory organ.

【References by the principal researcher】

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  Optical Amplification of the Resonance of a Bimetal Silicon Cantilever
  Applied Physics Letters, **90**, (2007), 243112-1~3.
- Takahito Ono, and Masayoshi Esashi
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【Term of project】 FY2008－2012	**【Budget allocation】** **77,600,000 yen** (direct cost)

【Homepage address】 http://www.mems.mech.tohoku.ac.jp/index.html

Combinatorial Search and Nanoprocessing of Pt-free Amorphous Alloys for Glass Molding Die

Seiichi Hata
(Tokyo Institute of Technology, Precision and Intelligence Laboratory, Associate Professor)

【Outline of survey】

In the production of micro and high-performance glass aspheric lenses with diffraction gratings, the process of molding the glass is critical. However, conventional molding die materials for glass lenses (WC or SiC) are sintered materials. It it difficult to produce diffraction gratings on them. In addition, a protective film of noble metal such as Pt alloy must be deposited on the die surface in order to prevent oxidation and fusion with the molten glass. This film blurs the edges of the gratings. The blurred edges degrade the optical performance of the molded lens. Industry has long desired a molding die material that is robust and that has a heat resistance comparable to those of conventional materials, that allows high-precision processing, and that requires no protective film.

The object of this project is to find a novel Pt-free amorphous alloy for the molding die and to perform high-precision fine processing (nanoprocessing) on the alloy. For creation and systematic search for a large number of alloy samples, combinatorial search is employed. Efficient search for the alloy and its nanoprocessing are realized by new combinatorial measurement method for the crystallization temperature of the amorphous alloys and new nanoprocessing that is not only diamond turning but also forming.

【Expected results】

This project will lead into miniaturizing and improving the performance of almost any optical glass component including lenses by realization of glass molding die with microstructures such as diffraction gratings made of the novel Pt-free amorphous alloy. The new combinatorial measurement methods and nanoprocessing methods are promising for a wide variety of technology field

【References by the principal investigator】

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・Seiichi HATA, Ryusuke YAMAUCHI, Junpei SAKURAI and Akira SHIMOKOHBE, Combinatorial Arc Plasma Deposition of Thin Films, Jpn. J. Appl. Phys., 45, [4A] 2708-2713 (2006)

【Term of project】 FY2008－2012	【Budget allocation】 82,100,000 yen (direct cost)

【Homepage address】 http://www.nano.pi.titech.ac.jp/hata-index.htm

Development of highly efficient fabrication process of thin film devices on plastic materials using atmospheric-pressure plasma

Hiroaki Kakiuchi
(Osaka University, Graduate School of Engineering, Associate Professor)

【Outline of survey】

During the last decades, there has been a steady increase in the utilization of plasma generated at atmospheric pressure. However, the application of atmospheric-pressure plasma seems to be limited to such fields as surface processing and material treatment. Our present study deals with the development of high-rate and low-temperature film growth processes using atmospheric-pressure very high-frequency (VHF) plasma, which is considered to be more appropriate than conventional low-pressure plasma processes for the fabrication of next-generation low-cost and high-performance thin film devices.

The aims of this survey are (1) to develop an electrode system for plasma excitation that can completely remove particulate contamination of the growing films, (2) to achieve high-rate and low-temperature (≤100 °C) depositions of good-quality functional thin films, such as microcrystalline silicon (μc-Si), silicon dioxide (SiO_2) and silicon nitride (SiN_x), and (3) to fabricate high-performance thin film transistors (TFTs) on plastic materials.

【Expected results】

On the basis of the atmospheric-pressure VHF plasma technology we have already developed for the high-rate deposition of functional thin films at low temperatures, we will realize a dust-free atmospheric-pressure plasma CVD system. Simultaneously, we will study critical deposition parameters to achieve highly efficient deposition processes of μc-Si, SiO_2 and SiN_x films having suitable structural and electrical properties for the fabrication of high-performance TFTs, which is very difficult only by improving the conventional low-pressure plasma processes. Consequently, the high potentials of our atmospheric-pressure VHF plasma technology will be demonstrated. The main positive contribution of this survey should be to give a motive force to accelerate practical applications of atmospheric-pressure plasma not only to surface processing but also to thin film fabrication processes.

【References by the principal investigator】

- H. Kakiuchi, H. Ohmi, M. Harada, H. Watanabe, and K. Yasutake, “Low-temperature formation of SiO_2 layers using a two-step atmospheric pressure plasma-enhanced deposition-oxidation process”, Appl. Phys. Lett. **91**, 161908 (2007).
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【Term of project】 FY2008－2012	【Budget allocation】 61,500,000 yen (direct cost)

【Homepage address】 http://www-ms.prec.eng.osaka-u.ac.jp/toptop.html

A Study on Lean Turbulent Premixed Flame and Its Nonlinear Controls by Multi-Dimensional/Multi-Variable Laser Diagnostics and Large-Scale DNS

Mamoru Tanahashi
(Tokyo Institute of Technology, Graduate School of Science and Engineering,
Associate Professor)

【Outline of survey】

To overcome the recent environmental problems, development of high efficiency and low emission combustors is required. Flow fields of various combustors are in turbulent state, whereas details of the turbulent combustion have not yet been clarified. Therefore, the combustors in many applications have been developed through a trial and error process. In this study, lean turbulent premixed flame, which is a promising combustion technology for high efficiency and low emission combustors, is investigated by multi-dimensional/multi-variable laser diagnostics and large-scale direct numerical simulation (DNS) to develop a nonlinear active control scheme based on a nonlinear relation between turbulent flame structure and pressure fluctuation in the combustor. Furthermore, a sensor for monitoring combustion state, a control device and an active control algorithm are comprehensively developed to realize high efficiency and low emission combustors based on the nonlinear active control scheme, and a simulator for turbulent combustion controls based on large eddy simulation with high accuracy turbulent combustion model is constructed for estimation of control efficiency and low cost design of the combustors in many engineering applications.

【Expected results】

In this study, a sensor, a control device and an active control algorithm, which are important for the nonlinear active control of the combustor, will be comprehensively developed. Nonlinear relations between local flame structure in turbulence and combustion oscillation (or combustion noise) will be clarified by large-scale DNS and multi-dimensional/multi-variable laser diagnostics, and an active combustion control scheme based on the nonlinear relations will be established. The results of this study will realize high efficiency and low emission combustors such as gas turbine, and will contribute to conquest of the environmental problems.

【References by the principal investigator】

・M. Tanahashi T. Hirayama and T. Miyauchi, Measurement of Fine Scale Structure in Turbulence by Time-Resolved Dual-Plane Stereoscopic PIV, International Journal of Heat and Fluid Flow, Vol. 29, pp.792-802, 2008.
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・M. Tanahashi, Numerical Simulation of Combustion, Maruzen (2001).

【Term of project】 FY2008－2012	【Budget allocation】 75,800,000 yen (direct cost)

【Homepage address】 http://www.navier.mes.titech.ac.jp/

Stretchable Large-Area Integrated Circuits by Nano-Printing Technology

Takao Someya

(The University of Tokyo, Graduate School of Engineering, Associate Professor)

【Outline of survey】

There has been growing interest in organic transistors, because these emerging devices have several advantages over existing devices based on roll-to-roll and/or printing processes.

In this project, we will exploit the nano-printing technology to realize stretchable large-area integrated circuits.

First, we will establish a novel nano-printing technology with combining atto-liter inkjet and self-assembled monolayer. We will realize interconnections for organic transistors by stretchable conductors using carbon nanotube. In these approaches, we will realize stretchable large-area integrated circuits that can be applied on the curved surface like rubbery.

Second, we will apply conductive rubbers or conductive gels to stretchable integrated circuits. We will study fundamental physics and interfacial physics of these stretchable electric materials and devices, and build up the basic of new field as stretchable electronics.

【Expected results】

In the forthcoming ubiquitous electronics in the next generations, large-area sheet-type devices will play an important role. In this project, we will miniaturize organic transistors in the real nanometer regime by using printing process, and we realize high-performance, large-area organic transistor. We will also reveal the fundamental physics and interfacial physics of the stretchable electric materials and devices to build up the new field as stretchable electronics.

【References by the principal investigator】

Tsuyoshi Sekitani, Yoshiaki Noguchi, Ute Zschieschang, Hagen Klauk, and Takao Someya, "Organic transistors manufactured using inkjet technology with subfemtoliter accuracy", Proceedings of the National Academy of Sciences of the United States of America, Vol. 105, Issue 13, pp. 4976–4980 (Online March 24, 2008; April 1, 2008).

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【Term of project】 FY2008－2012	【Budget allocation】 73,100,000 yen (direct cost)

【Homepage address】 http://www.ntech.t.u-tokyo.ac.jp/

Development of CO_2 Separation and Recovery Technology with High Performance CO_2 Separation Membrane for Emission Limitation of Greenhouse Gases.

Shuji Himeno
(Nagaoka University of Technology, School of Engineering, Associate Professor)

【Outline of survey】

For suppression of global warming world-wide, reduction of CO_2 emissions and development of new energy resources should be accelerated around the world. Particularly, CO_2 recovery from thermal power stations and during drilling of petroleum and natural gas, which are potential sources of CO_2 emission, and using innovative energy-saving technologies are urgent issues. Furthermore, as new energy conversion technologies, utilization of energy from sewage sludge or food residues is sought. The objective of this study is application of a DDR-type zeolite membrane to recovery of CO_2 from natural gas and biogas. We have been developing the membrane, which has high CO_2 separation performance from methane which the primary constituent of natural gas and biogas. And this membrane has high performance especially at high pressures region. Further improvement of the membrane for possible application to CO_2 recovery technology from natural gases will be attempted. Moreover, elucidation of CO_2 separation mechanisms and construction of separation processes for practical applications will be promoted.

【Expected results】

We expect our results will broaden the application area of small molecule separation and collection such as CO_2 and hydrocarbons. Outcomes of this study of the membrane using molecular sieving of oxygen-containing eight-membered rings that DDR type zeolite possesses are expected to be applicable to new abundantly available membrane materials with other zeolite membrane having oxygen-containing eight-membered rings.

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【Term of project】 FY2008－2012	【Budget allocation】 77,900,000 yen (direct cost)

【Homepage address】 http://shwmlab.nagaokaut.ac.jp/

Novel Processing of High Quality Aluminum Nitride Crystal using High Temperature Chemical Reaction Fields - Its Polarity and Growth Mechanism

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【Outline of survey】

Recent trend for semiconductor light emitting devices is headed for shorter wavelength and higher energy. Ultraviolet (UV) light emitting devices are expected for a variety of application: next generation light source, information technology, medical and biotechnology, excitation light source for photocatalysis and nanotechnology. Single crystalline AlN is an ideal material as a substrate for the UV LED from the viewpoints of lattice match and UV transmittance. There is strong competition among Japan, United States and EU to develop AlN crystal. It is extremely difficult to grow a bulk AlN crystal from its melt because of its high melting point and high sublimation pressure. Therefore, the HVPE, flux and sublimation-recondensation methods are currently employed for producing a bulk AlN crystal. However, the crystalline quality and size are far from satisfaction. The present study is positioned as the breakthrough for the limits of the current crystal growth technology. I developed a unique method forming AlN thin films by nitriding sapphire based on thermodynamic consideration. The purpose of this study is developing a new process of high quality AlN crystal with the help of the AlN film using high temperature chemical reaction fields. The crystal growth mechanism of AlN is also studied taking into account the polarity.

【Expected results】

High quality AlN crystal obtained by the present study will significantly contribute to make high luminous efficiency UV LED. Technical expertise on polarity and surface morphology control will be obtained through development of the process using high temperature chemical reaction fields. In addition, scientific contribution to the nitride crystal growth will be greatly expected.

【References by the principal investigator】

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【Term of project】 FY2008－2012	【Budget allocation】 75,800,000 yen (direct cost)

【Homepage address】 http://www.tagen.tohoku.ac.jp/labo/fukuyama/index-j.html

Observational study to determine the causes of the freak wave generation in the open ocean

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【Outline of survey】

Theoretical and experimental works suggest that the generation of freak wave is closely related to the instability of random water waves, but this has not been verified from field observation. Wave spectra in the ocean vary due to changes in the wind field and ocean current. In this study, we simultaneously measure the wind, current and wave to identify the environmental conditions that lead to the generation of the freak wave. Following hypotheses will be tested: i) dispersive energy focusing due to meteorological conditions; ii) geometrical energy focusing due to wave-current interaction; iii) generation of freak wave due to an instability of an abnormal wave spectra formed as a result of i) and ii).

We conduct the following: 1) establish a new buoy system to monitor freak waves in the deep ocean (near the Kuroshio extension); 2) analyses of the obtained time series from the moored buoy station containing freak wave; 3) comparison of the numerical simulation results and the satellite images with wave records and other measurements around the moored station from the intensive observational period.

【Expected results】

Simultaneous observation of wave, current and wind by moored and drifting buoys near a strong ocean current is rare. If a long-term monitoring is realized, the database of the wave-wind-current will be quite unique and we will likely be able to identify causes of the freak wave generation in the open ocean. We also expect to contribute to the study of the air-sea interaction (e.g. gas exchange) which is the original purpose of the moored buoy station in the Kuroshio extension.

【References by the principal investigator】

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【Term of project】 FY2008－2012	**【Budget allocation】** **58,900,000 yen** (direct cost)
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