Research area in Strategic Goal *"Innovation in measurement and analysis processes aimed at solving social issues"*

Creating innovative measurement and analysis systems aiming to solve social issues

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Overview

As the expression "Measurement is the mother of science" suggests, progress in science and technology begins with "seeing and noticing." The history of advances in science and technology can also be called the history of advances in measurement technology.

In resolving global social challenges such as the SDGs, beginning with becoming carbon neutral by 2050, it will be essential to develop various new practical materials, including from the standpoints of energy and recycling. At the front lines of leading science and technology research, the subjects of the research are shifting toward grasping and understanding the peculiarities of complex, uneven layered structures and substance changes. Understanding complex substances and phenomena like this is hardly achieved by simply improving conventional measurement technology or similar strategies, and so breakthroughs in measurement and analysis methods are essential.

In this research area, our aim is to bring about sophisticated advances in measurement and analysis methods and generate new measurement and analysis systems that are capable of resolving actual and various difficult challenges in measurement and analysis by combining advances in measurement technology with information technology such as advanced mathematical modeling and machine learning. We also aim at innovating measurement and analysis processes to offer Japan's research environments advantages over the coming 10 or 20 years. Moreover, the effectiveness of the new measurement and analysis methods produced in this research area should be verified in the real-world situation such as the development of actual new materials, and their generality should be explored in other research and development fields that face similar difficulties beyond the original target fields.

More specifically, the research will position "boundary-breaking advanced measurement," "adaptation of measurement data informatics," and "multiscale/multimodal measurements, and their use case development" as key research components, and will pursue measurement and analysis innovations by realizing a research environment that merges these components.

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

1. Basic Objectives

(1) Innovate measurement and analysis methods

Aim to innovate measurement and analysis methods by combining measurement technology and information technology. Examples include obtaining measurement data that are not currently measurable, and analyzing and understanding the measurement results that are too complex to directly understand.

(2) Tackle real challenges

Rather than pursuing innovation that simply tries to generate world-leading measurement results in benchmark environments, aim to provide breakthroughs to difficult problems that are being sought as real-world challenges, such as development of actual new materials, and demonstrate their effectiveness through the real-world challenges.

(3) Undertake research and development that contributes to innovating the processes of measurement, analysis and practical application.

Undertake research and development aimed at connecting the processes to visualize through measurement, understand through analysis, and furthermore, use in practical applications, such as developing actual new materials.

(4) Aim to develop generic measurement technologies for various fields

Rather than narrowing in on a specific field, aim to extend the measurement technologies to be applicable to many other fields.

(5) Undertake research and development that contributes to international competitiveness

Aim to lift Japan's international competitive superiority in the coming 10-20 year timeframe by the research and development.

2. Research Examples

In order to achieve the basic objectives mentioned above, “boundary-breaking advanced measurement,” “adaptation of measurement data informatics” and “multiscale/multimodal measurement, and their use case development” should be positioned as key research components in this research area. Example research images for each component are presented below, but in order to realize genuine innovation of useful measurement and analysis, it will be extremely important to closely coordinate these components in a research plan. Note that the following are merely demonstrative examples, and we welcome proposals in wide research areas.

(1) Boundary-breaking advanced measurement

This component is to measure (enable to see) things that cannot be measured (cannot be seen) currently. Not only by utilizing existing measurement principles or measurement devices and informatics, it should break boundaries by developing new measurement principles or measurement devices, and by combining them with informatics.

The followings are example measurements to be achieved (enable to see):

a) Time variable measurement of the non-homogeneous distribution of chemical reactions and electron states that occurs within materials in the mesoscale area.
b) Simultaneous achievement of temporal and spatial resolutions
c) Precise measurement of dynamical changes of physical/chemical states and formations in the inside or on the surface of a material
d) Trace constituent measurement and its tracking, and establishment of the measurement reproducibility
e) Elucidation of phenomena across different scales (multiscale measurement)
f) Elucidation of unknown relationships between different properties (multimodal simultaneous measurement)

(2) Adaptation of measurement data informatics

Even after the breakthrough of measurement boundaries is achieved, there are many cases that the obtained results appear to be too complex and difficult for people to understand. Some breakthroughs to address this problem should be achieved by fusing measurement science with information science, mathematical statistics, computational science and so on.

Followings are research examples addressing this issue:

a) For measuring the non-homogeneous distribution of chemical reactions and electron states at the mesoscale level, combine precise measurement technology producing large quantities of three-dimensional data with machine learning and simulation technology to develop an integrated system that presents hypotheses on – and discovers – correlations hidden within data.
b) Develop a system that optimizes measurement points to carry out highly accurate structural analysis of unknown materials in a short period of time, based on existing measurement data on similar materials as the training data.
c) Research and develop an artificial intelligence intervention-type measurement system that predicts follow-on measurement data from data that have already been obtained during past measurement experiments, and proposes appropriate measuring condition based on that.

(3) Multiscale/multimodal measurement, and their use case development

The phenomena that arise in many measurement subjects, beginning with practical materials in the real world, display complex behaviors in hierarchies of multiple time-space ranges from the sub-nanometer to the centimeter scale, and the attosecond to the hours. Furthermore, they are related to multiple components, including not only a mechanics component but also electric potential and temperature distributions. Analyzing and understanding the overall picture is difficult by using physical information resulted on a single scale or by a single measurement method.

Despite the progress on the resolution performance of individual measurement technologies, research on analysis and understanding by combining multiscale and multimodal measurement outcomes has only just begun. By promoting research and development in this field, we will strive to deepen understanding of practical materials and so on, and develop their use cases.

Following are research examples for this component:

a) Analyze the electrochemical deterioration mechanisms of various functional materials used for next-generation storage batteries to extend their service lives.
b) Analyze the destruction mechanisms of composite materials and adhesives to make them more resilient.
c) Develop new high polymeric materials of plastic, rubber etc. for recycling and upcycling.
d) Analyze the mechanisms of, or evaluate the impact of impurities etc. on, strongly correlated electron systems, such as high-temperature superconductivity, and develop materials for practical use by using those results.

3. Management of the research area

(1) Advisor team

Because this is a combined research area with a high degree of difficulty that requires knowledge of each variety of measurement technology, expertise at the front lines of the development of various subjects, and a broad understanding of informatics, a portfolio of advisors will be assembled from industries, real-world development, measurement technologies and informatics, and will engage in research area management as a team.

(2) Promoting interdisciplinary exchange

In order to achieve measurement and analysis innovations that are not trapped in specific fields, fora will be organized for exchanges between industrial companies that have needs and researchers that have technologies, or for exchanges between researchers possessing different measurement and analysis technologies or from different subjects and application fields. This activity will promote innovative developments and carry out use case development through exchanges between different fields. Furthermore, collaborations with other related research areas will be promoted.

4. Research periods and research funds

The research period will be no longer than five and a half years. The research budgets (direct costs) submitted will be the necessary amount for achieving the content of the proposal, with an upper limit of 300 million yen. However, applications that exceed the upper limit may be approved in cases where it is recognized as genuinely necessary as a result of the research content and the character of the research. In addition, please be aware in advance that in some cases research budgets will be adjusted when proposals are being selected, as a result of close examinations by the supervisor.

5. Principle of project selection

The following points will be considered for project selection:

(1) The proposal should be innovative and original and should provide innovations in measurement and analysis processes.

(2) The proposal should solve practical problems in measurement and analysis, and its effectiveness should be demonstrated within the research period.

(3) It is expected to contribute to the front lines of Japan's research and development and the front lines of Japan's practical technology development over the coming 10-20 years.

(Participants are not necessarily required to actually resolve social problems by developing specific products or generating practical commercial products during the research and development

period of this program).

6. Important notes for 2022 application

(1) The scale and field of measurement objectives

This research area shall cover measurement of phenomena ranging from the sub-nanometer to millimeter/centimeter scale.

Though the development of actual materials is stated as the example key exit field, proposals for other fields of measurement on the same scale, such as biomaterials, pharmaceutical compounds and healthcare, foodstuffs and agriculture, the environment and soil, and forestry and timber, are also welcome if they achieve generic innovations in measurement and analysis methods in many other fields.

(2) Formation of research teams

In this research area, in order to achieve innovations in measurement and analysis by closely merging the three components of “Boundary-breaking advanced measurement,” “Adaptation of measurement data informatics” and “multiscale/multimodal measurement, and their use case development,” and to confirm their effectiveness in the real application environment, the research on those three components under a single Principal Investigator is ideally expected.

On the other hand, we should avoid that jeopardizing originality and the spirit of challenge by placing too much emphasis on merging these three components.

With that in mind, even if proposed teams are formed for one or two research components, we intend to proactively select them as far as they satisfy “4. Principle of project selection”.

In any event, please be aware that merging the multiple components is important in this research area, and submit proposals after including or mentioning those merging.

In cases where proposals are selected that involve teams for one or two research components, collaborating and cooperating with other research teams in the research area may be explored in the latter phase of the research period.

(3) Items to be described in proposals

Based on the aims and selection policy of this research area, please clearly indicate the following items in proposals.

a) What are the actual measurement and analysis challenges that you want to achieve?

b) How will the front lines of Japan's research and development and the front lines of Japan's practical technology development change over the coming 10-20 years by your proposed innovations, or how do you want to change them? How are the proposed technologies or research outcomes expected to contribute to resolving social issues?

c) The evidence that the proposed measurement and analysis methods are expected to be useful not only in specific fields (for example specific materials and specific substances) but also in many other fields.