Research area in the Strategic Objective *"Information carriers and innovative devices"*

Information Carriers and Their Integrated Materials/Devices/Systems

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Overview

The aims of this Research Area are to create high performance/high functionality devices utilizing the features of the "information carrier," which holds the key to the information processing in devices, and furthermore, to create generic information system technologies that lead to social implementation by integration and systemization of those devices. In realizing a "super smart society" and the next-generation information society beyond it, more advanced devices and systems, which are responsible for information processing, will be indispensable. On the other hand, in conventional electronics, represented by miniaturization of CMOS, the limits of improvement in information processing capabilities are beginning to become apparent. Thus, novel material/device technologies that break through those limits and innovative generic technologies for their systemization are demanded.

Therefore, the focus of research in this Research Area is information carriers, which hold the key to information processing in devices. Here, "information carrier" is a general concept that connotes a degree of freedom capable of carrying a wide range of information such as physical quantities, and the network structures and molecular structures of physical systems that express information defined as state variables. The objects of this Research Area are not limited to electric charge, which plays the role of an information carrier in many existing devices, but encompasses all information carriers that can carry information: spin states and molecular structures, phase changes of materials, quanta, and structural networks. The aim of this Research Area is to conduct an in depth exploration of the diverse information carriers that form the basis for functions such as information acquisition, conversion, storage, computation, communication and outputting, and also to create innovative new devices by utilizing those information carriers at a high order. Moreover, for those efforts to lead to the construction of systems capable of social implementation, the activities of this Research Area aim to beyond functional expression by a single device, also include cooperation with the circuits, architecture, systems and application layers by integration/systemization, with the aim of innovation of novel information system infrastructure. In particular, in this Research Area, we put great efforts into basic research on challenging material, devices and systems, based on the ideas of individual researchers.

Research Supervisor's Policy for Call/Screening of Proposals and Management of Research Area

1. Background

To realize Society 5.0, which connects all people and things in networks that create unprecedented new value, a close integration of physical space and cyber space (virtual space) is demanded. For further progress in integration, it will be necessary to collect a wide range of diverse information on physical space, extract its value by advanced information processing and pioneer physical feedback techniques to physical space. In other words, in order to construct a CPS (cyber physical system) that combines physical space and cyber space, improvement in the performance of all types of devices that form its basis, development of novel functions and diversification of interfaces will be required.

Moreover, because we are also beginning to see the limits of the 2-dimensional miniaturization/low cost production technologies for the semiconductor devices that have supported the evolution of information systems, a qualitative transformation in conventional information processing systems and the materials, devices, circuit integration techniques, and architectures used in them, as well as the creation of new concepts and generic technologies, and the construction of the science that supports them, are also considered necessary.

2. Policy on Call/Screening of Proposals

Against the background described above, the aims of this area are to create innovative new devices that draw out the special features of information carriers as fully as possible, and to create basic information technologies by their integration and systemization, focusing on information carriers, which are the key to information processing in devices. Here, "information carrier" has the wide meaning of physical quantities, physical states, and physical phenomena, etc. that are capable of expressing information. Devices generally express information by using information carriers, and process and transmit various types of information by manipulating those information carriers. The information carriers in many conventional devices is "electrical charge"; that is, bits and analog quantities are expressed by charges, and various kinds of information processing operations are carried out by manipulating charges. Therefore, in this Research Area, we call for challenging research proposals that can lead to basic innovations in information system infrastructure, covering a range that extends to integration/systemization, while returning to basic principles and asking what kind of information carriers can be integrated in what ways by using what materials and structures, how can the functions and properties of devices be extracted, and how the different functions such as sensing, computing, actuation, communication, display and energy harvesting can be integrated to heighten the efficiency or performance of a system. In particular, we welcome original, creative proposals that explore methods for using diverse kinds of information carriers such as electrons, quanta, spin, ions,

substance phase changes, device structures, and network structures, etc. and pursue device operating principles, device structures, circuit configurations and system architectures that effectively control those information carriers, or their reliability assurance technologies.

In this area, there are no restrictions on the target information carrier or device function. Researchers are free to propose charge-type information carriers. Moreover, we will consider proposals in which the breakthrough technology that forms the core of the research proposal is the information carrier itself, or a device technology for extracting the features of the information carrier, or their integration/systemization technologies. We especially welcome original proposals based on the free concepts of the researcher.

The following presents concrete Research Projects by way of example. However, not limited to these examples, we welcome surprising research proposals from various standpoints of electronic layers, such as materials, devices, integrated circuits, architectures, etc., as well as diverse academic fields, including physics, chemistry, biology, information science and mathematical science.

(1) Search for diverse information carriers, and construction of the scientific principles of their properties and functions

- Research to physically and/or mathematically elucidate the properties of quanta, spin, ions, molecular structures, substance phase changes, physical network structures, etc. in order to realize diversification of technologies in information carriers
- Research to elucidate the compositions, structures, physical quantities, state variables, etc. that distinguish information carriers and the relationship between the functions and phenomena they express under designated environments

(2) Establishment of control techniques for information carriers and creation of novel device operating principles

- Development of the design techniques necessary for understanding and controlling information carriers and their states, information input/output techniques, and algorithms
- Development of technologies for highly efficient interconversion of information between different types of information carriers, including electrons, spin, light, and quanta
- Creation of device operating principles for efficient acquisition, conversion, storage, computation, communication, output, etc. of environmental, biological or other types of external information by optimization of information carriers
- Research to realize the information processing functions in living beings as devices

(3) Creation of novel devices

• Development of high-speed energy-saving devices for processing large volumes of data in real time
• Development of autonomous devices such as actuators that simultaneously realize information acquisition, computation and control in a single device

3. Points to Note in Applications

In preparing your proposal, please set an unsolved social problem or function as a target, clearly define the bottlenecks in solving it, and clearly describe the following. Please also describe the scientific and/or social significance of the topic. In particular, it is important to clearly express the Information carriers in 1.

1. Information carrier: What type of information carrier are you considering, and what and how is the method of information expression and information manipulation different from those of conventional information carriers?
2. Setting of the target area, and superiority of original technology
3. Benchmarks with existing technologies
4. Targets to be achieved at the end of research, and image of social implementation thereafter

In this Research Area, we hope to receive original ideas and challenging research topics in connection with the principles and science of information carriers, their control techniques, etc. that will contribute to the creation of innovative devices. Therefore, please clearly indicate the relevant international research trends, and clearly describe the superiority/originality of your research proposal in comparison with conventional research.

Also, please note that we expect an ambitious research proposal that opens a new starting point in science, which has the prospects of application contributing to the solution of a social problems in the near future, and is also preconditioned on achievement of the plan within the PRESTO research period. Please remember to lay out a vision aiming at a joint research system inside/outside of this Research Area in the future, while continuing to be based on individual research.

4. Policy for Management of Research Area

The following management policy is set for the Research Area as an effort toward maximizing research outcomes and social implementation.

• Area operation will be performed in close cooperation with CREST “Integrated Devices and Systems Utilized by Information Carriers” beginning at the same timing. Positive joint research within the PRESTO area is also recommended.
• We plan to provide opportunities for nurturing interdisciplinary collaborations among layers by holding events sponsored by the Research Area.

• Because building a research team and cooperation with private companies will be indispensable when aiming at social implementation, we will hold workshops to share research promotion know-how related to intellectual property and open innovation after the start of research. Furthermore, by introducing the progress of research in an external industry-academia collaboration consortium, etc., we aim to arouse interest in research from people in the industry and promote corporate collaboration.

5. Research Periods and Research Budget

The initial research budget has an upper limit of a total ¥40 million (direct expenses) for each project.

The research period is from FY 2022 to FY 2025 (within 3 and 1/2 years).