R&D Strategy for Nanotechnology and Material Science and Technology (Overview)

- Nanotechnology and material science and technology are areas in which Japan can exert its strengths. These are important areas that support the industrial base of Japan.
- There are signs of new game changers, such as the rapid development of materials using data-driven R&D methods utilizing AI/IoT/big data technologies, which are advancing at a mesmerizing speed.
- With society moving toward Society 5.0 and SDGs, the government will coordinate R&D strategies in the fields of nanotechnology and materials, widely disseminate them to the public, and accelerate the realization of a future society.

1. Changes in the situation surrounding the nanotechnology and material fields

(1) Past roles of nanotechnology and material science and technology

- A foundation that supports a wide variety of research and applied fields, and a pioneer that opens up new possibilities for the development of science and technology and society.
- The export value of industrial materials accounts for more than 20% of total export value along with automobiles. It is an important industry in which Japan is competitive and which supports the industrial base of Japan.

(2) Changes in R&D environment

- With the declining working-age population, it is becoming increasingly difficult to secure young researchers.
- Decrease in Japan's international share in papers in this field
- In the industrial sector, Japan's share has been declining and commoditization of materials is being accelerated due to the entry of emerging-market manufacturers.
- The world is entering a game-changing era due to the rise of data-driven material development, etc.

(3) Position in Japan's policy

- Position in the Science and Technology Basic Plan

2nd and 3rd Plans: Priority areas to which R&D resources are to be intensively invested

4th Plan: Nanotechnology is a cross-sectional basic technology necessary for solving social challenges, and advanced materials and components are a common base for strengthening industrial competitiveness.

5th Plan: Fundamental technologies with core strengths to create new value

(4) Japan's strengths in the nanotechnology and material fields

- Excellent knowledge, experience, know-how, and intuition are accumulated among researchers and engineers over many years.
- High quality data on physical properties and material creation processes
- NIMS is ranked 9th in the international ranking of paper citations.
- There are many items that have gained a very high share in the global market.

(5) Trends in other countries

- China, US, UK, Germany, and Korea are the top five countries in the international ranking of share in paper citations in the material field.
- Many countries position nanotechnology and materials as important key technologies in their policies, strategically continuing ongoing efforts.
- R&D efforts are also being made concerning new materials such as graphene.
- Data-driven material development methods are also being developed.

(6) Bringing about a new society

- Materials will play an even more important role as Japan moves toward a future society envisioned in Society 5.0 and SDGs.

2. Goals and basic stance in promoting nanotechnology and material science and technology

- **Goals are to break down many barriers that will be faced in the path to Society 5.0 and SDGs, etc., and contribute to both industrial revitalization and human wellbeing.**
- **To that end, Japan will promote the creation of materials* with appealing functions that are to be supported by people, including functions that have never existed before or those that replace conventional products. Japan aims to boldly transform society through what could be called "social revolution through materials (material revolution)."**

*The term "material" as used in this document includes substances, materials and devices.

*This R&D strategy will be updated once every two years to capture the latest scientific trends.

3. Challenges in bringing about the material revolution

- **Further advancement of required materials (1)**
- **Coping with long-term R&D efforts (1)(3)**
- **Measures to secure the quantity and quality of data and build databases to be used (3)**
- **Need to improve R&D productivity, as R&D funds and researchers are in short supply due to R&D budgets showing little growth and the declining birthrate (3)(4)**
- **Difficulty in commercialization of research projects due to costs and the difference in project scale between laboratories and private companies (2)(4)**
- **Addressing the distance between materials and final products, diversification and complexity of social needs and technology seeds, and challenges that the industrial sector faces in the basic research phase (2)**
- **Lack of support system to induce commercialization and new applications (4)**
- **Establishment of appropriate evaluation criteria for technical areas concerning which it is difficult to write papers, such as process technologies, which are related to building the foundation of international competitiveness (2)**

4. Efforts to bring about the material revolution

It is necessary to renew the concept of R&D in the nanotechnology and material fields, Taking into consideration the research trends in Japan and in the world and the paradigm shift caused by advances in AI technology. In this view, Japan will promote the development of the science base and human resources in order to respond to the new era ,and the reform of laboratories tapping into cyber and robot technologies. In addition, Japan will promote strategic and continuous R&D and the introduction of new approaches to creating attractive materials.

(1) Creation of materials with attractive functions that bring about social change

(i) Expansion of material functions based on a new approach

Establishment of cross-sectoral domains that are not limited to specific realms, and strategic induction of field fusion and new applications, in order to create materials with attractive functions

Super-composite materials with reciprocal physical properties; Utilization of non-equilibrium/metastable structure that greatly expand the functions of materials; utilization of biological mechanisms that have the potential for new functions and significant improvements

(ii) Research areas to be promoted in a strategic and sustainable manner

Continuous fostering of R&D areas where Japan has strength, and promoting nanotechnology and materials science and technology in view of realizing required functions that are indispensable in achieving Society 5.0 and SDGs.

Next-generation element strategy that contributes to the circulation of elements and substances and to the development of new functions; molecular technology; innovative devices in the IoT/AI era (including sensor and actuator technologies); bio-inspired materials; materials that innovate energy conversion, storage, and high-efficiency utilization; materials that produce innovative separation technology; structural materials; materials that innovate robots; Operand/highly-advanced measurement technology

(2) Establishment of a science base to deliver created innovative materials to the world

Establishment of a science base that gives guidelines on material design and development based on scientific knowledge, and translation of knowledge into technologies, with a view to achieving breakthroughs in conventional material creation processes, and making good use of developed materials.

(3) Laboratory reform for more efficient, faster and more advanced R&D

Bringing about more efficient, faster and more advanced R&D through the introduction of cyber and robot technologies (such as AI, IoT, and big data), expansion of exploration areas through sharing, and enhancement of shared facilities and support; creation of an environment that maximizes the creativity of researchers, which also encompasses education for young researchers

Smart laboratory (AI / Robot-driven Materials Research); data-driven R&D; development of measurement technology that is a source of data creation; enhancement of shared facilities

(4) Promotion measures to bring about the material revolution

Development of human resources who can make use of AI and robot technologies to the fullest extent, and who can create new materials through fusion of different fields of research; promotion of research and analysis to bring about strategic international cooperation