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Science & Technology

Japan

NEW DIAMOND FORUM LECTURES

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SCIENCE & TECHNOLOGY
JAPAN

NEW DIAMOND FORUM LECTURES

916C3809 Tokyo NEW DIAMOND FORUM: ABSTRACTS OF LECTURES AT 6TH GENERAL SESSION
SPECIAL LECTURES in Japanese Jun 91 pp 1-12, 1-31

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Future Prospect for Fine Ceramics

916C3809A Tokyo NEW DIAMOND FORUM: ABSTRACTS OF LECTURES AT 6TH GENERAL SESSION SPECIAL LECTURES in Japanese Jun 91 pp 1-12

[Article by Yoshihisa Ishiguro, Fine Ceramics Office chief, Consumer Goods Industries Bureau, Ministry of International Trade and Industry: "Future Prospect for Fine Ceramics"]

[Text] Industrializing New Diamond

4 June 1991
6th New Diamond Forum General Session

1. Presentation of Development Direction (Vision Making)

Expected industrial scale, conception

2. Promotion of Research and Development

Grasping of actual state of research and development

Promotion of key projects

(Example: Project for "hazardous environment monitoring system for solving earth environmental problems")

Promotion of related basic research

3. Completion of Industrial Foundation (Completion and promotion of NDF system)

Linkage with user industries

Database, standardization (test and evaluation method, etc.)

4. Positive Promotion of International Cooperation
Prediction of Market Scale for New Diamond Industry-Related Products

Source: "Fiscal 1988 New Diamond Industrial Measures Research Report"
Note 1: Results of questionnaire to NDF member firms
Note 2: Estimated at about ¥580 billion in fine ceramics vision.
Needs for Future Industries and Technologies Required To Be Developed—Possibilities of Diamond Application
<table>
<thead>
<tr>
<th>Industrial field</th>
<th>Applied parts, device</th>
<th>Characteristics of use</th>
<th>Final application technology system</th>
<th>Principal technological problems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Earth environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Ultraviolet sensor</td>
<td></td>
<td></td>
<td>Ozone concentration observation system</td>
<td>(1) High-purity diamond synthesis (2) Gold-diamond junction (3) High-density integration</td>
</tr>
<tr>
<td>2. Heat-resistant device</td>
<td></td>
<td></td>
<td>Engine control bille system</td>
<td>(1) Large-area single-crystal diamond synthesis (2) Method of manufacturing devices with semiconductor characteristics at high temperature</td>
</tr>
<tr>
<td>3. Corrosion-resistant, wear-resistant components</td>
<td></td>
<td></td>
<td>Desert environment observation system</td>
<td>(1) Coating technology (large area, bond strength, fineness, work under bad environment)</td>
</tr>
<tr>
<td>4. Hydrogen-shielding materials</td>
<td></td>
<td></td>
<td>Hydrogen fuel automobile</td>
<td>(1) Coating technology (large area, bond strength, fineness)</td>
</tr>
<tr>
<td><strong>II. Living, social environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. High-output device</td>
<td></td>
<td></td>
<td>Large-power control system</td>
<td>(1) n-type semiconductor resistance control (2) pn junction (3) Single-crystal diamond heteroepitaxial growth on cheap materials</td>
</tr>
<tr>
<td>2. High-output device substrate</td>
<td></td>
<td></td>
<td></td>
<td>(1) Area increasing, (2) Low-temperature high-speed film making, (3) Metallization adhesion, (4) High-purity diamond synthesis (reduce isotrope 13C)</td>
</tr>
<tr>
<td>3. Surface elastic-wave device</td>
<td></td>
<td></td>
<td>Satellite, vehicular communication equipment</td>
<td>(1) Manufacture smooth, few-remote-defects diamond substrate (2) High-accuracy piezoelectric thin film and electrode on diamond substrate formation</td>
</tr>
<tr>
<td>4. Biologically adaptive materials</td>
<td></td>
<td></td>
<td>Surgical knife, dental materials, etc.</td>
<td>(1) Processing technology (edging, edge polishing, etc.) (2) Coating technology (temperature lowering, direction control, etc.)</td>
</tr>
<tr>
<td><strong>III. Frontier environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Infrared parts</td>
<td></td>
<td></td>
<td>Space shuttle</td>
<td>(1) Area increasing ($1000$-$1,000$) (2) High-speed film making technology (2.108 $\mu$m) (3) Strength raising</td>
</tr>
<tr>
<td>2. Ultrahigh specific-intensity materials</td>
<td></td>
<td></td>
<td>Space observation system</td>
<td>(1) Diamond fiber manufacturing technology (2) Compounding technology</td>
</tr>
<tr>
<td>3. Cosmic-ray-resistant materials</td>
<td></td>
<td></td>
<td>Space station</td>
<td>(1) Size increasing (2) Strength raising</td>
</tr>
<tr>
<td>4. Fast-particle resistant materials</td>
<td></td>
<td></td>
<td>Artificial satellite</td>
<td>(1) Size increasing (2) Strength raising</td>
</tr>
<tr>
<td>5. High-vacuum low-friction materials</td>
<td></td>
<td></td>
<td>Planetary probe</td>
<td>(1) Coating technology (adhesion, fining) (2) High-accuracy processing technology</td>
</tr>
<tr>
<td>6. Corrosion-resistant, weatherproof components</td>
<td></td>
<td></td>
<td>Marine structures</td>
<td>(1) Coating technology (in water, on rust)</td>
</tr>
<tr>
<td><strong>IV. Natural resources, energy</strong></td>
<td></td>
<td></td>
<td>Nuclear reactor interior monitoring system</td>
<td>(1) High-purity diamond synthesis (2) Diamond and dissimilar materials junction technology</td>
</tr>
</tbody>
</table>
Trend of New Diamond Research and Development

<First phase>

1955   Artificial diamond (new diamond) synthesis by superhigh-pressure synthesis method

1955-75  New diamond development and application
         (Diamond-cBN grindstone, cutting tool, die, etc., using sintered diamond)

(Temporarily calmed due to oil crisis, etc.)

<Second phase>

1981   Synthesis by chemical vapor deposition (CVD) method at the National Institute for Research of Inorganic Materials

1980~   New diamond development by the CVD method and its application
         (Speaker diaphragm, cutting tool, bonding tool, etc., in which mainly structural characteristics were applied)

(Progress in atom- and molecular-level control technology)

<Third phase>

1990~   Challenge in functional diamond technology
Comparison of Typical Physical Properties Between Diamond and Various Materials

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Diamond</th>
<th>Si</th>
<th>cBN</th>
<th>SiC</th>
<th>GaAs</th>
</tr>
</thead>
</table>
| Symmetry            | Diamond type (Fd3m)  
Hexagonal diamond type (P63/mmc) | ZB type | ZB type (F43m) | ZB type | ZB Type |
| Lattice constant (Å) | 3.507Å (Cubic)  
a=2.52Å c=4.12Å (Hexagonal) | 5.430Å | 3.615Å | 3.956Å (C3C)  
a=2.076Å c=5.048Å (2H) | 5.633Å |
| Bond distance (Å)   | 1.544 | 2.352Å | 1.585Å | 1.888Å | 2.488Å |
| Bond energy (Kcal/mole) | 85.4 | 54.5 | 73.9 | 38.9 |
| Density (g/cm³)     | 3.52 | 2.30 | 3.49 | 3.10 | 5.32 |
| Thermal expansion coefficient (10⁻⁶ deg⁻¹) | 2.3 | 4.2 | 3.7 | 3.7 | 6.5 |
| Hardness            | Mohs   | 10 | 7 | 9.5 | 9 |
|                     | Knoop (Kgf/mm²) | 7,000–10,000 | 4,500–4,800 | 1,875–3,960 |
| Young's modulus (MPa) | 7,86 | 2.0 | 5.2 | 4.0 |
| Poisson ratio       | 0.20 | 0.2 | 0.2 |
| Specific heat (Cal/g-deg) | 0.122 | 0.180 | 0.121 | 0.17 | 0.038 |
| Heat conductivity (Cal/cm•cm•deg) | 5.0 | 0.36 | 1.4 | 0.65 | 0.13 |
|                     | 25°C | 100 | |
| Band gap (eV)       | Direct | 7.4 | 3.4 | 8.4 | 6.0 | 1.4 |
|                     | Indirect | 5.4 | 1.1 | 6.4–7 | 2.3 | 1.8 |
| Mobility (cm²/V•s)  | Positive hole electron | 2.100 | 450 | 70 | 420 |
|                     | Electron | 2.000 | 1,500 | <50–1,000 | 8,500 |
| Dielectric constant (at 1 MHz) | 5.7 | 12 | 6.5 | 10 | 13 |
| Electronic (specific resistance (Ω·cm)) | 10'' | 2×10'' | 10'' | 10'' |
| Refractive index     | 2.4195 | 3.448 | 2.117 | 2.65–2.69 | 3.4 |
Material Characteristics Required From Future Technology and Promising Fields of Diamond
Technical Problems for Diamond Applications and Results of Evaluation of Their Degrees of Difficulty

**Classification**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Starting from constructing fundamental scientific knowledge is necessary.</td>
</tr>
<tr>
<td>B</td>
<td>There is fundamental scientific knowledge, but drastic ideas are necessary for producing technologies.</td>
</tr>
<tr>
<td>C</td>
<td>There are ideas considerably, but a wide range of systematic research is necessary for establishing technologies.</td>
</tr>
<tr>
<td>D</td>
<td>It is enough to push on a business competition basis.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field</th>
<th>Parts</th>
<th>Technical problems</th>
<th>Degree of technical difficulty</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1</td>
<td>(1) Purity raising</td>
<td>A B C D</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) Junction</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3) Density increasing</td>
<td>O O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>(1) Single crystal</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polycrystal</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High-temperature operating</td>
<td>O O</td>
<td>~600°C</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>Coating (large area)</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coating (bond strength)</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coating (fineness)</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Coating (large area)</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coating (bond strength)</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coating (fineness)</td>
<td>O</td>
<td></td>
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<tr>
<td></td>
<td>4</td>
<td>Coating (large area)</td>
<td>O</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Coating (bond strength)</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coating (fineness)</td>
<td>O</td>
<td></td>
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<tr>
<td>II</td>
<td>1</td>
<td>n type</td>
<td>O</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>pn junction</td>
<td>O</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Heteroepitaxial growth</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Area increasing</td>
<td>O</td>
<td>Polycrystalline products will do.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Film low temperature</td>
<td>O O</td>
<td>Several 100 μm - mm order</td>
</tr>
<tr>
<td></td>
<td></td>
<td>making high</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Metallization</td>
<td>O O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High purity (low temperature &lt; 0°C)</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Smooth, flawless</td>
<td>O</td>
<td>2 - 3 GHz; diamond substrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manufacturing technology, piezoelectric thin film making</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrode</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Precision processing</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coating</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>Large area</td>
<td>O</td>
<td>φ 100 - φ 1000 (mm) Polycrystal will do</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High-speed film making</td>
<td>O</td>
<td>&gt; 100 μm / h</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Diamond fiber</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compounding</td>
<td>O</td>
<td>High heat conduction, lightweight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Same as III-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Same as III-w</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>5</td>
<td>Coating</td>
<td>O</td>
<td>Curved surface coating technology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Film thickness control</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>High-precision processing</td>
<td>O</td>
<td>Several nm</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Coating</td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>

Note: For the field, parts and technical problems, see Table 4-2
"Expected Fields for Diamond Application and Problems."
The Earth Is Weeping

Conception of "Earth Resuscitation Project"
Recent Trend of Science and Technology
( Establishment of New Science and Technology Division)

For Development of Materials Science
International Trend Over New Diamond

1. The United States

Even recently, the number of research groups is increasing (about several tens), well balanced with fundamental research.

(1) Material Research Laboratory/Pennsylvania State University
(2) Department of Material Engineering/North Carolina State University
(3) Department of Chemical Engineering/Case Western Research University
(4) Naval Research Laboratory
(5) Special Materials Department and R&D Center/General Electric Company
(6) Diamond Research Laboratory/Norton Company

2. Europe

The CVD method is used by several groups.

(1) London University (London, England)
(2) Croeckner-Wilhrmsburer (Germany)

3. The Soviet Union, East Europe

(1) Institute for High Pressure Physics (Moscow, Soviet Union)
(2) Institute for Superhard Material, Kiev (Kiev, Soviet Union)
(3) Institute for Physical Chemistry (Moscow, Soviet Union)
(4) Institute for High Pressure Academic Science (Potsdam, Germany)
(5) Institute for Electronic Materials Technology (Warsaw, Poland)

4. China, Asia

(1) Shanghai Silicate Research Institute
(2) Chengtu Science and Technology University
(3) Atomic and Molecular Physics Laboratory, Chilin University
(4) KAIST (Republic of Korea)
(5) National Physical Laboratory (India)
Approach to New Materials R&D

916C3809B Tokyo NEW DIAMOND FORUM: ABSTRACTS OF LECTURES AT 6TH GENERAL SESSION SPECIAL LECTURES in Japanese Jun 91 pp 1-31

[Article by Yuichi Maezawa, Materials Development Promotion Office chief, Research and Development Bureau, Science and Technology Agency: "Approach to New Materials Research and Development at the Science and Technology Agency"]

[Text] Main Lines of Science and Technology Policy Decided Upon by Cabinet on 28 March 1986

1. Basic Policy
   - Science and technology of full creativity
   - Harmonious development of science and technology and the human society
   - Development of science and technology with stress on internationality

2. Promotion of Priority Measures
   - Completion and strengthening of promotion system
   - Completion and strengthening of promotion conditions

3. Promotion of Important Research and Development Areas
   - Implementation of research and development with priority given to elementary and leading science and technology for various research and development areas
   - The prime minister works out research and development programs in succession for every area that must be promoted on a priority basis
Chapter 1. Basic Idea

Chapter 2. Principal Research and Development Goals

Chapter 3. Research and Development Promotion Measures

Basic Idea

(1) Contribution to Development of Economic Society

Foundation for developing other science and technology areas

Motive power for technical innovation toward the development of the human society in the 21st century

(2) Progress in Learning and Remarkable Development of Research Means

Atomic- and molecular-level control of substances and materials

Display of advanced functions through development of subtle processing technology, etc.

(3) Importance Attached to Elementary Research

1) Creation of substances and materials having innovative functions

2) Principle, phenomenon, and theoretical research that become the basis

3) Development of more advanced common and fundamental technologies

(4) Advancing of Application Technology and Existing Materials

(5) Completion of Conditions

Strengthening of elementary research

Positively contributing to international society
Outline of Principal Research and Development Goals in the Report for Inquiry No. 14 of the Council for Science and Technology
Principal Research and Development Goals

Direction of research and development to be pushed with the next 10 years in mind.

1. Probing of New Phenomena and Theoretical Clarification of Various Phenomena

   Understanding of substances and materials to a greater extent of perfection at the microscopic level

2. Creation of Innovative Substances and Materials

   (1) Control of reaction environment

       1) Use of exciting beam
       2) Use of hazardous environment
       3) Control of reaction environments other than those mentioned above

   (2) Control of structure

       1) Hybridization
       2) Purity raising
       3) Composition coordination
       4) Crystal structure control
       5) Surface and interface control
       6) Control of structures other than those mentioned above

   (3) Application of living-body functions

       1) Use of biological substances and materials
       2) Use of substances and materials other than biological ones

   (4) Design of substances and materials

3. Development of Materials Technology Responding to Needs

   Development of materials having advanced functions needed for each of a wide range of areas

   Establishment of processing technology, reliability technology, etc.

4. Development of Common and Fundamental Technologies

   (1) Beam generating technology (including fine processing technology)

   (2) Hazardous environment generating technology

   (3) Analysis and evaluation technologies
Research and Development Promotion Measures

1. How To Promote Research and Development

(1) Elementary research—All research institutions promote various types of research according to their purpose by making use of their respective characteristics and striving for exchanges among themselves.

In that case, it is also necessary to conduct research as a project according to circumstances.

(2) Application development and research—Themes responding to concrete needs will be established, and promoted through pertinent sharing and cooperation among industrial, academic, and government research institutions.

2. Completion of Research and Development Promotion Conditions

(1) Training and securing of personnel, amplification of research expenses, etc.

Research will be evaluated properly, and a soil for training researchers created.

Researchers with superior creativity and international view of things will be trained and secured.

While considering preponderant and efficient distribution of research expenses, efforts will be made more to amplify them.

(2) Strengthening of research and development foundation

1) Acceleration of information distribution

a) Information on the results, etc., of research and development activities will be quickly distributed and efficiently used to the greatest possible extent.

Consideration will be paid to its offering abroad.

b) Amplification of fact database

With internationality taken into account, consideration will be given to standardizing the expression of data.

c) Completion of database networking

2) Completion of development and supply functions of equipment, materials, etc.

a) Smooth supply of specific experimental materials, standard substances, etc.
b) Advanced equipment and facilities, which the private sectors can hardly cope with, will be developed and completed through national efforts.

c) They will be efficiently and effectively used through such means as accelerating joint use.

(3) Promotion of international exchange and cooperation

1) Information exchange, international exchange of researchers, promotion of joint research, acceptance of foreign researchers, cooperation with developing countries, etc.

2) Pertinent response about research and development for which international sharing is required
Government Materials Research and Development Promotion System

Technical Council for Aviation, Electronics, etc.

Prime Minister's Office

Council for Science and Technology

Science and Technology Agency

- National Institute for Research in Inorganic Materials (Research on inorganic materials creation)
- National Research Institute for Metals (Development of new metal materials, reliability evaluation research)
- National Aerospace Laboratory (Development of compound materials for aerospace use)
- Institute of Physical and Chemical Research (International frontier research system [frontier material], large SDR)
- Research Development Corporation of Japan (Exploratory Research for Advanced Technology System)
- Japan Atomic Energy Research Institute (Nuclear fusion reactor materials, clarification and research of radiation damage mechanisms, large SDR, etc.)
- Power Reactor and Nuclear Fuel Development Corporation (Nuclear reactor structural materials research and development, soundness evaluation)
- National Space Development Agency (Space materials, first materials experiment plan [FMI])
- Japan Marine Science and Technology Center (Materials development relating to marine science and technology, research submersible, etc.)
- Japan Information Center of Science and Technology (Database)

National Police Agency

- National Research Institute of Police Science (Inspection, identification, etc. of very small amount and microscopic part of samples)

Hokkaido Development Agency

Civil Engineering Laboratory (Research on concrete components in cold districts)

Ministry of Education

Universities (Scientific research)

Joint use facilities for national universities (Scientific research)

Ministry of Agriculture, Forestry and Fisheries

National Research Institute of Agricultural Engineering (Test and research) relating to materials for agricultural civil engineering facilities

Ministry of International Trade and Industry

Agency of Industrial Science and Technology (Next-generation industrial foundation technology research and development system, large-scale industrial technology research and development system, etc.)

- Research Institute for Polymers and Textiles (Polymers performance raising)
- Electrotechnical Laboratory (Research on application of physical properties and beam of electronic materials, etc.)
- National Chemical Laboratory for Industry (Research and development of fine ceramics, etc.)
- Mechanical Engineering Laboratory (Research on materials physical properties, plastic processing, etc.)
- Government Industrial Development Laboratory, Hokkaido (Inorganic functional materials development)
- Government Industrial Research Institute, Tohoku (Geothermal materials evaluation and research, etc.)
- Government Industrial Research Institute, Nagoya (Ceramics and other materials development)
- Government Industrial Research Institute, Osaka (Leading research on inorganic, organic and compound materials)
- Government Industrial Research Institute, Chugoku (Research on materials evaluation technology under special environment)
- Government Industrial Research Institute, Shikoku (Functional inorganic fibers research, etc.)
- Government Industrial Research Institute, Kyushu (Functional metal materials research, etc.)

Ministry of Transport

Ship Research Institute (Evaluation of strength under various marine environments)

Port and Harbor Research Institute (Port and harbor steel structures corrosion research, etc.)

Ministry of Posts and Telecommunications

National Research Institute of Communications (Telecommunications-related materials research, etc.)

Ministry of Labor

Industrial Safety Institute (Research, etc., of fatigue crack development characteristics, etc.)

Ministry of Construction

Public Works Research Institute (Cement and other materials test, and structural materials test)

Building Research Institute (Construction materials durability improving technology development, and performance evaluation)
ORGANIZATION

Administrative Department
Mitsuo Hayashi, department chief
General Affairs Section
Masahiro Sekita, section chief
Accounts Section
Chiaki Tomita, section chief
Planning section
Shimuya Sakamoto, section chief
Technical Section
Shigehisato Konno, section chief

1st Research Group, Compound zirconium oxide
Shinichi Shiroyori, general researcher, Doctor of Eng.

2d Research Group, Compound tantalum sulfide
Norihiro Ishii, general researcher, Doctor of Science

3d Research Group, Silicon-radical nonoxide
Yoshizo Inomata, general researcher, Doctor of Eng.

4th Research Group, Bismuth-radical oxyfluoride
Shigeo Horiiuchi, general researcher, Doctor of Eng.

5th Research Group, Copper perovskite
Satoshi Okai, general researcher, Doctor of Science

6th Research Group, Metallic typical element chalcogenide
Akira Era, general researcher, Doctor of Engineering

7th Research Group, Titanogallium acid chloride
Yoshinori Fujiki, general researcher, Doctor of Eng.

8th Research Group, Diamond
Yoichiro Sato, general researcher, Doctor of Science

9th Research Group, Tellurate glass
Akihiro Nukui, general researcher, Doctor of Eng.

10th Research Group, Niobic acid barium, sodium
Nobuo Sedaka, general researcher (concurrent service)

11th Research Group, Vanadium bronze
Katsuo Kato, general researcher, Doctor of Science

12th Research Group, Tungsten carbide
Yoshio Ishizawa, general researcher, Doctor of Science

13th Research Group, Rare earth garnet
Shigeyuki Kimura, general researcher, " " "

14th Research Group, Cobalt oxide
Toshinobu Chiga, general researcher, Doctor of Science

15th Research Group, Smectite
Hiromoto Nakazawa, general researcher, " " "

Superhigh Pressure Station
Nobuo Yamaoka, general researcher, Doctor of Eng.

Superhigh Temperature Station
Yusuke Moriyoshi, general researcher, Doctor of Eng.

Unknown Substances Probing Center
Noboru Kimizuka, general researcher, Doctor of Science

Guest researchers
Nobuo Sedaka, director, Doctor of Eng.
Advisers

[continued]
Advisers: Ryoichi Kiriyama, professor emeritus, Osaka University
Hideo Tagai, professor emeritus, Tokyo Institute of Technology
Shunkichi Yamauchi, professor emeritus, Tokyo Institute of Technology

Administrative Council: Kuniomi Umezawa, chairman, Technical Council for Aviation, Electronics, etc.
Hiroshi Okuda, consultant, Fine Ceramics Center Foundation
Mitsuyoshi Kouzumi, director, Science and Technology Joint Research Center, Ryukoku University
Masaru Goto, managing director, Research Development Corporation of Japan
Shinroku Saito, president, Nishi-Tokyo University of Science
Ryoichi Sadanaga, member of the Japan Academy
Sumio Sakuhana, director, Chemical Laboratory, Kyoto University
Taira Suzuki, professor, Basic Engineering Department, Science University of Tokyo
Hiroshige Suzuki, professor emeritus, Tokyo Institute of Technology
Hirokichi Tanaka, former director, National Institute for Research of Inorganic Materials
Kazuyoshi Arai, director, National Research Institute of Metals
Fumiyuki Marumo, director, Industrial Materials Laboratory, Tokyo Institute of Technology
Changes in budget and personnel

Budget, Personnel
Budget

Breakdown of FY 1991 research budget
Science and technology promotion and coordination expenses, personnel expenses, and facility expenses are excluded
FY 1990 SAT promotion and coordination expenses, amount to ¥397,888,000
FY 1990 science and technology promotion expenses amount to ¥33,558,000

Ordinary and common research expenses
21.1% ¥672,729,000

Mining and manufacturing industries technology promotion research
0.7% ¥25,000,000
Pollution control and other test and research
0.5% ¥16,853,000

Commissioned research and test
0.3% ¥9,297,000
Materials strength data sheet
5.4% ¥163,946,000

Atomic energy research
11.8% ¥374,211,000
Special research for metals
4.6% ¥145,536,000
Large research facility completion
3.1% ¥98,328,000

Power supply diversification technology development and evaluation expenses
8.8% ¥25,000,000
General control and operation
4.6% ¥146,518,000

New superconductive materials research and development (debt) ¥394,443,000
43.2% ¥1,370,056,000

Intelligent materials research
3.0% ¥119,068,000

Total
22

(Debt) ¥984,443,000
¥3,172,518,000
Real Estate and Building

<table>
<thead>
<tr>
<th></th>
<th>Head office</th>
<th>Tsukuba branch</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot size</td>
<td>45,072 m²</td>
<td>149,839 m²</td>
<td>194,911 m²</td>
</tr>
<tr>
<td>Building total floor space</td>
<td>37,063 m²</td>
<td>10,309 m²</td>
<td>47,372 m²</td>
</tr>
</tbody>
</table>
"Science and Technology Promotion and Coordination Expenses"

Since the establishment of a state on the basis of science and technology is an important measure of the government, it is important that the Council for Science and Technology, which is Japan's supreme deliberative organ on science and technology policy, strengthen its functions of general coordination on the basis of its great insight and view of things and play a leading role in the science and technology policy. In view of this fact, these expenses have been set for taking measures to comprehensively promote and coordinate important research activities in line with the policy of the Council for Science and Technology.

Six-Item Basic Policy

(1) Promotion of advanced and elementary research.

(2) Promotion of research and development that call for cooperation by multiple organizations.

(3) Strengthening of organic cooperation among industrial, academic, and government organizations.

(4) Promotion of international joint research.

(5) Flexible response to instances where it becomes necessary to conduct research urgently.

(6) Implementation of research evaluation and investigation and analysis of research and development.
Changes in Science and Technology Promotion and Coordination Expenses Budget

State of Operation of FY 1989 Budget (As of August)
Plan Making

Council for Science and Technology

- Policy Planning Committee
  - Concrete operation
    - Determined about April every year

- Basic Investigation Subcommittee
  - (Investigation for science and technology policy planning)

- Research Evaluation Subcommittee
  - (Implementation of evaluation of themes, etc., to be shifted to the second phase)

- Research Investigation Subcommittee
  - (Study on new themes for research)

Themes determined

- Science and Technology Agency

Coordination

- Ministries and agencies

Ministerial and private men of learning and experience
(Demands and opinions)

Plan Making

Through Organic Cooperation Among Industrial, Academic, and Government Organizations Centering Around Research Promotion Committee

Execution system

- Science and Technology Agency

Budget transfer
  - On commission

Ministries and agencies
  - Universities
  - Private sector

Research Promotion Committee

The research promotion committee, which comprises representatives of research conducting organizations and men of learning and experience, is established for every theme, and liaison and coordination are conducted with regard to important matters for research promotion.

26
<table>
<thead>
<tr>
<th>Description of theme</th>
<th>Budget (¥1 million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Research on analysis and evaluation technology using new beam technology for high-performance functional materials</td>
<td>1,940</td>
</tr>
<tr>
<td>(2) International joint research on new materials test and evaluation technology</td>
<td>758</td>
</tr>
<tr>
<td>(3) Research on fundamental technology for creating new functions by purity raising of rare metals</td>
<td>1,126</td>
</tr>
<tr>
<td>(4) Research on fundamental technology for functionally gradient materials development for decreasing thermal stresses</td>
<td>1,034</td>
</tr>
<tr>
<td>(5) Research on development of extremely high vacuum generation, measurement, and utilization technology</td>
<td>651</td>
</tr>
<tr>
<td>(6) Research on vacuum ultraviolet light generation and utilization technology</td>
<td>704</td>
</tr>
<tr>
<td>(7) Research on measurement, evaluation, and control of elementary functions in ultramicro area of substances and materials</td>
<td>599</td>
</tr>
<tr>
<td>(8) Research on database construction for superconductive materials research and development</td>
<td>171</td>
</tr>
<tr>
<td>(9) Elementary research on host and guest reaction practical use technology for new functional materials creation</td>
<td>161</td>
</tr>
<tr>
<td>(10) Research on fundamental technology for material interconnection by ideal surface creation</td>
<td>141</td>
</tr>
</tbody>
</table>
First Successful Creation of Various Functionally Gradient Materials

Since FY 1987, the Science and Technology Agency, under its science and technology promotion and coordination expenses, has been pushing a project entitled "Research on Fundamental Technologies To Develop Functionally Gradient Materials To Reduce Thermal Stress," with a view to developing very heat-resistant materials. This research is aimed at establishing fundamental technologies for creating the functionally gradient materials, which can be used under such environmental conditions as 1,700°C in maximum temperature and 1,000°C in maximum temperature difference, with the thermal protection system of a space plane, engine combustor walls or turbine blades, etc., as targets. As part of this research, through a project comprising domestic manufacturers and university and national laboratories, we have currently succeeded for the first time in the world in test manufacturing a 3-cm disk functionally gradient material that has been put up as the first-phase development target.

This material has been synthesized by controlling its internal composition and microstructure so as to form a continuous and optimal distribution for functional environment. This material has a specific high function that the distribution of its composition and structure is gradient, and is named the functionally gradient material.
Exploratory Research for Advanced Technology

Purpose

This system is aimed at initiating a new idea from elementary research, which will become the source of future science and technology, and also at positively creating the bud of innovative technologies. Out of recognition that prominent individual ability and elastic research management are essential for creative research activities, thoroughly human-centered research setup and operating method have been contributed.
Setup of Commission Development System

Setup of Advanced Technology Development Promotion System
International Frontier Research System

The international frontier research system is characteristic in that it conducts very advanced elementary research (frontier research) from a long-range standpoint by flowingly gathering researchers under an internationally opened system with a view to positively digging out new knowledge that could form the nucleus of technical innovation in the 21st century.

The international frontier research system will carry out research by providing a "research group" for each research area and posting "research teams" classified by research theme in each group under the leadership of a "system chief" who exercises general control over the research.
6. Budget

<table>
<thead>
<tr>
<th></th>
<th>FY 1991</th>
<th>FY 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science and technology research foundation completion measures investigation expenses (Intram ministerial bureaus)</td>
<td>(Debt) 4,981</td>
<td>((Debt) 1,305)</td>
</tr>
<tr>
<td>Radiation light expenses, construction expenses (Institute of Physical and Chemical Research)</td>
<td>2,733</td>
<td>(1,629)</td>
</tr>
<tr>
<td>(Japan Atomic Energy Research Institute)</td>
<td>(Debt) 3,304</td>
<td>((Debt) 994)</td>
</tr>
<tr>
<td></td>
<td>2,160</td>
<td>(1,167)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>(Debt) 8,285</td>
<td>((Debt) 2,299)</td>
</tr>
<tr>
<td></td>
<td>4,896</td>
<td>(2,801)</td>
</tr>
</tbody>
</table>

(The total does not agree due to the calculation by rounding to the nearest whole number.)

(Total amount of main-body facility construction expenses are about ¥100 billion)

7. 8 GeV SOR Conceptual Diagram

[Diagram of a synchrotron electron accelerator and linear electron accelerator, showing connections and labels such as 'Electron', '30m', '440m', 'Electron accumulation ring', and 'Radiation light.']
### 8. Foreign Large Radiation Facility Projects

<table>
<thead>
<tr>
<th>Project name</th>
<th>Place of facility</th>
<th>Energy</th>
<th>Scheduled completion</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>APS (U.S.)</td>
<td>Argonne National Laboratory</td>
<td>7 GeV</td>
<td>1995</td>
<td>Joint project by France, Britain, West Germany, Italy, Spain,</td>
</tr>
<tr>
<td>ESRF (Europe)</td>
<td>Grenoble (France)</td>
<td>6 GeV</td>
<td>1994</td>
<td></td>
</tr>
</tbody>
</table>

APS (Advanced Photon Source)
ESRF (European Synchrotron Radiation Facility)

List of Inquiries and Reports on Materials at the Technical Council for Aviation, Electronics, Etc.

<table>
<thead>
<tr>
<th>Inquiry</th>
<th>Date of inquiry</th>
<th>Date of report</th>
<th>Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 5 &quot;On Measures To Promote Comprehensive Research and Development on Hazardous Environment Science and Technology and Its Related Materials S&amp;T&quot;</td>
<td>13 May 79</td>
<td>28 Aug 80</td>
<td>Guideline for research on generation of such hazardous environments as very low temperature, ultrahigh temperature, ultrahigh pressure, and ultrahigh vacuum, and on creation, etc., of new materials using hazardous environments.</td>
</tr>
<tr>
<td>No. 7 &quot;On Promotion of Comprehensive Research and Development on Creation of New Materials Based on the Materials Design Theory&quot;</td>
<td>25 Jan 83</td>
<td>13 Sep 85</td>
<td>Guideline for research on theoretical foundation, materials design technology, structure control technology, analysis and evaluation technology, database, etc., as for materials design, the efficient materials development technique.</td>
</tr>
<tr>
<td>No. 9 &quot;On Priority Themes for Advancing Measurement and Control Technology Relating to New Materials R&amp;D, and Their Promotion Measures&quot;</td>
<td>19 Mar 85</td>
<td>28 Mar 86</td>
<td>Guideline for research on measurement and control technology relating to creation of new materials, such as microscopic-level composition and structure analysis and advancing of control technology by use of beam technology, finding of new phenomena, and new measurement technique using such phenomena.</td>
</tr>
</tbody>
</table>

33
<table>
<thead>
<tr>
<th>Inquiry</th>
<th>Date of inquiry</th>
<th>Date of report</th>
<th>Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 11 &quot;On Promotion of Comprehensive R&amp;D on the Advancing of Optical Science and Technology&quot;</td>
<td>15 Aug 86</td>
<td>14 Jul 87</td>
<td>Guideline for research on measures for advancing optical science and technology, such as laser beam and synchrotron radiation, technologies for using it for substances and materials, such as measurement and processing technologies using light, etc.</td>
</tr>
<tr>
<td>No. 13 &quot;On Promotion of Comprehensive R&amp;D on Creation of New Substances and Materials Capable of Functioning by Intelligently Responding to Environmental Conditions&quot;</td>
<td>14 Jul 87</td>
<td>30 Nov 89</td>
<td>Guideline for research aimed at clarifying the concept of such matters as creation of new substances and materials having the so-called intelligent functions, such as environment adaptation function, self-repairing function, and self-multiplying function.</td>
</tr>
<tr>
<td>No. 16 &quot;On Promotion of Comprehensive R&amp;D on the Advancing of Analysis and Evaluation Technology Relating to Materials Development&quot;</td>
<td>11 Mar 91</td>
<td></td>
<td>For promoting establishment and unification of new materials analysis and evaluation technologies under the efficient cooperation of the related organizations, deliberation is under way to acquire a guideline for research on the advancing of analysis and evaluation technologies relating to materials development.</td>
</tr>
</tbody>
</table>

Background, necessity

• Swelling of software in information society
  → Software built-into materials

• Capability limit of silicon-based semiconductors
  → Realization of (intelligent) information processing in materials

• Demands for materials that control themselves according to such living-body conditions as growth, cure, and condition of disease

• Demand for materials themselves to have self-diagnosing and self-repairing properties in such hazardous working environments as aviation, space, and atomic energy

Technical realizability

• Atomic- and molecular-level structure and function control

• Clarification and control of meso-scopic level (the level of massive group of about 100-10,000 atoms having specific properties) structure and function

• Biological function clarification and practical use of its results

Creation of substances and materials based on new concept

Materials themselves make multiple responses according to changes in environmental conditions.
Multiple functions (functions of responding by feeling, memorizing, and judging environmental changes) are connected and microscopically realized in materials.
(Realization in materials of atomic- and molecular-level systems that feel, judge and work.)

• Optical materials that change refractive index, transmission factor, reflecting factor, etc., according to environmental changes (Information, electronics area)

• Sensor and electronic materials that recognize multiple stimulations and make proper judgment according to changes in the environment conditions (Information, electronics area)

• Capsule materials that release medicines according to the body conditions (Medical area)

• Medical materials, such as veins and bones, that grow or decompose according to the situation of growth or cure of the living body (Medical area)

• Structural materials that foresee and prevent the development of cracks (Aviation, space, atomic energy area)
Advanced structural materials for aviation, space, and atomic energy use, which, in case of occurrence of deterioration, damage, etc., judge the condition of fulfillment of functions and the life of materials themselves, give a warning by such means as emitting sound and electrons, and restrict their development or effect self-repairing.

Condition of material changes depending on speed, strength, etc., of such forces as stimulation and impact.

C. Force

Expansion of the crack tip

Deterioration is made known outside by coloring, electron emission, etc.

Self-diagnosing properties
Foreseeability, predictability

Strength change, volume swelling, etc., at the crack tip restrict the development of crack.

Tip becomes round, tip hardens.

Gape, etc., are filled by melting out of components.

Self-repairing properties

Medical materials such as veins and bones implanted in the living body, which not only have the living-body affinity, but also grow or decompose according to the condition of growth or cure of the living body.

Living-body bone

Intelligent artificial bone

Self-replicating properties

By taking in Ca++ and other substances in living body, multiplication is made in line with living body growth.

Self-decomposing properties

Artificial living-body bone

To conduct operation again following the growth or cure of the living body is not needed

Optical materials for optical computer that can control refractive index, transmission factor, reflection factor, etc., by changing materials' optical characteristics according to changes in electric field, magnetic field, temperature, etc., automobile window glass and verifocal lens.

Response is made intelligently by identifying the amount, strength (wavelength), temperature, etc., of light

Environmental response characteristics

Molecular structure change

Light absorbed and stored as energy.

Computation, memory, amplification, etc., of light signals are carried out by materials themselves, and will thus be applied to future information processing and communications.

Not only is a fixed amount of light kept, but also the refractive index, reflection factor, etc., of materials are changed.
Superconductive Materials Research Multicore Project

Basic idea

- Stress laid on elementary and fundamental research
- Figureless laboratory putting existing potential to practical use
- Research system opened both at home and abroad
- Research system mainly composed of researchers

Promotion Mechanism of Project

Promotion Committee
- Conducts study on basic matters relating to promoting the project
- Comprises core-organization representatives, learned men, etc.
- Held at the Research and Development Bureau, Science and Technology Agency

Core Leaders Liaison Conference
- Study on necessary matters for concrete promotion of projects, and securing of close communication among research cores
- Composed of core leaders, and learned men, etc., as need
- Held at the Materials Development Promotion Office, General Research Section, Science and Technology Agency

(Research core)

Working Group
- Acceleration of joint research, etc.
  (Preliminary arrangement of research programs, research information exchange, etc.
  Composed of core researchers, etc.
  Held at each core as the occasion may demand

Research core
(Implementation of joint research, etc.)

- Foreign research institutions
- Private research institutions
- Universities

Other research institutions

Other national laboratories
## Research Cores

<table>
<thead>
<tr>
<th>Target area</th>
<th>Research core</th>
<th>Core institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory Database</td>
<td>Theory Database</td>
<td>National Research Institute of Metals</td>
</tr>
<tr>
<td>Technology development</td>
<td>Technology development</td>
<td>Research Development Corporation of Japan</td>
</tr>
</tbody>
</table>

(as of May 1991)
## Diamond Synthesis Research

### High-Pressure Synthesis

<table>
<thead>
<tr>
<th>Year</th>
<th>National Institute for Research of Inorganic Materials</th>
<th>Other research institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td></td>
<td>U.S. General Electric Co. invented the diamond grain synthesis method using metallic catalysis method</td>
</tr>
<tr>
<td>1969</td>
<td>8th Research Group (carbon) started diamond high-pressure synthesis research</td>
<td>GE successfully grew a large-sized diamond crystal by the metallic catalysis temperature-difference method</td>
</tr>
<tr>
<td>1970</td>
<td>Diamond grain high-pressure synthesis was made by the metallic catalysis method</td>
<td>GE established the sintered diamond synthesis method</td>
</tr>
<tr>
<td>1975</td>
<td>Large-sized diamond crystal was successfully grown by the metallic catalysis temperature-difference method</td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>Superhigh Pressure Station started operating, and conducted high-pressure synthesis technology development research</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>High-purity sintered diamond was successfully synthesized</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>Diamond synthesis method using nonmetallic catalysis was invented</td>
<td></td>
</tr>
</tbody>
</table>

### Vapor-Phase Synthesis

<table>
<thead>
<tr>
<th>Year</th>
<th>National Institute for Research of Inorganic Materials</th>
<th>Other research institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td></td>
<td>U.S., Soviet Union, etc.: Synthesis by vapor-phase method, ion-beam method tried</td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td>Soviet Institute of Physical and Chemical Research: Synthesis by vapor-phase method</td>
</tr>
<tr>
<td>1969</td>
<td>7th Research Group began diamond research</td>
<td></td>
</tr>
<tr>
<td>1974</td>
<td>Diamond Research Group began operation, began vapor-phase synthesis research</td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>Vapor-phase synthesis by thermal filament method successful</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>Vapor-phase synthesis by microwave plasma CVD successful</td>
<td></td>
</tr>
</tbody>
</table>
Technical Problems Relating to Diamond Vapor-Phase Synthesis

- Improvement in synthesis speed
- Area increasing, homogenizing
- Improvement in nucleus development density and bond strength
- Defect control
- Impurities control
- Improvement in epitaxy technology
- Diamond film evaluation technology

- END -