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# Space Environments, Microgravity, Materials Discussed

## Space Utilization Plans

*43067611 Tokyo CERAMICS JAPAN in Japanese Apr 87 pp 262-268*

[Article by Tetsuhisa Shirakawa, Office of Space Station Program, Research and Development Bureau, Science and Technology Agency: "Japanese Space Activities and Utilization of Space Environment"]

[Excerpts] Space utilization used to be an issue in fields such as communications, broadcasting, and meteorology. Such space utilization counts on the high "altitudes" of artificial satellites. Recently, additional interest has been shown in the utilization of such aspects of the space environment as microgravity and high vacuum. More concretely, interest is present regarding the possibility of material development, e.g., crystal growth, in a microgravitational environment where there is little difference in gravity between different materials and where no thermal convection is caused.

Movements in that direction are already active in the United states and Europe. In Japan, they are also tackling space environment utilization, regarding it as a new field of space utilization, coming after rockets and artificial satellites. This paper will discuss the present status of Japanese space utilization programs (Figure 2).

### 3. Future Space Experiment Plans of Japan

#### 3.1 First Material Processing Test (FMPT)

The FMPT is the first space experiment plan to be carried out by Japan utilizing the Spacelab. It is scheduled to be conducted in 1991.

To decide on the contents of the FMPT, a special section for determining the subjects for the first material experiments (headed by Shinroku Saito) was inaugurated within the space development committee in December 1979. Subsequently, in July 1984, a total of 34 experiment subjects comprising 22 material experiment subjects and 12 life science experiment subjects were selected by studying the proposals sent in from throughout the country. The main conditions which had to be met for each subject to be selected were as follows: the experiment is expected to produce great scientific and technological benefits; the technique required to carry out the experiment is available; and the experiment does not involve any safety problems.

The Japanese scientists to be sent into space to carry out the FMPT have already been selected and other preparations are progressing; development of the experiment equipment to be loaded in the Spacelab is in progress and preliminary experiments are being conducted.

#### 3.2 IML (International Microgravity Laboratory) Plan

The IML plan is to be carried out under international collaboration utilizing NASA's Spacelab. Whereas NASA offers space flight opportunities, the countries participating in the plan are to prepare the apparatus to be installed in the Spacelab for shared use by scientists of both the participating countries and the United States.

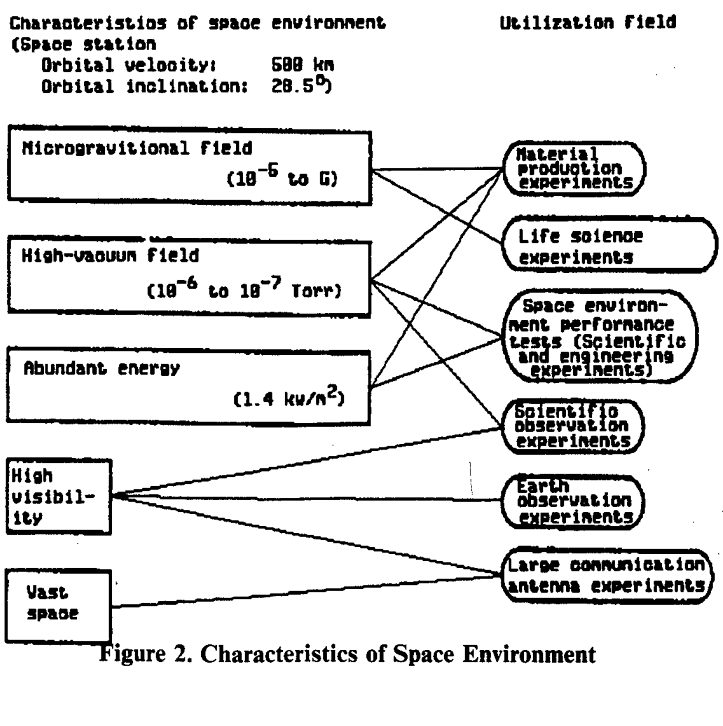


Figure 2. Characteristics of Space Environment

In this way, opportunities for carrying out space experiments can be created efficiently for the respective parties. At present, the IML-1 plan is scheduled to be carried out in April 1980. Subsequent flight plans are being studied. Japan's participation in the IML plan is being negotiated between Japan and NASA.

### 4.3 Space Station Mission Requirements of Japan

The space station program offers diversified experiment means to the users. An important factor of the program is determining the users' technical requirements. To probe the users' requirements, the special section for the space station program conducted a survey, including researchers working at national laboratories and universities, and different private institutions, in June 1983. Through the survey, a total of 165 research subjects were brought forth. The special section classified them into six fields: scientific observation, earth observation, communications, material experiments and production, life science, and scientific engineering. Eventually, they were further boiled down into 38 subjects comprising Japan's space station mission requirements (Table 2).

To make Japan's participation in the space station program significant, it is essential that the users' requirements be adequately reflected in the space station design. Based on such recognition, a space station utilization program (mission requirement) workshop was inaugurated in October 1985 in order to deepen the users' understanding of the space station program and to grasp their technical requirements so that the requirements would be reflected in the preliminary design. The workshop has already been held five times. In the first session, another survey of users' needs was conducted to update the mission requirements. As a result, 162 additional subjects were proposed. Of them, the proportion of those proposed by researchers in the private sector was as high as double that recorded in the first survey. Namely, about 40 percent of the new proposals were made by private-sector researchers. Therefore, it is assumed that the space station utilization plan is being recognized by the population with increasing familiarity (Table 3).

The space station utilization plan is still just taking shape in Japan, and many more ideas for space station utilization are yet to be brought forth. We, therefore, count on the prospective (or potential) Spacelab users to come out with more original subjects of research to make the most of the space environment.

### 4.4 Japan's Participation Plan

In an interim report on Japan's participation in the space station program compiled by the special section for the space station program, it is stated that, in participating in the program, Japan is to build a multipurpose experiment module (JEM: Japanese experiment module) which can meet the extensive needs of Japanese Spacelab users while enabling Japan to accumulate space technologies. The JEM consists of a pressurized section, an exposure section and a supply section. Each section is outlined in the following.

| | Initially proposed subjects (1) | Additionally proposed subjects (2) | (1 + 2) |
|---|---|---|---|
| Scientific engineering experiments | 29.7% | 22.9% | 26.3% |
| Life science | 24.8 | 31.5 | 28.1 |
| Material processing/production | 21.8 | 25.9 | 23.9 |
| Communications | 4.8 | 4.3 | 4.6 |
| Earth observation | 10.9 | 14.2 | 12.5 |
| Scientific observation | 7.9 | 1.2 | 4.6 |
| Total subjects | 165 | 162 | 327 |
| Private enterprises | 18.1% | 39.5% | 28.8% |
| National laboratories | 49.8 | 27.2 | 38.5 |
| Universities | 19.4 | 24.1 | 21.7 |
| Public agencies | 1.8 | 0.6 | 1.2 |
| Special corporations | 10.9 | 8.6 | 9.8 |
| Total subjects | 165 | 162 | 327 |

(1) The pressurized section is a laboratory where crewmen can make experiments in their ordinary attire. It is to be used for material experiments and life science experiments made in a microgravity environment. Manipulator operation for conducting experiments in the exposure section is also to be performed in this section.

(2) The exposure section consists of a laboratory table exposed in space. It is to be used to make scientific observation, earth observation, communications experiments, scientific and engineering experiments, and some material experiments.

(3) The supply section is used to supply, house, or transport samples, gases or apparatus for use in the experiments mentioned above.

### 4.5 Significance of Japan's Participation

Japan's participation in the space station program will enable scientists to stay in the laboratory in space for extended periods of time, enhancing the power supply and enlarging the work space available to them, and thereby allowing the sphere of their space activities to be drastically expanded. Its participation in the space station program is, therefore, expected to cause new knowledge and information to be obtained in the field of space

| Field | Subject | Outline |
| --- | --- | --- |
| Scientific observation | | Astronomical observation to be made over a wide range of wavelengths and development of techniques to support such observation; to be made utilizing the characteristics of space and space station unaffected by the earth's atmosphere. |
| S-1 | Astronomical observation platform | |
| S-2 | Infrared telescope | |
| S-3 | High-energy cosmic rays | |
| S-4 | Gamma-ray burst | |
| S-5 | Line gamma-ray observation | |
| S-6 | X-ray telescope | |
| S-7 | Interference device for gravitational radiation | |
| S-8 | Space VLBI | |
| S-9 | Solar activity monitoring telescope | |
| S-10 | Astronomical observation by submillimetric waves | |
| S-11 | Aurora and SAR arc photographing device | |
| Earth observation | | Development of various types of observation devices, such as composite and large sensors, as well as related observation techniques, and application of such devices and techniques to marine observation and land zone observation to be made using free fliers. |
| E-1 | Distance measurement by laser | |
| E-2 | Technical tests for earth observation | |
| E-3 | Atmosphere observation | |
| E-4 | Marine information realtime communication system | |
| E-5 | Earth observation data processor | |
| E-6 | Land zone observation | |
| Communications | | Assembly of large antennas, function tests on them, and assembly of large communications satellite. |
| C-1 | Research on measures against RFI in space | |
| C-2 | Function tests on high-precision specular surfaces of large antennas | |
| C-3 | Space communication technique tests | |
| C-4 | Function tests on gravity-stabilized-type antennas | |
| C-5 | Large geostationary satellite assembly and maintenance technique development and experiments | |
| Material experiment/production | | Production in space environment, e.g., in microgravity environment, of new materials unobtainable on earth, and experiments in relevant fundamental science and on production techniques. |
| M-1 | Fundamental scientific experiments on materials | |
| M-2 | New material production experiments | |
| M-3 | Tests on practical methods of material production in space environment | |
| Life Science | | Biosample separation and incubation unperformable on earth, and other space medicine experiments and closed ecosystem experiments to be made for promotion of life science in space environment and development of its practical applications. |
| L-1 | Biology | |
| L-2 | Space medicine | |
| L-3 | System for life maintenance in ecosystem | |
| L-4 | Biotechnology | |
| Scientific engineering experiments | | R&D on new space technologies needed to establish space technologies and develop space stations in the future. Development of solar energy conversion and utilization technologies. |
| T-1 | Space environment performance tests | |
| T-2 | Technology for large antenna systems | |
| T-3 | Large structure assembly techniques | |
| T-4 | Space energy experiments | |
| T-5 | Space robot technology | |
| T-6 | Bus module system technology | |
| T-7 | Two-dimensionally unfolding solar cell arrays | |
| T-8 | Light-condensing heat-engine generator | |
| T-9 | Liquid storage and transfer technology | |
| T-10 | Future space power generation system | |

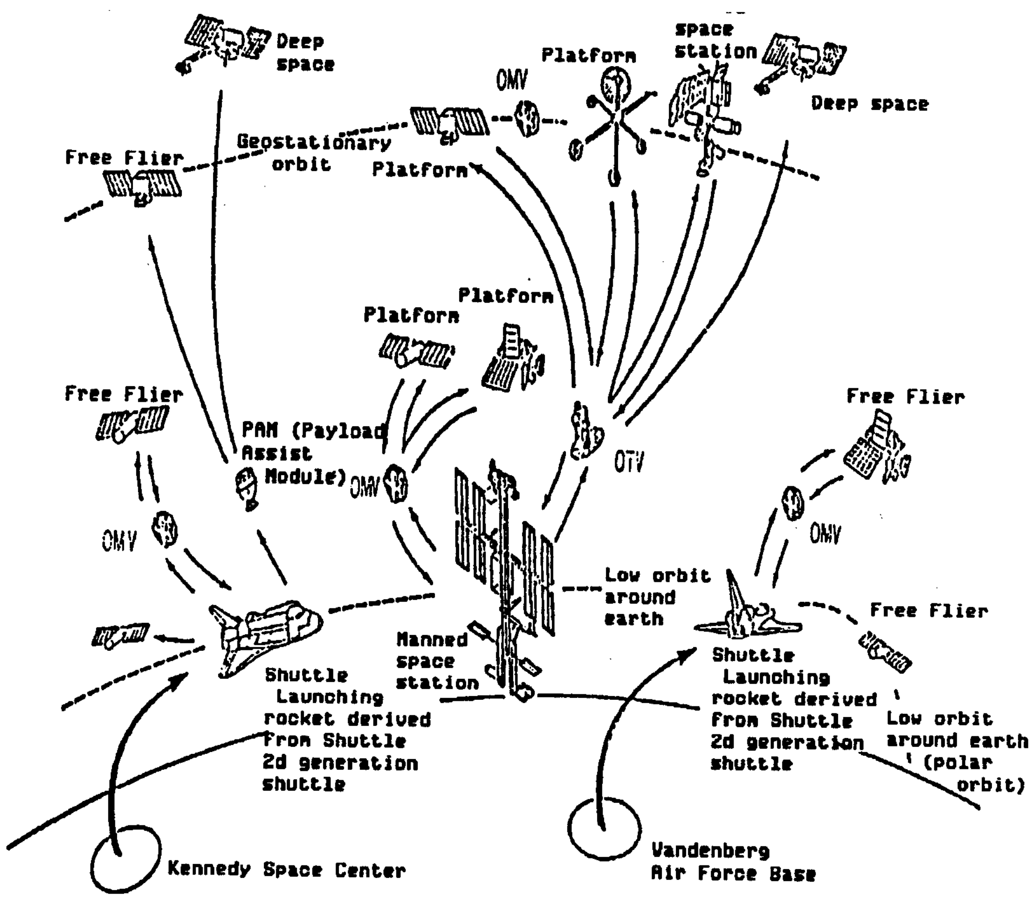


**Figure 6. Components of Space Infrastructure**

science, including astronomical and terrestrial observation. It is also expected that such new knowledge and information will prove useful in advanced technological fields, for example, in the development of new materials or in the production and refinement of medicines in a microgravity environment. Therefore, Japan's participation in the space station program is expected to result in the creation and enlargement of a new sphere of industrial activities. Developing a space station, on the other hand, must be accompanied by a high level of technological development, so that it may eventually contribute toward further advancing scientific technologies. The space station program may be said to call for the building of an asset of mankind in space by international cooperation. We think that participating in such a program will give Japan opportunities to play an increasingly greater role in international society.

### 5. Future Space Infrastructure

As mentioned above, Japan will build a multipurpose experiment module (JEM) while participating in the space station program. In the United states as well as Europe, expectations for future space utilization have recently been rising conspicuously. In the "Space Frontier Development," a report compiled by the national space committee of the United States in 1986, subjects to be promoted in the next 50 years are indicated. The subjects range over diversified fields. They include transportation along orbits around the earth, as well as between planets, and the construction of space ports and stations on the moon and Mars.

As for the direction of future space development, Japan is at the stage where it has started planning. As the needs for space activities increase in the future, it will become urgently necessary for Japan to put in order a new space infrastructure incorporating for example, a transportation system, a communications system, and space factories, needed to support enhanced space activities (Figure 6).

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## Space Experiment Plan FMPT

*43067611 Tokyo CERAMICS JAPAN in Japanese Apr 87 pp 269-276*

[Article by Toshihiko Kikuyama, National Space Development Agency of Japan (NASDA): "Curious Phenomena in Space Environment and Their Applications to Space Experiments"]

[Excerpt] 4. Japanese Space Experiments—First Material Processing Test

In Japan, the National Space Development Agency is playing a central role in promoting the planning of space experiments to be conducted utilizing the Space Shuttle/Spacelab. The plan being promoted is called the First Material Processing Test (FMPT). According to the plan, Japan is to install its experiment apparatus in the Spacelab, occupying about half the space available there, with the experiments conducted by a Japanese astronaut.

Figure 3 shows a flowchart of the FMPT plan from experiment subject selection to experiment apparatus fabrication, astronaut screening and training, Space Shuttle launching, space experiment, and experiment result analysis.

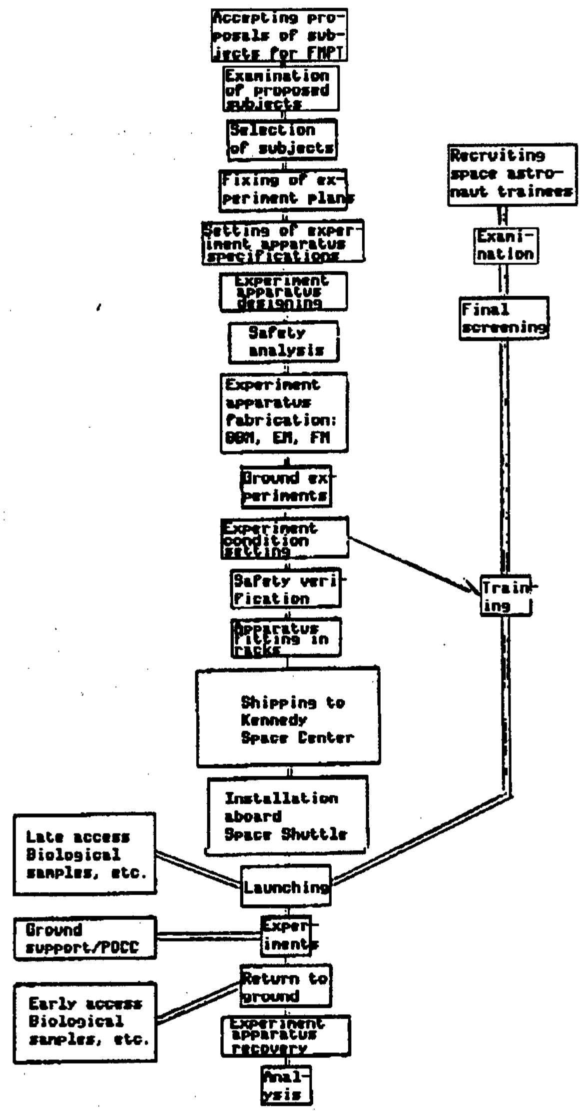


**Figure 3. Flowchart of Japanese FMPT (First Material Processing Test) Program**

### 4.1 Experiment Subjects for FMPT

For the FMPT, 34 experiment subjects have been selected. They are broadly classified into two groups, one comprised of 22 material experiment subjects, and the other consisting of 12 life science experiment subjects. The 22 material experiment subjects are outlined in Table 3. All the material experiment subjects selected are intended to make use of the foregoing effects of a microgravity environment. The life science experiment subjects also are largely comprised of ones utilizing the effects of a microgravity environment, but they also include, for example an experiment to observe the effects of cosmic rays on living things and another experiment to investigate the mechanisms of living things' body clocks; the latter experiment makes use of the fact that the Space Shuttle circles the earth every 90 minutes, letting the day and night cycle repeat 16 times every 24 hours.

**Table 3. Outline of Subjects for FMPT in Material Science Field**

| Subject Number/Subject | Proposed by | Experiment Apparatus | Field Involved | Space environment characteristics utilized |
|---|---|---|---|---|
| M-1 Crystal growth of narrow band-gap ternary compound semiconductor $Pb_{1-x}Sn_xTe$ under microgravity | Tomoaki Yamada, NTT | Temperature gradient-type electric furnace | Infrared sensor | No specific-gravity difference |
| M-2 Test manufacture of large single crystal of PbSnTe by zone melting method under microgravity | Yusaburo Segawa, Institute of Physical and Chemical Research | Image furnace | Infrared sensor | Effect of surface tension; No specific-gravity difference |
| M-3 Manufacture of compound semiconductor crystal by floating zone-melting method | Isao Nakaya, National Research Institute for Metals, STA* | Image furnace | Large single crystals | Effect of surface tension; No specific-gravity difference |
| M-4 New superconducting alloy production by melting method | Kyoji Tachikawa, National Research Institute for Metals, STA | Continuous-heating electric furnace | Superconducting magnets | No specific-gravity difference |
| M-5 Mechanism of formation of deoxidized products in composite-deoxidized steel ingots | Toshiyoshi Aritomi, National Research Institute for Metals, STA | High-temperature pressurization-type electric furnace | Improvement of steel production technique | No buoyancy |
| M-6 Production of particle-dispersed alloy | Sennosuke Takahashi, National Research Institute for Metals, STA | High-temperature pressurization-type electric furnace | Super heat-resistant alloys | No specific-gravity difference |
| M-7 Structure and construction of alloy and compound produced by causing two kinds of molten metal to interdiffuse and solidify | Kenichi Hoshimoto, National Research Institute for Metals, STA | Continuous-heating electric furnace | Development of new alloy | No specific-gravity difference |
| M-8 Behavior of glass at high temperatures | Naohiro Soga, Kyoto University | Image furnace | Development of new glass | Effect of surface tension |
| M-9 Growth of silicon spherical crystal and oxidation of its surface | Nobu Nishinaga, Tokyo University | Spherical crystal growth experiment apparatus | Analysis of silicon properties | Effect of surface tension |
| M-10 Research involving solidification and growth of nonmixing alloy | Akihiko Kamio, Tokyo Institute of Technology | Temperature gradient-type electric furnace | Crystal-controlled alloys | No thermal convection; No specific-gravity difference |
| M-11 Research involving production of high-rigidity super-low-density composite material composed of carbon fiber and aluminum alloy | Asao Suzuki, Tokyo Institute of Technology | Continuous-heating electric furnace | Super-light, high-strength materials; materials for aircraft and spacecraft | No specific-gravity difference |
| M-12 Research involving liquid-phase sintering mechanism | Hidero Obara, Tokyo University | High-temperature pressurization-type electric furnace | Cemented alloys, composite materials | No thermal convection |
| M-13 Production of Si-As-Te amorphous semiconductor under microgravity | Yoshihiro Hamakawa, Osaka University | Continuous-heating electric furnace | Optoelectronics materials, high-efficiency solar cells | No specific-gravity difference |
| M-14 Research involving vapor-phase metallic condensation mechanism under microgravity | Nobuhiko Wada, Nagoya University | Metallic microparticle generation experiment apparatus | Functional alloys, electronics materials | No thermal convection |

Table 3. Outline of Subjects for FMPT in Material Science Field

| Subject Number/Subject | Proposed by | Experiment Apparatus | Field Involved | Space environment characteristics utilized |
|---|---|---|---|---|
| M-15 Research involving behavior of liquid drips in sound wave floating apparatus and their acoustic interference history | Tatsuo Yamanaka, National Aerospace Laboratory, STA | Liquid drip manipulation experiment apparatus | Technique for handling liquid using no container | Containerless, contactless condition |
| M-16 Analysis of bubble behavior in field accompanied by temperature gradient and ultrasonic standing wave | Hisao Azuma, National Aerospace Laboratory, STA | Fluid-physical experiment apparatus | Development of fluid apparatus for use in space | No buoyancy |
| M-17 Research involving invisible-range optical materials | Junji Hayakawa, Agency of Industrial Science and Technology, MITI | Sound wave floating furnace | Infrared transmissive optical fiber | Containerless, contactless condition |
| M-18 Research involving Marangony convection in material production process under microgravity | Shintaro Shioji, Ishikawajima-Harima Heavy Industries | Fluid-physical experiment apparatus | Material production in space | No thermal convection |
| M-19 Research involving eutectic alloy solidification under microgravity | Atsumi Ono, Chiba Institute of Technology Continuous-heating electric furnace | Improved alloys, functional alloys | No thermal convection | |
| M-20 Samarskitei synthesis under microgravity | Shunji Takegawa, National Institute for Research in Inorganic Materials, STA | Image furnace | High-efficiency catalyst | No specific-gravity difference |
| M-21 Growth of organic metallic crystal in microgravity environment | Hiroyuki Anzai, Agency of Industrial Science and Technology, MITI | Organic crystal growth experiment apparatus | Superconductors, electronic functional materials | No thermal convection |
| M-22 Production of compound semiconductors in microgravity environment (Research involving InGaAs) | Shigeo Murai, Sumitomo Electric Industries | Temperature gradient-type electric furnace | Laser emitting/receiving elements | No specific-gravity difference |

*STA: Science and Technology Agency

### 4.2 Experiment Apparatus

Table 3 also lists the experiment apparatus to be prepared for conducting the experiments under the FMPT plan. The temperature gradient-type electric furnace, image furnace, continuous-heating electric furnace, and the high-temperature pressurization-type electric furnace are going to be used in experiments for two or more subjects. Figures 4 and 5 illustrate single-crystal production using the temperature gradient-type electric furnace. Figures 6 and 7 show single-crystal production by the floating zone-melting method using the image furnace.

The experimental apparatuses are to be set on double racks for installation in the Spacelab. For the FMPT, three double racks are to be prepared. Two of them, shown in Figure 8, are for holding the apparatus to be used in material experiments; the third, shown in Figure 9, is for the apparatus to be used in life science experiments.

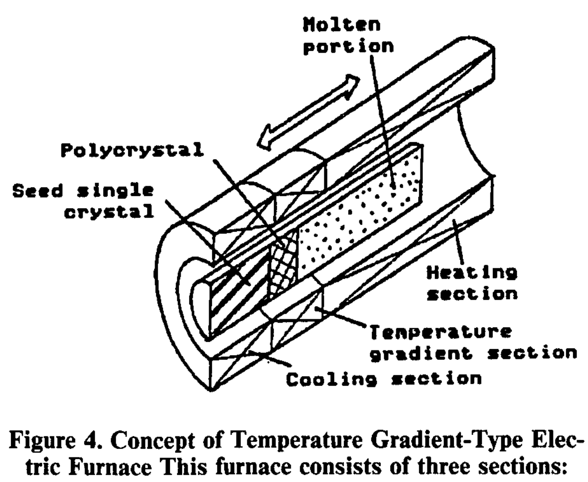


**Figure 4. Concept of Temperature Gradient-Type Electric Furnace This furnace consists of three sections: heating section, temperature gradient section, and cooling section. It moves along the sample**

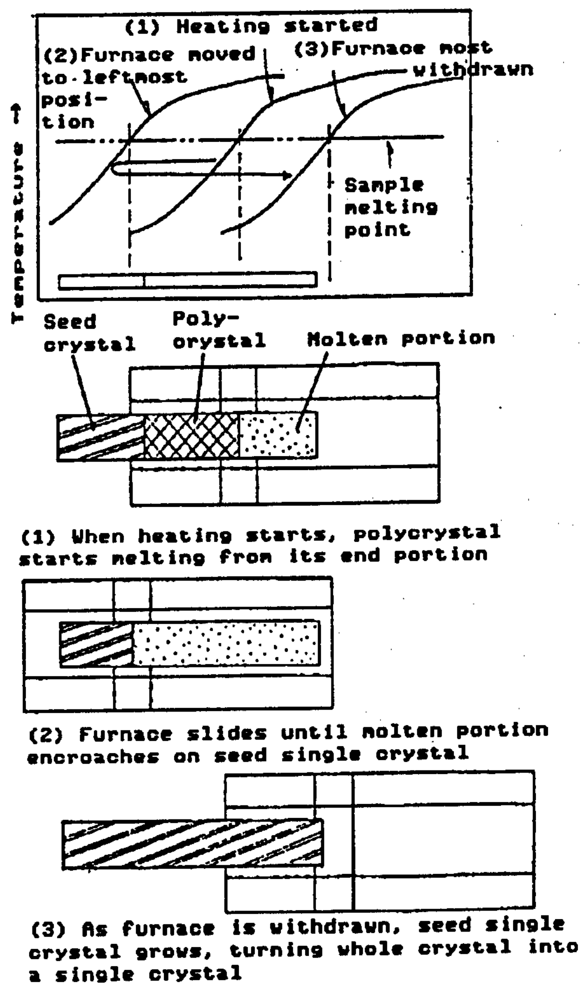


**Figure 5. Production of Single Crystal Using Temperature Gradient-Type Electric Furnace**

Development of the experiment apparatus is going to be carried out in three stages. The first stage is called "BBM." Its purpose is to make certain that the theory behind each apparatus to be fabricated works. The second stage is called "EM" (engineering models). Its purpose is to produce an engineering model for each apparatus, that is, a model of each apparatus nearly the same as the corresponding "FM" (flight model) that will be used for actual space experiments. When the engineering models are produced, they will be used to simulate space experiments on the ground. In addition, vibration tests and electrical noise tests will also be conducted on them. The results of each simulation and testing will be reflected in the fabrication of the flight models. Figure 10 [omitted] shows an engineering model of a temperature gradient-type electric furnace undergoing a simulation test.

When the flight models of experiment apparatus are fabricated, they will be placed in the racks. They will then be shipped to the Kennedy Space Center for installation in the Spacelab about a year before the scheduled launch date.

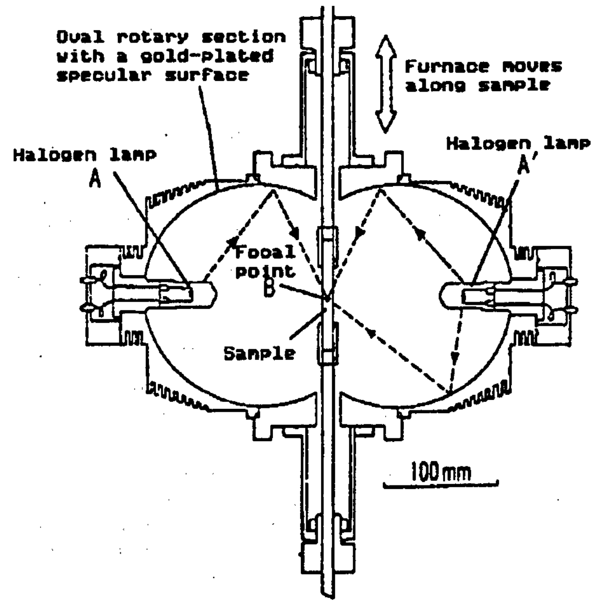


**Figure 6. Concept of Image Furnace The image furnace consists of two oval rotary sections. Their specular surfaces have a common focal point, while each has another focal point of its own. A sample to be processed is placed at their common focal point B, whereas two tungsten halogen lamps A and A' are set at their individual focal points, respectively. The light emitted from each halogen lamp is reflected at the gold-plated specular surface of the corresponding rotary oval section and converges on the common focal point B. As a result, the sample is locally heated, causing a floating melting zone to be formed.**

### 4.3 Effects on Advanced Technology Development

It was stated in Section 2 that the results of space experiments can include the production of semiconductors, alloys, composite materials, and medicines. In the present stage, however, it is, unfortunately, impossible to produce such materials in space, excluding some medicines, on a commercial basis. This is because space experiments require a large amount of launching expenses, equivalent to the freight expenses involved in ordinary commercial transactions, to be paid. For the FMPT being planned by Japan, Japan is to pay about Y10 billion to NASA in expenses to cover the launching of a Japanese astronaut and Japanese experiment apparatus, which weigh about 1.4 tons, aboard the Space Shuttle, and a week of space experiments. When the experiment apparatus production cost and the astronaut training fee are added to the above expenses, the total amount required to carry out the FMPT plan exceeds Y20 billion.

Even though such a large amount of money is involved, the amount of materials, such as semiconductors and alloys, producible through the space experiments is only

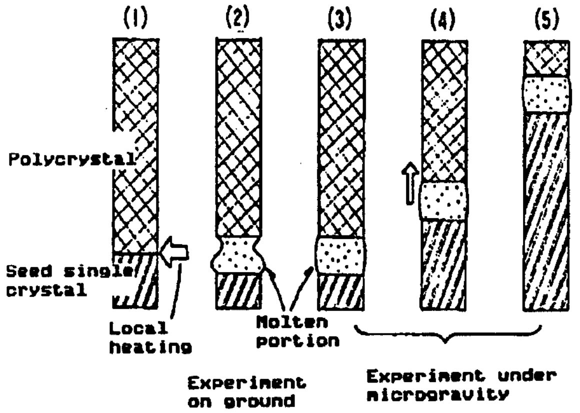


**Figure 7. Production of Single Crystal by Floating Melting Zone Method (1) The interface between the seed single crystal and the polycrystal (raw material) is heated locally. (2) On the ground, where gravity is greater than surface tension, a stable floating melting zone cannot be formed as the molten portion of the crystal tends to sag or fall. (3) In a microgravity environment in space, a stable floating melting zone can be formed due to the effect of surface tension. (4) The furnace is moved to cause the floating melting zone to shift toward the polycrystal side. (5) As the floating melting zone moves, the seed single crystal keeps growing, producing a larger single crystal.**

2 kg or so at the most. Therefore, even if the launching expenses alone of Y10 billion are taken into account, the expenses amount of Y10 billion per 2 kg of material, i.e., Y5 million per gram of material. Even in the United States, a leader in the field of space experiments, only very special medicines are produced in space on a commercial basis.

At the present stage, the purpose of space experiments is not to produce tons of materials in space. Space experiments are presently regarded as a means of making breakthroughs in scientific or engineering research. In technical R&D, cases often occur in which, although the progress of the R&D work on a certain idea is slow when the feasibility of the idea s uncertain, the same work can be advanced with relative ease once the idea is determined to be feasible.

As for optical fiber development, for example, it is expected that the potential of fluoride-based optical fibers for use as super-low-loss optical fibers will exceed fused quartz optical fibers. However, it is more difficult to obtain high-purity fluoride-based optical fibers, so, in the present stage, fluoride-based optical fibers are about 20 times inferior to fused quartz optical fibers in terms of performance.

If fluoride-based glass with super-high purity can be produced without using a crucible in a space experiment, and if the glass produced, even if its amount is very small, meets expectations with regard to performance, the achievement will mean a breakthrough in the endeavor to develop super-low-loss optical fibers for practical use.

Other fields in which technological breakthroughs may be achieved by space experiments include optical computers to replace the currently-used electron-dependent computers, high-performance solar cells, superconductors, light and strong materials for aircraft, spacecraft or space structures, and medicines.

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## Amorphous Semiconductors Made in Space

*43067611 Tokyo CERAMICS JAPAN in Japanese Apr 87 pp 277-285*

[Article by Yoshihiro Hamakawa, Faculty of Engineering Science, Osaka University: "Fabrication of Amorphous Semiconductors in the Microgravity Environment in Space"]

[Excerpt] The Si-As-Te amorphous semiconductor discussed in this paper has a particularly wide vitrification range. It is, as it were, a dream semiconductor which can be made, by controlling its composition, into different types, usable to replace all other types of semiconductors currently considered useful, such as crystal Ge, Si, GaAs, and GaAsP. However, it has been thought impossible to fabricate this on the grounds that such an amorphous alloy semiconductor consists of elements varying considerably in melting points and vapor pressures. The plan to experiment in the production of such an amorphous semiconductor in space as part of the FMPT (First Material Processing Test) program is intended to pursue the academic value of making a new attempt in the field of random-system physics, which has been regarded as an untapped field, and to research the development of material for three-dimensional ICs to meet the engineering needs involving future electronics.

In this paper, the author will first explain why the Si-As-Te semiconductor is regarded as a dream semiconductor, based on the results of preliminary ground experiments already conducted. He will next outline the experiment using the TT-500A rocket, and will then introduce its results. Finally, he will comment on problems regarding the FMPT.

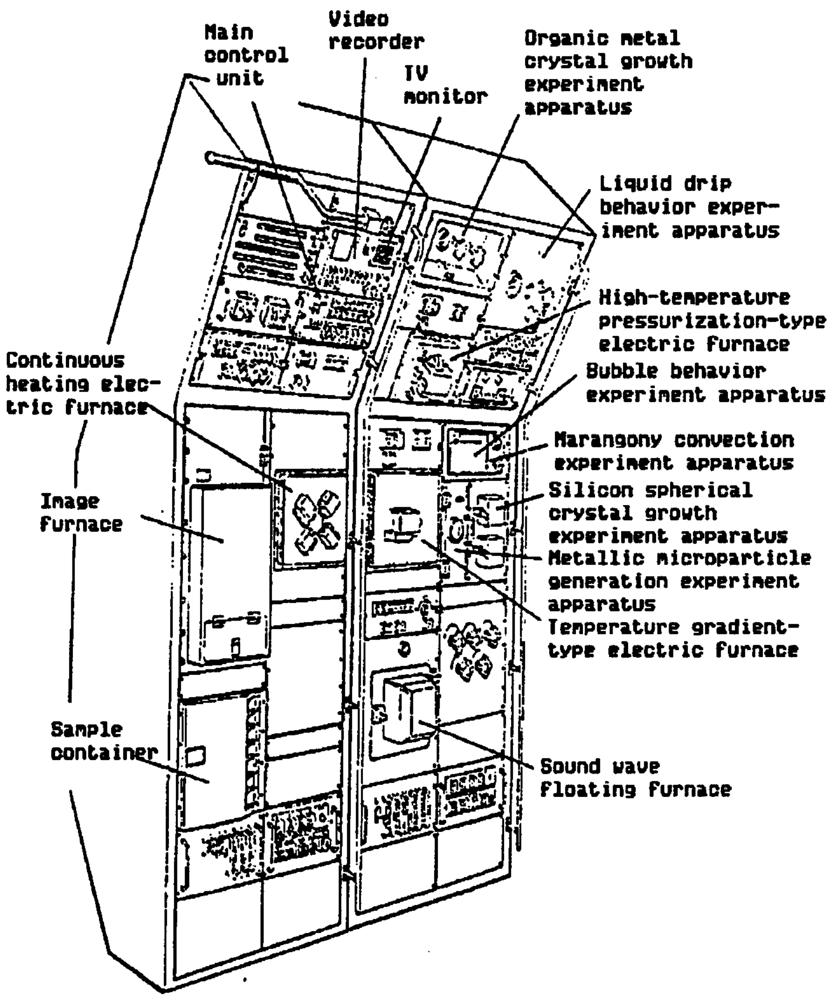



Figure 8. Material Experiment Apparatus for First Material Processing Test (FMPT)

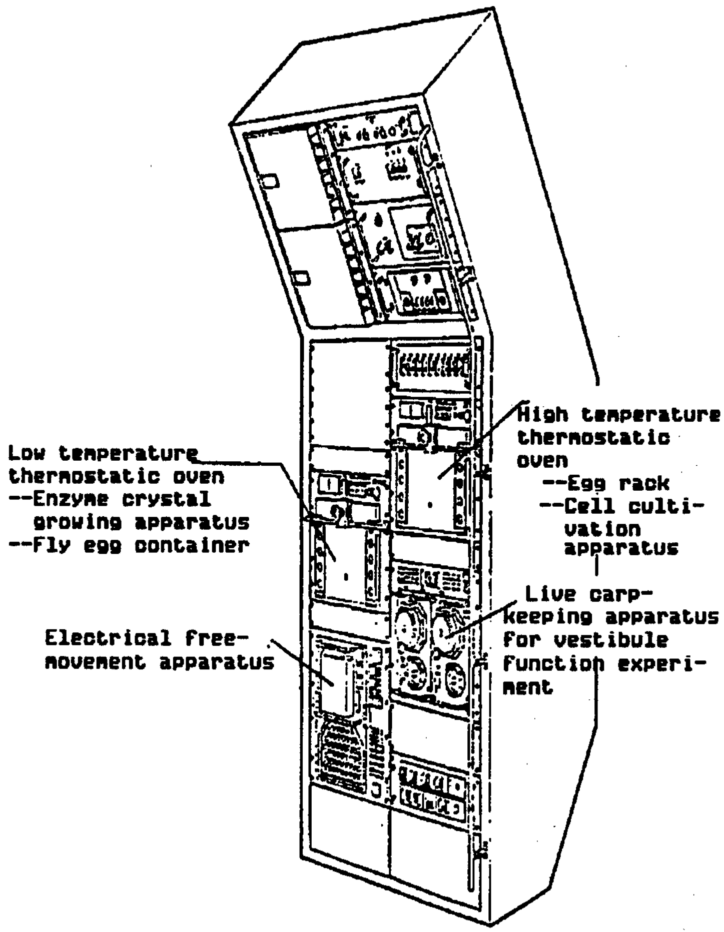



Figure 9. Life Science Experiment Apparatus for First Material Processing Test (FMPT)

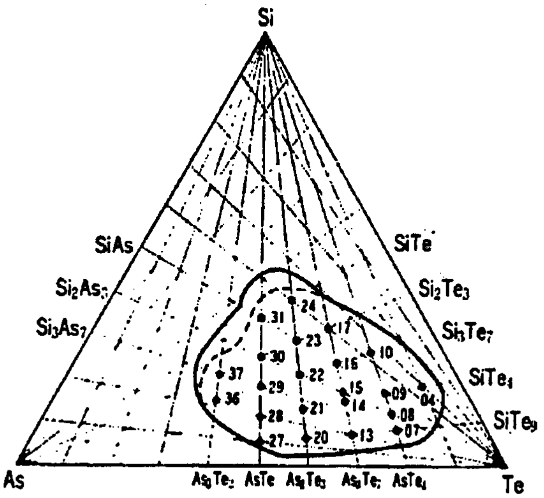



**Figure 1. Si-As-Te Amorphous Semiconductor Vitrification Range Generally, solid solutions consisting of three components are not formed outside the above range. Attempts to create a three-component solid solution outside the above range result, in many cases, in producing polycrystals composed of appropriately mixed two-component crystals. The vitrification range is affected to a certain extent by the speed at which the material in a high-temperature molten state is quenched. Speedier quenching results in a wider vitrification range. In the above diagram, the area described by the solid line represents the vitrification range resulting from quenching in water. The broken line indicates the vitrification range expected when quenching occurs in the atmosphere.**

**2. Reasons For Si-As-Te amorphous semiconductor Being Selected as experiment Object**

The Si-As-Te amorphous semiconductor is chalcogenide glass composed of bonding arms of 4, 3, and 2 coordination systems, respectively. It is produced by the melt quenching method. In Figure 1, the vitrification range of the Si-As-Te system is shown inside the Gibbs triangle. The electrical and optical properties of the system can vary widely, for example, as shown in Figures 2 and 3, by changing composition inside the relatively wide vitrification range. For example, the forbidden bandwidth can vary from 0.6 eV to 2 eV to cover the physical property constants equivalent to those of other semiconductors, ranging from single-crystal Ge and Si to GaAs. Therefore, its basic properties make it widely usable as a material for various electronic devices.

However, there is a drawback to the amorphous semiconductor due to the fact that the elements, Si, Te, and As, to be mixed to form the amorphous semiconductor vary considerably in melting points and specific gravities. Namely, as shown in Table 1, the melting point of Si, whose specific gravity is small, is as high as 1,412SDC, and it must be mixed with Te and As, each

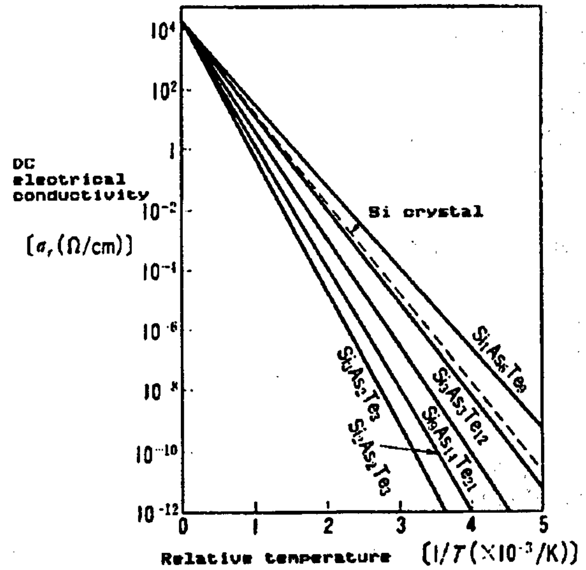



**Figure 2. Dependence on Temperature of the DC Electrical Conductivity of Si-As-Te Chalcogen semiconductors The broken line indicates silicon single crystal properties for comparison.**

having a larger specific gravity. Even if the three elements are heated prior to mixing at a temperature not lower than their eutectic temperature, 1,100SDC, for 20 hours or more, they do not make a homogeneous mixture easily. There are more technical problems. For example, it has not been ascertained if the mixture of the three elements is adequately vitrified in an ampule by the conventional melt quenching method. The experiment producing an amorphous semiconductor in space using a rocket was planned to initiate research on very important targets in sold state physics—test-manufacturing an ideal amorphous semiconductor system in a microgravity environment in space where homogeneous element mixing is possible and determining whether it is possible to control valence electrons on the amorphous semiconductor by adding impurities, such as Ni and Mn. In

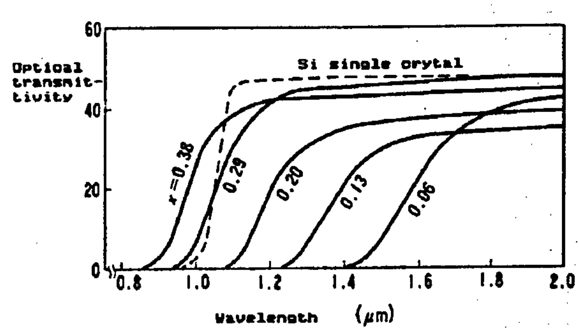



**Figure 3. Optical Transmittivity Spectra of Si-As-Te Chalcogen Semiconductors and Single-Crystal Silicon As seen from the above diagram as well as that shown in Figure 2, this type of amorphous material has properties characteristic of semiconductors.**

planning the experiment, it was also taken into consideration that such an amorphous material would proveuseful in an extensive range of applications, that the physical properties of the material would be widely controllable, and that the microgravity environment would be greatly advantageous to experiments conducted in space.

Table 1. Melting Point and Specific Gravity of Each Element Comprising Si-As-Te

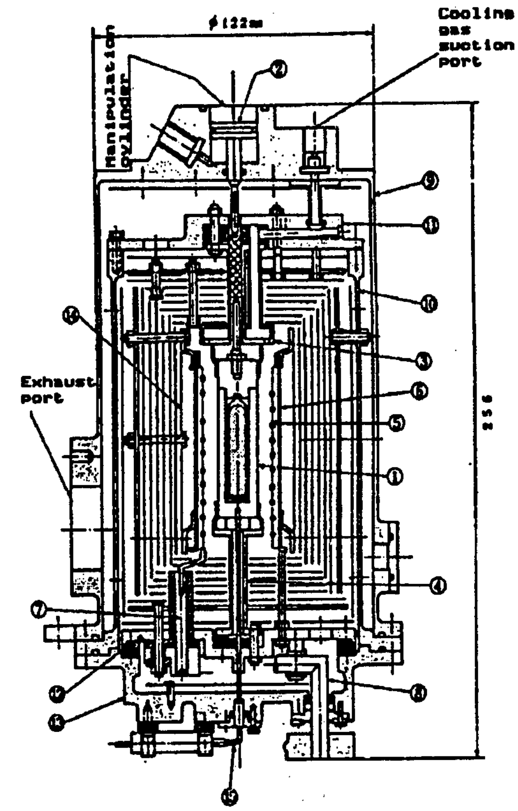
| Item | Si | As | Te |
|---|---|---|---|
| Melting point SDC | 1,412 | 817 | 449 |
| Density (g/cm$^3$ | 2.33 | 5.72 | 6.24 |

### 3. How Sample for Use in TT-500A Rocket experiment Was Prepared

The sample used in the TT-500A rocket was prepared by mixing the three elements at an atomic mole ratio of Si(9)-As(14)-Te(21). The composition is equivalent to that represented as No 22 in the Gibbs triangular coordinates shown in Figure 1. If such a sample, as it is, is heated in an ampule for melting, the vapor pressure of As rises beyond 10,000 atm. To prevent such a development, we melted the sample into an alloy using a large ampule measuring 5 cm in diameter and 8 cm in length; we then powdered the alloy and vacuum-sealed the powder in the ampules for use in the rocket experiment. The ampules had an external diameter of 9.5 mm (internal diameter: 7.5 mm) and a length of 38 mm (inner length of 33 mm). The ampule used in the experiment conducted in TT-500A No 8 contained a powdered sample with a net weight of 2 g; the one used in the experiment conducted in TT-500A No 12 contained 3 g of powdered sample.

Figure 4 shows a block diagram of the electric furnace used in the experiments conducted in the TT-500A rockets; Figure 5 is a block diagram of the experiment apparatus control system. The experiment system consisted of an electric furnace, an electronic control device, a control program, a temperature and power control device, a battery unit for the experiment conducting section, and a cooling system assembly.

The electric furnace was developed by the National Space Development Agency; it modified the ground experiment furnace developed by the National Research Institute for Metals of the Science and Technology agency, making it suitable for installation in the TT-500A rocket. The furnace measures 256 mm in height and 122 mm in diameter (Figure 4 for its cross-sectional view). Its crucible, made of carbon, measures 17 mm in diameter and 60 mm in length. The inner area of the crucible used to keep the sample measures 10 mm in diameter and about 40 mm in length. The sample for use in the experiment was sealed in a quartz ampule measuring 9.5 mm in diameter and 38 mm in length, and the




1 Crucible
2 Piston
3 Crucible support (front)
4 Crucible support (rear)
5 Bobbin
6 Heater
7 Ta electrode
8 Cu electrode
9 Outer cylinder
10 Inner cylinder
11 Inner cylinder flange (front)
12 Inner cylinder flange (rear)
13 Outer cylinder flange
14 Reflection plate
15 Thermocouple
16 Manipulation cylinder
17 Cooling gas suction port
18 Exhaust port

Figure 4. Section of Electric Furnace (for amorphous semiconductors)

ampule was loaded in the crucible. The space between the crucible and the quartz ampule was filled with carbon powder. To prevent the quartz ampule from being destroyed by the vapor pressure that builds up as the sample is heated during the experiment, a pressure of about 36 kgf/cm$^2$A was applied to the top lid of the ampule during the rocket flight. The heater was made of tungsten and had a diameter of 2 mm. It was used to heat the sample under a vacuum, using the power provided by the temperature and power control device. To enhance the heating efficiency of the electric furnace, the heater was surrounded by seven layers of tantalum reflector plates which were surrounded by two layers of reflector plates made of stainless alloy. When cooling the sample, the helium gas provided from the cooling system assembly was sprayed on the crucible via the coolant nozzle attached to the crucible support (front).

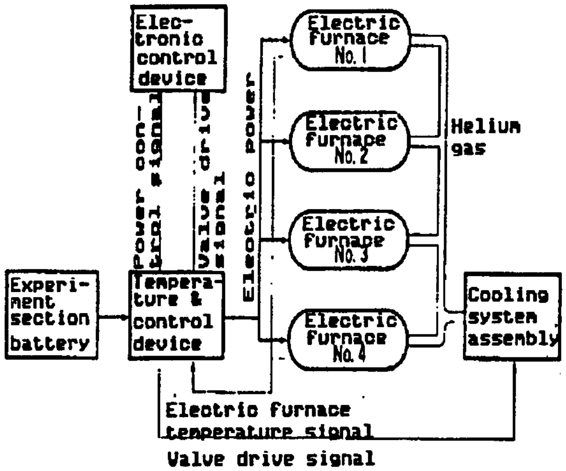



**Figure 5. Block Diagram of Experiment System Installed in TT-500A Rocket**

The electronic control device was comprised of a microcomputer incorporating an 8-kilobit RAM and a 33-kilobit PROM. It was designed to control such events as the start of sample heating and that of cooling, and also to control the electric furnace temperature according to the control program loaded from ground equipment prior to launching.

### 4. TT-500A Rocket and Its Flight Test

The TT-500A rocket is an improvement on the TT-500 rocket, Nos 1 through 7, which were launched by the National Space Development Agency for testing purposes, including the testing of the tracking system installed on the launching site. The TT-500A was designed to enable in addition to testing of the tracking system, material experiments in space and recovery of the rocket's nose portion from the ocean. The overall shape of the rocket is shown in Figure 6. It is a two-stage rocket propelled by solid fuel. It measures 10.5 m in length and 0.5 m in outer diameter. Its launch-weight totals about 2.4 tons. Its head portion measures 2.7 m in length, 0.5 m in outer diameter and weighs about 328 kg. Its payload includes an attitude angular velocity control device, radio equipment for telemetry and tracking, material experiment apparatus, and devices to enable recovery of the rocket.

The TT-500A rocket No 8 was launched at 7:00:01 (time X) am on 14 September 1980. The flight orbit and flight sequence followed are shown in Figure 7. Its first-and second-stage rockets burned normally, letting the No 8 rocket follow an orbit close to that scheduled. The electric furnace installed in the rocket to carry out an experiment involving amorphous semiconductor production reached the target temperature range of 1,250SDC +/-50SDC about 185 seconds after time X. It then maintained a uniformly heated state at about 1,260SDC for the period from (X + about 195 seconds) to (X + about 356 seconds). Furnace cooling by means of helium gas was started at (X + 355.8 seconds). When the cooling ended at (X + 485.8 seconds) the furnace temperature was about 790SDC. The transition during the experiment involving the electric furnace temperature is shown in Figure 8. After completion of the experiment, the nose portion of the No 8 rocket reentered the

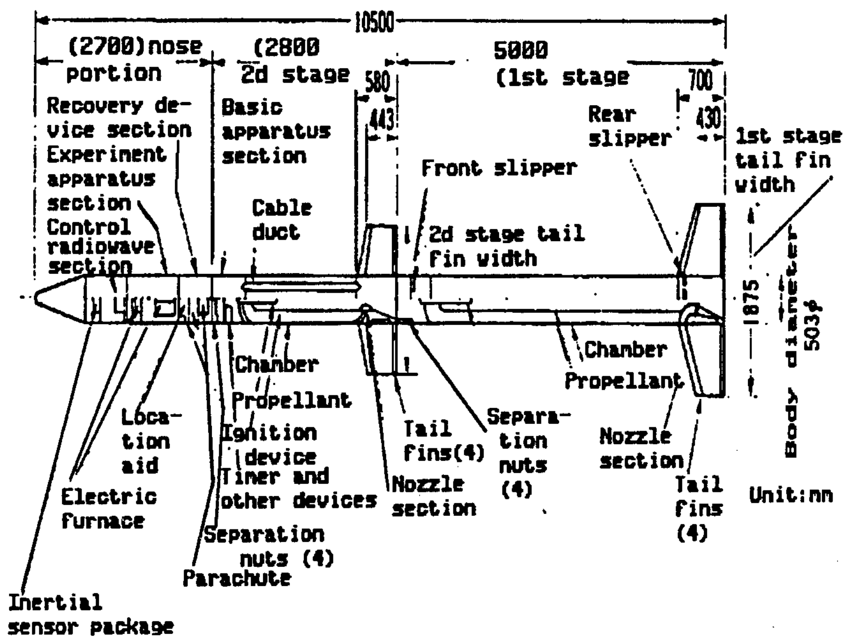



**Figure 6. Overall Diagram of TT-500A Rocket**

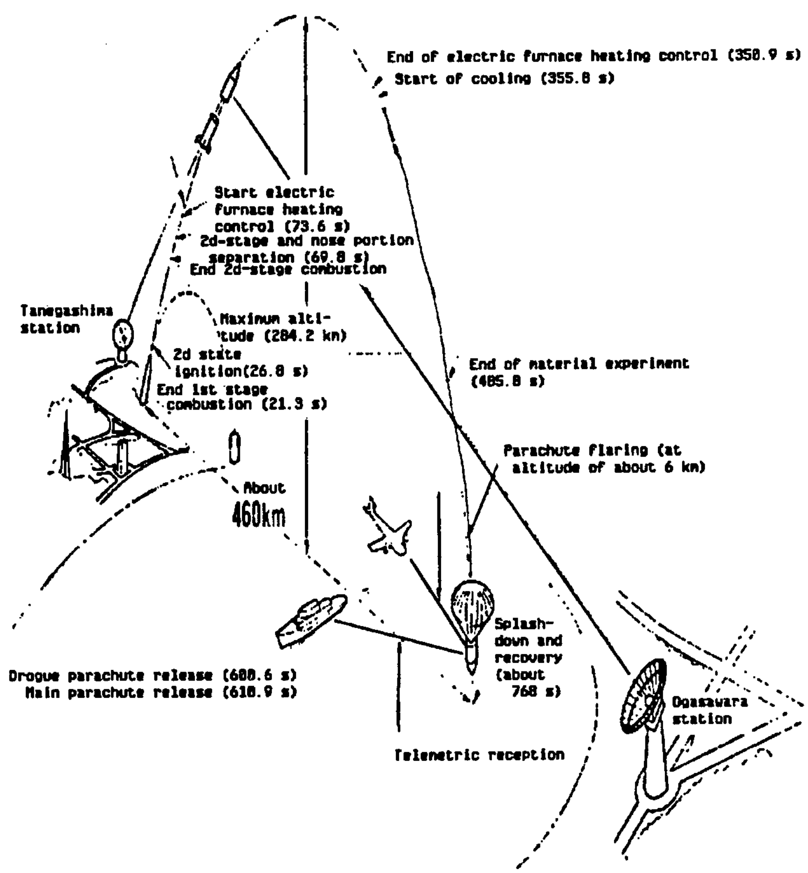



Figure 7. Outline of TT-500A Rocket Launch Schedule

atmosphere to be pneumatically decelerated. Subsequently, it shot out and let flare a drogue parachute, then a main parachute. it eventually splashed down in the ocean about 505 km east of Tanegashima Island approximately 768 seconds after time X. After the splashdown, its flotation system worked as intended until it was recovered by the recovery ship at 11:38 am.

Data regarding temperature control of the amorphous semiconductor production furnace used in the experiment conducted in the TT-500A No 8 rocket are shown in Figure 8. The sample temperature was raised to 1,250-1,270SDC (1,280-1,290SDC in the experiment conducted in the TT-500A-12) in about 2 minutes after beginning the sample heating. It was then kept in a molten state for about 3 minutes under a microgravity of $10^{-4}$ to $10^{-2}$. Next, it was cooled to about 800SDC in about 3 minutes, using helium gas to turn it into a solid amorphous semiconductor. the sample-containing ampule that underwent the above-described amorphous semiconductor production process and was later recovered is shown in Figure 9 [omitted] along with other ampules [one which underwent the same process performed in another space experiment and two more ampules, each containing an amorphous semiconductor produced on the ground]. Although the amorphous semiconductors produced on the ground are stuck in the

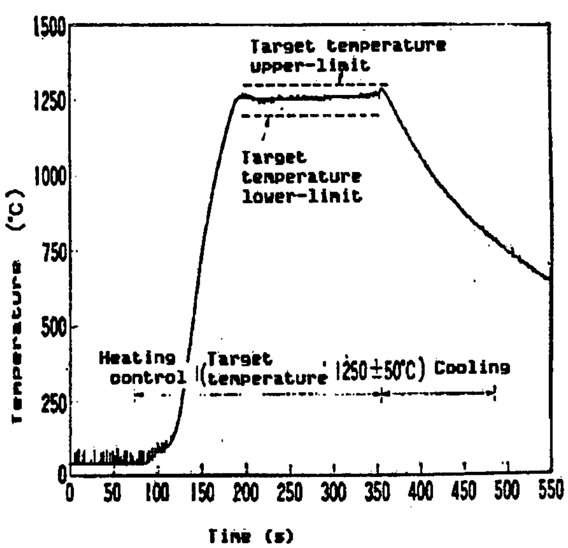



Figure 8. Temperature Changes Recorded by Electric Furnace Used for Amorphous Semiconductor Production Experiment Using TT-500A Rocket

bottoms of the ampules, those produced under microgravity in space appear to be entirely spread in the ampules.

**5. Results of Analysis of Sample Processed Under Microgravity**

**5.1 Verification of Amorphous Structure**

The ampule containing the sample processed in space was carefully cut with a diamond cutter, and the sample was removed. When the ampule was cut, the sample was found sticking uniformly to the entire inner surface of the ampule with some portion of the sample solidified n a drip-like shape inside the top portion of the ampule, in contrast to those produced on the ground which were solidified in the bottoms of the respective ampules, as shown in Figure 9.

In Figure 10 [omitted], microphotographs (5x) of polished surfaces of two amorphous semiconductors, one test-produced on the ground and the other produced in a space experiment, are compared. As shown, the polished surface of the sample produced in space looks beautifully uniform and specular, but that of the sample produced on the ground appears rough.

Generally, the degree of amorphousness of an atomic structure can be judged according to the halo image obtained by X-ray irradiation. In the present case, however, the amorphous semiconductors experimentally produced on the ground and in space showed nearly perfect halo images, respectively. Therefore, it is thought that their structural amorphousness cannot be accurately compared based on their halo images. So, in order to observe the amorphousness of the atomic structure of each sample, we examined the X-ray diffraction pattern produced by its Si element (111) which, of the three elements Si-As-Te, is the most difficult to make amorphous. Figure 11 compares the enlarged X-ray diffraction pattern spectra produced by three samples, one produced on the ground, another produced under microgravity ins pace, and the last produced over many hours in a ground laboratory. As a criterion for which to judge the degree of crystal structure perfection, we defined quantity gDA as shown in Figure 11. Table 2 gives the results of the gDA comparison made among the spectra of the three samples. as the table indicates, the value of gDA was 32 for the sample produced through 2-minute melting in a ground experiment, whereas the value was 17 for the sample produced in the experiment conducted in the rocket. The value recorded for the third sample also produced on the ground through an 18-hour melting process was 21. These results clearly indicate that the sample produced in the experiment conducted in the rocket had a nearly ideal amorphous structure.

Figures 12 through 14 [all omitted] are pictures of the Si-As-Te amorphous semiconductors taken out from the ampule processed in the experiment conducted in the TT-500A No 12 rocket. Another method of examining

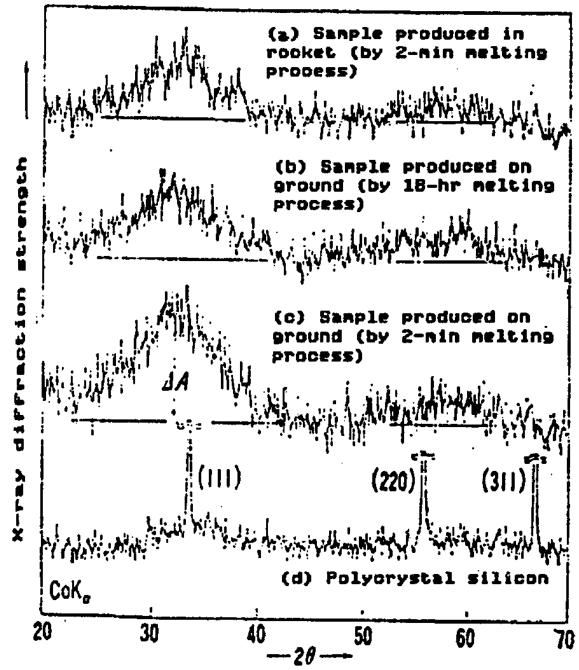



**Figure 11. X-Ray Diffraction Spectra at Diffraction Angle of 33.19SD of Test-Manufactured Amorphous Semiconductors and Silicon (111) Structure As shown above, the spectrum of the sample produced in the rocket is most amorphous-like.**

the degree of amorphous semiconductor vitrification (the degree of amorphousness) is differential thermal analysis. In Figure 15, crystalline and amorphous structures are compared as regarding their solidification processes and their internal energies. When a solid melted into a liquefied state A is gradually cooled to produce a crystal, it goes through states A to B (melting temperature Tm) to C to D, to be solidified in a state where its internal energy is minimal, as shown in Figure 15. If such a solid in a liquid state is quenched, turning it into an amorphous state, it goes through states A to B to E to F, causing its structure to become amorphous. As a result, as shown in Figure 16, it is solidified in a state where its internal energy is higher than in its crystallized state. In that manner, the solid eventually assumes a state of glass phase I.

| Sample type | $\Delta A$ (mm) | $\sigma_{25}$ ($\Omega^{-1}\cdot cm^{-1}$) | $\Delta\varepsilon$ (eV) | $\varepsilon_{g(opt)}$ (eV) |
|---|---|---|---|---|
| Produced on ground (2-min melting) | 32 | $1.58\times10^{-7}$ | 0.613 | 1.00 |
| Produced on ground (18-hr melting) | 21 | $2.05\times10^{-8}$ | 0.710 | 1.02 |
| Produced in rocket (2-min melting) | 17 | $1.35\times10^{-7}$ | 0.615 | 1.01 |

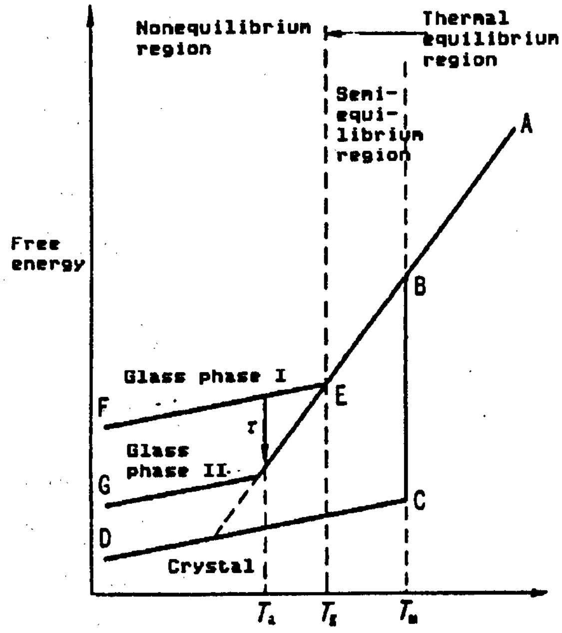



**Figure 15. Intramaterial Structure Energy and Thermal History With Regard to Solid Crystallization and Creation of Amorphousness**

The amorphous glass phase I can te transformed into glass phase II, which is more homogeneously amorphous than glass phase I. The differential thermal analysis method is used to examine the degrees of amorphousness

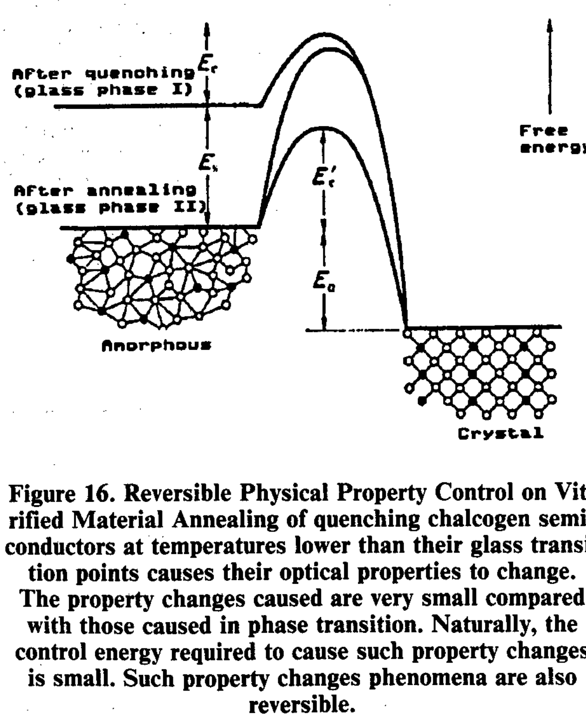



**Figure 16. Reversible Physical Property Control on Vitrified Material Annealing of quenching chalcogen semiconductors at temperatures lower than their glass transition points causes their optical properties to change. The property changes caused are very small compared with those caused in phase transition. Naturally, the control energy required to cause such property changes is small. Such property changes phenomena are also reversible.**

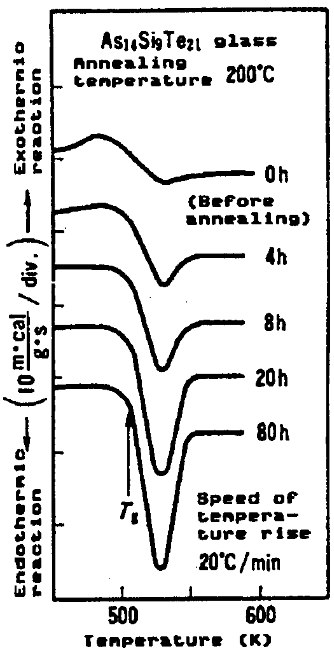



**Figure 17. Comparison Through Differential Thermal Analysis of Effects of Si-As-Te Amorphous Semiconductors Produced in Ground Experiments**

of solid structures. Figure 17 shows the results of differential thermal analysis conducted on Si-As-Te amorphous semiconductor samples which were annealed under various conditions after being experimentally produced on the ground. As shown, the curve plotted on each sample includes an endothermic peak located at a point right above the glass transition temperature Tg. it is observed that the peak grows larger as the heat and thermal treatment time are increased. In other words, it can be said that the magnitude of the endothermic peak is proportional to the magnitude Es of the energy difference between glass phase I and II, shown in Figure 16, and, therefore, that a larger value of Es represents a higher degree of structural amorphousness.

Figure 18 shows the results of differential thermal analysis conducted on the sample produced in the TT-500A No 12 rocket and another sample produced in the author's laboratory on the ground. As is clear from the figure, the amount of heat absorption (represented by the hatched area) by the sample produced in space is about 180 percent larger than that by the sample produced on the ground. Therefore, it is indicated that the sample produced in the space experiment is a better amorphous semiconductor.

### 5.2 Electrical and Optical Properties

The characteristics of an amorphous semiconductor can be analyzed most sensitively by measuring its electrical and optical properties. However in the present case, with only one sample having been produced in each TT-500A

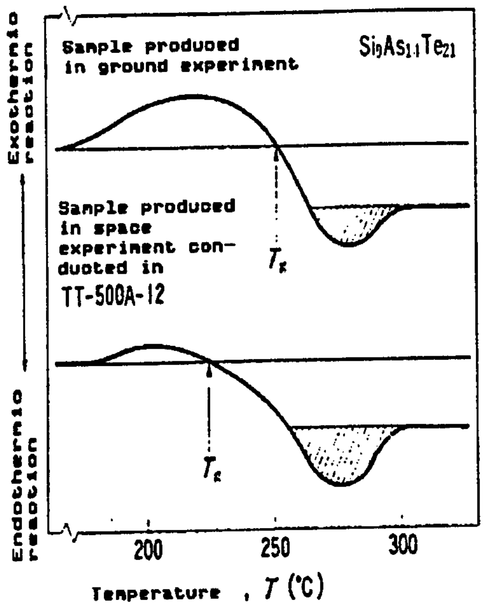



**Figure 18. Results of Differential Thermal Analysis Conducted on Samples Produced on the Ground and in the Rocket**

experiment, it will take more time to analyze in detail the characteristics of the samples, while taking into consideration the composition-dependence of their electrical and optical properties.

So far, we measured the DC electrical conductivity $gs_{25}$ at room temperature, its temperature-dependence activation energy $gDge_{gs}$, and the optical forbidden bandwidth $ge_{g(opt)}$ of each sample. In Table 3 the results of such measurements made on the samples produced in space are compared with the corresponding data obtained from samples produced on the ground. Judging from the data listed in Table 3, the samples produced in space constitute amorphous semiconductors clearly superior to that produced by a 2-minute melting process ont he ground, but they are slightly inferior to that produced by an 18-hour melting process on the ground. Taking the nonuniformity of the element composition ratio among the samples into consideration, it is a little too soon to draw a conclusion based on the data obtained from the four samples alone. At any rate, the data obtained so far is described as follows:

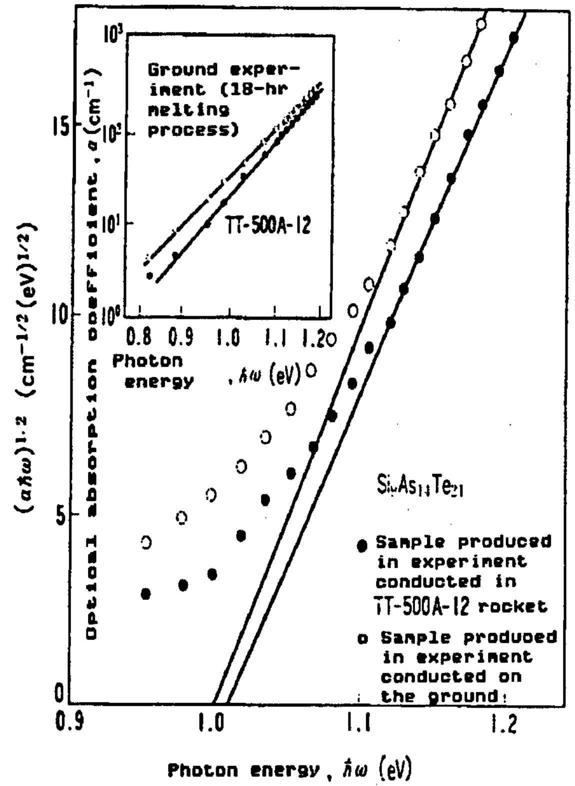



**Figure 19. Optical Absorption Coefficient Spectra of Samples Produced on the Ground and in Space**

In Figure 19, optical absorption coefficients measured on the sample test-produced in the TT-500A No 12 and another sample produced in an experiment conducted on the ground are compared.

As shown in Figure 19, compared with the data recorded for the sample produced on the ground, the band-tail energy of the sample produced in the rocket is high, at 1.1 eV, and its band tailing factor Es is apparently smaller than that of the sample produced on the ground. Therefore, it may be said that the sample produced in the rocket is closer to an ideal state.

Figure 20 shows optical conductivity $gs_{ph}$ data obtained based on optical current experiment$_L$. As replotted in the inset in Figure 20, the log $gs_{ph}$ curve of the sample produced in the rocket rises more sharply around the

| | $\Delta A$ | $\sigma_{25}$ ($\Omega^{-1}\cdot cm^{-1}$) | $\Delta\varepsilon_\sigma$ (eV) | $\varepsilon_{g(opt)}$ (eV) | $E_s$ (eV) | $\varepsilon_{g(el)}$(eV) |
|---|---|---|---|---|---|---|
| TT-500 A-8 | 17 | ($1.35\times10^{-7}$) | (0.615) | 1.01 | — | — |
| TT-500 A-12 | — | $1.20\times10^{-8}$ | 0.720 | 1.01 | 0.069 | 1.35 |
| Lab (2 min) | 32 | $1.58\times10^{-7}$ | 0.613 | 1.00 | 0.088 | 1.20 |
| Lab (18 h) | 21 | $2.05\times10^{-8}$ | 0.710 | 1.02 | 0.059 | 1.28 |

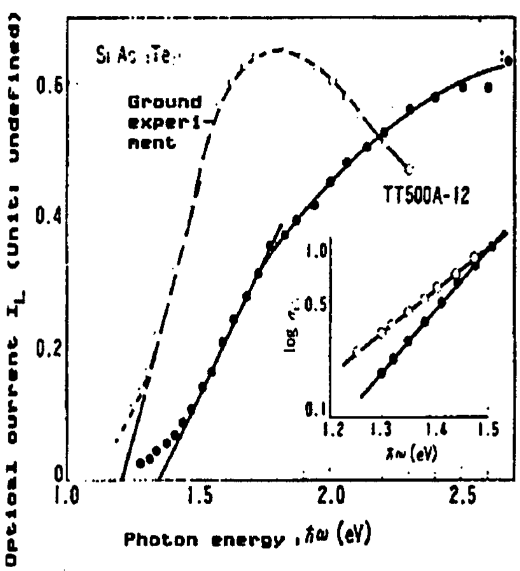



**Figure 20. Comparison of Optical Conductivity $g_{ph}$ of Amorphous Semiconductor Samples Produced on the Ground and in the TT-500A Rocket As is clear from the difference between the two samples in terms of the steepness of log $gs_{ph}$ plotting, the sample produced in the rocket has a more amorphous structure.**

band tail than that of the sample produced on the ground. This observation is consistent with the optical absorption coefficient data in log ga, shown in the inset in Figure 19. The spectrum of $I_L$, shown in Figure 20, is based on the peak value. What is strange is that the $I_L$ of the sample produced in space does not fall, even when the photon energy is increased. The reason or this is not yet clear. In the case of the sample produced on the ground, the value of $gs_{ph}$ (hgq) comes down in the high-energy range. This is thought to be due to the fact that, as the photon energy hgq increases, the absorption coefficient ga(hgq) grows larger and the optical penetration thickness reduces, causing the rate of $I_L$ reduction due to the photoproduction carrier surface recombination effect to rise. If this theory is correct, the fact that the surface recombination loss measured on the sample produced in space is small may be said to be another evidence of superior semiconductor amorphousness achieved in the space experiment.

The figures summarizing the data obtained in physical property measurements of the samples produced on the ground and in the TT-500A Nos 8 and 12 rockets in space are listed in Table 3.

### 6. Conclusion

The experiments involving the production of amorphous semiconductors conducted using TT-500A rockets were meant to pursue the academic task of making a new attempt in the field of random-system physics, which has been regarded as an untapped field, and to conduct research involving the development of material for three-dimensional ICs to meet the engineering needs of future electronics. Their concrete goal was to obtain a homogeneous alloy structure, as pursued in alloy production, making sue of a microgravity environment in which differences between materials in specific gravities and melting points would be eliminated. Although the number of experiments conducted were very few, the author feels that the experiments produced valuable data as expected.

Since the experiment in space was conducted only twice using two rockets, and that the samples were of the same composition, it cannot be said that the data obtained was enough to justify its public disclosure as an academic achievement. However, the experiments proved at least that utilization of a microgravity environment for new-material production has a very important significance. Considered from this point of view, the data obtained is certainly important, since it suggests that the significance of the new-material production experiments being planned under the FMPT (First Material Processing Test) program, as well as the space station program, is great enough to make such experiments worthy of completion. The experiments brought us additional fruit. That is, through the research, we obtained some know-how applicable to experiments to be conducted under microgravity, for example, regarding the "problem of ampule and sample wetting" or that concerning the effect of the sample being moved toward one end of the ampule when it reenters the gravitational field after leaving the microgravity environment. The technical knowledge obtained through the experiments will prove useful in future experiments.

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## Containerless Glass Melting

*43067611 Tokyo CERAMICS JAPAN in Japanese Apr 87 pp 286-290*

[Article by Toru Komiyama, Junji Hayakawa, and Misaki Makihara, Government Industrial Research Institute, Osaka: "Containerless Melting of Glass"]

[Excerpt] The First Material Processing Test (FMPT), scheduled to be carried out in 1991, is the first full-scale space experiment ever planned by Japan. Among the research subjects proposed for the FMPT is "research involving invisible-region optical material" proposed by the Government Industrial Research Institute, Osaka. This subject aims at test-manufacturing high-purity glass with a superior infrared ray transmission characteristic in a microgravity environment. We have been making preparations for the experiment. The preparations include ground experiments, apparatus development, and glass melting experiments in a microgravity environment obtained by making a trajectory aircraft flight. This paper outlines these preparations.

## 2. Glass Composition

As the technologies for utilization of light continue to develop, the optical wavelengths in light utilization have been spreading to outside the visible wavelength region, to include those in the ultraviolet and infrared regions. Under such circumstances, increasing needs have appeared for high-performance and high-workability glass for use as optical materials. Generally, however, melts composed to transmit infrared rays are highly corrosive against the melt container. Therefore, in order to produce this glass with high purity, it is desirable to melt the raw material while floating in space, without using any melt container. The experiment mentioned as planned to be part of the FMPT will produce high-purity glass in a sound-wave floating furnace (to be explained later) without using any melt container. In preparation for the experiment, we have been making studies of an optimal glass composition, preprocessing of the raw material, heating and cooling schedules, methods for bubble removal from the melt, methods to evaluate the glass lumps produced in the experiment, etc.

To produce glass permitting a high rate of infrared ray transmission, oxide-, halogenide- or chalcogenide-based material compositions free of $SiO_2$, $B_2O_3$ or $P_2O_5$ are highly likely to be adopted. However, the experiment to be conducted aboard the Space Shuttle is subject to various restrictions concerning the volatility and toxicity of molten components of the glass. Therefore, in determining the raw material to be used in the experiment under the FMPT program, we studied various oxides, relatively free of such volatility- or toxicity-related problems, regarding the vitrification ranges, infrared ray transmission characteristics, and the relationship between their compositions and physical properties. Eventually, we selected a $CaO$-$Ga_2O_3$-$GeO_2$ system, whose maximum wavelength of transmissible infrared rays is comparatively long and which is relatively easy to handle. Figure 1 shows the relationship between the vitrification range of the above system and the cooling speed. To vitrify this system on the ground using a container made of platinum, a cooling speed of 1,500SDC/min is required, even for its easiest-to-vitrify composition, $65CaO \cdot 25Ga_2O_3 \cdot 10GeO_2$ (mol percent). What the critical cooling-speed curve will become if nucleation between the platinum container and the melt is eliminated through containerless melting is worthy of attention. Figure 2 shows data regarding the corrosiveness of the above system against the platinum container. As the proportion of CaO increases, the rate of platinum dissolution rises, eventually causing the glass color to change from light yellow to brown and the transmissivity of the glass to decline. Figure 3 shows a transmissivity curve of glass made of $CaO$-$Ga_2O_3$-$GeO_2$ in the ultraviolet, visible, and infrared regions. The curve indicates that absorption occurs at wavelengths of about 420 nm, 2.7-3 gmm and 7 gmm. The phenomena are attributable to the platinum, OH radical, and $CO_3^{2-}$ components dissolved in the glass, respectively. In containerless melting of glass conducted in space, no container platinum can dissolve to mix into the glass. Most important in such a case is keeping the densities of the OH radicals and $CO_3^{2-}$ in the glass as low as possible, while preventing bubble formation.

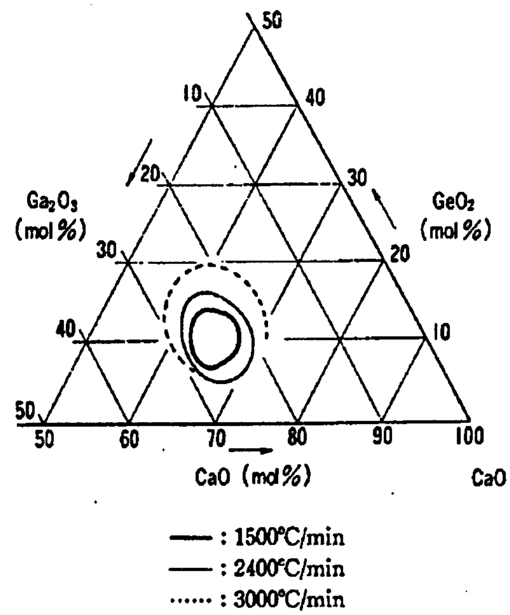
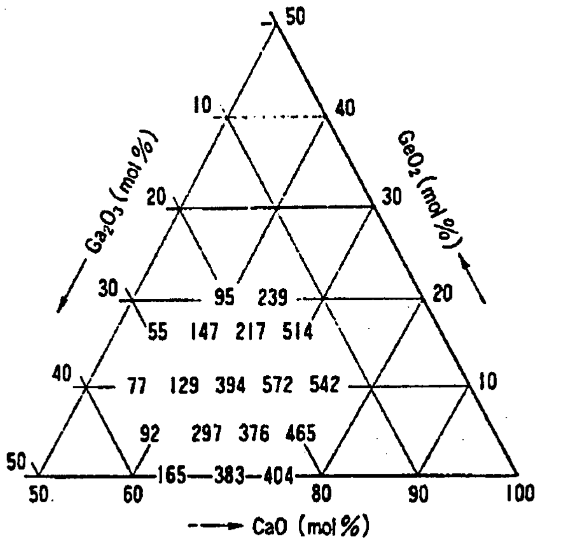



**Figure 1. Relationship Between Vitrification Range of $CaO$-$Ga_2O_3GeO_2$ System and Cooling Speed**

## 3. Sound-Wave Floating Furnace

The microgravity in the Space Shuttle is dependent on the balance between the gravitational force of the earth and the centrifugal force of the Space Shuttle. Therefore, the microgravity applied to an object installed in the Space Shuttle is greatly affected by its location relative to the gravitational center of the Space Shuttle, and also by things whose locations are changed inside the Space Shuttle. Roughly, it measures $10^{-4}$G or so. Therefore, to keep an object in a location where it does not contact any other object in the Space Shuttle, it is necessary to give it a force to counterbalance the microgravity. The sound-wave floating furnace is designed to generate a gas pressure which serves as such a counterbalancing force




Unit : ppm
Amount of platinum dissolved : 2g
Dissolution temperature : 1500°C
Dissolution time : 60 min
Dissolution atmosphere : Ar 80% + $O_2$ 20%

**Figure 2. Platinum Corrosiveness of $CaO$-$Ga_2O_3$-$GeO_2$ System**

by using compression sound waves. Figure 4 is a schematic diagram of the sound-wave floating furnace. The sound-wave floating furnace consists of a double oval-type image furnace designed to efficiently heat and cool a sample, floating in space under microgravity, without making any contact with it, and a sound-wave floating mechanism designed to hold the floating sample where light converges. The sound waves are generated by a speaker. It controls the sound-wave frequency in the range of 10 to 15 kHz according to the gas temperature (sound velocity) distribution, maintaining a standing wave with a wavelength of 2 cm. It poses some problems in maintaining a standing wave at high temperatures.

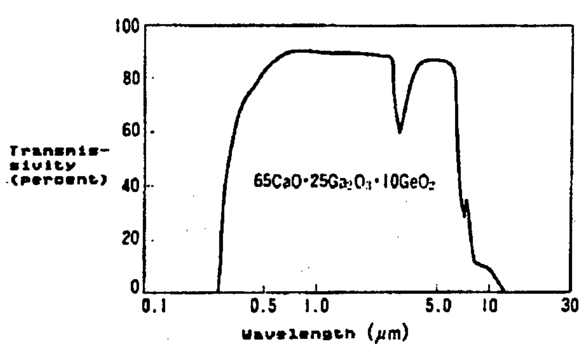



**Figure 3. Optical Transmittivity of $65CaO \cdot 25Ga_2O_3 \cdot 10GeO_2$ Glass**

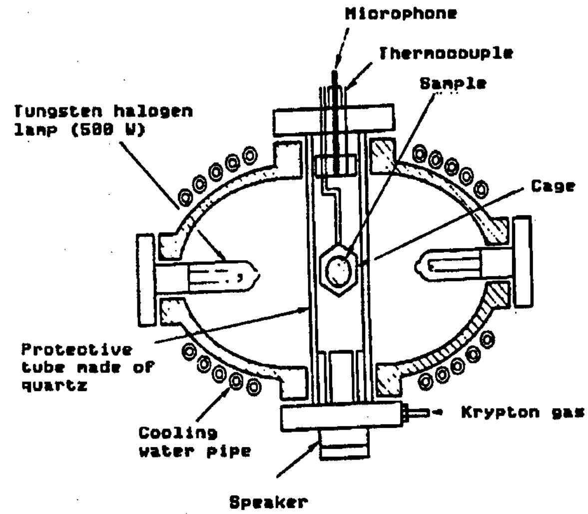



**Figure 4. Schematic Diagram of Sound-Wave Floating Furnace**

For the space experiment, a ball of raw material for glass, measuring about 10 mm in diameter, is to be placed in a cage, about 25 mm in diameter (made of platinum wires with a diameter of 1 mm), beforehand, which will subsequently be moved to the focal point of the image furnace. To produce glass in the experiment, the raw materia is to be heated and melted after its position is adjusted by sound pressure, preventing it from coming into contact with the cage. the cage is intended to enhance the efficiency in sample heating and to prevent the glass lump produced from getting out of the proper area range. In designing its shape, the following requirements were considered: the cage does not affect the standing wave produced in the experiment; its shape is symmetrical about its center so as not to complicate the temperature distribution inside it; it is structured to enable the sample to be inserted and removed; and it allows the molten sample to be observed. The main problems peculiar to glass production under microgravity and the corresponding countermeasures are outlined n Table 2. As for bubble removal, a method by which a temperature gradient is created in the molten sample to generate a surface tension used to move bubbles has also been proposed. In addition to the method by which the melt is spun to generate G.

**Table 2. Main Problems Occurring in Glass Production Under Microgravity and Countermeasures**

| Problem | Countermeasure |
|---|---|
| Existence of no thermal convection makes glass homogenization difficult | Agitation by Marangony convection |
| In the absence of buoyancy, bubble removal is difficult | Creation of G by rotation; Utilization of crystal-glass interface |
| Considerable wettability makes melt handling difficult | Collection of interfacial tension data |

The sound-wave floating technique is a fundamental space technique needed not only for containerless glass melting, but also for moving high-temperature and corrosive materials floating in space under microgravity. In fact, improving the technique is another purpose of the space experiment discussed.

## 4. Experiment Using Aircraft

To investigate problems which may be encountered in making containerless glass melting, we experimented floating a glass melt by flying a twin-engine jet plane MU-300 (Figure 5 [omitted]) in air space K east of Shima Peninsula on two occasions, first in March 1986, then in February 1987. We attempted to float a glass melt aboard the aircraft using an experiment apparatus (Figure 6 [omitted]) in a microgravity environment created by making 20-second trajectory flights.

The possible means of creating an antigravity state on the earth include falling towers, aircraft, and small rockets. In the above experiments using an aircraft, the experiment could be conducted for only about 20 seconds at a time, and the microgravity created was $10^{-2}$ G or so. Moreover, the microgravity varied considerably during the experiment. Therefore, the microgravity environment generated in that way is not necessarily satisfactory. However, using an aircraft in conducting experiments under microgravity has its advantages, too. It is an economical way of conducting such experiments, and experimental apparatus weighing up to 600 kg can be loaded aboard the aircraft. An experiment plan can be carried out shortly after the plan is conceived, and the experiment results can be obtained quickly. The experimenters themselves can conduct the experiment aboard the aircraft. In these regards, an aircraft is superior to a spacecraft as a means of conducting experiments under microgravity.

Figure 7 shows the trajectory flight pattern followed by the MU-300. The aircraft made a trajectory flight at an altitude of 6,000 to 7,000 m. In making a trajectory flight, it ascends using the maximum thrust. It then lowers the engine output until the engines start idling, and begins a trajectory flight while counterbalancing the air resistance. It made a total of 12 trajectory flights. Typical changes in G caused during the trajectory flights are shown in Figure 8. In the vertical direction (Gz), a gravity of about 2G is maintained for the 20 seconds, during which time the aircraft ascends by the maximum thrust. Following the start of a trajectory flight, a microgravity of $10^{-1}$ to $10^{-3}$G is maintained for 20 to 22 seconds. Next, as the aircraft lifts itself, a gravity of 2G is maintained for 15 seconds or so. The changes in G in the front-to-rear (Gx) and lateral (Gy) directions are small. The duration of microgravity achieved and gravitational changes caused during trajectory flights are dependent on the skill of the pilot.

The samples used in our experiments aboard the aircraft were composed of $65CaO \cdot 25Ga_2O_3 \cdot 10GeO_2$ (mol percent). The amount of powdery raw material per sample was determined so that it could produce 2 g of glass. Each

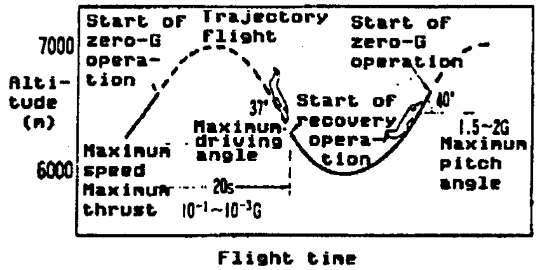



**Figure 7. Trajectory Flight Pattern Followed by MU-300**

sample, molded into a sphere was heat-treated at reduced pressure beforehand in order to minimize bubble generation during the melting process. In the experiment, the glass melt was observed becoming spherical due to its surface tension and being kept floating by sound pressure under microgravity around the location where light converged in the sound-wave floating furnace. While floating, the sample was vibrating due to microgravitational changes. Therefore, the experiment conducted using a test-fabricated sound-wave floating surface verified the practicability of containerless glass melting. The glass melt floating under microgravity was smashed against the speaker by the 2G created when the aircraft lifted, so that we were unable to recover the sample in its spherical shape. The results of gas temperature measurement made in the sound-wave floating furnace during the experiment indicate that the heated gas gathered around the central part of the furnace in the absence of thermal convection under microgravity. This also indicates that heating efficiency is higher under microgravity than on the earth. This phenomenon must be taken into consideration when designing electric furnaces for use ins pace experiments.

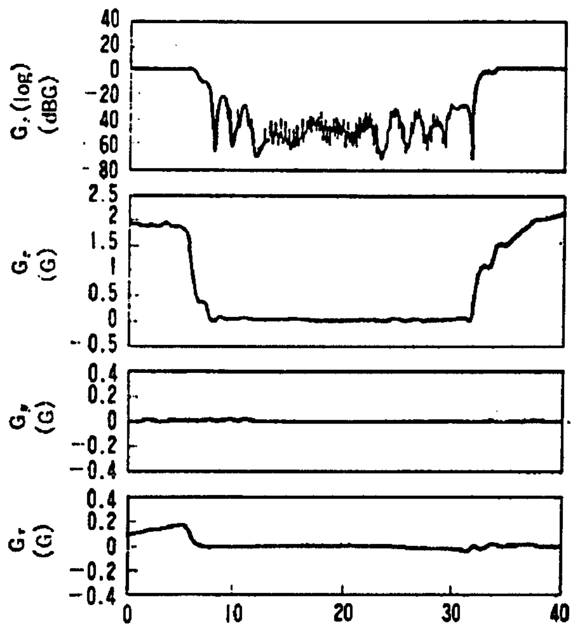



**Figure 8. Microgravity Achieved by Trajectory Flight**

**5. Conclusion**

The microgravity environment is an attractive environment for conducting experiments in the fields of glass and ceramics. The characteristics of the microgravity environment can be fully utilized particularly in fields associated with gases or molten materials. However, as far as the past space experiments are concerned, the results have not necessarily been satisfactory because information regarding fluid convection under microgravity and the effects of interfacial tension on experiments has been inadequate. To make future experiments more successful, the necessity of understanding such phenomena as wetting, convection, and diffusion under microgravity has been growing.

Generally, researchers cannot conduct space experiments themselves. When scientists are aboard spacecraft, they often suffer from space sickness. Considering such conditions, it is also necessary to develop telescience systems enabling scientists to conduct experiments in a fully prepared environment on the ground while having the feeling of being in space.

In addition, since the total electric power available for experiments is limited to 10 kw, even for the space station program, and that experiments in glass or ceramics production will require a large amount of energy, it will be necessary to develop an efficient space energy system which would enable solar energy to be used directly as light or heat sources, thereby keeping a certain amount of energy for use in space day and night.

Glass- or ceramic-related space experiments to be conducted in the future are in the planning stage, with the above-stated conditions and needs taken into consideration. It is desired that research in this area be promoted by cooperation of people in many fields, including the glass- and ceramics-related fields.

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## $Pb_{1-x}Sn_xTe$ Crystal Growth in Space

*43067611 Tokyo CERAMICS JAPAN in Japanese Apr 87 pp 291-296*

[Article by Tomoaki Yamada, NTT Electrical Communications Laboratories: "Crystal Growth of Narrow Band-Gap Ternary Compound Semiconductor $Pb_{1-x}Sn_xTe$ Under Microgravity"]

[Text]

**1. Introduction**

We are planning an experiment titled "crystal growth of narrow band-gap ternary compound semiconductor $Pb_{1-x}Sn_xTe$ under microgravity" as part of the First Material Processing Test (FMPT) to be carried out in May 1991 utilizing the Space Shuttle. The experiment was suggested by the idea that a microgravity environment where no thermal convection occurs may enable the growing of quality crystals.

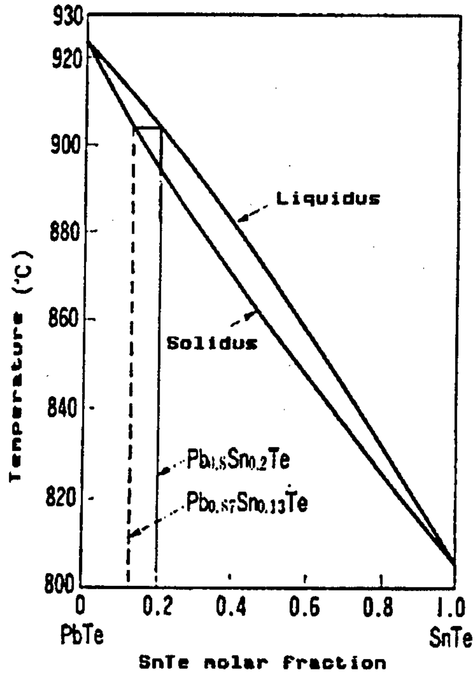



**Figure 1. PbTe-SnTe Psuedobinary System Phase Diagram ($Pb_{0.8}Sn_{0.2}Te$ is the composition adopted for the experiment to be conducted under the FMPT program)**

In determining subjects for space experiments, it is necessary, while attaching importance to the significance of the respective subjects from the viewpoint of academic research as well as practical applications, to consider conditions such as: since the resources available aboard the spacecraft are limited, the resource requirement of each experiment should not be too large; to ensure safety, the vapor pressures of samples to be used in experiments should not be too high; and experiments to be carried out should not require scientist astronauts to have special skills. In the field of space experiments, Japan is lagging far behind the United States and the USSR.

In this situation, it is rather difficult for Japanese researchers to come up with space experiment subjects which meet the above conditions. We proposed the experiment plan mentioned above thinking that it could be a candidate for inclusion in the FMPT subjects. In this article, the author will discuss the significance of the experiment and will describe the preparations for it.

## 2. Properties of $Pb_{1-x}Sn_xTe$

$Pb_{1-x}Sn_xTe$ is a mixed crystal composed of group IV-VI compound semiconductors PbTe and SnTe. As shown in Figure 1, it remains a solid solution over the entire molar fraction range, 0 is equal to or less than x is equal to or less than 1. It has an NaCl-type crystal structure.

$Pb_{1-x}Sn_xTe$ is a direct transition-type semiconductor

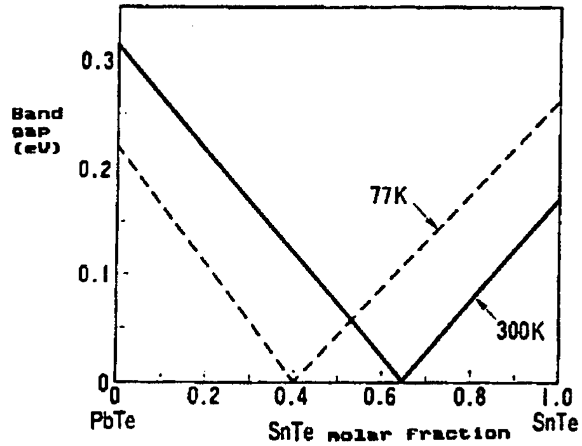



**Figure 2. Dependence on Band Gap on Composition at Room Temperature and 77 K**

which permits p and n control. Detailed analysis of its phase diagram has determined that the highest-temperature point along the solidus curve occurs slightly on the Te-excess side when compared with the corresponding point based on the stoichiometry-based composition. Therefore, $Pb_{1-x}Sn_xTe$ crystal, as it is grown, usually contains much /te and is a p-type conductor. Its band gap depends on x as shown in Figure 2. Because the band gap exists where the wavelengths are 4-5 gmm or longer in the infrared region, $Pb_{1-x}Sn_xTe$ is called a narrow band-gap semiconductor. As shown in Figure 2, its band gap can be changed considerably by varying its composition and temperature. A characteristic of this system is that the band gap of the mixed crystal, without being on the line interconnecting the band gaps of PbTe and SnTe, becomes zero at a certain molar fraction. Its Hall mobility is affected by the carrier density. The Hall mobility of its crystal, heat-treated to hold the carrier density at 1 x $10^{16}cm^3$ or less, is 1 x $10^6cm^2/V{\cdot}s$ or more at 4 K.

Mechanically, $Pb_{1-x}Sn_xTe$ is as soft as aluminum, and its thermal conductivity is as low as that of fused quartz. Therefore, its crystal is susceptible to plastic deformation due to thermal strain. This is a major reason for the difficulty in obtaining quality $Pb_{1-x}Sn_xTe$ crystal.

Since $Pb_{1-x}Sn_xTe$ permits its band gap to be controlled by means of composition or temperature control, it has a high potential for application to infrared optical devices. Figure 3 shows where the band gaps of principal semiconductors exist, just for comparison with the band-gap location of $Pb_{1-x}Sn_xTe$. Today, tunable infrared lasers and infrared ray detectors making use of $Pb_{1-x}Sn_xTe$ are available. The wavelength band of 7-12 gmm in the infrared region includes absorption spectra for many molecules, such as $CH_4$, $NO_2$, $SO_2$, and $H_2O$. Since the $Pb_{1-x}Sn_xTe$ laser enables such spectra to be separated and measured with high accuracy, it is used in such apparatuses as gas analyzers and environmental pollution monitors. $Hg_{1-x}Cd_xTe$ is another material falling

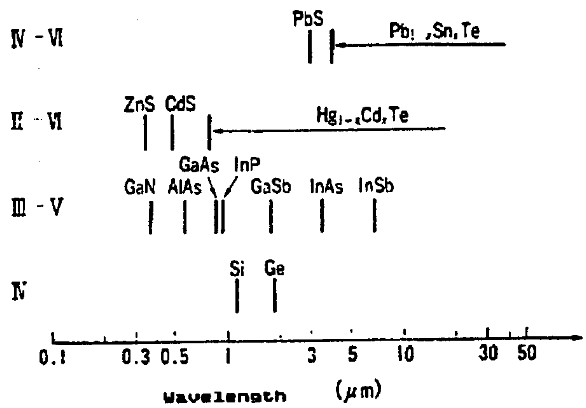



**Figure 3. Band Gaps of Principal Semiconductors**

along the same wavelength band as $Pb_{1-x}Sn_xTe$, but the latter is superior to the former in terms of luminous efficiency. The infrared ray detectors incorporating $Pb_{1-x}Sn_xTe$ are mainly of the type which uses photovoltaic effects. However, $Pb_{1-x}Sn_xTe$, with its dielectric constant, 400, being about 20 times larger than that of $Hg_{1-x}Cd_xTe$, is inferior in terms of response speed, so that not many infrared ray detectors incorporating $Pb_{1-x}Sn_xTe$ are in use. If such detectors can incorporate tow or more detection elements arranged for parallel operation, their low response speed can be made up for by processing signals in parallel. The output power of the $Pb_{1-x}Sn_xTe$ laser is about 10 mW at present. To develop a more powerful laser, quality substrate crystal, whose composition is identical to that of epitaxially grown film, is required. Furthermore, to enable arrayed detection elements to be used, it is necessary to make available large single crystals with uniform composition.

### 3. Significance of Space experiments

So far, various methods of growing single $Pb_{1-x}Sn_xTe$ crystals have been developed. Such methods include the Bridgman method, the Czochralski method, and the vapor phase growth method. Although the different methods have different advantages and disadvantages, crystal composition and defect control are difficult with any of them. At present, there is no method available by which large and high-quality single crystals of $Pb_{1-x}Sn_xTe$ can be obtained.

The occurrence of thermal convection in a crystal-growing system is a factor on which the nonuniformity of crystal composition and crystal defects are largely dependent. Since thermal convection is suppressed under microgravity, it is expected that better crystals will be grown in space.

In the crystal growth experiment being planned for the FMPT, single-crystal growth will be attempted by the Bridgman method. For the sample composition, the value of x has been determined to be 0.2 This is the composition needed to obtain a band gap of 0.11 eV (11.3 gmm wavelength) at 77 K. Figure 4 is a schematic diagram of the crystal growing system to be used in the experiment. In the system, the melt is to be solidified gradually from one end toward the other, gradually becoming crystalline. The speed of crystal growth is to be adjusted by controlling the moving speed of the temperature gradient-type electric furnace.

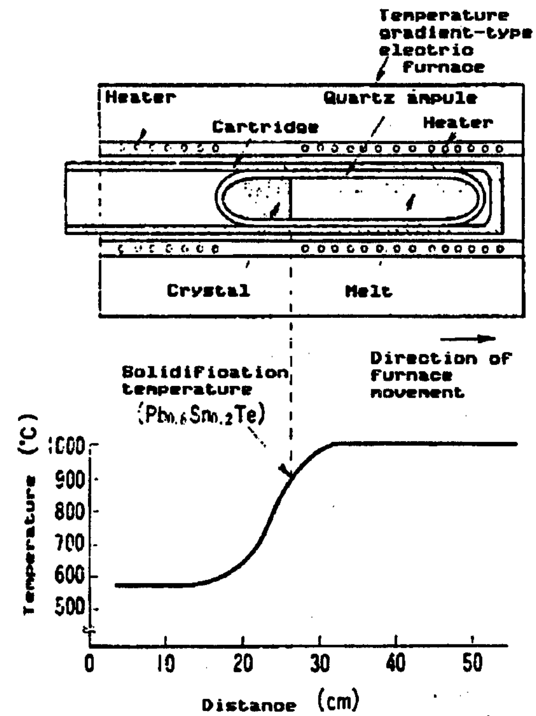



**Figure 4. Schematic of Crystal Growing by Bridgman Method**

When a mixed crystal, like $Pb_{1-x}Sn_xTe$, is grown from a melt on the earth, the crystal composition varies with the solidification ratio, as shown in Figure 5. Such changes in the crystal composition are phenomena attributable to the combination of segregation occurring when the melt is crystallized and the thermal convection taking place within the melt. When $Pb_{1-x}Sn_xTe$ is crystallized, the density of PbTe tends to become higher than that of SnTe. Therefore, in the melt, the SnTe density tends to grow higher. When the crystallization occurs on the earth, where thermal convection is caused, the excess SnTe is mixed with the remaining melt by agitation caused by thermal convection. Therefore, as the crystal growth progresses, the SnTe density in the melt rises. As a result, the SnTe density (Cs) in the crystal being grown also increases. The value of Cs is expressed by the equation, $Cs = kC_0(1-g)^{k-1}$. In the equation, k represents the segregation coefficient, $C_0$ represents the initial SnTe density, and g represents the solidification ratio. The manner in which the solute density changes is illustrated in Figure 6(a).

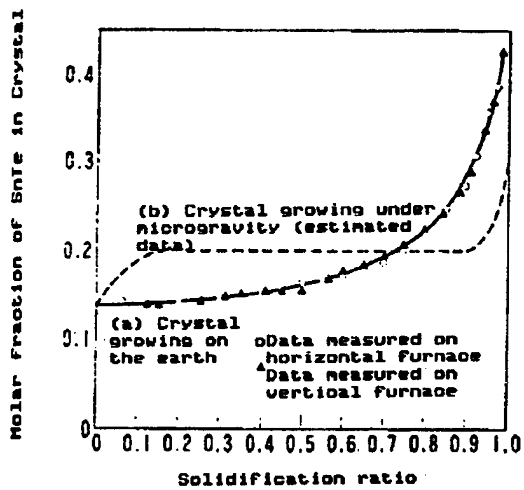



**Figure 5. SnTe Density Distribution Along the Axis of Single Crystal Growth From $Pb_{0.8}Sn_{0.2}Te$ Melt**

Under microgravity, the excess SnTe is mixed into the remaining melt only by the diffusion effect. As crystallization of the melt advances, the SnTe density at the melt-crystal interface increases until it becomes equal to $C_0/k$. After reaching the value of $C_0/k$, the SnTe density is kept constant in a stationary state. Such a process is illustrate in Figure 6(b). When the stationary state is maintained, the SnTe density in the composition of the crystal grown remains $C_0$, and the amount of excess SnTe which is released at the melt-crystal interface as the melt is crystallized is balanced with the amount of SnTe transferred into the melt by diffusion effects. Such an

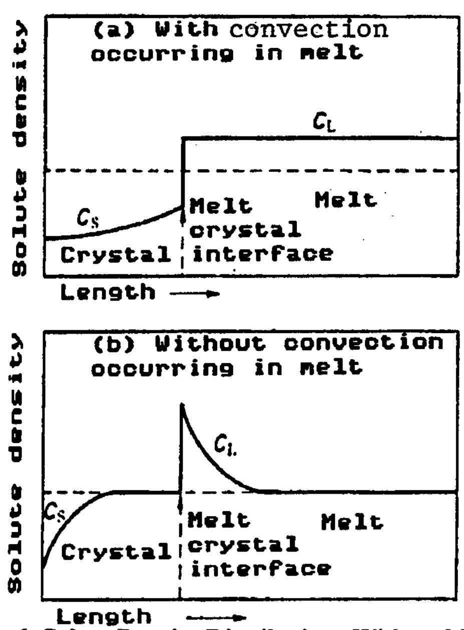



**Figure 6. Solute Density Distributions With and Without Convection in Melt $C_S$: Solid density in crystal $C_L$: Solute density in melt**

equilibrium state is created when the crystallization speed is made higher than the speed of SnTe transportation by diffusion. The single crystal grown in such a state is expected to contain a uniform-composition portion. The crystal composition distribution expected to be achievable in such a state is shown by the broken line in Figure 5.

Melt agitation by thermal convection results in mixing the low-temperature melt existing around the melt-crystal interface with the high-temperature melt existing away from the melt-crystal interface, causing temperature fluctuation in the melt. Such melt temperature fluctuations sometimes speed up the crystal growth and sometimes cause the grown crystal to melt again. Fluctuations in the crystal growth speed lead to local nonuniformity of the temperature crystal composition, referred to as striations. Such nonuniform crystal composition leads to the creation of dislocations. In a microgravity environment, melt temperature fluctuations due to thermal convection do not take place. Therefore, it may be possible under microgravity to grow crystals with uniform composition and reduce the generation of crystal defects attributable to nonuniformity of the crystal composition.

In the $Pb_{1-x}Sn_xTe$ melt with a kinematic viscosity coefficient several times smaller than that of water, thermal convection occurs easily. According to the results of simulation using a computer, the estimated gravity at which thermal convection is suppressed and at which the movement of heat and material due to diffusion becomes prevalent in the crystal production system to be used in the FMPT is $10^{-4}$G. Gravity of that order will be realizable without difficulty in the Space Shuttle.

In addition to the nonuniformity of crystal composition, thermal and mechanical stresses can also cause crystal dislocations. Thermal stresses which cause crystal dislocations are generated depending on the temperature distribution in the crystal being grown. The Bridgman method of crystal growing makes use of a temperature gradient. Therefore, when the Bridgman method is used, crystal dislocations due to thermal stress are essentially unavoidable. The density N of dislocations caused by thermal stress resulting from the temperature gradient utilized in the Bridgman method is given by the following equation:

$$N=\frac{\alpha}{b}\cdot\frac{dT}{dz}-\frac{2\tau_c}{G_m b}\cdot\frac{1}{D}$$

where ga represents the linear expansion coefficient of the crystal, b represents the magnitude of Burgers vector, dT/dz represents the temperature gradient, $gt_c$ represents

| Item | Crystal grown under micro-gravity | Crystal growth on the earth | | |
|---|---|---|---|---|
| | Bridgman | Bridgman | Czochralski | Vapor growth |
| Growth speed | 5.5 mm/h | 0.5~1 mm/h | 5~6 mm/h | ~0.03 mm/h |
| Shape | 15 mmφ×50 mm l | 25 mmφ×100 mm l | 30 mmφ×100 mm l | 25 mmφ×20 mm l |
| Composition uniformity ($\Delta x$) | ~0.01 | ≥0.05 | ≥0.05 | ~0.01 |
| Dislocation density | $\sim 10^4$ cm$^{-2}$ | $\geq 10^5$ cm$^{-2}$ | $10^4 \sim 10^5$ cm$^{-2}$ | $10^3 \sim 10^4$ cm$^{-2}$ |
| Carrier density | $\sim 10^{18}$ cm$^{-3}$ | $\geq 2\times 10^{18}$ cm$^{-3}$ | $\geq 4\times 10^{18}$ cm$^{-3}$ | $\geq 1\times 10^{19}$ cm$^{-3}$ |
| Remarks | -High growth speed -High quality obtainable | -Medium growth speed -High quality difficult | -High growth speed -High quality difficult | -Low growth speed -High quality obtainable |

the critical shearing stress, $G_m$ represents the modulus of rigidity, and D represents the crystal diameter.

In the case of $Pb_{1-x}Sn_xTe$, the value for $gt_c/G_m$ is very small, so that the value of N is determined by the first term of the equation; if dT/dz = 40SDC/cm, the value of N is calculated as $N = 1.4 \times 10^{4cm^{-2}}$.

Table 1 gives the causes of dislocations in $Pb_{1-x}Sn_xTe$ crystal and indicates whether such causes can be suppressed by the effect of microgravity.

**Table 1. Causes of Dislocations in $Pb_{1-x}Sn_xTe$ Crystal and Whether Microgravity Is Effective in Eliminating Such Causes**

| Causes of dislocation | Whether preventable by micro-gravity |
|---|---|
| Nonuniform composition | |
| —Fluctuation of Pb/Sn ratio caused by crystallization | Yes |
| —Fluctuation of (Pb+Sn)/Te ratio caused by crystallization | Yes |
| —Nonuniform composition resulting from temperature fluctuation | Yes |
| Thermal nonuniformity | |
| —Axial-direction temperature gradient at melt-crystal interface | No |
| —Radial-direction temperature gradient at melt-crystal interface | No |
| —Inadequate annealing after crystal growth | No |
| Mechanical stress | |
| —Thermal expansion coefficient difference between ampule and crystal | Yes |
| —Effect of ampule shape | No |

Table 2 indicates estimated properties of the $Pb_{1-x}Sn_xTe$ crystal to be produced under microgravity. It is expected that large crystals of highly uniform compositions, as good as those produced on the earth by the vapor phase growth method in terms of dislocation density and carrier density, will be producible under microgravity. With regard to the carrier density, it is expected that the foregoing mechanism of making the SnTe composition uniform in a stationary state also works for the (PB+Sn)/Te composition ratio and that, even if the stoichiometry-based composition does not coincide with the harmonic melting composition, the composition of crystal grown in a stationary state will become identical with the stoichiometry-based composition of the material being crystallized, causing suppression of the collection of excess Te and lowering of the carrier density.

**4. Determining Conditions for Crystal Growth**

To enable growing a $Pb_{1-x}Sn_xTe$ single crystal of uniform composition, it is necessary to make the crystal growing speed higher than the speed of SnTe transportation by the effect of interdiffusion between PbTe and SnTe. For that purpose, it is necessary to determine the interdiffusion constant. We determined this value making use of the fact that, in the melt existing in a capillary tube, convection is suppressed by viscosity. More concretely, we made $Pb_{0.8}Sn_{0.2}Te$ melts unidirectionally solidify in capillary tube sat different crystallization speeds, measured the SnTe density distribution in them, and compared the results with a theoretical equation which relates the solute density distribution in crystal being grown to the speed of SnTe transportation governed by diffusion. Through this process, we obtained (5.3 +/- 0.3) x $10^{-5}cm^2/s$ as the value of interdiffusion constant D. The diffusion length

$$\sqrt{Dt}$$

(t for time) calculated using the above-obtained value of D is 4.4 mm per hour. Therefore, in this case, it is necessary to set the crystallization speed at 4.4 mm/h or higher. If crystal is grown at a lower speed, the amount of SnTe transported by the effect of diffusion from the melt-crystal interface into the remaining melt exceeds that of the SnTe released into the melt as the melt-crystal interface moves. As a result, the composition of the crystal being grown gradually changes—a phenomenon similar to that caused by melt agitation due to thermal convection during crystal growth on the earth.

If the crystallization speed is set too high, it makes the crystal growth unstable. To enable stable crystal growth at a high crystallization speed, it is necessary to always make crystal growth take place at the end of the melt-crystal interface by creating a large temperature gradient. The effect of the temperature gradient on crystal growth is shown in Figure 7. As the crystallization speed increases, the gradient of solute density distribution around the melt-crystal interface becomes very steep. Correspondingly, the temperature along the liquidus of the melt becomes quite dependent on the distance from the melt-crystal interface. When the temperature gradient is larger than the tangential gradient of the liquidus at the melt-crystal interface, crystal growth takes place only at the melt-crystal interface. If the temperature gradient is smaller than the tangential gradient of the liquidus, compositional supercooling occurs around the melt-crystal interface, causing a nonuniform cell-like crystal to be grown. In this case, elements, such as Sn, tend to be easily mixed into the crystal as existent at the interface. Therefore, for such compositional supercooling to be prohibited from taking place, it is necessary to make the temperature gradient dT/dz larger than the value of

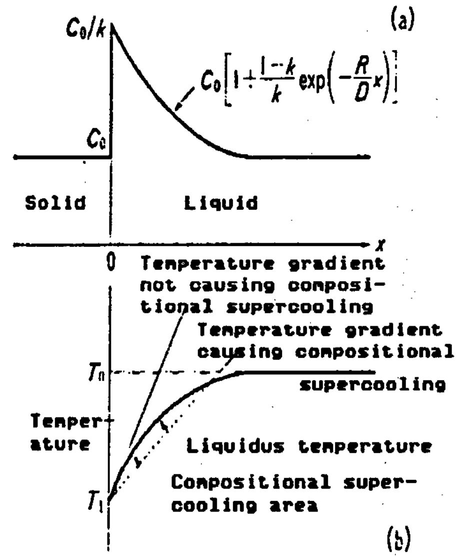
$$\frac{mC_0(1-k)}{Dk}R$$ 上

where m representsthe liquidus gradient shown in Figure 1 and R represents the crystallization speed. When R = 4.4 mm/h,

$$dT/dz \geqq 30^{\circ}C/cm$$

For the FMPT, our experiment will be conducted with R setat5.5 mm/h at a temperature gradient of 50SDC/cm.

Under microgravity, thermal convection in the melt is suppressed, however, if there is a free surface on which temperature differences or solute density differences exist, convection due to surface tension occurs near the melt surface. Such convection is called Marangoni convection. Marangoni convection makes up a sort of disturbance observed in the melt under microgravity. The magnitude of the Marangoni convection driving force can be estimated based on the Marangoni number Ma. The value of Ma we obtained for $Pb_{1-x}Sn_xTe$ by measuring the dependence on temperature of the surface tension is two orders of magnitude larger than the value for the driving force needed to make the Marangoni convection as fast as diffusion. In the space experiment being planned, it is necessary to




(a) Solute density
(b) Relationship between temperature gradient and liquidus

$C_0$ Initial density
$k$ Segregation coefficient
$R$ Crystallization
$D$ Diffusion constant
$T_0$ Liquidus temperature at density $C_0$
$T_1$ Liquidus temperature at density $C_0/k$

**Figure 7. Dependence on Temperature Gradient of the Occurrence of Compositional Supercooling**

prevent Marangoni convection. We are now working on a way to prevent it.

Other considerations to be taken for space experiments include safety measures in case the sample is broken and antivibration measures for apparatus protection at launch and recovery times. We are working on these measures, too.

### 5. Experiment Apparatus

The requirements to be met by the temperature gradient-type electric furnace for use in space experiments include, in addition to ordinary ones such as a high temperature gradient and safety at high temperatures, low-power consumption, so that the furnace will be usable with a limited power supply, and high stability of the furnace movement, so as not to impair the significance of microgravity. We ascertained the technical feasibility of such an electric furnace by fabricating and testing a prototype. At present, we are in the process of developing an electric furnace, as described in Figure 8, for use in space experiments.

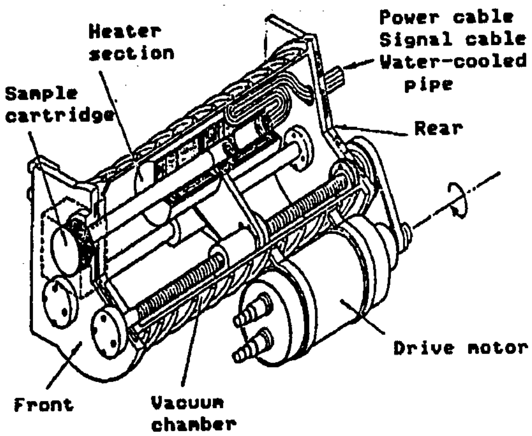



**Figure 8. Temperature Gradient-Type Electric Furnace**

## 6. Other Plans

Other plans have existed for growing $Pb_{1-x}Sn_xTe$ crystals under microgravity, one of which has already been carried out. Namely, NASA and (Vatter) Laboratory of West Germany experimented in jointly producing a $Pb_{1-x}Sn_xTe$ crystal from October to November of 1985 under the Spacelab D-1 project. In the experiment, the crystal was grown by annealing the melt while keeping a temperature gradient in a fixed furnace. The experiment results are expected to be disclosed shortly. In future experiments, the furnace movement method is scheduled to be used. NASA will conduct another experiment to produce the crystal in the IML-1 project, April 1990 at the latest. Vatter Laboratory is scheduled to conduct another experiment in the D-2 (July-September 1991) project. As for Japanese experiment plans, the Institute of Physical and Chemical Research is scheduled to experiment in growing crystals using the zone melting method under the FMPT program. The Space Environment Utilization Research Institute is also planning experiments in growing $Pb_{1-x}Sn_xTe$ crystal.

## 7. Conclusion

The significance of growing $Pb_{1-x}Sn_xTe$ crystal under microgravity has been discussed, and a plan to conduct such an experiment has been outlined. When crystal is grown in a microgravity environment, the environment is expected to have some favorable effects on the crystal quality, when compared with growing crystals on the earth. However, it does not mean that growing crystals under microgravity will not involve problems. It has been stated in this paper that, when crystals are grown under microgravity, solute transportation occurs only by diffusion effect. Whether such a mechanism will be maintained constantly during the experiment also must be ascertained.

From the viewpoint of commercial space-utilization, small-scale production of very expensive medicines or electronics materials is said to be most promising. To verify the favorable effects of space environment utilization and pave the way for industrial space-utilization, it is necessary to determine problems expected to be involved in space utilization and make steady efforts to solve these problems one by one. The preparations for the FMPT, scheduled for execution in May 1991, are nearing completion. When the crystal grown in space is obtained, we will closely examine its crystallographical and electrical properties. The author thinks that experimentally ascertaining phenomena which occur under microgravity is the true significance of the FMPT.

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## Japanese Space Station Module

*43067611 Tokyo CERAMICS JAPAN in Japanese Apr 87 pp 297-302*

[Article by Akira B. Sawaoka, Research Laboratory of Engineering Materials, Tokyo Institute of Technology: "Structural Materials in Space Development"]

[Excerpts]

### 1. JEM Construction Plan

Japan is scheduled to build a space station in the 1990s. It will not be a whole space station, but instead a space station module to be docked with the space station proper that is going to be built by NASA (National Aeronautics and Space Administration). The module to be built by Japan is comprised of a space laboratory called JEM (Japanese Experiment Module). The total cost of JEM, including the cost of experiment apparatus to be installed in JEM and the expenses for JEM operation in the initial stage, will amount to well over Y300 billion. JEM will measure about 4 m in diameter and 18 m in length. A total of four modules, including JEM, are scheduled to be docked with the space station proper.

In 1992, the 500th anniversary of the arrival of Columbus on the North American continent will be observed. The United States is going to build the space station as a national project in commemoration of the anniversary. President Reagan asked for the cooperation of ESA (European Space Agency), Canada, and Japan for the project. ESA is also scheduled to build a space station module. NASA initially planned to build three modules, but the number was reduced to two due to the reduced budget. The modules, antennas, generators, etc., are to be attached to a rectangular frame measuring 100 m by 145 m. Canada is in charge of fabricating a large magic hand (manipulator). Since the project is dependent on international collaboration, international conferences have been held frequently to coordinate preparations being made by the participant countries.

Phase B of the program, constituting a preliminary design stage, is to be finished by the spring of 1987, and phase C, for making the basic design, is to be entered around the summer of the same year. In the preliminary module design stage, it has already come to be known that the United states, ESA, and Japan differ considerably in terms of design concepts. Design of the JEM has been undertaken by the NASDA (National Space Development Agency) of Japan. Figure 1 shows the JEM concept. JEM consists of a pressure cabin, which is to be filled with air at 1 atm, to enable astronauts to work there without wearing spacesuit, an experiment table exposed to space, and a supply section where apparatus and gases are to be stored. JEM is designed so that it can be loaded with a wide variety of apparatus to enable extensive research and experiments, ranging from material science and life science to astronomical observation,

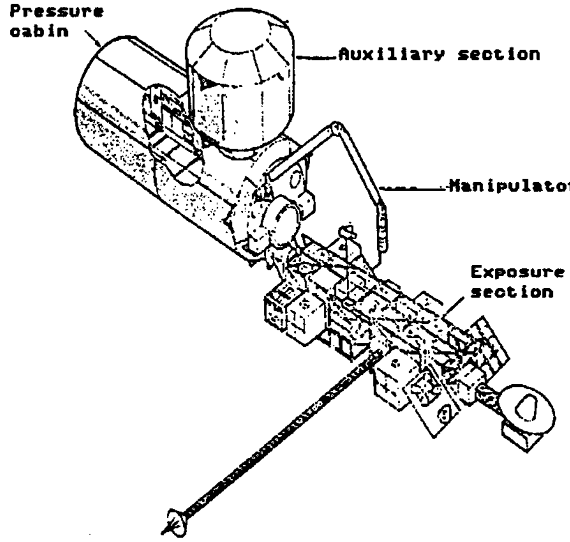


**Figure 1. Japanese Experiment Module (JEM) To Be Docked With the Space Station (Illustration obtained from National Space Development Agency of Japan)**

earth observation, and space engineering. What the ultimate multipurpose laboratory designed by Japanese scientists will be like is a focus of attention of scientists throughout the world.

The modules being designed by NASA are basically for single purposes. NASA's intention is to use the modules for some specific purposes for a certain period of time and then to replace the apparatus as required. A space shuttle is to be sent to the space station every 90 days to replace astronauts and replenish supplies. NASA asserts that the four modules should have different features and that they should be offered for shared use. Japan and Europe do not support the idea. They are afraid that, with NASA to shoulder more than 70 percent of the total cost of the space station project, it may exert too strong an influence under the name of "shared utilization," eventually making it difficult for Japan and Europe to carry out their own experiments.

Sixteen countries participate in ESA. Among them, West Germany and France have taken the initiative in the space station project. Although it is difficult to coordinate the intentions of the two countries concerning the project, ESA requests that it be allowed to fabricate a module under its own space station program and dock it alternately with NASA's station or ESA's space station, Columbus, as required. Such being the case, it has been difficult getting the countries participating in NASA's space station project to adjust their opinions.

Although the project has been facing difficulty in international collaboration, the preliminary design of the space station is almost finished. Among the project participants, no agreement has been reached as to the space structure materials to be used. NASA, ESA, and NASDA may even build their own modules made of totally different materials. The project also involves severe technological competition among the participants. NASA has fabricated space shuttles in the past. ESA previously built a spacelab that was launched by a space shuttle. Unlike them, Japan has no experience in building a space structure to be boarded by men. Therefore, Japan must exert more care than really needed to ensure safety. Furthermore, it is inevitable that Japan follow, in some respects, examples set by NaSA or ESA.

Japan has recently come to possess a high level of technology in the field of materials, too. However, when it comes to composite materials for use in aircraft or space structures, Japan's technological level cannot be termed adequately high. In particular, as for reliability evaluation technology, it is said that Japan is decisively lagging behind the United States.

**2. Japanese Space Shuttle**

Although Japan is certainly far behind both the United states and the USSR in the field of space technologies, the distance between them has been gradually narrowing. in the 20th century with JEM completed, Japan will enter an era in which some Japanese will be in space at all times. There is no doubt that the day will come when a Japanese space shuttle is launched by the Japanese. The thermal protection system made of pasted tiles indeed appears to represent an undeveloped form of technology and lacks reliability. Is it not possible to utilize the technology for flexible refractory materials such as those used to repair blast furnaces? Or, would it be possible to devise an innovative idea for obtaining an enhanced thermal protection system?

Preliminary design of the space station has been made based on the assumption that it will be used for 10 years. Recently, voices advocating the extension of its design life to 20 years have been gaining momentum. In the design work to begin in 1987, the design life of the space station is likely to be set at 20 years. The materials to be used in the space station will need to meet more severe safety requirements. There are a lot of problems in store. Even such highly durable polymers as Kapton and teflon can crumble when exposed to oxygen existing in an atomic form in the skies 300 km above the ground. How can astronauts and apparatus be protected from collisions with micrometeorites? It will become necessary to use ceramics in many parts of the space structures. To meet such needs, ceramists are required to ensure the reliability of ceramics.

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## Solar Cell Cover Glasses for Satellites

*43067611 Tokyo CERAMICS JAPAN in Japanese Apr 87 pp 303-308*

[Article by Tokio Kimura, Asahi Glass Co., Ltd.: "Ultra Thin Glass for Space"]

[Text]

**1. Introduction**

Since the world's first artificial satellite, Vostok I, was launched in October 1957, many artificial satellites have been launched for many purposes, including test satellites, observation satellites, probing satellites and applications satellites.

It is not generally know that such satellites incorporate glass parts which play important roles.

Such glass parts include the cover glasses for solar cell systems attached to satellites and the thermal control mirrors for the satellite proper.

These glass parts are used to protect satellites from radiation and heat, enabling them to function properly in space where environmental severity is beyond the imagination. The National Space Development Agency of Japan has developed important space technologies domestically ranging from rockets to artificial satellites, and has succeeded in producing important devices, parts and materials for use in space. It succeeded in domestic production of cover glasses jointly with Asahi Glass Co., in 1986.

This paper will deal with cover glasses only. First, the author will describe the space environment in connection with the use of cover glasses. Next, he will discuss

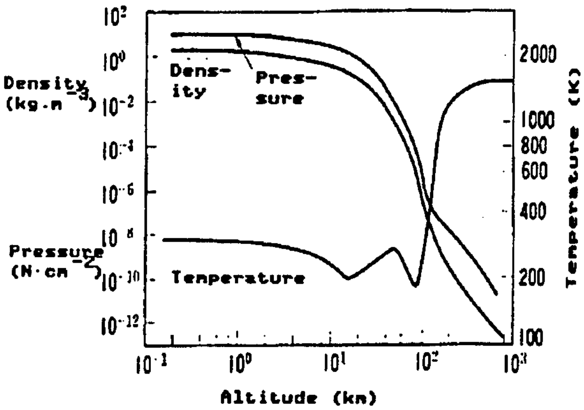


Figure 1. Density, Temperature, and Pressure Changes by Altitude

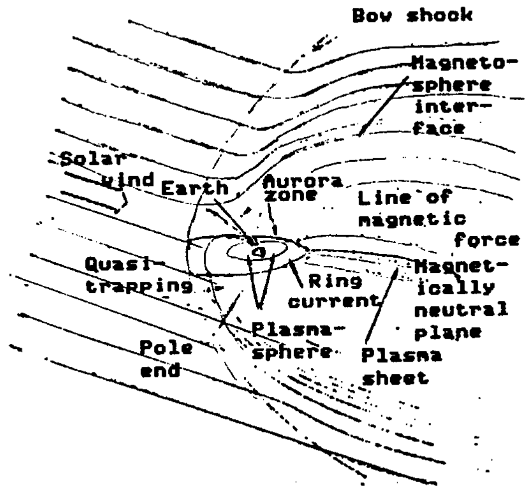


Figure 2. Structure of Earth's Magnetosphere

the purpose of using cover glasses and the functions required of them. He will then describe actual cover glasses and will explain cover glass reliability management.

## 2. Space Environment

### 2.1 Environment for Rocket Flight

When a rocket to boost a satellite lifts off, it ascends while accelerating at a considerable rate. Subsequently, after flying in the atmosphere at high speed, it thrusts the satellite into the target orbit. During that time, explosives are fired to sever or separate auxiliary boosters, as well as first- and second-stage rockets, for attitude control, orbital adjustment, etc. As explosives are fired for such purposes, the satellite is subjected to large vibrations and impacts, and it is locally heated to considerably high temperatures due to aerodynamic and radiant heat.

### 2.2 Vacuum

The vacuum in space is comprised of a mixture of low-density gases. Its main contents are hydrogen, helium, protons, and electrons. Figure 1 shows the pressure distribution in space, ranging from ground level to an altitude of about 1,000 km. As shown, the vacuum level at an altitude of 1,000 km is $10^{-9}$ torr.

In such a supervacuum, every vaporizable material vaporizes. All vaporizable materials, such as plastic and adhesives, vaporize, and some of the vapor deposition the surface of the satellite sometimes result in detrimentally affecting the solar cell performance.

### 2.3 Temperature

The temperature in space is thought to be as high as several thousand degrees C. However, the air density in space is lower than one-millionth that on the ground, so that the general energy in space can be ignored, even if the temperature of individual particles is high. Therefore, the temperature of the satellite orbiting the earth is determined by radiation from the sun and its re-radiation.

In reality, the temperature of the surface, directly exposed to the sun, of a satellite circling the earth becomes about 100-150SDC, and that of the satellite's shaded surface remains 100SDC or so.

### 2.4 Radiation

The radiation around the earth is comprised of electrons and protons captured in the earth's magnetosphere, particle beams generated by large-scale solar flares and cosmic rays of the galactic system. The earth's magnetosphere is illustrated in Figure 2.

As the solar corona gas expands, a plasma flow is generated. The plasma flow is called the solar wind. The solar wind flowing outward, passing by the earth's orbit, carries particles at a rate of as many as $10^{35}$ particles per second. Such particles mostly consist of protons whose average energy is several keV and whose density is on the order of $10/cm^3$. Furthermore, when the sort of explosion called a solar flare occurs, a group of high-energy particles is generated.

Figure 3 shows the distribution of atmospheric ion composition in space ranging from 100 km to 1,000 km in altitude.

### 2.5 Ultraviolet Radiation

The spectrum of sunlight intensity in the space zone, called air mass 0 (AMO) is shown in Figure 4.

The radiation in the 0.20-0.35 gmm region of the spectrum shown in Figure 4 is called ultraviolet radiation. The solar radiation in that region mainly comes from a solar atmosphere layer called the chromosphere. The

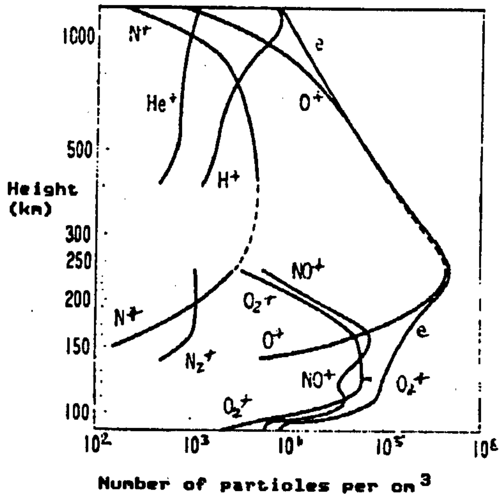


Figure 3. Distribution of Atmospheric Ion Composition

ultraviolet radiation of that wavelength is mostly absorbed by the ionosphere located in space beyond an altitude of 20 km. Therefore, only a small portion of the ultraviolet radiation reaches the earth. However, its energy is very high in space.

## 3. Cover Glasses

### 3.1 Purpose of Using Cover Glasses

The unprotected solar cells attached to a satellite orbiting the earth are damaged by the radiation of electrons and protons in the space environment, as described in Section 2 and, as a result, their performance deteriorates.

The solar cells can be protected from such electrons and protons by shielding them with a cover glass.

The cover glass prevents the solar cells from being damaged by particle radiation and eventually contributes toward enabling the satellite to remain in service for a longer period of time.

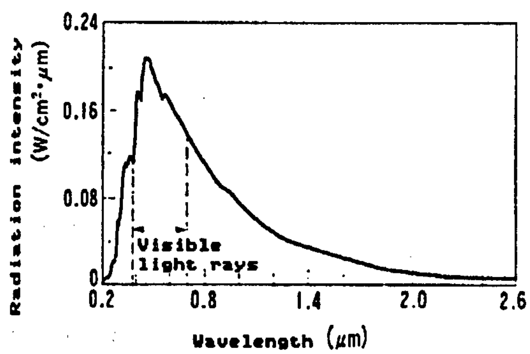


Figure 4. Sunlight Intensity Spectrum (AMO)

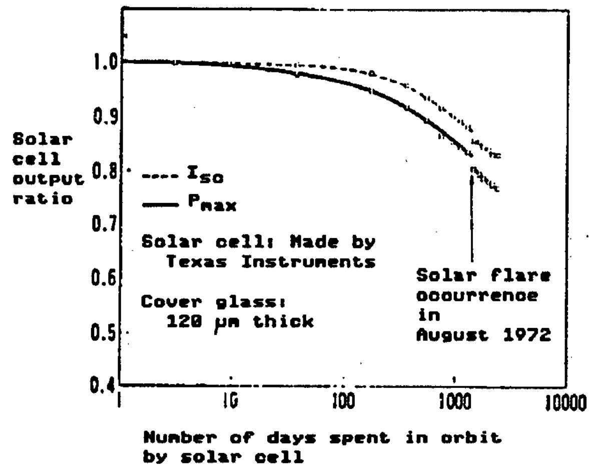


Figure 5. Solar Cell Output Transition With Passage of Time

The uncovered solar cells attached to the Japanese artificial satellite "Kiku No 3" became incapable of generation after 30 days. It is possible to extend the life of such solar cells to 5-7 years by protecting them with a cover glass. Since the life of a satellite is dependent on the amount of fuel left for use in correcting its position and the generation capacity of its solar cells, the cover glass is an extremely important part of a satellite.

Even if solar cells are protected with a cover glass, their performance deteriorates with the lapse of time. If they encounter a major solar flare, their performance deterioration is magnified.

Figure 5 shows the output transition with the passage of time of a solar cell protected with a cover glass. It shows how the solar cell performance deteriorates as the time passes and how the output drops when a solar flare occurs.

### 3.2 Cover Glass Function Requirements

When a cover glass is used to shield solar cells from radiation, it is incorporated in the solar cell system. Therefore, it must meet the following requirements:

1) Radiation shielding 2) Ultraviolet blocking 3) High transmittivity 4) Radiation resistance 5) Lightness 6) High emissivity 7) Low absorptivity

**Explanations of requirements 2) through 7) will be given in the following:**

The cover glass is to be bonded to the solar cell system. To bond it, a silicon-based adhesive, such as DC93500 (produced by Dow Corning), is used. Adhesives like that become slightly opaque upon exposure to ultraviolet radiation. As a result, the amount of sunlight incident on the solar cell surface is reduced, eventually causing the solar cell performance to deteriorate. To prevent such a problem, the cover glass is required to have an ultraviolet radiation blocking function.

The cover glass is also required to have as high a transmittivity as possible so as to allow solar rays to pass it with minimum loss. To meet this requirement, the front surface of the cover glass is usually coated for reflection prevention.

The cover glass itself must be free of degradation due to radiation n space. It is also desirable that the cover glass be light, i.e., thin, to minimize the satellite weight.

The cover glass is also required to reflect infrared radiation as much as possible since the infrared radiation, making no contribution to the solar cell output, raises the solar cell temperature, causing the solar cell output efficiency to decline. Therefore, it is desirable that the cover glass have the highest possible emissivity, while having the lowest possible absorptivity.

### 3.3 Actual Cover Glasses

#### 3.3.1 Radiation Shielding

The radiation blocking function of a cover glass is determined by the mass effect—it is not dependent on the cover glass material. In this regard, the cover glass should be made of a high-density thick material. However, using such a material contradicts the efforts made to minimize the cover glass weight—another requirement of the cover glass.

Among the solar cells available for practical use are silicon photocells measuring 50 gmm in thickness. The cover glasses used for such solar cells generally range from 50 gmm to 200 gmm in thickness.

Figures 6 and 7 show the electron and proton blocking effects of cover glass by thickness, respectively.

In real applications, the cover glass thickness is determined by such factors as the radiation resistance of the solar cells to be used, the satellite's orbit and the design life of the satellite.

#### 3.3.2 Ultraviolet Radiation

There are two methods of providing a cover glass to block ultraviolet radiation. In one method, a substance which absorbs ultraviolet radiation is included in the glass composition. In the other method, the cover glass surface is processed to make it reflect ultraviolet radiation.

The substances which absorb ultraviolet radiation of 0.28 gmm to 0.37 gmm in wavelength include Ce, Ti, V, Nb, At, Hf, and Zr ions. Such ions can be divide into two groups according to the wavelength of ultraviolet radiation they absorb. Of them, Ce, Ti, and V ions absorb

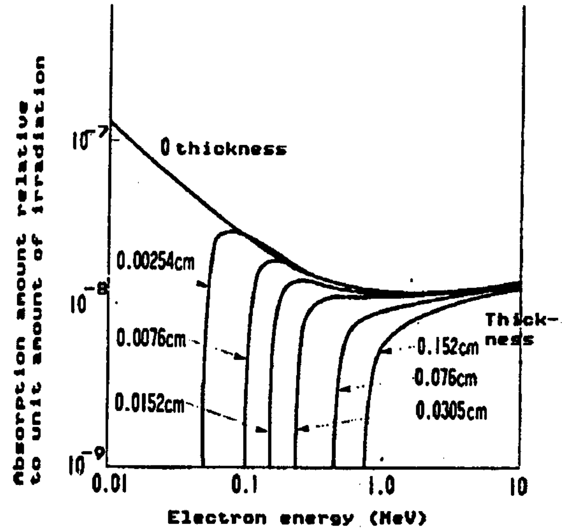


Figure 6. Electron Blocking Effect of Cover Glass by Thickness

ultraviolet radiation of longer wavelengths; the others absorb shorter-wavelength ultraviolet radiation. The former group of ions is more suitable for inclusion in the glass composition of solar cells.

Ce, Ti, and V all have a coloration effect when added to glass. Among them, the degree of absorption by Ce of ultraviolet radiation of wavelengths not shorter than 0.4 gmm is low compared with Ti and V. This means that Ce, if included in the cover glass composition, does not affect the solar cell efficiency much. Furthermore, glass containing Ce becomes less susceptible to radiation, so that adding Ce to glass is effective in preventing color

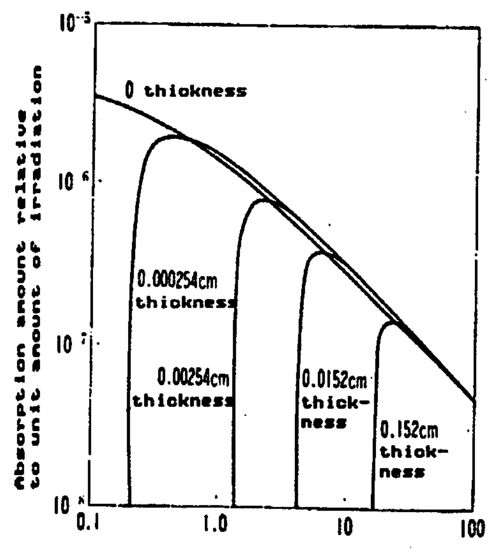


Figure 7. Proton Blocking Effect of Cover Glass by Thickness

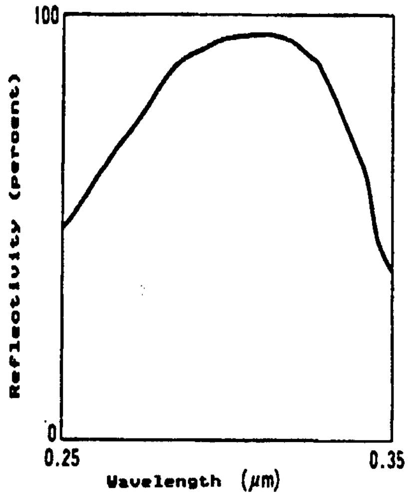


Figure 8. Ultraviolet Radiation Reflectivity Obtained by Surface Treatment

center formation in the glass. It is for these reasons that cover glasses designed to absorb ultraviolet radiation contain Ce in their glass composition.

In the other method of ultraviolet radiation blocking that is dependent on glass surface treatment, the back surface of glass is coated with At + Ti. The reflectivity for 0.25-0.35 gmm ultraviolet radiation of the coated glass is shown in Figure 8.

The ultraviolet cutoff wavelength $gl_c$ is used as a measure of the ultraviolet radiation blocking performance of glass. $gl_c$ represents the ultraviolet radiation wavelength for 50 percent transmissivity. A glass with a higher value of $gl_c$ is higher in ultraviolet radiation blocking performance. For practical purposes, an ultraviolet radiation cutoff wavelength of 0.345 gmm or greater is sufficient for cover glasses. For 50-gmm thick glass, the value of $gl_c$ can be obtained by adding 5 percent $CeO_2$ to the glass composition.

Cases occur in which irradiating glass with ultraviolet radiation causes its transmissivity to be reduced by solarization. Cover glasses containing $CeO_2$ do not show such a phenomenon at all, even if they are irradiated with ultraviolet radiation 10 times more intense than that of the sunlight in AMO for 30 days.

Recently, a technique for directly attaching a cover glass to the solar cell surface using no adhesive was developed. If the technique is made usable for practical purposes, the cover glasses will no longer require the ultraviolet radiation blocking function.

### 3.3.3 High Transmissivity

The values of transmissivity required of cover glasses are listed in Table 1.

**Table 1. Transmissivity Required of Cover Glasses**

| Wavelength (gmm | Transmissivity (percent) |
|---|---|
| 400 | 86 or more |
| 450 | 91 or more |
| 500 | 92 or more |
| 600 | 93 or more |
| 400-450 | Average 89 or more |
| 600-800 | Average 93.5 or more |
| 450-1,100 | Average 92.5 or more |

To obtain such values of transmissivity, the cover glass surface is processed for reflectionless coating, usually, $MgF_2$. The coated side of the cover glass is corner-cropped or laser-marked for easy distinction when the cover glass is to be attached to the solar cells.

### 3.3.4 Radiation Resistance

The radiation resistance of a cover glass itself is assessed by measuring the deterioration of its transmissivity caused when it is irradiated with electron, proton, and gg-ray radiation. There are two methods of making the measurement: the single irradiation method in which the sample is irradiated with electron, proton or gg-ray radiation, and the composite irradiation method in which the sample is irradiated sequentially with electron, proton, and ultraviolet radiation. The radiation resistance test conditions are specified in Table 2.

We conducted radiation resistance tests on cover glasses produced by the Ashai Glass Co. The declines in transmissivity caused by electron radiation in the 0.45-1.1 gmm wavelength region averaged 0.5 percent. In the case of protons whose energy is small, higher-density radiation causes a larger decline in the transmissivity of the samples. At any rate, the decline in the transmissivity of cover glasses caused by proton radiation is small. In our tests, it did not exceed 1 percent. Similarly, the transmissivity reductions caused by gg-ray radiation did not exceed 0.5 percent.

The results of testing by the composite irradiation method showed effects of the glass thickness. The declines in the transmissivity of 50-ggm thick glasses due to composite irradiation averaged 1.7 percent. the corresponding figures for 100-gmm and 150-gmm thick glasses were 1.4 percent and 0.4 percent, respectively.

| Irradiation method | Radiation type | Energy | Dose (density) |
|---|---|---|---|
| Single irradiation | Electron | 1 MeV, 2 | $10^{12} \sim 10^{16}$ n/cm$^2$ |
| | Low proton | 0.5 MeV, 0.75, 1 | $5 \times 10^{11} \sim 5 \times 10^{13}$ n/cm$^2$ |
| | Medium proton | 2 MeV | $5 \times 10^{11} \sim 5 \times 10^{15}$ n/cm$^2$ |
| | High proton | 5 MeV, 10 | $10^{11} \sim 10^{13}$ n/cm$^2$ |
| | Gamma ray | Co-60 | $10^7 \sim 10^9$ rad |
| Composite irradiation | Electron | 1 MeV | $10^{16}$ n/cm$^2$ |
| | Proton | 2 MeV | $10^{15}$ n/cm$^2$ |
| | Ultraviolet radiation | 10AM0 | 30 days |

### 3.3.5 Lightness

A lighter cover glass can be produced by adopting a glass with smaller specific gravity and a smaller thickness. However, there is a limit to reducing the cover glass weight in this way, since doing so results in lowering the radiation shielding function of the cover glass.

The cover glasses in use are 2 cm x 2 cm$^2$, 2 cm x 4 cm$^2$, or 2 cm x 6 cm$^2$. In thickness they range from 50 gmm to 200 gmm. A 50-gmm thick cover glass sized 2 cm x 2 cm$^2$ weighs about 50 mg.

As larger solar cell systems come to be used in the future, larger cover glasses will be required. If a large cover glass is made of very thin glass, it may warp. In addition, a larger and thinner cover glass will be more difficult to bond to a solar cell system and will require more care in handling. Considering these points, it is likely that, as the cover glasses are made larger in the future, their thicknesses will also be increased.

### 3.3.6 Emissivity and Absorptivity

The OCLI Corp. of the United States has marketed cover glasses frosted by chemical etching to raise the emissivity. Ordinary cover glasses have an emissivity of approximately 0.87.

When emissivity is high, absorptivity is low, according to the energy conservation law.

### 3.3.7 Types of cover glasses

The cover glasses are divided into two types as shown in Figure 9.

Figure 10 is a block diagram of the production process used by Asahi Glass Co. in producing type-1 cover glasses.

## 4. Reliability Management

If satellite parts malfunction in space, they cannot be replaced. Therefore, considering the huge amount of

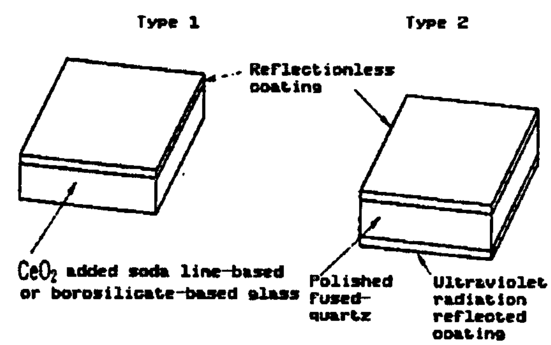


Figure 9. Types of Cover Glass

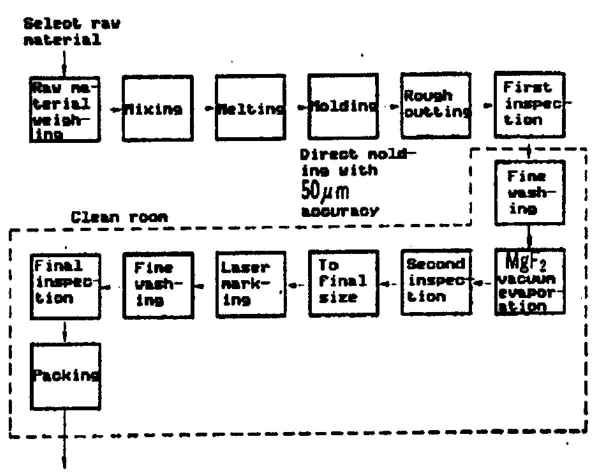


Figure 10. Cover Glass Production Process

money involved, satellite parts cannot be allowed to develop faults. Furthermore, since satellite parts are required to remain in service for extended periods of time in the severe space environment, their reliability must be higher than that of parts used on the ground.

For the above reason, even nonelectronic parts, such as cover glasses, must be produced under stringent quality control and the reliability of these parts must be managed strictly.

In the cover glass production process, detailed targets are set as to, for example, the type of raw material to be used, the degree of material refinement, the material melting temperature and the material molding temperature. Their production is controlled at least 10 times more severely than the production of parts for use on the ground.

For example, cover glasses are cut to size with an accuracy of within +/-0.05 mm, and their thickness deviation must be within +/-0.015 mm.

In terms of quality, too, performance specifications to be guaranteed are set in detail, and every part to be used must meet the specifications. In particular, as for durability, the criteria to be met are specified for the test items listed in Table 3; they are applied to parts for use both on the ground and in space. In the parts quality guarantee test, all the test items must be cleared.

**Table 3. Durability Test Items**

| For parts for ground use | For parts for space use |
|---|---|
| Fusibility | Thermal cycle |
| Moisture resistance | Vacuum resistance |
| Abrasion resistance | Ultraviolet radiation resistance |
| Adhesion | Radiation resistance |
| Storability | |
| Acoustic vibration resistance | |

Parts broken or damaged in the test are rejected. Even after passing the test, a part's performance is not allowed to deteriorate below the guaranteed specifications.

In the case of cover glasses, their transmissivity and ultraviolet radiation cutoff wavelengths are the main objects of performance guaranteed.

## 5. Conclusion

At present, the use of glass in space is limited to light parts, such as cover glasses and mirrors for thermal control, since the capacities of booster rockets are limited.

Unlike plastics, glass does not produce gases while in use. Its weather resistance in space is high, and is an optimal material for parts to be used in space.

As the expansion of space utilization continues, space stations or colonies will come to be built in the future. It is expected that durable-in-space metals, glass, and ceramics will be used in these future space structures for long periods of time.

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20109/9365

## Nuclear Development News Updated

### Exchange of Atomic Power Experience With Czech Officials

*43062005a Tokyo GENSHIRYOKU SHIMBUN in Japanese 10 Sep 87 p 1*

[Text] The Japan Atomic Industrial Forum held an expert-level meeting with Czech atomic energy officials in the Forum's Shimbashi conference room on the 7th. This is the first meeting of experts under the memorandum of cooperation the Forum concluded with the Czech Atomic Energy Commission in October, 1986. In his opening remarks, Forum vice chairman Tomiichiro Shirasawa referred to the level of Czech Science and industrial technology, which plays an important role in eastern Europe, and stressed the significance of an exchange of atomic energy technology between the two countries.

The Czechs who came to Japan were director (Kareru Mentseru) of the Czech Atomic Energy Commission's Atomic Power Bureau, deputy director (Jiri Bechibaru) of Fuels and Energy Ministry's Reactor Operation and Atomic Technology Bureau, chief PWR equipment and structure engineer Stanislav Stepanek of the (Sukoda) Public Corporation and (Iwan Furibunaku), science advisor to the director of the Basic Research laboratory of the Institute of Welding Research.

In 1984 the Forum accepted a proposal for cooperation made in a memo from the Czech Atomic Energy Commission's chairman S. Haaberu [phonetic], who came to Japan for the 17th annual meeting of the Forum, and the two sides exchanged draft memoranda. An observation team (headed by Tokyo University emeritus professor Yoshio Ando) went to Czechslovakia in 1986, at which time (Haaberu) and Ando signed and exchanged memoranda.

At the meeting, Shirasawa's opening remarks were followed by an address by Ando entitled "the Status of Atomic Energy Development in Japan." In that adress, Ando introduced the long-range plan for development and use of atomic energy that was revised in June, and described Japan's high rate of capacity utilization, which has been maintained at the 70 percent level for the last four years. In conclusion, he appealed to the participants of both countries to "produce great results through observation at this meeting."

Next (Mentseru) gave an address entitled "the Status of Atomic Energy Development in Czechoslovakia." He described the process that began with the first commercial reactor in 1977, and reported the present status: "at present there are eight Soviet light water VVER reactors (440,000 KW each) in operation and eight are under construction; of these, the two being built at Temelin (No. 1 and 2) and the two being designed for Temelin (No. 3 and 4) are of the million kilowatt class and will begin operation in 1992."

In regard to future plans, (Mentseru) revealed that "atomic power's share of total electrical power, which was 21 percent in 1986, is expected to reach 30 percent in 1996 and 52 percent in 2000."

He also introduced Czechoslovakia's thermal supply plan, stating that "we want reactor heat to supply 0.3 percent of total thermal demand in 1990, and 3 to 4 percent in 2000."

Mentseru went on to describe the "improved light water reactor plan" based on the science and technology agreement with the Soviet Union. In so doing, he revealed that "the improved reactor is improved in terms of equipment diagnosis, control system, seismic stability and so on, and is expected to begin operation at (Kaserottsa) in 1998." The meeting also included announcements and question/answer sessions on the topics of "operating experience," "welding technology," "quality assurance" and so on.

The Czechs are to tour Japanese manufacturers and atomic power plants until the 12th.

### Y370 Billion Budget Estimate for Atomic Energy Commission

*43062005b Tokyo GENSHIRYOKU SHIMBUN in Japanese 10 Sep 87 p 1*

[Text] The Atomic Energy Commission announced on the 8th it had put together an interagency budget request with estimates for expenditures related to atomic energy in fiscal 1988.

The estimate included all national budgets for atomic energy with the exception of the atomic energy field at universities under the Ministry of Education, Science and Culture. The total, which comes to Y182.7 billion from the General Account (down 0.4 percent from the previous year) and Y187.2 billion from the Special Account for Measures to Promote Development of Power Sources (up 5.8 percent), is Y369.8 billion (up 2.7 percent).

Looking at individual ministries, the General Account and Special Account for Power Sources together are to provide Y272.9 billion for the Science and Technology Agency (down 0.2 percent) and Y92.7 billion for the Ministry of International Trade and Industry (up 12.1 percent).

In addition the Ministry of Foreign Affairs is to get Y2.69 billion (down 1.9 percent); on the surface that is a decrease of Y53 million, but because the exchange rate is expected to be 145 yen/dollar, up 2 percent from the 163 yen/dollar at the time of the government draft budget at the end of last year, in real terms the figure is an increase. The IEA assessment and contributions of Y2.486 billion, the OECD/NEA assessment of Y189 million and Y16 million for participation in international conferences make up the total.

The figure for the Ministry of Transportation is Y35 million (up 7.3 percent); to deal with private plans for concentrated storage of low-level radioactive wastes at Rokkasho-mura in Aomori prefecture, MOT will put in Y24 million (up Y2 million) needed for the survey and analysis necessary for formulation of safety standards for transportation of radioactive substances and Y3.7 million to confirm the safety of transportation of radioactive substances. It will also spend Y3 million for lectures and guidance on the safe transportation of radioactive substances, and Y3.5 million for development of nucleared powered ships; these amounts are the same as last year.

The figure for the Ministry of Agriculture, Forestry and Fisheries is to be Y362 million (up 13.6 percent), all for a project for eradication of melon flies in the Amami Islands.

The figure for the Okinawa Development Agency is to be Y1.187 billion (up 3.7 percent), all for a project for eradication of melon flies on Kume Islands and the islands around Okinawa proper.

The Ministry of Health and Welfare is to receive Y580,000 (no change) for guidance, regulation and supervision over therapeutic equipment.

The Ministry of Home Affairs is to receive Y1.8 million (no change) for guidance on nuclear disaster measures.

## NUCEF Safety Inspection Requested

*43062005c Tokyo GENSHIRYOKU SHIMBUN in Japanese 10 Sep 87 p 2*

[Text] The Japan Atomic Energy Research Institute made application to the Science and Technology Agency on 31 August for safety inspection of its fuel cycle safety engineering research facility (NUCEF), which is being built in Tokai-mura. This facility will carry out safety research dealing with the back end of the nuclear fuel cycle, including research on critical safety, development of high-performance recycling processes and research on safety control systems for TRU (transuranic elements) waste. It will be the world's first large facility of its kind limited to peaceful uses.

Design and fabrication of equipment for the facility began in 1986. Because of the current request for safety inspection, it will receive its first safety inspection about the end of November, and the second by the end of March, 1988. Construction of the building will begin in fiscal 1988, and is to be completed by 1990.

The test facility will consist of criticality experiment equipment, reprocessing process experimental facilities, TRU waste substance experimental facilities and so on.

In critical safety research, fixed critical test equipment will be used to measure the concentration of uranium-plutonium mixed nitric acid solvent fuel and to measure the conditions of criticality with degree of enrichment as a parameter. Super-critical experiment equipment will model a critical accident, and basic data on calculation of nuclear output, temperature of solvent fuel and radiation generated will be obtained. Moreover, nuclear fuel regulation experimental facilities are being prepared for regulation experiments on critical safety of solvent fuels of different compositions.

With regard to high performance reprocessing processes, reprocessing process test equipment will be used for improvement of preprocessing through continuous welding and research on iodine capture concentration technology, research on an improved extraction process using an electrolytic mixer-settler, and improvment of the waste water recycling process to reduce core transfer to high-level waste water, all in order to improve safety measures and make processes more economical.

There will be research on application of the precipitation method, a simplified extraction method and the ion exchange method as methods to isolate TRU wastes included in high-level waste water (HLW). There are also separation test facilities which have the purpose of improving safety of HLW processing and disposal.

The facility will also develop technology for nondestructive discrimination of TRU in wastes and technology for nondestructive quality checks of conditions within solid bodies. It will establish technology for controlling generation of TRU waste substances, controlling categorization and checking quality. It is to provide basic data for setting values for categorization of TRU and non-TRU waste products.

Using this facility, the Research Institute plans to conduct joint research with universities, the Power Reactor and Nuclear Fuel Development Corporation and others.

## Hitachi Develops Equipment for Automatic Analysis of Strontium

*43062005d Tokyo GENSHIRYOKU SHIMBUN in Japanese 10 Sep 87 p 7*

[Text] Hitachi Ltd. has recently developed, jointly with six power companies like Japan Atomic Power and Tokyo Electric Power, equipment for automatic analysis of strontium with trace radioactivity.

Its purpose is quantitative analysis of very small amounts of radioactive strontium at atomic facilities and in the surrounding environment.

Analyses have been made of radioactive strontium-89 and strontium-90 in samples collected near or within atomic facilities. However, such analyses take about 100 hours per sample because they require preprocessing including precipitation, filtering and vaporization drying, and are thus difficult to automate.

Moreover, interfering radioactive substances mixed in the sample must be removed first; there is great need for automation of strontium analysis.

In response to that situation, Hitachi began development with the goals of analyzing concentrations down to .001 picocurie per milliliter without regard to the presence of other nuclei in the sample and of automating that process.

Specifically, researchers considered the method of separating and concentrating liquid-phase strontium by means of ion exchange and liquid chromatography after forming compounds of such interfering nuclei as cobalt-60 and chrome-51. They then developed beta ray detectors of the flow cell type that were capable of measuring samples in the liquid phase, and optimized them to give maximum efficiency for detection of strontium beta rays.

In this way they succeeded in automating the processes of separating interfering nuclei, concentrating the strontium and measuring the beta rays, all in the liquid phase. The working time needed for analysis is reduced sharply, to 12 hours per sample, and accurate quantitative analysis is possible even when other radioactive substances are 100 million times more concentrated than the strontium.

## AEC Establishes Expert Group to Promote Basic Technology

*43062005e Tokyo GENSHIRYOKU SHIMBUN in Japanese 17 Sep 87 p 1*

[Text] The Atomic Energy Commission decided on the 11th to establish a Group of Experts for Promotion of Basic Technology. The development of basic technology emerged as one of the highlights of the Long-term Plan for Development and Use of Atomic Energy. Four subgroups will be established under the group of experts; they will deal with (1) materials technology for use in atomic energy, (2) artificial intelligence technology for use in atomic energy, (3) laser technology for use in atomic energy, and (4) technology for evaluation and reduction of radiation risk. Their policy is to actively undertake creative development of technology in search of breakthroughs in the system of atomic energy technology.

Earlier atomic energy R&D had been intended to realize specific atomic energy facilities. That is, it has been largely an effort to catch up with advanced countries through implementation of projects.

Consequently, although the ability to solve immediate problems has been established, one can hardly say Japan has established the sort of broad technical base necessary for technical breakthroughs or the emergence of creative technology.

The goal of the basic technology development presently envisioned is to break out of the present status and actively undertake the development of creative technology that can be shared by a variety of atomic energy projects, and thus seek breakthroughs in the system of atomic energy technology.

The safety and reliability of the atomic energy system will be further enhanced by this means.

The commission will convene the first meeting of the group of experts in October. It is to work out a concrete R&D plan by the end of this fiscal year.

It has been decided that future studies will focus on (1) materials technology for use in atomic energy, (2) artificial intelligence technology for use in atomic energy, (3) laser technology for use in atomic energy, and (4) technology for evaluation and reduction of radiation risk.

The study of atomic energy materials technology is to focus on such things as R&D on materials which can withstand radioactivity, and development of materials which, when exposed to radiation, tend not to become radioactive themselves.

In the area of artificial intelligence technology, there will be an attempt to develop self-directing robots to break out of the constraints which radiation puts on the operating environment of atomic power stations. The group will also undertake development of autonomous plant control technology for control of complex operations.

In the area of laser technology, the group will attempt to develop technology to raise the level of existing lasers by increasing their power or providing variable wavelengths, and to develop new lasers such as free-electron lasers.

And in addition ot conventional epidemiological surveys for evaluation and reduction of radiation risk, there is to be research which extends to the genetic realm.

The following members will make up the group of experts: Makoto Ikegame (Federation of Electric Power Companies), Kunihiko Uematsu (Power Reactor and Nuclear Fuel development Corporation), Keiichi Oshima (formerly Tokyo University), Mikita Kato (Kyoto University), Eiichi Goto (Tokyo University), Toshisuke Kondo (Tokyo University), Toshio Sada (Institute of Physical and Chemical Research), Akira Sawaoka (Tokyo Institute of Technology), Koichi Shimoda (Keio University), Ken Sugiura (Electrotechnical Laboratory), Kozo Sugiyama (Nagoya University), Atsushi Suzuki (Tokyo University), Itsuhiko Seshima (Japan Electrical Manufacturers Association), Masami Tanaka (Saitama University), Yoshinobu Tsutsumi (formerly Nihon Keizai Shimbun), Toyozo Terashima (National Institute of Radiological Science), Ryuichi Nakagawa (National Research Institute for Metals), Bunjiro

Fukeda (Japan Atomic Energy Research Institute), Yoichi Fujiya (Tokyo Institute of Technology), Shigeteru Fujita (Kyoto University), Mitsuo Maeda (Kyushu University), Ryoichi Mori (Iron and Steel Institute of Japan), Kazuhisa Mori (Japan Atomic Industrial Forum ), Hirokore Yoshikawa (Tokyo University), Haruyoshi Akita (Tokyo University).

### STA Proposes Atomic Energy Regional Center

*43062005f Tokyo GENSHIRYOKU SHIMBUN in Japanese 17 Sep 87 p 2*

[Text] The Science and Technology Agency has drawn up the concept of an atomic energy regional center for Asian regional cooperation in technology acquisition and training in relation to atomic power systems and the use of radioactivity in medicine and agriculture. This concept is intended to make effective use of the Asian region's limited talent and capital, and to raise the level of the region as a whole. Japan, as an advanced atomic energy country, is to support the project and actively cooperate until the stage when the various countries can use the technology and reap its profits.

Because it would take large amounts of time and capital for each country to individually prepare all the facilities of this concept, the center will be jointly used by the Asian countries in accordance with the needs of each and focused on the fields considered most appropriate in terms of the research potential of the individual country.

Until now Japan, as the advanced atomic energy country of Asia, has cooperated with individual countries by establishing an atomic energy research exchange system, and by inviting in researchers of developing countries and sending out Japanese researchers.

In the midst of this activity, atomic energy research has been going forward among neighboring Asian countries in recent years, and at the same time there have been increased numbers of requests for Japanese cooperation in different forms. Thus in order for Japan to effectively provide cooperation suited to the needs of the particular situation of each country, STA came up with the concept of establishing an atomic energy regional center.

STA says that to promote this concept, it is important to have an accurate grasp of the situation of each country, and "to gain consensus; cooperation cannot be forced."

The first step of the process will be to build consensus and push a framework for support in FY 1988. Then there will be surveys of the situations of individual countries, concrete studies of what kind of center should be built, and studies of the content of cooperation that will be possible for Japan.

Then in 1989 Japan will undertake actual creation of the center and expansion of its domestic framework.

Looking at the status of atomic energy development in various Asian countries, South Korea has put its efforts into the safety field, and the PRC has expressed great interest in reactor operator training. Indonesia hopes to receive experts and exchange personnel in connection with construction and operation of a neutron diffraction device. Malaysia desires cooperation in the use of radioactivity in the fields of medicine and the agricultural industry. And Thailand has put its effort into irradiation of food products.

### Reprocessing Facility to Resume Operation

*43062005g Tokyo GENSHIRYOKU SHIMBUN in Japanese 17 Sep 87 p 2*

[Text] On the 16th the Power Reactor and Nuclear Fuel Development Corporation began shearing spent fuel for the final inspection in the Tokai Reprocessing Facility's 4th Regular Inspection. The Regular Inspection is to be completed in November. The facility will resume operation, and is expected to process a total of 27 tons of spent fuel by the end of the year. The plan is to reprocess about 50 tons during the entire fiscal year.

This year is the 10th anniversary of the Tokai Reprocessing Facility, which began reprocessing spent fuel in September, 1977. As of the end of August the cumulative amount processed had reahed 347 tons.

### "Mutsu" Moves Offshore

*43062005h Tokyo GENSHIRYOKU SHIMBUN in Japanese 17 Sep 87 p 2*

[Text] The Japan Atomic Energy Research Institute, on the 9th, moved the atomic-powered ship "Mutsu," which had been berthed at Ominato harbor in Mutsu, Aomori, about 10 km offshore in Mutsu Bay for inspection and repair of the wharf cranes.

The "Mutsu" will move under its own power, using an auxiliary boiler. It will stay out until the 21st, then return to Ominato harbor.

The crane at the wharf at Ominato harbor is to be transferred, following inspection and repair, to the new harbor at Sekinehama.

### Safety Commission Approves Use of New Fuel Form

*43062005i Tokyo GENSHIRYOKU SHIMBUN in Japanese 17 Sep 87 p 2*

[Text] The Nuclear Safety Commission approved, on the 10th, the use of "fuel rods with 36 elements of uranium dioxide plus gadolinia" and "fuel rods with 36 elements of mixed uranium and plutonium oxides with axially distributed enrichment" in the heavy water critical experiment facility at the Power reactor and Nuclear Fuel Development Corporation's Oarai Engineering Center.

It determined that safety could be assured in the design of fuel concentrates in that (1) the addition of chemically stable gadolinia would not have a deleterious effect on the rod sheathing and (2) maximum thermal output in the reactor core would not be changed by the use of fuel rods with an axial distribution of plutonium enrichment.

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## Expansion of Aircraft Markets Discussed

*43064031b Tokyo KABUSHIKI NIPPON in Japanese 5 Aug 87 pp 88-89*

[Article: "Aircraft and Space Industry Approaching New Periods"]

[Text] Expanding Aircraft Markets

The aircraft and space industry is approaching a new stage. The expansion of aircraft and space markets will become a mainstay for Japan, whose industries must be changed to knowledge-intensive industries. The technical influence is large, and it is expected that the aircraft and space industry will be highly advanced, becoming one of Japan's main industries in the future.

At present, there is the tendency for the Defence Agency's demand for aircraft to increase based on the medium-term defense build-up plan. This demand accounts for about 80 percent of the entire demand for aircraft. In particular, the development tendency for the FSX (Fighter Support X) has come into the limelight. The FSX is a next-generation support fighter, and is under the charge of mainly defense-related enterprises, such as MHI (Mitsubishi Heavy Industries, Ltd.), etc. The method for selecting the FSX is unclear, but it seems that the Japanese Defense Agency and the industrial world eagerly wish to adopt a Japan-United States joint development plan in which Japan can assume the leadership. According to the plan, the development cost will be earmarked for the next fiscal year budget, when the development will be started. At least 100 FSXs will be deployed in Japan in around the late 1990s. The decision in favor of the above method is attracting attention, because this plan will become a big project, requiring a total of Y1 trillion.

On the other hand, the international joint development project of the YXX and that of the V-2500 have been started in the civil aircraft field, which has lagged behind other fields. The YXX is a 150-seat-class next-generation passenger airplane, and is being undertaken by MHI, KHI (Kawasaki Heavy Industries, Ltd.), FHI (Fuji Heavy Industries, Ltd.), etc. The V-2500 is an engine for this passenger airplane class, and is being undertaken by MHI, KHI, IHI (Ishikawajima-Harima Heavy Industries Co., Ltd.), etc. Japan will participate in both projects on an equal footing with the West. In the future, Japanese enterprises will become indispensable for overseas aircraft industries, because they will bear a part of the development cost, which will reach more than Y500 billion, and will contribute advanced technology to the overseas aircraft industries.

In 1985, the Japanese aircraft industry sales totaled Y750 billion, and the SJAC (Society of Japanese Aerospace Companies, Inc.) anticipates that this amount will reach Y1.8 trillion by the year 2000. Therefore, it is highly expected that the aircraft market will be extended in the future.

According to a report published by the Long-Term Meeting of the Space Activities Commission, about Y6 trillion is required in development costs by the 21st century, and the importance of individual space development work is emphasized. A space plane will definitely be developed domestically, a space station will be completed by the late 1990s, and full-scale manned space activities will be developed in the late 1990s.

Up to now, space development work has referred to the use of space positions according to satellite launchings, but in the future, space development work will mean the use of environments for developing new technologies, such as biochemistry, new materials, etc., as well as the above use. In order to use space environments, a large amount of varied materials for constructing laboratories and plants must be transported to space, which requires rockets with high launching capacities.

The H-II Rocket, which was completed for launching in the summer of last year, has a launching capacity of 2 tons, and will be launched in 1992. The H-I Rocket has a capacity of 550 kg. The H-II Rocket is at the worldwide level, since the launching capacity of the Ariane-4 Rocket developed by the ESA (European Space Agency) is 2 tons. In addition, the production of the entire rocket, including a satellite storing section, will be accomplished in Japan. Enterprises in charge of this production are MHI, KHI, IHI, NEC Corp., MEC (Mitsubishi Electric Corp.), etc. The development cost will reach approximately Y200 billion, but it is anticipated that the space industry will reach a Y1 trillion in the year 2000 due to the fact that space development environments will be used on a full scale.

It is anticipated that the aircraft and space industry will be highly-developed, becoming a leading Japanese industry in the future, due to the following reasons: 1) the value added is high, 2) the aircraft and space industry is a knowledge-intensive industry, 3) the technical influence caused by the development work is very large, 4) from the beginning, the international division of labor is promoted, 5) there is a little trade friction between Japan and the West, etc.

The industrial world also expects the large expansion of aircraft markets, and asks for business opportunities in the aircraft and space field.

The main enterprises are shown below; the tendency for these industries to use high technology is attracting attention.

Rocket-related enterprises: MHI, KHI, IHI, and Nissan Motor Co., Ltd.

Satellite-related enterprises: Hitachi, Ltd., Toshiba Corp., MEC, NEC Corp., and Fujitsu, Ltd.

20143/09599

## Front-runners in Bioelectronics Technology Discussed

*43066502 Tokyo TOSHI KEIZAI in Japanese Oct 87 pp 42-43*

[Article by Yuta Sagara, science journalist: "Bioelectronics, Innovative Technology Stimulating Development"]

[Text] Front-runner in Biosensor Development

Targeted for realization at the beginning of the 21st century, research and development of bioelectronics, which combines biotechnology and electronics technology, have become active. Roughly speaking, trends of R&D are classified into those which place importance on application of brain and nervous systems to computers, development of bioelements, and development of a biosensor which makes use of a living body's identifying capability.

Some animals have the capability of identifying very minute amounts of substances which create smell and taste. The immunity system is at work in the body of a human being, and in this mechanism, the force which detects and identifies the very minute quantity of foreign substance is also at work. The biosensor is what measures the density of biochemical substance using the natural capability of identifying a very minute quantity of substance. The biosensor converts chemical signals created by a living body's substance identifying capability to electric signals.

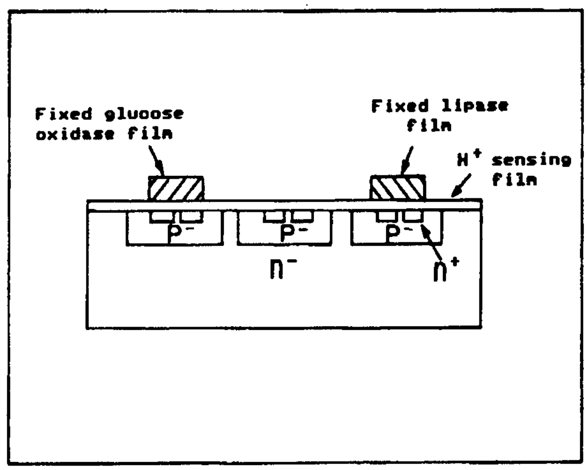
For a living body's substance identification, enzymes and antibodies are used as the "living body's catalyzers." The biosensors commercialized so far fix such living body catalyzers to transducers (converters) such as electrodes. The first biosensor was developed in the United States to measure the quantity of glucose (grape sugar) in the blood. This sensor is obtained by fixing thin films of the enzyme called glucose oxidase to enzyme electrodes.

In Japan, Fuji Electric Co., Ltd., Toa Electronics, Ltd., Toyobo Co., Ltd., and Omron Tateishi Electronics Co. have commercialized biosensors for glucose measurement. Also, Toyo Jozo Co., Ltd., has developed a food analysis biosensor for measurement of six items, including, glucose, lipid, alcohol, etc. and Nisshin Electric Co., Ltd., has developed a biosensor for measuring waste water BOD.

Recently, leading electronic device manufacturers, such as NEC Corp. and Mitsubishi Electric Corp., have succeeded in developing an ion sensing field effect transistor (ISFET) by applying semiconductor technology to a transducer that is attracting attention as a means for a breakthrough to the realization of bioelements.

### Realization of Biocomputer Sought

The biosensor, whose development is in progress, is still only an "introduction" to bioelectronics and the central figure to be realized is the biocomputer with functions comparable to that of man's brain. An approach to such biocomputers is to apply the living body's molecules,




**[Unnumbered figure] Structure of ISFET Semiconductor Sensor**

such as protein, to the material of an element which configures a computer. Such an element is called a "bioelement." The concept of bioelements was proposed for the first time in 1980 by Dr J.H. (McAleer) at Jentronics Laboratories Inc., a U.S. venture business.

The bioelement proposed by Dr (McAleer) consists of a unit called (molton). The molton joints monochronal antibodies and enzymes and its size is represented by one side of about 100 angstroms. (One angstrom is 100-trillionth of a meter.)

If moltons are spread over a 1 $cm^2$ chip, the entire surface would be covered by 1 trillion moltons. This means the birth of a memory element whose capacity is as large as 1,000G bits. Such a memory capacity is absolutely impossible for the current silicon semiconductor to realize.

Of course, whether such a memory element can be realized or not is unknown, but Japanese manufacturers have high expectations for such a memory element. Seven companies, e.g., Toshiba Corp., Sharp Corp., Toray Industries, Inc., Ajinomoto Co., Inc., Kao Soap Co., Ltd., are grappling with R&D of the element. MITI's Agency of Industrial Science and Technology last year also started a bioelement developmental project in cooperation with the private sector. Billions of yen have been budgeted for expenditure over a 10-year period.

As an approach to apply the living body's high molecules to electronic elements, Hitachi, Ltd., and Mitsubishi Chemical Industries, Ltd., are conducting research on a minute circuit-pattern forming technology. This technology utilizess a "molecular element" which uses molecules consisting of not only moltons, but also organic molecules whose molecular weight values are smaller than those of a living body's high molecules and the

| Enterprise name | Main research theme |
|---|---|
| NEC Corp. | Nerve function of nematode, semiconductor sensor |
| Mitsubishi Electric Corp. | Nerve function of sea hare, semiconductor sensor |
| Fujitsu, Ltd. | Biosensor, information processing function of living matter |
| Matsushita Electrical Industrial Co., Ltd. | Biosensor, water-soluble photopolymer |
| Hitachi, Ltd. | Biosensor, LB film |
| Toshiba Corp. | Biosensor, bioelements |
| Sony Corp. | Biosensor, opticomagnetic recording material |
| Sanyo Corp. | Biosensor, bioelement |
| Sharp Corp. | Molecule recognition, sense of sight information processing molecular element |
| Fuji Electric Co., Ltd. | Alcohol sensor, glucose sensor |
| Ajinomoto Co., Ltd. | Bioelement, biosensor |
| Kirin Brewery Co., Ltd. | Alcohol sensor |
| Nippon Suisn Kaisha, Ltd. | Sweetness sensor |
| Kyowa Hakko Kogyo Co., Ltd. | Biosensors for process control and medical treatment |
| Toyo Jozo Co., Ltd. | Food analysis device using biosensor |
| Toray Industries, Ltd. | Biosensor, bioelement, molecular memory |
| Kuraray Co., Ltd. | Biosensor |
| Toyobo Co., Ltd. | Sensors for medical treatment and protein measurement |
| Mitsubishi Chemical Industries, Ltd. | Bioelement, LB film |
| Kao Soap Co., Ltd. | Bioelement |
| Mitsui & Co., Ltd. | Bioelement |

Langmuir Blodgett (LB) film which is a pile of single molecule films each of which is an aligned molecular layer of 1 molecular thickness.

**Study of Brain and Nervous System Holds Key**

For biocomputer development, it is important to develop bioelements, clarifying the information processing mechanism of the brain and nervous system, and applying the results to biocomputer architecture. At present, the functions being sought are those which resemble that of a human being's brain, such as pattern recognition, emotion understanding, and association of ideas, for which the computer is not equipped. That is, requirements for the biocomputer are: 1) large memory capacity, compactness, and good efficiency; 2) automatic detection of and automatic correction of errors; 3) compatibility with a living body to allow implantation; 4) superiority in the function similar to a living body's sense and recognition system; and 5) possibility of inductive and creative thought.

At present, study of the brain and nervous system is the field which is drawing the most attention. Not only the Science and Technology Council (chairman: Prime Minister Nakasone), which is the highest consulting organ on scientific and technological policies in Japan, but also the Ministry of Education, Culture, and Science, the Ministry of Health and Welfare, and the Science and Technology Agency, will start grappling with this field soon.

Among private enterprises, NEC Corp. is promoting research on the nervous system function of nematodes and Mitsubishi Electric Corp. is researching the nervous system of the sea hare. This research is aimed at clarifying the nervous systems of simple structures in lower animals before attempting to clarify the brain and nervous system of a human being. The United States and European countries had been leading in research on the brain and nervous system but Japan is expected to make remarkable progress in this field. The government organizations and private companies mentioned above have been announcing results that surpass those attained by the United States and Europe.

20111/9365

## Government's AIDS Research, Control Measures

### Anti-AIDS Expert Council Report

*43066008 Tokyo PUROMETEUSU in Japanese Nov 87 pp 23-26*

[Article from the Life Science Division, Research and Development Bureau, Science and Technology Agency]

[Excerpts] Today, the number of AIDS patients exceeds 50,000, and the infection is considered a serious global issue. Under these circumstances, it is important for Japan, where the number of AIDS patients is still low, to urgently devise control measures and plan to stop to the spread of AIDS. As a consequence, the establishment of an anti-AIDS-related cabinet council was adopted orally at the 20 February meeting of this year to plan comprehensive promotional efforts with close liaison among related governmental organizations, thus embarking on a national AIDS control program.

**AIDS Onset Status in Japan (as of 16 June 1987)**

| Infectious route | No. of patients | No. of deaths |
|---|---|---|
| Male homosexuals | 12 (3) | 6 (1) |
| Heterosexual contacts | 4 (2) | 3 (2) |
| Coagulation factor preparations | 26 | 17 |
| Unknown | 1 | 1 |
| Total | 43 (5) | 27 (3) |

Note: ( ) entries are foreigners and duplicate listings.

On 24 February of this year, the immediate policies to be promoted as AIDS control measures were compiled, and the Anti-AIDS-Related Cabinet Council established general guidelines to counteract AIDS problems. These guidelines are categorized into two items of focal control measures and promotional structures. Regarding promotional structures, the establishment of an expert council consisting of learned and experienced persons was called for in order to seek opinions regarding specialty items related to AIDS control measures.

On 27 March of this year, the Anti-AIDS-Related Cabinet Council decided to establish the Anti-AIDS Expert Council in order to plan and promote policies related to AIDS control measures. The members of the above Expert Council are:

Yuichi Shiokawa (Professor Emeritus, Juntendo University), Chairman;

Yoji Igawa (Chief investigator, Institute of Physical and Chemical Research);

Nobuo Egami (Director, National Research Institute of Environmental Pollution);

Akira Oya (Deputy Director, National Institute of Health);

Toshitsugu Oda (Director, National Hospital Medical Service Center);

Ken Odaka (Professor, Institute of Medical Science, University of Tokyo);

Shiro Someya (Advisor Emeritus, Institute of Public Health);

Shoshichi Nojima (Dean, Faculty of Pharmaceutical Sciences, Teikyo University);

Harumi Haneda (President, Japan Medical Association);

Yorio Hinuma (Professor, Institute of Virus Research, University of Kyoto);

Masanao Miwa (Deputy Director, National Cancer Center Research Institute);

Yuichi Yamamura (Former President of Osaka University).

The above Expert Council held its first meeting on 9 April and began deliberation on policies to advance AIDS research. Subsequently, the Expert Council held another meeting, and the drafting committee established under the Expert Council met twice. The report was compiled on 7 July at the third Expert Council meeting and was submitted on 16 July by the chairman, Shiokawa, to the health and welfare minister, Saito, who supervises the Anti-AIDS-Related Cabinet Council. The following is an excerpt of the report.

**Policies for Advancing Research**

**(1) Building a Research Support System**

In order to advance AIDS research, it is necessary to reinforce the organizational structure for conducting HIV and related virus research at existing research facilities, further increase the funding level for AIDS-related research, and at the same time, build a supply structure for the procurement of research materials such as infected serum and virus, etc., to promote research and technology development, and establish related medical information systems.

**(2) Nurturing Researchers**

In Japan, the number of researchers in AIDS-related fields is limited at present. In order to advance AIDS research in the future, many outstanding researchers are required in both the basic and clinical fields. Consequently, it is necessary to encourage the participation of researchers in broadly related fields and take measures to bring in new concepts by employing young researchers. It is, therefore, important to promote a research residency system, actively utilize a mobile research staff system, and exchange researchers between the industry, academe, and the government.

**(3) Promoting International Exchange**

Due to the characteristic nature of AIDS that it is mainly spread through blood and semen, not only geographic conditions, but also the lifestyle of people or historic and social factors are very much involved in its epidemic. In addition, individual countries are at different levels of research progress in various fields related to AIDS.

Consequently, to promote AIDS research in Japan, it is necessary to strive for an exchange of research results from the international viewpoint according to the achieved status in Japan. For example, in fields where excellent results in basic and clinical therapeutic research have been observed in other countries, it is important to send researchers overseas as well as invite researchers from abroad in those fields to actively promote an exchange of researchers and information among research organizations; and to promote the necessary cooperation with those nations seeking the transfer of research technologies from Japan.

As policies to promote these goals, it is important to promote the international exchange between nations and enhance cooperation with WHO's AIDS special program.

**(4) Utilization of Private Resources**

In advancing AIDS research, collaboration between industry, academe, and the government is strongly desirable. In particular, the active utilization of private capabilities in research and development is expected in the area of developing pharmaceuticals such as AIDS-related vaccines, diagnostics, therapeutics, onset preventives, etc.

Furthermore, it is necessary to assist private organizations advancing AIDS research and actively nurture these organizations so that the utilization of private resources will proceed smoothly.

**Conclusion**

The advancement of AIDS research is the essence of AIDS control measures in various nations.

The Anti-AIDS Expert Council will hold appropriate conferences as needed in the future and deliberate on specialty items related to AIDS control measures.

## AIDS Research at STA

*43066008 Tokyo PUROMETEUSU in Japanese Nov 87 pp 26-29*

[Article from the Life Science Division, Research and Development Bureau, Science and Technology Agency]

[Excerpts] **AIDS Research in FY85**

In Japan, an AIDS patient was formally confirmed in 1985 for the first time. Because of the concern that the number of patients may rapidly increase as observed during the onset phase in various countries, there has been a quest for urgent establishment of a monitoring system. An especially urgent task was to develop diagnostic techniques to discover AIDS patients in early stages of the disease.

The STA's Science and Technology Adjustment Fund (abbreviated as "Adjustment Fund" hereafter) is used according to the policies of the Science and Technology Council, which is the core of the Japanese science and technology policy development; it is used to promote leading-edge, basic research. One of the policies for use of the Adjustment Fund involves a flexible response in the case of a need arising for urgent research work. The development of diagnostic techniques for AIDS patients was expedited as "Urgent Research on Development of an AIDS Diagnostic Technique" in the FY85 Adjustment Fund.

**AIDS Research in FY86**

The number of AIDS patients continued to increase in FY86, and the monitoring system established has estimated a fairly high number of HIV carriers, who are infected by HIV but have not yet developed the disease. Meanwhile, AIDS therapeutics have been developed in the United States, etc. and the clinical experiments have progressed to become actual routines. Although the efficacies of these therapeutics must be determined in the future, the earlier it is done, the more carriers will be prevented from developing disease and AIDS patients will become treatable. As a consequence, it has become necessary to develop a method for rapidly and accurately determining the disease state of a carrier, which is the reference point of the above determination, and "Urgent Research on Development of an AIDS Virus Assay Technique" was scheduled in the FY86 Adjustment Fund.

In the past, immune function tests were used to determine a carrier's disease status. However, this is not a specific method for AIDS, and it was difficult to obtain quantitative data. Therefore, an attempt was made to develop a method to measure the blood HIV gene level which is believed to increase as the disease progresses.

The task was given to a research team at the Health and Medical Services Bureau of the Ministry of Health and Welfare with a total research fund of Y53 million.

A part of the HIV gene is isolated from the carrier's blood, which is labeled and used as a probe for measuring the HIV gene level. Since the probe will only bind to the complementary base sequence of the gene (i.e., HIV gene), if present, the blood HIV gene level can be quantified by measuring the amount of label bound to the probe. In the study, they successfully prepared probes from Japanese carriers. The results indicated the necessity of further increasing the detection sensitivity in order to measure the actual blood HIV gene level.

**Future AIDS Research**

In July 1987, the Anti-AIDS Expert Council presented a report on the basic policy to advance AIDS research. Of the research topics proposed in the above report as the future research to be emphasized in Japan, research on the elucidation of infection and onset mechanisms of HIV and related retroviruses in cells and animals and on the elucidation of the defense response mechanism of the body against HIV and related retroviral infections were scheduled to be dealt with in the "Research on the Development of Basic Technologies for the Elucidation

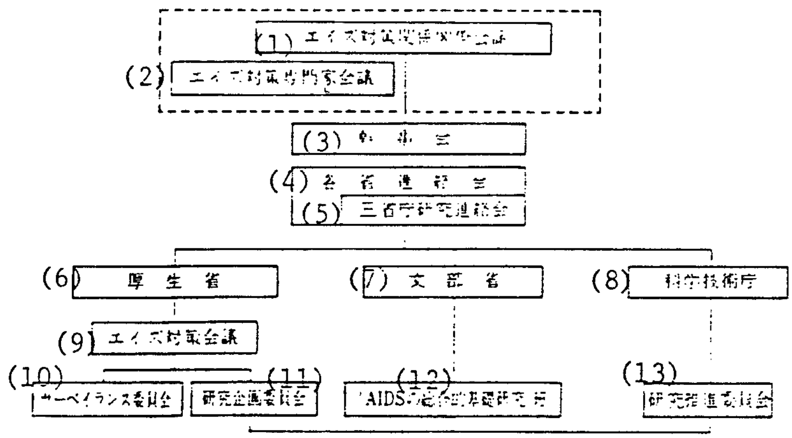



**Figure 1. AIDS Research Promotion System Chart**

Key:
1. Anti-AIDS Related Cabinet Council
2. Anti-AIDS Expert Council
3. Executive meeting
4. Interagency liaison meeting
5. Triministry and agency research liaison meeting
6. MHW
7. Ministry of Education
8. Science and Technology Agency
9. Anti-AIDS Council
10. Surveillance Committee
11. Research Planning Committee
12. "AIDS General Basic Research" team
13. Research Promotion Committee

of Immune Response Mechanisms," a research project from the FY87 Adjustment Fund. In other words, in research regarding the immune system, which is the target of HIV and related retroviruses (abbreviated as "HIV, etc." hereafter) as well as the defense against infections with HIV, etc. and disease onset, scheduled research includes: basic studies such as the preparation of immune cells and virus-infected experimental animals used in research on HIV, etc. and the development of tools to analyze the interaction between HIV, etc. and immune cells; research on HIV receptors on immune cells; analytical studies of changes in immune cells during infection with HIV, etc.

In addition, the Institute of Physical and Chemical Research is currently studying a special HIV research and exchange program with various foreign research organizations abroad to be started in FY88.

## AIDS Research at MHW

*43066008 Tokyo PUROMETEUSU in Japanese Nov 87 pp 29-32*

[Article from the Office of Infectious Disease Control, Health and Medical Services Bureau, Ministry of Health and Welfare]

[Excerpts] **Introduction**

AIDS research at the Ministry of Health and Welfare (MHW) began in earnest in 1983. The research results achieved thus far form an important foundation for specific contents of AIDS control measures. In addition, at the end of last year, an interagency research promotion system, diagrammed in Figure 1, was established in order to further advance research systematically, and the means for advancing research is to be discussed at the MHW also led by the research planning committee.

### AIDS Control Measures and Research Advances at MHW (Table 1)

Anti-AIDS measures began at the MHW in 1983 with the establishment of the "Fact-Finding Research on Acquired Immune Deficiency Syndrome" team. At the time, we were beginning to understand that AIDS infections occur through blood or body fluids, and in the United States, the number of patients reported was rapidly increasing. Therefore, the major goal was to survey the status of AIDS in Japan. The research team also formulated the first AIDS diagnostic standards in Japan and built the foundation for a surveillance system for AIDS which began subsequently.

AIDS patient surveillance also began in Japan in 1984, and in order to establish a testing technique and further assure the safety of blood, the "Post-Transfusion Infections Research" team began studying AIDS. Based on these research results, antibody tests will be required for all donated blood beginning in 1986.

In addition, since it has been proven that the causative virus of AIDS is a type of retrovirus related to the ATL (adult T-cell leukemia) virus, the "ATL Onset, Prevention, and Treatment Research" team of the Anticancer 10-Year Strategic Task Force also began examining the virus as an ATL-related virus.

Furthermore, because of the fact that AIDS became a socially important issue by the end of FY86, the team for "Research on HIV Carrier Infections and Onset Mechanisms" was established with the cooperation of the Science and Technology Agency, as well as the "Urgent Research on Development of an AIDS Virus Assay Technique" (from the Adjustment Fund for the Promotion of Science and Technology of the Science and Technology Agency). Consequently, not only the past research centered on infection prevention and diagnosis, but also urgent research has begun to save the already infected patients from onset or death.

**Table 1. Anti-AIDS Measures for Preventing an Epidemic**

| | |
|---|---|
| I. Early Detection of AIDS Patients, etc. | |
| September 1984 | Established "AIDS Survey Study Committee" according to the bureau chief's advice and began AIDS surveillance with the cooperation of approximately 600 medical service organizations. |
| May 1986 | Decided on the policy to increase the cooperative medical service organizations to approximately 2,000 locations. |
| December 1986 | Dissolved the "AIDS Survey Study Committee" to be superseded by "Anti-AIDS Expert Council," under which the "AIDS Surveillance Committee" was established. |
| February 1987 | Added asymptomatic carriers to the AIDS surveillance survey targets according to the bureau chief's advice. |
| March 1987 | "Anti-AIDS Expert Council" was renamed "MHW AIDS Control Council," under which the "AIDS Research Planning Committee" was newly established. |
| II. Preventing Secondary Infection | |
| July 1985 | According to the division chief's advice, "Points to keep in mind at the time of AIDS onset in patients" was released. |
| February 1987 | Along with expanded surveillance, "Points to keep in mind in health care guidance" was distributed to cooperative medical services organizations. |
| February 1987 | According to the office chief's advice, "Points to keep in mind in the prevention of AIDS infection" was released. |
| III. Setting Up Counseling Corners for People Concerned With AIDS | |
| July 1985 | According to the division chief's advice, notifications were made to set up AIDS counseling corners. |
| March 1987 | According to the joint advice by the Health Policy Bureau's Planning Division chief and Office chief, notification was made to expand the counseling program. |

**Table 1. Anti-AIDS Measures for Preventing an Epidemic**

| | |
|---|---|
| IV. Setting Up a Testing System | |
| A screening test (primary test) is available at various medical service organizations. | |
| In order to verify screening test results, a system for carrying out an IFA test (verification test) at the National Institute of Health and 16 Regional Institutes of Health was established. | |
| March 1987 | According to the Health Policy Bureau's Planning Division chief's and Office chief's joint advice, notification was made to facilitate the testing system. |
| V. Blood Control Measures | |
| July 1985 | Approval of heat-treated preparations of factor VIII. |
| December 1985 | Approval of heat-treated preparations of factor IX. |
| February 1986 | Donated blood testing for anti-HIV antibodies began in Tokyo and Osaka. |
| July 1986 | Donated blood testing for anti-HIV antibodies was expanded to eight prefectures. |
| November 1986 | Testing for anti-HIV antibodies began on all donated blood. |
| VI. Publicity Activities | |
| October 1985 | Prepared "AIDS, Acquired Immune Deficiency Syndrome," a leaflet for the general public. |
| February 1986 | Prepared "AIDS in Japan" as a textbook for guidance purposes. |
| February 1987 | Prepared a pamphlet, "What Is AIDS?" |
| March 1987 | Prepared "AIDS" (the U.S. Public Health Service Surgeon General's report and commentaries), a revised edition of the textbook for guidance purposes, "AIDS in Japan," "Handbook on AIDS Treatment," and posters. |
| VII. Training for Workers | |
| February 1986 | Held seminars for guidance personnel working at AIDS counseling corners. |
| March 1987 | Held seminars for guidance personnel working at AIDS counseling corners. |
| VIII. Research Promotion | |
| FY83 | Prepared AIDS diagnostic standards. |
| FY84-85 | Trial monitoring tests carried out to determine the presence of AIDS antibodies. |
| FY84-86 | Research on the safety of blood. |

**Table 1. Anti-AIDS Measures for Preventing an Epidemic**

| | |
|---|---|
| FY85 | Research on IFA (indirect fluorescent antibody technique) modification.<br>Research on IAHA (immune adherence hemagglutination technique) development. |
| FY86 | Research on AIDS infection and onset mechanisms.<br>Research on onset prevention and the treatment of HIV carriers.<br>Urgent research on development of an AIDS virus assay technique. |

**Future AIDS Research**

**The FY87 AIDS research plan has four major components.**

The first component involves research on onset prevention and treatment which was urgently initiated at the end of last year. They will strive to expand and substantiate research based on the latest scientific findings.

The second component involves research to improve testing techniques. In this project, they will consider the development of a detection method for new markers such as antigens as well as precision and control systems for conventional testing methods. In addition, they will consider HIV-2 as a future problem.

The third component involves substantiation of immunological research. Through continued immunological studies that began in FY86 and research analyses, they will advance the research to develop the important foundation for future AIDS control measures in Japan.

And, the fourth component involves research from the social viewpoint. AIDS is an issue involving not only the field of medicine, but also sociology, politics, education, etc. The problems ranging over these broad areas have become major issues in various nations worldwide; Japan should also examine measures to solve major issues of tomorrow. In addition, research should be advanced concerning a support system for infected people.

## AIDS Research at Ministry of Education

*43066008 Tokyo PUROMETEUSU in Japanese Nov 87 pp 32-34*

[Article from the Research Grant Division, Science and International Affairs Bureau, Ministry of Education]

[Excerpt] **AIDS Research at the Ministry of Education**

The "AIDS Basic Research" team was organized in FY87 as a spontaneous act by researchers desiring to advance comprehensive basic research on AIDS. This research team is composed of a total of 28 researchers with Professor K. Odaka representing the research team. Its goal is to emphatically advance basic research, which is in particularly strong demand in order to allow effective primary prevention, onset prevention, and treatment of AIDS.

In parallel with the overall advancement of research concerning (i) viral structure, function, and vaccine, (ii) HIV infections, (iii) AIDS pathology, (iv) HIV and AIDS therapeutic substances, this research project also has plans for information exchange and research presentations, etc. among the researchers.

In addition to the research introduced above, there are numerous AIDS research projects that are under way at universities supported by the MOE's science research grants which have already demonstrated many accomplishments toward the eradication of AIDS. MOE plans to further promote AIDS research at these universities, etc.

## Status of Industry's Anti-AIDS Measures

*43066008 Tokyo PUROMETEUSU in Japanese Nov 87 pp 35-36*

[Article by J. Ozaki, Nikkei Biotechnology]

[Excerpt] At least 10 corporations are developing therapeutic drugs in Japan. Many of them are basically immunoregulators (stimulate the patients' immune system and attack cancer cells), which were developed as anti-cancer drugs. Some of these firms are conducting clinical trials in the United States, where there is a large number of AIDS patients. Although many specialists take a dim view of these drugs as somewhat lacking efficacy against cancers, their mild efficacies and minimal side effects are highly valued for AIDS use.

Table 2. Summary of AIDS-Related Research

| Research team | Team leader | budget 83 84 85 86 |
|---|---|---|
| Research team on AIDS fact-finding (FY83) | Team leader: A. Abe (Professor, Teikyo University) | |
| Research team on Post-transfusion infections (FY84 - ) | Team leader: Y. Hinuma (Professor, Institute of Virus Research, Kyoto University) | |
| Research team on ATL onset, prevention, and treatment (FY84 - ) | Chief investigator: M. Miwa (Deputy director, National Cancer Center Research Institute) | |
| Research team on AIDS diagnosis and treatment (FY85) | Team leader: Y. Shiokawa (Professor emeritus, Juntendo University) | |
| Research team on AIDS infection and onset mechanisms (FY86 - ) | Team leader: Y. Shiokawa (Professor emeritus, Juntendo University) | |
| Research team on Pharmaceuticals development (FY86 - ) | Team leader: K. Kanei (Deputy director, National Institute of Health) | |
| Research team on onset prevention and treatment of HIV carriers (FY86 - ) | Team leader: K. Yamada (Professor, St. Marianna School of Medicine) | |
| Urgent research on development of an AIDS virus assay technique (FY86 -) | Team leader: K. Kurimura (Professor, Tottori University) | |

**Defensive Manufacturers of Blood Preparations**

AIDS has unmistakably brought forth trying times for pharmaceutical manufacturers of blood preparations. Unless they successfully overcome this period, it may destroy them.

The number of AIDS patients in Japan is publicly 43 (as of July) and most of them are hemophiliacs. This is because the AIDS virus is transmitted through blood. Blood preparations are produced for various uses by the fractionation and purification of blood collected through donation and purchase. The AIDS virus readily contaminates the fraction in which blood coagulating factor VIII and IX, fibrinogen occur (called the "second fraction").

Although no one suspected contamination by the AIDS virus, blood preparations have always been suspected of being contaminated with unknown pathogens.

In Japan, concentrated factor preparations produced in the United States were used from 1978 to 1984, and 30-60 percent of hemophiliacs have been already infected.

7722/6091

Table 1 Major AIDS therapeutics Japanese firms are developing and supplying

| Name of drugs | Developing firm | Achievements |
|---|---|---|
| Retrovir (azido-thymidine) | U.S. Burroughs Wellcome; Imported by Nippon Wellcome | Approved by the U.S. Food and Drug Administration in March 1987. Due to harmful side effects caused by using large doses, combined use with other antiviral and immunoregulators such as acyclovir is a problem. Virus reverse transcriptase inhibitor. |
| Lentinan | Ajinomoto | A polysaccharide extracted from Shiitake mushroom is the major ingredient. Originally an anti-cancer action enhancer by immunostimulation. |
| Picibanil | Chugai Pharmaceutical | Anticancer drug with immunostimulation. Killed hemolytic streptococcus is the chief ingredient. |
| Minophagen C (glycyrrhetinic acid | Minophagen Pharmaceutical Main Office | Immunostimulant and antiviral actions have been reported. Since it has no reverse transcriptase inhibiting activity, it demonstrates the action through interferon induction. |
| Isoprinosine | Newport Pharmaceuticals, U.S.A.; Imported by Mochida Pharmaceutical | Therapeutic for subacute sclerotic total encephalitis. Inhibits viral proliferation. |
| Sumiferon (alpha-interferon) | Wellcome, U.K.; Produced by Sumitomo Pharmaceutical through technical licensing | Immunostimulating anticancer drug. Also effective against hepatitis B. |
| Feron (beta -interferon) | Toray | Immunostimulating anticancer drug. Also effective against hepatitis B. |

*Lentinan and picibanil are in clinical trials in the United States. In addition, there is a plan for clinical trials in the United States for immunostimulants developed by Fujisawa Pharmaceutical and Ueno Pharmaceutical.

## Characteristics of LSI-Wiring Expert System Discussed

*43063815 Tokyo DENSHI ZAIRYO in Japanese Sep 87 pp 132-135*

[Article by Dr T Goto, director of Application System Research Division, C & C System Laboratory, NEC]

[Text] NEC Corp. has developed the LSI-wiring expert system "WIREX" which expresses the know-how of experts with rule formats.

This system is mainly applied to wiring between terminals, which has not been accomplished by the LSI automatic wiring program. The intellectual processing portion is written in PROLOG, and the procedure processing portion is written in FORTRAN, in an attempt to shorten the calculation time and reduce the necessary memory capacity. The program for procedure processing has an advantage in that conventional programs can be applied to this program without any changes or modifications. Even for non-experts in the area of wiring design, this system enables the achievement of good quality designs in a short time. For instance, it usually takes more than 2 hours for a specialist to complete the wiring design of a gate array LSI with 2,100 gates. However, this same design can be done within a half hour by a non-specialist when applying this system.

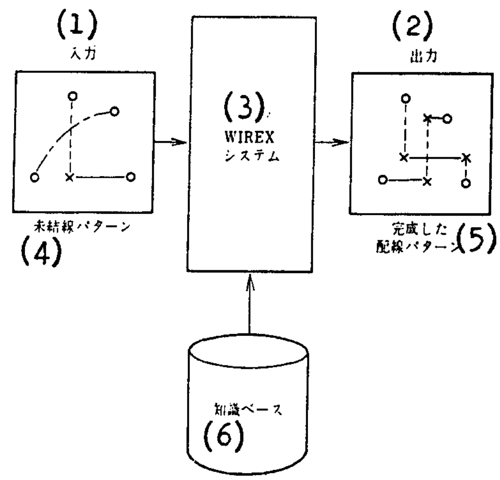



図1 WIREXシステム
**Figure 1. WIREX System**

Key:
1. Input
2. Output
3. WIREX system
4. Unconnected pattern
5. Completed wiring pattern
6. Knowledge base

### Necessity for Expert Systems

The LSI wiring design determines the wiring pattern of a circuit on a chip base by satisfying the following three conditions:

(1) Circuit connecting conditions: theoretical connecting relationships;

(2) Geometrical conditions: items to be determined by manufacturing processes (width of wiring, magnitude of contact, wire pitch, contact pitch, pitch between wiring and contact);

(3) Electrical conditions: delay time, noise.

This problem falls within a difficult combination problem (integer-type various-kind of flow problem involving network theory). As the scale of the problem (the amount of wiring demanded) becomes larger, calculation procedures (calculation time and memory capacity) necessary to solve the algorithm increase exponentially. Accordingly, for a problem of a practical scale (more than several hundred wiring portions demanded), the method by which a complete wiring pattern is obtained only from an algorithm (automatic wiring program) should be discarded (refer to Figure 1).

At present, both the automatic wiring program and the interactive manual wiring system are provided for the CAD system. First of all, wiring patterns are determined, as much as possible, with the application of the automatic wiring program (normally, 98 to 99 percent wiring ratio achieved). Regarding signal wires which cannot be connected, an expert repeats work for the modification and addition of patterns by looking at the wiring pattern diagram on a display device, and reaches a complete wiring pattern.

The time required for automatic wiring is from several minutes, in the case of a small-scale LSI, to several hours, in the case of large-scale LSIs. However, in the case of interactive designing, it takes more than 10 times longer than the time required for automatic wiring, even with the application of a high-function interactive system. When attempting to shorten the total design time, a key item is how the time necessary for the interactive design process is reduced (refer to Figure 2).

In order to realize a shorter time for interactive designing, automatization to eliminate interactive designing is the basic approach. For this reason, automation is sought for the procedures which experts currently operate on a display.

**A designer conducts the following procedures on a display:**

(1) The location of a pair of unconnected terminals on a chip base is found, and then it is determined which pair of terminals should be connected first.

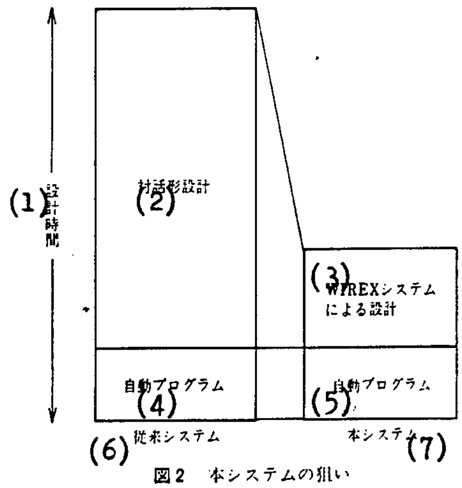


**Figure 2. Purpose of This System**

Key:
1. Design time
2. Interactive design
3. Design by WIREX system
4. Automatic program
5. Automatic program
6. Conventional system
7. This system

(2) The existing wiring which disturbs the connection of a pair of unconnected terminals is found, and a method to connect a pair of unconnected terminals is sought by considering how the pattern of the existing wiring should be altered.

(3) Based upon a tentative solution, a tablet and a function key board are operated on a display, and the existing wiring pattern is altered, with a new wiring pattern being generated. At this time, error-free wiring is carried out which satisfies both geometrical and electrical conditions.

(4) If a tentative solution is unsuccessful, the design returns to item (1) or (2) to try another pattern.

The time required to complete the design is drastically influenced by the method used to determine the wiring and how the wiring is selected. A competent designer is able to successfully handle these procedures. If a skilled technique and mechanism to determine the procedures are known in the beginning, they are easily programmed and placed in an automatic wiring program. However, there is currently no definite way to determine the procedures. This means that case-by-case treatment and intuition through experience are the only tools available at this moment. This kind of a tool, called design know-how, accumulates in the brain of an expert through his or her experience. It grows as a high-level property, along with its alteration, modification, and adjustment.

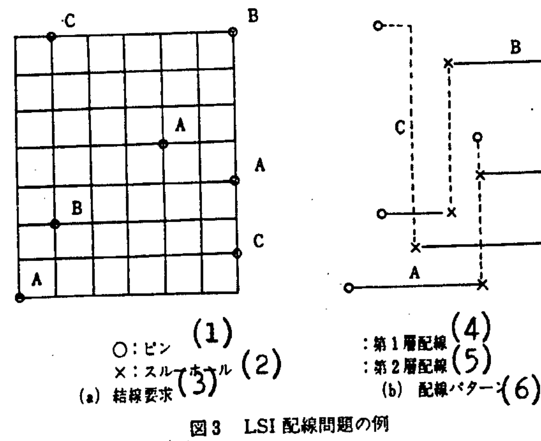


**Figure 3. Example of LSI Wiring Problem**

Key:
1. gO:Pin
2. x:Through hole
3. (a) Wiring demanded
4. First-layer wiring
5. Second-layer wiring
6. (b) Wiring pattern

When this design know-how is incorporated into an existing program, drastic changes in the program are needed as the addition and modification of functions occur. This operation is feasible, but the development and management of the program, along with the upgrade of functions, become very difficult (refer to Figure 3).

Therefore, a method to easily express the design know-how of an expert and to facilitate its storage in a computer must be developed. The WIREX system is an expert system for LSI wiring developed in response to the above considerations.

**Composition of WIREX System**

Figure 4 shows the block diagram of the hardware composition. The host computer used is a minicomputer (NEC MS190) with a main memory of 16 M-bytes and processing speed of about MIPS. The wiring conditions of a chip base are indicated in a 21-inch graphics display, and text pictures which illustrate rules are displayed on the personal computer PC 9800.

Figure 5 shows the block diagram of software composition. This system is composed of an inference system, a knowledge base, and a CAD data base. Experimental rules which a designer utilizes during the wiring design process are stored in the knowledge base. These include the knowledge of wiring conditions around unconnected terminals, the investigation of the cause of unconnected wiring, and operations to find the path of a pair of unconnected terminals.

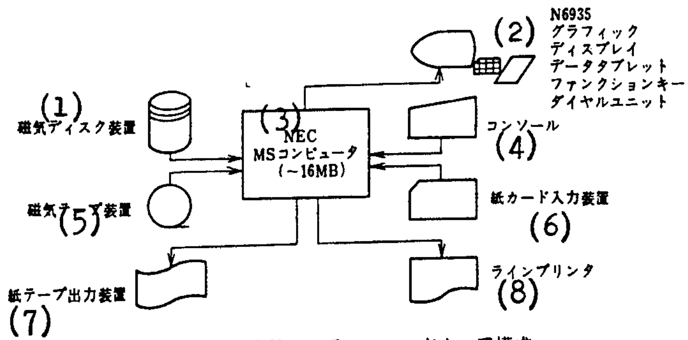



図4 WIREXシステムのハードウェア構成

**Figure 4. Hardware Composition of WIREX System**

Key:
1. Magnetic disk device
2. N6935, graphic display, data tablet, function key, dial unit
3. NEC MS computer (approx 16 MB)
4. Console
5. Magnetic tape device
6. Paper card input device
7. Paper tape output device
8. Line printer

On the other hand, the CAD data bases is similar to a conventional CAD data base. Data for wiring design, such as a set of terminals which consists of a pair of terminals, the coordinates of these terminals, and segmental data for already connected wiring, are stored.

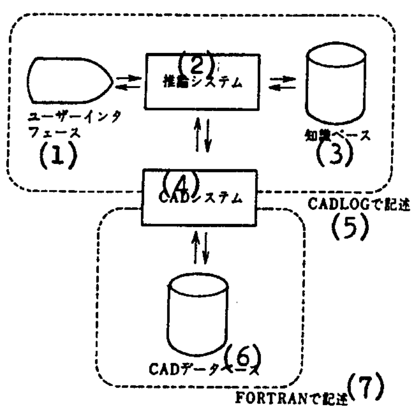



図5 WIREXシステムのソフトウェア構成

**Figure 5. Software Composition of WIREX System**

Key:
1. User interface
2. Inference system
3. Knowledge base
4. CAD system
5. Written by CADLOG
6. CAD data base
7. Written by FORTRAN

The CAD system consists of groups of FORTRAN subroutines that are used for a conventional CAD system. These groups of subroutines are generally classified into groups which have access to a CAD data base, those which execute procedure processing, such as path searches, and those which control graphics. These FORTRAN subroutines are registered in an interpreter as subroutines corresponding to the external function predicate of the inference system (CADLOG).

The inference system used a PROLOG interpreter [CADLOG]. This interpreter can call a FORTRAN subroutine from a PROLOG program in order to make a connection with an existing CAD system. The CADLOG itself is composed of two phases. One actualizes the functions of PROLOG (Subset of DEC-10 PROLOG), and the other provides an interface with FORTRAN subroutines.

In this system, the predicate which calls a PROLOG subroutine from the PROLOG program is named the external function predicate, and "$" is added before the first letter of the predicate to distinguish it from general predicates. When the external function predicate is unified upon the execution of the PROLOG program, the interpreter transfers its control to the link phase. After the execution of the FORTRAN subroutine, the interpreter transfers the control to the PROLOG execution phase, and continues processing by referring the FORTRAN subroutine execution result.

**Characteristics of WIREX System**

Many expert systems have already been developed. This system, however, has the following characteristics which are utilized in actual design operations:

(1) Since the know-how of an expert, which can be utilized by a non-expert, is provided in the knowledge base, it is possible for a non-expert to accomplish high-level designing usually done by an expert.

This system provides the strategy to solve problems, corresponding to various situations, in the form of rules, starting from the beginning. Accordingly, it is possible to suggest the most appropriate rules to a designer depending upon the wiring circumstances. The designer checks the adequacy of the rules (wiring strategy) proposed by the system, and then gives approval or demands another strategy. Because relevant information necessary for the designer's judgment is indicated on the display, even a non-expert is able to accomplish high-level design, usually done by an expert.

(2) An LSI designer who is not a specialist of software development is able to store design know-how in the knowledge base by himself/herself. Using this advantage, an LSI designer can build up the optimal CAD system, corresponding to the design object, with ease.

The device technique (MOS, CML, etc.), structure (gate array, building block), and scale (1,000 approx 100,000 gates), which become the design subjects, differ with users. Therefore, depending upon these differentiae, the strategy of wiring design varies. On the contrary, however, the conventional CAD system is only able to change some control parameters which are prepared from the beginning, and it is an unadaptable system. In addition, when attempting to add new functions to the conventional CAD system, not only must a program for the new functions be prepared and the main program be rewritten, but also compiling and linking processes are always needed. For a system in which the renewal of design know-how occurs very often, the application of the conventional programming technique will turn out to be inefficient from the aspect of program development and control.

In this system, even an LSI designer who has no experience in the preparation of a program is able to express design know-how in the form of a rule, and also to add it to the knowledge base. A designer can modify the CAD system in order to match his/her own design problem by conducting his/her designing in parallel. Namely, this system can be utilized to construct an optimal system with ease in accordance with each user's intentions. Figure 6 shows an example of knowledge used to solve unconnected wiring, and Figure 7 illustrates the description of a rule.

(3) It is an expert system capable of processing a problem of a practical scale with high speed.

PROLOG is a language suitable for knowledge processing. However, it is nearly impossible to work on a large-scale problem in a reasonable time and of an appropriate memory size using the current computer hardware. We should wait for the advent of the practical

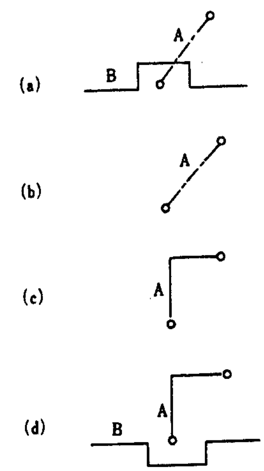



**Figure 6. Solution for Unconnected Wiring**

application of the fifth generation computer. Due to this fact, in order to make the most of the advantages offered by PROLOG and to make up for its disadvantages, procedure-type language FORTRAN and PROLOG processing language [CADLOG] which enable linkage have been developed, and applied to this system. The conventional CAD system written by FORTRAN is used for procedure processing of data on a large-scale, and PROLOG is applied to the portion which requires knowledge processing, such as design know-how.

(4) This is an expert system which effectively utilizes existing program properties.

In the past, when attempting to construct an expert system, it was supposed to be entirely written in such languages as LISP and PROLOG. On the other hand, most existing CAD programs were developed using FORTRAN. In constructing an expert system, rewriting

```
RULE 30 (*NET_A) : -
  BLOCKING (*NET_A. *NET_B).
  $DELETE (*NET_B).
  $CONNECT (*NET_A).
  $CONNECT (*NET_B).

BLOCKING (*NET_A. *NET_B) : -
  GETPIN (*NET_A. *LAY. *XS. *YS).
  EQ (*LAY. 1).
  DIRECTION (*YS. *DIR).
  $GRIDSEARCH (*DIR. *LAY. *XS. *YS. *NET_B).
```

図7 CADLOGによる未結線解決の記述例

**Figure 7. Example of Unsolved Unconnected Wiring-(CADLOG)**

existing FORTRAN programs in PROLOG or LISP is not practical in respect to the success inherent in software properties.

Since FORTRAN subroutines can be applied without any modifications and used in connection with the PROLOG processing system, which has an inference mechanism in this system, it is characterized as capable of constructing an expert system with the practical application of existing software.

As mentioned above, the LSI wiring design expert system was introduced as an example of the application of CAD to knowledge information processing. It should be pointed out that this system is characterized by its capability to process a large-scale problem at a high speed. For example, it can complete an LSI wiring process design problem with 2,100 gates within a half hour, even for a non-expert, while it usually takes more than 2 hours for an expert.

It is thought that the application of knowledge processing using CAD/DA will expand and diffuse in a natural manner from the standpoint of the extensive utilization of a computer. The trend in which a computer approaches a human being strongly indicates the optimal assigning of roles for each computer and human. That is, work assignments which will essentially require human handling will become clear as progress is made involving knowledge processing techniques.

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[Table]

| | Piston Crown | Cylinder Head | Valve | Cylinder Liner |
|---|---|---|---|---|
| Conventional material | SCM 415 | FCD 40 | SUH 31 | RIK 61 |
| Insulation 1 | SUH 31 | $ZrO_2$ Injection Coating | $ZrO_2$ Inj. Coat. | $Si_3N_4$ Sleeve |
| Insulation 2 | $ZrO_2$ Inj. Coat. | Same | Same | Same |

## Technical R&D Institute Reports Summarized

### Single Cylinder Diesel Engine

*43062531a Tokyo BOEI GIJUTSU in Japanese Sep 87 p 42*

[Article by Masatoshi Hashimoto, Yukio Kaneuchi, Koki Jumonji and Noboru Kanzawa, and Captain Hisami Hamazaki, members of the First Motor Research Office, Second Division, Fourth Research Institute: "Performance Confirmation Tests of Single Cylinder Diesel Engine"]

[Text]

**1. Purpose**

In order to raise the performance of engines for combat vehicles, we have been conducting research on insulated turbo compound diesel engines. The following describes the results of tests for performance comparison conducted using combustion chamber parts made of conventional materials and those made of the same conventional materials coated with molten ceramics.

**2. Test Procedures and Their Contents**

Using the combinations shown in the table, we conducted smoke limit tests by changing the fuel injection nozzle chips, fuel injection timing, etc.

**3. Results and Discussion**

**(1) Results**

The figure [omitted] shows the relationships between the rate of fuel consumption (be) and the maximum pressure inside the cylinder (Pmax) to a given amount of fuel injection in each of the cases; that is, when the combustion chamber consists of parts made of conventional materials and when the combustion chamber incorporates parts made of those same conventional materials with a thermal spraying of $ZrO_2$, under the conditions that the engine rotation speed is 2,100 rpm, the axial output is 126 PS, the nozzle chip is 12 x 0.22 - 155, and the fuel injection timing is 16 and 18 degrees BTDC. As the insulation level of the combustion chamber wall rises, the maximum pressure inside the cylinder decreases while the fuel consumption rate increases.

**(2) Discussion**

It is thought that in the troidal combustion chamber, when the insulation level of the combustion chamber wall is raised, the temperature inside the combustion chamber increases and, as a result, the delay time for the fuel's igniting becomes shorter, which leads to a sluggish burning of the fuel, lowering the combustion efficiency and increasing the rate of fuel consumption while diminishing the maximum pressure inside the cylinder. But, it shows that with a combustion chamber made of conventional materials, the rate of fuel consumption can be lowered by keeping the maximum pressure inside the cylinder low and by advancing the fuel injection timing.

Therefore, by improving the combustion through such measures as swirling the air supply and remodeling the combustion chamber into an open combustion chamber to prevent the fuel mist from colliding with the high temperature piston, we plan to continue research on a combustion chamber appropriate for insulated turbo compound diesel engines.

### Heat Exchanger Block

*43062531a Tokyo BOEI GIJUTSU in Japanese Sept 87 p 43*

[Article by Yoichi Nakamura, Takaaki Shimazu, and Toru Yoshitomi, members of the Second Motor Research Office, Second Division, Fourth Research Institute: "On Steady Performance of Heat Exchanger Blocks"]

[Text]

**1. Purpose**

The problem involving the heat exchanger's reliability and endurance has been said to be one of the problems that must be solved if gas turbines are to be used as

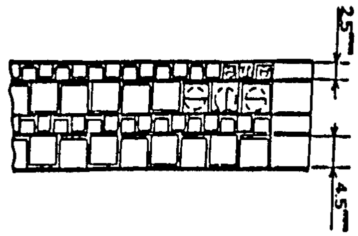

Figure 1. Cross Section of Passage

vehicle engines. To solve the problem, we measured the temperature distribution and temperature effectiveness of fluids using a heat exchanger block, a device roughly equivalent to a real one, manufactured in 1985, and confirmed its performance. We also conducted simulation calculations in order to obtain estimates of the temperature distributions of fluids inside the heat exchanger, and the values obtained proved to be appropriate when compared with the experimental values.

**2. Test Procedures and Contents**

(1) The exhaust gas from a gas turbine was the gas source (heat exchanger's inlet temperature: about 400 degrees C), and a compressor was used as the air source (normal temperature). Measurements were taken of various combinations of the two types of gases, each flowing at a velocity in the 0.05 - 0.08 kg/sec range.

**(2) Figure 1 shows a cross section of the heat exchanger block's interior.**

The passages on the gas side are made up of square blocks, each side measuring 4.5 mm, piled in seven tiers, while the passages on the air side are square blocks, with sides of 2.5 mm, stacked in eight tiers. For accelerating heat conduction, a spiral ribbon is inserted in the counterflow section.

(3) Temperature measurements were taken at four points each on the inlet and outlet ports for gas and air, and measurements were also taken at 13 points on the gas side to obtain the passage outlet distribution.

(4) For simulation calculations, a method of mesh division, as shown in Figure 2, was employed. By taking into account the temperature dependency of the various properties of the fluids and materials, heat balance calculations were made for each of the elements as needed, and the inside temperature distribution was inferred.

**3. Results and Discussion**

In Figure 3 [omitted], the actual values are plotted on the heat exchanger's thermal efficiency map, obtained based on simulation calculations. It has been confirmed that the thermal efficiencies cleared the targeted threshold of 70 percent for the rated flow levels of 0.05 to 0.06 kg/sec. Since the two values are in agreement for each of the flow

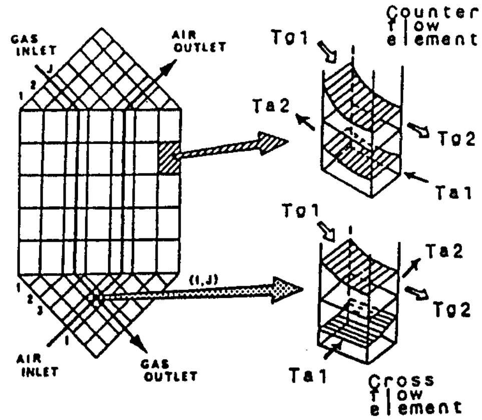


Figure 2. Mesh Division Diagram

combinations, we think that the internal temperature distribution can be fully simulated. On the other hand, accumulations of soot inside the gas passages, the so-called "dirt coefficient," greatly reduces the efficiency, and it is a problem that needs to be solved.

## Optical Fiber Dosimeter

*43062531a Tokyo BOEI GIJUTSU in Japanese Sept 87 pp 44-45*

[Article by Masaaki Miyahara and Toyozo Matsumura, members of the Counter-Nuclear Power Research Office, First Division, First Research Institute: "Optical Fiber's Characteristics for Use in Dosimeter"]

[Text]

**1. Purpose**

Evans and others have proposed devising a high dosage dosimeter taking advantage of the coloring of an optical fiber, but it seems this idea has not yet been put to practical use. We have been studying the basics of a method to measure dosages using optical fibers in an effort to apply this technology to direct-read-type portable dosimeters to be used by our military units. This article describes certain characteristics of dosage measuring, such as energy characteristics.

**2. Test Methods and Contents**

By connecting an optical fiber, either irradiated or not-yet-irradiated, to a measuring system as shown in Figure 1, we measured changes in optical absorptance. Two types of optical fibers were used: one type was purchased on the market and the other type was specially made, using different materials. For exposure to radioactive rays, X-ray generating equipment, as well as $^{137}Cs$ and $^{68}Co$, were used to examine energy characteristics.

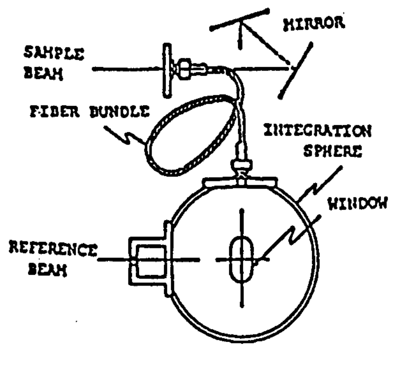


**Figure 1. Measurement Diagram**

## 3. Results and Discussion

### (1) Energy Characteristics

Figure 2 shows differences in sensitivity when an optical fiber purchased on the market (the average atomic number of the core material is 41) is irradiated by various radioactive rays. In viewing the scope of energies of the targeted radioactive rays, the large differences in sensitivity need to be improved.

As for the method to improve the characteristics in the low energy X-ray domain, it has been confirmed that the problem can be solved by the filter method in which the detector section is covered with a lead plate, about 1 mm thick.

In order to improve characteristics in the high energy region, we manufactured an optical fiber with phosphate glass (average atomic number of 12) as its core and silicon resin as its clad. The fiber was irradiated with gamma rays from $^{137}$Cs and $^{68}$Co, and measurements of the optical absorption are shown in Figure 3. As shown in the figure, the absorption rates of the two elements are roughly the same, indicating that energy characteristics can be improved by proper selection of the constituent materials.

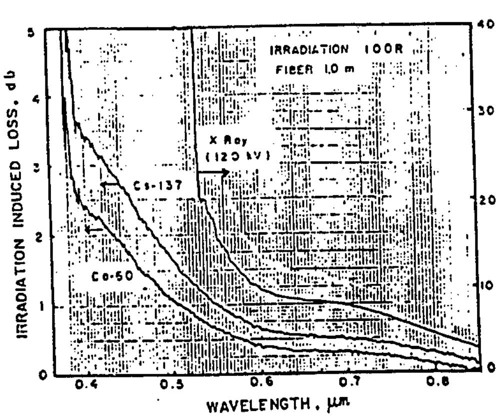


**Figure 2. Differences in Energy Sensitivities**

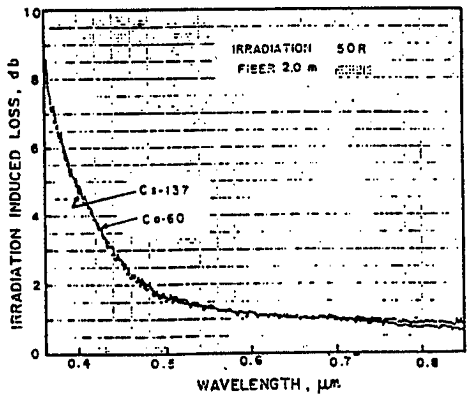


**Figure 3. Sensitivity of Phosphate Glass Fiber**

### (2) Fading Phenomenon

The coloring of glass brought about by irradiation usually fades with time. If glass is to be used as a dosimeter, it is necessary that the material be less prone to color loss. The optical fiber manufactured here lost about 10 percent of its coloring within 3 hours following its irradiation.

From the above results, it was learned that the energy characteristics of a dosimeter incorporating an optical fiber can be improved through the proper selection of the constituent materials and the use of an appropriate filter. We think that future research must be conducted on sensors, to read fading phenomenon, and on measuring devices, to read optical absorption.

## Suppression Limits of TSL

[Article by Shinkichi Nishimoto, assistant to Technical Development Officer (in charge of guided weapons): "Suppression Limits of Time Side Lobe Through Optimization in Pulse Compression"]

[Text]

### 1. Purpose

In pulse compression radar, it is important to fully suppress the time side lobe (TSL), one cause of an erroneous warning, if its target detection credibility is to be raised. The conventional method of TSL suppression does not guarantee the realization of the minimum peak TSL level for a mismatch loss accompanying pulse compression. Therefore, in drawing up a design for a radar system, it is beneficial to quantitatively grasp the relationship between the mismatch loss and the minimum TSL level achievable for each of the pulse compression methods targeted for adoption. Therefore, we defined the mismatch loss associated with system gain and, under the definition, introduced, by means of

$$L(G:\lambda)=\sum_{i=1}^{N} g_i + \sum_{l=1}^{2N-1} \lambda_l(\varepsilon_l - q_l - f_l^2)$$

where

$g_i$ : weight coefficient of filter

$\lambda_l$ : Lagrangian multiplier

$\varepsilon_l$ : Permissible value of peak TSL electric power

$q_l$ : Residual variable

$f_l^2$ : TSL electric power

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non-linear mathematical programming, the pulse compression filter constant that enables realization of the minimum peak TSL level. Applying a constant achieved a compressibility that agreed with the theory. The following is a report of the exercise.

**2. Procedures and Contents**

This paper mainly describes coded pulse compression methods using binary random series with maximum entropy. In other words, we used binary series of code length N, obtained in Bernoulli's method, for modulation borrow codes and employed transversal-type filters, with delay steps of the same length as the code length, for pulse compressors. We then defined the maximum permissible levels of the mismatch loss and the peak TSL electric power, and obtained the optimal filter constant that will make the signal output amplitude the largest under non-linear restraining conditions by the following method. We introduced the Lagrange's function listed below, and obtained the constant in numerical calculations based on the most rapid dive method, by taking advantage of the fact that, under Kuhn-Tucker's condition, the maximum value of the objective function in the first paragraph agrees with the maximum value of L (G:gh).

**The Lagrangian is:**

The diagrams below compare the pulse compression response characteristics obtained by the method mentioned above with the matching filter's characteristics for the code series N=16.

**3. Results and Discussion**

As a result of numerical calculations, the mismatch losses to the specified values of 1 dB and 2 dB were 1.06 dB (peak TSL=-14.3 dB) and 2.00 dB (peak TSL=-.16.0 dB), which are considered appropriate in view of the numerical calculation processes conducted independently. The method mentioned above provides a generality, making it applicable to low side lobe aerial wires for the most widely-used chirp pulse compression method and radar, and we think that it provides an effective design method.

## Electromagnetic Radiation

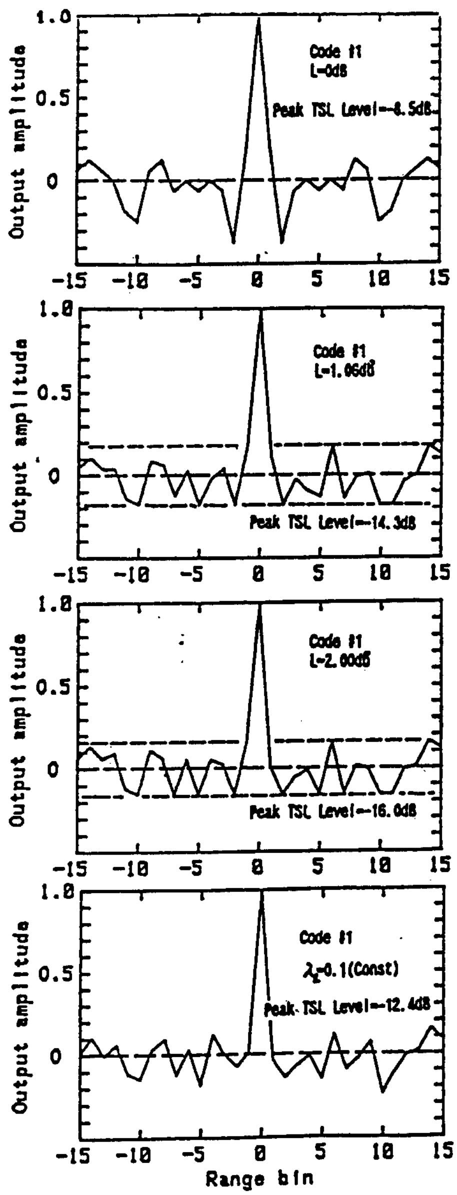
*43062531a Tokyo BOEI GIJUTSU in Japanese Sept 87 pp 46-47*

[Article by Hajime Sakamoto, Yasufumi Onishi, Masaki Kurosawa and Hiromichi Murai, and Toshiaki Tanabe, members of the Special Communications Equipment Research Office, Fourth Division, First Research Institute: "On Electromagnetic Emission from Displays"]

[Text] Electromagnetic waves generated by electronic equipment have conventionally been regarded as interfering waves, and various studies have been made on EMI countermeasures.

On the other hand, an increasing amount of important data has come to be processed by electronic equipment centered around computers, and it has been pointed out that the electromagnetic waves emitted by this electronic equipment contain the very information that has been processed inside the machines, thus making it impossible to treat electromagnetic waves as mere interfering waves. Therefore, it has become necessary to develop a new security technique that will prevent important information from leaking from these electromagnetic waves. The research in question aims at the establishment of a security technique that will prevent leakage of information from electromagnetic waves emitted by electronic equipment.

This paper outlines the characteristics of electromagnetic waves emitted by electronic equipment as obtained from a basic experiment.




**Figures. Pulse Compression Response Characteristics**

**2. Test Procedures and Contents**

Since electromagnetic waves emitted by electronic equipment are very weak, in the basic experiment stage they are greatly affected by electromagnetic waves from other sources. Therefore, experiments were conducted in an anechoic chamber. Figure 1 shows the measuring system, with a personal computer display used as the measuring target. The experiment proceeded as follows: Electromagnetic waves emitted by the display were detected by an aerial wire and were amplified by a front-end amplifier; they were then led to a wave monitor for measurement of the frequency spectrum. Next,

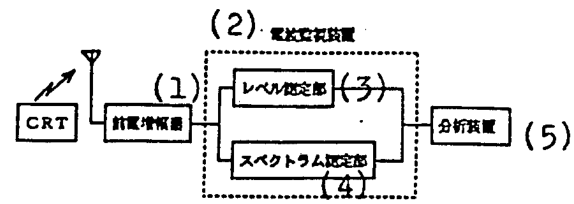



**Figure 1. Measuring System**

Key:
1. Front-end amplifier
2. Wave monitor
3. Level measuring
4. Spectrum measuring
5. Analyzer

using an analyzer, the spectrum was compared and checked against the reference data input in advance to obtain the correlation between the two. The photo (omitted) shows an example of the spectrum. Figure 2 shows the correlation between the letter X, displayed on the display equipment, and the reference data. The electromagnetic wave for the display letter X has the highest correlation with the reference data X, indicating the possibility that the contents of data processed by the computer could have been leaked.

**3. Results and Discussion**

(1) It is known that the weak electromagnetic waves emitted by the display can be detected by the wave monitor if an appropriate aerial wire and an amplifier are selected.

(2) It is known that a powerful correlation exists between the display letter and the reference data, thus showing the possibility for the data processed by the computer being leaked.

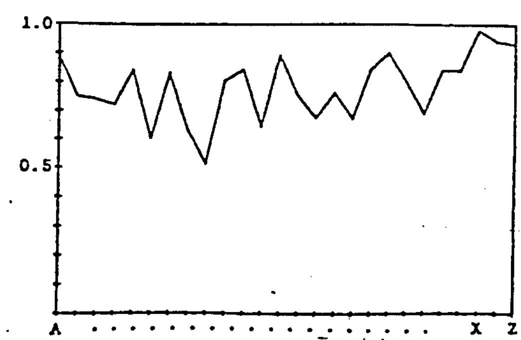



**Figure 2: Correlation Between Display Letter and Reference Data**

The current measurements were taken when the entire screen displayed the same letter and, therefore, problems remain concerning sweep time and reception level. We now plan to analyze the frequencies of demodulated signals while taking into account sweep time and other factors.

## Pulse Compression of Laser Signal

*43062531a Tokyo BOEI GIJUTSU in Japanese Sept 87 pp 47-48*

[Article by Katsuhiko Komatsu, Second Photo-electric Research Office, Fifth Division, First Research Institute: "On Pulse Compression of Laser Signal Using SAW Device"]

[Text]

### 1. Purpose

In an active laser radar that obtains information by beaming light at an objective and utilizing the reflected light, the S/N of the light received affects the system's performance to a great extent. The simplest way to improve the S/N of the light received is to raise the intensity of the outgoing beam, but the disadvantage in this is that the equipment becomes larger. In order to improve the S/N while making the system smaller and more lightweight, we conducted experiments and research involving compressing the laser pulse signal using a SAW device. The following describes the results.

### 2. Experiment Procedures and Contents

Figure 2 shows a schematic diagram of the equipment used. In the current experiment, we used a Hybrid Tea $Co_2$ laser for generating chirping laser pulses. The Hybrid Tea $Co_2$ laser consists of a Tea-type excitation system—8 mm in discharge height, 6 mm in discharge width, 150 mm in discharge length, 5 x 5 x 20 cm in outer diameter—and a low-pressure excitation system made of a glass tube, 8 mm inside diameter and 30 cm in length, both of which are pulse operated. The resonator measures 86 cm long and is fixed in place using an invar bar for stabilization. The chirping pulse light mixes with the local laser light (waveguide path type CW $CO_2$ laser) and is detected through heterodyne reception. The output of the detector (HgCdTe) is amplified to an appropriate level, compressed by the SAW device, and then is observed on an oscilloscope.

The SAW device has a center frequency of 58 MHz, band zone of 53 to 67 MHz and diffusion time of 1.6 microns.

### 3. Results and Discussion

Photo 1 [omitted] shows the detection waveform of the HYBRID TEA $CO_2$ laser pulse. The pulse width is 2 microns, the center frequency of the beat is about 20 MHz, and the variation in the frequency shows an up chirp [as published] at about 11 MHz. Photo 2 [omitted]

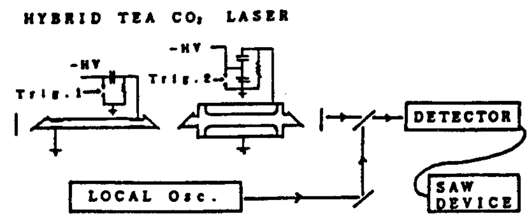



**Figure. Schematic Diagram of Experimental Equipment**

shows the output of a similar laser pulse's detection output, with a center frequency of about 55 MHz, that has been pulse compressed. A side lobe equivalent to about one-third of the peak value of the laser pulse is observed, but the pulse, at a mesial magnitude, is compressed to about 200 nS.

## Si-IRCCD Crosstalk

*43062531a Tokyo BOEI GIJUTSU in Japanese Sept 87 pp 48-49*

[Article by Toshio Sugano and Kazuo Uchiyama, Components Research Office, First Research Institute]

[Text]

### 1. Purpose

Aiming for development of a lightweight and small infrared imaging device with high sensitivity, we have been advancing research on two-dimensional array infrared ray detection devices (IRCCD). As part of the effort, we manufactured, on an experimental basis, a Si-IRCCD, taking advantage of a silicon Schottky barrier. Since Si is used, the IRCCD can be fabricated into a fine device structure, with as many as 256 X 256 pixels. The IRCCD, however, has the disadvantage of image blurring, probably caused by crosstalk within the devices, and, therefore, cannot obtain as clear an image as would be expected to correspond to its numerous pixels. The crosstalk is expected to become even more of a problem if the system is to incorporate many more devices.

By conducting theoretical calculations of the optical crosstalk within devices using an approximate model of the device structure, we understood its cause and intensity, and examined the countermeasures. The following describes the results of our research.

### 2. Research Procedures and Contents

#### (1) Modeling of Device Structure

Since the actual device structure is complex, we conducted theoretical calculations using the model shown in Figure 1.

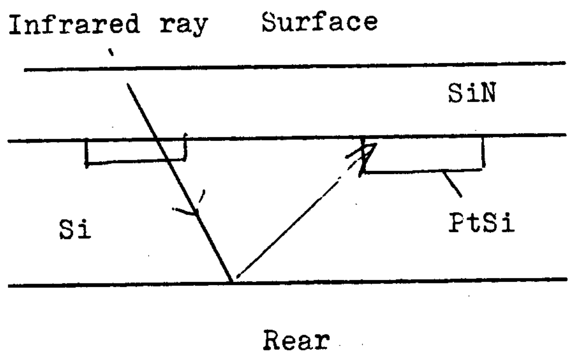



**Figure 1. Approximate Model**

**(2) Measuring of Characteristics of Output to Step Light Input**

Using a lens for which the MTF is already known, we directed step light incident upon the devices, and measured the output in the vicinity of the boundaries between light and darkness.

**(3) Studies of Methods to Prevent Crosstalk**

We considered several countermeasures against crosstalk and studied their effects by means of calculations.

Table: Comparison of Methods

| | Method | Crosstalk (%) | Sensitivity Ratio |
|---|---|---|---|
| | Current | 19.7 | 1 |
| Back Surface | Masking Others Except PtSi | 4.8 | 0.48 |
| Back Surface | Ar Coating of Reverse Surface | 4.1 | 0.47 |
| Back Surface | Masking & Ar Coating | 0.5 | 0.47 |
| Front Surface | Incident on Reverse Surface Only | 1.8 | 0.74 |
| Front Surface | Ar Coating of Si Surface | 0.4 | 0.95 |
| Front Surface | Reflecting Film on PtSi Surface | 1.7 | 1.45 |
| Front Surface | Ar Coating & Reflecting Film | 0.5 | 1.86 |

**3. Results and Discussion**

Figure 2 [omitted] shows the output waveform in relation to the input step light.

The results reveal that, when the lens MTF is taken into account, the crosstalk to adjoining picture elements is about 18 percent. The cause, it has been determined, is due to an incident infrared beam at an angle, after penetrating through the surface, being reflected back to the reverse side, only to be absorbed again at the surface by neighboring light-receiving surfaces. The calculated values, based on the approximate model and those actually measured, are roughly in agreement, thereby showing the model's effectiveness. Shown in the table are results of calculations conducted to measure the effectiveness of the various crosstalk prevention methods. It indicates that the best results can be obtained under conditions in which the light is incident upon the rear, the Si surface is provided with a reflection-reducing coating, and the PtSi surface is coated with a reflecting film. Under these conditions, it was discovered that the crosstalk disappeared almost completely and the sensitivity increased 1.86 times.

## Gas Dynamic Laser and Oxygen

*43062531a Tokyo BOEI GIJUTSU in Japanese Sept 87 pp 49-50*

[Article by Katsushi Kitagawa and Kiyoshi Kato, Second Photoelectric Research Office, Fifth Division, First Research Institute: "Effect of Oxygen in Gas Dynamic Laser"]

[Text]

### 1. Purpose

Combustion-type gas dynamic lasers (GDLs) have been developed as compact high-output gas lasers. To further reduce their sizes, it is necessary to make a transition from the conventional gaseous fuel oxidant to a liquid fuel oxidizing agent. In this case, 20 to 30 percent oxygen is sometimes contained in the combustion gas as an impure gas, in addition to $CO_2 + N_2 + H_2O$ which forms the conventional gas. Experimental studies had been conducted on the effect of $O_2$ on the GDL laser gain, but the theoretical explanation could not be termed fully convincing. An analysis of the GDL's vibration relaxation, after taking into account the $O_2$ vibration mode and the V-V relaxation process between $O_2$ and $CO_2$, shows good agreement with the experimental value.

### 2. Procedures and Contents

Figure 1 shows the vibration energy levels and various vibration relaxation processes for $CO_2 + N_2 + O_2 + H_2O$. In the conventional vibration relaxation model, widely used for GDL analysis, the relaxation processes (1) through (5) are taken into account. In the current analysis, added to the model were the following factors of the $O_2$ vibration mode—the V-V process (6), in which the $O_2$ vibration energy transfers to the $CO_2$ ($v_2$) mode, and the V-V process (7), in which the $CO_2$ ($v_3$) mode is relaxed through the $O_2$ vibration mode.

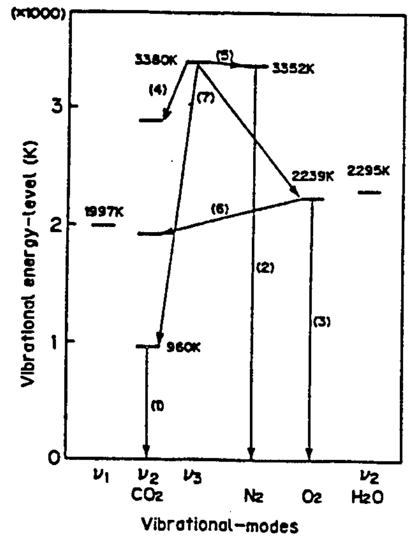



**Figure 1. Energy Levels and Relaxation Processes**

### 3. Results and Discussion

Figure 2 shows the relationship between $O_2$ density and laser gain. Model A (broken line) shows the results of calculations based on the conventional vibration relaxation model, and Model B (solid line) shows the results of the current analysis conducted using the additional factors of the $O_2$ vibration mode and the V-V processes, (6) and (7). It can be seen that Model B is a good agreement with the experimental value.

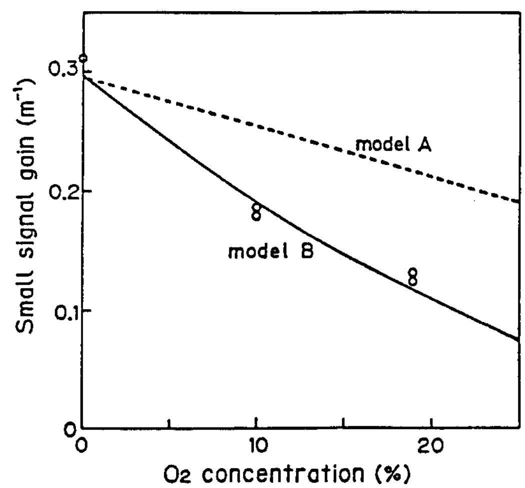



**Figure 2. Relationship Between Oxygen Density and Laser Gain**

The laser gain declines by about 1.3 percent when the oxygen density increases by 1 percent. Taking into account the fact that the liquid fuel oxidizing agent contains 20 to 30 percent oxygen, it could be said from the above relationship that the laser gain could drop by 25 to 40 percent. However, since the liquid fuel oxidizing agent has a density five times (500 percent) as high as that of the gaseous fuel oxidizing agent, the disadvantage arising from a drop in the gain can be more than fully compensated for by its high density.

In addition, the effect of oxygen can be reduced to a great extent by the adoption of an after-mixing-type GDL.

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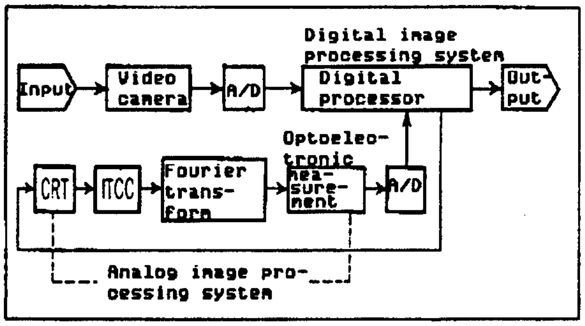



Figure 1. Block Diagram of Discriminating System

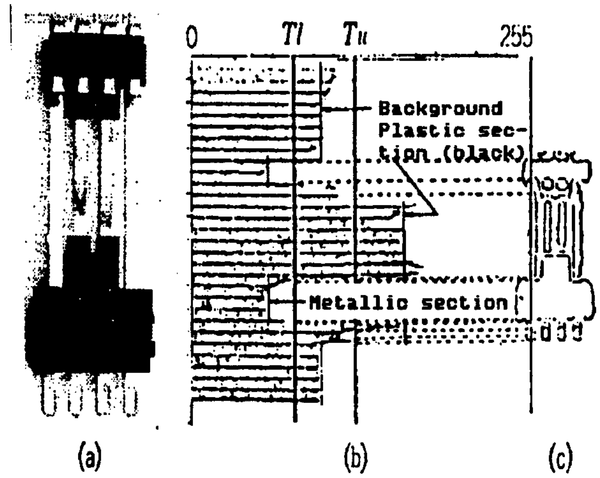



Figure 2. Image Outline Extraction (a) Object image (input image); (b) Intensity distribution of input image (section represented by vertical lines in (a)); (c) Result of outline extraction

## Recent Developments in Optoelectronics Reported

### Analog/Digital Image Processing Equipment

*43063803 Tokyo O PLUS E in JapaneseAug 87 pp 41-43*

[Text] Moves to automate visual examinations have been contributing to fast progress in computer-assisted digital image processing. Real-time digital processing, however, is impossible with small computers, especially microcomputers and personal computers.

The Minemoto Laboratory of the Instrumentation Engineering Department of Kobe University's Engineering Faculty has developed image processing equipment that employs both digital and analog processing. This achievement was announced at the second symposium on industrial image sensing technology which took place on 2-3 July.

The laboratory's research is designed to develop high-speed and simple equipment that can measure an object freely, regardless of its position and direction, and can follow the object even when the distance between the photographic system and the object surface is changed. The equipment carries out the image's real-time, two-dimensional Fourier transform, which is difficult by digital processing, at a high speed by using a simple optical system (analog processing), employing digital processing only to extract simple feature amounts that can be done in a relatively short period of time. The discrimination system is shown in the block diagram in Figure 1.

In digital processing, two kinds of threshold values are used to obtain an initial binary image. This is because, if only one threshold value is used and the object has a section inside with a different reflection factor, the image obtained often represents a shape different from the original object.

These two threshold values are set as follows: Figure 2(a) is a photo of an electromagnetic relay. The gray level distribution on lines in the photo is shown in (b). As shown in the figure, the two threshold values are set at Tu and Tl, with pixels brighter than Tu and darker than Tl given as l's, and the remaining pixels being O's. This represents an effort to remove the background and take in only the object.

A contour-emphasized image is made by raster scanning of the boundary lines of the binary image obtained by this method and output to a cathode ray tube (CRT) as an input signal image for the analog optical processing system. At the same time, the following four feature amounts are extracted:

1. Area of sections darker than Tl/total area

2. Total area/square of distance d from the object surface to the imaging system

3. Sum of boundary line lengths/distance d from the object surface to the imaging system

4. Number of boundary lines

As for analog processing, a BSO image transformation element (ITCC), in which input picture signals are recorded, is placed on the x-y plane of the optical system shown in Figure 3. When it is hit by collimated coherent light, the image's Fourier spectrum is obtained on the focal plane (gm-gu plane) behind the lens. Photometrical measurement of the spectrum is done photoelectrically through a rotating sector which has a fan-like opening, as shown in the figure. This way, the Fourier spectrum's two-dimensional strength distribution is transformed into a one-dimensional function on variant gv of the columnar coordinates. From this one-dimensional function I(gv), the function J(gv) is derived peculiar to the object, which does not change even when the object is moved or rotated, with distinction based on the following three feature amounts:

5. The peak number of J(gv) (the number of different kinds of parallel-edge axes in the figure)

6. The minimum value of peak intervals (it must be 0 when the peak number is 0 or 1) (the minimum value of angles made by different kinds of parallel edge groups in the figure)

$$\int_{\pi/4}^{3\pi/4} J(\theta)d\theta \Big/ \left\{\int_{0}^{\pi/4} J(\theta)d\theta + \int_{3/\pi 4}^{\pi} J(\theta)d\theta\right\}$$

The recognition of the object is, therefore, accomplished based on the seven feature amounts. Actually, however, the distance d is also considered to be a feature amount since it is another source of influence, and the adopted judgment method is a combination of the distinction tree and feature space methods.

The equipment manufactured based on the above idea is shown in Figure 4. The section encircled by the dotted line is the imaging system, which, in the actual equipment, is placed vertically. An auto-focus camera is used. To obtain distance information, the telescopic travel amount of the lens is converted into voltage by a potentiometer and sent to a processor after analog-digital conversion.

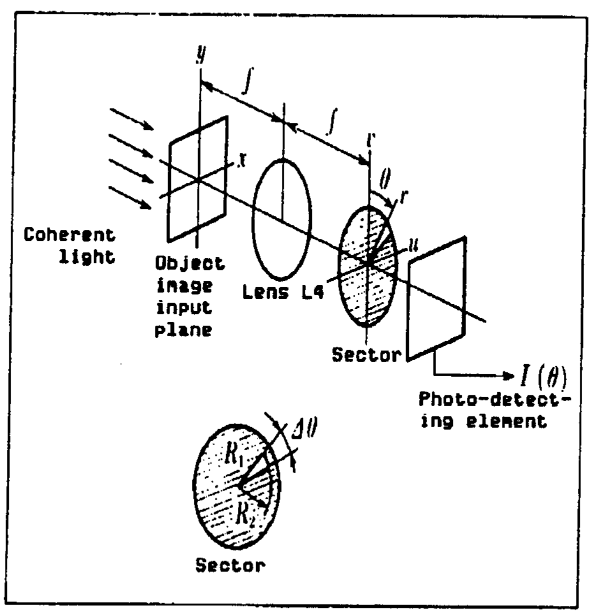
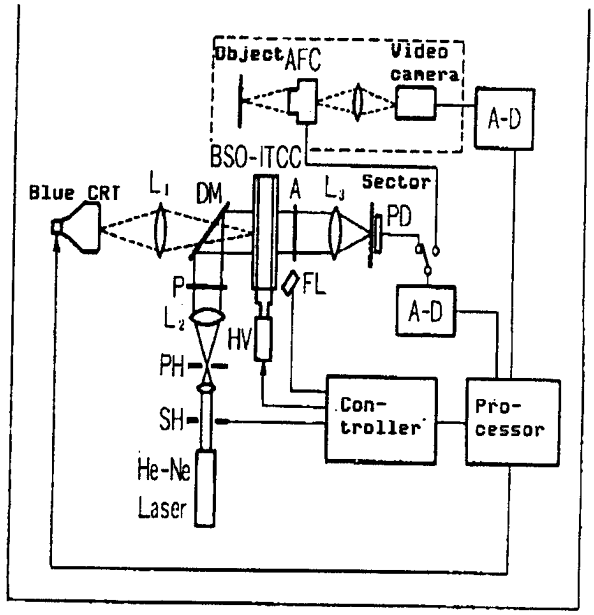



**Figure 3. Basic Structure of Optical Analog Processing System**




A: Analyzer; A-D: A/D converter;
AFC: Auto-focus camera; DM: Dichroic mirror;
FL: Flash lamp; HV: High-voltage power source;
$L_1$-$L_4$: Lenses; P: Polarizer; PD: Photodiode;
PH: Pinhole; SH: Shutter

**Figure 4. Structure of Experiment**

Feature amounts extracted beforehand from a reference object are stored as reference data, and judgment results are output after calculations are made using the reference data and the seven feature amounts extracted by the above-mentioned methods.

Experiments were conducted in seven parts (shown in Figure 5 [omitted]). The range of distance d was set at 50-65 cm, and was divided into three sections of 5 cm each. Reference data were prepared by extracting feature amounts, changing d and the direction in each section while keeping the position of the object unchanged. The distance was changed by units of 1.5 cm, and a total of 55 judgments were made, using the reference data, on each of the parts placed at five different arbitrary positions and directions at each distance. Table 1 shows the results. Input objects are in the left column and the figures show the number of judgments. Accuracy was 94 percent.

The achievement is significant in that real-time processing by a digital processor at the microcomputer level, with free position and direction of the object but without precise positioning, has become possible, that complicated illumination stages, such as a diascopic illumination stage, are not required, and that the distance between the imaging system and the object can be variable.

## Direct Adhesion Solder

*43063803 Tokyo O PLUS E in Japanese*
*Aug 87 pp 43-44*

[Text] Asahi Glass Co. has recently developed solder (trade name: Cerasolsa) that makes direct adhesion to

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | I |
| 1 | [illegible] | 54 | | 1 | | | | |
| 2 | [illegible] | 3 | 51 | 1 | | | | |
| 3 | [illegible] | | | 55 | | | | |
| 4 | [illegible] | | | | 53 | 1 | | 1 |
| 5 | [illegible] | | | | | 43 | 12 | |
| 6 | [illegible] | | | | | 4 | 51 | |
| 7 | I | | | | | | | 55 |

glass and ceramics possible. It was announced at the laser'87 gathering held recently in Munich, West Germany.

The unique solder is a general lead-tin (Pb-Sn) alloy plus zinc (Zn), antimony (Sb), aluminum (Al), tin (Ti), silicon (Si), copper (Cu), etc. A special solution process is employed to make a uniform alloy without segregating these elements. It is said that oxides, which then combine with metallic oxides or oxygen of glass and ceramics to provide adhesion. Therefore, the new solder can bond anything inorganic.

For this chemical bonding, unlike conventional soldering, no surface active materials, like flux, are required. Rather, flux and other organic matter make adhesion impossible. Therefore, it is necessary to eliminate beforehand obstacles to bonding, such as an air layer, organic substances or foreign objects on the interface. organic substances and foreign objects can be removed, but an air layer cannot. Therefore, supersonic vibrations are applied to remove the interface air layer (Figure 1). The supersonic vibrations are said to contribute to increasing adhesive power. Supersonic wave frequencies are 10-100 kHz, with outputs of 10-1,000 watts.

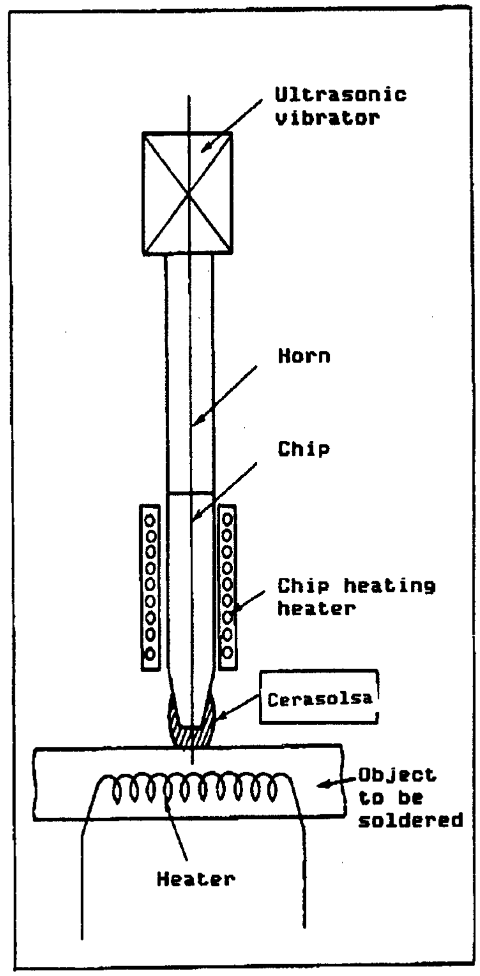



**Figure 1. Cerasolsa Soldering System**

Figure 2 shows Cerasolsa's peeling and shearing strengths. Type numbers represent boiling points (SDC) for easy understanding. The products also have good resistance against heat and humidity.

The advent of a solder that can be used on glass is significant in the optical field. Since, unlike other adhesives, it is stable against temperature changes, it is suitable for the bonding of fibers, lenses, mirrors, and other optoelectronic parts.

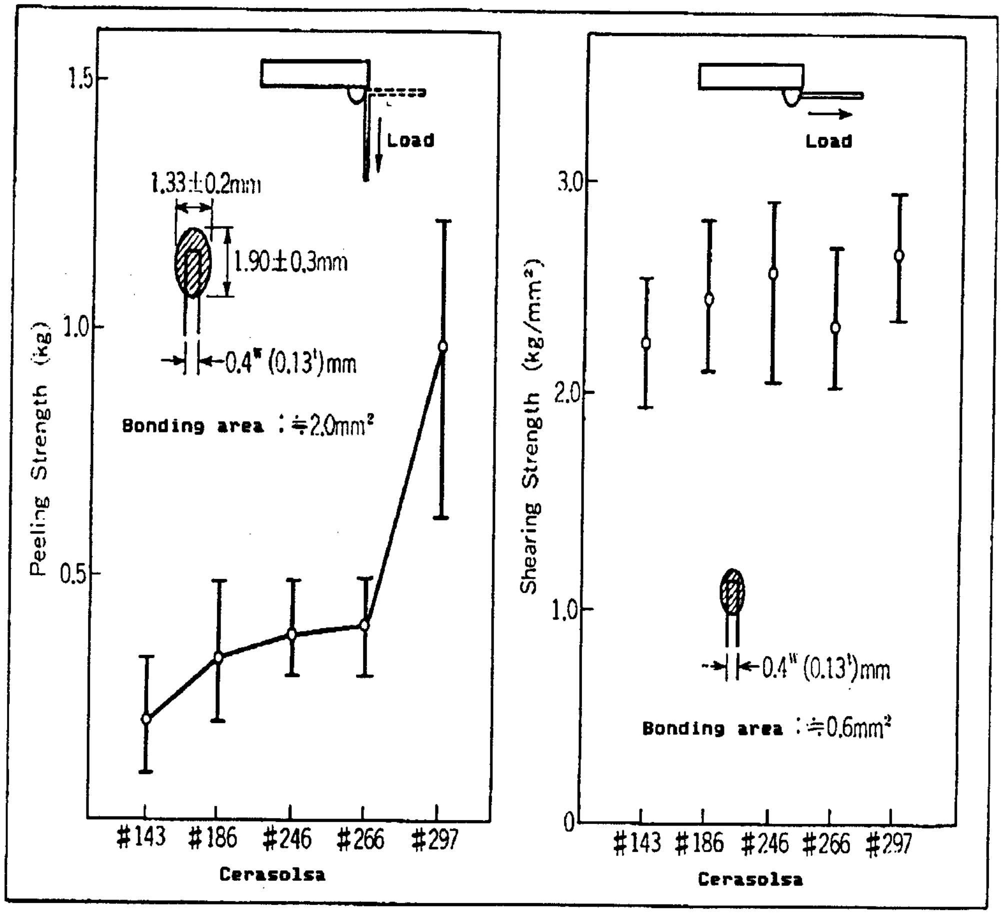
## Superlattice Optical Waveguide

*43063803 Tokyo O PLUS E in Japanese Aug 87 pp 44-46*

[Text] The Optical Semiconductor Laboratory of Matsushita Electric Industrial Co. has recently developed superlattice manufacturing technology for II-VI family compound semiconductors, using the modified organometallic vapor-phase deposition (MOVPE) method. Using this technology, the company formed a superlattice layer, consisting of 100 layers of II-VI family zinc selenium/zinc sulphur (Zn/Se/ZnS), on gallium arsenide (GaAs), a III-V family compound semiconductor. It also manufactured a loaded optical waveguide by employing the superlattice and, for the first time, conducted successful visible light guiding experiments on a superlattice three-dimensional optical waveguide with the use of a helium-neon (He-Ne) laser beam.

This means that the way has been opened for the manufacture of a waveguide needed for optoelectronic integrated circuits (OEICs) with II-VI family compound semiconductors. That could also make the use of II-VI family compound semiconductors in various optical devices possible.

II-VI family compound semiconductors, such as ZnSe and ZnS, have a very wide direct-transition type band gap and nonlinear optical effects. For these reasons, they are said to be promising materials for short-wavelength optical devices, such as high-efficiency blue light emitting diodes (LEDs) and blue laser diodes (LDs) that




(a)Peeling Strength (b)Shearing Strength

**Figure 2. Kinds of Cerasolsa**

cannot be manufactured with GaAs and indium phosphorus (InP) III-V family compound semiconductors, and active efforts to develop epitaxial growth technology for II-VI family compound semiconductors have been made.

Unlike the III-V family, however, the II-VI family has few combinations of dissimilar materials with lattice matching. There are also other problems, such as high prices for quality II-VI family substrates and the need to use dissimilar substrates with unmatching lattices. These factors have hindered the development of well-established epitaxial technology for thin film forming.

Matsushita's Optical Semiconductor Laboratory noted the effectiveness of technology in making a strained superlattice (SLS) layer, consisting of multiple layers of very thin films, as a means of obtaining a heterostructure suitable for realizing blue optical devices and freely controlling the band gap and other physical constants, and the lab has therefore been conducting research activities.

The lab achieved good results by making a superlattice, using fully airtight MOVPE equipment and a methyl organic metal as the source material, at 550SDC, higher than the usual temperatures of 400SDC or lower, and a pressure of 100 Torr.

Figure 1 shows an outline of the experimental superlattice three-dimensional optical waveguide. The SLS layer consists of 50 pairs of ZnSe (50A)/ZnS (50A), and the total thickness is 0.5 gmm. A silicon dioxide ($SiO_2$ film, 0.25 gmm thick, 20 gmm wide, and 1-5 mm long, is formed to make a loaded optical waveguide. Photo 1 [omitted] is the device's SEM image.

When an He-Ne laser beam (67328A) was led into the optical waveguide, a near field view image of outgoing light was obtained, demonstrating that the He-Ne laser beam was contained three-dimensionally. Therefore, guiding of visible light by a superlattice optical waveguide was confirmed for the first time.

Figure 2 is a three-dimensional chart of transmittance characteristics. Although attenuation exists, as the figure shows, the minimum transmission loss is less than 1

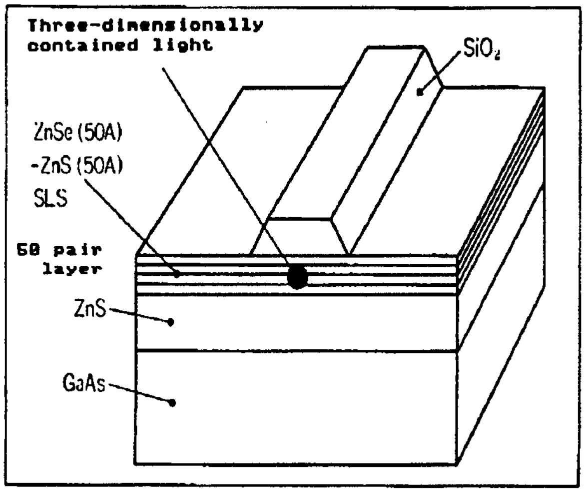



**Figure 1. Structure of Loaded Optical Waveguide Device**

$cm^{-1}$. The lab thinks the device will become fully usable as an optical waveguide with the use of epitaxial growth and optimization of the structure.

Superlattice manufacturing technology is, therefore, effective in combining a II-VI device and a III-V device. Its advantages include no need to take into account lattice mismatching in selecting substrates, which expands the latitude of substrate selection.

The technology has opened the way for the development of OEICs through the combination of III-V and II-VI family compound semiconductors by making a III-V optical or electrical device on a GaAs common substrate and then making a II-VI optical device.

## Coherent Optical Communications

*43063803 Tokyo O PLUS E in Japanese Aug 87 p 46*

[Text] A Fujitsu, Ltd., laboratory has recently experimentally fabricated a coherent optical communications system (photo [omitted]) employing the frequency shift keying (FSK) filter detection system. It achieved transmission of information over 140 km, without a booster station, at a speed of 600 megabits/second and, at the same time, demonstrated the effectiveness of the frequency multiplexing system.

In coherent communications, the spectral width is small and a semiconductor laser with a very stable frequency is required. The frequency of a semiconductor laser changes, depending on shifts in ambient temperatures and electric current noise, causing noise. Coherent communications systems tested so far were all very delicate systems requiring close observation, even on vibration and air flows, and many of them worked on a vibration isolation table for only a short time. MOreover, they required specially-structured light sources to narrow the oscillation line width, and were far from practical use.

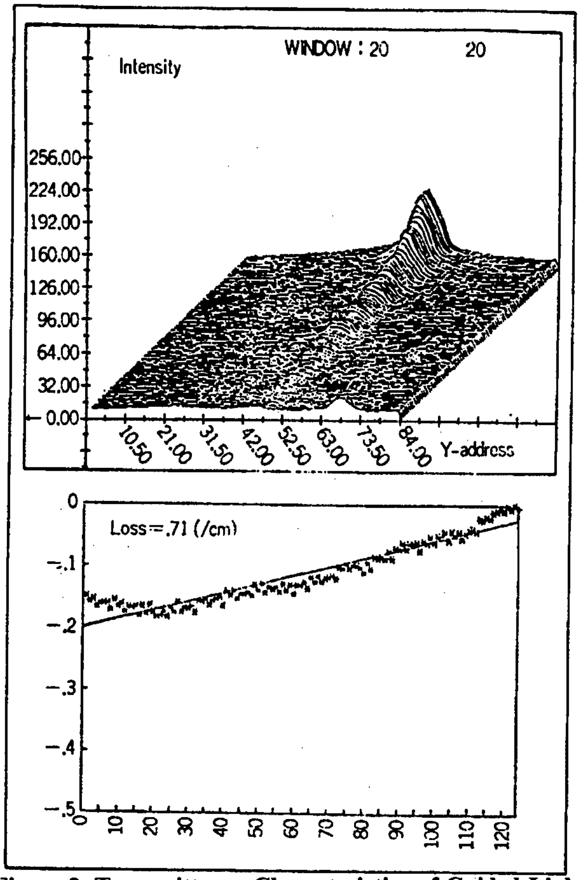



**Figure 2. Transmittance Characteristics of Guided Light**

The Fujitsu, Ltd., lab made delicate sections into modules to ensure stability. Specifically, the lab achieved coherent optical communications under normal temperature and vibration conditions using a distributed feedback (DBB) semiconductor laser it developed by: 1) controlling the temperature to a precision of 0.01SDC; 2) ensuring precision coupling with an optical fiber; and 3) employing an isolator that removed reflected feedback light. At the same time, the lab made the equipment into a compact system that could be carried by a man. The lab also conducted an experiment involving two-wave frequency multiplex transmission using the same system, and succeeded in extracting desired information at the receiving end by tuning out.

The latest success marks a major step toward the practical use of coherent optical communications to dramatically boost transmission capacity, by using the single-mode optical fiber network now being built, without any modifications.

## Cyclodextrin for Photochromic LB Film

*43063803 Tokyo O PLUS E in Japanese Aug 87 pp 46-48*

[Text] The National Chemical Laboratory for Industry of the Agency of Industrial Science and Technology,

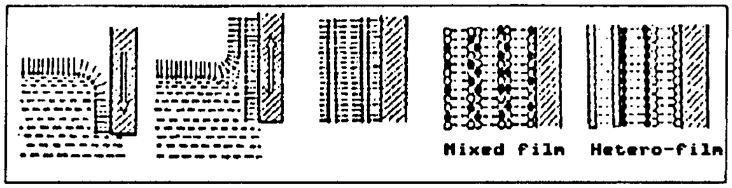



**Figure 1. LB Film Manufacturing Method Single-molecule film of organic molecules in the water surface accumulates on the substrate, layer by layer, by moving the substrate up and down. It is also possible to make mixed-LB film by mixing organic molecules, and hetero-LB film by accumulating layers while changing expanded layers, one after the other.**

which is conducting research on functional organic ultrathin film using Langmuir-Blodgett (LB) film that allows molecular polymerization through orderly control of organic compound arrangement and orientation, has recently developed an epoch-making method for manufacturing functional LB film that is totally different from existing LB film technology. Using the method, photochromic LB film was found to have excellent characteristics.

Research on LB film is underway for development of materials with new functions and high performance due to the film's following characteristics: 1) it is possible to make ultrathin film of uniform thickness that can be adjusted within the single molecular level layer (20-30A); 2) molecular-level control of the arrangement and orientation of functional molecules is possible; 3) high-density packing of functional molecules occurs; 4) the possibility exists to make wide-area ultrathin film with few pinholes and other defects; and 5) the film can be manufactured under normal temperature and pressure, allowing film to be made without destroying the functions of thermally unstable compounds. Figure 1 shows the LB film manufacturing method.

To make functional LB film, it used to be necessary to synthesize film-making molecules for LB film, making single-molecule film on the water surface. For example, it had been necessary to introduce hydrophobic long-chain alkyl and hydrophile carboxyl into functional molecules. The synthesis process was difficult and posed problems, resulting in low yield and expensive compounds (Figure 2(a)).

After studying the possibility of turning functional compounds,without long-chain alkyl, directly into LB film, the lab found that a long-chain alkyl derivative of cyclodextrin, having a unique structure allowing the inclusion of functional molecules, (photo [omitted]): 1) could make a stable single-molecule film on the water surface; 2) could accumulate on a solid substrate, such as LB film; and 3) could be turned into LB film with various organic molecules included. it also found that 4) LB film including azobenzene (photo [omitted]) has an optical memory capability, switching from the trans- to cis-structure with the application of an ultraviolet ray, and from the cis- to trans-structure with a visible ray. The conventional azobenzene LB film (with long-chain alkyl) does not transform from the trans- to cis-structure, which is accompanied by an increase in the area occupied by molecules, because of rigidity. However, the cis-trans reversible reaction (photochromism) (photo [omitted]) is possible with good repeatability using the new LB film, due to the free space offered by cyclodextrin's hollow sections (Figure 2(b)).

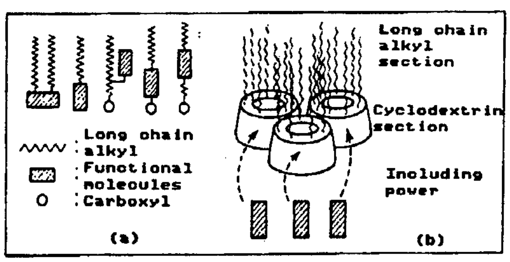
This is the first example of LB film making with normal photochromic molecules. The method is promising because it can easily turn various photochromic molecules and other functional molecules into LB film.

## Robot Movements Measured Precisely

*43063803 Tokyo O PLUS E in Japanese Aug 87 p 48*

[Text]The demand is rising for technology to measure the three-dimensional position of an object, such as a robot, traveling over a wide range of space, with high precision. The Technology Development Department of Kawasaki Heavy Industries, Ltd., (KHI) has developed a high-recision triangular system to measure the position for an object equipped with a light-emitting diode (LED) (infrared) by using two cameras (Figure 1).

To increase the response speed and precision, the system uses position sensor diodes (PSDs). It also has two axes of rotation, for swinging the cameras vertically and horizontally, to widen the field of view for measurement, and a function to detect the angles of rotation with




(a) Conventional method: Long-chain alkyl derivative of functional compounds
(b) New method: Introduction of functional compounds with cyclodextrin LB film

**Figure 2. Making Functional LB Film**

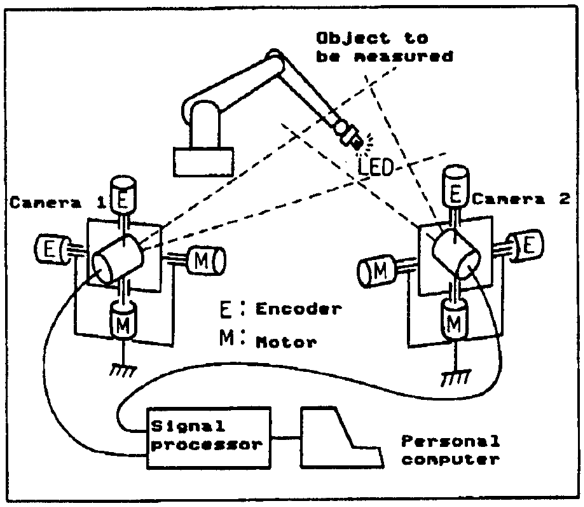



Figure 1. System Configuration

encoders. It should also be noted that, because individual PSDs have different nonlinear position detecting characteristics, the system improves precision by correcting the nonlinearity.

The department uses the following method to obtain the LED coordinate on the traveling object based on the PSD coordinate.

From Figure 2, the absolute coordinate of point P can be obtained as follows:

$$[h_1X_{C1} \quad h_1Y_{C1}h_1]^t = C_1[XYZ1]^t$$
$$[h_2X_{C2} \quad h_2Y_{C2}h_2]^t = C_2[XYZ1]^t$$

where $h_1$ and $h_2$ are coefficients.

$C_1$ and $C_2$ are 3 x 4 matrices with each of the 12 elements called a camera parameter. The 12 unknown figures can be obtained from the three-dimensional coordinates of six points that are not on the same plane, and corresponding coordinates in the camera images. The department works them out by measuring more than six points and using the least squares method for better precision. However, it is time-consuming to do the above calculations every time the cameras are rotated. Therefore, the system carries out subsequent calculations based on encoder rotation angles.

When measurement was made by the above method, putting the LED on an XYZ table that could be positioned in units of 20 gm, high precision of +/-0.5 mm was achieved for about 85 percent of the experiments within a space of 300 $mm^2$.

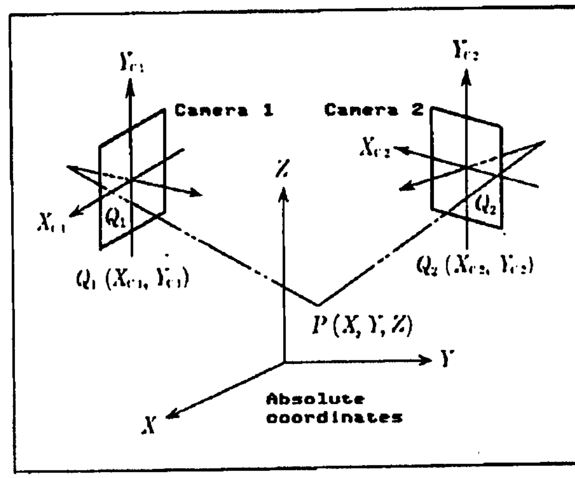



Figure 2. Principle of Three-Dimensional Position Measurement

The KHI department apparently hopes to apply the system to position detection of numerically-controlled (NC) robots and locus measurement of robots required to move three-dimensionally, such as painting and welding robots.

## Visible Light Semiconductor Laser Output

*43063803 Tokyo O PLUS E in Japanese Aug 87 pp 49-50*

[Text] NEC Corp. has recently succeeded in continuous 27 mW output operation of an aluminum-gallium-indium phosphorus (AlGaInP) lateral-mode control visible light (red) semiconductor laser with a 683 nm wavelength. This is the first time that output of more than 5 mW has been achieved with a lateral-mode-control visible light semiconductor laser with a 600 nm wavelength range.

The newly-developed laser has a selective mesa imbedded structure, in which a thin film layer, having a crystal composition different from that of the p-type clad layer, is introduced between the active layer and the p-type clad layer. It is marked by lateral-mode control, which enables a high-quality beam and high output, and a device structure with excellent processing precision and high repeatability, making the device suitable for mass production. Figure 1 shows the structure of the semiconductor laser and Figure 2 presents current/optical output characteristics.

NEC has also succeeded in optical disk write/read experiments using an optical head equipped with this high output visible light semiconductor laser. It has confirmed that the laser allows 1.5 times higher density writing compared with a conventional infrared semiconductor laser with an 830 nm wavelength range.

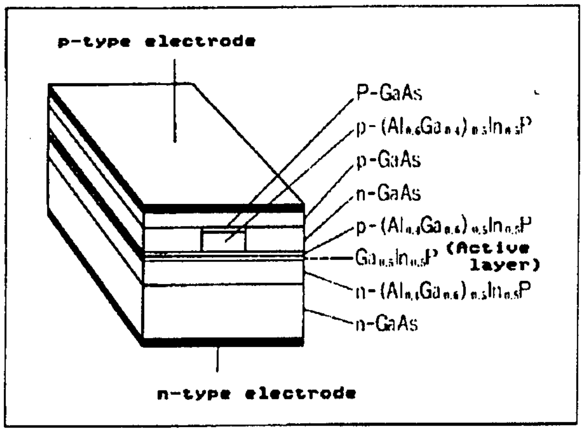



**Figure 1. Structure of High-Output Visible Light Semiconductor Laser**

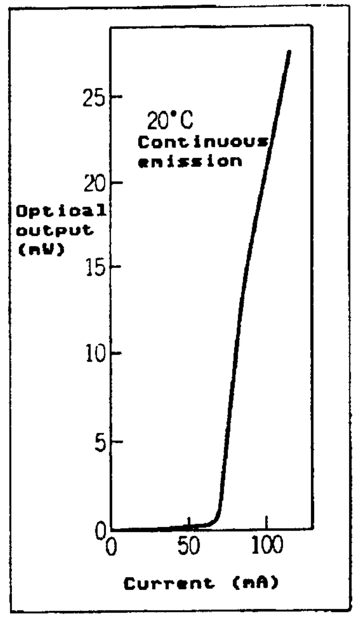



**Figure 2. Current/Optical Output Characteristics**

## New Excimer Laser

*43063803 Tokyo O PLUS E in Japanese Aug 87 pp 51-52*

[Text] Hamamatsu Photonics has recently put on the market the C2926 Series excimer laser, with international performance levels, which the company developed using its electron tube technology (photo [omitted].

The series consists of the C2926 (maximum repeat frequency 50 Hz, Y8.7 million), the C2926-01 (100 Hz, Y9.2 million), and the C2926-02 (200 Hz, Y10.5 million).

The 200 Hz maximum repeat frequency of the C2926-02 is one of the highest offered by domestic excimer lasers. The life of the argon-fluorine (ArF) excimer laser (the number of light emissions until optical output halves) is 1 million shots, also among the top Japanese excimer lasers (the use of gas-purifying equipment is said to treble the life). Other features of the series include high output stability (within +/-3 percent), good operation characteristics (the separation of the operation section from the main unit sharply expanded installation site selection and a compact design (the size of the beam-emitting section is 1,200 mm wide, 800 mm deep, and 450 mm high). Because the lasers are solely domestically-made, they also feature good maintenance service.

20159/9365

## Developments in Atomic Energy Industry Reported

### Joint Venture With West German Company

*43062006 Tokyo GENSHIRYOKU SANGYO SHIMBUN in Japanese 10 Sep 87 p 5*

[Text] Mitsubishi Metal Corporation (headquarters, Tokyo; president, Ken Nagano) announced on the 1st that it would establish a joint venture with Sankei Building subsidiary Sankei Building Management (headquarters, Tokyo; president, Shigeo Takayanagi) and West Germany's (Shina) Company (headquarters, Pforzheim; president, Rainaa Baruterusu), which specializes in radiation protection and removal of pollution. (Serunakku), the joint venture, will enter the field of atomic energy services.

Atomic energy now provides 28 percent of Japan's electrical energy, and the trend is for dependence on atomic energy to continue to rise. As it does, the number of atomic facilities of various sorts is expected to increase; it has come to be recognized that services for these facilities, including facility management, maintenance, radiation shielding, removal of pollution and dismantling of facilities will become extremely important.

Mitsubishi Metal has long undertaken such things as development of technology and engineering for the atomic fuel cycle and radioactive waste processing and disposal, and use of radioactive isotopes. On the basis of its experience and knowhow, it has decided to expand its operations into the services which will be essential for the development and establishment of the atomic energy industry.

The new company will establish a framework for international cooperation and for cooperation between different industrial sectors, in that Sankei Building Maintenance has knowhow in building maintenance and other administrative services and (Shina) Company has experience in radioactive shielding and removal of pollution. It will thus be possible to provide more finely tuned services.

Company headquarters will be in Nihonbashi Kakigaracho, Chuo-ku, Tokyo. Chief Engineer Takaaki Kashiwagi of Mitsubishi Metal's Atomic Energy Division has been appointed president. Capitalization will be 10 million yen, of which 51 percent will come from Mitsubishi Metals, 34 percent from Sankei Building Management and 15 percent from Shina Company. The new company will begin operation on the 10th.

### Report on Returned Waste from Overseas

*43062006 Tokyo GENSHIRYOKU SANGYO SHIMBUN in Japanese 10 Sep 87 p 6*

[Text] On 27 August the Nuclear Safety Commission accepted as correct the report "Ideas on the Safety of Waste Products Recovered in the Course of Overseas Reprocessing," and made a commission decision of it. That report was put together by the Expert Working Group on Safety Standards for Radioactive Waste (Science University of Tokyo Professor Masao Sawai, chairman). High-level returned wastes from overseas (Britain and France) are fundamentally the same as those to be classified domestically; the report says that because there is data on returned wastes in the foreign countries that carry out reprocessing, "it is important to conduct a full exchange of information among concerned institutions" in advance. The French Nuclear Fuel Corporation has already presented methods of handling returned waste products to Japanese power companies; the focus hereafter will be on creation of concrete standards. In this issue we will introduce the main points of the report.

#### Handling Equivalent to that of Domestic Wastes

When Japan accepts returned waste products, it is of course necessary to ensure that the waste products are suitable in terms of safety, and also to ensure safety in connection with transportation and storage.

A study of safety in connection with transportation had been made by the Expert Working Group on Safe Transportation of Radioactive Materials, so this report indicates basic thinking on the handling of recovered waste in connection with storage. It also indicates the basic conditions required in storage facilities when storing returned waste and the matters that must be given consideration in studies of storage safety.

Because there is much in regard to post-storage disposal that will be left to future R&D, on this topic the report only indicates, on the basis of current knowledge, matters that will have to be considered in future evaluations of the safety of disposal of returned waste materials.

This report was drafted on the basis of present knowledge and experience and the latest information received so far. It will be revised as necessary in response to later experience, new knowledge or the receipt of useful information.

The processing and disposal of waste generated during the reprocessing of spent fuel, like that of waste generated in other atomic facilities, has been carried out in accordance with the report of the Nuclear Safety Commission Expert Working Group on Radioactive Waste Policy reports entitled "Methods for Processing and Disposal of Radioactive Wastes" (dated August 1984 and October 1985). But because the same basic thinking applied to waste generated domestically is pertinent to the safety of storage and disposal of returned wastes generated in connection with reprocessing overseas, it is necessary to make a comprehensive study based on the results of R&D on waste generated domestically.

Particulars of returned waste: Radioactive wastes in gaseous, liquid and solid forms are generated in the reprocessing of spent fuel, which can include processes of cutting, dissolving, clarification, separation, refining, denitrification and recovery of acids and solvents. It is anticipated that of these waste products, the liquids will be solidified and the solids will be returned to Japan. Of these, the report considers high-level radioactive wastes, unsheathed cuttings, products of liquid waste treatment, and miscellaneous waste products.

(1) High-level radioactive wastes: The liquids remaining following the first extraction cycle of the separation process make up the biggest share of high-level radioactive liquid waste. It is thought that after they are evaporated and concentrated they will be stabilized through solidification in borosilicate glass.

(2) Unsheathed cuttings: The endpieces of spent fuel elements from the cutting process and the unsheathed cuttings (hulls) from the dissolving process are expected to be solidified in cement.

(3) Liquid waste products remaining after removal of high-level radioactive liquids wastes: The liquids and other wastes generated in the process of recovery of acids and solvents are expected to be solidified in cement and asphalt.

(4) Miscellaneous waste products: Other miscellaneous solid wastes generated in the course of maintenance and repairs in the reprocessing plant (discarded equipment, paper, clothing etc.) are expected to undergo solidification processing.

Basic thinking on studies of handling of returned waste: Studies on the handling of returned waste products will essentially focus on the handling of the waste products themselves. But in order to determine whether the returned waste products to be handled in Japan can be received safely, it will of course be necessary to evaluate the characteristics of the waste products themselves, and also to study whether such wastes can be safely stored in the storage facilities that are to store them.

Moreover, it is considered realistic to say that returned waste products can be processed without great variation in the form of the waste, but the specific methods of reprocessing are still in the R&D stage, and it will take some time before the processing can actually be implemented. It is therefore desirable at this time to strive to obtain as much information as possible that is considered necessary for evaluation of the safety of processing.

It will then be necessary to consider such characteristics as that TRU [transuranic] waste products may be included in the wastes generated by reprocessing.

### Necessity of Full Exchange of Information

The safety of returned waste product storage can be assured through solidification and confinement by the combination of containers and storage facilities.

Thus, when studying the safety of storage of returned wastes it is first necessary to evaluate the conditions pertinent to safe storage of waste products. Then it will be possible to evaluate whether the waste products to be handled can be stored safely.

It is conceivable, however, that the details of the storage facilities will not be clear when the handling of returned waste products is studied. In such a case, it will be confirmed, on the basis of the fundamental thinking on storage of waste products contained in the Reprocessing Facility Safety Screening Principles, that storage facilities will be designed to safely store the returned waste to be handled.

As for the storage facility evaluation parameters to be used at that time, an evaluation will be made within the scope of considered suitable under present technology. If there is no problem with the results of that evaluation, it will be decided that the returned waste products to be handled can be stored safely.

Evaluation of returned waste products: In order to evaluate the conditions pertinent to the safe storage of returned waste products, it is first necessary to evaluate the state of the wastes, including their solidification, whether their containers are sufficiently resistant to corrosion and so on. There is also the matter of the information needed for evaluation; it is necessary to evaluate whether such information is accurate.

Among the items to be evaluated from the perspective of storage are the source, state and processing of returned waste products, amount of internal radiation, solidification medium and chemical composition, and the material, shape and measurements of the container.

Thermal analysis will require such things as heat generated, thermal conductivity, specific heat and thermal radiation at the surface of the container. Factors of exposure analysis include amount of internal radiation, material, shape and measurements of the container, and also mass of waste product, surface dosage and surface contamination density. Of these items for evaluation for which handling cannot be assured, it will be necessary to evaluate information which can be substituted.

Basic requirements for storage facilities: The safety of storage of returned waste products can be assured by a combination of solidification, containers and storage facilities. The following can be considered as the basic conditions required of storage facilities for high-level radioactive wastes: (1) basic site requirements, (2) normal conditions, (3) emergency conditions, (4) confinement mechanism, (5) radiation shielding, (6) radiation exposure management, (7) extraction of radioactive substances, (8) radiation monitoring, (9) cooling function, (10) earthquakes, (11) fires, (12) consideration of accidents, (13) consideration of inspections and maintenance.

It is thought that the basic requirements for facilities for storage of radioactive wastes with low levels of radioactivity will be no different from those for storage facilities for wastes from such sources as radioactive power plants.

Safety evaluation: To confirm that returned waste products can be stored safely in storage facilities, it will be necessary to evaluate safety in both normal and emergency circumstances.

In regard to safety in normal circumstances, it is considered necessary to evaluate whether radiation shielding and cooling of heat-producing wastes are being carried out properly. It is also necessary to study leakage of the radioactive substances contained in solids within the container and the volatilization and scaling of radioactive substances that might adhere to the surface of the container, and to evaluate to possibility of their transfer to the environment.

In regard to safety in emergency circumstances, incidents which could release radioactive substances—such as mechanical breakdown, accident, operating error or operator error—will be hypothesized, and safety will be evaluated in terms of possibility of incidence. Breakage in connection with the handling of waste products and deterioration of seals can be considered among the incidents which should be hypothesized.

In selecting technically correct analysis models and parameters for analysis of such incidents, and in evaluating their safety, the avoidance of marked exposure of the general public to radiation will be made the standard of judgement.

In regard to storage of waste products, it is important to accumulate and coordinate a broad range of necessary technical data, including the situation in other countries, and to accord adequate study and coordination to methods for analysis of safety.

In regard to disposal, there is presently safety research safety evaluations and guidelines and standards, together with R&D aimed at disposal facilities in Japan. It is necessary, in carrying out this research, to proceed in a coordinated way while keeping returned wastes in mind.

In addition to studies of handling, it is necessary to provide a framework of safety standards, in a timely manner, in relation to safety inspection of storage facilities and receipt of materials when returned.

Because returned wastes will be generated and solidified in connection with overseas reprocessing, it will be important to study quality assurances and quality control. Since data on wastes are basically found in the countries that carry out reprocessing, it will be important to have a full exchange of information with the institutions involved.

9601/9604

## Report: Safety of Transporting Returned Waste

### Returned Waste Transport Safety

*43062024 Tokyo GENSHIRYOKU SANGYO SHIMBUN in Japanese 12 Nov 87 pp 1, 6*

[Text] As previously reported, the Nuclear Safety Committee's Departmental Meeting of Experts on the Safe Transport of Radioactive Materials recently submitted and received approval from the committee for a report on the transport safety of waste returned from Great Britain and France for reprocessing. According to this report, they decided that after a review of national laws and ordinances, they "could guarantee the safety of returned waste transport." We here present a summary of their report.

**A Safety Evaluation of Vitrified Transport Units**

**Vitrification Specifications**

They established the parameters necessary for their safety evaluation on the basis of COGEMA specifications on July, 1986, and BNFL specifications of November, 1986.

**Safety Evaluation**

Because these transport units are type-B (called BM transport units or BU units under present domestic and IAEA regulations), in their safety evaluation, they studied their suitability to technical standards for transport units both for normal shipping as determined by transport regulations and under general and special test conditions.

**1) Structural Analysis**

Because these transport units are Type-B, they principally studied their safety and soundness after a drop from nine meters.

The dimensions, shape, construction, and materials of the hypothetic shipping containers resemble those used in proving tests for shipping containers for spent fuel. The calculated values for maximum acceleration and stress at the time of drop impact are thought to be appropriate on the basis of proving test results.

Although there was some concern over the fact that the vitrified units were knocked out of shape by the nine meter drop, this had no effect on their safety as transport units.

**Principal Specifications for the Vitrified**

| | COGEMMA | BNFL |
|---|---|---|
| 1) Total height | About 1.3 m | About 1.3 m |
| 2) Outside diameter | About 0.4 m | About 0.4 m |
| 3) Weight | About 500 kg | About 500 kg |

**Principal Specifications for the Vitrified**

| | COGEMMA | BNFL |
|---|---|---|
| 4) Heat generated (at time of transport) | Less than 2 kW per unit | Less than 2k kW per unit on average |
| 5) Radiation intensity | | |
| (Beta, gamma) | About 7.6 x $10^5$ Ci/unit | About 7.1 x $10^5$ Ci/unit |
| (Alpha) | About 3.8 x $10^3$ Ci/unit | About 3.5 X 103 Ci/unit |
| | (4 years after removal from reactor) | 6 years after removal from reactor) |
| 6) Solidified content density | About 2.7 g/cm3 | About 2.7 g/cm3 |
| 7) Solidified container materials | Z15CN2413 | BS 1449 309S24 |
| | (JIS SUH309) | (JIS SUH309) |

### 2) Heat Analysis

The amount of heat generated by each vitrified unit averages less than 2 kW. When 20 of these units are laced in a shipping container, the total heat generated per container is less than 40 kW. This is not an especially severe condition in light of the heat design of shipping containers presently used for spent fuel, and it is possible to design them using present techniques.

### 3) Seal Tightness Analysis

As a result of their evaluation, seal tightness is considered adequate with standard leakage values approved for general and special test conditions.

**Summary of the Hypothetic Vitrified Waste Shipping Container**

| | Proposed Shipping Container | Notes (COGEMA acceptance conditions) |
|---|---|---|
| 1) Type of transport unit | Type-B | — |
| 2) Maximum weight of the shipping container | About 100 tons | — |
| 3) Maximum weight of the transport units | About 110 tons | 110 tons |
| 4) Outside dimensions of shipping container | Outside diameter: about 2.5 m | Maximum outside diameter: 2.5 m |
| | Total length about 6.9 m | Maximum length: 7.0 m |
| 5) Principal materials of shipping container | | |
| -main body | carbon fiber steel | |
| -neutron shielding | resin | |
| -cover | stainless steel, aluminum alloy | |

**Summary of the Hypothetic Vitrified Waste Shipping Container**

| | Proposed Shipping Container | Notes (COGEMA acceptance conditions) |
|---|---|---|
| -basket | stainless steel, aluminum alloy | |
| -shock absorbers | wood, stainless steel | |
| 6) Unit capacity | 20 (4 tiers of 5) | At least 20 |

### 4) Shielding Analysis

The dose rates obtained by their testing satisfied the standards for normal transport under general and special test conditions. Judging from data in reliability tests for spent fuel shipping containers or in tests on neutron shielding materials, these figures are considered acceptable.

### 5) Critical Analysis

The infinite multiplication coefficient obtained by their testing was extremely small when compared to a critical condition of one. There will be no problems from a critical safety standpoint.

In addition, even when a shipping container filled with vitrification units is flooded with water, there is no problem with critical safety.

### 6) Quality Assurance and Inspection

Vitrification transport units are considered to have the same level of quality assurance and inspection as spent fuel shipping containers. If they are treated in this way, they are considered problem-free.

## A Safety Evaluation of Bitumen Solidified Transport Units

### Bitumen Solidification Specifications

Because bitumen solidifieds are not used by BNFL, they established the parameters needed for their safety evaluation based on COGEMA specifications of March, 1984.

**Principal Specifications for the Bitumen Solidifieds**

| | |
|---|---|
| 1) Total height | About 0.9 m |
| 2) Outside diameter | About 0.6 m |
| 3) Weight | 250-300 kg |
| 4) Heat generated | 0.6 W/unit |
| 5) Radiation intensity | |
| (Beta, gamma) | About 170 Ci/unit |
| (Alpha) | About 1 Ci/unit |
| 6) Density of the solidified contents | 1.3-1.5 g/cm$^3$ |
| 7) Solildified container materials | Z8CT17 (JIS SUS430LX) |

**1) Structural Analysis**

Because the transport units are Type-B, they principally studied their safety and soundness after a drop of nine meters.

The shape, construction, and materials of the hypothetic shipping containers resemble those used in proving tests for shipping containers for spent fuel. The calculated values for maximum acceleration and stress at the time of drop impact are thought to be appropriate on the basis of proving test results.

**2) Heat Analysis**

The amount of heat generated per bitumen solidified unit is 0.6 W. Because almost no heat is generated internally, it has been possible to hypothesize a rational shipping container. However, it is important to give design attention to temperature increases in solidified contents which are due to external heat increases under special test conditions.

According to the analysis results and to the result of fireproofing and heat conductivity tests which used a partial model shipping container, it is considered possible to hypothesize a heat-safe shipping container by lowering the combustion point and the solidification treatment temperature during manufacture.

**A Summary of the Hypothetic Bitumen Solidified Shipping Container**

| | Hypothetic Shipping Container (COGEMA Common Immersion Sludge) | Notes (COGEMA Acceptance Conditions) |
|---|---|---|
| 1) Transport unit type | Type B | — |
| 2) Maximum weight of the shipping container | About 35 tons | — |
| 3) Maximum weight of the transport units | About 40 tons | 40 tons |
| 4) Outside dimensions of shipping container | Outside diameter: about 2.5 m | Maximum outside diameter: 2.5 m |
| | Total length: about 2.8 m | Maximum length: 2.8 m |
| 5) Principal Materials of shipping container | | |
| -main body | Carbon fiber steel | |
| -neutron shielding | — | |
| -cover | stainless steel | |
| -basket | stainless steel | |
| -shock absorber | wood, stainless steel | |
| 6) Unit Capacity | 12 (2 tiers of 6) | At least 12 |

**3) Seal Tightness Analysis**

As a result of their analysis, the seal tightness of the shipping units is considered adequate with standard leakage values approved for general and special test conditions.

**4) Shielding Analysis**

They analyzed their calculations for special test conditions under the assumption that the shock absorbers had been lost. Thus they used calculation coding and a simplified calculation method identical to those under general test conditions, during normal transport.

The dose rates obtained by these calculations satisfied standards for normal transport under general and special test conditions. Judging from data in reliability tests for spent fuel shipping containers, these figures are considered acceptable.

**5) Critical Analysis**

**Critical safety is considered satisfactory.**

**A Safety Evaluation of Concrete Solidified Transport Units**

**Specifications**

They established the parameters necessary for their safety evaluation based on COGEMA specifications of July, 1984, and BNFL specifications of September, 1986. They performed their safety evaluation on COGEMA's full end piece concrete solidifieds which have maximum dimensions, weight, and radiation intensity.

**Principal Specifications of Concrete Solidifieds**

| | |
|---|---|
| 1) Total height | About 1.7 m |
| 2) Outside diameter | About 1.1 m |
| 3) Weight | About 4000 kg |
| 4) Heat generated | 130 W/unit |
| 5) Radiation intensity | |
| (Beta, gamma) | About 2.7 x $10^4$ Ci/unit |
| (Alpha) | About 4 Ci/unit |
| 6) Density of the solildified contents | About 2.8 g/$cm^3$ |
| 7) Solidified container materials | Z2CN1810 (JIS SUS304L) |

**1) Structural Analysis**

The dimensions, shape, construction, and materials of the hypothetic shipping containers resemble those used in proving tests for spent fuel shipping containers. The calculated values for maximum acceleration and stress at the time of drop impact are considered to be appropriate on the basis of proving test results.

**2) Heat Analysis**

The amount of heat generated per concrete solidified unit is 130 W. Because of the low amount of heat generated, it is possible to hypothesize a rational shipping container.

**3) Seal Tightness Analysis**

**A Summary of the Proposed Concrete Solidified Transport Container**

| | Hypothetic Shipping Container (COGEMA: Full end piece) | Notes (COGEMA acceptance conditions) |
|---|---|---|
| 1) Transport unit type | Type B | — |
| 2) Maximum weight of the shipping container | About 75 tons | — |
| 3) Maximum weight of the transport unit | About 85 tons | 110 tons |
| 4) Outside dimensions of shipping container | Outside diameter: about 2.5 m | Maximum outside diameter: 2.5 m |
| | Total length: about 7.0 m | Maximum height: 7.0 m |
| 5) Principal materials of shipping container | | |
| -main body | Carbon fiber steel | |
| -neutron shielding | — | |
| -cover | stainless steel | |
| -basket | stainless steel | |
| -shock absorbers | wood, stainless steel | |
| 6) Unit capacity | 3 units (3 tiers of 1) | At least 3 |

As a result of their evaluation, the seal tightness of the transport units is considered to adequately satisfy approved leakage standards.

**4) Shielding Analysis**

The dose rates obtained by their calculations satisfy standard values and are considered acceptable on the basis of proving tests for spent fuel shipping containers.

**5) Critical Analysis**

The amount of fissionable material contained in one of the hypothetic shipping containers is thought to exceed 15 grams, and thus they are classified as transport units for fissile materials under present national law. However, because the amount is small, critical safety is considered satisfactory.

The above gives the results of the study into safety concerns and the various items needed to apply transport standards to the transport of waste returned from overseas for reprocessing. However, in the future once the returned waste is actually shipped, methods will become more definite. Correspondingly we will be ready with transport containers. In regards to the actual transport at that stage, safety inspections will be performed under a system of regulation based on related Japanese laws and ordinances, and safety will be enforced and thus guaranteed.



## Natural Analog Research

*43062024 Tokyo GENSHIRYOKU SANGYO SHIMBUN in Japanese 12 Nov 87 p 1*

[Text] The Working-Group leading the Science and Technology Agency's natural analog (phenomena resembling nature) research (chief investigator: Tsuyoshi Amanuma) has decided on a plan in which they will shortly place the Tono Uranium Deposits (Gifu Prefecture) of the Power Reactor and Nuclear Fuel Development Corporation to function as the Natural Analog Research Center. However, starting in 1988 with the participation of the National Research Institute for Metals, their policy will be to promote the broad-based research that has also included the efforts of universities and the private sector.

In order to evaluate the isolation functions and long term stability of natural and man-made barriers for high-level radioactive waste geologic disposal, the working group is studying surveys related to beneficial, similar natural phenomena. Three agencies will join in the actual research: the Power Reactor and Nuclear Fuel Development corporation (PNC), the Japan Atomic Energy Research Institute (JAERI), and the Geological Survey Office.

The division of responsibilities between these agencies will center on the PNC which will perform its research from a system development standpoint. JAERI meanwhile, will establish a database on nuclide shift from the standpoint of ground safety evaluation research.

They also decided that PNC's Tono Uranium Deposits will serve as the Natural Analog Research Center. They have established a policy that the Geological Survey Office and university and private-sector research organizations will also be able to perform research at the center.

Based on their estimated needs for 1988, they will receive a seven percent budget increase over this year, for a total of Y323 million.

The National Research Institute for Metals will join them as a new participant. They are expected to perform corrosion-resistance evaluation studies on man-made barrier materials (especially metallic materials) for geologic disposal.

In addition they also decided that PNC will concentrate on studying the performance of man-made barriers of natural glass, bentonite, metallic materials, etc., and natural barriers at the Tono Uranium Deposits and vicinity.

JAERI will participate in the "International Alligator River Analog Project," a cooperative endeavor of five countries: the United States, Great Britain, Australia, Sweden, and Japan. They will continue their studies based on international cooperation.

The Geological Survey Office plans to continue its geological studies on deep strata isolation at Tono and Ningyotoge.

The Science and Technology Agency is hoping to make the Natural Analog Project into a broad-based endeavor by striving for the active participation of university and private-sector research organizations.



13008/9738

## Function of Japan Fine Ceramics Center Described

*43067010b Tokyo NIKKO MATERIALS in Japanese Sep 87 pp 3-7*

[Excerpt] According to a questionnaire given by the Japan Fine Ceramics Association to 324 companies, Y870.6 billion will be spent on the production of fine ceramic materials this year, a slight increase of 1.5 percent over 1986's Y857.7 billion. Seventy percent of this is made up of IC packages and boards, due to the fact that electromagnetic materials (Y607.2 billion) influenced by the semi-conductor slump, grewonly 1 percent. Looking at the distribution ratio, mechanical materials (grinding tools, combining materials, friction resistance materials, etc.) make up around 12 percent, chemical and medical materials (sensors, catalysts, artificial teeth and bones, etc.) make up about 7 percent, thermal materials (semiconducting thermal jigs, thermal generators, general thermal materials, etc.) come to approximately 6 percent, and optical materials (optical fibers, etc.) come to approximately 5 percent. However, prospects are good for an overall market expansion as it is estimated that the production amount in 1987 will be Y925.1 billion or an estimated 6.3 percent increase over 1986, and furthermore that the amount in 1988 will top Y1 trillion.

Furthermore, MITI predicts that the new materials market consisting of fine ceramics, new metals, and composite materials will be worth Y57.9 trillion by the year 2000, with the fine ceramics market alone growing to approximately Y5 trillion. This surely makes fine ceramics a promising new material.

However, fine ceramics differs from metallic materials in that its crude fabrication, firing, processing technology, and evaluation methods have yet to be firmly established. In fact, only a small portion of fine ceramics' properties is being exploited given limited raw materials and production technology. Fine ceramics in particular has a high fixed structural sensitivity due to fact it is a chemically composed material, and its quality performance is highly influenced by raw material manufacturing conditions and product processing. As a result, its reliability and duplicability is low, great barriers to its actual use.

Thus JFCC was created as an experimental laboratory comparable to none in order to develop the future potential and utility of fine ceramics. It is a national center created with the assistance and cooperation of the Tokyo area financial world, MITI, and scholars, and cheered on by Central Japan's financial world.

### Research Staff of 77

JFCC is constructed on a building site approximately 17,500 $m^2$. To the main steel-gridded five-story testing, research and office-display wing is added a two-story experimental research wing, a warehouse, and so on, for a total floor area of 10,878 $m^2$. Its total operating capital is Y11 billion. It employs 77 staff members including 50 researchers, and its business got underway in April. It carries out a wide variety of functions, such as establishing and standardizing fine ceramics testing and evaluation procedures, training and advising engineers, providing information, promoting small to medium business and communicating internationally.

However, one of the main reasons JFCC was founded was to promote the establishment and standardization of testing and evaluation methods which although crucial to the progress of fine ceramics have nevertheless been lacking until now. Without these standardized methods, fine ceramic has been of inferior reliability compared with metallic and organic high polymeric materials and the efficiency of R&D has been impeded. Unified testing and evaluation methods must therefore be established in order to quantitatively clarify the material properties and performance of fine ceramic and compile a substantial body of basic data. For example, the only test and evaluation methods that come under Japan Industrial Standards thus far are for bending strength and elastic modulus. It is therefore desirable for instantaneous rupture strength tests (tensile strength, torsional strength, shearing strength) and delayed rupture strength tests (fatigue and creep) to be quickly standardized, making the development of these testing methods a major theme for the time being.

R&D linked to expediting the implementation and application of fine ceramics is naturally also an important matter. JFCC has therefore dedicated itself to bridging the gap between basic research done by university and national research institutions, and R&D on actual applications done by corporations. This year JFCC is focusing on: 1) developing techniques for analysis and clarification; 2) developing nondestructive inspections, test evaluations, and endurance testing methods; 3) conducting investigatory research into standardizing test methods; 4) conducting investigatory research into impact fatigue destruction; 5) doing R&D on the manufacture and processes of molding the raw powder material; and 6) doing R&D on high-performance fine ceramic materials.

### JFCC Responsibilities and Tests and Research Accepted

Responsibilities

1. Structural Chemistry

Chemically analyse and clarify the constituents of fine ceramics, measure their chemical and crystal constituents, and research the relation between the foregoing and the physical properties of fine ceramics by observing their microstructures (on the atomic and molecular levels).

2. Functional Materials

Measure the composition and physical properties of fine ceramic electronic, optical, and organic materials. Develop new functional materials and application areas. Research fine ceramic physical characteristics, especially electric characteristics.

3. Structural Characteristics

Research methods for measuring the thermal, mechanical, and chemical characteristics of fine ceramic structural materials and develop a standard measurement method. Also, clarify the breakage characteristics of fine ceramics, accumulate basic data for part design, and establish design standards.

Develop a usable method of measuring the composite thermal, chemical, and mechanical characteristics of fine ceramics, and furnish basic implementation data.

Research a variety of techniques for detecting microdefects in fine ceramics, and establish a measurement method.

4. Manufacturing Technology

Research the synthesis of fine ceramic particles and methods of measuring their characteristics.

Research methods of preparing fine ceramic particles, molding (injection molding, CIP, etc.), and firing techniques (atmospheric firing, hot press, HIP, etc.). Develop new fabrication and firing techniques.

5. Processing and Joining

Research the cutting, grinding, polishing, electrical and chemical processing of formed and fired fine ceramic pieces.

Research methods for joining fine ceramic pieces to metal or to each other.

6. Others

Process information (construct a data base).

Tests and Research Accepted

1. Structural Chemistry

Qualitatively and quantitatively analyse the chemical and mineral constituents of fine ceramics, analyse superficial and internal defects, conduct tests to clarify the microstructures of fired pieces. Through the above, illuminate problems in fine ceramic manufacture and design.

2. Functional Materials

Develop fuel cells such as a fixed electrolytic fuel cell.

Develop new functional materials.

Carry out tests on the characteristics of fine ceramic electronic materials.

3. Structural Characteristics

Measure the thermal, mechanical, and chemical characteristics of fine ceramics. Compile test equipment, test jig, and test piece standards. Develop standard testing methods.

Develop and carry out fine ceramic composite characteristic tests and a variety of rig test methods.

Develop a nondestructive fine ceramic inspection system. Compile a standard measurement manual for every type of material and shape. Compile standards on test pieces for nondestructive inspections.

4. Manufacturing Technology

Carry out tests to measure the characteristics of fine ceramic particle materials.

Carry out every type of fine ceramic molding and firing test.

Develop a very tough fine ceramic.

5. Processing and Joining

Conduct tests on fine ceramic cutting and polishing tests.

Develop methods for quickly processing fine ceramics.

**Superconducting Materials Also Researched**

The center is also involved with research on superconducting materials. A special team has been formed from various functional materials groups to approach these promising materials by testing and evaluating their characteristics, chemical composition, and analysing and clarifying their microstructures. This research may yield a new solution to the struggle over high temperatures with fiber optics.

In addition to running their own research projects, the center must also accept R&D tasks from the outside. In 1987, it has been commissioned to conduct 11 different research projects from around the country on such themes as advanced processing systems. In order to facilitate such work, the center has established a private contract development department. The fact that the center is accepting tasks which require long-term R&D and highly reliable analysis and evaluation by an outside public institution means that the center's work necessarily must encompass a wide spectrum of tests and inspections from test method standardization, nondestructive inspection methods, research into ion conductive elements, and development of very tough fine ceramic materials.

Another important theme of JFCC is fostering small to medium-sized businesses. It is fairly easy for small to medium-sized businesses to go into fine ceramics because they are originally a knowledge-intensive, large-variety, small-production product. JFCC therefore not only provides a consultant to answer every kind of question businesspeople might have, it also is active nationwide in the clarification and dissemination of fine ceramics, offering technical advice and conducting workshops. The center engages in every aspect of the support of small to medium-sized businesses, even holding lectures and opening study groups to introduce new technology and basic topics. In 1987, the center even began a supporting membership system. This system allows members wide access to test research facilities and research results. In the future, JFCC plans to build a nationwide network with these members. Finally, the center is committed to the vigorous promotion of international exchange, including the presentation of international conferences, invitations to foreign researchers, and seminars by foreign instructors.

### Most Advanced Equipment Installed

Incidentally, JFCC is installing the most advanced equipment in order to carry out its many sophisticated tests and R&D tasks. To meet the demand for high performance, quality fine ceramics, for instance, the following equipment had to be introduced: high frequency plasma mass spectrometer equipment to conduct highly sensitive elemental analyses and comparative isotopic analyses; a hi-tech analysis meter for nitrogenous, oxide, and carbide compounds; a transparent electronic microscope capable of magnification up to 80 thousand times for clarifying structures and analysing elements in the microscopic realm; an electronic microanalyser capable of video processing; and high temperature X-ray diffraction equipment.

Because it is crucial that ceramics used in structures have high temperature characteristics, the center has installed equipment that can measure bending strength and dynamic elasticity at up to 1,500 degrees C. It also has equipment such as tools for measuring hardness such as microviscosity, and general-purpose high temperature precision material testers for measuring high temperature torsional and bending strength. The center even has a microscope for nondestructive inspections that uses supersonic waves for internal observation and defect detection.

For evaluating electromagnetic functions, there is equipment that can measure the insulation, conductivity, dielectricity, and piezoelectricity of functional ceramics. In addition, the center has installed a meter that decants and optically correlates particle distribution and equipment for measuring comparative surface area for work involving particle body characteristics and manufacturing processes. Finally, the center has obtained a cold and hot hydrostatic pressure press, an injection molder able to mold 220 t, and a high temperature atmospheric reactor.

The amount invested in these 86 high-tech machine models was approximately Y1 billion. An additional Y800 million will be spent in 1987 and Y200 million in 1988, for a total initial investment of Y2 billion to fully equip the center.

Thus JFCC has established its main branch in Central Japan, where there is a great concentration of fine ceramic technology, and begun operating with gusto. Because of its comprehensive contribution to testing, R&D, and implementation, Japan's ceramic industry has taken a major step forward.

**Equipment Introduced to the Center**

| Function | Equipment Name | Manufacturer |
|---|---|---|
| Element analysis | Hi-frequency light emission analysing equipment (ICP) | Nihon Jarrell Ash |
| | ICP-mass spectrometer (ICP-MS) | VG-Isotope |
| | Nitrogen and oxygen analysis meter | Horiba, Ltd. |
| | Carbon analysis meter | Horiba, Ltd. |
| | Gas chromato graph | Hitachi, Ltd. |
| Structural analysis | Transparent electronic microscope (TEM) | Nihon Denshi |
| | Scanning electronic microscope (SEM) | Hitachi, Ltd. |
| | Scanning electronic microscope (SEM) | Hitachi, Ltd. |
| | Electron beam microanalyser | Nihon Denshi |
| | Hi-temperature X-ray diffraction equipment | Phillips |
| | Photoelectronic spectral equipment | VG-Scientific |
| | Light spectrometer | Hitachi, Ltd. |
| | Metal microscope | Nippon Kogaku |
| Thermal characteristics | Differential heat scale, heat expansion meter | Rigaku |
| | Heat constant measurement equipment | Rigaku |
| Particle characteristics | Decanting type particle distribution measurement equipment | Shimadzu Corp. |

**Equipment Introduced to the Center**

| Function | Equipment Name | Manufacturer |
|---|---|---|
| | Optical correlating particle distribution measurement equipment | Malburn |
| | Comparative surface area measurement equipment | Yuasa Ionics |
| | Powder tester | Hosokawa Micron |
| Electric characteristics | Resistivity measurement equipment | Rigaku |
| | Network analyser | YHP |
| | Spectrum analyser | YHP |
| | Piezoelectric and dielectric strength measurement equipment | YHP and others |
| | Electrode creator | Nihon Vacuum Technology |
| | Electric meter | Yokogawa Elec. Corp. |
| | Oscilloscopes (three) | Sony Tectronics & others |
| Mechanical characteristics | High-temperature all-purpose precision material tester | Instlon |
| | Normal temperature all-purpose strength tester | Shimadzu Corp. |
| | Vickers hardness meter | Matsuzawa Precision Tools |
| | Microvickers hardness meter | Matsuzawa Precision Tools |
| | Rockwell hardness meter | Matsuzawa Precision Tools |
| | High-temperature dynamic elasticity meter | Motoyama & others |
| | Roughness meter | Lank Taylor Hobson |
| Nondestructive testing | Supersonic wave microscope | Hitachi, Ltd. |
| | Micro-focus X-ray transparent viewing system | Rigaku |
| Material preparation | Potmill | Makino Ironworks |
| | Fine particle grinder | Ashizawa Ironworks |
| | Explosion-proof drier | Chuo Chemical Industrial Machinery |
| | Spray drier | Nippon Sharyo Seizo |
| Press molding | Cold hydrostatic pressure press | Kobe Steel, Ltd. |
| | Metal press molder (20 t) | Riken Kagaku |
| Injection molding | Pressure kneader | Toshin |
| | Lab plasto-mill | Toyo Seiki Seisakusho |
| | Two axle bent extruder | Nakatani Machines |
| | Injection molder | Japan Steel Works, Ltd. |
| | Sheet roller | Ohta Precision Industries |
| | Pelletizer | Ohta Precision Industries |
| | Pressurized oil removal furnaces (two) | Tokai Konetsu |
| Furnaces | High-temperature atmospheric furnace | Fuji Denpa Industries |
| | Hot press | Fuji Denpa Industries |
| | Hot hydrostatic pressure press | Kobe Steel, Ltd. |
| | Super kanthal furnace | Tokai Konetsu |
| | Super kanthal furnace | Chugai Engineering |
| | SiC generator furnace | Tokai Konetsu |
| | SiC tube furnace | (Nemusu) |
| Processing machinery | Slicing machine | Multo [phonetic] |
| | Flat grinder | Amada Co., Ltd. |
| | All-purpose tool grinding board | Matuzawa, Ltd. |
| | Lathe | Mori Precision Machinery |
| | Piezoelectric tool dynamism meter | Kissler |
| | Miller | Amada Co., Ltd. |
| | Flat polishers (four) | Multo |
| | Curved grinder | Toyoda Machine Works, Ltd. |
| | Supersonic wave processor | Nihon Denshi Kogyo |
| | Precision cutting machine | Kuroda Precision Industries |
| | Other measurement tools | |
| Others | Scales (15) | Mettler [phonetic] |
| | Driers (11) | Tarvis Peck |
| | Clean benches (3) | Hitachi, Ltd. |

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## Report on New Functional Rare Metal by S&T Agency

*43067010a Tokyo NIKKO MATERIALS in Japanese Sep 87 pp 42-43*

[Text] The Science and Technology Agency has now completed its "Investigatory Report Into Basic Techniques for Creating New Functional Rare Metals Through Purification." Rare metals and their compounds are of great interest as high-tech materials, but Japan has almost no rare metal resources. This and the fact that rare metals must be made extremely pure in order to give them new functions led the S&T Agency to conduct its study of 55 types of metals, including high-purification techniques and accompanying ultramicro-analytic technology, the feasibility of creating new functions, and the future direction of R&D. Rare metals are becoming even more significant for applications such as super conducting materials.

The report is enormous, consisting of 374 pages of size B4 paper. It can be broadly divided into the four areas of "Techniques for the high-purification of rare metals and their compounds," "Techniques for the analysis of micro-impurities in rare metals," "The creation of new functions using highly purified rare metals," and "A standardized data base and standard properties."

The S&T Agency intends to use this report to draw up concrete plans for a 3-year research project that will begin this year on basic techniques for creating new functions using highly purified rare metals.

What follows is a description of the new functions and their benefits, as well as the probable research topics, that the purification of rare metals is expected to yield for four functional material fields (see classification chart).

**The High-Purification of Superconducting Materials (Electronic Materials)**

- By highly purifying ULSI-related materials, not only could they be used as super high-integrated materials 16 megabit DRAMs, 64 megabit DRAMs, and above, but the most advanced, high-speed, and reliable semi-conducting device could be achieved.

ULSI-related research topics are creating a more sophisticated metal sputtering target with a high melting point and developing microanalytic techniques for 0.01ppbc-level radioactive elements.

- The purification of III-V group compound semi-conducting materials is expected to achieve a high-temperature semi-conductor and a high-speed device using a good quality highly resistant substrate for ICs.

III-V group research topics include highly purifying compound semi-conductors for ICs and controlling defects, fabricating a very pure, highly semi-conducting thin film, and using purity control to grow semi-conducting boron crystals.

- Highly purifying II-VI compound semi-conducting materials would make it possible to control conductivity and achieve short-wave long light emission using pn junction device.

Research topics with II-VI materials include the control of conductivity in a highly-pure V-VI group compound semi-conductor.

- Highly purifying semi-conducting super lattice materials would mean the successful creation of new functions such as new magnetic structures using rare earth super lattices and semi-conducting lasers and super high-speed lattices using a quantum-well effect.

A related research topic is the fabrication of a semi-conducting super lattice.

- A very pure conducting material would clarify the structure of super conductors and make possible the high critical temperatures using Exciton and (Frielich) type super conductors.

The research topics in this area are the development of a super semi-conductor with a high critical temperature, a substance that stably controls lattices, and a high temperature super-conductor.

**Laser Applications (Optical Materials)**

- The purification of optical crystal materials is linked to great reductions in absorption loss and optical damage and the achievement of a high-output laser, and is also expected to lead to the successful fabrication of a temperature compensating optical element crystal through the addition of elements.

The related research topics are: growing a crystal for large-output fixed lasers, fabricating an optical element crystal that compensates for temperature, and developing a highly reliable electro-magnetic optical crystal.

**Research Categories and the Functions Hoped for in Each of the Four Areas of Investigation**

| Areas | Research | Functions/Effect |
|---|---|---|
| Electronic functions | LSI-related materials | -super high integration, speed |
| | | -radiation resistance |
| | III-V series compound semi-conductors | -high-temp operation |
| | | -high speed |
| | II-VI series compound semi-conductors | -short-wave, long light emission |
| | super lattices | -non-axial electro-conductivity |
| | | -quantum-well effect |
| | super conductors | -high critical temperature |
| | | -(Frielich) type super conductor |
| Optical functions | optical crystals | -temperature compensation |
| | | -large output |
| | compound optical fiber | -super low optical loss |
| Magnetic functions | rare earth magnets | -high coercive force |

**Research Categories and the Functions Hoped for in Each of the Four Areas of Investigation**

| | | |
|---|---|---|
| | | -corrosion resistance |
| | high-density memory | -high density |
| | magnetic f-electron compound | -high-temp magnetic refrigeration |
| | | -valence fluctuation |
| Other functions | catalysts | -new catalytic actions |
| | | -long life |
| | | -high activity |
| | nuclear reactors | -heat and radiation resistance |
| | shape memory alloys | -corrosion resistance |
| | | -high energy storage |
| | hydrogen absorption and storage alloy | -longer and more storage capabilities |

- A very pure compound optical fiber material would make it possible to lower transmission loss to theoretical boundaries and pave the way for long-distance intercontinental optical transmission.

Related areas of research are creating various compound fibers with extremely low loss using fluoride glass and halide crystals.

### Purification of Rare Earth Magnetic Materials (Magnetic Materials)

- Highly pure rare earth magnetic materials would improve corrosion resistance and yield good coercive strength.

Research needs to be done on lowering the oxidation of rare earth magnets.

- Purifying high density memory materials would improve the corrosion resistance of optical magnet memories, vertical magnetic recording medium, and bluff-line memories as well as reduce bit defect and achieve ultra-high density.

Related research includes improving corrosion resistance by highly purifying optical magnet memory sputtering target, making a low-defect magnetic garnet single-crystal thin film for bluff-line memories, and micro-structuring and chrome segregating cobalt chloro-vertical magnetic recording medium.

- Highly purifying f-electron (lanthanide series rare metal) compound magnetic materials would promote the development of high temperature magnetic refrigeration materials as well as the analyses of the basic properties of heavy fermium and valence fluctuation.

Research in this area centers on creating very pure rare earth metals and analysing the latest properties, developing amorphous magnetic materials, and developing magnetostrictive materials.

### Applications to Catalysts Also Promising (Other Functional Materials)

- Highly purifying catalytic materials would make it possible to clarify the mechanism of catalytic actions, and is expected to yield a longer-lived and more active new catalytic actions.

Research topics include clarifying catalytic mechanisms, developing technology for designing catalysts, creating a database, developing alternative techniques for platinum and rhodium, and prolonging the life of catalysts.

If a highly pure nuclear fusion reactor material could be developed, reactor wall loss from high temperature plasma and radiation-caused segregation could be prevented, and a reduction in long-lived residual radiactivity could be achieved.

Research here hinges on the development of a highly pure fusion reactor material.

- Very pure shape memory alloys would yield bio compatible devices through the improvement of corrosion resistance, with the possibility of storing mechanical energy as well.

Research must be done on improving the characteristics of shape memory alloys through purification and developing an energy storage system.

- If a hydrogen absorption and storage alloy material could be made very pure, it could be made to last longer and store more efficiently.

Research here involves improving the performance of 4f (lanthanide series rare metal) hydrogen absorbant and preserving alloys.

### Five Important Research Topics

The foregoing topics can be narrowed down to five major research issues. These are: 1) research on electronic materials made of 4f metallic compounds (developing a superconductor with a high superconducting critical temperature); 2) research on magnetic materials made of 4f metallic compounds (developing amorphous magnetic action materials); 3) R&D on optical materials made of 4f metallic compounds (greatly lowering the optical loss of fluoride glass fibers); 4) R&D on transition metallic compound catalysts; and 5) developing of semimetallic high temperature semi-conducting materials.

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