Research Areas in the Strategic Objective, “Elucidation of basic principles for innovative energy conversion, and synthesis of new materials, development of new energy harvesting devices, and other core technologies, that will contribute to the high-efficiency conversion of ambient microenergy into electricity and their new advanced applications.

6.2.10 Scientific Innovation for Energy Harvesting Technology

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Overview

The aim of this research area is to create innovative core technologies for converting heat, light, vibration, microwaves, and other types of ambient microenergy into electricity in the range of μW–mW for use in self-powered sensors as well as in other types of devices.

More specifically, the research will be promoted along two principal lines of inquiry. One will focus on the development of core technologies and their underlying basic principles for the highly efficient conversion of ambient microenergy. This research will develop substances and devices to convert untapped microenergy into electricity based on new principles. It will address the challenge of discovering new principles contributing to innovative energy conversion and developing new materials with physical properties far surpassing the characteristics of substances to date. The other principal line of research will be on theories, analytical evaluation, and material design to develop the core technologies mentioned above. This research aims to develop new analytic formulations for the physical phenomena that come into play during energy conversion, and will propose guidelines for the design of new material based on condensed matter physics or the application of computer simulation. It is extremely important to pursue these two principal lines of research in a mutually complementary way.

Accordingly, this Research Area calls for highly challenging proposals that endeavor to produce innovative

principles, substances and devices to be tested and verified in their final stages, and which will lead to follow-on research and development stages.

This research area will therefore be a CREST/PRESTO joint program, in which work will be pursued under the strong leadership of the Research Supervisor and Deputy Research Supervisor. Efforts will correspondingly be made to reorganize research teams and promote strong communication among researchers investigating different themes in order to maximize research achievements.

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

Background and Basic Directions

In the advanced information-oriented society of the future, energy supplies for wireless nodes and sensors, the numbers of which will grow to an enormous scale, will be critical. Therefore, how to secure electric energy will be a key concern, for example, in relation to power supplies and battery, etc. If it becomes possible to use ubiquitous untapped energy as power sources, the concept of a "power source" will change because of qualitative differences in the use of these new power sources.

In order to realize such a society, work in this research area will endeavor to develop core technologies for the highly efficient conversion of untapped microenergy into electricity and for their advanced application. Success will require the development of energy conversion principles based on novel concepts and ideas, and it will be necessary to progress existing principles, substances, and devices that are yet in their embryonic stages.

In order to promote the research mentioned above, this research area will receive proposals from a wide array of research fields. Points that should be borne in mind regarding research proposals and research area management are given below.

Targeted Research Fields and Research Approaches

Thus far, the research on energy harvesting has focused on technologies for the conversion of particular forms of energy, such as heat, light, vibration, or microwaves, into electric energy. The advanced information-oriented society, however, requires innovative technologies for the generation of electricity. Phononics, photonics, and the two areas in which there have been significant advances recently — spintronics and multiferroics — are all fields in which Japan has a competitive advantage on the global research stage. All these fields would offer exciting new

physical properties that can be utilized for innovative energy harvesting technologies.

We actively solicit original, ambitious proposals for electric energy conversion methodologies based on new ideas and perspectives from ongoing advanced researches. We particularly welcome proposals addressing physical properties not previously considered in energy conversion, which surpass the bounds of our typical considerations. Of course, there is no intent to discourage proposals for research on conventional energy harvesting technologies. Such proposals, however, should not be for work representing a mere extension of existing research, and which is hence predictable in terms of its results.

In other words, selection will heavily depend in all cases on whether outstanding characteristics of the technology are clearly shown and whether there are significant increases in power generation.

For material research, trial-and-error experiments should be avoided from a long-term perspective. It is necessary to show within the research period that the research strategy is scientifically valid, i.e., based on physics, computer simulations, or other evidence, before embarking on the actual search for substances or materials design. To accomplish this, researchers submitting proposals must clearly present their own original ideas. In doing so, they must pursue a universal principle that is not limited to particular substances and create a model to represent such principle. Of course, there is no intent to reject serendipity in the research process; indeed, this research area is characterized by difficulty in setting clear milestones. However, the solid bases for new physical properties to be manifested or substances to be discovered should be made clear. It is expected that efforts will then be focused on commercialization after elaborate scientific research on achieving their high performance or realizing new functionality.

※PRESTO program will not in this fiscal year be soliciting proposals on storage battery technology, electric energy generation technology based on artificial photosynthesis, and new devices for implantation in the living body.

※ In addition to innovative, challenging proposals from various technology fields, we actively encourage proposals for electric energy generation technology in the following fields, light, radio wave, vibration, piezoelectric.

※ We actively encourage proposals to be directed to application for flexible devices.

※ We also actively encourage proposals for device structure, circuits, and packaging in order to extract electric

power effectively.

Research Period and Research Expenses

The research period for this research area started in fiscal 2015 and tentatively extends through fiscal 2022. Management of the Research Area will be divided into two research phases. The first will be a time for creating core technologies to convert untapped microenergy into electricity. The second phase will be a time for selecting promising core technologies developed in the first phase and finding new applications for them.

Based on the above, research proposals for the current fiscal year will be solicited as described below.

Research periods for PRESTO projects will begin in fiscal 2017 and end by fiscal 2020 (four fiscal years). Research expenses will be up to 40 million yen (total expense).

For PRESTO project, specifically in the final fiscal year of each project, research progress will be evaluated based on monitoring throughout the research period. The progress evaluation will be performed addressing the practical value of the research achievements with an eye to future commercialization. As a result of the evaluation, certain research projects will be restructured to maximize achievements in the second phase. This work will take place as a collaborative effort of the research teams and researchers in the research area (for both the CREST and PRESTO programs), who will form a mutually complementary new team covering different fields. Work will focus on resolving problems, considering the research results achieved to date and future potential. This reconstruction-based research will be conducted under the responsibility of the Research Supervisor and Deputy Research Supervisor.

* Please develop an efficient research expense plan through active utilization of shared research facilities in Japan.

Points to be noted in research proposal preparation

In the “Future Prospect of Research” section of the proposal form, be sure to provide a scenario clearly describing what actions will be required during the research phase immediately after the end of the research period in order to advance the work described in the proposal to the development stage of targeting commercialization. Assume that the objectives of the proposed research will have been achieved during the research period.

Overview of Selection for Fiscal Year 2015 and 2016 (excerpt)

The research proposal solicitation for this research area commenced in the fiscal year 2015. Research proposals were solicited for creating basic technologies for the conversion (energy harvesting) of untapped ambient microenergy to electricity in μW–mW ranges for sensors and information processing devices.

In the near future, society will utilize very diverse, big data on networks obtained by using a massive number of environmental sensors. That future society will need handy sensors powered with new forms of energy, including heat, light, vibrations, microwaves, and living bodies. Proposals were solicited that would create new scientific principles, new materials, new devices, or new analytical techniques for the conversion of the various energy forms to electricity. These included proposals addressing the underlying basic theories of this conversion.

Applications for energy harvesting grants were received from various technological areas (72 proposals in 2015 and 59 proposals in 2016). A fair and strict document screening was performed by 10 advisors, who were chosen from pertinent scientific areas and who were mostly experts in the academic and industrial sectors. The advisors chose 24 proposals in 2015 and 20 in 2016 for interviews.

In the interviews, the proposals were evaluated on the basis of the following criteria:

(1) A proposal in the research area of conventional energy harvesting should be expected to yield a result that is not simply an extension of past research but clearly presents a pathway to improved efficiency of energy conversion to electricity.

(2) A proposal in a new research area should add new ideas and perspectives to research results based on theories and experiments and should be expected to yield a breakthrough in the method of energy conversion to electricity.

As this is a combined research area for CREST and PRESTO, it was important that the research teams and researchers mutually cooperate, aiming for the integration of different areas and complementary collaboration. Therefore, the following viewpoints were also considered important:

The research proposal must have the potential to be a technological seed for CREST. In the interview, the project leader must be able to discuss these future opportunities.

Finally, nine proposals each were selected to the research stage of PRESTO in 2015 and 2016, in the area of energy

harvesting based on correlated electronics and spintronics in addition to the utilization of conventional heat, vibration, radio wave, and light.

There were many world-class studies and challenging proposals among the submitted research proposals that did not reach the interview stage. These proposals were not chosen, because they did not adequately explain the pathways to the practical device concepts beyond the creation of new principles or new materials, methods to solve issues in research and development, or any clear advantage of the proposed technologies, which were a stated requirement for the proposals in the research overview. It is hoped that they will be corrected to meet these requirements and submitted for application in the next round.

Note: A solicitation session for this research area is scheduled as shown below. It is hoped that many interested parties will attend the session.

Date & Time	Venue
April 24 (Mon)12:30-14:00	<Kanto-Area> JST Tokyo Headquarters Annex, 4nd Floor, room F

For more information, please visit the following site: http://www.senryaku.jst.go.jp/teian-en.html.