NIMS Award 2021 Goes to Prof. Tsuneya Ando,

Prof. Allan H. MacDonald and Prof. Pablo Jarillo-Herrero

National Institute for Materials Science (NIMS)

Overview

The National Institute for Materials Science (NIMS) (Kazuhito Hashimoto, President) has selected the following scientists as the winners of the NIMS Award 2021.

Prof. Tsuneya Ando
Honorary Professor, Emeritus Professor, Tokyo Institute of Technology / Emeritus Professor, University of Tokyo
For "Fundamental theoretical studies on quantum states of low-dimensional materials"

Prof. Allan H. MacDonald
Professor of Physics, University of Texas at Austin
Prof. Pablo Jarillo-Herrero
Cecil and Ida Green Professor of Physics, Massachusetts Institute of Technology
Jointly awarded for "Pioneering work of new quantum physics by twistronics"

Prof. Tsuneya Ando

Prof. Allan H. MacDonald

Prof. Pablo Jarillo-Herrero

The NIMS Award 2021 will be given to three scientists who have conducted groundbreaking research in the field of "research on quantum materials, such as materials and structures that exhibit quantum effects or research that leads to the innovative use of the materials." Their efforts have been recognized as outstanding achievements that have led to a breakthrough in the development of next-generation quantum devices using ultimate two-dimensional materials such as graphene.

The Award Ceremony and a series of the Award Winning Lecture will take place as a part of NIMS WEEK 2021, which will be held online from November 17, 2021.

【NIMS Award】

Since 2007, the NIMS Award has been given to researchers around the world in recognition of their outstanding achievements in materials science and technology. This year's recipients were selected by a selection committee comprised of staff members at NIMS and scientists from other organizations based on nominations from top scientists around the world in the area of "Basic Materials Science."

【NIMS WEEK】

NIMS WEEK is an annual event hosted by NIMS consisting of an Academic Symposium and a Showcase. The participants can encounter "cutting edge materials research" through a variety of activities, such as the NIMS Award symposium to honor the award recipients and the exhibitions of the latest materials research at the NIMS Showcase.

NIMS WEEK 2021 will be held online for two days from Wednesday, November 17 to Thursday, November 18, due to safety concerns regarding COVID-19. Details will be announced later on the NIMS official website.

NIMS WEEK 2021
NIMS Award 2021 Winners

Awardee 1: Prof. Tsuneya Ando
(Honorary Professor, Emeritus Professor, Tokyo Institute of Technology / Emeritus Professor, University of Tokyo)
Awardee 2: Prof. Allan H. MacDonald (Professor of Physics, University of Texas at Austin)
Prof. Pablo Jarillo-Herrero (Cecil and Ida Green Professor of Physics, Massachusetts Institute of Technology)

Awardee 1

Prof. Tsuneya Ando
(Honorary Professor, Emeritus Professor, Tokyo Institute of Technology / Emeritus Professor, University of Tokyo)

[Research field] Condensed Matter Physics
[Research achievement title] Fundamental theoretical studies on quantum states of low-dimensional materials
[Research summary]

At surfaces and interfaces of materials, or in nanometer-scale thin films, the movement of electrons is restricted and the energy of electrons is quantized. Since such quantization leads to a variety of interesting physical properties of the materials, it is expected to bring about innovations in various fields. For example, the precise control of quantum effects and electron-electron interactions is a fundamental technology that forms the basis of current electronics and optical technologies, and is directly related to the control of electrical conduction and light absorption and emission.

In addition, various research is being actively pursued to utilize quantum effects, such as the quantum Hall effect, ballistic electrical conduction, and single electron tunneling effect. This is expected to contribute greatly to the realization of a safe and secure society, including an ultra-low energy consumption society, advanced use of big data and AI, and information security.

Prof. Ando conducted pioneering research focused on the quantum effects in electron transport phenomena and the effects of multi-electron interactions, and provided many theoretical insights into interesting quantum phenomena such as ballistic electrical conduction, conductance fluctuations, quantum Hall effect, edge states, and quantum chaos. In particular, in his research on quantum effects in semiconducting two-dimensional electron systems, he clarified that carbon nanotubes and graphene are low-dimensional materials that have essentially the quantum electrical conductivity properties. This achievement has greatly contributed to the development of the research field of "nanocarbon" materials.

[Impact on the academic and industrial sectors]

Prof. Ando's theoretical research on semiconducting two-dimensional electron systems is a pioneering study that provided the basis for electrical conduction in two-dimensional materials, and is used as a fundamental framework for understanding low-dimensional conduction. For example, Prof. Ando's theory has been applied to the analysis of scattering factors that determine the electrical conduction of two-dimensional electrons, and has made a significant contribution to the characterization of silicon MOS transistors and GaAs heterostructure devices, which are widely used today. Also, based on the theory by Prof. Ando, a precise resistance standard utilizing the quantum Hall effect has been realized. Prof. Ando's theoretical work on carbon nanotubes and graphene continues to lead low-dimensional condensed matter physics research and continues to influence a wide range of research fields including physics, materials science, and electronics.

Awardee 2

Prof. Allan H. MacDonald (Professor of Physics, University of Texas at Austin)

Prof. Pablo Jarillo-Herrero (Cecil and Ida Green Professor of Physics, Massachusetts Institute of Technology)

[Research field] Condensed Matter Physics

[Research achievement title] Pioneering work of new quantum physics by twistronics

[Research summary]

Graphene is a sheet of carbon with a thickness of one atom. Since the establishment of the method for extracting high-quality graphene by Professor Andre Geim and Professor Konstantin Novoselov (Nobel Laureates in Physics 2010), numerous experimental studies have been conducted, and its unique electronic properties have attracted attention from basic science to applied research in a wide range of fields. However, in order to use graphene as an electronic material, it is essential to develop new material technologies, such as technologies to modify semi-metallic properties into semiconductor properties and technologies to control the quantum effects that appears on graphene.

Prof. MacDonald conducted a theoretical study on two-layer graphene stacked at slightly different angles (twisted bilayer graphene), and predicted that the electronic state of the graphene changes depending on the twist angle, and that a quantum-mechanically remarkable electronic state called flat band appears at certain twist angles (magic angles). Materials with a flat band, in which the electron-electron interaction effect is enhanced, are especially interesting and they are expected to exhibit useful properties unique to strongly correlated materials, such as magnetism and superconductivity. Prof. MacDonald's theoretical study showed that strongly correlated phenomena appear in twisted bilayer graphene, a material composed entirely of carbon atoms. It was a remarkable, pioneering achievement.

Prof. Jarillo-Herrero developed a technique for creating twisted bilayer graphene, and experimentally proved that unique electronic states appear near the magic angle as predicted by Prof. MacDonald. He found two phases which are thought to be derived from electron correlation: an insulating phase and a superconducting phase near the insulating phase. The similarity of the phase diagram drawn by Prof. Jarillo-Herrero et al. to that of copper oxide high-temperature superconductors was also of great interest, and those achievements triggered an explosion of research on twisted bilayer graphene and related materials.

[Impact on the academic and industrial sectors]

The theoretical work of Prof. MacDonald in 2011 and the experimental work of Prof. Jarillo-Herrero et al. seven years later led to the development of a new material control technique called "twistronics." Since then, it has been theoretically clarified that the electronic state of twisted bilayer graphene is very unique in that it is related not only to the strong correlation effect but also to the topology. As the control of physical properties through twistronics in three- or four-layer graphene and atomic-layer transition metal dichalcogenides has also been studied, it can be said that their research achievements have opened up a new field. In addition, their achievements in providing a new method for controlling physical properties, which are useful for the development of devices using atomic layer materials, have been highly evaluated worldwide in terms of opening up new avenues for applied research.

<Reference> NIMS Award winners of the past five years and their achievements (Affiliation is at the time of the award)

2016 **Dr. Koichi Mizushima** (Toshiba Research Consulting Corporation, Japan)
"Discovery of a suitable cathode material for the lithium-ion battery ($LiCoO_2$)"
Dr. Akira Yoshino (Asahi Kasei Corporation, Japan)
"Development of the lithium-ion secondary battery"

2017 **Prof. John Ågren** (Royal Institute of Technology, Sweden)
"Development of kinetic simulation packages for computational thermodynamics"
Prof. Bo Sundman (Royal Institute of Technology, Sweden)
"Development of thermodynamic calculation packages for computational thermodynamics"
Prof. Kiyohito Ishida (Tohoku University, Japan)
"Alloy design and development of structural materials based on thermodynamics of phase diagrams and microstructures"

2018 **Dr. Masato Sagawa** (Daido Steel Co., Ltd., Japan)
"Invention and practical application of neodymium magnets"
Prof. Terunobu Miyazaki (Tohoku University, Japan)
"Development of tunneling magnetoresistance elements capable of generating giant magnetoresistance at room temperature and application thereof to spintronics devices"

2019 **Prof. Gerbrand Ceder** (University of California Berkeley, USA)
"Pioneering data-driven materials research based on the first-principles calculations"
Dr. Pierre Villars (Materials Phases Data System (MPDS), Switzerland)
"Development of Pauling File, inorganic materials database"

2020 **Prof. Hiroshi Julian Goldsmid** (The University of New South Wales, Australia)
"Pioneer work on bismuth telluride thermoelectric material and its application for large-capacity optical communication systems using the Peltier cooling phenomenon"
Prof. Kunihito Koumoto (Nagoya University, Japan)
"Development of environmental-friendly inorganic thermoelectric materials"

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