Research area in Strategic Objective "Development of innovative materials and device technologies based on understanding and manipulation of nanoscale thermodynamics"

6.1.2 "Creation of Innovative Core Technologies for Nano-enabled Thermal Management"

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Overview

This research area aims to create innovative core technologies for the fundamental understanding, high-level control, and high-level utilization of heat to solve various heat-related problem and effectively utilize thermal energy.

More specifically, this research area will be promoted in accordance with three policies.

The first policy aims to understand nanometer-scale thermal behavior, develop innovative core technologies for nano-enabled thermal control, and consequently create novel materials for high-performance heat dissipation, thermal insulation, heat storage, and thermal conversion and develop novel devices to markedly improve properties and increase functionalities of conventional devices.

The second policy aims to promote the research and development of important theories, measurement technologies, simulation technologies, and processing technologies, which are to be developed in the process of creating the core technologies described above. These new technologies will be useful for not only predicting and verifying the physical properties of nanoscale thermal behavior but also investigating new materials and devices.

Because this research area covers various heat-related challenges based on the understanding nanoscale heat behavior in a wide range of application fields, the third policy aims to promote the fusion of various disciplines and a wide range of academic and technological fields.

This research area is expected to create nano-enabled thermal management techniques to effectively utilize heat and construct a next-generation society that utilizes heat with excellent efficiency in order to contribute to realize of an advanced information society; environmentally friendly electronics, transportation systems, and housing; and new industries and markets in the field of health and medical care.

Research Supervisor's Policy on Call for Application, Selection, and Management of the Research Area

Background and basic policies

While technological innovations are progressing toward a highly information-oriented society, heat generation problems become an obvious obstacle to upgrading miniaturized and high-density memories, power electronics devices for high-speed information processing and communications and to performance enhancement for instruments and systems incorporating them. To solve these issues, high-level thermal control technologies are expected to be developed. Furthermore, a large quantity of unused thermal energy is emitted from factories, automobiles, and houses. The effective utilization of this thermal energy is considered essential for the realization of an energy-saving society.

Considering the contribution to future society, this research area aims at building base technologies for thermal control to efficiently transport, transform, or utilize heat. This requires the creation of thermal control technologies based on a novel concept and idea that has not ever exist before. For example, the electronic state in a semiconductor is precisely controlled by "band engineering" based on a hetero-structure material growth technology involving nano-structure fabrication processing or atomic layer control. Consequently, many innovative electronic devices and optical devices have been developed to contribute to the success of a large electronics sector. Concerning heat, on the other hand, crystal lattice vibrations, the so-called phonons, which have not yet been actively utilized in applications like semiconductors, are subject to "phonon engineering", in which we design and control phonons. It is necessary to extract or upgrade the maximum potential of such new principles, substances, and devices, which are still under development at present.

To implement these ideas in practice, this research area expects proposals from a wide range of research fields. Points of caution for the proposed research and the operations of the research area are provided below.

Research area and approach to research subjects

We welcome novel and challenging proposals aiming to create new thermal control technologies that introduce news ideas and viewpoints to advanced current research topics, such as "heat dissipation", "heat transport", "heat generation", "heat insulation", "heat storage", "heat conversion", and "radiation". Furthermore, we do not discount proposals for research on conventional thermal

control and utilization techniques; however, these must be based on understanding nanoscale (microscale) thermal behavior and its control. That is, a requirement of adoption is to clearly demonstrate the originality and excellence of a proposed technique and its applicability as a practical thermal control technique.

In addition, the requirements include not only verification of the theory but also continual efforts to identify practical applications and ways to reach the goal. For this purpose, the participation of a business firm in the team is recommended, although it is not compulsory. Collaboration with a business firm is particularly recommended in fields that anticipate imminent practical applications, such as measurement technology, guidelines and theory (including computational science) of material design, and device simulation techniques. We may ask participating teams without business firms to include ones during the research period.

Possible proposals in this research area include, but are not limited to, those described below.

① Basic understanding of thermal phenomena at the nanoscale (localized heat generation, localized temperature change, changes in material properties, effects on surfaces, miniaturization entailing decreased thermal conductivity, phonon transport, and effects on electrons and spin) and thermal control technologies

② Heat transport simulation techniques at multiple scales ranging from the micro- to the macroscale

③ Building designs and theories for innovative materials to greatly diminish or increase thermal conduction and their synthesis and processing techniques

④ Measuring techniques with spatial and temporal resolution exceeding those of conventional techniques for nanoscale heat

⑤ Development of novel devices and systems to realize thermal control and utilization (for example, new non-volatile memory chips, thermal diodes, and sensors and LEDs with low power consumption)

⑥ Building a database of nanoscale thermal properties for controlling and actively utilizing heat; establishing guidelines for designing new materials or new measuring techniques based on the database.

We accept proposals by teams composed only of researchers studying measurement technologies. However, regarding the subjects to be measured, such a team will be required to collaborate with

internal or external teams of the project under the coordination of the research supervisor to perform measurements with the developed measuring techniques. Furthermore, patenting measuring techniques and proposing them as international standards should be considered.

Teams involved in theories and simulations are expected to not only develop techniques or interpret experimental results, but also to use these techniques to propose experimental research subjects for the preparation of new materials and devices. Proposed experimental research subjects during CREST projects are evaluated by the research supervisor and they will be coordinated joint study with the experimental team, which will promote collaborations of theory/simulation and experimental teams. Additional funding may be considered for new collaboration themes generated during a CREST research period, if needed. We welcome not only methods for the computation of quantum states, such as those of electrons and phonons, but also computational science approaches to the analysis of reaction processes related to material synthesis and processing techniques. We encourage to use large facilities for joint use, such as the Kei super-computer, nanotechnology platforms, and TIA.

In the 2017 fiscal year, a collaboration will be established with researchers from different research areas including those of “Thermal Science and Control of Spectral Energy Transport” of the PRESTO research project established under the same strategic objective, and if needed, joint conferences and workshops will be held. In addition, we will promote collaboration with related academic associations and research organizations and hold international symposia to make results available internationally.

Research period and research expenses

The scheduled period for this research area is from the fiscal year 2017 to the fiscal year 2024. The research must be conducted between the fiscal year 2017 and the fiscal year 2024 (5.5 fiscal years). The research expenses must be up to 250 million yen.

*Actively utilize joint-use facilities available nationwide to prepare efficient research expense plans.

Notes for the preparation of research proposals

Describe a general idea for future application development of the proposed research and collaboration with a business firm for all proposals, including those related to the basic understanding of nanoscale thermal phenomena.

*Proposal invitation and explanation session will be held as scheduled below. We expect many people to attend the session.

	date	venue
Kanto	10:00 – 12:00 April 24 (Monday)	Hall on the 1st floor of Annex JST Tokyo head office

See the following website for details:

http://www.senryaku.jst.go.jp/teian.html