【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project：Challenges to the remaining issues of therapeutically valuable pseudo-natural peptides and products

SUGA Hiroaki
(The University of Tokyo, Graduate School of Science, Professor)

Research Project Number: 20H05618　　Researcher Number：00361668
Keyword：nonstandard peptide, pseudo-natural products, mid-sized molecules, drug discovery

【Purpose and Background of the Research】

The ultimate goal of this project is to establish an empirical guidance how membrane permeable mid-sized molecules on the basis of macrocyclic peptides and pseud-natural products could be discovered and developed. The RaPID (Random non-standard Peptides Integrated Discovery) system devised by this PI revolutionized the discovery process of de novo bioactive "nonstandard" macrocyclic peptides that are peptidase-resistance, potent binding to target proteins in the order of nM–pM range, and occasionally cell membrane permeable; however, it has yet a remaining issue of the reliability to devise the highly cell membrane and small intestine permeable, *i.e.* oral available, molecules. To establish the guidance for devising such mid-sized molecules, similar to "Lipinski's rule of five", two critical experimental data must be accumulated. First, we need to have a method to reasonably predict the cell membrane permeability and ideally also small intestine permeability. Second, to establish such a method, we need to have more examples for cell membrane permeable and non-permeable peptides where their structures are somewhat similar.

【Research Methods】

The PI has proposed four specific aims that challenge the remaining issues of this topic as follows.

① Establishing the empirical guidance of membrane permeable peptides and pseudo-natural products
② RaPID display of cyclic β-, cyclic γ-, and unsaturated cyclic amino acids-containing (exotic) peptide libraries and selection of active species
③ RaPID display of pseudo-natural products generated by post-translational modifying enzymes and selection of active species
④ Studies on cell membrane and Caco-2 permeability of exotic peptides and pseudo-natural products

We will design and execute the experiments based on the above specific aims, and challenge the unsolved issues.

【Expected Research Achievements and Scientific Significance】

This project will be executed by a feedback cycle of experimental plans as follows: We execute the specific aim ① based on our currently available cell membrane permeable and non-permeable peptides; execute the specific aims ② and ③ to build "smart" libraries to obtain potent binders against intracellular target proteins of interest; and test them for cell membrane permeabilities in the specific aim ④; the data will be feedback to the specific aim ① to increase our knowledge of structure-activity relationships, and the knowledge will be fed to the design of "smarter" libraries of ② and ③, followed by ④ including small intestine permeability of active species. We expect that such collective data and knowledge will lead us to a useful guidance and possibly "a rule" for accessing desired mid-sized molecules faster and more reliably.

【Publications Relevant to the Project】

- Ribosomal synthesis and de novo discovery of bioactive foldamer peptides containing cyclic β-amino acids; T. Katoh; T. Sengoku; K. Hirata; K. Ogata; H. Suga* **Nature Chemistry,** (2020) DOI: 10.1038/s41557-020-0525-1
- Promiscuous enzymes cooperate at the substrate level en route to lactazole A; A.A. Vinogradov; M. Shimomura; N. Kano; Y. Goto; H. Onaka, H. Suga* **Journal of the American Chemical Society,** in press (2020) DOI: 10.1021/jacs.0c05541
- Introduction to Thiopeptides: Biological Activity, Biosynthesis, and Strategies for Functional Reprogramming; A.A. Vinogradov; H. Suga* **Cell Chemical Biology,** Accepted article (2020) DOI: 10.1016/j.chembiol.2020.07.003
- Ribosomal Elongation of Cyclic γ-Amino Acids using a Reprogrammed Genetic Code; T. Katoh; H. Suga* **Journal of American Chemical Society**, 142, 4965-4969 (2020) DOI: 10.1021/jacs.9b12280

【Term of Project】 FY2020-2024

【Budget Allocation】 485,800 Thousand Yen

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Title of Project : Challenge from mechanical self-organization to elucidate the physical properties of non-equilibrium soft matter / amorphous material

TANAKA Hajime
(The University of Tokyo, Graduate School of Frontier Sciences, Visiting Researcher)

Research Project Number: 20H05619 Researcher Number : 60159019
Keyword : Soft matter, amorphous materials, mechanical self-assembly

【Purpose and Background of the Research】

Materials without a periodic structure, including soft matter and amorphous materials, have unique mechanical (elasticity, yield and fracture behavior, and moldability) and thermal properties (specific heat and thermal conductivity) that are very different from those of crystalline materials, and have been shaping human history through their application in various fields. The structure of irregular systems has been studied based on the position of the center of gravity of the constituent particles, but the structural characteristics of these systems remain elusive. Therefore, a fundamental understanding of their structure-property relationships still lags far behind that of crystals. We are convinced that the momentum conservation law is closely related to determining the system state in the non-equilibrium state, even in the seemingly motionless solid state. By combining thermodynamic and kinetic approaches with the entirely new kinetic perspective of “self-organization of the mechanical network percolated throughout the system,” we aim at elucidating the structural features of materials in the non-equilibrium solid state, such as glasses and gels, as well as the physical mechanisms that determine their specific mechanical and thermal properties.

【Research Methods】

(1) Mechanical self-assembly of soft matter: We aim to elucidate the universal physical principles behind the mechanical self-assembly of soft matter by directly comparing simulations incorporating hydrodynamic effects with single-particle resolution imaging of phase separation and gelation in colloidal dispersions using 3D confocal microscopy.
(2) Mechanical topology, flow, and fracture: We will approach nonlinear rheology of colloidal systems (shear-thinning and thickening) from a new perspective, focusing on the relationship between flow and the topology of the network of force chains formed by colloidal and granular particles dispersed in a fluid.
(3) Understanding the properties of amorphous materials based on interaction network topology: Crystals are in thermodynamic and mechanical equilibrium, and the periodicity of their structures maintains their solidity. On the other hand, glass is in a non-equilibrium state and has no structural periodicity. Therefore, the principle of self-assembly, leading to the solidity of the structure of amorphous materials, is still unknown. We aim to elucidate the peculiar physical properties of amorphous materials based on the idea that solidification is a consequence of the mechanical self-organization of their structures. Specifically, we will elucidate the properties of the spatial mechanical network in amorphous solids by experiments and simulations, and challenge long-standing problems such as the mechanism of elasticity, fracture mechanisms, and the anomalies of heat conduction and specific heat at low temperatures, which are unique to amorphous materials.

【Expected Research Achievements and Scientific Significance】

Materials with a nonperiodic disordered structure are characterized by their unique mechanical properties, including deformation and fracture characteristics. We believe that the topology of the force transfer path is a critical structural factor governing their physical properties. In this research project, we aim to elucidate the structure-property relationships of aperiodic materials, focusing on the cooperation of thermodynamic and kinetic factors in their structuralization, which has not been considered before. We expect that this would deepen our physical understanding of the long-standing unsolved problems associated with aperiodically structured materials and create a new trend in developing highly functional materials with irregular structures.

【Publications Relevant to the Project】

- T Yanagishima, J Russo, H Tanaka, Common mechanism of thermodynamic and mechanical origin for ageing and crystallization of glasses, *Nature Communications* **8**, 15954 (2017).
- H Tsurusawa, M Leocmach, J Russo, H Tanaka, Direct link between mechanical stability in gels and percolation of isostatic particles, *Science Advances* **5**, eaav6090 (2019).

【Term of Project】 FY2020-2024

【Budget Allocation】 373,900 Thousand Yen

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【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project： Science of fairy chemicals and their application development

KAWAGISHI Hirokazu
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Research Project Number: 20H05620 Researcher Number：70183283
Keyword：fairy rings, fairy chemicals, plant hormone, mushroom, natural products chemistry

【Purpose and Background of the Research】

"Fairy rings" is a phenomenon that turfgrass grows as a ring that is more prolific or inhibited than the surrounding area, and later mushrooms develop. We discovered the two plant-growth regulators responsible for this phenomenon, 2-azahypoxanthine (AHX) and imidazole-4-carboxamide (ICA), from a fairy ring-inducing mushroom, and a metabolite of AHX, 2-aza-8-oxohypoxanthine (AOH), from rice. Subsequently, these three compounds were found to be universally endogenous in plants and significantly increased the yields of crops in field experiments. The three compounds, collectively called fairy chemicals (FCs), have been shown to be biosynthesized in the purine metabolic pathway. In this study, we will elucidate the full picture of the biosynthetic and metabolic pathways of FCs and figure out a new purine metabolic pathway common to all plants and fungi. In addition, we will elucidate the molecular mechanism of FCs activity by identifying their signaling factor(s) and receptor(s) and generating biosynthetic enzyme-deficient strains. Furthermore, we will clarify effects of FCs on crops and their mechanism of action through cultivation experiments, and create safer and more potent FCs derivatives by synthetic organic chemistry. The above studies will prove FCs as a new family of plant and fungus hormones.

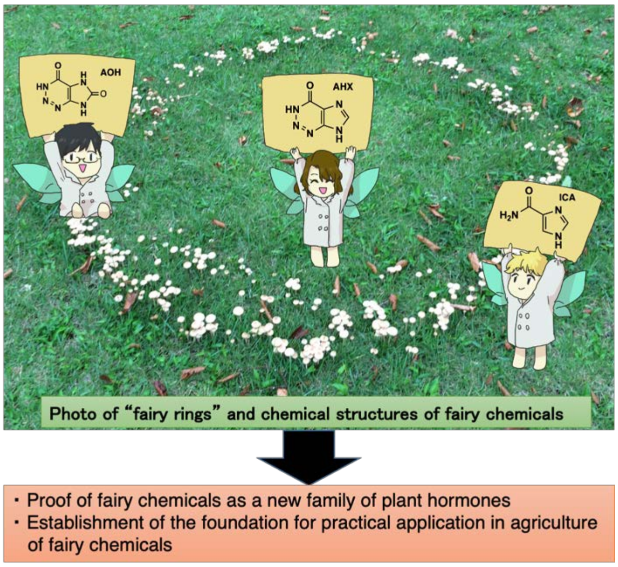

Figure. Overview of the project

【Research Methods】

1. Proof of FCs as a new family of plant and fungal hormones
1.1. We will isolate further FCs metabolites, determine the structures, and map out the biosynthetic pathways of the compounds.
1.2. We will search for and identify signaling factor(s) and receptor(s) for which FCs show biological activity. We will use strains of rice and Arabidopsis that are deficient in biosynthetic routes of the identified signaling factor(s) or receptor(s) for FCs to elucidate the signaling pathways.
2. Basic research for the practical application of FCs in agriculture
2.1. We will elucidate the molecular mechanisms that FCs confer resistance to adverse environmental conditions (high temperature, low temperature, drought, high salt concentration, etc.) to plants.
2.2. We will create safer and more active FCs derivatives by synthetic organic chemistry.

【Expected Research Achievements and Scientific Significance】

There are seven plant hormones (the Obunsha Biological Dictionary). If FCs is recognized as a new family of plant hormones, it will be the second plant hormone original to Japan after gibberellin. If the molecular mechanism of the yield-increasing effect of FCs on staple crops such as rice, wheat and potatoes is clarified in this study, it will pave the way for the practical application of FCs in agriculture.

【Publications Relevant to the Project】

・ Choi, J-H., Kawagishi, H. *et al*., Disclosure of the "fairy" of fairy-ring forming fungus *Lepista sordida*, *ChemBioChem*, 11, 1373-1377 (2010)
・ Kawagishi, H., Fairy chemicals – a candidate for a new family of plant hormones and possibility of practical use in agriculture –, *Biosci. Biotechnol. Biochem.*, 82, 752–758 (2018)
・ Kawagishi, H., Are fairy chemicals a new family of plant hormones?, *Proc. Jpn. Acad.*, *Ser. B*, 95, 29-38 (2019).

【Term of Project】 FY2020-2024

【Budget Allocation】 474,500 Thousand Yen

【Homepage Address and Other Contact Information】

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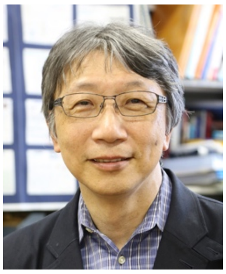

Title of Project： Chemistry and Physics of Molecular Systems with Mathematically-Defined Strong Isotropic Lattice Structures

AWAGA Kunio
(Nagoya University, Graduate School of Science, Professor)

Research Project Number: 20H05621 Researcher Number：10202772
Keyword：Strong isotropy, Geometric topology, Band-filling control

【Purpose and Background of the Research】

While the carbon materials, such as graphite, diamond, and nanocarbons, has been studied extensively, the graph theory recently has predicted the K_4 structure as a new carbon allotrope. It is mathematically demonstrated that only the three lattices, namely honeycomb, diamond and K_4, which are lattices of the carbon allotropes, exhibit the property of “strong isotropy”. It is notable that the band structures of the three carbon allotropes include exotic band dispersions, which are characterized as Dirac cone, Dirac nodal line and triplet Dirac cone, respectively. Therefore, if the Fermi levels can be freely controlled in them, Dirac fermion systems would be newly constructed. However, it is hard to realize this idea in the carbon allotropes, so that we propose to make molecular mimics of the carbon allotropes, and then to carry out the band filling controls, taking advantage of their porous structures and redox activities. The purpose of this project is to exploit the electronic/spin functions originating from the topology of strong isotropic lattices, developing electrochemical band-filling control. We also elucidate the solid-state electrochemical functions, derived from the synergetic effects between electron and ion transport in the molecule-based strong isotropic lattices.

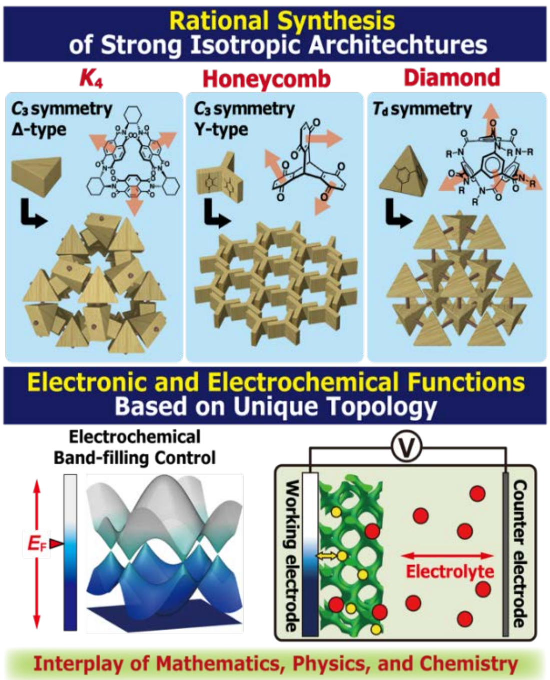

Figure 1 Research concept

【Research Methods】

1. Rational Synthesis

We work on a new methodology for making molecule-based strong isotropic materials, using “polyhedral π-conjugated molecules” with the C_3 or T_d symmetry. They respectively play the roles of sp^2 or sp^3 carbon in the carbon allotropes, to form their molecular mimics.

2. Electrochemical Band-filling Control

The band structures of molecule-based strong isotropic materials authentically include Dirac cones and flat bands. After confirming these band structures by the angle-resolved photoelectron spectroscopy and the scanning tunneling spectroscopy, we carry out the electrochemical hole/electron doping to these bands without destroying the framework lattices.

3. *Operando* Measurements

We have already developed the *operando* measurement systems on XAFS, XRD, NMR, etc. under solid-state electrochemical reactions. The present research on the strong isotropic materials is conducted under the guidance of these *operando* measurements.

【Expected Research Achievements and Scientific Significance】

Combining physics and mathematics of strong isotropy by means of chemistry, we contribute to the science and technology of topological materials. Establishing the authentic ways to form Dirac cones and flat bands, and the methodology of electrochemical band filling control, we develop novel electronic functions. The electrochemical functions such as high energy storage are also realized.

【Publications Relevant to the Project】

・ A. Mizuno, Y. Shuku, M. M. Matsushita, M. Tsuchiizu, Y. Hara, N. Wada, Y. Shimizu, and K. Awaga, “3D Spin-Liquid State in an Organic Hyperkagome Lattice of Mott Dimers”, *Phys. Rev. Lett.*, **119**, 057201 (2017).
・ A. Mizuno, Y. Shuku, and K. Awaga, “Recent Developments in Molecular Spin Gyroid Research”, *Bull. Chem. Soc. Jpn.*, **92**, 1068-1093 (2019).

【Term of Project】 FY2020-2024

【Budget Allocation】 426,500 Thousand Yen

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【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project : Light emitting synthesizer : aiming to create the ultimate lighting devices

KAWAKAMI Yoichi
(Kyoto University, Graduate School of Engineering, Professor)

Research Project Number: 20H05622 Researcher Number : 30214604
Keyword : light emitting synthesizer, semiconductor 3D-structures, photonics in the next generation

【Purpose and Background of the Research】

Recent progress in the research of nitride semiconductors has been remarkable, and blue light-emitting diodes (LEDs) with extremely high efficiency have been commercialized using InGaN quantum wells as the active layer. However, the "Droop" phenomenon, in which luminous efficiency decreases with high current injection, the "green-gap" problem, in which the efficiency of green LEDs with increased In content in the active layer is reduced, and the "UV-threshold" problem, in which the efficiency of deep UV AlGaN LEDs with increased Al content in the active layer is reduced, have not been solved. In this project, we propose that the control of high-efficiency, multi-wavelength luminescence is a key issue to be overcome for next-generation lighting applications.

We aim to develop a new functional device (light emitting synthesizer) that can emit light of any wavelength with a high radiation recombination probability, focusing on the synthesis of luminescence wavelengths by a three-dimensional semiconductor structure, polarization control, and plasmonics effects. This enables the realization of the ultimate tailor-made light source with arbitrary color rendering and the deep UV multi-wavelength light source required for advanced processing and environmental sensing. Furthermore, we will demonstrate Li-Fi (light fidelity) wireless communication by multi-wavelength and high-speed switching of light sources, and establish a foundation for next-generation communication systems.

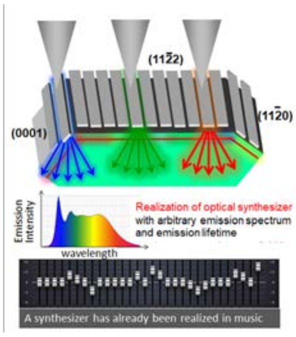

Fig.1 Concept of light emitting synthesizer

【Research Methods】

Towards multi-wavelength control and high efficiency luminescence in three-dimensional (3D) InGaN (AlGaN) structures, it is useful to work on potential fluctuations in micro and nano scales, respectively. In other words, the former leads to multiple wavelengths due to differences in alloy composition and polarization effects in each 3D structure, and the latter contributes to higher efficiency because it can induce exciton localization by potential fluctuations in the nanoscale. Furthermore, we aim to enhance the luminescence transition probability by utilizing the transfer of elementary excitations from excitons to plasmons as well as the control of exciton localization. This enables multi-wavelength luminescence control, increased luminescence efficiency, and faster luminescence switching speed.

【Expected Research Achievements and Scientific Significance】

The evolution of spectral synthesis using a light emitting synthesizer will create a new field of application called tailor-made lighting, in which the emission spectrum of a multicolor LED is tuned according to the circadian rhythm and preferences for color temperature and color rendering, as shown in Figure 2. In addition, there are also significant spillover effects to deep-ultraviolet photonics and high-speed optical communications.

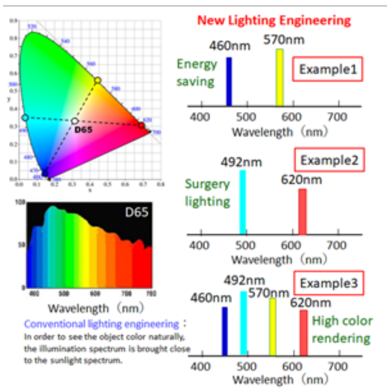

Fig.2 The concept of new lighting engineering

【Publications Relevant to the Project】

・Y. Matsuda, M. Funato, and Y. Kawakami, “Polychromatic emission from polar-plane-free faceted InGaN QWs with high radiative recombination probabilities”, *Appl. Phys. Exp.* **10**, 071003/1-4 (2017).

【Term of Project】 FY2020-2024

【Budget Allocation】 431,500 Thousand Yen

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【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project： Creation of multi-element high entropy nano-alloys by non-equilibrium synthesis methods

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(Kyoto University, Graduate School of Science, Professor)

Research Project Number: 20H05623 Researcher Number：90234244
Keyword：Multi-element alloy, High entropy, Non-equilibrium synthesis, Catalysis

【Purpose and Background of the Research】

In this research, we will develop a new nano-sized solid solution alloys with many elements by the multi-element high entropy effect, and create an innovative catalytic functionalities. The supercritical solvothermal continuous flow synthesis method, which was originally developed by our research group, alloys various elements at the atomic level and we explore for new fusion-elements, new chemical substances, and new materials. Specifically, no one has succeeded so far in 1) fabrication of high-entropy solid-solution nanoalloys composed of multiple elements of precious metals, 2) high-entropy solid-solution nanoalloys composed of the elements of precious metals and base metals, 3) high-entropy solid-solution nanoalloys composed of noble, non-precious, and light elements.

Furthermore, by applying process-informatics, we will develop a comprehensive and innovative chemical process. Through this research and development, it is expected that we will be able to learn "advantages and characteristics of the elements" related to individual catalytic reactions through machine learning, which cannot be obtained from human experience.

【Research Methods】

We will establish solid-solution nano-alloys technology that makes full use of methods such as non-equilibrium synthesis, nanosizing, hydrogen process, and solvothermal continuous flow synthesis. So far, we have conducted research and development to mix metallic elements that never mix in the bulk state at the atomic level by using nanosize and non-equilibrium synthesis methods. However, in the method of reducing metal ions by spraying a metal precursors solution, there has been a limit to the increase in reduction speed, and it is difficult to instantly and simultaneously reduce metal ion species having largely different redox properties, so that they uniformly mixed was not successful. Therefore, by applying the ultrafast reduction continuous synthesis method (solvothermal continuous flow synthesis method) using hydrothermal and solvothermal reactions, we will establish a synthetic technology of multi-element solid-solution alloys in a non-equilibrium state in supercritical and subcritical. Solvothermal synthesis is a method of synthesizing a solid materials using a high-temperature and high-pressure solvent (or supercritical fluid), and when the solvent is water, it is called hydrothermal synthesis. Using this method, a solvent in which various metal ions are dissolved is instantly transferred to a supercritical/subcritical fluid, and each metal ion is instantly reduced and together alloyed into metal atoms under high temperature and high pressure, and the temperature is instantly decreased into room temperature. It is a method that enable the synthesis of a 1 nm class solid-solution alloy. With the exception of metal oxides such as ceria, there was no example of the synthesis of alloy nanoparticles until a few years ago. The features of the solvothermal continuous flow synthesis method originally developed by this project are 1) pressurized and heated up to 40 MPa and 450 °C, 2) even ethanol can be used as a reducing agent up to 300 °C, 3) metal ions can be reduced even when diluted with water to 10% ethanol, 4) three liquids injection at once is available, and 5) stable synthesis and mass production of solid-solution nanoalloys are possible.

【Expected Research Achievements and Scientific Significance】

Through this research and development, it is expected that we will be able to learn "advantages and characteristics of the elements" related to individual catalytic reactions through machine learning, which cannot be obtained from human experience.

【Publications Relevant to the Project】

- Platinum-group-metal High-entropy-alloy Nanoparticles, D. Wu, K. Kusada, T. Yamamoto, T. Toriyama, S. Matsumura, S. Kawaguchi, Y. Kubota, H. Kitagawa, ***J. Am. Chem. Soc.***, 142, 32, 13833-13838 (2020).
- New Aspects of Platinum Group Metal-based Solid-solution Alloy Nanoparticles: Binary to High-entropy Alloys, K. Kusada, D. Wu, H. Kitagawa, ***Chemistry - A European Journal***, 26, 5105-5130 (2020).

【Term of Project】 FY2020-2024

【Budget Allocation】 486,100 Thousand Yen

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【Grant-in-Aid for Specially Promoted Research】
Science and Engineering

Title of Project : Development of the JSNS2 experiment at J-PARC Material and Life science research Faciliy (MLF)

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(High Energy Accelerator Research Organization, Institute of Particle and Nuclear Studies, Associate Professor)

Research Project Number: 20H05624 Researcher Number : 80375401
Keyword : Neutrino, Sterile Neutrino, Liquid scintillator detector

【Purpose and Background of the Research】

The discovery of the neutrino oscillation provides the Novel Prize to Dr. Kajita and Dr. Mcdonald in 2015. The neutrino oscillations provide the flavor (electron, muon, tau, (sterile)) changing of neutrinos as functions of their energy and flight length. This research aims to search for the sterile flavor in the oscillation with high precision.

The sterile neutrinos have no weak interactions, thus the standard model of the elementary particle physics can't explain them. Once the existence of the particle is established, the standard model will be changed drastically.

The search for the sterile neutrino is performed using the neutrino oscillation between active and sterile neutrinos. There are some indications from some experiments, but the certain conclusion has not yet been obtained. This research aims to have a conclusion with the fastest time-scale among the experiments in the world with various upgrades.

With the upgrades of this project, we also aim to strengthen the capability of J-PARC MLF as a facility.

【Research Methods】

Fig.1 shows the setup of this project. The current JSNS2 experiment uses one detector located on MLF 3rd floor with the baseline of 24 m from the mercury target. Total 50 tons of liquid scintillator is immersed in the detector, and search for the anti-ν_e signal oscillated from anti-ν_μ during 24m. The data taking was started from 2020 June.

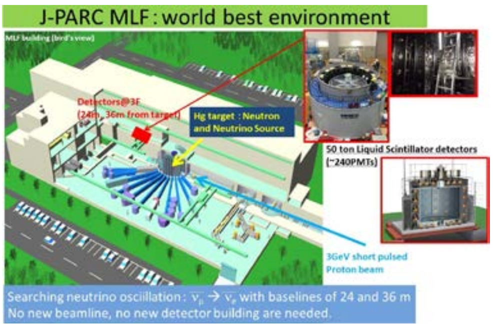

Fig.1 ; The setup of the JSNS2

We improve the sensitivity putting the new 50 tons of detector with 36 m baseline. The different oscillation pattern of the signal, and the better understanding of backgrounds are available from this upgrade.

The upgrades of liquid scintillator, electronics, the proton beam final focus, and precise cross section meas. for parent particles of neutrinos and neutrons in Hg-proton reaction also provide not only significant improvement of the sensitivity but also that of the facility capabilities.

【Expected Research Achievements and Scientific Significance】

Fig.2 shows the improved sensitivity with all upgrades. The horizontal axis corresponds to the mixing angle between anti-ν_μ to anti-ν_e, and the vertical one shows the square of difference between 4th and other mass eigen-states. The shaded region can be searched with this experiment while the blue areas (99%, (90%) C.L.) show the indicated regions from prior experiments. We improve the most important region of indicated region (lower Δm^2: recent stronger indicated region (dashed ellipse)) compared to the current JSNS2 (dashed red lines).

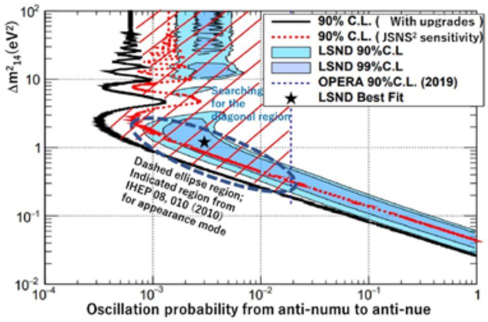

Fig.2: The improved sensitivity of JSNS2 with upgrades

In addition, we upgrade the MLF capability as mentioned, and the xsec of the monochromatic 236 MeV ν_μ (created at Hg in Kμ2) and LS can also be measured precisely.

【Publications Relevant to the Project】

・ S.Ajimura et al, arXiv:1705.08629 (TDR)
・ M. Harada et al, arXiv:1310.1437 (Proposal)

【Term of Project】 FY2020-2024

【Budget Allocation】 474,500 Thousand Yen

【Homepage Address and Other Contact Information】
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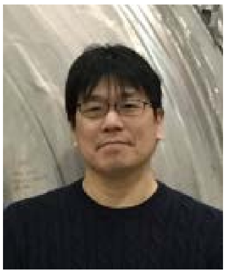
【Grant-in-Aid for Specially Promoted Research】

Science and Engineering



Title of Project : Super high precision measurements of anomalous magnetic moment and electric dipole moment of muon

MIBE Tsutomu
(High Energy Accelerator Research Organization, Institute of Particle and Nuclear Studies, Associate Professor)

Research Project Number: 20H05625 Researcher Number : 80536938
Keyword : muon, anomalous magnetic moment, electric dipole moment, high precision

【Purpose and Background of the Research】

The standard model of particle physics is a successful theory to quantitatively describe varieties of phenomena in particle physics. However, new laws of physics beyond the SM (new physics) are strongly required as this theory is not able to explain recent observations such as origin of neutrino masses, mass hierarchy of quarks and leptons, origin of dark matter and matter-dominant universe.

The anomalous magnetic moment g-2 (or a_μ) of muon has been known for its sensitivity to prove new physics. It was measured at BNL with a relative precision of 540 ppb (parts-per-billion, 10^{-9}). This is more than three standard deviations larger than the SM prediction (Fig. 1). Inputs to the SM calculation have been given by the large number of experiments. It is not meaningful to blame the SM calculation without allowing inconsistencies elsewhere. On the other hand, there is no other experimental measurement of g-2 with precision of the BNL experiment so far.

In this research proposal, we employ a completely different experimental technique to precisely measure the g-2 and electric dipole moment (EDM) of muon. Our experiment naturally has a different source of systematic uncertainty. Therefore, the scientific value of the research will remain unchanged even after the release of the Fermilab experiment, a successor of the BNL experiment. The objectives of this research are to obtain a decisive conclusion on the question whether the g-2 value is indeed larger than in the SM, and to carry out a search for muon EDM with the best sensitivity ever achieved.

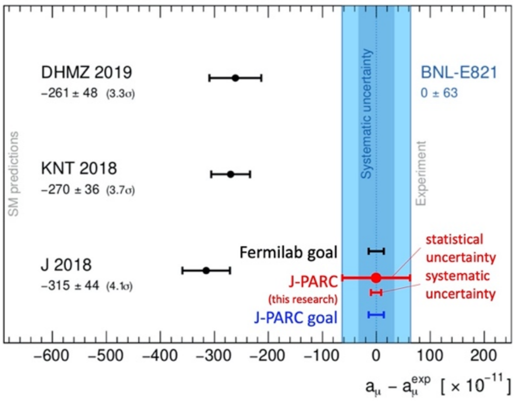


Figure 1 Difference between theory predictions and measurements of muon g-2

【Research Methods】

In our reseach methods, we emphasise importance of beam emittance. A muon beam is in general produced in two steps. First, a proton beam hits a pion production target to generate pions through nuclear reactions. Next, a pion decays into a muon and a muon neutrino. At these steps, the beam emittance (phase space volume of the beam) inevitably inflates. A typical value of emittance is ~1,000π mm･mrad. We plan to reduce the emittance by three orders of magnitude, i.e. ~1π mm･mrad by a cooling followed by acceleration. This allows to use much more efficient beam injection, a compact storage ring with a better controlled magnetic field distribution, large coverage of the decay-positron tracking detector. Our approach is immune to all major systematics of the BNL and Fermilab experiments.

【Expected Research Achievements and Scientific Significance】

The expected research achievements are to start data taking of the experiment to measure the muon g-2 and EDM with completely different technique in the period of this research. After construction of experimental apparatus and its commissioning, data taking will follow. The target precision of g-2 is a 450 ppb statistical uncertainty (similar to the BNL result) with a systematic uncertainty less than 70 ppb (four times better than BNL, similar to the Fermilab goal). The same data will be used to search for muon EDM with a sensitivity of 1.5×10^{-21} *e* ･cm (100 times better than the BNL limit).

【Publications Relevant to the Project】

・ M. Abe, et al., Prog. Theor. Exp. Phys. 2019, 053C02 (2019).
・ T. Aoyama, et al., arXiv:2006.04822 (KEK Preprint 2020-5) (2020).

【Term of Project】 FY2020-2025

【Budget Allocation】 489,400 Thousand Yen

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