Microbial Fuel Cell

Water treatment technology to mitigate wastewater treatment problems in the world

Research background

Wastewater left over from production activities brings a big environmental impact on the ecosystem. Local Okinawa industries such as awamori production and livestock industry including hog raising and poultry farming, discharge a large quantity of organic wastewater. The running and maintenance cost of wastewater facilities for the wastewater treatment is not inexpensive at all, and has become an issue pressing on management for companies and business owners.

Research

At OIST, researchers created a device called "microbial fuel cell" that cleans wastewater containing environmental pollutants while also generating electricity in the process. Special microbes are contained in the equipment, and when wastewater passes through the inside of the equipment, they break down the organic matter in the wastewater. Furthermore, electricity is generated by passing electrons generated at breaking down of organic matter to the electrode. This device is very promising as a practical technology because it produces more energy than it consumes, it costs less and maintenance is easy.

In 2016, it was adopted by a program for new industry creation started–up from universities (START) grant from the Japan Science and Technology Agency (JST), and now at the awamori brewery in Okinawa Prefecture, researchers are working on increasing the wastewater treatment capacity and improving the efficiency of using energy generated from microorganisms. Moreover, the combination of the microbes in equipment was changed and the microbial fuel cell which can operate stably for a long-term against various kinds of wastewater was successfully developed. Pilot studies are proceeding at both domestic and overseas sites, such as hog farms, a whiskey distillery in Scotland, and a winery in California, USA, in addition to the awamori brewery.

This technology can generate sustainable energy while treating wastewater and also is inexpensive and easy to handle. Therefore, it is effective not only in the industrial world but also in cleaning water for drinking in developing countries, and it is expected to contribute to water resource improvement around the world.

MFCs in the OIST Biological Systems Unit lab containing treated and untreated wastewater from the Okinawa Prefectural Livestock and Grassland Research Center.

The OIST Biological Systems Unit has placed MFCs at an Awamori distillery in Okinawa.

Keywords

Microbial fuel cell, Sustainable energy, Bioelectrochemical system

Applications/Future development

- Increasing the wastewater treatment capacity and improving the utilization efficiency of energy generated from microbes
- Identifying microbes for applying to different kinds of wastewater
- Developing a new technology to recover and remove substances such as nitrogen and phosphorus produced in the breakdown process of microbes

Opportunity for joint research and technology transfer

- Currently accepting contacts from companies interested in joint research and licensing of this technology

Patent protection
US : provisional 62/464,736

Introduction of the research unit

Biological Systems Unit

Unit leader : Igor Goryanin Adjunct Professor

The Biological Systems Unit is working on devices in which microorganisms break down waste, releasing energy in the process. Key Okinawa industries such as awamori distilleries, pig and chicken farms, sugar manufactures, and municipal wastewater treatment facilities stand to benefit economically and environmentally from this approach.

<Related research theme>

Wastewater cleaning in hog farms

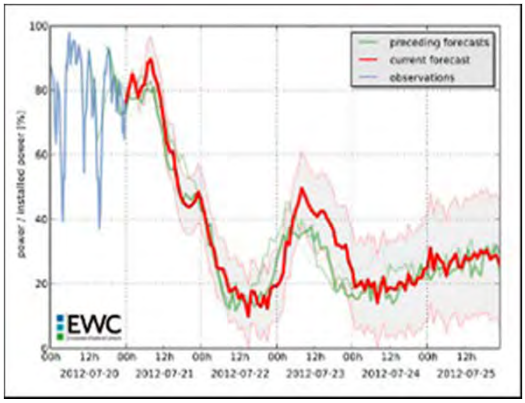
From the agricultural and livestock industry such as hog farming, a large amount of sewage containing organic substances, odor-causing substances and others is discharged. Usual methods of treating and recycling such wastewater include aeration, utilizing it as fertilizer, and in abroad, confining it to specialized ponds and wetlands to undergo natural cleansing processes. In areas with many hog farms like Okinawa, wastewater treatment and recycling are major issues, and OIST researchers are working on wastewater cleaning by microbial fuel cells. (Posted on "Scientifica")

Research unit website : https://groups.oist.jp/bsu

Improving Output Power Prediction in Renewable Energy Use

Contribution to prevention of income loss and of power transmission grid instability caused by power generation fluctuation

Research background



Predictive model currently created by EWC (European Weather Consult)
Predicted renewable energy data and actual power production data are shown. The blue line shows the actual power generation value, the red line shows the expected value for 5 days, the green line shows the predicted value before that, the portion indicated by the shadow represents the confidence interval of the expected value for 5 days. As the time series progresses, the confidence interval of the prediction becomes larger and the reliability falls.

The amount of energy generated by renewables fluctuates depending on the natural variability of resources at any given time. Unlike thermal power generation and nuclear power generation, production volume of renewable energy cannot be controlled. Moreover, since there is no electric storage device in the power grid, the produced energy must be consumed immediately, otherwise a possible risk of collapsing the grid may occur. Particularly on windy days, power surges have been known to overwhelm the electrical grid, causing power outages.

For this reason, when utilizing renewable energy, operators (power producers etc.) of power generation facilities predict fluctuations in power generation during a planned period using a forecast model in order to properly control the operation of facilities and to protect the power grid from power generation instability.

However, since the accuracy of forecasting based on these models is limited, inappropriate driving control and oversupply are incurred, resulting in transmission system instability due to excess or deficiency of electric power.

Moreover, these forecast models are not only used by operators for mitigating the power generation fluctuation and efficient facility operation but also used for trader's decision making in a power transaction markets.

Research

The new forecast model developed by the assistant professor Mahesh Bandi of OIST enables quantification of time series of forecast error from the actual power generation amount when using renewable energy, and by correcting and improving this forecast model, it can lead to prevention of revenue loss caused by power generation fluctuations and to prevent power transmission system instability. Advantages of the forecast model are that 1) forecast error can be analyzed by utilizing minimum data (power generation amount forecast in time series and actual power generation amount) and 2) data sample period can be set freely.

Keywords
Renewable energy, Wind power generation, Marine power generation, Solar power generation, Forecasting, Operation control, Penalty, Energy market, Spot energy market, System stabilization of electricity grid

Applications/Future development

- Construction of an accurate prediction model for generated electric energy by various types of renewable energy through utilization of renewable energy observation data (big data)
- Contribution to an evaluation method of business feasibility for renewable energy related businesses

Opportunity for joint research and technology transfer

- Currently accepting contacts from companies etc. interested in licensing of this technology
- Results of proof of concept by real environment data for feasibility verification are available.

Patent protection
PCT/JP2016/000950 System and method for determining prediction error for variations in renewable energy（Japan : 2017-542194）

Introduction of the research unit

Collective Interactions Unit

Unit leader : Mahesh Bandi Assistant Professor

The Collective Interactions Unit is an experimental group with broad interest in soft matter physics, applied mathematics, dynamics, and their application to biological problems. The unit researchers are working on research in the general field on macroscopic, nonrelativistic substances and their interactions. Currently I am interested in research topics on interfacial hydrodynamic, powdery solids, and biological mechanisms of the human foot.

<Related research theme>

Research on spectrum of wind power fluctuation

While governments try to phase out coal-fired energy that can be stably supplied over the coming decades, having a stable supply of renewable energy becomes increasingly important issue. In order to mitigate and manage fluctuations in renewable energy supplies, we need to understand the causes of fluctuations in energy supplies and the nature of fluctuations in energy production. (A single-author paper explaining the statistical characteristics of wind fluctuation is published in Physical Review Letters)

Research unit Website : https://groups.oist.jp/ciu

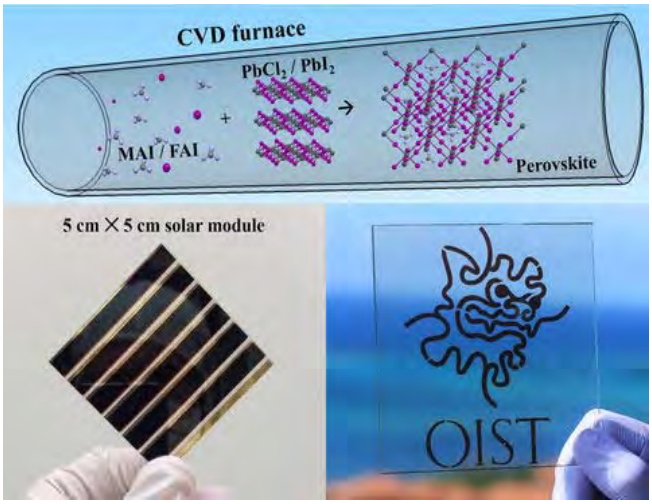
Research and Development of Low Cost High Efficiency Organic Solar Cells

Aiming for practical mass production of perovskite films by chemical vapor deposition

Research background

Perovskite solar cells are one promising candidate for next generation solar cells. Although perovskite solar cells are still at the stage of R & D, the conversion efficiency has reached to a level equivalent to mainstream silicon solar cells and the production is made possible with a coating process in a normal temperature and normal pressure environment, without a high temperature and vacuum process. Therefor, perovskite solar cells have an advantage that manufacturing cost can be drastically reduced. On the other hand, there were problems that stability being low, degradation being fast, and the cell module size being difficult to be increased.

In Energy Materials and Surface Sciences Unit led by Associate Professor Yabing Qi, the research team has developed solar cells using halogenation perovskite films. This technology improves the conversion efficiency compared to conventional solar cells and contributes to stabilization and upsizing.



Top photo depicts how perovskite films are made using the chemical vapor deposition (CVD) technique. Bottom left shows a perovskite solar module produced using the CVD technique. Bottom right displays the OIST logo made from perovskite using the same technique.

Research

The research unit discovered that the use of a methylamine solution during post-annealing of organo-metal halide perovskite MAPbI3 led to a decrease in problems associated with grain boundaries. Grain boundaries appear as gaps between crystalline domains and can lead to charge recombination. This is a common occurrence in perovskite films and can reduce their efficiency. The above post-annealing process to fuse crystal grain boundaries reduced charge recombination and showed an outstanding conversion efficiency of 18.4%. Furthermore, the perovskite films treated in this way exhibited exceptional stability and reproducibility, proving useful for industrial production of solar cells.

While perovskite films can be made with relative ease on a small scale in laboratories, they can be difficult to replicate on the large scale needed for mass production. The research unit used chemical vapor deposition, a cost-effective process commonly used in industry, to create large solar cells and modules of FAPbI3 perovskites. The solar cells and modules commonly used in the industry are significantly larger, e.g., 12cm^2, than those commonly studied in academia, typically <0.3cm^2. Furthermore, these solar modules show enhanced thermal stability and maintain relatively high efficiencies. Many perovskite solar cells lose efficiency drastically as they are scaled up, and this feature is noteworthy. This research has contributed greatly to practical application of perovskite solar cells. (The paper is published in Journal of Materials Chemistry A magazine)

Keywords

Perovskite, Organic solar cell, Chemical vapor deposition

Applications/Future development

The unit has published research results on the discovery of some special products of perovskites decomposition, and is working on the problem of lifetime in addition to increasing the efficiency and size of perovskite solar cells. Further research in this field aims at bringing the dream of utilizing cost-effective renewable energy resources into reality.

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Opportunity for joint research and technology transfer

- The unit has numerous patented technologies for perovskite solar cell production and evaluation including their peripheral technologies.
- Licensing to solar-cell makers is available.

Patent Protection

PCT/JP2015/005541 Doping operation Hole transport layer for perovskite based devices（Japan : 2017-523004), PCT/JP2015/004078 Perovskite film based on low pressure chemical vapor deposition and method of manufacture (Japan 2017-509804）, PCT/JP2015/003450 System and method for manufacturing perovskite film based on multi-source deposition (Japan : 2017-505580）, PCT/JP2015/002041 System and method for manufacturing perovskite film for solar cell applications（Japan : 2016-565516）

Introduction of the research unit

Energy Materials and Surface Sciences Unit

Unit leader : Yabing Qi Assistant professor

Energy Materials and Surface Sciences Unit is developing cost effective and large area photovoltaic films (organic thin film solar cells) made from an organic material (plastics). Such an organic thin film solar cell is lightweight and flexible. In addition, it can be produced by roll-to-roll method like newsprint, and will be a solar cell to cover windows, walls, and many other surfaces.

The EMSS Unit uses state-of-the-art advanced material characterization instruments and a clean-room device fabrication facility to investigate the properties of various individual materials consisting the solar cell and the interactions at their surfaces/interfaces between materials. Based on the research results, the unit is working on improving the solar cell performance by optimizing materials selection and device structures.

<Related research theme>

- Research on performance improvement of perovskite solar cells
- Development of perovskite-based LED lights

Research unit website : https://groups.oist.jp/emssu

Off-grid Electricity Distribution System

Stable and efficient electric supply from renewable energy

Research background

The operation of a generation/distribution system of energy with high versatility called Open Energy System (OES) is seen as the future vision of renewable energy. Unlike intensive types of power generation/distribution by large-sized electric power plants, the OES enables power generation of power generation/distribution by small-sized business proprietors, such as detached houses, local communities, and towns and villages, using renewable energy sources, such as wind power and sunlight. By making generation/distribution of energy local, the OES is expected to boost a stable supply of renewable energy and help developed nations breakaway from dependence of fossil fuels.

Moreover, highly humid areas where air conditioners are a necessity, such as in monsoon climates, has spread throughout the Asian region, and with rapid population growth, it is expected that CO2 emissions will continue to rise from this point forward. Also in Japan, although the energy consumption in the industry sector has reduced about twenty percent over the past 30 years, the energy consumption in the residential sector has doubled. So, in countries where future growth is expected, long-term countermeasures for energy consumption in the residential sector is considered to be much more necessary.

DC-power-transmission network system installed at the teacher lodgings of OIST

OIST sustainable living experiment building

Research

In the OIST open energy system, solar panels attached to the roofs of a total of 19 residences generate electricity, and an energy server is placed at each house.
In order to exchange information directly among servers, the houses interchange electric power mutually, and electric power is automatically distributed according to users' demand. Surplus power is stored in a lithium ion battery (Phospho-olivines Lithium Ion battery) using the olivine type iron phosphate developed by Sony, and can be used for days with few amounts of solar radiation. And an administrator can supervise the amount of generation and consumption of electricity in real time, and can grasp the situation of the distributed electric power supply. At the teacher lodgings at OIST, the off-grid system there has supplied a stable source of electrical power without breaking off since December 2014.

OIST is promoting “Sustainable Living Project" with Misawa Homes as joint research using a sustainable living experiment building and equipment. Also in areas of Asia, Africa and the Middle East where infrastructures, such as electric and electrical equipment and water are not in place, electric power (7 kW at maximum) from the solar battery generated by 88 solar panels installed on the roof of the experiment building, purposely offers energy for a comfortable living environment. The electric power generated by the two sets (1 kW each) of wind power generators installed on the outside of the experiment building, charge electricity with direct current (DC) and with a DC supply system, the house demonstrates it can power and make use of DC air-conditioners and DC consumer electronics.

Keywords

Renewable energy, Open energy system, Sustainable living

Applications/Future development

In the area of Asia Africa and the Middle East where infrastructures, such as electricity and water, are not yet in place, the “Sustainable Living Project" aims at offering a comfortable living environment. The project aims at introducing the structure utilizing renewable energy to the utmost as well as Open Energy Systems carried out at OIST to the community of island areas and developing countries.

Opportunity for joint research and technology transfer

At the present time, the “Sustainable Living Project“ is carrying out joint research with Misawa Home Institute of Research and Development Co. Ltd. and Pues Corporation, and OIST and Sony Computer Science Laboratories, Inc. (Sony CSL) jointly designed the DC-power-transmission network system installed at the faculty lodgings of OIST. In the future, we will develop OIST as a major institution of sustainable research and build R & D clusters in this research field, aim to expand international cooperation with universities, research institutions, and companies, and establish start-up companies.

Introduction of the research unit

Integrated Open Systems Unit

Unit leader : Hiroaki Kitano Professor (Adjunct)

Globally health care and sustainability are particularly important problems in our present-day setting. These are highly integrated open systems such as living organisms and social systems such as energy and transportation systems. The Integrated Open System Unit aims to understand the fundamental principles of these open complex systems and to apply the knowledge to the real world. From now, we will deploy our activities internationally through Garuda Alliance and Sustainable Living.

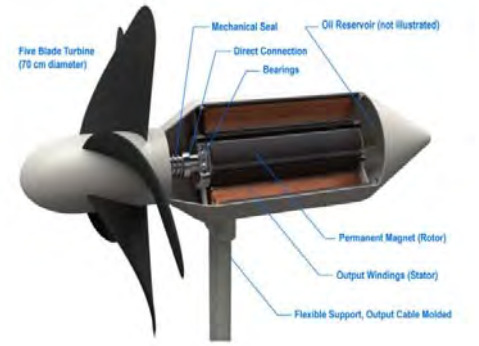
<Related research theme>

- Open energy system
- Micro grid system using exchangeable cells for electric vehicles
- Sustainable life in highly humid areas

Research unit website : https://groups.oist.jp/obu

Development of Wave Power Generator

Sustainable future with cheap and clean energy



The blades of this five-blade turbine rotate on their axis when influenced by ocean waves. The axis is attached to a permanent magnet electric generator, which is the part of the turbine that transforms the ocean wave energy into usable electricity. The ceramic mechanical seal protects the electrical components inside of the body from any saltwater leakage.

Research background

Energy use of fossil fuel pushed the industrial revolution and contributed to subsequent technological development. However, its reserves are limited and efforts to shift to a low-carbon society is an urgent task. The day when energy resources, such as oil and coal, hit the bottom is coming soon.

Solar power and wind power generation can be said to be the flagship of the energy revolution, but as the world's energy consumption continues to increase, it is impossible to cover all the necessary power with these two energy sources.

One effective energy sources that can be a solution to this is the wave power, which is the power of a wave as it strikes the coast.

The inline small wave power generators generate electricity by utilizing a flow of a eddy generated from crumbling waves. (Imaged figure)

Research

In the Wave Energy Converter (WEC= Wave Power Generator) project started in 2013, we install power generator turbines in locations where the waves occur near the coastline, such as wave-breaking blocks and coral reefs. In these places the generator turbines are exposed to ideal waves, not only producing clean and renewable energy, but also it can help to protect the coast from erosion. The power generating turbine itself is designed to bear not only the force of an intense wave but extreme weather like a typhoon. The blades are designed to rotate carefully at the calculated speed and to allow creatures to escape even if caught between the blades.

Now, Professor Shintake and the researchers of a research team complete the first phase of the project, and for the first commercial experiment, we are preparing to install a turbine with a diameter of 0.35 m equipped with blades of half the size of the actual size blades. In this project, we will install two wave power generators and turn on LEDs as an actual proof experiment.

Keywords

Renewable energy, Ocean energy, Wave energy, Wave power generation

Applications/Future development

30% of the coastline of Japan mainland is covered with tetrapod and wave barrier, and if these are replaced with special wave blocks and wave barriers, it is possible to protect the coast and to generate about 10 GW (equivalent to ten nuclear power plants) of clean and renewable energy at the same time by using only 1% of the mainland coastline.

Opportunity for joint research and technology transfer

- Under inquiry reception from the companies interested in the joint research and licensing of this technology

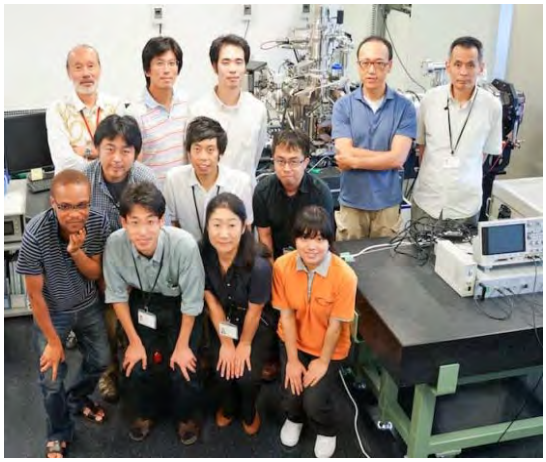
Patent information
PCT/JP2015/003576 "Wave energy transducer" (Japan: 2017-501431)

Introduction of the research unit

Quantum Wave Microscopy Unit

Unit leader : Tsumoru Shintake Professor

A low energy electronic microscope which the quantum wave optical microscopy unit newly assembled can create DNA and the clear hologram of a virus not using a lens.
The time-consuming crystallographic method becomes unnecessary by using this new technology, and we expect to obtain a one-molecule picture with sub nanometer resolution. In the renewable energy power generation project which has a big different aspect, we are studying the electricity conversion of marine energy by taking advantage of the geographical conditions of Okinawa.



<Related research theme>

1. Development of an atomic resolution microscope technology for biological research
- 1-1. Development of an atomic resolution microscope of new principle using electron coherent scattering and digital holography
- 1-2. Technology development of new electron beam crystal structure analysis by forming nanocrystals of membrane protein by FIB and analyzing using low energy electron diffraction
- 1-3. Technological development of X-ray microscope based on a completely new principle

2. Technology Development to generate power using wave force

3. Life activity observation by laser interferometer

Research unit website : https://groups.oist.jp/qwmu

New Contactless Magnetic Couplings for Applications in Microfluidics, Renewable Energy, and Nautical Propulsion

New possibilities of contactless magnetic gear

Research background

In conventional mechanical gears, gears and gears directly mesh to transmit power. Therefore, there are drawbacks such as vibration, noise, generation of dust due to abrasion of gears, and maintenance such as lubricating oil periodically and replacing gears is necessary.

Research

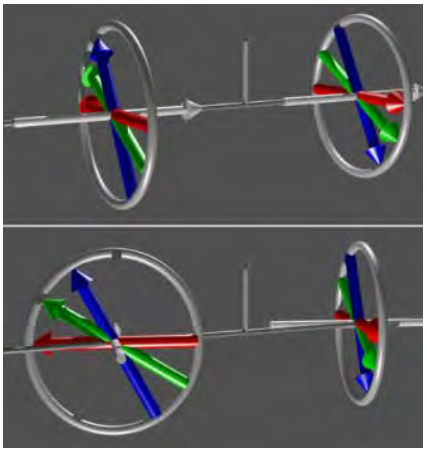
By using a powerful permanent magnet made of an alloy of iron, boron, and neodymium, a contactless magnetic gear is constructed to solve the drawbacks of the conventional contact type gear.

Moreover, it makes it possible to establish freely the angle of gradient of an input axis and an output shaft (left figure B). Depending on arrangement of two magnets, the third magnet is added to a specific location, and it becomes possible to maintain a smooth connection (right figure).

Possibilities of the smooth magnetic coupling which can produce uniform operation are great, and the applications to nano technology, micro fluidics, robot engineering, etc. are anticipated.

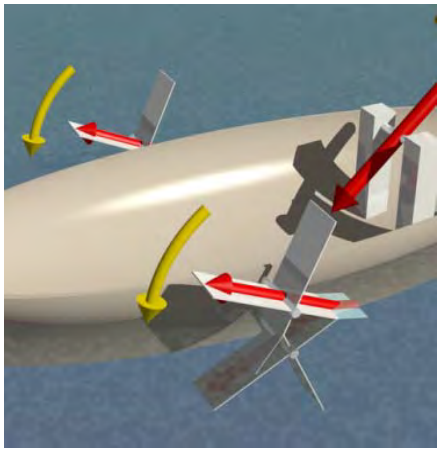
A

B



A) Classical configuration where the two rotating magnets (shown in rotation in red, green and blue arrows) share the same rotation axis (gray arrows). A similar setup is used in modern milk whisk and food mixers, as well as magnetic stirrers in chemistry labs.

B) One configuration studied in this research with the rotating magnets having their rotation axes (gray arrows) perpendicular to each other.



Illustrative example of a paddle boat using three interacting rotating magnets (red arrows) as a drive. Two magnets are connected to the paddles and one to the driver. If the driver magnet is rotated, the paddles move accordingly (yellow arrows).

Keywords

Non-contact, Magnetic coupling, Magnetic gear

Applications/Future development

- Application to nano technology, micro fluidics, robot engineering, etc.
- Theory verification by the actual proof experiment using a trial product.

Opportunity for joint research and technology transfer

· Under inquiry reception from companies interested in the joint research and license of this technology

Patent information
US : 15/846,565

Introduction of the research unit

Mathematics, Mechanics, and Materials unit

Unit leader : Eliot Fried Professor

Soft matter is a relatively new field of research that has been rapidly progressing with substances composed of multiple atoms and molecules as research targets.

Generally soft matter is a substructure belonging to the micro-mesoscopic region, and as the name implies, it refers to substances that are easily deformable. In Mathematics, Mechanics, and Materials unit, statistical mechanics, the continuum mechanics , differential geometry, asymptotic analysis, a bifurcation theory, large-scale computing science processing, etc. unifying all methods, we research them broadly from the foundation to application. Now, we are researching disc-shaped high-density lipoprotein, perforated lipid duplex film, bacterial suspension which is an agent with self propulsive force, three phase boundary line dynamics under the evaporation / condensation state of the droplets on a surface.

<Related research theme>

Expansion of application field of soft matter

The "soft matter" of the field of surface tension, Kirchhoff Plateau's problem, the stability of soft material, flow patterns, etc.

Research unit website : https://groups.oist.jp/mmmu

Smart Gas Sensing Platform for Mobile Devices

Production method of uniform iron nanocubes

Research background

Scientists have tried to understand nanoparticles for many years. Production of nanocubes has especially attracted attention because of applicability for biosensors and gas sensors.

Nanoparticles can be made by physical or chemical methods, but the advantage of the physical method is that there is no contamination by the organic substances normally found in chemical methods. However, with the physical method, there was a problem that it was difficult to produce a required amount of uniformly sized nanocubes.

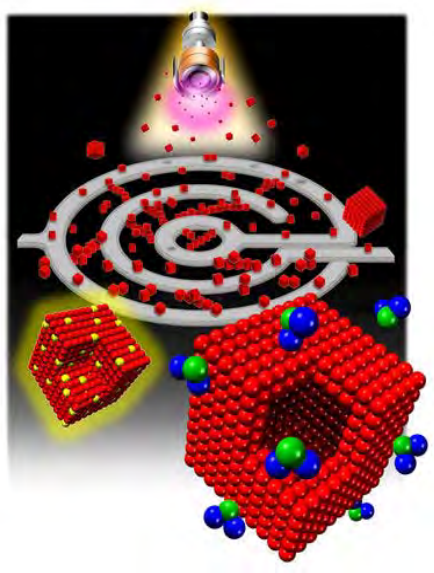
The Smart Gas Sensing Platform (SGSP) monitors gases such as carbon monoxide (CO), oxygen (O_2), ammonia, fluorine, nitrogen oxides, etc. in consumer and industrial applications, and has a wireless function which enables seamless connection with smartphones and tablets. If uniform iron nanocubes can be produced, electronic devices as SGSP of nitrogen dioxide can be manufactured.

Research

In order to make it possible to manufacture electronic devices for SGSP aiming at miniaturization of gas detection devices, OIST researchers and colleagues have proposed a method of producing unique iron nanocubes using magnetron-sputtering inert-gas condensation method. With the process, argon gas is heated first and is plasma ionized next.

And since the target material is iron, a magnet is appropriately installed behind an iron target. This manipulates the shape of plasma and determines that argon ions surely irradiate the target (target of sputtering). As a result, iron atoms are sputtered out from the target (sputtering occurs), and argon atoms and iron atoms collide with each other to form nanoparticles. It makes it possible to carry out precise operation of the plasma and to produce uniform iron nanocubes by controlling the magnetic field.

Uniformity is an important point to apply for sensors. In the production stages of nanocubes, the method of controlling the size, shape, and quantity is indispensable. And it became possible to produce the uniform iron nanocubes applicable to mass production by the above-mentioned physical process, and SGSP for nitrogen dioxide became possible.



This schematic depicts the production of iron nanocubes using magnetron-sputtering inert-gas condensation and the use of these cubes in NO_2 sensors.

Keywords

Nano sensor, Gas sensor, Nano particle, Nano cube

Applications/Future development

The applications to mining, medical facilities, industrial processes and management, architectural skills and amenity, home NOX detection, etc. are possible.

Opportunity for joint research and technology transfer

- Gas sensor makers, joint research, and licensing agreements are possible.

Patent information
PCT/JP2017/024566 "Very high sensitivity nitrogen dioxide gas sensor based on an iron nano cube"

Introduction of the research unit

Nanoparticles by Design unit

Unit leader : Mukhles Ibrahim Sowwan Associate professor

An aggregate of nanometer sizes formed by aggregation of tens to millions of atoms is called nanocluster / nanoparticle. In nano metric size, physical and chemical properties can be operated by controlling the chemical composition and grain size of material. The applications to catalytic reaction, nano electron devices, and medical-engineering technology are anticipated, and especially the nano cluster of metal is attracting interest. At this research unit, we create the nanocluster / nanoparticles which consists of one or two kinds of metal, and the nano cluster / nano particles of core shell structure with various grain sizes using the vapor growth of the magnetron sputtering method, we research those structural characteristics, magnetism, the electronic state, the chemical property, and the applied technology.

<Related research theme>

Expansion of the applicable field of nano cluster
Applicable fields are expanded to super high power silicon cells, Lycurgus cup, CO nano sensor, nanowire, etc.

Research unit website : https://groups.oist.jp/ndu

Efficient Goal Estimation for Intelligent Systems

Development of an autonomously adjustable reinforcement learning algorithm

Research background

Machine learning to create performers of various tasks based on data has been put to practical use in the field of image recognition and speech recognition, and it is the center of current AI technology. Among them, reinforcement learning has been attracting attention due to various success stories recently, which makes it possible to acquire action selection strategies adapted to the environment through trial and error based on the remuneration for behavior.

The Human brain is choosing essential things from various information, using the past learning for solving new problems, or changing actions suitable for a specific situation, and more reliable and safer action at any time, and it has realized practical learning.

For example, the person can instantaneously identify the person and obstruction that should be watched even in a crowded place according to the direction to which he wants to go, and can avoid a collision.

In addition, it is common that a person who can play Shogi to some extent progresses to play chess early, and it is possible to switch depending on the situation whether you point it as determined or think deeply during Shogi 's game.

However, conventional reinforcement learning has the problem that a designer needs to designate beforehand the information which should be observed or it is necessary to redo learning for every problem, and its application in real life is restricted.

The product image of this joint research

Research

OIST and Fujitsu Laboratories has focused on such a brain learning method, adopting the mechanism based on the latest brain science findings, and makes it possible for AI to adjust autonomously in the situation which conventional manual reinforcement learning could not adjust. We will start joint research to develop more applicable reinforcement learning algorithms that can be adjusted in a timely manner.

Specifically, we mainly developed new technologies in the following three areas that are more demanding among the issues for practical application.

1. Technology of extracting information suitable for reinforcement learning automatically out of mass data which changes dynamically
2. Transition learning technology of putting past experiences to action selection policy of the other problems
3. Cooperation and parallel reinforcement learning technology which chooses the best action among two or more policies according to the conditions

The research team of professor Kenji Doya of OIST was responsible for making a mathematical model of the nerve calculating mechanism from a viewpoint of brain science, and reflecting it to the reinforcement learning algorithm. Fujitsu Laboratories participated in making its algorithm from a viewpoint of optimization and control engineering, and developed simultaneously the programming method which utilizes calculation resources best.

Keywords
Objective function, Assumption aim, Intelligence system, Robot engineering, Robotic control, Reverse reinforcement learning

Applications/Future development

OIST and Fujitsu Laboratories will work on the issue of adapting to a large amount of input information, flexible correspondence for environmental change, and conservative correspondence, etc. in order to learn multiple strategies in parallel and make use of it for action selection.

In addition, based on the results of collaborative research, we will develop an AI solution that enables computers to acquire environmentally adapted measures more efficiently in real-world applications such as ICT system management, energy management, etc. without manual setting and adjustment.

Opportunity for joint research and technology transfer

・ Licensing to energy management system-related companies

Patent information
PCT/JP2017/004463 "DIRECT INVERSE REINFORCEMENT LEARNING WITH DENSITY RATIO ESTIMATION" (U.S.: 15/425,924)
Japan: 2016-066470-"control equipment of hybrid car both systems and hybrid car both systems, and control method of hybrid car both systems", 2016-066572-"working vehicle"

Introduction of the research unit

Neural computation unit

Unit leader : Kenji Doya Professor

Neural computing unit aims to understand the biological basis of the human mind by fusion of top-down theoretical models and bottom-up biological experiments.

<Related research theme>

Mathematical modeling and proof experiment of brain and environment

This research aims at understanding the biological base of the human mind by fusion of top-down theoretical models and bottom-up biology experiments. The molecule and gene relevant to various mental disorder, such as schizophrenia and depression, are clarified by progress of molecular biology in recent years. However, many of these mental disorders are caused as a result of complicated interaction with the environment of molecules or genes.

In order to understand such interaction, mathematical modeling including dynamics of brain and environment, computer simulations and robot experiments are indispensable.

So, We work on three major subjects:
1. development of a novel computational framework for system identification of biological networks;
2. neurobiological experiments to study the dynamic functions of neuromodulators in regulating adaptive behaviors;
3. robotic experiments to explore adaptive mechanisms necessary for survival and reproduction in dynamic environments.

By combining theoretical, biological, and engineering approaches, the research shall produce novel software tools for dynamic modeling, highly adaptive robots with emotion-like regulatory functions, and new approaches to therapy and prevention of psychiatric disorders.

Research unit website : https://groups.oist.jp/ncu

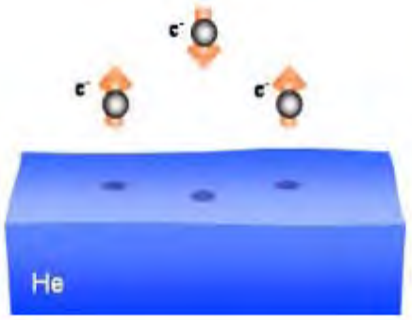
New Quantum System towards Quantum Computing

Creation of the same quantum bit using a liquid helium system

Research background

The future vision of the quantum computer has become a topic among many companies, governmental organizations as well as specialists.

Instead of calculating and saving data within a transistor or a memory in the form of the conventional binary bit "1" and "0", in the world of a quantum computer, it calculates in infinite combination also including the state of taking 1 and 0 simultaneously (superimposition), using systems, such as atoms, ions, or electrons, as a "quantum bit". Since the defect and impurity in material affect the function of each quantum bit at random, one of the problems in research of the quantum computer using a solid is that it is very difficult to make the same quantum bit consistently.



On liquid helium electrons move freely and are easy to control.

Research

In the quantum dynamics unit of OIST, an extremely small device was created utilizing the property of the electron which floats on the liquid helium surface, and it discovered the electron on liquid helium becomes a new candidate for the realization of quantum computer, and increased the possibility of the early realization of quantum computer.

It is because the system of liquid helium is pure, and has no defects and makes the production of identical quantum bit possible theoretically, makes electron movement possible, which might be said to be almost impossible by using the other systems.

In order to utilize the electron on the liquid helium surface for quantum computing, it is necessary to isolate each electron on the helium surface and to control quantum degrees of freedom such as electron movement and spin.

Moreover, as an electron needs to be moved to somewhere else, it becomes important to understand the physics of the interaction between an electron and the helium surface.

The electron on liquid helium can form a two-dimensional (2D) crystal, and it was discovered before this that a peculiar phenomenon occurred by the interaction between electron and surface wave, when this crystal moved along the helium surface.

However, the researchers of OIST searched for how these phenomena were influenced with the size of an electronic crystal for the first time in the world, and they created the device with a very small channel with which the electron trap was incorporated in order to isolate the only one two-dimensional electronic crystal which consists of a comparatively small number of electron.

By applying alternating voltage to one of the electrodes of this device, the electronic crystal is moved on the liquid helium surface.

Since the movement of this electron induces electric current to another electrode by the mirror image effect, it is detectable by measuring that electric current using a commercial current amplifier and lock in detector.

Keywords

Quantum computing, Quantum bit, Quantum dynamics, Quantum information processing

Applications/Future development

- Realization of a clean and integratable system using the existing mobile quantum bit
- Quantum computer

Opportunity for joint research and technology transfer

- Under inquiry reception from companies interested in the joint research and license of this technology

Introduction of the research unit

Quantum dynamics unit

Unit leader : Denis Konstantinov Associate professor

When particles, such as electrons, are trapped in a narrow area, the property as wave motion becomes remarkable.

In order to understand this behavior, quantum-mechanical explanation is needed.

Unlike the classical mechanics objects which move along a clear orbit, such particles are explained by probability density and the uncertainty principle.
In quantum dynamics, movement of the particles which cannot fully be explained according to classical mechanics and electromagnetism is explored.
In this unit, we research the complicated multi-particle systems, the foundations of the many interesting quantum phenomena.

By explaining logically the phenomena confirmed by experiments, we aim at applications from various fields, such as realization of quantum information processing.

The super-conductive magnet used for the quantum experiment

<Related research theme>

Research of the very-low-temperature complicated quantum system which is greatly separated from an equilibrium state using Magneto-optical transport and spin resonance.
The development for very-low-temperature atomic gas, solid state nano structures, nano optical devices, next-generation nano devices

Research unit website : https://groups.oist.jp/qdu

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