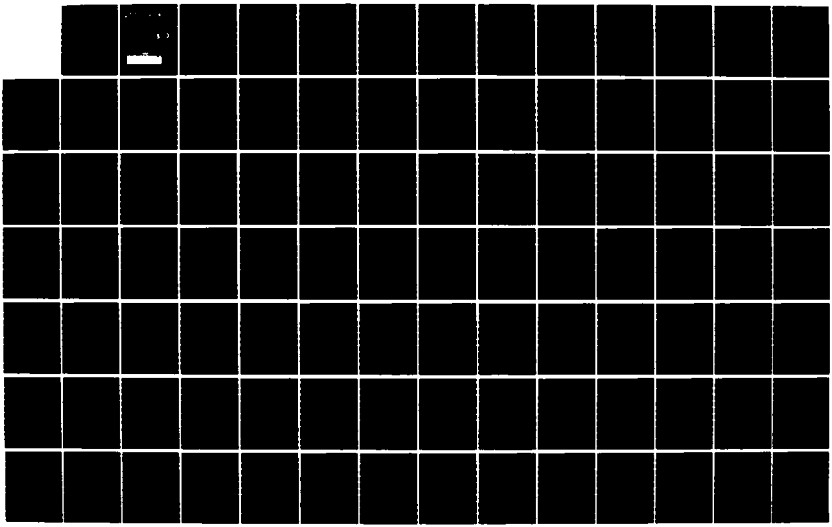
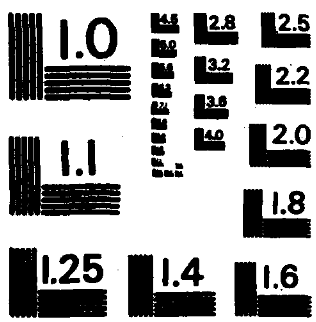
AD-A162 667 ONR (OFFICE OF NAVAL RESEARCH) FAR EAST SCIENTIFIC BULLETIN VOLUME 10 NUM..(U) OFFICE OF NAVAL RESEARCH LIAISON OFFICE FAR EAST APO SAN FRAN.. N A BOND ET AL. JUN 85

1/2

UNCLASSIFIED F/G 5/2 NL





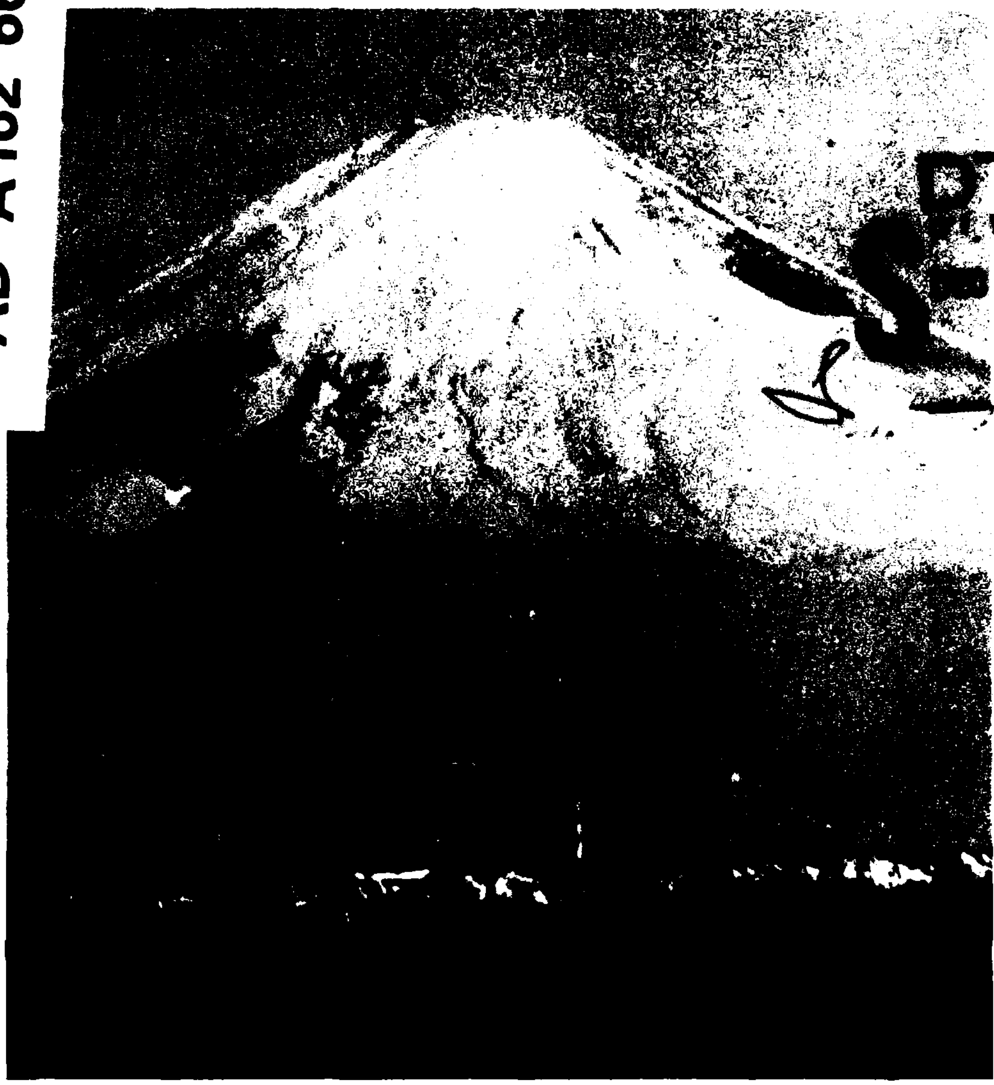
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APRIL TO JUNE 1985 VOL. 10, NO. 2

(72)

SCIENTIFIC BULLETIN

DEPARTMENT OF THE NAVY OFFICE OF NAVAL RESEARCH FAR EAST
DEPARTMENT OF THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH FAR EAST



85

NAVSO P-3580

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD-A162 667

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
APPROVED FOR PUBLIC RELEASE:
DISTRIBUTION UNLIMITED

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
ONRFE Vol 10, No 2

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
Office of Naval Research/Air Force Office of Scientific Res

6b. OFFICE SYMBOL (If applicable)

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS (City, State, and ZIP Code)
Liaison Office, Far East
APO San Francisco 96503-0007

7b. ADDRESS (City, State, and ZIP Code)

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL (If applicable)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State, and ZIP Code)

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

11. TITLE (Include Security Classification)
ONR FAR EAST SCIENTIFIC BULLETIN

12. PERSONAL AUTHOR(S)
Nicholas A. Bond, Jr., Director; Mary Lou Moore, Editor

13a. TYPE OF REPORT

13b. TIME COVERED FROM ______ TO ______

14. DATE OF REPORT (Year, Month, Day) April-June 1985

15. PAGE COUNT

16. SUPPLEMENTARY NOTATION
ISSN: 0271-7077

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Biotechnology, Enzymes, Shipbuilding, Japan, Biomass, Republic of Korea, Amino acids, Pharmaceuticals, Shipyards

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This is a quarterly publication presenting articles covering recent developments in Far Eastern (particularly Japanese) scientific research. It is hoped that these reports (which do not constitute part of the scientific literature) will prove to be of value to scientists by providing items of interest well in advance of the usual scientific publications. The articles are written primarily by members of the staff of ONR Far East and the Air Force Office of Scientific Research with certain reports also being contributed by visiting state-side scientists. Occasionally, a regional scientist will be invited to submit an article covering his own work, considered to be of special interest.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION

22a. NAME OF RESPONSIBLE INDIVIDUAL

22b. TELEPHONE (Include Area Code)

22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

18. Subject Terms (Key Words) continued

Ship research centers
Offshore structures
Electroslag technology
Welding process
Casting
Japan
Overlay process
Computers and communication
Electronic materials
Software
Optoelectronics
Software
NEC Corporation
Superlattice devices
Basic technologies
New materials
Future electron devices
Three-dimensional ICs
Physiological sciences
Republic of Korea
Environmental physiology
Muscle physiology
Diving physiology
Biomedical research
Malaysia
Thailand
Molecular genetics
Genetic engineering
VLSI technology
Three-dimensional integrated circuits
Japan
Microelectronics
Pulsed power research
Stored energy
Japan
Microsecond technology
Microbiological research
Universiti Sains Malaysia
Infectious diseases
Microbiology
Australia
High technology
Microsurgery
Biomedical technology
Manufacturing base
Cryogenic steels
Superconducting magnets
Structural application
Japan
Cooperative research
Corrosion
Steel
Japan
Corrosion resistance
Magnetics
Permanent magnets
Rare-earth compounds
Research
Laboratories
Japan
Korean Physical Society
Particle physics
Solid state physics
Quantum electrodynamics
Acoustics
Inertial confinement fusion (ICF)
Laser particle beams
Deuterium-tritium target
Miniature nuclear explosion
ICF research
Japan

CONTRIBUTORS

Nicholas A. Bond, Jr., from May 1984 until August 1985, the director of ONR Far East, is an engineering psychologist at the California State University at Sacramento. Dr. Bond's main interests are in man-machine interface, decision aiding, and the maintenance of complex systems by humans. He is a fellow of the American Psychological Association.

Kimiko O. Bowman is a mathematical statistician and was born in Tokyo, Japan, but received her Ph.D. degree in statistics from the Virginia Polytechnic Institute. Dr. Bowman is on the staff of the Engineering, Physics and Mathematics Division of the Oak Ridge National Laboratory in Oak Ridge, Tennessee. Dr. Bowman's research interest lies in statistical research using high speed computing and estimating parameters.

Thomas W. Eagar, recently a liaison scientist with ONR Far East, is an associate professor of materials engineering at the Massachusetts Institute of Technology. Dr. Eagar's professional interests are broadly in manufacturing processes for metals and ceramics with more specific interest in welding and joining technology.

C. D. Graham, Jr., is professor of materials science and engineering at the University of Pennsylvania. His research interests are in magnetic materials and magnetic measurements. In 1961, while an employee of the General Electric Research Laboratory, he spent a year as a Guggenheim fellow at the Institute for Solid State Physics of the University of Tokyo, and in the spring of 1985 spent five months working in the Masumoto amorphous materials project of the Research Development Corporation of Japan, at the Laboratory for Electric and Magnetic Alloys in Sendai.

P. F. Iampietro, a physiologist, was recently on the scientific staff of the Air Force Office of Scientific Research, Far East. Previously he directed the Air Force basic research program in the life sciences. His scientific interests include environmental physiology and a more recent interest in membrane phenomena. Dr. Iampietro is a member of the American Physiological Society.

Magne Kristiansen was born in Elverum, Norway, and received his Ph.D. degree in electrical engineering from the University of Texas in 1967. Dr. Kristiansen is currently the P.W. Horn Professor of Electrical Engineering at the Texas Tech University, Lubbock, Texas. His current research interests lie in plasma dynamics, pulsed power technology, and physical electronics.

Clifford G. Lau is a scientific officer at the Office of Naval Research Pasadena Detachment, Pasadena, California. Dr. Lau's research interests lie in electronic circuits; more specifically, integrated circuits, VLSI technology, and microelectronics.

Sung M. Lee is professor of physics and also director of the Keweenaw Research Center of the Michigan Technological University in Houghton, Michigan. Dr. Lee received his Ph.D degree from Ohio State University in 1965. Dr. Lee was a NATO Senior Fellow in 1974 and his research interests include infrared optics, acoustics, and applied physics.

Herman W. Lewis is deputy director of the Division of Molecular Science at the National Science Foundation in Washington, D. C. Dr. Lewis' research interests lie in biochemical, physiological, and molecular genetics; biophysics and cytology of genetic material; and human cell biology. Dr. Lewis recently spent a three-month period in Tokyo with the Office of Naval Research, Far East, as a liaison scientist. Dr. Lewis is a member of the Genetics Society of America and the American Biophysics Society.

E. McCafferty is head of the surface protection section at the Naval Research Laboratory in Washington, D. C., and a professional lecturer at George Washington University. His research interests include corrosion inhibition, localized corrosion and surface modification by laser processing and ion implantation. Dr. McCafferty is currently chairman of the Corrosion Division of the Electrochemical Society and has been a scientific officer at the Office of Naval Research, Arlington, Virginia.

Harry I. McHenry, recently a liaison scientist with ONR Far East, is now with the National Bureau of Standards in Boulder, Colorado. He received his Ph.D. from Lehigh University in 1970. Dr. McHenry's principal duties are to conduct fracture mechanics research relating to the structural safety of ships, pipelines, offshore structures, and cryogenic systems. Prior to going to NBS in 1974, Dr. McHenry served as a project structures engineer for General Dynamics Corporation (1963-1974), where he applied fracture mechanics to the design and evaluation of aircraft structures.

Yoon Soo Park is currently a senior scientist with the Air Force Office of Scientific Research, Far East. Prior to his assignment in Japan in September 1983, Dr. Park was a task manager and research physicist at the Avionics Laboratory, Air Force Wright Aeronautical Laboratories. His research interests lie in the areas of solid state physics, electronic materials and devices. Dr. Park is a fellow of the American Physical Society and a senior member of IEEE.

M. Frank Rose is currently a senior research physicist in the Electronic Systems Department of the Naval Surface Weapons Center, Dahlgren, Virginia. Dr. Rose received his Ph.D. degree in solid state physics from Pennsylvania State University in 1966. Dr. Rose's current research interests are in pulse power technology, advanced energy conversion, and high power fast switch technology.

Yuko Ushino, a technical information specialist for ONR Far East, was born in Kyushu prefecture, Japan, but attended secondary schools in San Francisco and received a bachelor of science degree from Brigham Young University at Provo, Utah. Her special interests lie in information processing from complex data bases, computer science, information production methods, and cultural comparisons between education systems.

Partial

CONTENTS

Cover: Mt. Fuji, or simply known as Fujisan in Japan, at 3776 meters is the highest mountain in Japan. Fujisan has been dormant since 1707; however, it is classified by geologists as an active volcano. Fujisan's summit is a crater of about 500 meters with a depth of about 250 meters. Mt. Fuji is actually a composite volcanc formed by three separate volcanoes known as Komitake, Ko Juji, and Shin Fuji. Shin Fuji is the most recent beginning its activity 10,000 years ago. Mt. Fuji is now climbed for pleasure but it originally started as a religious practice. Fritz Stahr contributes this photograph of Fujisan taken on a clear day in December from Morito Beach which is near the town of Hayama on the Shonan Coast of Sagami Bay. The *torii* and the sailboats reiterate Japan's relationship with the traditional and the modern.

MACHINE TRANSLATION RESEARCH AT KYOTO UNIVERSITY

Japan has several computerized translation projects, and these vary widely with respect to their proximity to practical application. Fujitsu is now demonstrating the Atlas system, which translates English, French, and German into Japanese; it is being shown at the Tsukuba Science Expo. The Atlas standard input is news service stories. Toshiba has a medium-priced English-to-Japanese configuration which is near the marketing stage; English words that it cannot handle are "left in English" on the terminal screen, for an operator to interpret or to disambiguate. In one of the lowest-priced machines, the "Brother" translator has a dictionary of several thousand words, and can perform English-to-Japanese translation of ordinary declarative statements. Commercial economics and market data will soon be offered in six languages, with machine translation from the Japanese. Under favorable conditions, all these machines can produce some acceptable output; but they all fail when faced with complex material, and certainly none can yet "stand alone."

At Kyoto University, Toyoaki Nishida is experimenting with one of the more interesting translation systems in Japan. Nishida's ultimate goal is practical English-to-Japanese translation of scientific and technical material, such as hardware and software manuals. The approach is semantic, so that groups of words are analyzed, not just single words. Nishida spent a year at Yale University, so his program incorporates some of the ideas now current in American linguistics. When an input sentence is presented, the parser attemps to identify subject, verb, and verb usage; some sentences may have many different ways of interpretation, and these alternatives are explored through "branches" at the points of ambiguity. When a human operator resolves one ambiguity, the program moves on until it encounters another ambiguity; and so on. When the program reaches the state where all ambiguities are satisfied, the final translation is printed out, in Japanese. The flowchart for a typical simple translation is shown in Figure 1.

Nishida's program is a large one; it runs on the university's M382 FACOM computer, and is written in UTILISP (University of Tokyo version of interactive LISP). There are three "levels" of kanji vocabulary, with about 3000 and 6000 kanji in the first two levels. The program needs four megabytes of memory. A remarkable thing about the present interface mode is that the user person does not necessarily need to know the Japanese language to resolve the ambiguities; this feature is expected to be very important for real world practical translations.

A large sample of sentences, over a hundred, has been assembled to explore the adequacy of the program. A native Japanese observer, seeing the Japanese output, would probably agree that the translation of direct declaratives is quite adequate, say for an equipment description in a tech manual. As would be expected, the more complex the input English sentence, the less satisfactory the Japanese output. Since Nishida has so many examples, one can get a realistic impression of the program's capability by feeding in English sentences of increasing complexity.

Though the Kyoto program is still far from routine commercial use, it already shows that a semantic scheme can yield interesting output; and perhaps Nishida's intensive exploration of sentences at all levels of complexity will yield some very valuable data on "what cannot be done" with such programs. That knowledge may, in turn, specify what kinds of input will be most acceptable for machine translation in the near future rather than seeking an "ultimate" machine. The Japanese prefer to develop systems that will accomplish useful processing in some more-or-less restricted domains.

Kimiko Bowman
Oak Ridge National Laboratory

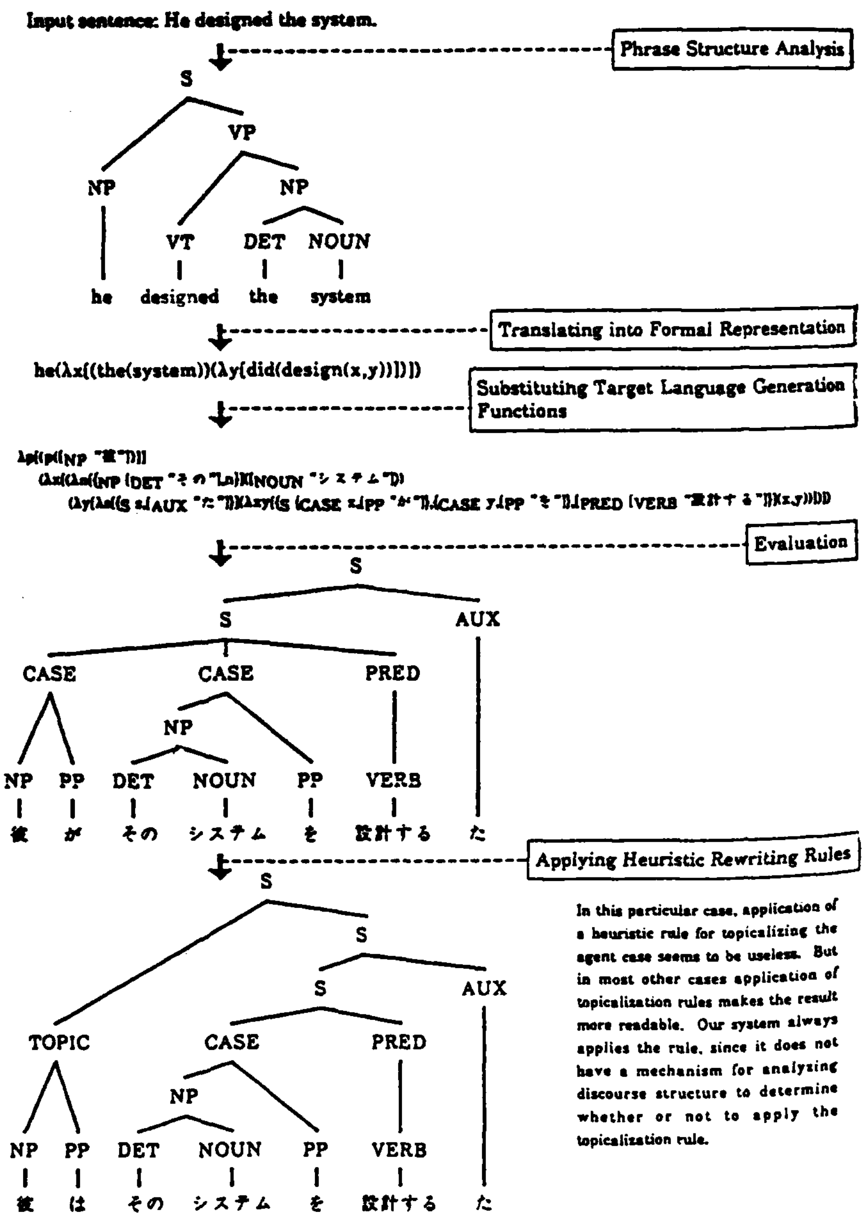


Figure 1. Sketch Description of Translation Process

JAPANESE INITIATIVES ON NEW MATERIALS

In March 1985, the Basic New Materials Office of the Japanese Ministry of International Trade and Industry (MITI) announced the creation of a Center for Research on Fundamental Technology. MITI estimates that new materials will constitute a $40 billion industry by the year 2000. In order to facilitate research in these areas, the new center will finance up to 70% of the R&D on specific new materials whenever two or more companies form a partnership for such work. For single firms, the government will provide interest-free loans which are repayable at 7 to 8% interest if the venture is successful.

This new center is capitalized with $50 million with 50% coming from the government, 25% coming from the Japan Development Bank and 25% from the private sector. It is proposed that several national laws will be changed so that private companies can use facilities available at national laboratories. The initial program includes the establishment of two new testing and evaluation centers on fine ceramics and new metallic materials in order to accelerate the introduction of these new materials in commercial codes and standards.

In addition, as further inducement to production of new materials, biotechnology, and electronics, the government will provide a special 7% corporate tax credit for investment in production, processing, analyzing, experimenting or controlling of such new materials. This will increase the maximum deduction for such investment to 15%.

Other subsidized private research programs include $1.3 million for powder metallurgy aluminum alloys, shape memory alloys, and high performance and conductive polymers. There is also a $14 million subsidy program on oxygen enrichment membrane technology and a similar cost program on ceramic coatings for high temperature and corrosion resistant metals. These programs are concurrent with the seven national projects on Basic Materials for Future Industries as listed in the table below. It is hoped that the eighth and ninth projects will be added in the next few years. It should be noted that these governmental research budgets are often only 20 to 30% of the total program once the private sector contributions to these programs are added.

PROGRAM	FISCAL 1985 BUDGET $ Million	CUMULATIVE 1981-84 BUDGET, $ Million
Fine ceramics	3.8	11.0
Membrane technology	2.2	7.0
Conductive polymers	1.5	4.0
High performance polymers	1.2	4.0
Microcrystalline alloys	2.4	7.2
Composites	2.9	8.0
Photoreactive materials	0.3	--*

*Project initiated in 1985

Thomas W. Eagar
ONRFE/AFOSRFE

TSUKUBA--SCIENCE EXPO AND SCIENCE CITY

Nearly every foreign visitor to Tsukuba makes two standard comments. The first one is about the accessibility of the place: though only 40 miles from downtown Tokyo, at least two train lines and one bus or taxi usually have to be negotiated, and even with special Science Expo buses in the summer of 1985 it was a hassle to get there. A second frequently-heard remark addresses the relative dullness of the city of Tsukuba itself; compared to Tokyo, the area is drab and uninteresting.

With Science Expo '85 drawing at least a hundred thousand visitors a day, the summer crowds gave a bustling and populist flavor to Tsukuba. But when Expo closed in September, the crowds vanished and the original idea of a gigantic Science City at Tsukuba once more became the focus.

The original hope was that, in a relatively roomy area, not too far from Tokyo, a critical mass of scientific facilities and research people could be assembled "from scratch," and could quickly attain R&D eminence. This original Science City would be the model for others, perhaps even dozens of others, in the Japan of the 21st century. Much of the physical plant is impressive, and there is no doubt that some of the finest laboratories in Japan have been constructed at Tsukuba: at least two of them (Electrotechnical Laboratory and Electromechanical Laboratory) are already known and respected all over the world.

There are problems with Tsukuba, though, of a more subtle sort. For one thing, it has turned out that many Japanese scientists simply do not want to live on a roomy flat flood plain; they prefer the stimulation of a metropolis, despite all the big-city crowding and inconvenience. This means that, for a surprising fraction of the scientific and technical staff, Tsukuba is a place where you go to work, and it is not a place where you live. And so it is also not a place where one finds the bookstores, theatres, concert halls, galleries, and "intellectual coffee houses" ordinarily associated with academic tradition. As far as one can tell, there are no "academic heroes" in Tsukuba, as there are at Cambridge or Paris or Princeton. Apparently, you can not rapidly engineer a creative academic environment, in the same way that you can build an industrial plant or laboratory center.

Another concern is the comparative lack of international exchange of professionals in the Tsukuba laboratories. Since much of Tsukuba science is government funded, some of the controlling Tokyo bureaucracies may have discouraged open scientific communication across countries. One finds very few long-time foreign resident scientists at Tsukuba, although there are innumerable short-term visitors. And visiting scientists, when they do come to Tsukuba, often do not relish the miles of brand-new buildings and the straight boulevards without a single area that "feels academic" and congenial. In fact, along with the Tsukuba scientists themselves, most visitors escape to Tokyo at the first opportunity. Reportedly, all foreign lecturers at Tsukuba University have been discharged; for some time, the foreign faculty have been "under the gun."

Tsukuba Science City, then, is probably best viewed as a continuing and only partly successful project. Its merits can be seen from an airplane: gleaming new facilities and plenty of room to grow. But its planners seem to have ignored much of the history and sociology of science and they have adopted a "project" stance toward Tsukuba Science City. There is no doubt that under unusual conditions, great things can be programmed and accomplished in a project format. The Manhattan project, Polaris, Nautilus, and the NASA space series are American examples; in Japan, the remarkable Toyota, MAZAK, and FANUC manufacturing facilities have been built in remote areas of the country, and are successful. But such project successes had a rather firm scientific base before the projects began; thus no profound new discoveries were required, and the basic accomplishments were then mainly in the coordination of extremely complex technologies. When real innovation is demanded, though, something more may be needed, and so far there seems to be no substitute for the Western academic atmosphere. Thus, it is significant that the most prestigious and most productive Japanese universities resemble European and American campuses so closely; in fact, both Tokyo and Kyoto universities feel very much like the scenes at Ann Arbor, MIT, or Bloomington. (Many American visitors are surprised at the genteel shabbiness of the buildings at Kyoto and Tokyo; you stay in a gleaming new hotel a few blocks away, and then you find peeling paint, battered doors, and dusty laboratories on the campus itself. But you also find there some of the best scientists in the country.)

It is possible that Tsukuba Science City will reach the levels of achievement which the planners had in mind. Perhaps more likely, the Tsukuba complex will keep going about as it now does--a big new scientific complex just on the edge of excellence, and one that is seeking to develop its own local institutions and atmospheres to break out of the "project" mold.

Nicholas A. Bond, Jr.
ONRFE/AFOSRFE

PUPILLARY MEASUREMENT AND COGNITION

About twenty years ago, Eckhard Hess (1965) observed that widening or narrowing of the pupils could indicate emotional arousal or attitude. Thus, men's pupils usually widen when a female pinup picture is shown, whereas women's pupils tended to widen when shown male pinups and pictures of babies. These response patterns are not universal, however; and there are many factors that influence the physiological output. Consequently, the original Hess observations have been difficult to confirm and most psychologists do not trust the method as a reliable indicator (Woodmansee, 1970).

At the Tokyo Institute of Technology, Yasutaka Shimizu has a new pupillary-measurement setup, and is now reexamining the possibilities. Cameras are built into goggle-type glasses, and images of the pupils are measured 30 times a second, fed into a computer, and displayed in a terminal. Hard copy records also furnish a large data base.

Shimizu has shown the feasibility of the new measurement method on a sample of undergraduates. Besides the usual "pinup responses," he has also been exploring the method's suitability as an aid in school learning. If "interest" is correlated with pupillary expansion, then "interesting" factors can be determined experimentally. One example is that when gradeschool students are asked to find a hidden dog in a complex scene, significant widening occurs over that shown in the original observation of the scene. Another interesting set of correlations may be found in the "lie detector" kinds of situations. It already appears that a joint index of "emotional response" based on both skin resistance and pupillary reaction has more retest reliability than does either index alone.

REFERENCES

"Attitude and Pupil Size," by E. H. Hess. *Scientific American*, February 1965.

"The Pupil Response as a Measure of Social Attitudes." In G. F. Summers (Ed.), *Attitude Measurement*, Chicago, Rand McNally, 1970.

Nicholas A. Bond, Jr.
ONRFE/AFOSRFE

HIGH-DEFINITION DISPLAYS IN JAPAN

Several Japanese companies can now demonstrate high-definition television (HDTV) pictures; the usual tradeshow setup has 1125 lines at a frame rate of 30 per second (60 fields per second). Eighty of these lines are spent in vertical blanking, so that an effective 1045 displayable lines are shown. The picture is flickerless and is noticeably finer grained. (An "ideal" picture, or one which approaches the one-minute arc of resolution limit in the human eye, would need some 2000 or 3000 lines, at close viewing range.) Many observers say the image is near the quality of a projected 35 mm slide.

There are many problems with HDTV; but the main one is the bandwidth; about five times as much information is in the 1125-line picture as in the 525-line (actually 480-line) present Western TV image. Tricks for reducing the severe information requirement include different coding (expressing only changes in the field pixels) doing some decoding within the transmission cables, very "smart" receivers equipped with processors, and perhaps eventually fiber optic delivery to consumers. Theoretically, one or two cables could provide enough bandwidth. The cameras required are rather special too, and there are no immediate hopes for a cheap portable camera that would have the requisite performance parameters.

High resolution liquid-crystal displays are now also being shown in Japan. NEC Corporation has perhaps the most impressive one. The image is written on a laser-addressed liquid-crystal light value (LCLV), and is displayed *via* ordinary projection optics. Reportedly, a picture of 3000 x 3000 pixels can be written in a 30 mm x 30 mm area. As seen in the sketch in Figure 1 below, two LCLV's can be employed; in demonstrations, for example, one LCLV can be given over to a red pointer, while the other LCLV displays a green map [Kubota *et al.* (1983)].

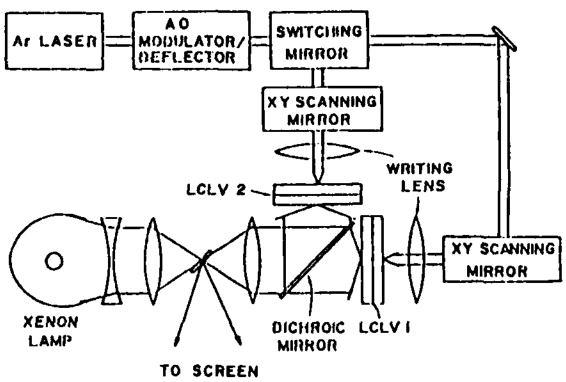


Figure 1. Optics for two-color LCLV display

The Tsukuba Science Expo '85 has both kinds of displays on continuous view. The NEC light crystal setup, for instance, is used to transmit newspaper pages to the Expo site. Now that the basic high resolution feasibility has been demonstrated, investigators will devote their efforts to the many questions and compromises that will make such devices practical.

Actual viewing of these displays is not always as impressive as one might expect. The NEC LCLV system, for instance, is rather dim in ordinary ambient; so that even though a big map of two meters square is shown at a fine grain, the presentation does not "glow" very well. The television pictures are not perfect yet, either, with line "crawling" and other limitations noticed by some observers [Lu, (1985)]. It will be interesting to see how many of the problems will yield to a "quick fix," and how many will take many years to solve. Japanese manufacturers seem determined to go for a "real" 1125-line display rather than refreshing only part of the picture as the CBS Laboratories scheme does. As fiber optic delivery becomes cheaper, the pressure for HDTV should intensify.

REFERENCES

High-Resolution Large-Screen Display System for Teleconferencing, Kubota, K., Sugama, S., Kato, Y., Naemura, S., Nishida, N., Sakabe, T., Naganuma, M. NEC Corporation, Kawasaki, Japan (1983).

"High Definition TV Comes at High Cost," Lu, Cray. *High Technology*, 45 (1983).

Nicholas A. Bond, Jr.
ONRFE/AFOSRFE

ROBOTS IN AUSTRALIA

Australia now has about 1000 operating robots, with arc and spot welding being the most popular industrial applications. Nearly all of these machines are imported. As recently as four years ago, America supplied more than 80% of the machines classified as robots; at the moment the American share of the Australian market has declined to 43%, while Japan's proportion has increased sales to 31% (Sweden ranks third in Australian robot sales). The Australian government has various incentive programs designed to favor the use of robots, and the market is expected to grow at a rate of 30% annually for the next few years. A few Australian research grants in the robotics area have been funded; so far, these have been small by Western standards, and Australian work is not well represented in robotics journals and at international meetings. Of course, Australia has had first-rate research in much of the mathematics and statistical theory which underlie robotics applications.

For some years, Australian robotics progress may have been hindered by a government policy which assumed that R&D is expensive for a small country, and therefore that technology should be imported principally from the U.S. and Western Europe. There has also been a popular political belief that "small business" is good and "big business" is bad, and this view has been reinforced by strict antimerger laws. However, it is now being recognized, at least by the scientific and technical communities, that it takes big projects and big money to bring advanced new products and processes up to world standard. There are movements about to restructure Australian industry and to make it less directly owned by foreign investors. For example, there are indications that pension funds and insurance companies will be pressured toward investment in enterprises that will favor the improvement of quality in Australian technology.

Nicholas A. Bond, Jr.
ONRFE/AFOSRFE

GaAs SIS DEVICES

The Electrotechnical Laboratory (ETL) at Tsukuba Science City has recently reported the fabrication of a heterojunction GaAs MIS-like FET-SISFET (semiconductor insulator semiconductor FET). The GaAs SISFET consists of an n^+-GaAs/undoped GaAlAs/undoped GaAs grown by MBE on a SI LEC (100) GaAs substrate.

In the structure, the n^+-GaAs is used as a gate and an undoped GaAlAs as an insulator. The SISFET operates as a normal off-type FET with the threshold voltage of +0.035 V and the transconductance of 170 mS/mm at V_{DS}=1.0 V and V_G=0.6 V. Unlike HEMTs, since it employs undoped GaAlAs, no impurities diffuse into the heterointerface during the annealing. Therefore, a high electron mobility at the heterointerface can be retained even after annealing. The device exhibited a small dispersion of the threshold voltage over a large number of samples (0.031 V for 41 samples) and appears very attractive for high speed LSI applications.

Furthermore, they have observed the two-dimensionality of the electronic system in a new self-aligned SIS structure by demonstrating the angular dependent Shubnikov de Haas (SdH) oscillations at 4.2 K and V_G=0.6 V; they found the mobility of two-dimensional electron gas to be 120,000 cm^2/V.s with a sheet carrier concentration of 6.6×10^{11} cm^{-2}. The quantized Hall effect was realized by changing the gate voltage as in Si-MOSFETs instead of changing the magnetic field strengths. At a magnetic field as low as 3.5 T, a Hall plateau of Landau number 6 was obtained. ETL workers believe that a future quantitized resistance standard system can be realized with the 2DEG GaAs SISFET.

Yoon Soo Park
ONRFE/AFOSRFE

ROOM TEMPERATURE CW LASER AT 671 nm

The NEC Corporation has announced the fabrication of a cw visible InGaAsP DH laser at 671 nm operating at room temperature. The laser structure was grown by hydride VPE and consists of an undoped 0.4 μm, InGaAsP cap layer, a p-type (Zn-undoped) 1 μm, InGaP clad layer, an undoped 1800 Å, In GaAsP active layer, and an n-type (Se-doped) 2 μm, InGaP clad layer grown on a $GaAs_{0.62}P_{0.38}$ substrate. The laser has a mesa stripe structure with a cavity of 5 μm width and 125 μm length. The cw lasing at 671.5 nm was achieved at 25°C at the threshold current density of 4.5 kA/cm^2. The characteristic temperature To of 90 K was obtained. They claim that this is the shortest wavelength room temperature cw laser reported.

Yoon Soo Park
ONRFE/AFOSRFE

ABRUPTNESS OF MOCVD AlAs/GaAs HETEROINTERFACES

The Sony Corporation Research Center has recently examined AlAs/GaAs monolayer superlattice structures grown by atmospheric pressure--MOCVD by TEM, and found that the heterointerfaces are as sharp as one atomic layer. The TEM image and the TED pattern have also shown that the heterointerfaces are free of islands. These observations demonstrate that the heterointerfaces of the MOCVD grown superlattices are as abrupt as those grown by MBE. AlAs/GaAs superlattices were grown in a vertical reactor using TMG, TMA, and 5% of arsine/H_2 as the source materials at a total H_2 carrier gas flow rate of 11 ℓ/min. The heterointerfaces were grown at the GaAs growth rate of 4 A/s and at the growth temperature of 750°C which is much higher than the critical temperature Tc=610°C, a superlattice growth by MBE. Since the optical and electrical qualities

qualities of AlGaAs crystals are known to be improved with high growth temperature, high-quality superlattices, better or comparable in quality to those grown by MBE, are expected to be grown by MOCVD.

Yoon Soo Park
ONRFE/AFOSRFE

HIGH g_m MOCVD GROWN 2DEG FETS

The Musashino Electrical Communication Laboratory, NTT, has reported the fabrication of a high transconductance ($g_m \sim 330$ mS/mm) 2DEG AlGaAs/GaAs FETs by low pressure (~ 80 Torr) MOCVD.

They report this high g_m to a high 2DEG mobility in the structure results from the use of triethylaluminum (TMA) and triethylgallium (TEG) instead of commonly employed trimethylaluminum (TMA) and trimethylgallium (TMG), in their low pressure MOCVD growth system. At 77 K, the electron mobility and the sheet electron concentration of the 2DEG structure were found to be 27,000 cm^2/V.s and 1.3×10^{12} cm^{-2}, respectively. Previously, they reported a 2DEG mobility of 450,000 cm^2/V.s at 2 K. Though there had been reports of the fabrication of 2DEG FETs by MOCVD, the g_m of the fabricated devices were lower than that of the MBE grown structures. It is believed that the use of TMA and TMG will result in the incorporation of carbon impurities into AlGaAs, thus lowering the 2DEG mobility in the structure.

Yoon Soo Park
ONRFE/AFOSRFE

HIGH POWER DOUBLE HETEROJUNCTION HEMTs

Fujitsu Laboratory has reported the fabrication of high power double heterojunction HEMTs for DBS communication use. The AlGaAs/GaAs DH structure with Lg=1 μm and Wg=2.4 mm produced power outputs of 1 W with 3 dB gain at 20 GHz and 0.55 W with 2.4 dB gain at 30 GHz. A maximum of 0.55 W/mm gate width was attained. With the use of the heterojunction structure and low doped layer (2×10^{17} cm^{-3}) large current and high gate voltage operations were possible. At present, the microwave output is about the same level as that of conventional GaAs MEFETs. In order to attain higher gain, Fujitsu is reducing the gate length to a submicron order.

Yoon Soo Park
ONRFE/AFOSRFE

TOSHIBA'S ION IMPLANTED GaAs POWER FETs

Toshiba Corporation has begun marketing high power and high gain GaAs power FETs in the C-band region (5 to 8 GHz). They claim that their new S8825A series, 10 W output power with a 7- to 10-dB gain is the highest in the world suitable for TWT replacement. A salient feature of their power devices is the fact that these devices are being fabricated totally by ion implantation. With ion implantation technology, they were able to achieve good device uniformity from device to device. Because of internal matching networks, the rated performance can be easily obtained in a 50 ohm circuit with no external tuning. These are the first ion implanted power devices available on the market.

Yoon Soo Park
ONRFE/AFOSRFE

ALUMINUM ALLOY MBE SYSTEM

Seiko Instruments and Electronics, Ltd., has recently announced the development of a new MBE system. The system, SAV 1100, employees aluminum alloy for the growth chamber, analysis chamber, and pumping system instead of stainless steel which is used in the conventional MBE system. With the use of low outgasing aluminum alloy, an ultrahigh vacuum of 10^{-12} Torr is readily obtained in five-six hours, shortening the attainment time by $\frac{1}{8}$ in comparison with the conventional system. The system can also be baked at less than 120°C in about eight-nine hours. Seiko was to deliver the first aluminum alloy MBE system to the University of Tokyo in March at the cost of $440 thousand. The University of Tokyo intends to use the system for the growth of thin film superconductors.

Yoon Soo Park
ONRFE/AFOSRFE

OHMIC CONTACT FORMATION BY ION BEAM MIXING

NEC Corporation has reported the formation of NiGe ohmic contacts in epitaxial GaAs layers by ion beam mixing. The n-type epitaxial layer grown on semi-insulating crystals was processed with the following procedures: Ge (810A) deposition--ion beam mixing; 800°C anneal--Ni (690A) deposition; 600°C alloy. Si ions with a dose of 3×13^{13} cm^{-2} were used for the ion beam mixing. A contact resistivity of 7×10^{-6} ohm-cm^{2} was obtained, which is an order of magnitude lower than that measured on alloyed NiGe contacts without ion beam mixing.

Yoon Soo Park
ONRFE/AFOSRFE

BIOTECHNOLOGY IN JAPAN

Herman W. Lewis

INTRODUCTION

This study was initiated by the Office of Naval Research (ONR) and jointly supported by the National Science Foundation (NSF). Japan's special push in biotechnology started in 1981 with a report issued by the Ministry of International Trade and Industry (MITI), outlining a ten-year program. The present report is an assessment of the first two years of that program. It is based on visits to universities, government ministries, government laboratories, associations, and industrial facilities from September to December 1983. The author is a biologist and science administrator whose observations and conclusions are related to the technological aspects of biotechnology. The report does not deal with Japanese marketing strategies and tariffs, patent law, antitrust law, tax incentives, industrial financing, regulatory controls, or international technology transfer; important factors affecting the commercialization of biotechnology. The report is presented in two major parts: (1) the organization of the biotechnology enterprise and an assessment of its infrastructure, and (2) a survey of accomplishments as of early 1984.

- Background

An understanding of the status of biotechnology activity in Japan can be enhanced b considering certain historical and cultural factors. For example, one may ask: Why did biotechnology receive national priority status in Japan, and why in 1981?

The term "the next generation" is frequently used by those involved in implementing biotechnology as a national program in Japan. It refers to the change from an economy based on smokestack industries to an economy based on high technology or knowledge-based industries. Biotechnology is the latest of the science-based areas of commercialization that the government is trying to stimulate through special efforts in the public and private sectors. It follows in the wake of the revolutions in the electronic and computer industries. A number of factors contribute to the blueprint for the next generation: limited national resources, existence of a highly literate and skilled middle-class society, the emergence of new industrial competitors in southeast Asia, and Japanese vulnerability due to dependence on Middle East oil. Biotechnology has an especially attractive role in planning for "the next generation" because of its breadth which touches many areas of the economy and its promise of relative independence from Japan's raw resources situation.

Through the applications of procedures developed within the last decade, biotechnology might impact on several domains:

- the pharmaceutical industry by the production of new drugs, vaccines, and diagnostic tests,

- the specialty chemical market for the production of high value-added products such as amino acids, hormones, enzymes, and food additives,

- the commodity chemical market with products derived from biomass rather than fossil fuel,

- energy production derived from biomass rather than fossil fuel, and

- agriculture through genetically engineered plants and animals.

Even before the advent of recombinant DNA and hybridoma techniques which make possible such opportunities, the Japanese recognized the role of bioprocessing and large-scale fermentation in the nation's economy. In 1971, the Science and Technology Agency (STA) proposed a national program to promote biotechnology but it never caught on to the extent of having funds allocated specifically for its implementation. Ten years later, MITI announced a grand plan for which funds were quickly allocated. This grand plan and the manner in which it was announced accomplished several purposes. It signaled to the Japanese public that the national purpose now included the promotion of biotechnology, it established MITI as the lead agency for promoting biotechnology in Japan, and it announced to the rest of the world that Japan had left the starting post in the biotechnology race for world markets. Why was the MITI plan accepted so readily? Part of the answer is good salesmanship and the appeal of a plan that superficially was well suited to Japanese visions of "the next generation." A more important factor, perhaps, was fear that the race could be won by U.S. industry before Japan became a serious contender. MITI officials and their industrial advisors were moved into action in response to two events that took place in the U.S. in 1980. The first was the U.S. Supreme Court decision that microorganisms can be patented, which was quickly followed by the Cohen-Boyer patent for the construction of recombinant DNA molecules. This signaled to the Japanese that it was possible, that *via* patent rights, the U.S. could gain world dominance in the commercialization of biotechnology. The second event was the record-setting initial Wall Street reaction to the public offering of Genetech stock coupled with the attraction of venture capital to start up many other biotechnology companies. This signaled to the Japanese that flexible financing could accelerate the commercialization of biotechnology in the U.S., and thus make it possible for American companies to establish markets rapidly. The publicity that was generated in the U.S. to attract investments, also convinced MITI that biotechnology was an important new commercial enterprise that required the status of a national program to accelerate Japan's entry into the area.

The MITI plan defined biotechnology in terms of three technologies, namely, fermentation, cell culture, and recombinant DNA. It was certainly natural for fermentation technology to be one of the program areas (Saito, see references). Japanese expertise in the art of fermentation is well-known and the analysis of why this is so can be conceived into two stages: those factors whose roots were established 100 years ago or more, and those whose roots were established after World War II. An important factor in the first stage was the influence of a large manpower resource, a product of the structure and patterns established in the imperial universities. All of the imperial universities had, as the national universities now have, schools of agriculture which include as a standard organizational unit a department of applied microbiology, or, department of applied biochemistry as it is called in some universities. These departments were established by people who had been trained and influenced largely by German professors; the Germans viewed applied microbiology or fermentation as an important branch of organic chemistry. These departments were generally large and many of Japan's best chemists were trained in them and became oriented toward research in fermentation. Graduates of these departments became leaders in the industries that manufactured sake (rice wine), miso (bean paste), and shoyu (soy sauce); such products played a major role in the cultural and economic life of Japan. The professors perpetuated the nature of the departments of applied microbiology or applied biochemistry and sustained their influence on successive generations of industrial leaders. The large number of scientists in Japan trained for industrial fermentation assured a continuing source of technical expertise.

The more recent history of fermentation in Japan was dominated by events during the U.S. occupation of Japan after World War II. Much of Japan's industry was destroyed or made obsolete during the war and new industries were needed to replace them. In 1946-47, the U.S. provided Japan with commercially useful strains of penicillium and encouraged the development of new companies to produce the antibiotic. In a short period of time, 70 Japanese companies were founded to produce penicillin. Almost the entire class of 1942 of the department of applied microbiology of the University of Tokyo became the chief officers of these companies. The competition was fierce and only four of the 70 companies survived. They launched the antibiotic production and drug industry of Japan which is now highly successful globally. Many innovations in large-scale fermentation were developed in the surviving companies. New types of fermentors using aeration and agitation were produced for large volume cultivation in closed systems. When microbial genetics became an area of research, it was given high priority in the antibiotic companies and this circumstance led to the discovery of R factors, the transferable elements in bacteria that confer antibiotic resistance. Later, the R factors, now known as plasmids, became an integral part of the recombinant DNA concept. An important spinoff of the innovative use of fermentation developed in industry was the development, in 1957-60, by the Kyowa Hakko Kogyo Company of a method of producing monosodium glutamate using microorganisms. This was followed by the development of metabolic suppression fermentation technology, which led to the manufacture of various substances related to amino acids and nucleic acids, and which culminated in the mass production of amino acids. Since 1970, enzymes have been used to manufacture amino acids and isomerized sugars. The company today is the world's largest producer of glutamic acid and other amino acids. Taking a lesson from this history, a number of depressed companies in Japan today are looking to innovative applications of fermentation to revitalize themselves.

An observation about the Japanese attitude about their naturally occurring microbial flora must be coupled to this historical account of fermentation in Japan. Japan does not have an abundance of natural resources as usually defined, but it does have a rich variety of microorganisms in its soil and these are regarded as natural resources. All departments of applied microbiology or biochemistry, many companies and government laboratories have their own unique, highly valued collections of naturally occuring microorganisms, and there are also several national repositories. Additions to collections are highly prized and there is active soil collecting in the semitropical areas of other Asian countries.

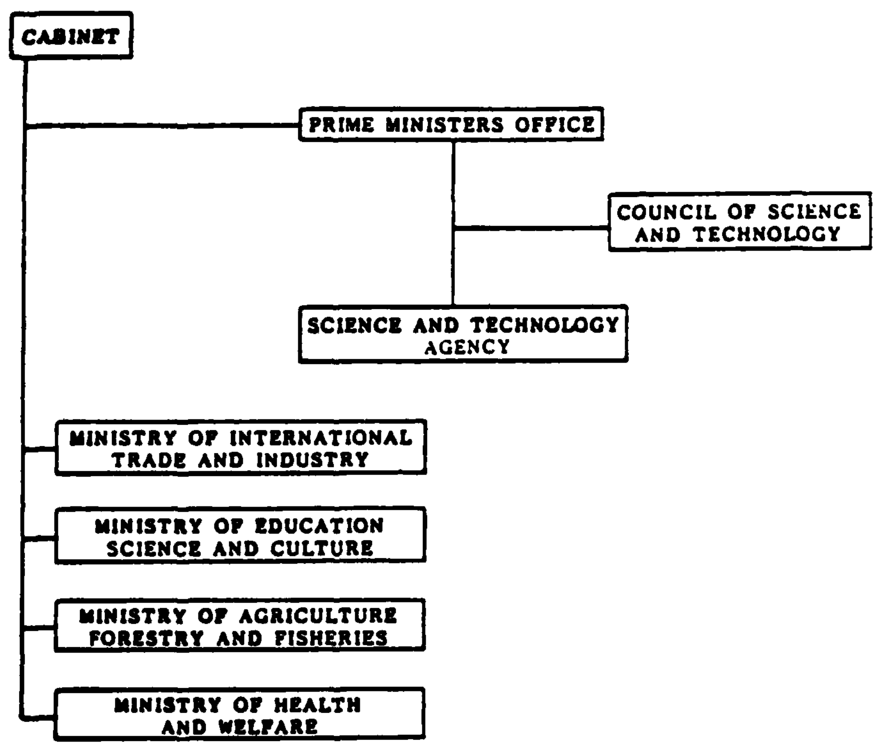
Japanese scientists "mine" this resource very systematically. All laboratories conducting applied fermentation research follow a standard approach. This forms the basis of bioreactor research. First, a decision is made as to what new or modified reaction or product is to be sought. Then, a projection is made as to the likely classes of microorganisms that might have the property. Next, using an appropriate assay to detect the sought property, organisms in the laboratory's collection are systematically screened to select a strain with the desired properties. In this process, thousands of strains may be screened. Japanese scientists view a biosynthetic pathway as a single whole, not a system of dependent steps. That is, in the pathway A-> B-> C-> D, attention is given only to the detection of product D with no concern about intermediates or alternate steps that could be manipulated to also produce D. The rationable behind such "tour de force" methodology, which was probably rooted in oriental religion and philosophy, is that all the variability that can be useful is produced by nature. It is the scientist's job, then, to search until he finds the desired natural property, not to tamper with nature. Thus, one sees no attempts to manipulate the genome by directed mutagenesis, cell fusion, transformation, transduction, recombinant DNA, transposons, etc., even though these approaches could achieve the goals more efficiently.

STRUCTURE AND ORGANIZATION OF BIOTECHNOLOGY ENTERPRISE

GOVERNMENT

Five government organizations promote biotechnology in Japan through the support of research and related activity: the Science and Technology Agency (STA), the Ministry of International Trade and Industy (MITI), the Ministry of Education, Science and Culture (MESC), the Ministry of Agriculture, Forestry and Fisheries (MAFF), and the Ministry of Health and Welfare (MHW). Each supports research to promote its objectives at research institutes or through public corporations or associations. Through these subsidiary institutions, the government interacts with the universities and industry. These interactions will be discussed in a later section of this report; in this section only the parent or sponsoring agency is described.

ADMINISTRATIVE STRUCTURE OF BIOTECHNOLOGY RELEVANT SCIENCE AND TECHNOLOGY IN JAPAN



COUNCIL FOR SCIENCE AND TECHNOLOGY (CST)

The Council of Science and Technology is advisory to the Prime Minister and serves as the highest deliberative council on science and technology (Takahashi, see references). The council makes recommendations and submits opinions at the request of the Prime Minister concerning the establishment of basic and general policies on science and technology. The council has 11 members and is chaired by the minister of state for science and technology with STA serving as its secretariat. The Council includes the minister of finance, the minister of education, a representative from the agency for economic planning, a delegate representing industry, as well as the science-related ministries.

It should be noted that in Japan, long-range plans are made in ten-year intervals and are generally continued until a built-in evaluation point is reached. Therefore, plans are not dropped because of changing interests or lack of apparent progress. This *modus operandi* has its obvious strengths and weaknesses.

In 1981, the council established the "Special Coordination Funds for Promoting Science and Technology." These funds are intended to promote coordination among the research programs pursued by various ministries and agencies, reinforce the systematic cooperation among government laboratories, industries, and universities, provide flexible responses to the need for temporary research under special circmustances, provide active reinforcement of surveys and analysis, and reinforce international joint research. The Special Coordination Funds are administered by the STA. In JFY 1982, the Special Fund was allocated $30 million and this was increased by $750,000 in JFY 1983 (Yen, see references). In 1982, the fund was used to subsidize coordinated research in the following areas of biotechnology:

- coordinated research relating to the safety of recombinant DNA technologies,

- coordinated research relating to the utilization (such as for the manufacture of vaccines by utilizing *Echerichia coli*, etc.) of recombinant DNA technologies,

- coordinated research relating to the scientific corroboration of Chinese medical treatment and acupuncture, and for securing natural drug resources,

- research for developing technologies for the extraction, analysis, and synthesis of recombinant DNA,

- research relating to the productive functions of marine biological resources and marine environments,

- research for developing technologies for the development and utilization of microorganisms and plants living in tropical and subtropical habitats,

- research for developing technologies for the analysis of biological membrane functions and their utilization.

- Science and Technology Agency (STA)

STA's major responsibility related to biotechnology is the promotion of recombinant DNA research (see references, *Science and Technology in Japan*, April-June 1983 issue). In 1980, when the Council for Science and Technology recommended the promotion of recombinant DNA research, STA was given specific responsibility for:

- research related to safety evolution,

- development of safe and useful host-vector systems,

- development of technologies for DNA structure analysis and synthesis,

- elucidation of expression mechanisms of foreign genes,

- development of technologies for the manufacture of useful substances by application of recombinant DNA technology and technologies for the effective utilization of microorganisms and enzymes.

STA will also have responsibility for coordinating research to be done in the national P4 facility to be completed in Tsukuba Science City. In 1983, STA completed a major revision of the guidelines for governing the conduct of research involving the use of recombinant DNA molecules. As in the U.S., the current Japanese guidelines delegate much of the responsibility for monitoring recombinant DNA research to local institutional committees. Those matters not delegated to institutional committees for research conducted in national research institutes or in the private sector must be referred to the STA. The Ministry of Education handles such matters for research conducted in public or private universities.

The STA has its own budget for research. The Council for Science and Technology has recommended that the agency's life science department promote certain areas of biotechnology research. STA has no intramural research facilities but has two mechanisms for accomplishing the research it wants done:

- By contract to the Institute of Physical Chemical Research (Riken). This is a public corporation that conducts advanced scientific research, both basic and applied, in a wide range of fields. At the time the writer was in Japan, contracts were let for research on:

    - the development of bioreactors,

    - the development of a system for finding biologically active substances in nature,

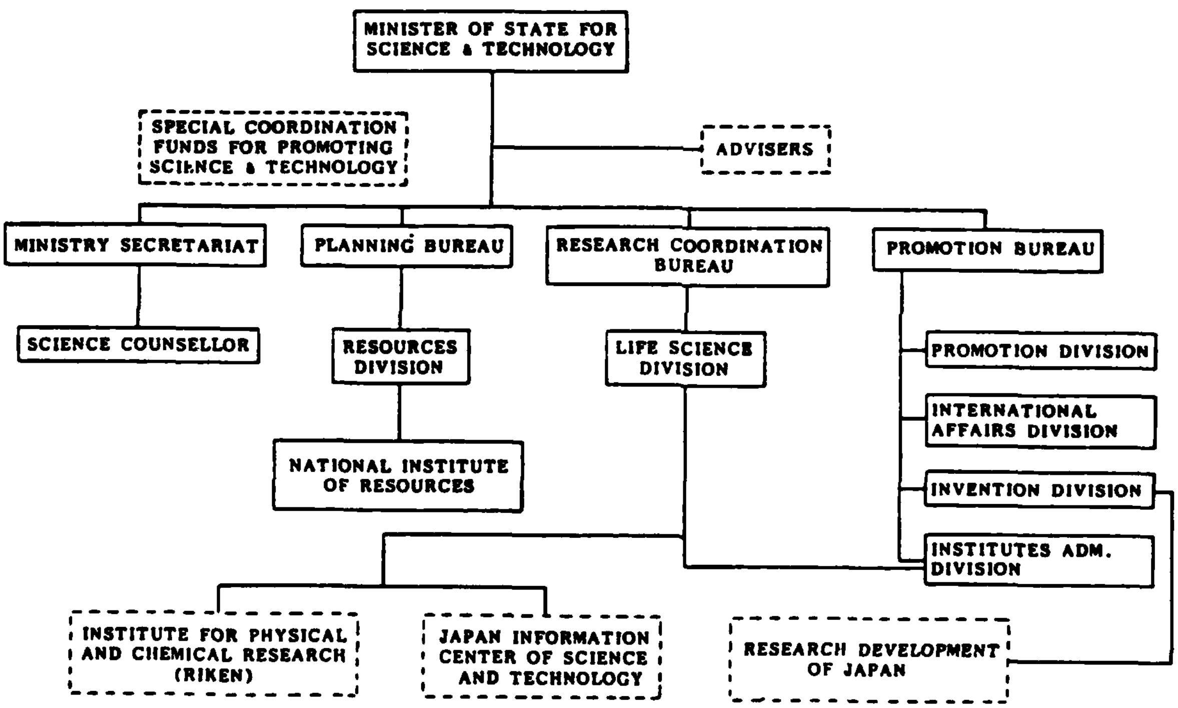
    - the development of new microbial technologies relating molecular genetics, organic chemistry, and bioengineering.

- Through the Research Development Corporation of Japan (JRDC). This is a public corporation or foundation established by STA through which the agency puts together teams of researchers to perform exploratory research the agency thinks should be done. The aim is to develop seeds of new technologies using the best researchers available. Generally, a director of a project is chosen and he creates a team of researchers using people from academia and industry. The average project lasts about five years, involves about 20 researchers and costs about $10 million. If the research is successful and leads to profit through royalties or license fees, the JRDC pays back the STA the amount of their investment. If there is no profit, there is no payback. In FY83, the JRDC budget was approximately $38 million, of which $21 million came from the government.

As stated in the introduction, the Japanese view living organisms as a natural resource. In December 1982, members of the Diet drafted a proposal recommending an organized management of such resources for the promotion of science. They prefaced their proposal by pointing out that the genes of various organisms are an invaluable asset to mankind and securing these genes is indispensable for the promotion of science. Specifically, they proposed that the government assume leadership for (1), the collection of bioresources under a coordinated system, (2) development of preservation techniques, (3) organization of information about collections and development of data bases, and (4) establishment of a center or national organization for promoting these activities. The responsibility for fulfilling these objectives is shared by several government agencies, including STA.

In design, the STA has a coordinating function among government bodies, "an adjustment role" to quote Dr. Tohru Takahashi, Science Counsellor, Planning Bureau, STA. In practice this role is exercised minimally and each organization protects its independence. As one consequence, there are no across-the-board statistics about government activity and funding in biotechnology in Japan. The statistics from each agency cannot readily be pooled because they are based on different definitions and criteria.

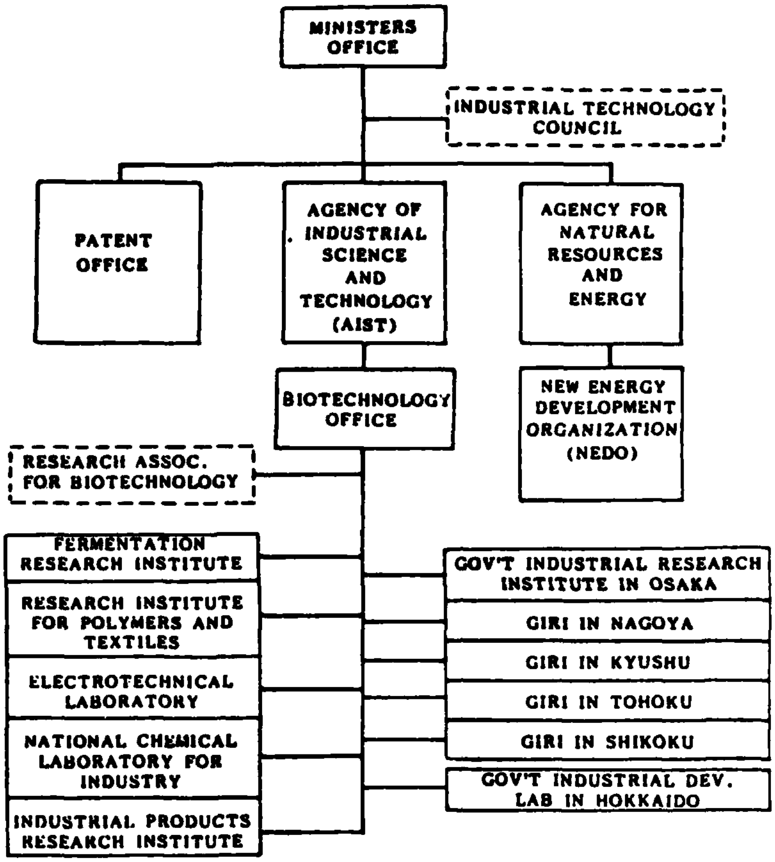
ORGANIZATION OF STA RELEVANT TO BIOTECHNOLOGY



- Ministry of International Trade and Industry (MITI)

MITI is the most prominent government organization in Japan involved in biotechnology (Tanaka, see references). This flows from the fact that most thinking about biotechnology in Japan relates to its commercialization and Japan's position in the development of world markets.

ORGANIZATION OF MITI RELEVANT TO BIOTECHNOLOGY



MITI's agenda also includes the revitalization of depressed companies, particularly in the chemical industry, where the application of biotechnology is a natural remedy. As indicated earlier, in 1981, MITI announced the "Research and Development Project of Basic Technology for Future Industries," henceforth referred to as "the Project." In essence "the Project" is a national program for biotechnology. The aim of "the Project" is to develop basic technologies which are indispensable for the progress of industries expected to play leading roles in the 1990s. Three technologies were selected for research during the next ten years.

- development of bioreactors,
- development of technologies for large-scale cell cultivation,
- development of technologies for utilizing recombinant DNA methodologies.

In Japan, biotechnology is defined narrowly to include only these three technologies. Other technologies that are included in broader definitions of biotechnology are not absent in Japan, but they are not labeled "biotechnology" or given priority attention. The major technical weakness in this narrow definition is the slow start of the use of monoclonal antibodies in Japan. This fourth technology was proposed by MITI, but eliminated for budgetary reasons though the term "cell fusion" has appeared in recent statements about target areas.

In June of 1982, MITI established the Bioindustry Office, which was charged with planning and other activities related to research and the field called "bioindustry." It is a MITI principle that innovative research and development that involves large economic risks should be supported partly by government, not wholly by the private sector. Consequently, MITI is actively carrying out research and development on biotechnology on its own initiative as well as subsidizing private corporations in various ways. Further, "the Project" calls for implementation of its goals by close cooperation among industrial, academic, and national research institute (government) researchers.

The central organization for conducting research on biotechnology in the private sector with a MITI subsidy is the Research Association for Biotechnology. Its structure, organization, and activities will be described in a later section. The association was established by the Agency for Industrial Science and Technology of MITI. The agency also sponsors national research institutes, and eight of MITI's 16 national institutes are engaged in biotechnology research. Some of these will be discussed in a later section, but a sampling can be listed here.

- The National Chemical Laboratory of Industry--engaged in research involving chemical synthesis of DNA and its utilization.

- Government Industrial Research Institute, Osaka--engaged in research on the utilization of untapped timber resources.

- Fermentation Research Institute--engaged in research on the utilization of nitrogen-fixation by microorganisms.

- Research Institute for Polymers and Textiles--engaged in research on macromolecular materials with medicinal effects.

- Industrial Products Research Institute--engaged in research on suitability of synthetic polyamine acid composite film as surface coating material.

MITI's projected subsidy for "the Project" over a ten-year period is 26 billion yen or $130 million. The initial growth of MITI support of research directly related to "the Project" is indicated in the following budget data.

	(In million yen)	(In thousand dollars)
JFY 81	680	3,400
JFY 82	1043	5,215
JFY 83	1191	5,955

In addition to its direct support for "the Project," MITI subsidizes research designed to develop a synthetic fuel produced from substances other than oil. Partial subsidy has been provided to the Research Association for Petroleum Alternatives Development (RAPAD), a technical association which is concerned with technical solutions of problems related to petroleum. In FY83, MITI commissioned the New Energy Development Organization (NEDO) as a route for subsidizing industry research on the conversion of biomass to alcohol. The goal of NEDO is to promote research and development on alcohol fermentation using microorganisms of the genus *Zymomonas* that have a faster fermentation rate and that are more heat-resistant than yeast. NEDO is entirely supported by MITI and its initial allocation for research in FY83 was $1 million.

MITI also promotes joint research with Indonesia, Thailand, the Philippines, and Brazil on the utilization of biomass resources, particularly for alcohol production.

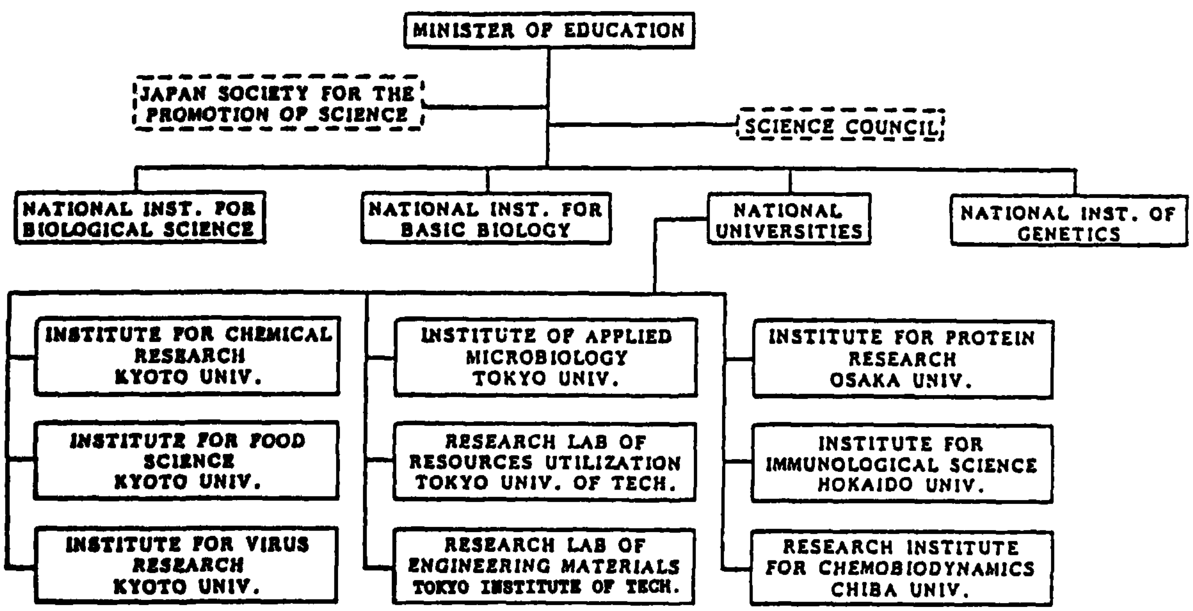
In addition to the support of research, MITI conducts surveys to get information useful for their biotechnology planning and activity. These studies range from profiles (size, number of researchers, type of product) of companies using biotechnologies, to technical surveys on the cultivation and fermentation of seaweeds usable as possible biomass resources.

- Ministry of Education, Science and Culture (MESC)

This ministry has responsibility for the support of university research and for basic research in specialized national institutes throughout Japan (NST, Tokyo office, see references). Support for the basic research related to biotechnology is carried out primarily via grants for specific projects; these are generally initiated by the principal investigator. Most of the ministry's support for scientific research, estimated to be $1.3 billion in FY83, goes to the national universities and the national research institutes under the jurisdiction of the ministry; but approximately $10 million of this amount was appropriated to subsidize scientific research at private universities and colleges. The proportion of this support that is biotechnology related is not known.

The ministry has responsibility for monitoring that portion of recombinant DNA research at universities and institutes that cannot be handled by local committees, as specified by the current guidelines for conducting such research.

ORGANIZATION OF MINISTRY OF EDUCATION
SCIENCE AND CULTURE RELEVANT TO BIOTECHNOLOGY



The Japan Society for the Promotion of Science (JSPS) conducts a variety of activities to enhance government policies. These include support of cooperative research, fellowships, and exchange programs for researchers, and the implementation of various international scientific cooperative programs. In FY83, a total of $16.25 million was allocated to JSPS, an increase of $645,000. This subsidy to the JSPS was made to implement some new activities including:

- fellowships to invite young researchers to Japan from advanced foreign countries,
- expansion of programs to promote scientific exchanges with developing countries, including exchanges by "core university" systems and fellowships for dissertational studies, and
- expansion of cooperative projects under various U.S.-Japan science and technology cooperative arrangements.

As noted earlier, each of the government agencies involved in biotechnology may pursue its own activities and policies to fulfil its mission. The MESC has initiated programs to encourage innovation and raise the level of Japanese academic science. An analysis of the FY83 budget published by the JSPS states, "In scientific research, excellent results can best be obtained when researchers are free to follow their own ideas and interests for research. Thus, for the promotion of excellent scientific research it is crucial to have a maximum regard for the researchers' own initiatives and independence." Further, the ministry is trying to encourage increased quality of academic research by improving research facilities, and favoring a more flexible research organization. Not surprisingly, the reaction of academic scientists was not one of joy when the ministry seemed to reverse its previous policies and began to take measures to promote cooperation between industry and academia. Starting in FY83 these measures include:

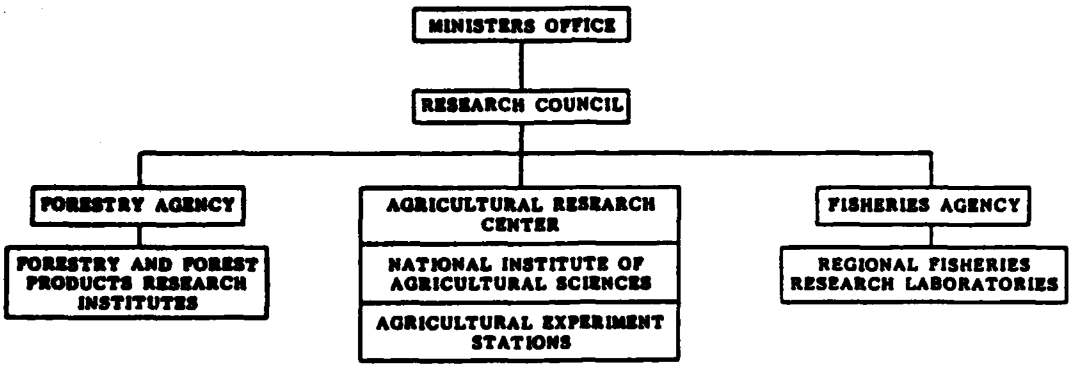
- adding researchers from industry to the committee that selects experimental areas for science research grants provided by the ministry,
- allowing industrial researchers to conduct collaborative research at national universities, and
- establishing a committee under JSPS to study specific projects for industry-university cooperation.

It is too early to assess the impact of these measures on biotechnology in Japan, but further observations will be made in a later section (Japan fiscal year, see references).

- Ministry of Agriculture, Forestry and Fisheries

The MAFF is the largest agency discussed in this report; its FY83 budget is $302 million, of which $10 million is biotechnology related (Takata, see references). This budget represents a 7.7% increase over FY82, a notable fact since the total MAFF budget was reduced almost 4% between FY82 and FY83. To date MAFF research has had little impact on biotechnology, though some of its biotechnology-related programs predate the program initiated in 1981 by MITI.

ORGANIZATION OF MAFF RELEVANT TO BIOTECHNOLOGY



The organizational chart above only includes major units because in December 1983, the ministry inaugurated a new plan involving organizational changes and even top administrators were not fully aware of the details at the time of the writer's visit. The MAFF operates through ten agricultural institutes at Tsukuba and 30 additional national institutes and agriculture experiment stations throughout the country. There are six national experiment stations and each prefecture has its own station. The plan announced in December 1983 is a ten-year plan that provides policy guidance for all of the research organizations under the ministry. The objective of the new plan is to promote cooperation and build linkages between ministry laboratories and scientists in industry and in universities. This objective is similar to the changes announced by the Ministry of Education a year earlier. In this case, the stated goal is to infuse agricultural science with the sophisticated tools and methodologies of biotechnology, electronics, and computer science. The new plan also gives entry for industry into new areas like breeding and species improvement, which previously had been the exclusive domain of government. Problems to be resolved are the possession and right-to-priority use of new varieties, and the form of registry of new varieties resulting from joint research. New varieties developed by national research organizations are registered by name through the Nomenclature Registration Inquiry Committee separately from the registration according to the Seedling Law. It is intended that under the newly announced plan, MAFF will provide seed money (no pun intended) to get collaborative projects started. At present, it is expected that patent rights to inventions developed from research jointly funded by the ministry and private companies will be determined on a case-by-case basis.

Biotechnology related projects included in the FY83 MAFF budget are the following:

- "The green energy project." This is a ten-year project which was started in 1978 for the purpose of developing new technologies for utilization of natural sources of energy (photosynthesis and solar energy). This projct was allocated $4.4 million in FY82 and $4.0 million in FY83.

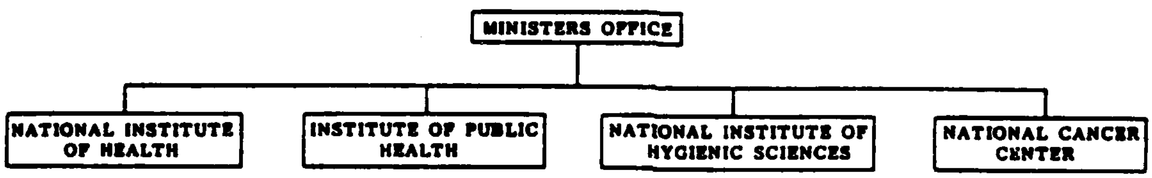
- "The biomass conversion project." This is a ten-year project initiated in 1981 for the purpose of developing technologies for the utilization of biological resources which are untapped or can be recovered for reutilization such as food, feed, or energy. This project was allocated $1.58 million in FY82 and $1.96 million in FY83.

- Development of new biological resources through cell fusion and nuclear transplant. This is a five-year project initiated in 1982 for the purpose of developing technologies involving the fusion of different kinds of cells or the transplanting of their nuclei to generate novel cells that cannot be produced by breeding or mutation techniques. This project was allocated $1.13 million in FY82 and $1.14 million in FY83.

- Ministry of Health and Welfare (MHW)

MHW has the least impact of the major agencies that conduct or support biotechnology-related research. The research institutes under the supervision of the ministry are engaged in very modest research aimed toward health preservation or medical treatment. Each of the institutes in the organization chart receives support from the Special Coordination Funds for Promoting Science and Technology disbursed by the STA for research involving the analysis or synthesis of DNA. In addition, the National Institutes of Health and Institute of Public Health are conducting research on the safety of recombinant

ORGANIZATION OF MHW RELEVANT TO BIOTECHNOLOGY



DNA technologies. The ministry has national responsibility for regulating new drugs and it is conducting research related to the inspection of pharmaceuticals produced by recombinant DNA. There is also some clinical research on the application of interferon.

NATIONAL LABORATORIES AND RESEARCH INSTITUTES

The national institutes and research laboratories are an important hinge in "Japan Incorporated" because they are sites where government and/or industry and/or academia interact at the research level. Contrary to a common perception in the U.S., in this interaction the government does not seem to be the controlling partner, but rather a junior partner concerned with national interests *per se*. Many such facilities are involved in biotechnology, either sponsored by a government ministry or agency or attached to a national university. This report will describe only a few of the public research institutes as examples of different types of institutes. Generally there are two types of research carried out in these facilities: (1) long-term basic research projects, and (2) limited-term applied research projects.

- Fermentation Research Institute

This institute belongs to MITI and is located in Tsukuba (Takahara, see references). It is organized into three major research departments, each of which is subdivided into divisions.

- Microbe Exploration Department

Microbe Exploration Division
Gas Utilizing Microbe Division
Geomicrobiology Division

- Microbial and Biochemical Application Department

Carbohydrate Fermentation Division
Synthesized Material Fermentation Division
Enzyme Technology Division
Genetics and Breeding Division

- Microbe Engineering Department

Resources and Energy Producing Microbe Division
Biochemical Engineering Division
Petroleum Fermentation Division
Industrial Waste Treatment Division

The institute also has prime responsibility for maintaining the depository for those microorganisms which are cited in Japanese patents.

In FY83, the institute employed 63 researchers and had a budget of $4.46 million. This budget is essentially the same as in the previous year. A sample of the biotechnology projects and the funds allocated for them in FY83 (excluding salaries and administrative costs) includes the following:

- research on bioreactor for reduction process by using coenzyme recycling system ($365,555).

- development of new host-vector system using *E. coli*, *Bacillus subtilis* and yeast. This will be extended to use of thermophilic bacteria ($332,000).

- Microbial engineering for (1) carbohydrate production using cellulase, transglucosidase, and amylase including a debranching enzyme; (2) nitrogen fixation by intact cells and by cell-free extracts of C-utilizing microorganisms; and (3) decomposition of mercury compounds and PCBs ($187,900).

- The use of microbes to produce new biologically active substances such as protease inhibitors, phosphodiesterase inhibitors and hormone-like substances; synthesis of polymer derivatives of ATP and NAO for bioreactors ($137,400).

- Cooperative research on ethanol production from biomass with scientists from the Philippines, Malaysia, and Thailand and from Brazil using casaba as a resource ($16,100).

- National Institute of Genetics

The National Institute of Genetics is supported by the Ministry of Education, Science and Culture and is located in Mishima (Hirota, see references). It is currently classified as a "special class" institution and is not permitted to do contract research for industry but action has been initiated to change the classification to a "general class" institution, which would be allowed to perform contract research. Its FY83 budget is $1.1 million excluding salaries and maintenance costs. This is a 5% increase over the previous year, about the same as the rate of inflation. The institute employs 59 researchers. It is organized into ten research departments plus a genetics stock center as follows:

Department of Cytogenetics
Department of Physiological Genetics
Department of Biochemical Genetics
Department of Applied Genetics
Department of Human Genetics
Department of Microbial Genetics
Department of Population Genetics
Department of Molecular Genetics
Department of Morphological Genetics
Department of Induced Mutations

The genetic stock center does research on the preservation of germplasm in rice and wheat species, rodent embryos, *E. coli*. It is also interested in the construction of DNA banks of several species.

Almost all of the research carried out in the institute is basic research (even in the Department of Applied Genetics which is involved in basic studies on poultry, forest trees, and weed species). Much of the work is biotechnology-related (e.g., recombinant DNA expression of biological function, energy transduction, mechanism and genetics of cell division); but the only project specifically identified as biotechnology related is an investigation of nitrogen fixation in rice. This is a collaborative project to continue until 1986. The main professionals are Y. Hirota (microbial genetics), S. Iyama (applied genetics), T. Fujii (head of the experimental farm) and Y. Sano (stock center). They found several bacterial species that live in rice paddies that fix nitrogen. The most promising are *Spirium lipoferum* and *Klebsiella oxytoca*. It also appears that nitrogen fixation depends on the genotype of both the bacteria and the associated plant. While the level of nitrogen fixation is low, the institute screening program has identified a *K. oxytoca* strain that increases the nitrogen fixing efficiency by 20%. This research is still in progress.

The National Institute of Genetics contributes to Japan's national goals in biotechnologies, as other government institutes do, by training researchers from Japanese industry and from developing countries, specifically from southeast Asia and Brazil.

- Institute of Physical and Medical Research (Riken)

The Institute of Physical and Chemical Research is an independent public corporation, but most of its research is supported by the government. It is a major site of research for the life science program of the Science and Technology Agency. There are more than 400 researchers. The institute's FY83 budget is $52 million, of which $47.25 million is from the government. Perhaps the closest U.S. institutions to Riken in purpose, scope, and stature is the Stanford Research Institute or the Battelle Memorial Institute. Riken's research activity can be separated into three classes:

- General Research: This is basic or applied research carried out in each laboratory under the leadership of the head of the laboratory. The subject is determined by the head of the laboratory after discussion with researchers in the laboratory.

- Project research: This is research that grows out of the general research carried out in each laboratory. It involves systematic investigation of specific aspects of the general research that are of interest to the public, government, or academic researchers.

- Grant or contract research: This is research carried out under a contract from industry or under a grant from government.

The laboratories in which biotechnology-related research is conducted are: biophysics, chemical engineering, biochemistry, microbiology, radiobiology, and phytochemistry.

- National Institute for Basic Biology

This institute operates under the auspices of the Ministry of Education, Science and Culture and is located in Okazaki, a city close to Nagoya (Fujita, see references). Its goal is to promote and facilitate basic research in biology. Its FY83 research budget is $1.08 million excluding salaries and overhead costs. The institute is an interuniversity research facility with two objectives, the promotion of intramural research and the conduct of cooperative research. The institute is organized into three departments and 12 research divisions. Current research interests are as follows:

- Department of Cell Biology

  Division of Cell Mechanisms--Mitochondrial division and cytoplasmic streaming in *Physarum polycephalum*.

  Division of Biological Energy Conversion--Light capturing in photosynthetic pigments and photochemistry in the reaction center in blue-green algae. Also, electron flow between the two photosystems and the role of plastoquinone.

  Division of Cell Fusion--Genetics of mammalian cells in culture, utilizing cell fusion by Sendai virus.

  Division of Cellular Communication--The molecular basis of hormone action to activate cell functions and the interaction with specific cell surface receptors.

  Division of Cell Proliferation--Mechanisms of synthesis of proteins and nucleic acids at various stages of the cell cycle, formation of the mitotic apparatus and chromosome movement, and cytokinesis.

- Department of Development Biology

  - Division of Reproductive Biology--Investigation of the cellular and molecular mechanisms of formation and release of gametes and the mechanisms involved in fertilization, using starfish.

  - Division of Cell Differentiation--Regulatory mechanisms of the fibroin and sericin genes which are expressed at specific stages of development in the posterior and middle portions of the silk glands of *Bombyx mori*.

  - Division of Morphogenesis--Just established but no research team selected yet.

. Department of Biological Regulation

- Division of Sensory Processing--Morphology of the retina and identification of spatial-temporal filtering of retinal neurons using the catfish system.

- Division of Chronobiology--Genetic and biochemical analysis of the clock that controls conidiation in *Neurospora*.

- Division of Biological Regulation--research on a phytochrome that mediates plant development and the primary action of photoreceptors regulating functions of biological membranes.

- Division of Behavior and Neurobiology--Neuronal mechanisms of taste in *Drosophila*.

Each of the divisions listed above has a full professor, an associate professor, and two research associates with two research technicians. Five of the listed divisions are under adjunct professors who hold joint appointments in other institutions. Adjunct divisions have resident research associates and technicians.

The laboratories and facilities of the institute are available for use by any scientist in Japan whose research interests are compatible with that of the intramural staff. Visiting scientists stay for periods of a few days up to a few months. About 100 visiting researchers come to the institute each year. Space is made available to the visiting researchers in the laboratories of the permanent staff. Obviously, this arrangement and the frequent absenteeism of the adjunct professors place a burden on permanent staff members.

The support facilities of the laboratories are superb. These include the world's largest spectrograph, tissue and cell culture laboratories, a plant culture laboratory, computer facilities, a radioisotope facility, high voltage electron microscope facility, a center for physical and chemical analysis, circulating saltwater for marine studies, low temperature facilities, animal care facilities, amino acid analyzers, peptide synthesizers, nucleotide synthesizers, a cell sorter and an experimental farm. The facilities seem to be underutilized. The Japanese attitude clearly is that it is better to have facilities and equipment in good order and waiting to be used than not to have them when needed.

The laboratory has started an international cooperative program on the utilization of biomass in the chemical and energy industries. To date, the collaboration has been confined to European researchers, but the government is trying to promote collaboration at the institute with researchers in southeast Asia. Right now, a main goal is to train some southeast Asian students in fundamentals.

- Institute of Applied Microbiology

The Institute of Applied Microbiology is attached to the University of Tokyo (Saito, see references). It is an independent research organization but its staff all have academic appointments and rank, i.e., they have teaching responsibilities in various university departments, but they do their research at the institute. The institute was established by the government to coordinate basic and applied research in microbiology. It is organized into 12 divisions and a cell center collection. Each division has a professor, an assistant professor, about six graduate students, and, on the average, two investigators from industry receiving training in new techniques. The "trainees" from industry stay in the institute for varying lengths of time, from a few months to a few years. The average division research budget is $130,000 per year excluding salaries and indirect costs. Most of the funds come from competitive grants and industry, but each laboratory receives from the university $15,000 per year for research, salaries, and indirect costs. The institute accepts donations from companies in exchange for training researchers, but does not accept funds for contract research. The divisions of the institute and their general interests are:

Division of Supramolecular Biology--Bacterial cell duplication and the functions of cell surfaces involved in the process.

Division of Microbial Genetics and Breeding--Development of new vector systems in *Bacillus subtilis*. Restriction and modification in *B. subtilis*.

Division of Microbial Taxonomy--Taxonomic analysis of microbial strains in collection.

Division of Physiology--Microbial cell activity and fermentation physiology of several species.

Division of Enzyme Research--The mechanism of bacterial enzyme synthesis and its primary structure, structure and function of biomembranes.

Division of Antibiotics--New antibiotics. Studies on structure, biogenesis, and action of various antibiotics.

Division of Biosynthesis I--Photosynthesis and chloroplast development.

Division of Biosynthesis II--Biosynthetic pathways in growth and differentiation of microorganisms.

Division of Chemistry--Biosynthesis and chemical synthesis of biologically active metabolites.

Division of Biophysics--Theoretical and experimental studies on physical aspects of bacteria.

Division of Bioengineering--Process analysis of microbial growth and product formation, process design of reactor or fermentor and quantitative approach to energy conversion through biological membranes.

Division of Biological Activity--Investigation of action of antimicrobial and antitumor antibiotics.

UNIVERSITIES

There are two types of universities in Japan: the national universities and the private universities. The former, originally the imperial universities, have their origin in the Meiji Restoration of 1868 and were styled after the Prussian universities of the time. They became the national university system in the post-World War II era. The system is operated by the Ministry of Education, Science and Culture and all persons employed by the universities are government employees. Administration of universities generally is the responsibility of its professors and decisions are made by academic committees. The private universities, generally smaller, are more varied in scope and structure. Except where indicated otherwise, the comments that follow refer to the national universities.

Viewed from the point of view of biotechnology, departments concerned with basic research and departments concerned with applied research are distinctly separated. Frequently they are even located on separate campuses. Applied research oriented departments, such as departments of applied microbiology, or applied biochemistry are found in colleges of agriculture, in departments of chemical engineering, or in colleges of engineering. They carefully nurture their contacts with industry and try to anticipate industrial needs. Often the professors are important advisors to industry, and they maintain contact *via* their former students. Industrial leaders in turn depend upon their former professors to provide them with their best students for job vacancies. Most students in applied departments do not seek doctoral degrees because this will only delay their entry into a company hierarchy and they often do not consider the advantages of the advanced degree to be sufficient to overcome the career lag. For example, the applied biochemistry department of Tokyo University graduates 75 persons each year. About half of these go to graduate school, but about half of them will stop at the master's level. This is the most prestigous department in the country and its graduates are readily placed in such companies as Ajinomoto, Tanabe Seiyaku, or Kyowa Hakko.

In contrast to applied science departments, researchers in basic science departments take great pride in their independence. They are quick to announce that they do not carry out applied research, and would never comply with requests from industry or from government if the request impinged on their academic freedom. Professors in basic science departments do interact quite a bit with industry, but insist that it is "on their own terms" in the case of a project supported by a company, or "to further national goals" in the case of training company workers. The meaning of "on our own terms" is essentially limited to the right to refuse. Funds from companies to specific laboratories to support research or to compensate for training company workers cannot go directly to the laboratory to be spent at the investigator's discretion. Rather, such money goes to the university *via* the Ministry of Education. It can be used for supplies or equipment, but not for salaries which are not part of research budgets. The strict regulation of corporate funds to universities is a consequence of student influence, which has been a respected force in Japan since the 1960s. Professors at national universities are quick to state that they are forbidden from consulting because they are government employees. All scientists in Japan read *Science* and *Nature* and are familiar with the attention U.S. scientists have received in their relations with industry for personal gain. Japanese professors equate the word "consulting" with personal gain and do not consider their interactions with companies as consulting because the remuneration is channeled through the university and must be used for research-related items. Actually, many Japanese professors offer the same kinds of advice to companies as do their U.S. counterparts. Their remuneration is used not only for special research equipment and supplies, but also for the purchase of books or journals or for trips abroad. Of course, this is not the same as in the U.S. where consultant fees can be used for personal purposes. Japanese professors are not happy with the restrictions placed on their use of such funds. Similarly, until recently, professors at national universities were not permitted to own patents and collect royalties on inventions generated by their research, though their counterparts at private universities were allowed to do so. This was changed in 1981, but even now professors in basic science departments do not seem to be as patent conscious as their U.S. counterparts. On the other hand, Japanese professors enjoy much higher prestige and social status than do U.S. academics, and this status is highly valued. I did not meet a single academic who said he would exchange this status for the much higher material benefits offered by industry. This explains in part the extremely low mobility between universities and industry in Japan. Only after retirement (which is mandatory at age 60 in some universities and 62 in others) do professors go to industry.

The smallest academic organizational unit in Japanese universities is the "koza." It typically consists of a professor, an associate professor, and a research assistant or assistant professor. In some disciplines, the professor may have two associate and two assistant professors. The professor is responsible for teaching and research in his disciplinary area and uses the others in his unit in any appropriate way to carry out this responsibility. Each academic department has a number of kozas. Interactions in Japanese universities are of vertical not horizontal structure. Thus, members of a koza are a closely linked, highly interactive team; but there can be virtually no interaction between researchers in different research groups within the university.

The Ministry of Education provides support for academic research through two channels: (1) formula-based research funds, and (2) competitive research grants. The former is distributed to universities on the basis of the number and types of koza. The highest allocation per koza, from an experimental research unit in a medical school, is about $35,000 per year. This is intended to provide funds for minimal supplies and small equipment needs and to cover indirect costs. Additional support for research is channeled to the universities through investigator-initiated research grants. Proposals are evaluated by a two-tier peer review system, and these seem not to be influenced by industry pressure or needs. (But see the section above on the Ministry of Education, Science and Culture.) It is interesting to note that the national commitment to biotechnology has not resulted in any changes in the basic science departments with respect to the number of students accepted, the size of faculty, or the curriculum though there are pressures from students and industry for such changes. Again, this shows the independence of the universities' faculties.

The Ministry of Education budget allocations for academic research are presented below for the purpose of comparisons (NSF Tokyo Memo 16 and 24, see references). It was not possible to identify the proportion of the research budget that supports biotechnology-related research.

(Dollars in millions)

Fiscal Year	Formula-based Research Funds	Scientific Research Grants
1981	$445	$179
1982	454	190
1983 (estimated)	451	197.5

About 56% of the basic research in Japan is carried out in universities, with 15% in research institutes, and the remainder in corporate institutions. Support of basic research comprises about 21% of the total government R&D expenditure and basic research comprises about 5% of total corporate R&D expenditures.

INDUSTRY

Three types of companies are engaged in biotechnology-oriented activity in Japan:

- Large, fermentation-strong, diversified companies for whom adopting new biotechnology was a logical progressive step to maintain their competitive position. Examples are Ajinomoto, Kyowa Hakko and Meiji Seika,

- Companies that are cash-rich and are expanding into high growth, diversified areas of biotechnology as investments. Examples are Kao Soap Company, Kirin Brewery Company, and Suntory, Ltd.

- Companies that are now financially depressed and must seek new markets to restore their vitality. Examples are Asaki Chemical Industry Company, Mitsubishi Chemical Industries, and Sumitomo Chemical Company.

In Japan, biotechnology is being actively applied in companies that primarily manufacture chemicals, drugs, textiles, paper, pulp, foodstuffs, cosmetics, and electrical products as well as in companies engaged in refining oil and in engineering. While the range of opportunities for new ventures is much more restricted than in the West, Japanese financiers are aware of the role of venture capital and some of the cash-rich companies may even experiment with it as investments in the near future. Also, at the managerial level of some companies, modest enterpreneurial action is emerging. Thus, the first Japanese pharmaceutical companies to introduce recombinant DNA technology in their research were the Green Cross Corporation and the Hayashibara Company which entered into agreements with foreign companies to get the new technology, and Suntory, Ltd., which hired scientists from the U.S. to head their new departments.

To date, industrial application of the new biotechnologies in Japan is largely rooted in U.S. experiences. Several of the companies visited were primed to move in several directions, but the final commitment will not be made until there are signals from U.S. firms that a specific move is low risk and highly profitable. Such a signal was perceived in the case of interferon, touted as a wonder drug, and to which a number of prominent U.S. firms committed research funds. An unusually large number of Japanese firms followed by committing major research resources to interferon projects, hoping to get a competitive lead in the domestic or global markets. Now that much of the industrial research is completed, and interferon is given away for clinical research and its market potential is still undetermined, all Japanese firms that made major investments in interferon research say the project was undertaken merely as a learning experience in the new technologies.

Prior to the announcement of biotechnology as a MITI priority, a survey of corporate activity and plans was conducted by *Nikkei Sangyo Shimbun*, an industrial-oriented daily newspaper, which prints science pages three times each week. In this survey, conducted in June 1981, of the 132 companies that responded, 85 indicated they were engaged in or had plans to apply biotechnology in their research. These companies and some features of interest are listed below:

COMPANY	KEY TECHNOLOGIES	APPLICATIONS	1981 R&D BUDGET	NUMBER OF RESEARCH-ERS
Ajinomoto Company, Ltd.	Recombinant DNA, Immobilized Enzymes	Amino Acids, Food, Pharma-ceuticals	2 billion yen	150

Asahi Breweries, Ltd.	Recombinant DNA Immobilized enzymes, Monoclonal antibodies	Pharmaceuticals, food	---	40
Asahi Chemical Industry Company, Ltd.	Recombinant DNA	Pharmaceuticals, enzymes	---	---
Asahi Denka Kogyo KK	Semisynthetic enzymes, Immobilized enzymes	Chemicals, food	50 million yen	<10
Asahi Glass Company, Ltd.	To be chosen	To be chosen	---	---
Banyu Pharmaceutical Company, Ltd.	Recombinant DNA, monoclonal antibodies	Pharmaceuticals	---	---
Calpis Food Industry Company, Ltd	Semisynthetic enzymes, monoclonal antibodies	Pharmaceuticals	---	20
Chisso	Fermentation	Pharmaceuticals	50 million yen	10
Dainippon Ink and Chemicals, Inc.	Fermentation, recombinant DNA, monoclonal antibodies	Agricultural chemicals, specialty chemicals, pharmaceuticals	100 million yen	<10
Disai Company, Ltd.	Recombinant DNA, monoclonal antibodies, cell culture	Pharmaceuticals, veterinary medicine instrumentation	---	---
Godo Shusei, Ltd.	Immobilized enzymes	Ethylalcohol biomass transformation	100 million yen	20
Green Cross Recombinant DNA	Cell culture,	Pharmaceuticals	3 billion yen	---Corporation
Hayashibara	Cell culture, Immobilized enzymes	Pharmaceuticals	1 billion yen	120
Hitachi Shipbuilding and Engineering Company	Bioreactors	Environment	---	---

Hokko Chemical Industry Company	Recombinant DNA	Pharmaceuticals	---	---
Hokido Sugar Company	---	Sugar, enzymes	40 million yen	6
Idemitsu Kosan	Cell fusion, recombinant DNA	Biomass energy, chemicals	100 million yen	---
Japan Maize Products Company, Ltd.	Immobilized enzymes	Food, pharmaceuticals	---	---
JCC Corporation	Immobilized microbes	Energy	100 million yen	<10
Jujo Paper Company, Ltd.	Semisynthetic enzymes	Food, pharmaceuticals	---	6
Kao Soap Company, Ltd.	Recombinant DNA, immunizing enzymes, monoclonal antibodies	Food, chemicals	500 million yen	40
Kanebo, Ltd.	Immobilized enzymes, cell culture, monoclonal antibodies	Pharmaceuticals, diagnostics	40 million yen	10
Kanegafuchi Chemical Industry	Recombinant DNA, fermentation	Pharmaceuticals	---	400
Kansai Paint Company, Ltd.	Immobilized enzymes	Chemicals, specialty chemicals	---	5
Kikkoman Corporation	Fermentation, recombinant DNA, semisynthetic enzymes	Food, pharmaceuticals	800 million yen	40
Kirin Brewery Company, Ltd.	Recombinant DNA, cell culture, monoclonal antibodies	Food	50 million yen	170
Kojin	Recombinant DNA, semisynthetic enzymes	Pharmaceuticals, chemicals	100 million yen	20
Kumiai Chemical Industry Company	Cell wall dissolving enzymes	Enzymes, agricultural chemicals	---	5

Kuraray Company, Ltd.	Recombinant DNA	Agricultural chemicals, pharmaceuticals	150 million yen	5
Kyowa Hakko Kogyo Company, Ltd.	Recombinant DNA, biomass conversion fermentation, immobilized yeast cell culture, monoclonal antibodies	Agricultural chemicals, energy, food pharmaceuticals	800 million yen	90
Lion Corporation	Recombinant DNA, immobilized enzymes, monoclonal antibodies	Agricultural chemicals, energy, enzymes, food	900 million yen	100
Matsushita Electric, Ltd.	Biomass conversion, immobilized enzymes	Methane, biosensors	300 million yen	3
Meiji Milk Product Company, Ltd.	Recombinant DNA	Food, pharmaceuticals	---	20
Meiji Seika Kaisha, Ltd.	Fermentation, recombinant DNA, monoclonal antibodies, immobilized enzymes	Agricultural chemicals, enzymes, pharmaceuticals	200 million yen	30
Meito Sanyo, Ltd.	Fermentation	Enzymes	---	---
Mitsui Engineering and Shipbuilding Company	Fermentation	Environmental control, food, instrumentation control, food	---	7
Mitsui Petrochemical, Ltd.	Biomass conversion fermentation, monoclonal antibodies, cell culture	Agriculture, energy, pharmaceuticals	200 million	10
Mitsui Chemicals, Inc.	Cell culture	Pharmaceuticals, single cell protein	---	---
Mitsubishi Chemical Industries, Ltd.	Semisynthetic enzymes, monoclonal antibodies, immobilized enzymes, recombinant DNA	Chemicals, diagnostics, food, pharmaceuticals, reagents	2.5 billion yen	25

Mitsubishi Petro-chemical	Fermentation, recombinant DNA cell culture, mono-clonal antibodies	Reagents, phar-maceuticals, diagnostics, agricultural chemicals	---	---
Mitsubishi Rayon	Immobilized enzymes	Specialty chemicals	30 million yen	4
Miyoski Oil and Fat Company, Ltd.	Immobilized enzymes	Lipids	20 million yen	3
Mochida Pharma-ceutical Company, Ltd.	Monoclonal antibodies, cell culture	Diagnostics, enzymes, instruments, pharmaceuticals	---	---
Morinaga and Company, Ltd.	Monoclonal antibodies, recombinant DNA	Agricultural chemicals, diagnostics, food, pharama-ceuticals	200 million yen	30
New Japan Chemical Company, Ltd.	Fermentation	Chemicals, food	700 million yen	---
Nippon Kayaku Company, Ltd.	Recombinant DNA, immobilized enzymes	Agricultural chemicals, pharmaceuticals	30 million yen	---
Nippon Oil Company, Ltd.	Immobilized bacteria, fermentation	Energy, pharma-ceuticals	200 million yen	---
Nippon Paint Company, Ltd.	Cell culture, recombinant DNA	Specialty chemicals, pharmaceuticals	10 million yen	5
Nippon Shokubai Kagaku Kogyo	Recombinant DNA,	Chemicals	---	5
Nippon Soda Company, Ltd.	Recombinant DNA, fermentation	Chemicals, phar-maceuticals	---	5
Nitto Boseki, Ltd.	Immobilized enzymes	Diagnostics, enzymes	50 million yen	5

Oji Paper Company, Ltd.	Monoclonal antibodies, cell culture, recombinant DNA	Forestry	---	---
Orient Yeast Company, Ltd.	Immobilized enzymes, monoclonal antibodies	Enzymes, reagents	---	---
Otsuka Pharmaceutical Company	Monoclonal antibodies	Pharmaceuticals	6 billion yen	30
Riken Vitamin Company, Ltd.	Fermentation	Food	---	---
Sankyo Company, Ltd.	Monoclonal antibodies, recombinant DNA	Enzymes, pharceuticals	---	---
Samaku Ocean Company, Ltd.	Immobilized enzymes, recombinant DNA, monoclonal antibodies	Pharmaceuticals, reagents, veterinary medicine	400 million yen	60
Sapporo Breweries, Ltd.	Monoclonal antibodies cell culture	Food, agriculture	20 million yen	10
Sankyo Chemical Industries, Ltd.	Immobilized enzymes	Reagents	75 million yen	---
Sanyo Kokusaku Pulp Company, Ltd.	Cell culture, immobilized enzymes	Chemicals, energy, forestry	50 million yen	4
Seitetsu Kagaku Company, Ltd.	Recombinant DNA,	Pharmaceuticals, fermentation	20 million yen	10
Sekisui Plastic Company, Ltd.	Fermentation	Environmental	---	---
Shionogi Company, Ltd.	Recombinant DNA, immobilized enzymes, monoclonal antibodies	Pharmaceuticals, reagents	100 million yen	---

Showa Dneko KK	Recombinant DNA, fermentation, semisynthetic enzymes	Agriculture, pharmaceuticals	---	10
Showa Brand Milk Products	Immobilized enzymes, fermentation, semisynthetic enzymes	Food, pharma-ceuticals	10 billion yen	100
Sumitomo Chemical Company, Ltd.	Monoclonal antibodies bioreactors, recombinent DNA, cell culture	Agricultural chemicals, pharmaceuticals	2.5 billion yen	60
Sunstar, Inc.	Cell culture, monoclonal antibodies	Health care pharmaceuticals	250 million yen	---
Suntory	Immobilized enzymes, recombinant DNA	Food, pharma-ceuticals	---	60
Taito Company, Ltd.	Fermentation	Food, pharma-ceuticals	---	---
Takeda Chemical Industries, Ltd.	Monoclonal antibodies, cell culture, recombinant DNA	Food, pharma-ceuticals	---	---
Takii Seeds and Plants	Cell fusion	Plant breeding	15 million yen	3
Tanabe Seiyaku Company, Ltd.	Immobilized bacteria	Energy, pharma-ceuticals	---	---
Teijin, Ltd.	Recombinant DNA, fermentation cell culture	Pharmaceuticals	---	---
Tokyo Tanabe Company, Ltd.	Immobilized enzymes	Pharmaceuticals	---	10
Toray Industries, Inc.	Recombinant DNA	Pharmaceuticals	---	---
Toyo Engineering	Fermentation	Cellulose processing plant	100 million yen	3
Toyo Jozo Company, Ltd.	Cell culture, recombinant DNA	Pharmaceuticals	---	30

Toyo Soda Manufacturing Company, Ltd.	Immobilized enzymes, recombinant DNA	Food, instrumentation, pharmaceuticals, reagents, specialty chemicals	350 million yen	30
Unitika, Ltd.	Immobilized enzymes	Bioreactors, chemicals, pharmaceuticals, reagents	350 million yen	20
Yakult Honsha Company, Ltd.	Recombinant DNA	Foods, pharmaceuticals	---	5
Yamanouchi Pharmaceutical Company	Semisynthetic enzymes, monoclonal antibodies, recombinant DNA	Pharmaceuticals	---	---
Yoshitomi Pharmaceuitical Industries, Ltd.	Recombinant DNA	Pharmaceuticals	---	---

In August of 1982, MITI conducted a survey to which 200 corporations responded, 157 of which indicated they were engaged in biotechnology activity (Tanaka, see references). The profile of Japanese industry that follows is based on this survey.

- Distribution of Biotechnology Activity by Industry

In terms of numbers of corporations using biotechnology, the chemical industry was the most active, but in terms of the ratio of firms engaged in biotechnology, the food industry is the most active. The distribution of activity is summarized in the following table.

Research	Medical Drug	Chemical	Textile, Paper & Pulp	Food	Others	All Industries Total
In progress	23 (77)	60 (79)	13 (81)	30 (91)	31 (69)	157 (79)
Planned	5 (17)	4 (5)	0	2 (6)	1 (2)	12 (6)
No plans	2 (7)	12 (16)	3 (19)	1 (3)	13 (29)	31 (16)
Number of respondent firms	30 (100)	76 (100)	16 (100)	33 (100)	45 (100)	200 (100)

Note: Figures in ( ) indicate ratio to total respondent firms (%).

- Research Expenditures for biotechnology

Expenditures for corporate biotechnology research increased about 20% in FY81 and FY82, which is roughly double the rate of increase of total research expenditures. The total expenditures for FY80, 81, and 82 distributed by industry are summarized in the following table.

Total Research Expenditures and Biotechnology Research Expenditures

Unit: ¥1 million

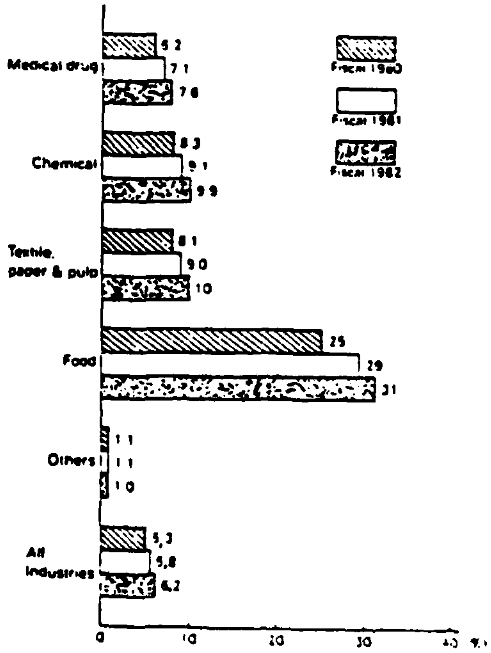
Fiscal Year	Medical Drug: Total research expenditures	Medical Drug: Biotechnology research expenditures	Chemical: Total research expenditures	Chemical: Biotechnology research expenditures	Textile, Paper & Pulp: Total research expenditures	Textile, Paper & Pulp: Biotechnology research expenditures
1980	77,417	4,831	161,562	13,616	50,898	4,131
1981	80,993 (4.6)	5,711 (18.2)	176,394 (9.2)	15,912 (16.9)	56,570 (11.1)	5,090 (23.2)
1982	90,063 (11.2)	6,860 (20.1)	193,046 (10.7)	19,113 (20.1)	61,212 (8.2)	6,123 (20.3)

Fiscal Year	Food: Total research expenditures	Food: Biotechnology research expenditures	Others: Total research expenditures	Others: Biotechnology research expenditures	All Industries (Total): Total research expenditures	All Industries (Total): Biotechnology research expenditures
1980	27,734	6,979	308,351	3,502	625,962	33,059
1981	32,668 (17.8)	9,318 (33.5)	346,737 (12.4)	3,873 (10.6)	693,362 (10.8)	39,904 (20.7)
1982	38,352 (17.4)	11,920 (27.9)	390,795 (12.7)	3,837 (Δ1.7)	773,468 (11.6)	47,823 (19.8)

Note: 1. These figures represent tabulation of replies from 112 firms.
(medical drug 12, chemical 47, textile, paper & Pulp 9, food 22 and other industries 22).
2. Figures in ( ) show increases over the preceding fiscal year.

The ratio of biotechnology research expenditures to total research expenditure is 5.3%, 5.8%, and 6.2% in FY80, FY81, and 82 respectively, showing a trend of increasing corporate commitment to biotechnology. The distribution of this ratio by industry is shown below, illustrating a steady growth trend even more emphatically for the major industries.

Ratio of Biotechnology Research Expenditures to Total Research Expenditures



Total research expenditures by Japanese corporations in 1980 was 3,142.3 billion yen according to a report on *Science and Technology* put out by the Bureau of Statistics of the Prime Minister's Office. The MITI survey indicates biotechnology research expenditures for 1980 were 33.1 billion yen. Therefore, we can assume that in that year the corporate expenditures for biotechnology research was about 1% of total corporate research expenditures.

Tallying the replies to the MITI survey according to the size of the biotechnology research investment in 1982 reveals that almost half of the companies budgeted less then 100 million yen for such research and only 9% of the companies budgeted more than a billion yen for biotechnology research. The distribution is shown below.

Breakdown of Biotechnology Research Expenditure
by Scale (FY1982)

Expenditure (million yen)	Number of Companies	%
100	61	48
100 ~ 500	38	30
500 ~ 1,000	16	13
1,000 ~	12	9
Total Replies	127	100

The FY 1982 expenditure of funds per researcher as distributed by industry and size of research budget is shown in the table below. (One million yen is about $4,000 U.S.)

Biotechnology Research Expenditures per Researcher (Fiscal 1982)

Unit: Number of Firm

Biotechnology expenditures per researcher (Unit: ¥1million)	Medical Drug	Chemical	Textile Paper & Pulp	Food	Others	All Industries Total
Up to 5	2 (13)	5 (11)	1 (11)	4 (16)	8 (31)	20 (16)
5 up to 10	5 (33)	14 (30)	3 (33)	10 (40)	6 (23)	38 (31)
10 up to 20	4 (27)	26 (55)	5 (55)	10 (40)	11 (42)	56 (46)
Over 20	4 (27)	2 (4)	0 (0)	1 (4)	1 (4)	8 (7)
Total	15 (100)	47 (100)	9 (100)	25 (100)	26 (100)	122 (100)

Note: Figures in ( ) show share in industry (%).

- Research Manpower

The number of researchers in the private sector engaged in biotechnology research increased 14.6% from FY 80 to 81 and 12.2% from FY 81 to 82. This is approximately a fourfold increase over the incremental rate for total researchers in the private sector in that period. The distribution of researchers by industry is summarized below.

Total Researchers and Biotechnology Researchers

Unit: Persons

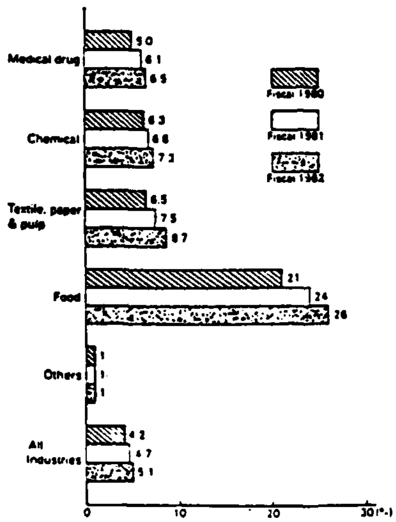
Fiscal Year	Medical Drug: Total researchers	Medical Drug: Biotechnology researchers	Chemical: Total researchers	Chemical: Biotechnology researchers	Textile, Paper & Pulp: Total researchers	Textile, Paper & Pulp: Biotechnology researchers
1980	7,670	382	20,027	1,271	6,405	415
1981	7,996 (4.3)	484 (26.7)	20,988 (4.8)	1,435 (12.9)	6,600 (3.0)	498 (20.0)
1982	8,351 (4.4)	541 (11.8)	21,686 (3.3)	1,593 (11.0)	6,768 (2.5)	588 (18.1)

Fiscal Year	Food: Total researchers	Food: Biotechnology researchers	Others: Total researchers	Others: Biotechnology researchers	All Industries (Total): Total researchers	All Industries (Total): Biotechnology researchers
1980	3,608	770	38,386	378	76,096	3,216
1981	3,764 (4.3)	891 (15.7)	39,501 (2.9)	379 (0.3)	78,849 (3.6)	3,687 (14
1982	3,984 (5.8)	1,014 (13.8)	40,836 (3.4)	402 (6.1)	81,625 (3.5)	4,138 (12..

Note: 1. These figures represent tabulation of replies from 120 firms.
(medical drug 14, chemical 49, textile, paper & pulp 9, food 24 and other industries 24).
2. Figures in ( ) show increases over the preceding fiscal year (%).

The ratio of number of researchers involved in biotechnology research to the total number of corporate researchers was 4.2%, 4.7%, and 5.1% in FY 80, 81, and 82 respectively. The distribution of this ratio by industry is shown below and even more emphatically illustrates the increasing commitment to biotechnology in the major Japanese industries.

Ratio of Biotechnology Researchers to Total Number of Researchers



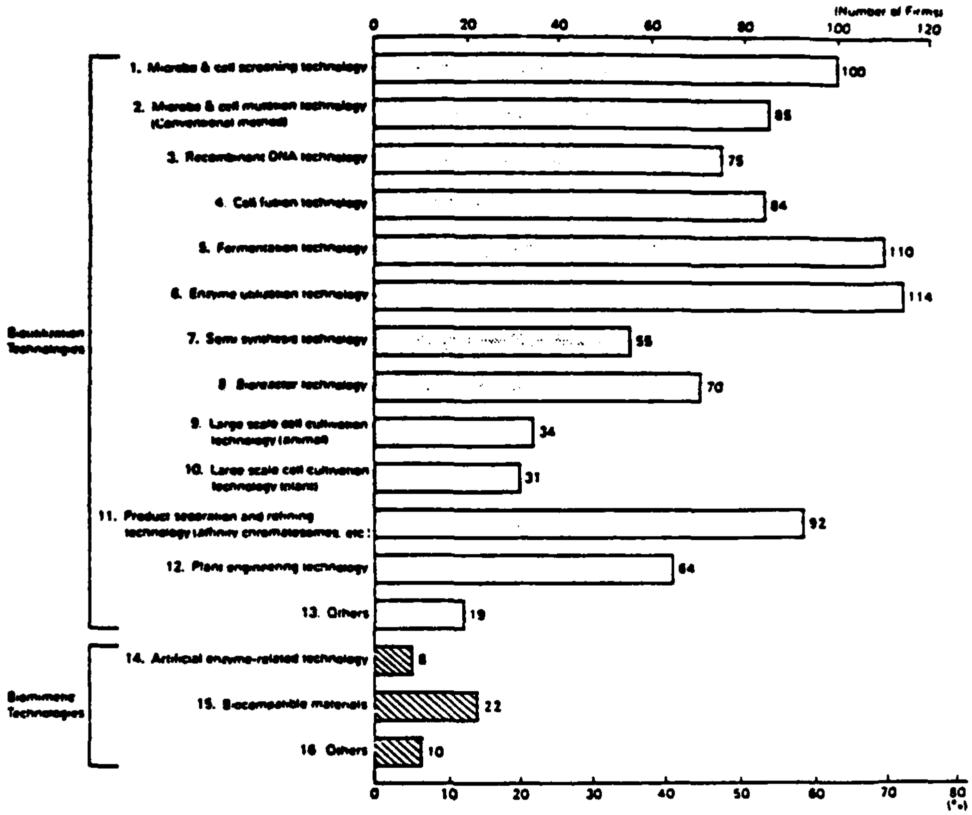
Tallying the replies to the MITI survey according to the number of researchers engaged in biotechnology research in 1982 reveals that 41% of the responding companies employed less than ten researchers while 17% of the responding companies employed more than 50 researchers.

Number of Researchers	Number of Companies	%
∿ 10	57	41
10 ∿ 20	30	22
20 ∿ 50	28	20
50 ∿	24	17
Total Replies	139	100

- **Types of Biotechnology Used in Industry**

The types of biotechnologies used in the research of the companies that responded to the MITI survey are shown below. Over 70% of the companies used enzyme and fermentation technology, over 60% exploited microbial and cell screening techniques, and over 50% reported the use of mutagenesis and cell fusion techniques. Thus, most of the industrial biotechnology research reported in 1982 can be classified as conventional biotechnology, and is not based upon discoveries of the previous ten years. It should be noted that the 1981 announcement of MITI priority areas attempts to promote the newer technologies.

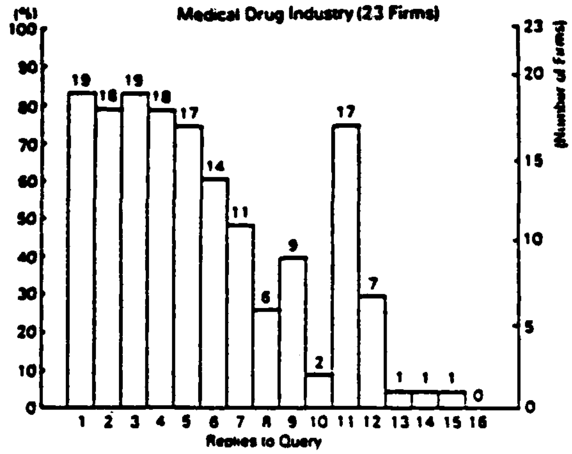
Specific Field of Biotechnology Research (157 Respondent Firms, Including Duplicate Replies)

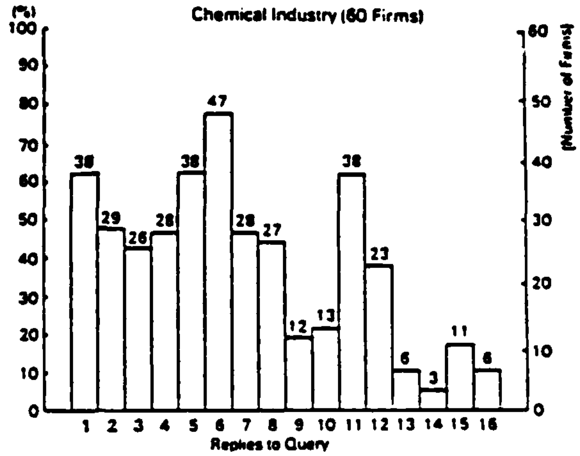


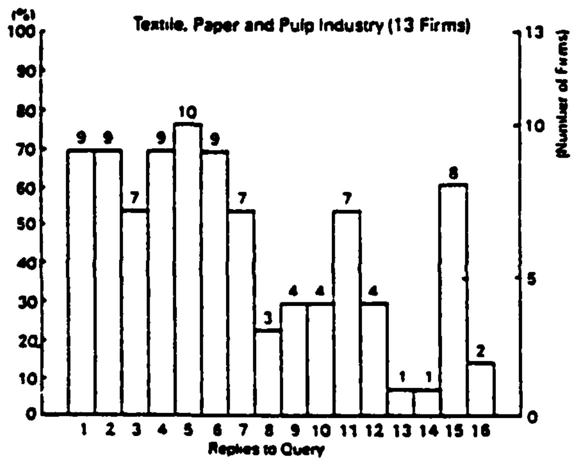
The distribution of the types of techniques used within each industry are shown below. Note that the proportion of companies that employ recombinant DNA techniques is greater in the drug industry than in the other industries. This is the same pattern as in the U.S. and largely reflects the fact that the linkage between basic research and the production of a drug, particularly if it is a peptide or gene product, is shorter than the R&D linkage connecting basic research and the final product of other industries. Note also that in the chemical industry, the most widely used technologies are enzyme utilization, fermentation, microbial screening, and separation techniques. This reflects the strong interaction between the chemical companies and university departments of applied microbiology (or applied biochemistry) referred to earlier.

Technological Fields Under Research (By Industries)

Notes:
1 Number of firms in ( ) indicates total number of respondent firms.
2 Number at top of bar shows number of respondent firms
3 Vertical axis shows ratio of respondent firms to total respondent firms (%)







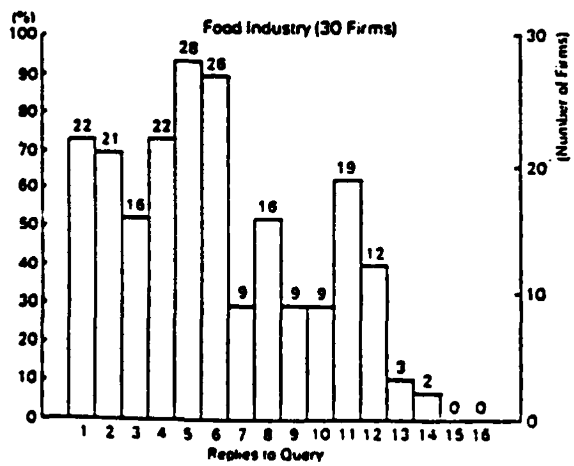
● Replies to Query on Technological Fields Under Research

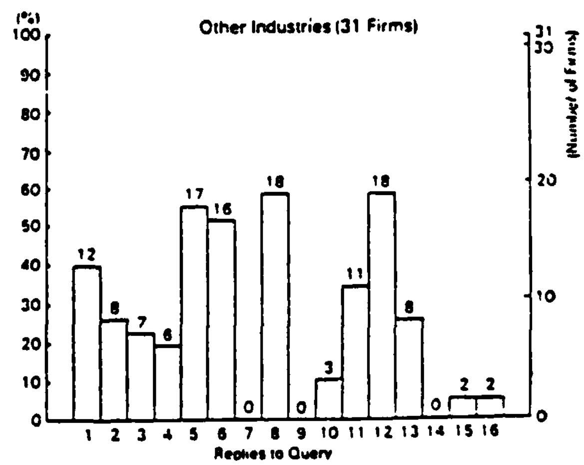
Bioutilization Technologies

1 Microbe and cell screening technology
2. Microbe and cell mutation technology (Conventional method)
3. Recombinant DNA technology
4 Cell fusion technology
5. Fermentation technology
6 Enzyme utilization technology
7. Semi synthesis technology
8. Bioreactor technology
9 Large scale cell cultivation technology (Animal)
10 Large scale cell cultivation technology (plant)
11 Product separation and refining technology (Affinity chromatosome, etc.)
12. Plant engineering technology
13 Others

Biomimetic technology

14 Artificial enzyme-related technology
15 Biocompatible materials
16 Others

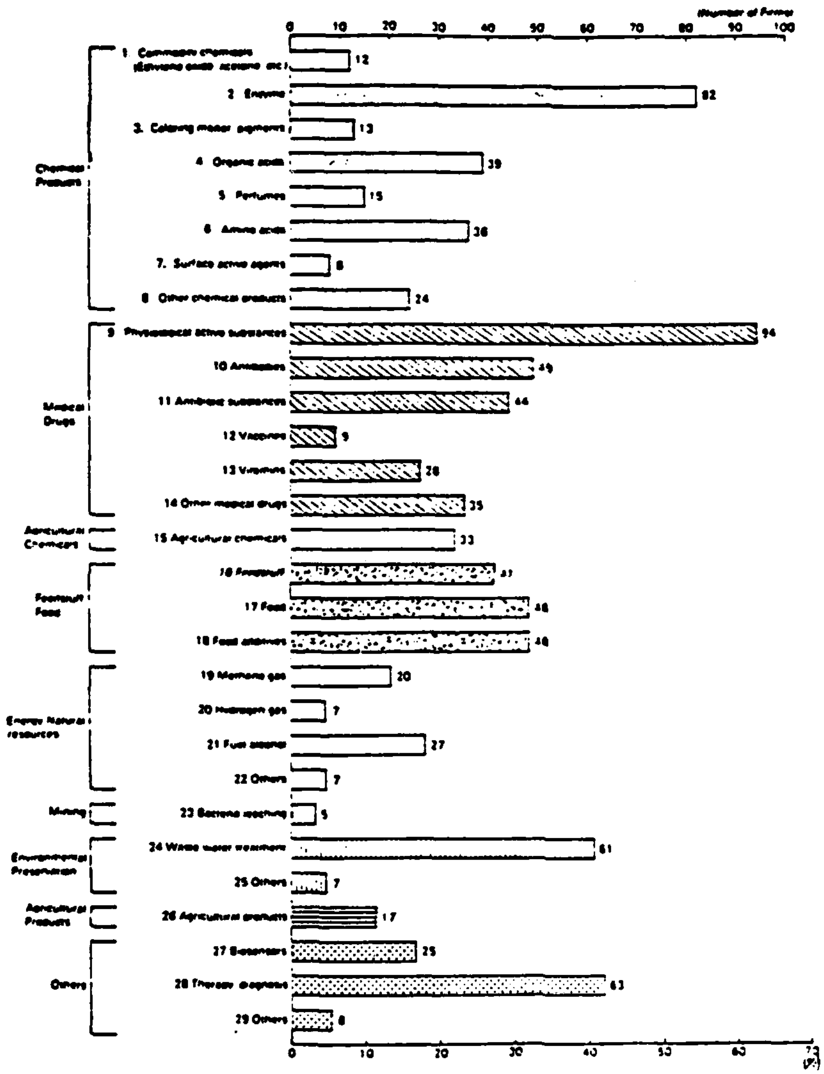




- **Industrial Products of Biotechnology**

At the time of the MITI survey about one-third of the products being developed were drugs and about one-quarter were chemical products. The applications of all other areas of biotechnology R&D was much less. The distribution is shown below.

Fields of Application Under Research (155 Respondent Firms, Including Duplicate Replies)



The distribution of these applications within each industry is shown below.

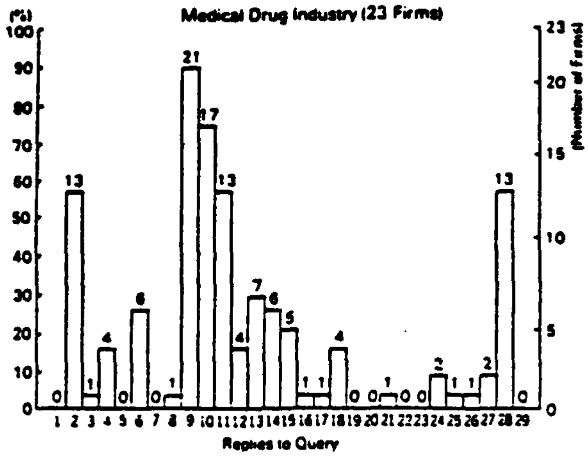
Fields of Apprications Under Research (By Industries)

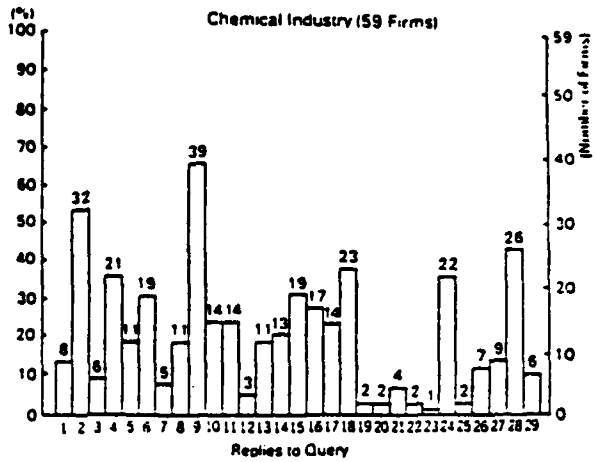
Notes:

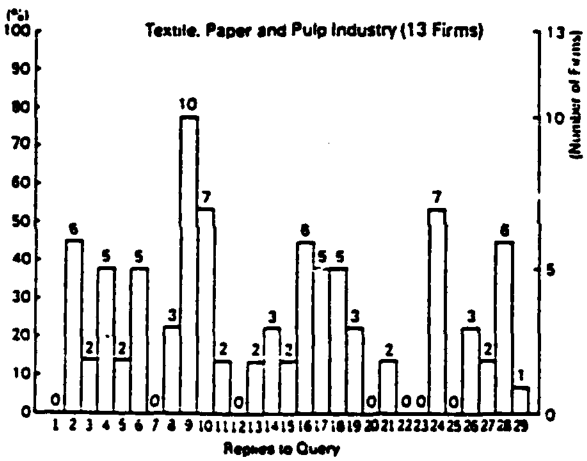
1 Number of firms in ( ) indicates total number of respondent firms.

2 Number at top of bar shows number of respondent firms.

3 Vertical axis shows ratio of respondent firms to total respondent firms (%).







● Replies to Query on Fields of Application Under Research

Chemical products
1. Commodity chemicals (Ethylene oxide, acetone, etc.)
2. Enzyme
3. Coloring matter, pigments
4. Organic acids
5. Perfumes
6. Amino acids
7. Surface active agents
8. Other chemical products

Medical drugs
9. Physiological active substances
10. Antibodies
11. Antibiotic substances
12. Vaccines
13. Vitamins
14. Other medical drugs

Agricultural chemicals
15. Agricultural chemicals

Feedstuff, food
16. Feedstuff
17. Food
18. Food additives

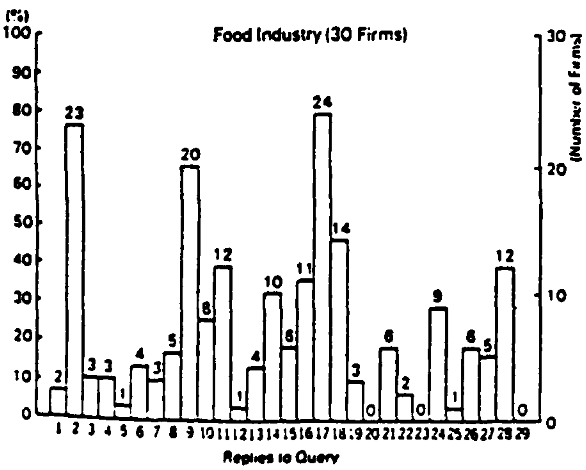
Energy·Natural resources
19. Methane gas
20. Hydrogen gas
21. Fuel alcohol
22. Others

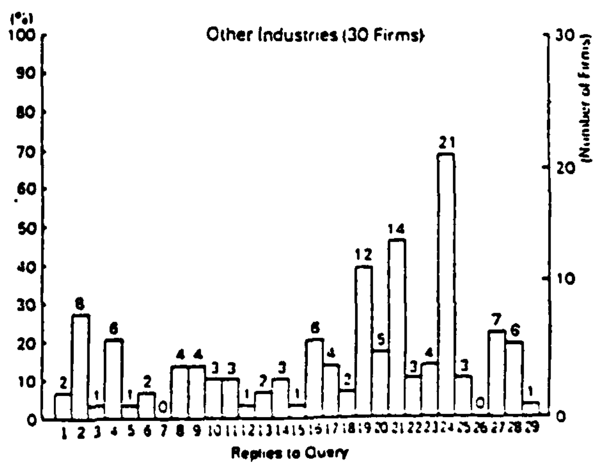
Mining
23. Bacteria leaching

Environmental preservation
24. Waste water treatment
25. Others

Agricultural products
26. Agricultural products

Others
27. Biosensors
28. Therapy, diagnosis
29. Others



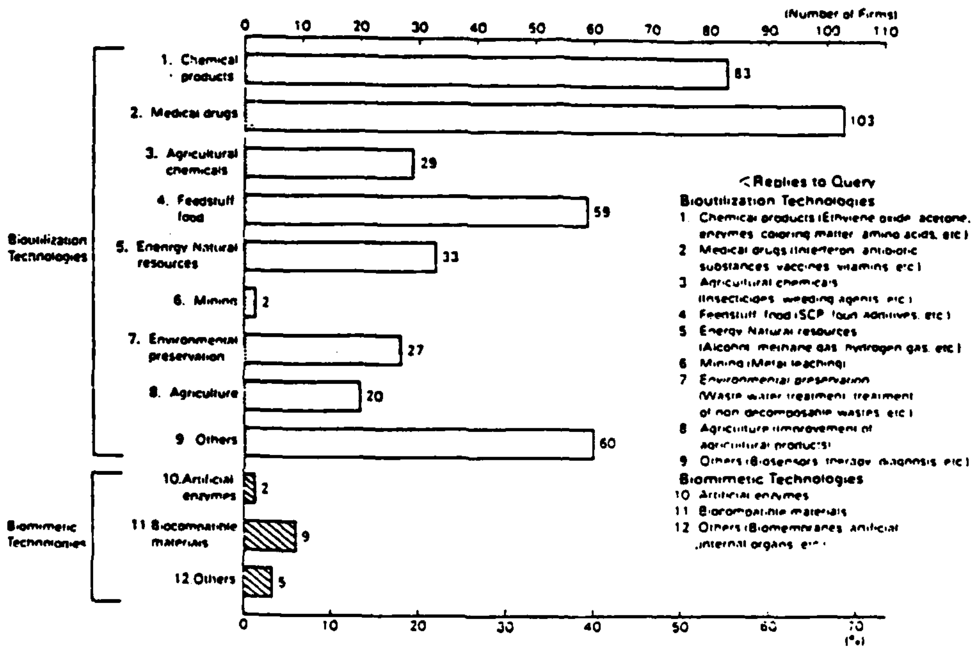


Among the chemical products, 53% of the companies are engaged in research on enzyme production, about 20% of the companies are doing research on organic acids and on amino acids, but very few companies view biotechnology as a means of producing commodity chemicals at this time at the research level. Among the medical drug products, about 60% of the companies are doing research on physiologically active substances and about 30% of all companies are interested in antibodies and antibiotics.

- Projected Industrial Priorities

One of the questions included in the MITI survey concerned priority areas of biotechnology applications in the next five to ten years. Over 65% of the responding companies put drugs on their priority list, about 55% listed chemicals and almost 40% included food and foodstuff. The responses are summarized below.

Future Fields of Priority Research (153 Respondent Firms, Including Duplicate Replies)

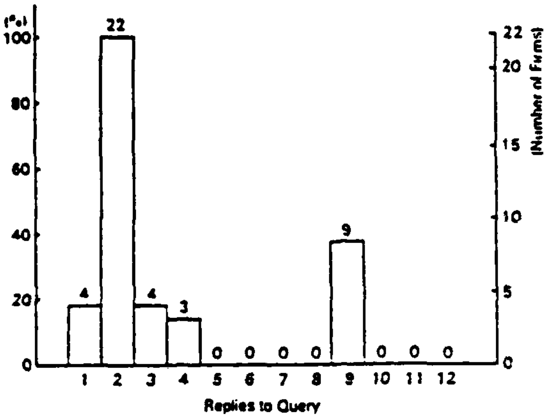


When the responses are tallied according to industry, it can be seen that the drug companies are planning to use biotechnology primarily for the drug market. A few of them, however, plan to move into other markets, specifically chemicals and foodstuffs. Corporations that are identified primarily as belonging to the chemical industry are more versatile and include in their plans priority research in the areas of drugs, diagnotics, biosensors, and foodstuffs. This may be a reflection of the fact that the chemical industry is one that MITI feels is in need of revitalization. The same observation might be made of the textile and food industries. It is interesting to note that within the food industry more corporations are planning priority research on drug production than on food products.

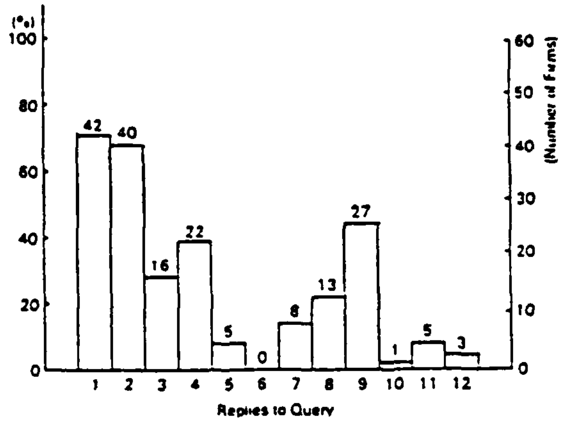
Future Fields of Major Research (By Industries)

Notes:
1. Number of firms in ( ) indicates total number of respondent firms.
2. Number at top of bar shows number of respondent firms.
3. Vertical axis shows ratio of respondent firms to total respondent firms (%).

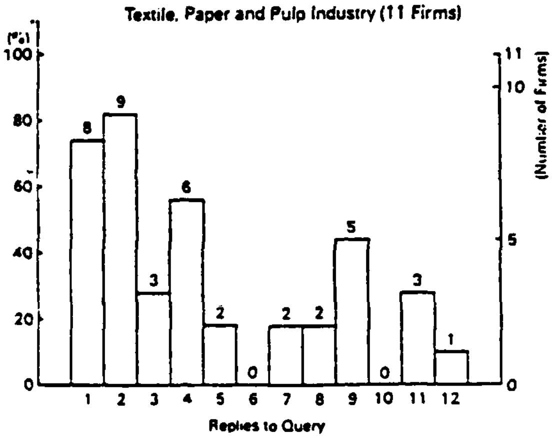
Medical Drug Industry (22 Firms)



Chemical Industry (60 Firms)



Textile, Paper and Pulp Industry (11 Firms)



<Replies to Query>

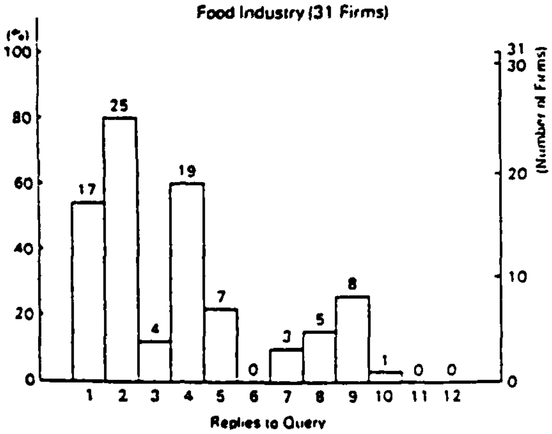
Bioutilization Technologies

1. Chemical products (Ethylene oxide, acetone, enzymes, coloring matter, amino acids, etc.)
2. Medical drugs (Interferon, antibiotic substances, vaccines, vitamins, etc.)
3. Agricultural chemicals (Insecticides, weeding agents, etc.)
4. Feedstuff, food (SCP, food additives, etc.)
5. Energy Natural resources (Alcohol, methane gas, hydrogen gas, etc.)
6. Mining (Metal leaching)
7. Environmental preservation (Waste water treatment, treatment of non-decomposable wastes, etc.)
8. Agriculture (Improvement of agricultural products)
9. Others (Biosensors, therapy, diagnosis, etc.)

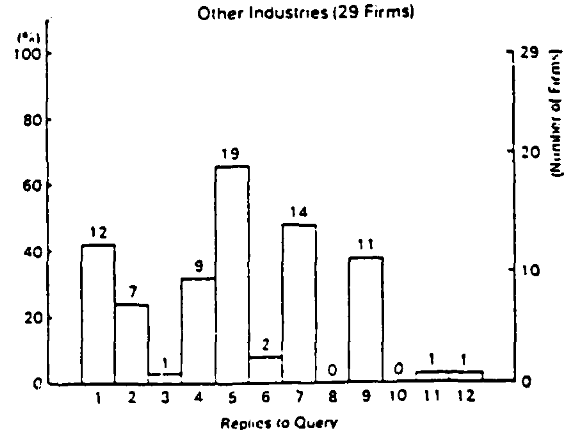
Biomimetic Technologies

10. Artificial enzymes
11. Biocompatible materials
12. Others (Biomembranes, artificial internal organs, etc.)

Food Industry (31 Firms)



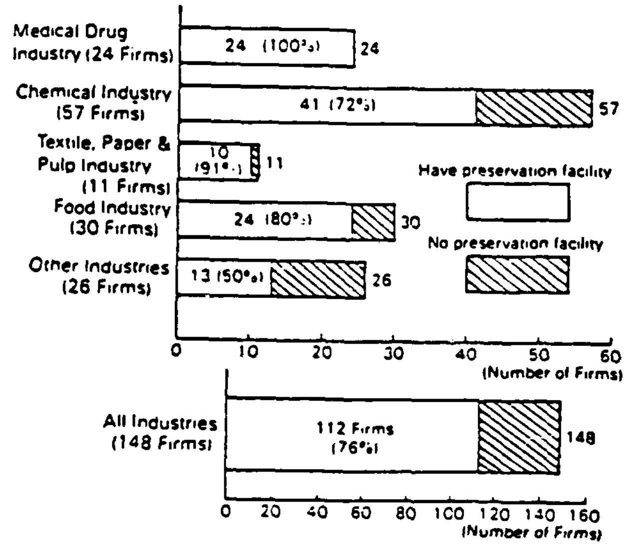
Other Industries (29 Firms)



- Preservation of Microbial Germplasm

It was mentioned earlier that the Japanese place a great deal of importance on the collection and preservation of microbial germplasm. This observation is further emphasized by the fact that the MITI survey included questions about such collections. The Japanese maintain large type culture collections and but they do not have much interest in preserving mutant cell lines. The large national collections are at the Institute of Applied Microbiology at the University of Tokyo (*ca.* 3500 strains), The Institute of Fermentation in Osaka (*ca.* 8000 strains) and the Fermentation Research Institute in Tsukuba (*ca.* 5600 strains). The indicated size of the collections are 1982 figures. The first two facilities sell strains to the public, the last facility is a depository for patented microbial strains. In spite of the fact that a large number of strains are available from the national collections, 112 companies of 148 respondents indicated they have their own collections. Perhaps this is for proprietary reasons. The distribution of these by industry is shown below.

Facilities for Preservation of Microbes and Cells
(148 Respondent Firms)

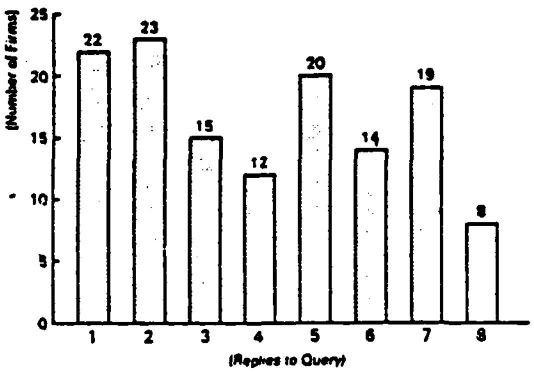


Twelve of the companies had collections larger than 5000 strains (representatives of up to 500 species) and thirty of the companies maintain collections between 1000 and 4999 strains.

- International Interactions

The MITI survey included several questions inquiring about interactions with foreign companies. Sixty out of 157 companies or 38% indicated some sort of interaction with foreign firms. The types of interaction and the number of companies engaged in each type are shown below.

Form of Participation in International Cooperation (60 Respondent Firms, Including Duplicate Replies)



Replies to Query
1. Information exchange.
2. Personnel interchange (dispatch and reception of researchers).
3. Joint research
4. Investment (establishment of new company independently or by joint investment, etc.).
5. Technology import (exclusive license or Non-exclusive license know-how, microbe and cell stock, etc.).
6. Technology export (exclusive license or Non-exclusive license know-how, microbe and cell stock, etc.).
7. Agreements on manufacture and/or sale.
8. Others.

These interactions with foreign companies are independent of the size of the responding company. This is seen in the following table in which the respondents are classified by size.

Situation of Participation in International Cooperation (By Corporate Scale)

Unit: Number of Respondent Firms

Capital (Unit: ¥1 Billion) \ Reply	1	2	3	4	5	6	7	8	Number of Respondent Firme
Up to 1	5 (50%)	5 (50%)	1 (10%)	2 (20%)	2 (20%)	3 (30%)	4 (40%)	2 (20%)	10 (100%)
1 up to 5	3 (23%)	4 (31%)	4 (31%)	1 (8%)	6 (46%)	4 (31%)	6 (46%)	0	13 (100%)
5 up to 10	5 (50%)	3 (30%)	2 (20%)	0	3 (30%)	0	3 (30%)	1 (10%)	10 (100%)
10 up to 30	3 (21%)	4 (29%)	4 (29%)	7 (50%)	3 (21%)	4 (29%)	4 (29%)	2 (14%)	14 (100%)
Over 30	6 (50%)	7 (58%)	4 (33%)	2 (17%)	6 (50%)	2 (17%)	2 (17%)	3 (33%)	12 (100%)
Total Replies	22 (37%)	23 (39%)	15 (25%)	12 (20%)	20 (34%)	13 (22%)	19 (32%)	8 (14%)	60 (100%)

Note: Duplicate replies included.

Replies to Query
1. Information exchange.
2. Personnel interchange (dispatch and reception of researchers).
3. Joint research.
4. Investment (establishment of new company independently or by joint investment, etc.).
5. Technology import (exclusive license or Non-exclusive license know-how microbe and cell stock, etc.).
6. Technology export (exclusive license or Non-exclusive license know-how microbe and cell stock, etc.).
7. Agreements on manufacture and/or sale.
8. Others.

- Patents

The distribution of biotechnology patents is shown below. Most of the patents (65.5%) are owned by the nine companies with the largest research budgets.

Breakdown of Registered Biotechnology Patents
by Number of Companies

Number of Registered Patents (total biotechnology)	Number of Companies
~ 10	88
10 ~ 50	30
50 ~ 100	8
100 ~	9

Number of Companies	Number of Registered Patents	Share (%)
upper 9 companies	2,822	65.5
126 other companies	1,422	34.5
Total replies 135	4,244	100.0

DYNAMIC ASPECTS AND INFRASTRUCTURE

PLANNING

Does Japan have a grand strategy for developing and commercializing biotechnology? What was the planning process that catapulted biotechnology to a "national" priority?

In America, one often hears that Japan's economic policy is determined largely to achieve an advantage in international competition. When national goals are identified that enhance this policy, then government uses its power to bring the private sector and academia together to promote those national goals. This is sometimes facetiously referred to as "Japan Incorporated." Is this perception accurate? Yes, and no.

In Japan, individuals and institutions do accept as a responsibility the promotion of national goals to a much greater degree than in most societies. But this is cultural and is not demanded by government decree. At present, it is not apparent that government wields its power to coerce industry or academia. To the contrary, in interactions between the sectors government often appears to be a benign partner providing priming funds or logistics and industry seems to be the strong partner while academia protects its independence. It was industrial leaders of major Japanese chemical companies that became alarmed at the burst of biotechnology activity in the U.S. and brought their concerns to MITI whose response was to quickly develop a plan for biotechnology as a priority area. A MITI plan extended to biotechnology the types of ideas that had been developed for other new technologies. The plan was rapidly and globally publicized and developed an aura of being Japan's grand strategy for biotechnology. In essence, the plan was a list of very general goals, not a carefully crafted scheme indicating awareness of obstacles or an attempt to promote anything other than the extrapolation of on-going lines of research. Subsequently, the plan will be filled in. As in most Japanese plans, projections were made for a ten-year period, but these are general and conservative.

Should the plan announced by MITI be viewed as Japan's national plan? While it is true that MITI is a strong ministry, its plans are not imposed on other ministries and cannot be viewed as central plans of the government. The Ministry of Agriculture, Forestry and Fisheries has only recently developed plans designed to encourage the application of new, sophisticated tools and approaches, including biotechnologies, to its activities. The lag behind MITI was due in part to a desire to further assess the new technologies and in part as an expression of the ministry's independence. The other ministries involved in biotechnology have yet to take the step of identifying biotechnology as a special priority for the same reasons. Thus, Japan does not really have a grand strategy for the development and application of biotechnology because there is no activation and integration of biotechnology activity between ministries. There is strong competition among the ministries, each protective of its jurisdiction and constituency. To some Japanese, MITI has performed fast and aggressive maneuvering, and has broadly dominated biotechnology activity. This is resented by the other ministries whose jurisdiction includes applications of biotechnology. It is likely that in time other ministries will develop programs to emphasize biotechnology as a special effort, not because of MITI's leadership, but because it will be in their best interests to fulfill their mission.

Recognizing that MITI's constituency is industry, it can be concluded from the above that the MITI plan will accelerate the commercialization of biotechnology, particularly in the industries in need of revitalization.

GOVERNMENT-INDUSTRY-ACADEMIA INTERACTIONS

The major mechanism by which MITI interacts with industry and academia is through the formation of research associations. These associations are formally established by the private sector, but are initiated by invitation from MITI. The associations are "independent" of MITI, but operate under the latter's auspices. They operate under the Research Association Law which permits the participating companies to do cooperative research without violating Japan's antitrust laws. There are five such research associations currently in existence concerned with:

- new materials,
- ceramics,
- electronic devices,
- high polymer formation, and
- biotechnology.

This report describes only the last.

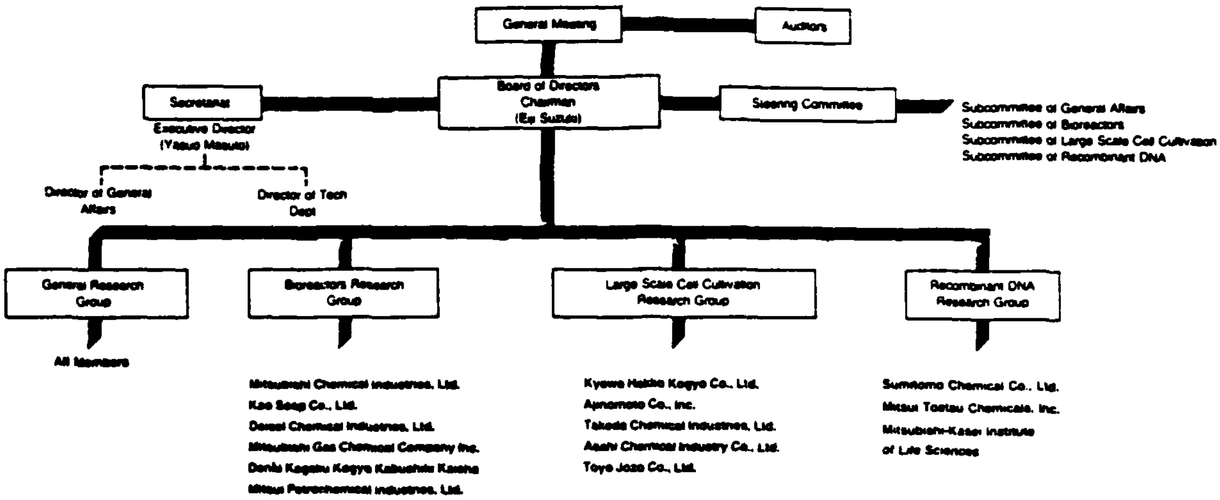
- Research Association for Biotechnology

The Research Association for Biotechnology was organized by 14 member companies from the chemical industry in September 1981 (Masuto, see references). Membership in the association is voluntary. Seven of the 14 participating companies were selected by invitation and seven volunteered. A few companies that were initially invited by MITI to participate in the association declined the honor, but none of the organizing companies has dropped out and it is unlikely any will drop out because that would entail a loss of prestige. The purpose of the association is to carry out research in the three areas targeted by MITI through tripartite collaboration among government, industry, and academia. Most of the research funds are allocated to laboratories of the participating companies, but about 10% of the funds support research in government laboratories Members of the academic community serve on the committee for research evaluation. As of 1984, the three areas of research were:

- bioreactors,
- large-scale cell cultivation,
- recombinant DNA.

The association is divided into three working groups, one for each of the research areas. The company assignments are shown in the organizational chart below. It is noted that in most cases the companies are not in the research group in which they have previous experience. One might hypothesize that either they did not want to share their expertise, or else they want to use the subsidized research as a learning experience.

ORGANIZATION CHART OF THE RESEARCH ASSOCIATION FOR BIOTECHNOLOGY



Research carried out by each group is intended to be cooperative and is funded by MITI *via* the association through contracts to the companies or government laboratories. The contracts provide direct costs only and in actual practice the companies supplement the MITI funds at a ratio of 5:1 or in some cases 10:1. The underlying concept of the research association is that its funds should be used for long-range basic research projects. MITI allocates approximately $5 million per year for the association's research budget and each of the participating companies contribute approximately $25 thousand per year for the associations administrative expenses. The research association law that permits the participating companies to do cooperative research without violating antitrust laws also stipulates the research association be a nonprofit organization that cannot hold patents. Consequently, the results of the research supported by the association belongs to the government which also claims all patent rights on inventions generated from association-supported research. This may partly explain why some big companies declined the invitation to join the association.

It was stated above that the research carried out by each research group in the association is intended to be cooperative. Ideally, the resources of each company would be directed to generic problems that none of the companies could efficiently solve by themselves, but the solution to which could be exploited by one or more companies. During the first two years of the association's history, this has not been accomplished. Within each of the three research groups there has been what is generously labeled "cooperative competition" which is a euphemism to describe consensus on the broadest general terms but not agreement on specifics. Within this framework, the three research groups can be characterized with respect to degree of communication within the group. The recombinant DNA research group displayed the least desire to exchange information or ideas between the companies within the group, while the large-scale cell cultivation research group seems to be willing to exchange certain kinds of information. The bioreactors research group gets an intermediate score on its performance, primarily because Denki KKKK and Mitsui Petrochemical Industries have coordinated some research using the facilities of the Fermentation Research Institute, a MITI-sponsored government institute. To publicize the efforts of the Research Association for Biotechnology and to account for the funds allocated by MITI, a symposium was organized at which the particiating companies in the Association presented their early research results (Proceedings, see references). This symposium was held in December 1983, and was the first public revelation of the projects being supported. These progress reports are described below and it is clear that each company is conducting independent research within its research group.

- Kao Soap Company--Microbial Oxidation of Higher Alkyl Compounds

  Some twelve thousand domestic and foreign soil samples were collected and the following strains were isolated: n-hexadecane assimilating microorganisms, alkyl chloride assimilating microorganisms, and n-hexadecane assimilating thermophile microorganisms. These microorganisms belong to the genus *Micrococcus*, *Corynebacterium*, *Nocardia*, *Rhodococcus*, *Pseudomonas*, and *Mycobacterium*.

- Daicel Chemical Industries--Fermentation Utilizing Carbon Dioxide as Raw Material

  The goal of this project is to develop a bioreactor that can produce acetic acid using CO_2 and hydrogen. Anaerobic bacteria from bottom mud of rivers, lakes, and seas in Japan and elsewhere were screened for strains that accumulated large amounts of acetic acid. A strain was found that could concentrate over 20 g/ℓ of acetic acid. This is a new species of the genus *Acetobacterium*.

- Denki Kagaku KKK and Mitsui Petrochemical Industries--Screening of Microorganisms with High Aldose Reductase Activity

  Sorbitol producing microorganisms have aldose reductase so high sorbitol producers were screened from soil samples and type culture collections. It was found that in 24 hours only yeast had high sorbitol productivity and a strain of *Candida tropicalis* was isolated that produced 73 g/ℓ of sorbitol.

- Kyowa Hakko Kogyo Company--Mass Propagation of Animal Cells on Middle-scale

  A chemically defined medium was made using a basal medium supplemental with insulin, transferrin, pyruvate, and selenious acid. This was used in a continuous suspension culture system in which they grew 7×10^6 cells/mℓ. Virus infected cells were used in this system to produce interferon. Yields were five times higher than in batch systems.

- Ajinomoto Company--Cultivation of Spontaneous Interferon Producing Cell Line in a Serum-free Medium

  E-B virus transformed lymphocytes are grown in a medium in which cyclodextrin and linoleic or archydonic acids replace serum albumin. Interferon production increases if L-Arg, L-Ser, L-Asn and glucose are added to the suspension just before the cells enter the stationary phase.

- Asahi Chemical Industry Company--Differentiation-Induction Culture of Myeloid Leukemia Cells

  Preliminary experiments have been attempted to induce myeloid leukemia cells to differentiate into macrophagelike cells by adding 12-0-tetradecanoyl-phorbol-13-acetate (TPA) to the suspension medium. It is proposed that the maturated macrophages can be activated to produce biological response modifiers when treated with mitogens such as lectins.

- Sumitomo Chemical Company--DNA Cloning of Rat Hepatic Cytochrome P-450 Monooxygenase

  The cytochrome P-450 enzyme system of liver microsomes is a versatile catalyst of oxidative reactions with broad substrate specificity. Microorganisms with enhanced monooxygenase activity can be useful in large-scale applications such as the oxidation process of various industrial chemicals and the removal of hydrocarbons from industrial waste. To contribute to these applications, cDNA clones coding for cytochrome P-450 were obtained. The 18 S fraction of mRNA with the highest enzyme synthesizing activity was treated with reverse transcriptase and converted to double stranded cDNA by DNA polymerase I. This was cloned in *E. coli*.

- Mitsui Toatsu Chemicals--An attempt to Construct a Secretory Host-Vector System in *Bacillus subtilis*

  A neutral protease from *Bacillus amyloliquefaciens* was inserted into the Eco RI site of plasmid pVB110. When cloned in various strains of *B. subtilis*, it enhanced the secretion of protease. Similar experiments were planned using the a-amylase gene with HindIII sites to see if this enzyme would be secreted by *B. subtilis* in large amounts.

- Mitsubishi-Kasei Institute--Construction of Yeast Cells Useful as Chemical Resources

  Fungal amylases are secretory proteins and may be secreted by yeast cells when cloned in them. If so, this could lead to the construction of a secretion vector in yeast. As a prototype experiment the amylase gene of *Bacillus circulans* was cloned and found to be expressed. Experiments are planned to clone the amylase genes of *Aspergillus awamori* and *A. oryzae* to see if they act as secretory proteins.

The General Research Group shown in the organization chart of the Research Association for Biotechnology is responsible for basic technology assessment in Japan compared to technological developments in foreign countries. It also has responsibility for assessing safety and other issues that have relevance to any of the research carried out under the auspices of the association.

For purposes of planning and review, the Research Association for Biotechnology research activity during the period 1981-1990 is divided into three stages. This is shown in the diagram below.

Research Groups	STAGE I	STAGE II	STAGE III
Bioreactors	Screening of microorganisms and/or enzymes	Studies on optimum conditions of each bioreactor	Evaluation of new bioreactors in bench scale
Large Scale Cell Cultivation	Selection of cell lines, Research of media	Studies on optimum conditions of cell culture	Evaluation of cell culture process in bench scale
Recombinant DNA	Development of new host-vector system. Cloning of useful genes	Studies on efficient expression of new genetic materials	Evaluation of new genetic materials in bench scale

It is concluded from the above that the Research Association for Biotechnology has not yet succeeded in pooling the resources of the participating companies to carry out long-term cooperative research. It can be argued, however, that the bioreactor research group is laying the groundwork for longer term, cooperative research on oxidative and reduction reaction systems; that the cell culture research group is developing a defined, cheap medium for long-term cooperative research on animal cells in culture; and that the recombinant DNA Research Group is developing new host-vector systems for *Bacillus subtilis* and yeast for long-term cooperative research.

- Bioindustry Development Center

Providing direct support and commissioning specific research through the Research Association for Biotechnology is not the only way MITI interacts with industry. It also expedites industrial biotechnology activity through the Japanese Association of Industrial Fermentation (JAIF). This organization has been in existence for more than 40 years. It has over 300 sustaining company members and over 10,000 individual members. In April 1983, with guidance and financial support from MITI, JAIF established the Bioindustry Develop Center (BIDEC) (Arima, see references). Initially, 120 companies affiliated with the center and several more have subsequently become affiliated. These are listed below.

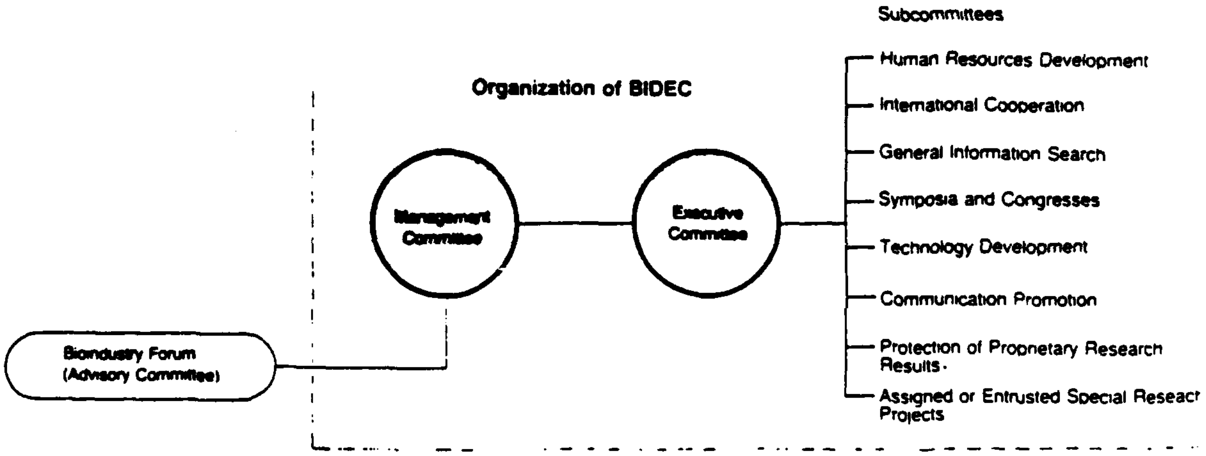
Ajimotomo Company, Inc.
Asahi Breweries, Ltd.
Asahi Chemical Industry Company, Ltd.
Banyu Pharmaceutical Company, Ltd.
Bridgestone Tire Company, Ltd.
Chiyoda Chemical Engineering and Construction Company, Ltd.
Chugai Pharmaceutical Company, Ltd.
Coca-Cola "Japan" Company, Ltd.
Dai-Ichi Kogyo Seiyaku Company, Ltd.
Daicel Chemical Industries, Ltd.
Dainippon Ink and Chemicals, Inc.
Dainippon Pharmaceutical Company, Ltd.
Denki Kagaku Kogyo K.K.
Dowa Mining Company, Ltd.
Eisai Company, Ltd.
Fuji Electric Company, Ltd.
Fuji Oil Company, Ltd.
Fujisawa Pharmaceutical Company, Ltd.
Godo Shusei Company, Ltd.
Hayashibara Company, Ltd.
Hitachi Chemical Company, Ltd.
Hitachi Zosen Corporation
Hitachi, Ltd.
Idemitsu Kosan Company, Ltd.
Ishikawajima-Harima Heavy Industries Company, Ltd.
Japan Ethanol Company, Ltd.
Japan Organo Company, Ltd.
Japan Synthetic Alcohol Company, Ltd.
Japan Synthetic Rubber Company, Ltd.
JGC Corporation
Kanebo, Ltd.
Kanagafuchi Chemical Industry Company, Ltd.
Kao Corportion
Kikkoman Corporation
Kirin Brewery Company, Ltd.

Kobe Steel, Ltd.
Konishiroku Photo Industrial Company, Ltd.
Kobota, Ltd.
Kuraray Company, Ltd.
Kureha Chemical Industry Company, Ltd.
Kurita Water Industries, Ltd.
Kyowa Hakko Kogyo Company, Ltd.
Life Engineering Corporation
Lion Corporation
Matsushita Electric Industrial Company, Ltd.
Meiji Milk Porducts Company, Ltd.
Meiji Seika, Ltd.
Meito Sangyo Company, Ltd.
Mitsubishi Chemical Industries Ltd.
Mitsubishi Electric Corporation
Mitsubishi Gas Chemical Company, Ltd.
Mitsubishi Heavy Industries, Ltd.
Mitsubishi Kakoki Kaisha, Ltd.
Mitsubishi Oil Company, Ltd.
Mitsubishi Petrochemical Company, Ltd.
Mitsubishi Petrochemical Engineering Company, Ltd.
Mitsui Engineering and Shipbuilding Company, Ltd.
Mitsui Petrochemical Industries, Ltd.
Mitsui Toatsu Chemicals, Inc.
Morinaga Institute of Biological Science
Morinaga Milk Industry Company, Ltd.
NGK Insulators, Ltd.
Nihon Shokuhin Kako Company, Ltd.
Nippon Alcohol Trading Company, Ltd.
Nippon Flour Mills, Company, Ltd.
Nippon Kayaku Company, Ltd.
Nippon Kokan K.K.
Nippon Mining Company, Ltd.
Nisshin Oil Mills, Ltd.
Nippon Oil and Fat Company, Ltd.
Nippon Oil Company, Ltd.
Nippon Reizo K.K.
Nippon Roche K.K.
Nippon Soda Company, Ltd.
Nippon Steel Chemical Company, Ltd.
Nippon Zeon Company, Ltd.
Nissan Chemical Industries, Ltd.
Nitto Chemical Industry Company, Ltd.
Obayashi-Gumi, Ltd.
Oji Paper Company, Ltd.
Okura Shuzo Company, Ltd.
Oriental Yeast Company, Ltd.
Pentel Company, Ltd.
Sankyo Company, Ltd.
Sankyo Enterprise Company, Ltd.
Sanraku-Ocean Company, Ltd.
Sanyo Chemical Industries, Ltd.
Sanyo-Kokusaku Pulp Company, Ltd.
Sapporo Breweries, Ltd.
Seiko Instruments and Electronics, Ltd.
Shell Kosan K.K
Shimadzu Corporation
Shimizu Construction Company, Ltd.
Shionogi and Company, Ltd.
Shiseido Company, Ltd.
Showa Denko K.K.
Snow Brand Milk Products Company, Ltd.
Sumitomo Chemical Company, Ltd.
Sumitomo Electric Industries Company, Ltd.
Sumitomo Metal Industries, Ltd.
Suntory, Ltd.
Taisho Pharmaceutical Company, Ltd.
Takara Shuzo Company, Ltd.
Takasago Thermal Engineering Company, Ltd.
Takeda Chemical Industries, Ltd.
Tanabe Seiyaku Company, Ltd.
Teijin, Ltd.
The Bank of Tokyo, Ltd.
The Dai-Ichi Kangyo Bank, Ltd.
The Taiyo Kobe Bank, Ltd.
Toa Nenryo Kogyo K.K.
Toagosei Chemical Industry Company, Ltd.
Toho Chemical Industry Company, Ltd.
Toray Engineering Company, Ltd.
Toray Industries, Inc.
Toyo Engineering Corporation
Toyo Jozo Company, Ltd.
Toyo Soda Manufacturing Company, Ltd.
Toyobo Company, Ltd.
Tsukishima Kikai Company, Ltd.
Ube Industries, Ltd.
Unitika, Ltd.
Wakamoto Pharmaceutical Company, Ltd.
Yakult Honsha Company, Ltd.
Yamanouchi Pharmaceutical Industries, Ltd.
Yamasa Shoyu Company, Ltd.
Yanmar Diesel Engine Company, Ltd.
Yoshitomi Pharmaceutical Industries, Ltd.

In its own words, BIDEC's founding is explained as follows:

> We anticipate the emergence of a new industrial field called bioindustry soon, which may change the industrial framework of Japan and contribute toward progress of high-grade technologies in the area. However, since the bioindustry of today is still in its infancy, it is imperative that the foundations for research and development, and those for supporting the new industry should be built firmly in an orderly manner to secure its healthy and rapid progress. This fundamental need promoted both the industrial and academic sectors (of JAIF) to unify their efforts in establishing a core organization...with the object of systematically promoting the bioindustry.

In addition to the initial seed funds provided by MITI, the ten largest companies contribute approximately $4,000 annually and the remaining companies contribute $2,000 annually to support BIDEC activities. This pays for rental of office space, staff salaries, and the cost of publishing a newsletter. Some of the staff are employees of participating companies who have been transferred to BIDEC for specific responsibilities. Shortly after it was established, BIDEC became an active organization. The president of JAIF is Dr. Kei Arima and the chairman of the BIDEC management committee is Dr. Hirotoshi Samejima. The organization of BIDEC is shown below.



At the very least, BIDEC serves as a clearinghouse of information for the whole industry but is intended to serve a much broader role. The role of the eight subcommittees is as follows:

- Human Resources Development

  The purpose is to upgrade the knowledge and skills of the personnel involved in biotechnology R&D:

  planning, discussing, and decision making on education programs,

  curricula preparation,

preparation for educational training material, and execution of training sessions (book studies and experimentations).

. International Cooperation

For the international exchange of information and research personnel, with laboratories, universities, business enterprises, and associations, etc., concerned with biotechnology, the following activities are conducted:

exchange of information both overseas and domestic,

invitation of foreign visitors,

planning of dispatch/visits abroad of domestic personnel concerned,

translation service describing foreign activities,

contact foreign institutions for exchange of personnel program.

. General Information Search

The collecting of up-to-date information on biotechnology, both overseas and domestic, and the rapid transmittal to BIDEC members are the main activity of this subcommittee:

the collecting of various up-to-the-minute information,

the supplying service of such new information (through *BIDEC News* and a yearly bulletin).

. Symposia and Congresses

By direct sponsoring or supporting, by cosponsoring, and by cooperation with other organizations, symposia or congresses on the following subjects are to be planned and held actively:

recombinant DNA,

bioreactors,

cell fusion,

large-scale cell cultivation,

fields related to bio-mass.

. Technology Development

In order to improve and develop technologies, and determine future directions, the following are planned at present:

studies related to technologies for the microanalysis of minor quantities, studies related to technologies for the separation and purification of new biotechnological products such as interferon, etc.

. Communication Promotion

In order to promote mutual communications or view exchange among industries, governments, and academicians, various small meetings including lectures by leading researchers are planned and held domestically.

. Protection of Proprietary Research Results

In order to clarify the current position and background regarding problems relating to the subject, the following are planned:

investigation of contemporary status overseas,

studying of future directions.

. Assigned or Entrusted Special Research Projects

Investigations on biotechnology in general:

influence of biotechnology on industries,

experimentation systems related to biotechnology,

search for penetration status of biotechnology among medium- and small-size industries, and for their introduction,

research collaboration activities concerning biologically active substances,

analyses of the influence of biotechnology on the industrial structure of the nation.

Investigations related to biomass conversion technology:

petroleum plant (microalgae) studies,

fuel production from marine biomass,

feasibility study on the production of methane gas through new fermentation processes,

study on an alcohol production system utilizing acid conversion or other fermentation processes,

coordination activities with domestic organizations to cooperate R&D for the biomass energy development projects in Indonesia.

To promote international cooperation, the BIDEC subcommittee for international cooperation will publish an English-language newsletter starting in early 1984 entitled *Japan Bioindustry Letters*.

- Research Park Development

Much of Japan's biotechnology activity is located in Tokyo and its environs. There is also a concentration of activity in the Osaka-Kyoto-Kobe urban complex. There is a movement in Japan to decentralize high technology industries to less crowded areas. In each prefecture, there is a biotechnology coordinator and collectively they make up a network for monitoring current industrial biotechnology activity of interest to MITI. These coordinators are also important for developing potential new sites for research parks. These would be sites where new industrial development could take place in close priority to academic institutions or government research laboratories. Expansion of applied research departments of universities to less crowded areas has already taken place in a number of cases and this could be an important inducement for encouraging industry to follow. Examples are the Institutes of Chemical Research, Food Research, Wood Research and Atomic Physics of Kyoto University which are located on the Uji campus about 30 miles southwest of Kyoto, and the departments of chemical and bioengineering, applied chemistry and fermentation technology of the University of Hiroshima which are located in Saijo, about 25 miles east of Hiroshima.

MANPOWER: SUPPLY AND TRAINING

As noted above, influential professors with ties to industry pump a steady flow of university graduates into industry. For the most part, these are entry-level researchers with bachelor or master's degrees from departments of applied microbiology, applied biochemistry, or fermentation engineering. Japanese companies prefer to train their research personnel in the company and therefore recruit men with general knowledge rather than men with expertise in specialized areas or techniques. With the extension of biotechnology by MITI to companies in need of revitalization, there is need for increased numbers of graduates from the applied departments of universities. Despite appeals from industry and students, the applied departments have not increased their enrollment. Within the academic community these departments are not so influential that they can overcome the barriers of limited space, staff, and budget.

There is also a shortage in Japanese industrial laboratories of researchers trained in the basic science departments of universities, that is, molecular biologists, cell biologists, immunologists, or more specifically, experts in recombinant DNA and monoclonal antibody techniques. Students trained in the basic science departments are more oriented toward advanced degrees and careers in academia than toward industrial careers, and job opportunities in industry do not hold the same lure as in the U.S. It must also be noted that the guidelines for conducting research using recombinant DNA molecules were not promulgated in Japan until 1979. These guidelines were very restrictive and not relaxed until late 1983, delaying the development of sophisticated modern molecular and cell biology, not only in industry, but also in Japanese universities.

To fill the manpower needs created by the burst of biotechnology activity after the MITI plan was announced, companies sent researchers in large numbers to Japanese universities for training in recombinant DNA and cell culture techniques. They also sent large numbers of researchers abroad, primarily to the U.S., to receive training in the newer techniques. Government encouraged this training by allowing all costs associated with overseas training as tax deductible expenses for the companies.

Training many hundreds of industrial researchers in the new techniques extramurally in a period of two years is an impressive feat, but it is not without negative aspects. Most of this task was carried out in the better laboratories in the basic science departments of Japanese universities. Professors were not assigned this task, nor did they volunteer their services. But when asked to take someone from industry into their laboratory for training, it was difficult to refuse because this would conflict with their sense of national purpose. The host laboratories were compensated for their services, but the compensation usually covered only the cost of supplies used in the training ($500 to $1,000). The length of time trainees remained in the host laboratory ranged from a few months up to a year. Usually the trainee worked on a specific research problem of interest to the company, not necessarily research of interest to the host laboratory. The professors and their assistants conscientiously provided the training, but it taxed their space, facilities, and time.

How adequate is training of this type? Undoubtedly it serves the short-term purposes of the company, but is not likely to prepare the industrial researcher so trained as an innovative user of the new technology. By design the training is narrow. Will persons so trained be able to develop the technology further or adapt it for new purposes? When new technologies are developed, will industry have to repeat this pattern of extensive extramural training? These questions, of course, concern industrial and governmental managers of biotechnology in Japan. Since biotechnology is a knowledge-based endeavor, the absence of the type of knowledge and skills gained during doctoral and postdoctoral training presumably should place limits on the research goals of industrial laboratories for work at the moving edge of science. One may hypothesize that the traditional fiscal conservatism of Japanese companies will remain the major force in personal planning.

EQUIPMENT AND FACILITIES

The major academic departments and laboratories visited (those doing research primarily in microbial genetics, molecular genetics, biochemistry, biophysics, cell biology, fermentation, and plant sciences) have an impressive inventory of equipment for state-of-the-art exploitation of spectroscopy, chromatography, microscopy, electrophoresis, amino acid analysis, peptide synthesis, nucleotide synthesis, cell sorters, computers, and other types of equipment and instrumentation used in modern biological research. In addition to equipment made in Japan, researchers purchase a surprising amount of equipment made in the United States and in Europe. Service and parts replacement on foreign as well as domestic equipment seems prompt and satisfactory. The one area where instrumentation is not luxuriant is that of counting equipment for radioactivity. The Japanese aversion to radioactivity results in a minimum use of radioisotopes in research. Individual laboratories do not have counting devices, but in most institutions there are central facilities for working with radioisotopes which are very well equipped.

What is true of academic laboratories with regard to equipment is even more true of government laboratories and industrial laboratories. That is, procurement of equipment is given a high priority. In a number of conversations, I was told that it is better to have equipment in working readiness even if it is not used much, than to have need of certain equipment and not to have it available. This attitude is compatible with the observation that there is little horizontal interaction in Japanese institutions, so the use of someone else's equipment is not an alternative to having a less than completely equipped laboratory.

The same attitude and importance that Japanese individuals place on equipment can be extended also to facilities. As a general rule, it can be stated that all facilities that support biotechnology research are adequately supported in both public and private institutions. They are designed to accommodate to potential as well as actual uses. (The facilities and the National Institute for Basic Biology are described in the "National Laboratories and Research Institutes" section in this article.) There is also adequate support for microbial type culture collections, seed collections, and for special germplasm repositories like that for rice, wheat, rodent embryos and *E. coli* maintained at the National Genetics Institute. Collections maintained in the private sector were described earlier. There are also a number of special purpose research facilities. Three of these at the National Institute for Basic Biology are described here to give an idea of national facilities with trained staff that are available to researchers from anywhere in the country.

- Okazaki Large Spectrograph for Photobiological Research

This spectrograph is available for research by staff of the National Institute for Basic Biology as well as by external researchers. The computer-operated spectrograph was recently built at Okazaki, Japan. Different specimens can be placed on a horseshoe shaped focal curve (10 m long) covering a wavelength range of 250 to 1000 nm so that they can be irradiated simultaneously. Specimens are set in microcomputer controlled threshold boxes so that wavelengths, photon fluence rates, photon fluences and timing of irradiations are controlled automatically according to a preprogrammed schedule. An optical fiber system is provided for remote irradiations.

- Electron Microscope Center

The facility maintains the following microscopes for use of intramural and extramural researchers.

transmission microscopes:

Hitachi H 500	125 kV
JOEL 100-CX	100 kV
JOEL 200-CX	200 kV
Phillips 400 HM	120 kV

transmission scope, analytical:

JOEL 200-CX	200 kV

scanning scope:

Hitachi S-450	25 kV

- Physical and Chemical Analysis Facility

This facility with technical staff is organized into five sections. Each section is equipped with instruments for general use as listed below.

- Section for chemical analysis:

amino acid analyzer (Hitachi 835)
peptide sequence analyzer (JOEL JAS 47K)
peptide synthesizer (Beckman 990B)
high performance liquid chromatography (JASCO Tri Rotar III)
dual wavelength TLC scanner (Shimadzu CS-910)

- Section for preparation of biological materials

  preparative ultracentrifuge (Beckman L8-80)
  cell sorter (Becton-Dickinson FACS II)
  Coulter counter (Coulter ZB)

- Section for spectroscopic analysis

  spectrophotometer (Gilford 250)
  spectrophotometer (Hitachi 330)
  spectrophotometer (Hitachi 557)
  spectrofluorometer (Hitachi MPF 4)
  infrared spectrophotometer (JASCO A-302)
  atomic absorption spectrophotometer (Perkin-Elmer 603)
  laser-Raman spectrophotometer (JASCO R-800)
  spectropolarimeter (JASCO J-40S)
  light scattering photometer (Chromatix KMX-60C)

- Section for physical analysis

  superconductive FT NMR spectrometer (Bruher WM 360 Wb)
  EPR spectrometer (Bruker ER 200D)
  gas chromatography mass spectrometer (Hitachi M-80)
  quadruple mass spectrometer (JOEL JMS-QH 100)
  analytical ultracentrifuge (Hitachi 282)
  viscometer (Contraves RM-30)
  differential scanning calorimeter (Perkin-Elmer DSC-2)

- Section for microscopic analysis

  microscope photometer (Zeiss MPM 03-FL)
  image analyzer (Kontron MOP-AM 03)
  image analysis system Kontron IBAS-I, II
  microdensitometer (Joyce Loebl 3CS)
  motion analysis system (NAC Movias GP-2000)

Another exception to the statement about the adequate support and completeness of equipment and facilities in Japan may be found in the area of x-ray diffraction facilities for three-dimensional studies of proteins. The author was not aware of any crystallographic laboratories engaged in such research during his visits to Japanese research institutions. While much protein engineering can be done without a detailed knowledge of the three-dimensional structure of the molecule, much cannot be done and lack of such knowledge could well be limiting in the future.

- Information Transfer

By a number of criteria, Japan may be classified as a relatively closed society, but there is no doubt the Japanese have a fine appreciation of the importance of information transfer. The gathering of information from abroad is extensive as is the controlled dissemination of information.

Most academic scientists in Japan are fluent in English. Private sector funds to their laboratories for consulting and other services rendered can be used to purchase books and journals and for travel abroad. Consequently, most professors' offices have a useful and up-to-date library of English-language books and journals and they regularly read *Science* and *Nature*, current copies of which are found in almost every office. Most professors also attend at least one meeting overseas each year and many go abroad more often. This exposure to the world scientific community enhances the role of professors as clearinghouses of information. This role is built on their high status in Japan, their network of former students in industry and government, and their role as key advisors to industry and government. It was emphasized earlier that there is rather little horizontal communication within university campuses, but this does not extend between institutions. The network of information brokering between prominent professors and their contacts is most extensive.

To some extent, frequent travel overseas is also done by directors of research and research planners in industry.

For those less facile with English, abstracts of published papers and summaries of symposia and meetings around the world are printed in Japanese trade publications. Newsletters as those published by BIDEC are distributed industry-wide. In addition, similar publications are prepared and distributed within companies. *Nikkei Biotechnology* is a national newsletter that summarizes biotechnology news from industry, government, and academic institutions before the results are formally published in professional journals.

Literature survey services, translation services, and computer accessed abstracts are adequately supported in Japan. Government documents refer to the establishment of data bases pertinent to biotechnology, but it is ambiguous as to whether these already exist or are still only in the planning stage. For example, several persons told the author that Japan has a nucleotide sequence data bank. On further probing, however, it became evident that serious discussion was underway about coordinating a proposed Japanese data bank with the U.S. Genetic Sequence Data Bank (GenBank) and the European Molecular Biology Nucleotide Sequence Data Library to develop an international compendium of nucleotide sequences. At the time, however, the Japanese data base was just being organized.

The government hoped that Japan would be able to develop channels for exchange of information and resources with its neighbors with the establishment of the Asian Molecular Biology Association (AMBO), but AMBO has become an almost exclusively Japanese organization. The Japanese International Cooperative Association, however, as mentioned elsewhere, does arrange some personnel exchanges with some Asian countries.

SUMMARY

Promotion of biotechnology by the Ministry of International Trade and Industry (MITI) has made this activity very visible outside of Japan, and there is no doubt that MITI is an important force facilitating industrial use of biotechniques within Japan. The ten-year MITI plan, proposed in 1981, promotes three specific technologies; fermentation, large-scale cell culture, and recombinant DNA. Other government agencies whose constituencies are involved in biotechnology (Science and Technology Agency; Ministry of Education, Science and Culture; Ministry of Agriculture, Forestry and Fisheries; and the Ministry of Health and Welfare) have not designated biotechnology as a priority area. Thus, the MITI plan is not a coordinated national plan. Other agencies may soon encourage interaction of their constituents with industry, but any biotechnology component of this interaction will be independent of MITI influence. A Special Coordinating Fund, administered by the Science and Technology Agency, is appropriated specifically to link activities and catalyze interaction between ministries, but thus far there is no obvious coordinating effect of the use of these funds with respect to biotechnology.

Unlike the U.S., Japan has no newly-established biotechnology companies. But it does have a large number (more than 150) of established companies that have moved into biotechnology activity. These companies include the traditional industries that use fermentation processes such as pharmaceutical and food companies; additionally, MITI has facilitated the introduction of biotechnology activity into companies in need of revitalization. Thus chemical, cosmetic, soap, textile, paint, ink and even shipbuilding companies are engaged in biotechnology activity. As the new technologies were introduced into industrial R&D, the task of training company researchers was primarily carried out in academic laboratories. The training of a large number of people in a relatively short period of time is an impressive accomplishment, perhaps unique in the world. It is an imposition on faculty time and facilities, however, and has been a strain on university-industry relations.

Much more applied research is carried out in Japanese universities than in the U.S. In addition to departments of fermentation in engineering schools and departments of food science, all schools of agriculture have departments of applied microbiology or applied biochemistry. There are very strong linkages between these applied departments and industry. Professors control the placement of graduates in companies and maintain the respect of former students as the latter rise to leadership positions in industry. Historically, the large and powerful applied departments in universities had an important influence on the fermentation industry in Japan. Within the universities, however, there is little or no interaction between the applied departments and the basic science departments. Also, the interaction between the basic science departments and industry is limited and guarded. Professors in these departments do some advising to industry and perform some contract research for industry, but these arrangements are cautiously controlled and the independence of academia is protected.

The Japanese regard the natural microflora in their soil as a natural resource and aggressively add to their collections from soil samples throughout southeast Asia. Applied departments in universities as well as most companies and government laboratories maintain their unique type culture collections. Mutant strains are not considered stable and therefore are not part of these collections. Research in the applied departments of universities and in many company laboratories is primarily fermentation research and follows a standard approach. The search is for specific metabolic reactions that can be used in bioreactors or that can make a specific product in large fermentation vessels. This is done by brute force screening of large numbers of microbial strains. In the basic science departments, biotechnology-related research is broader, more sophisticated and comparable to basic research in the U.S.

Mechanisms exist to expedite interaction on biotechnology research between government, industry, and academia. Within each sector, the spirit of competition is frequently stronger than the spirit of cooperation; and between sectors, each participant maintains its independence. When the interaction occurs, industry and not government often seems to be the stronger partner. A principal mechanism designed to facilitate such interactions is the Research Association for Biotechnology. This is a consortium of 14 companies established under the auspices of MITI to conduct subsidized, cooperative research in the three areas targeted in the MITI biotechnology plan. A steering committee for each area, consisting of top-ranking academic researchers advises in the planning and conduct of the cooperative research. MITI-controlled facilities are available to members of the association and one project is being conducted at the Fermentation Research Institute at Tsukuba. However, during the first two years of the association's existence only a small movement has been seen toward its goals. The participating companies, that are otherwise competitors, have not been able to agree on specific areas or means of cooperation. The MITI funds to date have been used for independent, but somewhat complementary research.

Another mechanism by which MITI is trying to enhance biotechnology activity through cooperative interaction between companies, and between industry and academia, is through the Bioindustry Development Center. Guided and subsidized by MITI, the Japanese Association of Industrial Fermentation established the center to promote training, international exchange and cooperation, information exchange, organization of symposia and congress, protection of proprietary research results, and studies and research of special interest to biotechnology. It is too early to assess fully the effectiveness of the Center, which was established in April 1983.

There are plans underway to establish a network of research parks throughout Japan. It is intended that this will enhance the interaction within and between the industrial, academic, and government resources.

Most laboratories in Japan involved in biotechnology research are well equipped with state-of-the-art equipment. However, some of the more active laboratories, particularly in universities, are understaffed with respect to support personnel. Much planning, however, has been devoted to the facility needs of the research community and these needs have been filled with well-designed, fully equipped, excellent facilities. Exceptions to this pattern are facilities to carry out x-ray diffraction studies of protein structure. Apparently the Japanese do not consider this to be a useful approach to biotechnology research at this time.

Overall: The commercialization of biotechnology in Japan is still at an early stage and may be overly visible as a result of promotion by MITI. The quality of Japan's research activity is comparable to that in the West and the R&D infrastructure is strong. Restraints imposed on biotechnology activity in industry by fiscal conservatism could be a barrier to rapid progress. On the other hand, Japan has shown a remarkable ability to adapt to change which is driven by markets; and MITI has occasionally shown its skill in "nudging" technical progress in certain directions. In the next issue of this *Scientific Bulletin*, a survey of some applications will be presented.

REFERENCES AND ACKNOWLEDGEMENTS

Discussions with Hiuga Saito, director of the Institute of Applied Microbiology, Tokyo, and Kei Arima, professor emeritus, Tokyo University and president of the Japanese Association of Industrial Fermentation were especially useful in providing information and insight into the historical development of the fermentation industry in Japan.

Special acknowledgement is extended to Tohru Takahashi, science counsellor of the Science and Technology Agency Planning Bureau for his informative discussion about CSI, STA, and JRDC.

In this report, all budget data given in dollars are converted from yen at a rate of 200 yen equal $1.00.

"Research and Development of Life Sciences in Japan." *Science and Technology in Japan*, April-June 1983.

Special acknowledgement is extended to Masami Tanaka, director of the Bioindustry Office, Basic Industries Bureau, MITI, for his very informative discussion.

Pertinent information about MESC comes from discussions with Charles T. Owens of the Tokyo Office of the U.S. National Science Foundation. Budget data are extracted from *Gakujutsu Geppo* (Japanese Scientific Monthly) translated by M. Miyahara and distributed as Report Memorandum #24, NSF/T, 20 October 1983.

The government fiscal year in Japan starts on April 1. Thus, FY 83 covers the period 1 April 1983 through 31 March 1984.

Special acknowledgement is extended to Yasutsugu Takata, counsellor, Research Council, MAFF, and Shigeru Kimura, research coordinator, MAFF, for their useful discussions and sharing of pertinent documents and publications.

Special acknowledgement is extended to Yoshimasa Takahara, director general and T. Suzuki of the Fermentation Research Institute for their helpful and informative discussions.

Deepest gratitude is acknowledged to Yokinori Hirota, head of the Department of Microbial Genetics for his general discussions of biotechnology in Japan and his specific information about the research conducted at the National Genetics Institute. Appreciation is also acknowledged to S. Iyama, Y. Sano, and T. Fujii for their informative review of their biotechnology-related research with rice.

Acknowledgement is extended to the following people for their very informative discussions about the National Institute for Basic Biology: Yoshihiko Fujita, acting institute director general and head of the Cell Biology Department; Goro Eguchi, head of the Department of Developmental Biology; Yoshiaki Suzuki, professor of cell differentiation and Takeru Yamakawa, head of the Research Cooperation and International Affairs Division of the Okazaki National Research Institutes.

Very grateful acknowledgement is extended to Hiuga Saito for his insightful and informed discussion of biotechnology in general and the Institute of Applied Microbiology specifically.

Pertinent information in this section is extracted from NSF/T Report Memorandum #16, 4 April 1983 and NSF/T Report Memorandum #24, 20 October 1983, dealing with the MESC operations and budget.

Special thanks are given to Masami Tanaka, director of the MITI Bioindustry Office for data presented in this section. Most of the tables in this section are from "Research on Biotechnology in Japan," published by the Japan External Trade Organization, (JETRO) Tokyo, Japan.

Special gratitude is extended to Yasua Masuto for his informative discussions on the Research Association for Biotechnology.

Proceedings of *Biotechnology; First Symposium on Research and Development Project of Basic Technology for Future Industries*. Tokyo, December 1983.

Acknowledgement is gratefully extended to Dr. Kei Arima, professor emeritus, Tokyo University, and president of the Japanese Association of Industrial Fermentation for his informed, gracious, and insightful discussion of biotechnology in general and the Biotechnology Development Center specifically.

SHIPBUILDING IN KOREA

Thomas W. Eagar

OVERVIEW

In the decade from 1974 to 1984, new shipbuilding in the Republic of Korea increased by a factor of ten to 2.28 million gross tons, which is currently about 20% of the world's total shipping and 16% of Korea's total export volume. The early growth of shipbuilding was due primarily to low labor costs, with most of the higher technology designs and machinery purchased abroad; however, Korean shipbuilding has now grown to world-class size with prospects of developing new domestic technologies in the future.

Most of the growth in Korean shipbuilding is due to the development of three major new shipyards: the Hyundai Heavy Industries yard at Ulsan which is currently the world's largest single facility, producing one-eighth of all world tonnage; the new Daewoo shipyard at Okpo which was dedicated in 1981 with a capacity of 1.5 million annual gross tons and the Samsung Koje yard which started operation in 1979 with a capacity of 450 thousand annual gross tons. As seen in Table I, along with Korean Shipbuilding Engineering Company, these three yards accounted for 97% of all Korean ship orders in 1984. It is also clearly seen from Table I that the Korean shipbuilding industry relies heavily on foreign demand for their services. This has created considerable friction with competitors, such as Japan, who have accused the Koreans of recklessly expanding shipbuilding capacity. The friction is not eased by the fact that the Korean shipyards are operating at over 75% of capacity and have nearly three years worth of orders while the Japanese shipyards, even with half of the world's tonnage, are glaringly underutilized and are rapidly seeking to diversify into other types of heavy construction such as pressure vessels. A price war has begun with ship prices falling by 50% over the past two years and all sides claiming that they cannot make a profit at current levels. Although they were successful in obtaining 120 new ship contracts in 1984 (13 in December alone), the major Korean shipbuilders did not receive a single order in January 1985 and they are afraid that the competition is becoming even more severe. Many people in both Korea and Japan especially fear the Chinese entry into the shipbuilding market in the future. As a result, the Koreans are attempting to expand into higher technologies, such as offshore work which began production in 1980, and they hope to receive contracts for LNG ships in the future. Many new research institutes are being established to help lead Korean shipbuilding into this new era of high volume but also high technology shipbuilding.

In March 1985, the author visited a number of these new ship research centers and toured several shipyards. The general impression is that Korea has firmly established a high volume, high quality shipbuilding industry toward which they have a long-term commitment to at least maintain, if not to expand, slightly. As the world's fourth largest debtor nation, Korea requires these ship exports as a source of foreign capital and the huge investment already made in these shipyards cannot be readily transformed to other markets. As a result, Korea must maintain their share of world shipbuilding yet remain competitive with developing nations which have even lower labor costs; one way of doing this is to increase their level of technology which is currently good but not outstanding.

SEOUL NATIONAL UNIVERSITY

Professor M. J. Koczak presented an introduction to the college of engineering at Seoul National University (SNU) in a previous *Scientific Bulletin*, [*Bulletin*, *8*, (2) 18, (1983)], hence, this general view will not be repeated here. It should be noted, however, that SNU only accepts students in the top 2%; hence, it is a very special university and leads the nation in many ways. Currently, there is rapid growth in the college of engineering. For 1984-85, the faculty number 143, the undergraduates number nearly 4000 (up from 2400 only three years ago) and the graduate students number 1000 (up from 300 five years ago) with authorization to expand to 1600 graduate students in the future.

The facilities are expanding in a similarly rapid manner. There was a large increase in equipment monies from the Korean government seven years ago, and one year ago the Japanese government gave a $5 million grant, most of which was used for new research facilities. A partial listing of the equipment in the Material Testing and the Instrument Analysis Centers is given in Table II. With so much recently acquired equipment and so many new graduate students, the faculty are encouraged to begin more active research in their specialties.

My host for the visit to SNU, and the person who kindly arranged all of my visits, was Professor J. E. Park, chairman of the department of naval architecture. The department consists of eight faculty members and has both graduate and undergraduate programs. Approximately one-third of all master's students continue their studies for a doctoral degree. The major facility is a new towing tank commissioned at the end of 1984. The tank is 117 m x 8 m x 3.5 m with a maximum design speed of 5 m/s. This facility has been under development for ten years and was completed with part of the $5 million grant from the Japanese government.

- Korean Welding Society

Professor J. E. Park is also the founder and president of the Korean Welding Society which was started in October 1982. They have rapidly grown to 800 members, holding two one-day meetings each year which are attended by 300 to 400 people. They began publication of a semiannual journal in 1983, a few titles of which are given in Table III. The organization and functions of the Korean Welding Society are patterned after the Japan Welding Engineering Society and the Japan Welding Society (which will be described in a subsequent *Scientific Bulletin.*) It is hoped that Korea will begin to participate more actively in the International Institute of Welding in the near future.

- Professional Training

The rapid growth of shipbuilding in Korea has required a large number of trained engineers. It was reported that the number of students majoring in shipbuilding in Korea in 1984 was 540 at all universities and 440 at junior technical colleges. This compares with 1300 engineers and 3100 technicians currently employed by the four largest shipbuilders (*cf.* Table I). Some 85 of these practicing engineers and 17 of the technicians were trained overseas.

Korea's rapid economic development of the past decade, not only in shipbuilding, but in all areas, has demanded many more highly trained people. From 1974 to 1984, the number of annual college graduates tripled to 120,000 and the total number of college students has expanded by 4.5 times to 870,000. Korea now ranks second behind the United States in proportion of college graduates (see Table IV). It has been estimated that the Korean economy must grow at 7 to 8% per year to provide jobs for these new graduates. While the growth rate from 1962 to 1980 was 8.8%, it has slowed in recent years. Of the 120,000 college graduates this year, large businesses hired 10,000; small businesses hired

30,000; 10,000 joined the armed forces and 31,000 went abroad to graduate schools. The remaining one-third are either underemployed or unemployed. At the junior college level, the problem is even more severe; only 15% out of 385,000 graduates are employed. Only 3.6% of women graduates found jobs last year and only 2% were successful this year. It is clear that Korea's rapid growth is beginning to slow down and the educational system must adjust quickly to these changes. Unfortunately, there already are many students enrolled and it is difficult to adjust the supply as quickly as necessary. Such problems will no doubt lead to many new tensions in the next few years.

KOREAN SHIP RESEARCH INSTITUTE

Professor M. Koczak also provided a general overview of the Korean Institute of Machinery and Metals (KIMM) in a previous *Scientific Bulletin*, [*Bulletin*, *8*, (2) 1, (1982)]. That review listed the general research areas at the Ship Research Institute in Daeduk but did not include details of some of the research.

The Ship Research Institute consists of 220 people, 100 of which are professionals and 10% of which have doctorates. The institute has many spacious buildings and a five-year old towing tank which was described in the previous article. All of the research is performed on a contract basis with two-thirds provided by the government and one-third by industry. The goal when this institute was started in 1978, was to provide a centralized research facility to serve the needs of the shipbuilding industry; however, in recent years the expanding shipyards have chosen to develop their own facilities. For example, Hyundai Heavy Industries established a Welding Research Center in November 1983 and a Maritime Research Institute (with towing tank, cavitation tunnel, and circulating water channel) in October 1984. Both of these research centers duplicate the facilities at the Ship Research Institute. In addition, Daewoo has announced the establishment of a new welding research center at their shipyard and Samsung Heavy Industries and Pohang Iron and Steel are also starting new welding research groups. As a result, the Ship Research Institute has had a relatively level budget for the past few years and they fear that industrial support may decrease even further.

The welding group at the Ship Research Institute consists of 11 engineers and 14 technicians under the direction of Dr. S. H. Hwang who spent many years studying and working in West Germany. Their research includes development of submerged arc and shielded metal arc fluxes as well as flux-cored electrodes; spatter formation; residual stresses; electron beam welding of 7075 aluminum; development of a welding data base; cold cracking of HY80; diffusion bounding of tool steels and ceramics; seam tracking and fracture toughness of medium strength steels. Their equipment consists of an Instron 1324 15-ton unit for uniaxial and torsional fatigue; an instrumented Charpy tester; diffusion bonding equipment; a 6 kW electron beam welder; plasma spraying equipment and other general purpose welding facilities. Additional facilities adjacent to the welding laboratories include a large structures testing laboratory, 200-HP, 50-HP, and 30-HP dynamometers and a fire test laboratory.

The strong emphasis on welding flux development is due partly to the influence of the first welding division head, Mr. L. Choi, who had done flux work with Lincoln Electric and the Linde Division of Union Carbide in the United States, and partly by a desire to develop domestic expertise in this field. There are currently four manufacturers of welding consumables in Korea with annual usage by Korean industry of 90,000 tons. It is hoped that Korea can become a major exporter of welding consumables in the future.

HYUNDAI HEAVY INDUSTRIES--ULSAN SHIPYARD

In March 1984, Hyundai Heavy Industries (HHI) celebrated the construction of 10 million deadweight tons at their Ulsan Shipyard. Perhaps the most remarkable thing about this event was that the shipyard had only delivered its first ship ten years before! In the first decade they produced an average of 30 ships per year ranging in size from 8000 tons to 260,000 tons. In 1984, 41 new ships were delivered and in 1985, 60 ships are scheduled for completion.

The scale of HHI is impressive. The panel shop is in fact the equivalent of four large shops operating in parallel. It is not really practical to tour the shipyard on foot as is done at most facilities because this yard is on an entirely different scale than other shipyards. Table V lists the seven docking facilities and provides some idea of the enormity of this shipyard.

There are 13,000 employees at HHI, 7000 of whom are welders. It was surprising to see how much of the work was still done manually, especially as compared with Japanese shipyards which often use less then 25% shielded metal arc processes. The steel plates were generally small in size and irregular, since most steel must be purchased from Pohang Iron and Steel Company (POSCO). POSCO has a captive market in Korea and is not as advanced as Japanese steel mills; e.g., POSCO is only now researching accelerated cooled plates and does not have production facilities for such steels yet. Sixty percent of the plate in HHI's offshore construction is accelerated cooled plate from Japan. HHI merely rolls it into cylinders and welds the seams; they do not use any of this plate in ship construction. The reasons given are the requirements to buy from POSCO and the fact that Japanese steel mills will not share technology on distortion control during flame cutting of these new steels.

The weld quality appeared excellent. After commenting that it was the best that I had seen anywhere, my guide, Dr. D. H. Park, proudly told me that Hyundai welders had won gold medals at the last three International Welding Skills Olympics. Although their skill is excellent, the small plates and large fraction of manual welding makes HHI relatively inefficient compared to shipyards in many other countries. They recognize this and, since 1979, have reduced construction manhours by 50% in many areas. Through this and improved shipyard scheduling, they claim to have increased productivity by 40% in the past three years. They hope to close the productivity gap with their Japanese competitors within five years.

In order to improve their technology, HHI established the Welding Research Institute in 1983. There are currently 25 engineers and 50 technicians with most working on shipyard development projects; but five or six engineers are working on new products and procedures. Some of this research is being led by Dr. D. H. Park, who has a Ph.D. from Northwestern University, and Dr. H. J. Kim, who recently graduated from the University of California at Berkeley.

Research goals of the Welding Institute include increased use of accelerated cooled plates; automation and development of their own robots; bonding of dissimilar metals and ceramic-to-metal bonding; low temperature material weld procedures (for LNG, LPG) and high temperature material weld procedures (9 Cr-1 Mo, stainless steels); development of expertise in failure analysis; development of new welding consumables with a sister company and welding procedures for HY80. These goals are admittedly applied, but they are designed to help HHI increase its capability to bid for higher technology fabrication jobs.

The laboratory which has an area of 2000 square meters is well-equipped with conventional welding facilities. They have a hydraulic tensile machine and are purchasing a scanning electron microscope. Future acquisitions include a transmission electron microscope, a "Gleeble," thermomechanical test unit, electron beam, laser and plasma spray equipment. Although modestly equipped at present, the laboratory was the busiest that I have ever seen as the technicians scurried around producing test procedure plates.

The other new Maritime Research Institute is directed by Professor Ir. A. J. W. Lap who helped establish several such research centers in Europe. Dr. Lap proudly points out that HHI has tested as many hulls in the towing tank in the first five months of operation as were tested in the nearly identical tank at the Ship Research Institute in its first five years. With approximately 50 new ships to be built each year, there is little doubt that the HHI towing tank will be busy.

The HHI shipyard at Ulsan is both massive and impressive. While their level of technology is good, there is still room for growth. One can only wonder what their capacity will be when they achieve the current world standards for productivity. They already produce one-eighth of the new ships in the world. How much larger can they become?

KOREA SHIPBUILDING AND ENGINEERING COMPANY

Korea Shipbuilding and Engineering Company (KSEC) in Pusan is the oldest of the four large builders in Korea, having started as a public corporation in 1937. It became private in 1968 and today has capacity for 13 ships per year up to 80,000 deadweight tons. Last year they produced ten ships and this year they will produce 13. There are 3000 people working in the yard, one-half of whom are welders. They use a large amount of shielded metal arc welding (SMAW), but are rapidly increasing to semiautomatic, especially gas-free welding. In 1984, the welding fraction was:

TYPE	PERCENT
semiautomatic	7
vertical down	7
automatic	10
gravity	29
SMAW	47

In 1985, semiautomatic is expected to be 10% and by 1987 they expect it to grow to 30% almost entirely at the expense of SMAW.

It was interesting to see that KSEC uses one-side submerged arc welding (with Japanese consumables) in the yard, but does not use the process in the hull shop. They suffer from the same problem of small, odd-size steel plates as HHI, but it is perhaps less of a problem with the smaller size ships that KSEC builds.

CONCLUSION

Shipbuilding has expanded rapidly in Korea such that they now have 20% of the world market. This is in spite of the fact that the shipyards still have considerable progress to be made in production methods and materials and they have not bid on some of the higher technology ships. The productivity is improving and a number of new research centers will, it is hoped, provide the expertise to construct a wider variety of ships. The number of trained engineers is increasing rapidly. On several occasions, I was told that the naval architecture department at the Massachusetts Institute of Technology has over 30 Korean graduate students. If so, Korea is second only to the U.S. Navy in numbers of naval architecture students at MIT.

With expected improvements in productivity, Korea already has enough shipbuilding capacity to expand their share of the world market, and if they hope to fully employ all of their new engineers they must continue to expand; however, the growth of Chinese shipbuilding and the probable slow decrease in Japanese shipbuilding will make maintenance of market share difficult. This is yet another area of world trade that could produce severe tensions in the years to come.

TABLE Ia

KOREAN SHIP ORDERS IN 1984

(in thousand G/T)

COMPANY	FOREIGN		DOMESTIC		TOTAL	
	No. of ships	G/T	No. of ships	G/T	No. of ships	G/T
Hyundai	41	1,542	5	212	46	1,754
Daewoo	32	564	1	85	33	649
KSEC	7	116			7	116
Samsung	4	208			4	208
Korea-Tacoma			1	0.1	1	0.1
Donghae	2	8	1	5 3	13	
Daedong	1	0.4			1	0.4
Daesun	3	17			3	17
Shin-A	6	3	3	3	9	6
Inchon	14	32			14	32
Kirim	10	1			10	1
Total	120	2,494	11	306	131	2,800

TABLE Ib

KOREAN PRODUCTION RECORD BY SHIP TYPE IN 1984

(in thousand G/T)

SHIP TYPE	FOREIGN		DOMESTIC		TOTAL	
	No. of ships	G/T	No. of ships	G/T	No. of ships	G/T
Tanker	11	353			11	353
Product carrier	9	175			9	175
Combined carrier	1	22			1	22
Bulk carrier	51	989	5	148	56	1,138
General cargo carrier	8	31	1	4	4	36
Full container	10	398	2	24	12	422
Multipurpose cargo carrier	3	31	1	4	4	36
Reefer	8	71			8	71
Passenger carrier			2	0.2	2	0.2
Others	17	35	5	3	22	39
Rig			1	12	1	12
Total	111	2,084	17	196	128	2,280

TABLE II

FACILITIES AT THE MATERIALS TESTING AND
INSTRUMENTAL ANALYSIS CENTERS OF SEOUL NATIONAL UNIVERSITY

JEOL Scanning Electron Microscope
JEOL Microprobe with wavelength and energy dispersion
JEOL 100 C 120 kV Transmission Electron Microscope
JEOL 200 CX 200 kV Transmission Electron Microscope
Instron 1125, 10 ton
Instron 1332, 20 ton
Four fatigue testing machines
Five creep frames
Impact testing equipment
Rapid solidification melt spinning equipment
High temperature microhardness
Four Rigaku X-ray diffractometers
Perkin Elmer ESCA/Auger
Carbon, hydrogen, oxygen and nitrogen analyzers
IR, UV and visible spectrometers
X-ray fluorescence
Jarrell Ash 0.75 m emission spectrometer
Shimadzu Inductively Coupled Plasma spectrometer
100 MHz Nuclear Magnetic Resonance Unit
Mass spectrometer
Two gas chromatographs

TABLE III

TECHNICAL PAPERS PRESENTED IN THE

- Vol. 1, No. 1, August 1983

Title	Authors
A Study on the Fracture Mechanical Behavior of Cruciform Welded Joint With Fracture Cracks	D. S. Um, S. W. Kang, D. S. Yu
A Study on the Mechanical Properties on High Heat Input Welds of High Strength Steels	Y. S. Kim, C. H. Bae

- Vol. 1, No. 2, December 1983

Title	Authors
Study on the Disbonding of Stainless Steel Overlay Welded Metal (Report 1)	Y. H. Lee, E. P. Yoon
Effects of Specimen Sizes on Crack Opening Displacement (COLD) for Submerged Arc Weldments of Fine Grained Steel	J. G. Youn, D. H. Kim, S. H. Hwang, M. I. Kim
Effect of the Grain Size of Temperature Dependence on the Creep Behavior of SUS 316	S. W. Oh, O. Kang
Effect of Initial AE Counts during Plastic Deformation in Friction Welding of Dissimilar Steel Tubes on the Weld Quality Control	S. K. Oh, D. J. Kim L. K. Chung
Study on the Addition and the Transfer of Alloying Elements in FCAW	K. J. Kim, K. H. Park

- Vol. 2, No. 1, March 1984

Title	Authors
Study on the Disbonding of Stainless Steel Overlay Welded Metal (Report 2)	Y. H. Lee, E. P. Yoo
Investigations about the Fracture Behavior on High-Temperature-Brazed NiCr 20 TiAl/BNi-5 Joints	H. D. Steffens, S. C. Bae, B. Wielage R. Dammer
Effects of Welding Parameters on Bead Width and Penetration in Electron Beam Welding	S. H. Kim, C. S. Kang, J. W. Yoon, S. H. Hwang
Effect of Moisture in Arc Welding Electrode on Mechanical Properties of Weld Metal	H. M. Yun, Y. S. Kim, J. E. Park

A Study on Evaluation of Plastic Strain at Notch Tip of Weld HAZ in Steel	T. Y. Kim, J. K. Lim, S. H. Chung
L. C. F. Behavior of AISI 304 L Austenitic Stainless Steel Weldment	H. T. Kim, S. H. Hwang, S. W. Nam

TABLE IV

PROPORTION OF COLLEGE GRADUATES PER 1000 POPULATION

United States	33.6%
Korea	22.5%
France	18.4%
Japan	15.3%
Great Britain	5.3%

TABLE V

AREA AND BUILDING CAPACITY OF BUILDING DOCKS AT HHI-ULSAN

*No. 6 Drydock is for Redocking Service

Site	7,200,000 m^2				Works	1,400,000 m^2			
Dock	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	Shipway	Ship Lift
Length (m) Width (m) Depth (m)	400 m 80 m 12.7 m	500 m 80 m 12.7 m	660 m 90 m 13.2 m	380 m 65 m 12.7 m	260 m 65 m 12 m	260 m 43 m 11 m	175 m 25 m 11 m	215 m 40 m	120 m 20 m
Cranes	2x450 T Gantry 2x30 T Jib		2x450 T Gantry 1x150 T Jib 1x30 T Jib	1x200 T Jib 1x150 T Jib 2x80 T Jib		1x150 T Jib 2x80 T Jib	2x30 T Overhead	1x150 T Jib 1x30 T Jib	1x60 T Jib 1x30 T Jib
Max Size (DWT)	500,000	700,000	1,000,000	400,000	250,000	150,000	15,000 8,000 Dis- placement	47,000	3,300 T Lifting Capacity
Outfitting Quay	Combined Length: 5,000 m								

APPLICATIONS AND TRENDS OF ELECTROSLAG TECHNOLOGY IN JAPAN

Thomas W. Eagar

INTRODUCTION

Electroslag welding and casting processes have been used in Japan for approximately two decades, with generally good success. This report describes the amount of electroslag welding performed in Japan in 1981 along with typical product applications. It also describes briefly an electroslag casting and an electroslag overlay process, as well as recent trends in the usage of electroslag technology. A brief discussion of the reasons for the trends is also included.

ELECTROSLAG WELDING

Professor Isao Masumoto of Nagoya University reviewed the application of electroslag welding in Japan in 1981 [Masumoto *et al.* (1981)]. His survey, which does not claim to be comprehensive, but appears to include most of the larger users of electroslag welding, indicates that more than 250 tons of electroslag weld metal was deposited in 1981. This was estimated to be 0.064% of the total volume of weld metal used in Japan; hence, in Japan, electroslag is a specialized process which is used for a limited number of applications. Nonetheless, Japanese industry has a wide range of experience with the process. Welds of 0.3 m to 9 m length have been made in section thicknesses ranging from 16 mm to 2.1 m. Welding currents range from 280 A to 8000 A with joint gaps from 18 mm to 50 mm. Materials welded include mild steel, high strength steel, stainless steel, and Cr-Mo steels. As can be seen from Figure 1, three-quarters of the weld metal is produced by the nonconsumable electrode guide process and most of this is used by the industrial machinery and pressure vessel industries. It should be noted that these overall figures are heavily biased by several 2 m x 4 m x 50 mm joints made in large castings for the industrial machinery industry. Each such weld contains over 10 tons of weld metal which is 4% of the total annual electroslag usage in Japan! Although, Professor Masumoto's report does not indicate actual figures, it is believed that the shipbuilding and building construction industries produce the largest number of ESW joints, but these are of considerably smaller average size than those of the industrial machinery and pressure vessel industries.

Typical applications for electroslag welding in Japan include the following:

- longitudinal stiffners of the upper deck of ships (see Figure 2a),
- joining of large castings (see Figure 2b, 2c, and 2d),
- longitudinal welds in cylindrical pressure vessels,
- shells for blast furnaces and basic oxygen furnaces, and
- corner joints and tee joints in building box columns.

It can be appreciated that most of these applications involve low strength steels. When higher strength steels are used or greater toughnesses are required, complete normalization is necessary (e.g., the water turbine in Figure 2d and the pressure vessel). Indeed, the greatest limitation of electroslag welding in Japan is the poor fracture toughness of the weld heat affected zone. As a result, ESW is used only where toughness is not a concern, or where renormalization is not a prohibitive expense.

In the past few years, there has been much greater use of high strength steels in

Japan (greater than 60 ksi yield strength) The high heat input of ESW is generally not acceptable for these steels and narrow gap and electrogas processes are being used. In a January 1985 summary of welding processes for 22 major industrial products, Mitsubishi Heavy Industries listed electroslag as a current process for only three products with a projection for the future that ESW will be used in only one application, *viz.* steel rolling mill stands. Narrow gap welding will replace ESW in both of the other current applications because it is becoming faster, cheaper, more amenable to repair, and produces better weldment properties than ESW.

Japanese welding experts are unanimous in their belief that the low fracture toughness of the weld zone is the greatest barrier to increased utilization of ESW in Japan. The second most difficult problem is repair of weld restarts, although this is a minor problem compared to the question of toughness. A former problem was hydrogen cracking; but, as in the United States, this has been solved by better process control.

Japanese investigators have tried a number of methods of reducing the toughness limitation. Process variations to reduce heat input, e.g., metal powder additions, reduced joint gap, multiple electrodes and the like have been made, but are not deemed to be of sufficient magnitude or practicality to solve this problem. For some steels, the twofold reduction in heat input permitted with electrogas welding is sufficient to improve toughness to acceptable limits, but for most steels, narrow gap is the best welding process which provides good toughness. In a few applications, electron beam welding is preferred but this process, like ESW, is very specialized.

In summary, Japan has a great deal of experience with electroslag welding of steels. The process works well, but the degradation of mechanical properties due to the high process heat input, limits ESW to a few specialized applications. Current trends indicate less use of ESW in favor of narrow gap, electrogas, or electron beam processes. This trend is accelerated somewhat by the increased use of higher strength steels which have more restrictive heat input limitations.

ELECTROSLAG CASTING

Although there appears to be considerably less experience in Japan with electroslag casting as compared with electroslag welding, Mitsubishi Heavy Industries has considerable commercial experience with a process called "yozo" which can be translated as "melt forming." Both large diameter pressure vessel cylinders or small diameter tubes can be produced by variations of this process as shown in Figure 3a and 3b. A number of interesting production materials and shapes have been made using this technology in Japan. These include oval tubes of HK40 alloy, heavy section "H" beams of 25Cr-35Ni-2Mo heat resistant steel, bent steam reformer tubes of varying wall thickness and large diameter stainless steel elbows. The product quality is excellent. The only difficulty is that the electroslag casting process is relatively slow compared with alternative casting processes. With the advent of AOD and VOD refining techniques to steel casting technology in recent years, it appears that the use of yozo electroslag forming is rapidly declining for economic rather than for technical reasons.

As with electroslag welding, electroslag casting in Japan is declining; however, it is a technically sound process which may have a number of advantages in specialized applications.

ELECTROSLAG SURFACING

One of the areas of electroslag technology where applications are increasing is surfacing. This process, called MAGLAY, was developed by Kawasaki Steel in the late 1970s and is now used extensively in Japan and has been licensed to several European manufacturers. As far as the Japanese know, there has been relatively little interest in this development from the United States.

The MAGLAY process is a strip cladding process in which high electrical conductivity flux (containing greater than 50% fluorides) is used to promote electroslag rather than submerged arc performance. This process was studied extensively in Europe in the early- to mid-1970s, but the major problem was undercutting at the overlap regions between weld deposits. Kawasaki Steel recognized that this undercutting was due to an unfavorable convection pattern in the liquid metal and slag. By introduction of external magnetic coils, they were able to alter the normal convection pattern and eliminate the undercutting (see Figure 4). The result is a very uniform weld overlay bead with exceptional smoothness. In addition, the low heat intensity of the electroslag process, as compared with the submerged arc process, greatly reduces dilution which is an advantage in cladding operations. The usual strip cladding width with MAGLAY is 150 mm, but 300 mm wide coils have been used successfully. Since its introduction, some four or five years ago, MAGLAY has overtaken virtually all cladding operations in Japan. Submerged arc cladding is only used in some specialized operations where higher dilution is desired or on complex curvatures, such as conical heads. In these later cases, narrower beads must be used and the higher heat intensity of the submerged arc process permits more rapid travel speed. In most cases, where bead width is not restricted by vessel geometry, the MAGLAY process is preferred. The travel speed of MAGLAY is slower than submerged arc but the practical bead widths are greater.

SUMMARY

Japanese industry has considerable experience with electroslag technology in a wide range of materials and product sizes. The process is generally considered to operate well, but its uses are declining in most cases. In the case of electroslag welding, the major disadvantage is the low fracture toughness in carbon and low alloy steels due to the high process heat input. Narrow gap, electrogas, and in some cases electron beam welding processes are increasingly preferred due to lower heat inputs, similar costs, and more versatile positional capability.

Electroslag casting in Japan has never been a major technology, but in recent years it has been nearly totally replaced by other processes which can refine the metal much more rapidly and economically. One exception is the MAGLAY electroslag surfacing process which has gained rapid acceptance in the pressure vessel industry.

There has been relatively little research on the electroslag process in Japan for nearly a decade. One expection is that descibed by Nakano *et al.* (1978), which was apparently done in conjunction with development of the MAGLAY process. Indeed, some Japanese researchers question why the United States is still interested in ESW. As far as they are concerned it is a well understood but limited process of declining interest. At a welding society meeting held in November 1984, attended by representatives of some 40 Japanese companies, only two companies noted current use of electroslag welding, and these two applications both involved joining of castings.

There is some interest, but no research experience, on electroslag technology for titanium in Japan. Kawasaki Heavy Industries and Mitsubishi Heavy Industries are competing for a contract to build a 2-m-diameter, 60-mm-thick spherical titanium submersible. The tenative welding process is electron beam, but the researchers were interested to learn that ESW may be a good process for titanium. In the area of electroslag casting, several Japanese steel companies would like to make large, rectangular titanium castings for production of rolled heavy section titanium plates. At present, such work is only in the planning and basic research stage. It is not known whether electroslag casting of titanium would be considered for production of such shapes.

In conclusion, Japanese experience with electroslag technology is broad, but its use is declining in favor of other processes. There is no evidence that this trend will reverse in the future.

ACKNOWLEDGEMENTS

The author wishes to thank a number of Japanese researchers who have helped him gather information for this review. These include Professor I. Masumoto of Nagoya University, Professor K. Iida of Tokyo University, Dr. T. Kobayashi of the Japan Welding Engineering Society, Dr. S. Shono and Mr. G. Takano of Mitsubishi Heavy Industries, Dr. H. Nomura of Nippon Kokan K.K., Dr. H. Homma of Nippon Steel Corporation and Mr. S. Nakano of Kawasaki Steel Corporation.

REFERENCES

"Application of Electroslag Welding in Japan," I. Masumoto and I. Sejima. IIW Document *XII-A-16-81*.

"Fabrication of Large Water Turbine Runner by Electroslag Welding," S. Sato, O. Matsumoto, S. Kawaguchi, Y. Kitamura, and K. Kimura. Mitsubishi Heavy Industries Technical Review, 1, (1983).

"Development of New Metal Forming Technique Using Electroslag Welding Process," A. Ujiie, T. Nagata, T. Nagaoka, and N. Sakamoto. Document *XII-468-68* of International Institute of Welding.

"Production of Yozo Tubes of Special Shapes," S. Sato, J. Nagata, M. Fujimoto, H. Kuwabara, and A. Ujiie. Mitsubishi Heavy Industries Technical Bulletin, *156*, (1983).

"MAGLAY Process-Electromagnetic Controlled Overlay Welding Process with ESW," S. Nakano, N. Nishiyama, T. Hiro, and J. Tsuboi. Kawasaki Steel Tecnnical Report, *2*, 31, (1981).

"Slag-Metal Reactions and Origins of Oxygen in ESW Process," S. Nakano, K. Tamaki, and J. Tsuboi. IIW Document *XII-J-67-78*.

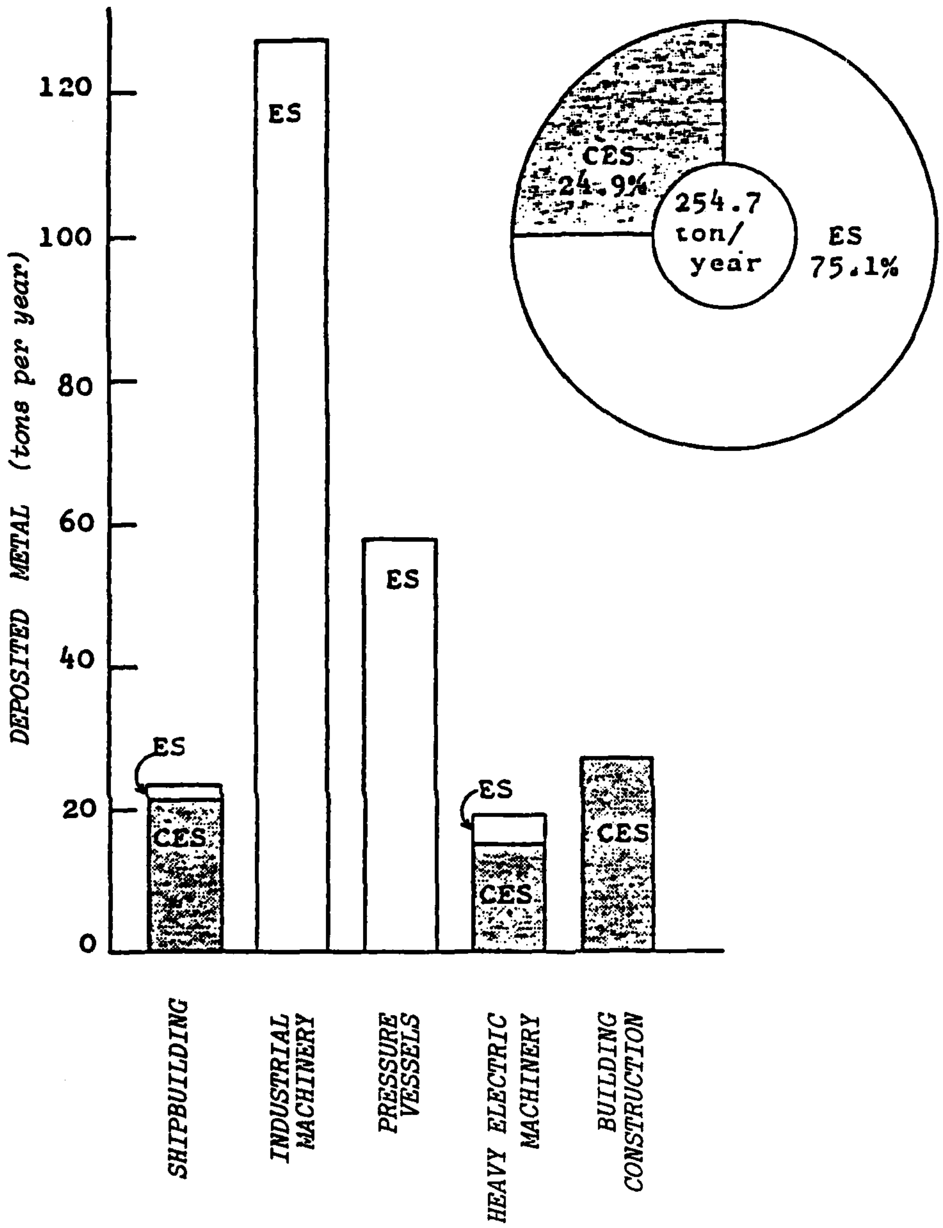


Figure 1. Weight of electroslag weld metal deposited in Japan in 1981. [Masumoto *et al.* (1981).]

CES - Consumable guide process
ES - Copper electrode guide process

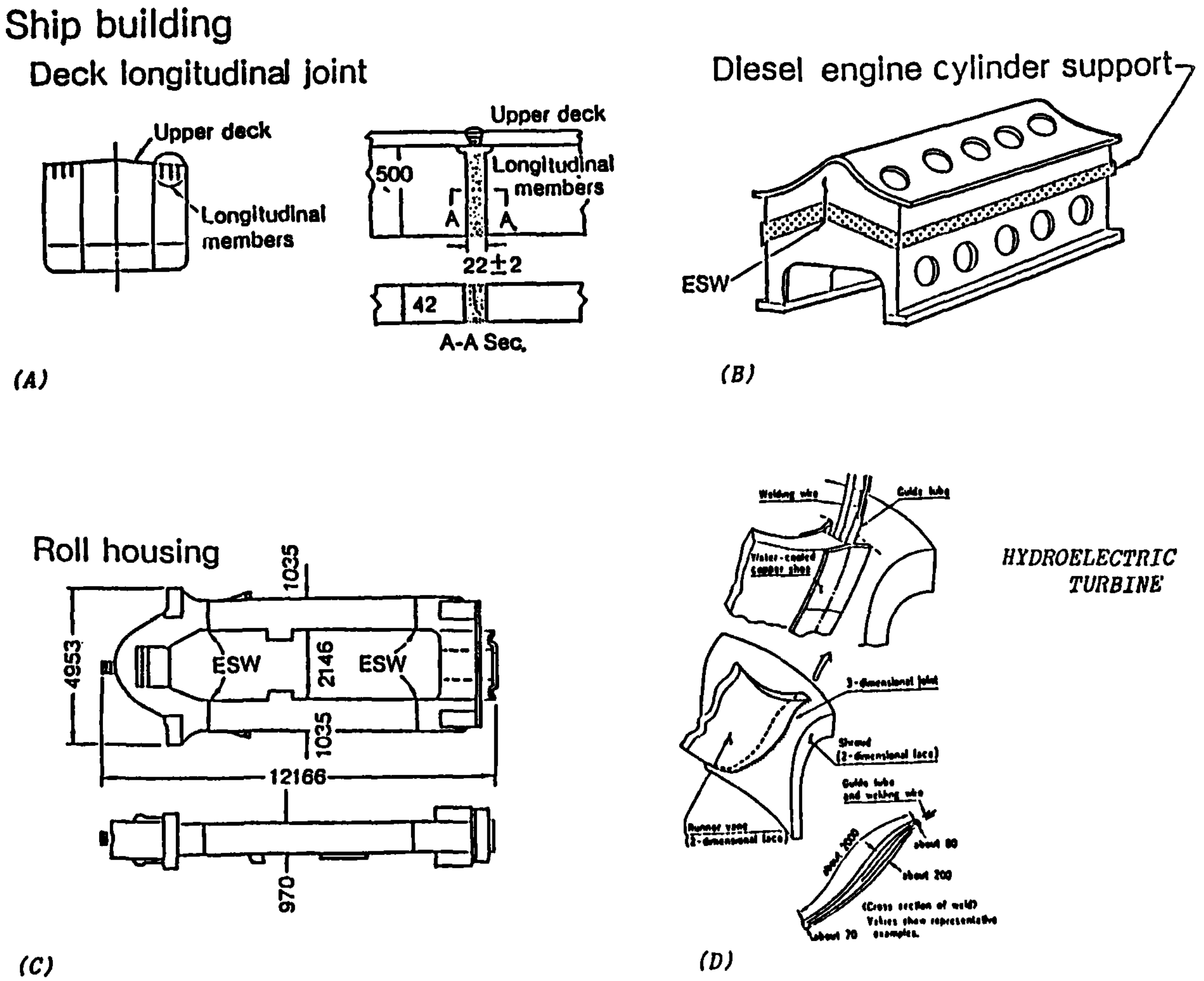
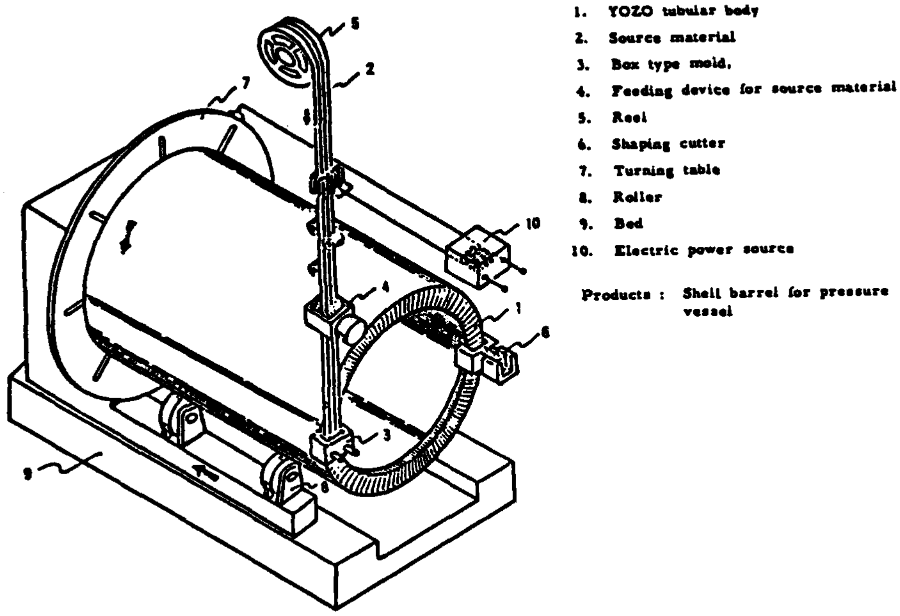
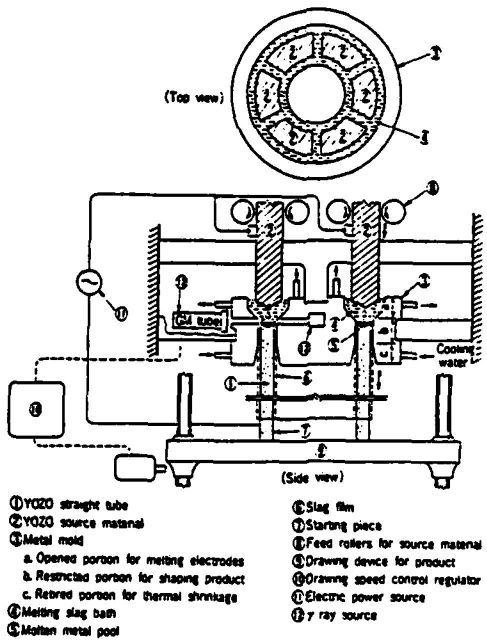


Figure 2. Examples of product applications using electroslag welding in Japan. Note all dimensions are in millimeters. [Masumoto *et al.* (1981), Sato *et al.* (1983).]

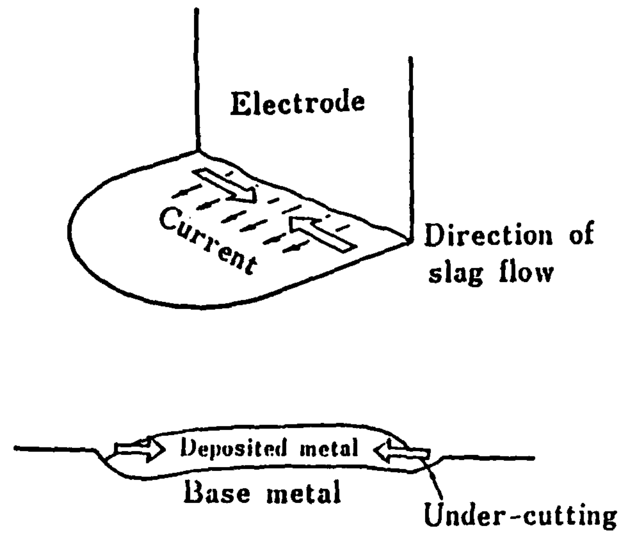


(A)

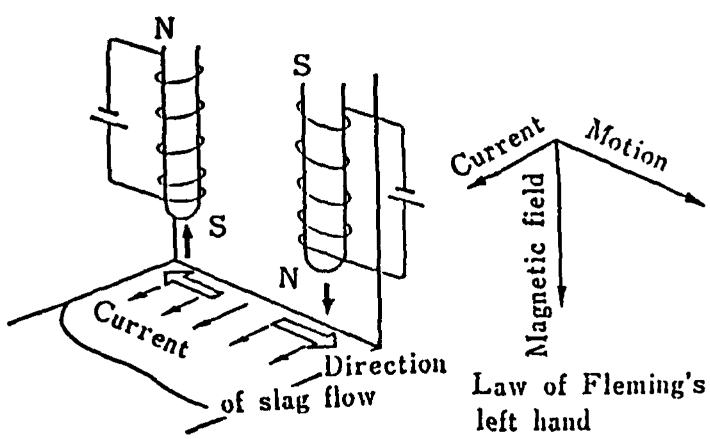


(B)

Figure 3. Examples of electroslag casting of tubular shapes by the yozo melt forming process. (Ujiie *et al.* (1968), Sato *et al.* (1983).]



(A) Schematic mechanism of under-cutting caused by parallel welding current



(B) Control of slag flow with outer magnetic field

Figure 4. Principle of operation of MAGLAY electroslag surfacing process. Addition of electromagnetic coils alter the convection pattern and eliminate undercut. [Nakano *et al.* (1978).]

RECENT ACCOMPLISHMENTS IN ELECTRONIC MATERIALS AND DEVICES AT THE NEC CORPORATION

Yoon Soo Park

INTRODUCTION

In order to meet the challenge of the computer and communication age (C&C), the research and development (R&D) group of the NEC Corporation is conducting research and development for "the day after tomorrow" technology. As one of the largest suppliers of electron devices, home electronics, computers and communication systems, the scope of their research activities encompasses wide areas that form the basis of the future C&C technologies. The R&D group is located in the city of Kawasaki, outside Tokyo, and includes approximately 940 staff members. The research projects include:

- electronic materials and electron devices,
- VLSI technology,
- optoelectronics,
- C&C systems,
- software production technology, and
- resources and environmental protection.

The R&D group is being organized into the following structures:

- R&D Administration Division,
- R&D Planning and Technical Service Division,
- Fundamental Research Laboratories,
- Microelectronics Research Laboratories,
- Optoelectronics Research Laboratories,
- C&C Systems Research Laboratories,
- Software Product Engineering Laboratory,
- Resources and Environment Protection Research Laboratories, and
- Scientific Computer Center.

In this report, research activities and accomplishments of three research laboratories--fundamental, microelectronics, optoelectronics--which were presented to the author during his visits to NEC will be discussed.

RESEARCH ACTIVITIES AND ACCOMPLISHMENTS

- Materials Growth

. LEC growth of $InAs_xP_{1-x}$ bulk crystals

NEC is engaged in, among other bulk crystal growth activities such as InP growth, the growth of InAsP ternary substrates. Currently, many III-V ternary or quaternary device structures are grown on binary compound substrates such as GaAs and InP. If these device structures are grown directly on ternary or quaternary alloy substrates, limitations due to lattice constant mismatch will be greatly reduced and the freedom in the design of the device structure would be increased. For example, long wavelengths (1.7-3.0 μm) lasers or high speed InGaAs transistors grown on InAsP alloy substrates may provide higher performances than those grown on InP lattice-matched InGaAs.

With these objectives, NEC has successfully grown single crystal ingots of $InAs_xP_{1-x}$ by the liquid encapsulated Czochralski (LEC) method. Under optimal growth conditions, with seed melt-back followed by slow cooling and the pulling rates of less than 100 μm/min, a single crystal ingot of 15-20 mm was grown from the 80%-InP melt with a small polycrystal region. Dislocation density in the core was found to be $5x10^3$ to $2x10^4/cm^2$.

- Hydride vapor phase epitaxy

At NEC, the halogen transport method, particularly hydride vapor phase epitaxy is being extensively employed in the growth of InGaP and InGaAsP alloys with the dual growth chamber (DGC) technique developed at NEC. In comparison to the LPE technique, the hydride VPE technique has permitted the growth of multilayer structures with a greater junction abruptness, higher purity, and better thickness control. In addition, the hydride VPE technique results in a larger growth area and is, therefore, adaptable to mass production.

In the DGC system, the substrate is transferred between two independent chambers and a multilayer structure is continuously grown without interruption. The technique was used previously to grow 160Å InGaP/100Å GaAs superlattice structures and room temperature cw InGaAsP/InGaP DH lasers in the wavelength range of 7200-7800Å. Formation of abrupt and flat interfaces has been demonstrated.

Recently, purification methods for vapor-grown InP layers have been developed. By increasing the indium source temperature (∿910°C) and by introducing a small amount of oxygen (∿1.2 ppm), InP with a 77 K mobility of 40,000 $cm^2/V.s$ and a carrier concentration of $5x10^{14}$ cm^{-3} was grown. It is believed that the In source has a gettering effect for impurities in HCL from a cylinder and the oxygen produces nonvolatile oxides of residual impurities, resulting in a reduction in the impurity incorporation.

By using the DGC VPE method, a long wavelength InGaAsP MQW laser having a well thickness of 130-310Å was also fabricated. The laser operated at a threshold current density of 960 A/cm^2.

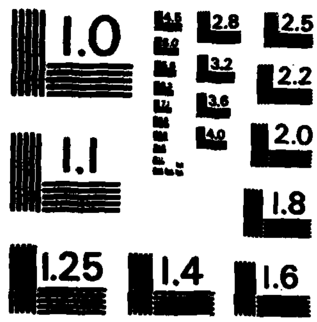
. Optoelectronic Devices

The research and development projects in optoelectronics components at NEC includes:

sources	visible lasers/LEC 1.3 μm LD, 1.3 μm DFB-LD, 1.5 μm LD
detectors	Ge-APD InGaAs-APD
integrated optics	PIN-FET, LD-FET, bistable LD
signal processing	acousto-optic correlator
gas laser	excimer laser
solid state laser	Er glass laser

AD-A162 667 ONR (OFFICE OF NAVAL RESEARCH) FAR EAST SCIENTIFIC BULLETIN VOLUME 10 NUM.. (U) OFFICE OF NAVAL RESEARCH LIAISON OFFICE FAR EAST APO SAN FRAN.. N A BOND ET AL. JUN 85 2/2

UNCLASSIFIED F/G 5/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

- Visible Lasers

. 0.65 μm InGaAsP/GaAsP visible laser diode

Another recent accomplishment with hydride VPE is the fabrication of a visible laser diode operating at 0.65 μm using a InGaAsP/GaAsP system. Both planar and mesa stripe DH laser structures were fabricated. Under a pulsed condition, the threshold current density of as low as 5.6 kA/cm² was obtained. This is the lowest current density reported for the diode operating at 0.65 μm. A cw operation up to -27°C was also possible with this diode.

. 626.2 nm AlGaInP DH laser grown by MOCVD

In pursuit of visible laser diodes operating below 0.7 μm, NEC is also examining an AlGaInP material system grown by MOCVD. They have achieved the room temperature pulsed operation of an AlGaInP DH laser at 626.2 nm wavelength by low pressure (70 Torr) MOCVD at the substrate temperature of 800°C. The laser structure has a current confinement stripe width of 20 μm. Threshold current density of about 50 kA/cm² was obtained.

. 590 nm orange electroluminescence from AlGaInP DH diodes grown by MOCVD

NEC has demonstrated the MOCVD growth of $(Al_xGa_{1-x})_{0.5}In_{0.5}P$ with the entire aluminum composition (0<x<1) in order to cover the lasering wavelength region of 580-680 nm. Recently, they have obtained 590 nm orange electroluminescence from an $(Al_{0.5}Ga_{0.5})_{0.5}In_{0.5}P/(Al_{0.3}Ga_{0.7})_{0.5}In_{0.5}P/(Al_{0.5}Ga_{0.5})_{0.5}In_{0.5}P$ DH structure at a dc injection current of 20 mA at room temperature. This is the shortest wavelength ever reported for this material system. They attribute the achievement to improved doping and luminescence efficiency by introduction of a simple air lock system in the LP MOCVD reactor chamber to prevent the reactor wall from exposure to the air. For n-type $(Al_xGa_{1-x})_{0.5}In_{0.5}P$, a resistivity of a few hundreds ohm-cm was obtained for the entire Al composition and a resistivity of a few tens of ohm-cm was attained for p-type $(Al_xGa_{1-x})_{0.5}InP_{0.5}$ with $x \leq 0.6$. They expect further improvement in crystalline quality for high aluminum composition materials if more extensive precautions are taken regarding water or oxygen contamination.

. 1.3 μm high-speed surface emitting In GaAsP/InP LED for Gbit/s modulation

In response to the need in intermediate-range transmission systems, such as local area networks, as an alternate to laser diodes, NEC has developed 1.3 μm surface-emitting InGaAs/InP DH LEDs grown by LPE. The LED has a 0.6 μm-thick p-type active layer heavily doped with Zn to $1.3x10^{19}$ cm^{-3} and the current confinement region of a 17μm diameter built in the n-type InGaAsP capping layer. A 2000 Å-thick SiO_2 film is inserted between the capping layer and the p-contact to reduce parasitic capacitance. By shortening the crystal growth time, the Zn diffusion to the n-type InP buffer layer was minimized. Using this LED, they have achieved 2 Gbit/s 500 m transmission.

. Ultrahigh speed device research

Ultrahigh speed device research at NEC is carried out mainly at the Ultrahigh

Speed Device Research Laboratory of the Microelectronics Laboratories, which have four other laboratories: the Ultra-LSI, Electron Device, Memory, and Sensor Research Laboratory. The R&D topics at the Ultrahigh Speed Device Research Laboratory include:

Josephson Junction

logic ICs
memory ICs
process technology

GaAs ICs

digital ICs - logic ICs
- memory ICs
analog ICs - microwave ICs
process technology

Advance High Speed Devices

MOD heterostructure FETs
InP MISFET

- Discrete Microwave Devices

. MESFETS

Recent performance data of GaAs MESFETs developed at NEC for low noise and high power applications are:

. NEC low noise GaAs MESFET

L_G (μm)	Lithography	Gate Metal	Frequency (GHz)	NF (dB)	Gain (dB)
0.3	D-UV	Al/Ti	12	1.22	10.5

Feature: p-n-n^+ 3 epitaxial layers with a deeply recessed gate.

. NEC high power GaAs MESFET

	L_G (μm)	Gate Metal	Gate Width (mm)	Freq (GHz)	Pout (W)	Gain (dB)	Eff (%)
(1)	0.5	Al	1.5	28.5	0.2	3	7.3
			6	18	2.0	3	16
(2)	0.5	Ti/Al	7.5x4	11.2	10	3	17
			3x2	15.2	3	5.7	40

Features: (1) a deep recess gate structure,
(2) a recessed gate, plated heat sink (PHS), and via holes

. MODFET

Though R&D work on FETs based on an n-AlGaAs/GaAs had been a monopoly of Fujitsu, Ltd., in Japan, recently many other Japanese device houses have begun producing HEMT devices.

NEC has also fabricated a 0.5 μm gate MODFET which exhibited room temperature performances of 310 mS/mm transconductance, 1.2 dB noise figure with 11.7 dB associated gain at 12 GHz, and 0.34 dB noise figure with 14.8 dB associated gain at 4 GHz. These performances are just on par with the state-of-the-art HEMTs announced by other laboratories.

While many other HEMTs which have a recessed gate structure, their devices have a planar p^+ gate structure--an Al electrode and an interposed p^+-GaAs thin layer on the n-type surface layer. The gate, therefore, has a large potential barrier due to a p-n junction, providing high reliability and a small gate resistance.

The device structure was grown by MBE and consists of p^+GaAs(200Å)/ n-GaAs(100Å)/n-AlGaAs(graded, 200Å)/n-$Al_{0.3}Ga_{0.7}As$(100Å)/undoped $Al_{0.3}Ga_{0.7}As$ (spacer, 50Å)/undoped GaAs(1 μm)/SI GaAs. The p^+GaAs was doped with Be to $2x10^{19}$ cm^{-3} and the n-GaAs layer doped with Si has a carrier concentration of $2x10^{18}$ cm^{-3}. The 2DEG mobilities were found to be 89,000 cm^2/V.s at 77 K and 6,500 cm^2/V.s at room temperature.

. A novel short period AlAs/n-GaAs superlattice

In order to eliminate the threshold voltage instabilities normally encountered in two-dimensional electron gas field effect transistors (2DEGFET) with n-$Al_xGa_{1-x}As$/ GaAs heterojunctions such as in HEMT or TEGFET, NEC has fabricated a novel 2DEGFET with a short period AlAs/n-GaAs superlattice as an electron supplying layer by MBE and a conventional recess gate process. The threshold voltage instabilities due to temperature change or light illumination were thought to be caused by the existence of deep electron traps in n-$Al_xGa_{1-x}As$ called DX centers. Coexistence of Al and Si or Al and Ga is postulated to give a generation of the DX centers in the n-$Al_xGa_{1-x}As$/GaAs system. If the deep electrons are eliminated by the spatial separation of these atoms, it has been thought that the threshold voltage could be stabilized.

Based on this postulation, NEC workers have formed a short period AlAs/n-GaAs superlattice with Si doped only in the GaAs layer instead of conventional n-$Al_xGa_{1-x}As$.

The layer structure consists of Cr-doped SI GaAs substrates, a 0.5 μm undoped GaAs buffer layer, 400Å multiple layers, and 500Å n^+-GaAs top layer. The multiple layers contain a one-period AlAs/GaAs space layer (40Å), a three-period AlAs/n-GaAs superlattice (3x40Å), and a graded superlattice which has a constant n-GaAs layer (23Å) and graded AlAs layers (12-3Å) toward the surface. The doping concentration in the superlattice is about $2x10^{18}cm^{-3}$. At 77 K, the two-dimensional electrons at the superlattice/undoped-GaAs interface had a mobility of 85,000 cm^2/V.s and a sheet carrier concentration of $8x10^{11}$ cm^{-2}.

When a 3 μm recessed gate FET was fabricated from this structure, the threshold voltage changes due to temperature changes (300-77 K) and light illumination are effectively suppressed to ΔV_T=0.1 V as a result of low deep electron concentrations in the superlattice. The intrinsic transconductances of 325 mS/mm at 77 K and 146 mS/mm at 300 K were obtained. With a thinner AlAs/n-GaAs superlattice layer (∿300Å) and shorter gate length (∿1 μm), high transconductance (>700 mS/mm at 77 K) is expected.

. Enhancement-mode GaInAs MISFETs with X-band operation

Because of their potential for high-speed and high-frequency, NEC is investigating GaInAs-based devices. Recently, they fabricated enhancement-mode GaInAs MISFET operating at X-band which exhibited good dc characteristics.

The MISFET structure is formed on an undoped, n-type (n∿1.5×10^{16} cm^{-3}) GaInAs layer grown by VPE on an Fe-doped semi-insulating InP substrate. The channel length of ∿1 μm was formed by etching to the thickness of ∿1500Å and the Al gate metal was employed with the 1000Å thick CVD SiO_2 gate insulator. The maximum transconductance of 120 mS/mm was obtained. They claim that this value is about four times higher than the values reported so far in enhancement-mode GaInAs MISFETs. The MISFETs exhibit a maximum power gain of 13.5 dB at 4 GHz and 5.6 dB at 12 GHz. The cutoff frequency of 24 GHz was extrapolated from the frequency dependency of power gain.

- MMIC

In order to meet demands for inexpensive receiver front ends for direct broadcasting satellite (DBS) systems, NEC has recently developed one- and two-stage 12 GHz-band low noise GaAs monolithic amplifiers, and a dual-gate FET mixer and a IF buffer amplifier.

The characteristics of one- and two-stage amplifiers are:*

MONOLITHIC LOW NOISE AMPLIFIER

	ONE STAGE AMP.	TWO STAGE AMP. DIRECTLY MATCHED INTERSTAGE	TWO STAGE AMP. 50Ω MATCHED INTERSTAGE
BANDWIDTH	11.7 ~ 12.7 (GHz)		
GAIN (MAX)	>9.5 dB (12 dB)	>16 dB (21 dB)	>20 dB (24 dB)
NOISE FIGURE (MIN.)	<2.5 dB (2.2 dB)	<2.8 dB (2.7 dB)	<3 dB (2.6 dB)
INPUT/OUTPUT VSWR	< 3 (INPUT) < 2.5 (OUTPUT)	< 2.5 (INPUT) < 2 (OUTPUT)	< 4 (INPUT) < 2.5 (OUTPUT)
CHIP SIZE	1mm x 0.9mm	1.5mm x 0.9mm	2mm x 0.9mm

*Through the courtesy of Dr. Y. Takayama

The amplifiers employed 0.5 μm gate closely spaced electrode (CSE) FETs with an ion implanted active layer. In the CSE FET structure, instead of a recessed gate structure, source-gate and drain-gate spacings are shortened to 0.5 μm to reduce source resistance. The FET active layers are formed by ion implantation of $^{29}Si^+$ into a Cr-doped, semi-insulating HB-grown GaAs. To realize the threshold voltage V_T=-1.7 V, 70 keV energy and 3.2×10^{12} cm^{-2} dose was used. The implanted wafer was annealed with a CVD-SiO_2 cap at 800°C for 20 minutes. Both the 12 GHz-band dual-gate GaAs MESFET monolithic mixer and the single gate buffer amplifier employs a CSE FET with 1 μm gate length and 320 μm gate width. Chip size is 0.96x1.26 mm for the mixer and 0.96x0.6 μm for the buffer.

In IC fabrication, ion implantation was also employed to form resistive layers. They obtained 1 K ohm/□ sheet resistivity with the implantation of Si with a 3.8×10^{12} cm^{-2} dose at 130 keV. For capacitors, the MIM type consisting of Al-.2 μm SiO_2-Ti-Pt-Au was formed. The microstrip lines were formed by Ti-Pt-Au and .25 μm Au plating.

The final receiver consisting of a monolithic preamplifier, an image rejection filter, a mixer, and a monolithic IF amplifier provided a 46.8±1.5 dB conversion gain with a 1.8±0.2 dB noise figure. NEC currently is in the process of developing the DBS receiver as a single chip.

- Digital ICs

Keeping pace with other Japanese major device houses such as Fujitsu, Toshiba, Mitsubishi, and NTT, at NEC the high speed digital application of GaAs MESFET ICs is being explored intensively. Since the development of a low power, high speed GaAs 1 Kb static random-access memory (S-RAM) in 1983, NEC's effort has progressed to the fabrication of a 4 Kb S-RAM. The GaAs 1 Kb S-RAM exhibited 30 mW power dissipation and 6 ns address access time. They claim that the 180 pJ access time-dissipation power product obtained is the smallest in the GaAs 1 Kb S-RAMs. In these LSI circuits, the closely spaced electrode FET fabrication technology, planar two-level interconnect technology, and selective ion implantations are being employed.

Examples of logic circuits under development are a GaAs MSI 32-bit adder, having 420 gates (2100 FETs and 420 diodes) within an area of 4.6 mm x 2.5 mm with this IC, 32-bit parallel addition can be executed at the speed of 2.9 nsec with the power dissipation of 1.2 W.

SUMMARY

The NEC Corporation, as one of the leading giants of the world's computer and communication industries, is truly demonstrating leadership in both basic and applied research in electronic materials, processing, and devices. The scope of their research activities encompasses wide areas that form the basis of future C&C technologies. The work on AlAs/n-GaAs superlattices, for example, to suppress persistent photoconductivity (ppc) observed frequently in Si-doped Al_xGa_{1-x} As films is particularly impressive. By eliminating persistent photoconductivity, they were able to fabricate high performance 2DEGFETs with stabilized threshold voltages. They have achieved many firsts in the areas of optoelectronic devices and microwave and high speed devices. The NEC Corporation is truly a leader in the advancement of "the day after tomorrow" technology.

ACKNOWLEDGMENTS

I would like to express my sincere thanks to Dr. Teiji Uchida, vice-president of the R&D group, who acted as my host and arranged meetings with many investigators at NEC.

APPENDIX

Listed below are the individuals at NEC who provided information discussed in the text and their specific areas of interest:

T. Uchida	Vice-president and director, R&D Group	Briefing of NEC activities
D. Shinoda	General Manager, Fundamental Research Laboratories	MBE, superlattices
F. Saito	General Manager, Optoelectronics Research Laboratories	Optoelectronic device activities
K. Ayaki	General Manager, Microelectronics Research Laboratories	Microelectronics activities
Y. Takayama	Manager, Ultrahigh Speed Device Research Laboratory	GaAs microwave devices and ICs
S. Matsushita	Manager, Optical Device Research Laboratory	Optoelectronic devices
H. Watanabe	Manager, Semiconductor Research Laboratories	Bulk crystal growth and hydride VPE
Y. Mita	Research Specialist, Optical Basic Research Laboratory	Ion implantation
M. Kazuhara	Researcher, Ultrahigh Speed Device Research Laboratory	Ion implantation

JAPANESE PROGRESS IN FUTURE ELECTRON DEVICES: SUPERLATTICES

Yoon Soo Park

INTRODUCTION

In order to nurture "revolutionary basic technologies," in 1981, the Japanese government launched several large-scale national projects. In particular, one of the projects--the Research and Development Project of the Basic Technology for Future Industries program has received much publicity and attention among national policymakers and the scientific and technical communities in Western countries because of its spirit, breadth of projects covered, and philosophy of project management and organization.

The project is based on the spirit of laying groundwork for basic technologies essential to the establishment of new industries which are expected to flourish in the 1990s. It covers leading-edge technologies such as new materials, biotechnology, and future electron devices. The project began with twelve subject categories, six in new materials, three in biotechnology, and three in future electron devices. Beginning in April 1985, two new categories, one in new materials and the other in biotechnology are to be added, bringing the total to fourteen categories. The detailed project categories and budget are summarized in Appendix I [see also, the *Scientific Bulletin Briefs*, *Scientific Bulletin*, *10*, (1) 1 (1985)].

The project, under the sponsorship of the Agency of Industrial Science and Technology (AIST), the Ministry of International Trade and Industry (MITI), is carried out by active involvement and participation of industries, universities, and government laboratories. To undertake research, five associations have been formed by private companies under contracts with MITI--three in new materials, one in biotechnology, and one in future electron devices. This way, companies working together in certain research fields are fully informed about each other's progress, and research results are freely disseminated among the scientists.

Several articles have appeared derived from MITI publications describing the project (Hilton, 1982). In this report, recent progress and the achievements of the subproject, superlattice devices in the future electron devices portion of the Research and Development Project of the Basic Technology for Future Industries program are summarized based on discussions held with investigators (Appendix II), and the information extracted from the proceedings of the symposium on new functional devices (see references).

PROJECT ORGANIZATION

The future electron devices project was initiated in 1981 and involves three subprojects:

- superlattice devices,
- three-dimensional ICs,
- hardened ICs for extreme conditions.

The first two subprojects will cover a period of 10 years (1981-1990) and the third subproject will cover an eight-year period (1981-1988). A total ten-year budget of 25,000 million yen ($100 million) has been earmarked for the entire project. Budget figures,

including 1984 and 1985 figures, for each field are:

	SUPERLATTICE, 3-D ICs			HARDENED ICs
Total	**$100,000**	**$32,000**	**$36,000**	**$32,000**
1981	**2,652**	**720**	**1,200**	**720**
1982	**4,512**	**1,200**	**2,000**	**1,200**
1983	**5,804**	**1,688**	**2,904**	**1,216**
1984	**5,921**	**1,720**	**2,948**	**1,244**
1985	**6,340**	**1,808**	**3,224**	**1,308**

(calculated at 250 Yen=$1, figures are in thousands of dollars)

The project is being carried out by eleven companies and a national research institution--the Electrotechnical Laboratory, and administered by the Research and Development Association for Future Electron Devices. The association organized by eleven participating companies originally has expanded now to include thirteen other companies (Appendix III), and has been tasked by MITI to carry out research and development work.

The eleven companies conducting R&D work for MITI are:

- superlattice devices--Fujitsu, Hitachi, Sumitomo Electric, and Sony
- three-dimensional ICs--NEC, Melco, Toshiba, Oki, Matsushita, Sharp, and Sanyo
- hardened ICs for extreme conditions--Hitachi, Toshiba, and Melco.

As a means of disseminating the research results to the public, the association is holding an annual symposia and an international workshop. The Third Symposium on Future Electron Devices was held 4-5 July 1984 and the First International Workshop on Future Electron Devices--Heterostructures and Superlattice Devices was held 6-7 February 1984.

PROGRAM OBJECTIVES

- Superlattice devices--establish basic technologies for superlattice devices having an ultrafine structure--tailored to atomic scale capable of ultrahigh speed processing in order to realize multifunctional information systems.

- Three-dimensional ICs--establish basic technologies for three-dimensional devices yielding multifunctional, ultrahigh density ICs in order to obtain ultrasmall, high-efficiency information processing systems, having an artificial intelligence- (AI) like, multifunctional capability.

- Hardened ICs for extreme conditions--establish basic technologies for hardened ICs which can withstand extreme conditions such as radiation, heat, and mechanical shock in order to realize a high-degree information system capable of functioning under severe environmental conditions such as encountered in space, aircrafts, automobiles, atomic reactors, and power plants.

R&D PLAN

- Superlattice devices

first stage (1981-84)	-	**materials search** **device structure design technology** **device structure fabrication technology**
second stage (1985-87)	-	**device fabrication** **superlattice characterization** **new device structure**
third stage (1988-90)	-	**finalization** **device advancement**

- Three-dimensional ICs

first stage (1981-84)	-	formation of multilayer processing technology
second stage (1985-87)	-	test pattern
third stage (1988-90)	-	function-verifying devices

- Hardened ICs

first stage (1981-83)	-	device structure test methods process technology
second stage (1984-85)	-	integration technology evaluation technology
third stage (1986-88)	-	IC technology for extreme conditions

RESEARCH ACTIVITIES--SUPERLATTICE DEVICES

- Electrotechnical Laboratory

The MITI's Electrotechnical Laboratory (ETL) located at the Tsukuba Science City is playing an important role in the R&D on superlattices at the basic research end. The research activities at ETL focus, in general, on three areas:

. structural design and the physics of superlattices,
. device design and process technology,
. studies on multiheterostructure lasers and on new monolayer superlattices.

ETL has made remarkable progress in the following research areas:

. a computer-aided design system,
. experimental and theoretical study of band discontinuities in heterostructures.

They have developed a method to determine ΔE_C from C-V measurements on MBE grown $GaAs/Al_xGa_{1-x}As$ and established the ΔE_C dependence on Al composition.

. Monte Carlo simulation of particles in superstructure devices
. MBE growth

In MBE, it is a well-known problem that a "metamorphic layer" is formed at the growth-interrupted interface causing depletion of carriers which will provide an electrically high-resistant nonohmic interface. At the solid state device section, to eliminate the metamorphic layer, an amorphous (a-As) passivation technique is being tried. The technique involves: (1) deposition of a-As in the MBE system and sample processing outside the MBE system; (2) deposition of an a-As and second epitaxial layer in the MBE system. When the carrier concentration depth profiles of the growth-interrupted n-type GaAs:Si samples with As-passivation were measured with the C-V technique, no interfacial carrier depletion at the interface was observed in contrast to an air-exposed growth-interrupted n-GaAs:Si.

Experiments show the protection of the surface with As-passivation against air, heat treatment (180°C) in room air, and deionized water.

. a new high-electron monolayer superlattice (MSL)

In the proposed MSL structure consisting of alternating $(InAs)_n(GaAs)_n$, a high electron mobility of $6x10^5 cm^2/V.s$ (50 K, $N_D-N_A=1x10^{16}cm^{-3}$, $N_A/N_D=0.5$), which is an order of magnitude higher than $In_{0.5}Ga_{0.5}As$ alloy, can be expected.

. Simulation of electrons in CHIRP--a new negative resistance device

A novel superlattice device structure has been proposed by ETL workers. It is called a CHIRP (coherent heterointerface for reflection and penetration) device with the possible application as a negative-resistance device. The CHIRP diode is made of a superlattice consisting of alternating thin layers of two different semiconductors such as GaAlAs/GaAs with a gradually changing periodicity sandwiched in between two highly-doped semiconductors, emitter and collector. In such an aperiodic structure device, at a certain bias of the electric field E_b, the injected electrons encounter the minigap of the superlattice at the interface between the injector and the superlattice, and are reflected at the interface. A strong dip in I-V characteristics, therefore, is expected by the electron reflection. For instance, the minigap of 35 meV repels almost completely the injected electrons of the barrier if the minigap is more than 1000Å.

In the CHIRP diode, the diode parameters such as the width and the position of the current dip are controlled almost independently by changing E_o (the conduction band edge discontinuity between two semiconductor materials) and E_b. The ultimate limit to the response time estimated by a computer simulation shows the time elapse of ∿0.1 ps by a reflecting electron for the CHIRP superlattice which has the minigap of 35 meV (corresponding to a $GaAs/Ga_{0.95}Al_{0.05}As$ superlattice with 50% GaAs duty ratio), E_o of 50 meV, and E_b of 6.67 kV/cm.

Because of the design flexibility and high-frequency operation capability, the CHIRP devices are considered very attractive as a negative-resistance diode.

. Multilayer heterostructure lasers.

Recently they have developed a distributed feedback surface emitting laser diode with a multilayer heterostructure of AlGaAs/GaAs. The threshold current of 120 mA at 150 K was achieved with 3 μm wide and 6 μm thick optical cavity.

- Fujitsu Limited

. Hot Electron Transistor

At Fujitsu, particular attention is being paid to the understanding of the nature of current transport perpendicular to AlGaAs/GaAs heterojunctions grown by MBE.

The first tunneling hot electron transistor (HET) employing GaAs/AlGaAs heterojunctions grown by MBE and sophisticated process technology has been fabricated. The heterostructure HET consists of GaAs and $Al_{0.3}Ga_{0.7}As$ layers grown successively on an n^+ GaAs substrate at 600°C. Tunneling occurs between GaAs emitter and base layers through an AlGaAs potential barrier when a positive bias is applied to the base with respect to the emitter. If the thickness of the base is less than a mean free path of injected hot electrons, the hot electrons will surmount the AlGaAs potential and a substantial fraction of the hot electrons will be collected at the collector.

At 77 K, the transfer efficiency of 0.28 was obtained for hot electrons through the 100-nm-thick GaAs base. The transit time for the base region was estimated to be 0.1 ps.

. Superlattice Growth

Recently they have grown an $Al_xGa_{1-x}As$/GaAs(x=0.3) superlattice structure of 37 wells (well thickness=50Å, barrier thickness=100Å, 76 layers) by MBE. From the half-width of the photoluminescence peak from the quantum well at 77 K, they found that fluctuation in layer thickness was less that the lattice constant (5.65Å).

. Lamp annealing on GaAs/N-AlGaAs

In order to study the redistribution of the doped Si atoms in the AlGaAs during annealing, short-time, lamp annealing using tungsten-halogen lamps was carried out on selectively-doped (SD) GaAs/N-AlGaAs grown by MBE. At the 900°C, 20 sec annealing, very little changes in the electron mobility and the electron concentration of the two-dimensional electron gas (2DEG) were observed in contrast to the conventional furnace annealing. The electron mobility and concentration at 77 K remained very high, 74,000 cm^2/V.s and 4.8×10^{11} cm^{-2}, respectively, which are 73% and 94% of the "as-grown" samples.

The ion implantation of Se into MBE grown, undoped AlGaAs is being conducted to form highly doped n-layers. Considerable implantation damage was observed in electrical profiles in the vicinity of the projected range for the samples implanted at room temperature even after lamp annealing at 1000°C, 10 sec. Hot implantation or multiple implantation at a low dose was necessary to reduce the amount of the implantation damage.

- Sumitomo Electric Industries, Ltd.

Sumitomo Electric Industries, Ltd., is investigating MBE growth of superlattices other than GaAs/AlGaAs.

. MBE growth of InGaAs/InP

Efforts are being made to grow high purity InGaAs layers and to develop the technique of controlling InGaAs alloy compositions by attaching an In- and Ga-source purification system directly to the MBE growth chamber through a load-lock mechanism. Therefore, the In and Ga source materials are not exposed to air after being baked for purification and are always maintained at 10^{-9} Torr.

$In_{0.53}Ga_{0.47}As$ layers with a 2-3 μm thickness grown on two-inch InP wafers had a carrier concentration of 3.7×10^{15} cm^{-3} with a room temperature electron mobility of 8450 cm^2/V.s. For a thin, 0.56 μm layer, the electron mobility of 7000 cm^2/V.s was obtained at room temperature. The photoluminescence spectra at 4.2 K showed a donor-valence band transition at 800 meV.

By introducing an $In_xGa_{1-x}As$ multilayer buffer, high quality InAs layers, whose lattice constant is considerably different from that of the substrate, are also grown on InP. First, $In_{0.53}Ga_{0.47}As$ was grown on the InP substrate, and then multiple layers of $In_xGa_{1-x}As$ having graded compositions, 2000Å thick, with lattice constant differences of 0.8% were successively grown. Final InAs layers grown on the multilayer buffer showed mirrorlike surfaces. Mirrorlike surfaces were obtained as a result of layer strains relieved by a large amount of misfit introduced by the lattice mismatch. Electron mobilities of 11,000-12,000 cm^2/V.s for the $InAs/In_xGa_{1-x}As/InP$ structures were obtained.

Another area of investigation at Sumitomo involves $In_xGa_{1-x}As$ strained-layer superlattices (SLS). If the layers in SLSs are kept sufficiently thin, the lattice mismatch can be totally accommodated by layer strains, and generation of misfit defects is minimized. In view of flexibility in the tailoring of electronic properties through the choice of layer materials and thickness, work on $In_xGa_{1-x}As$ SLSs is in progress. So far, 256 periodic $In_xGa_{1-x}As$ layers having a period thickness of 90Å were grown on InP with the lattice mismatch of 7×10^{-3}. No misfit defects were observed by TEM. Optical and electrical properties of the SLSs are currently under investigation. Sumitomo is also evaluating the InAs/GaAs monolayer superlattice (MSL) proposed by the Electrotechnical Laboratory.

- Hitachi Central Research Laboratory

In support of the superlattice device project, Hitachi's Central Research Laboratory is actively engaged in the MBE growth of silicon with the aim of developing Si superstructure devices. Activities include the development of the Si MBE technique, the growth of epitaxial silicides, and a double heterostructure involving Si/silicide/Si.

. MBE growth of silicon

Good epitaxial Si is grown on atomically clean surfaces of Si prepared by thermal treatment at <800°C. Device quality layers are grown at the substrate temperature of greater than 450°C. Thickness uniformity of less than 1% over a 75 mm wafer can now be achieved with thickness fluctuations of less than 300Å.

The doped superlattice structure consisting of 400Å thick n-layers (Sb-doping) and p-layers (Ga-doping) was obtained by operating shutters located in front of the dopant cells. Periodic changes in uniformity profiles with an abruptness of less than 100Å are grown. With ionization doping, the doping level on the order of 10^{20} cm^{-3} for Sb, which exceeds the solubility limit, was attained. For the Sb-doped MBE layers, the room temperature drift mobility comparable to that of bulk crystals can be obtained.

. Epitaxial silicides

High quality $NiSi_2$ films with good surface morphology have been obtained by stoichiometric codeposition of Ni and Si beams. An atomically clean surface of Si (111) at 550°C $NiSi_2$ is being considered as an attractive candidate for high quality heteroepitaxy because of small lattice mismatch (∿0.4%) to Si. The growth temperature of 550°C in MBE growth is far below the minimum formation temperature encountered in conventional methods and the film is formed directly without intermediate formation phases.

. Si/$NiSi_2$/Si double heterostructure

Epitaxially grown silicides have been found to surpass polysilicon silicides in conductivity, thermal stability, and reproducibility of interface properties. Recently, workers at Hitachi have overgrown a Si epitaxial layer over a NiSi epitaxial layer grown on a Si substrate by MBE.

In order to make buried $NiSi_2$ grids in the Si, the $NiSi_2$ layer was patterned in the form of fingers with 1-5 μm width, and then Si overlayer was grown on the patterned substrate at a substrate temperature of 650-750°C and a growth rate of 1Å/sec. In the SIMS depth profiling, a small number of Ni (∿20 ppm) were detected in the Si overlayer due to the outdiffusion of Ni from the $NiSi_2$.

- Sony Corporation Research Center

Sony Corporation Research Center is pursuing the MOCVD growth and characterization of AlGaAs/GaAs superlattices, quantum wells, and an n^+GaAs/AlGaAs/n^+GaAs tunneling diode under the program. Special attention is paid to such aspects as the abruptness of the heterojunctions, controllability of and fluctuations in layer thickness, optical quality, and transport properties of heterobarriers.

. MOCVD growth

AlGaAs/GaAs superlattices including quantum well structures are grown in an atmospheric-pressure vertical reactor which enables the composition of the gas over the wafer to quickly form abrupt heterojunctions. Typically, TMG, TMA and AsH_3 are being employed as the source materials and are carried by H_2 gas at a total flow rate of 11 ℓ/min. For n- and p-type doping, H_2Se and DMZ are used.

. Heterointerface abruptness

The heterojunction interface abruptness has been evaluated in the several superlattice systems by Auger electron spectroscopy (AES) and photoluminescence measurements. The abruptness of the heterointerface as determined by AES profiling was estimated to lie at about 20-25Å, which includes the depth resolution of the apparatus (∿15Å). Photoluminescence measurements indicated that the interface was about one-two monolayers.

. Photoluminescence evaluation

Four GaAs quantum wells of 30, 40, 70 and 100Å thick separated by 500Å thick $Al_{0.54}Ga_{0.46}As$ barrier layers were grown on a GaAs wafer. It was found that the measured photoluminescence peak wavelengths at 70 K corresponding to each well thickness agrees well with the values calculated for a rectangular well. The sharp photoluminescence line width at 77 and 4.2 K in the region of narrow wells suggest that the fluctuation in well thickness is less than one atomic layer.

Photoluminescence analysis was also made on a 30Å wide double quantum well coupled through a 20Å $Al_{0.5}Ga_{0.5}As$ grown on Cr-doped GaAs at 780°C. Distinct photoluminescence peaks arising from degenerate single well states through the thin barrier were observed. A doublet nature of the luminescence was confirmed by the temperature dependence study of the PL spectra. There were no spurious peaks due to alloy clustering or other extrinsic effects which were frequently seen in the multiple quantum well structure grown by MBE.

. Transport properties of heterobarriers

Using the MOCVD technique, Sony has fabricated a tunneling diode consisting of a n-GaAs/i-$Al_{.70}$GaAs/n-GaAs diode in order to study transport properties of heterobarrier. The three layers of n-GaAs (5000Å, n=6-x$10^{17}$$cm^{-3}$), $Al_{0.7}Ga_{0.3}As$ (200Å, undoped) and GaAs (2000Å, n=$10^{18}$$cm^{-3}$) were grown on a GaAs substrate at 730°C. The diode area was 240x280 μm^2 and nonalloyed Au contacts were employed as electrodes.

The current-voltage characteristics were measured at both room and liquid nitrogen temperatures and their temperature dependence was investigated in detail. A theoretical model is being developed to explain the diode current characteristics which exhibit both thermionic and tunneling components.

SUMMARY

Phase I of the superlattice devices project covering the period from 1981 to 1984 is nearing an end. As seen in the summary of accomplishments of the past year, steady progress has been made towards advancing the technologies for future devices of high frequency operations and high speed information processing. Some significant accomplishments in the R&D of basic technologies of superlattice devices are:

- proposal for modulation doped, multilayer CHIRP superlattice devices,
- simulation of ballistic effects in superlattice devices,
- establishment of MBE technologies for AlGaAs/GaAs superlattices,
- fabrication of a hot electron transistor (HET),
- MBE growth of high-quality InGaAs/InP strained-layer superlattices,
- growth of Si/$NiSi_2$/Si by MBE,
- formation of embedded monocrystalline $NiSi_2$ grid layers in Si by MBE,
- ionization doping of n- and p-type dopants in Si by MBE,
- establishment of MOCVD technologies for AlGaAs/GaAs superlattices,
- fabrication of a tunneling diode by MOCVD.

In phase II, which begins April 1985, efforts are to be focused on device fabrication, characterization of superlattices, and new device structures. Progress in Phase II should be carefully followed because productive and vigorous research activities are anticipated.

REFERENCES

"Government Subsidized Computer, Software and Integrated Circuit Research and Development by Japanese Private Companies," by Barry Hilton. *Scientific Bulletin, 7* (4) 1, (1982).

Proceedings of the 3rd Symposium on New Functional Devices, (in Japanese), 3-5 July 1984 (Tokyo, Japan).

APPENDIX I

R&D PROJECT OF BASIC TECHNOLOGY FOR FUTURE INDUSTRIES
(AIST, MITI)

Fourteen special categories have been selected:

	BUDGET ($U.S. thousands)	
	JF YEAR 1984	JF YEAR 1985
NEW MATERIALS	$13,032	$4,112
high performance ceramics	3,452	3,856
synthetic membranes for new separation technology	2,108	2,228
synthetic metals	1,360	1,496
high performance plastics	1,204	1,192
advanced alloys with controlled crystalline structures	2,272	2,440
advanced composite materials	2,632	2,888
*photoreactive materials	0	340
BIOTECHNOLOGY	4,804	5,008
bioreactors	1,812	1,780
large-scale cultivation	1,532	1,716
utilizing recombinant DNA	1,460	1,508
*biodevices	0	340
NEW ELECTRONICS DEVICES	5,912	6,340
superlattice devices	1,720	1,808
three-dimensional ICs	2,948	3,224
hardened ICs for extreme conditions	1,244	1,308

* FY 1985 additions
(Budget: computed on 250 yen=$1.00)

APPENDIX II

VISITS

Listed below are the institutions and laboratories that were visited by the author where discussions on R&D activities in future electron devices were specifically held, with those investigators who provided assistance.

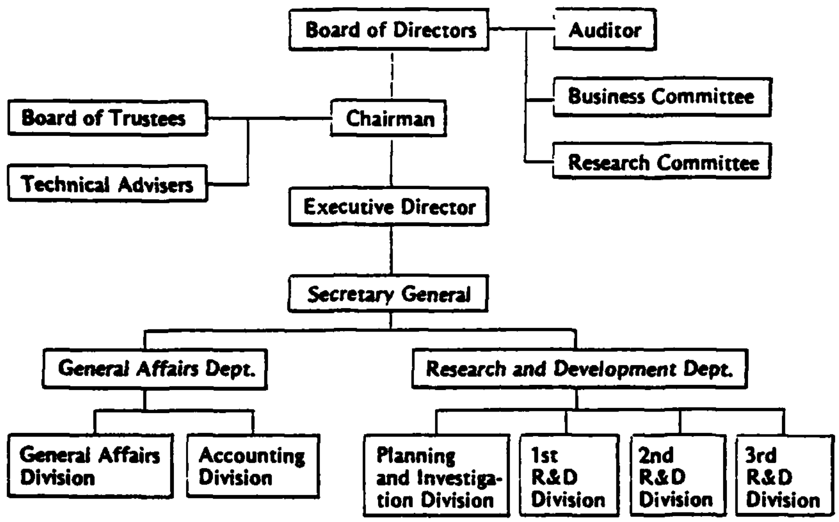
INSTITUTION	INVESTIGATOR	SUBJECT
Electrotechnical Laboratory	Dr. N. Hashizume	Superlattice devices
	Dr. T. Yao	CHIRP devices monolayer superlattice (MLS)
Fujitsu, Ltd.	Dr. S. Hiyamizu Dr. N. Nishi	MBE growth of AlGaAs/GaAs hot electron transistors
Sumitomo Electric Industries	Dr. H. Hayashi Dr. H. Nishi	InGaAs/InP strained-superlattices (SSL)
Hitachi Central Research Laboratory	Dr. Y. Shiraki	Si MBE
Sony Corporation Research Center	Dr. H. Kawai Dr. N. Watanabe	MOCVD growth of AlGaAs/GaAs superlattices
Osaka University	Dr. S. Gonda	MBE growth of superlattices
Institute of Industrial Science, University of Tokyo	Dr. H. Sakaki	Superlattices
R&D Association for Future Electron Devices	Mr. S. Fukuda	Program outline

APPENDIX III

THE RESEARCH AND DEVELOPMENT ASSOCIATION FOR FUTURE ELECTRON DEVICES

**Fukide Building No. 2, 4-1-21
Toranomon, Minato-ku
Tokyo 105, Japan**

ORGANIZATION



MEMBERSHIP LIST

ANELVA Corp.
Cannon K. K.
Fujitsu Ltd.
Hitachi Ltd.
JEOL, Ltd.
Matsushita Electric Industrial Co.,Ltd.
Mitsubishi Electric Co., Ltd.
Mitsubishi Metal Corp.
Mitsui Company, Ltd.
NEC Corp.
Nippon Kogaku K. K.
Nissin Electric Co., Ltd.
Oki Electric Industry Co., Ltd.
OMRON Tateishi Electronics Co., Ltd.
Sanyo Electric Co., Ltd.
Seiko Instrument and Electron, Ltd.
Sharp Corp.
Sony Corp.
Sumitomo Electric Industries, Ltd.
Sumitomo Metal Mining Co., Ltd.
Toppan Printing Co., Ltd.
Toshiba Corp.
ULVAC Corp.
Victor Co. of Japan Ltd.

SOME NOTES ON PHYSIOLOGICAL RESEARCH AT FOUR MEDICAL SCHOOLS IN THE REPUBLIC OF KOREA

P. F. Iampietro

INTRODUCTION

Two national and two private medical schools were visited in Seoul, Taegu, and Pusan, Republic of Korea. The purpose of the visits was to become familiar with research currently being conducted in the physiology departments and to ascertain the directions the work might take in the future. Korean physiology studies are not nearly as well-known in the West as Japanese physiology studies. There are a number of reasons for this, but possibly the most important is that Korean researchers do not publish widely in English-language scientific journals. Also, attendance by Koreans at international meetings is very limited. For example, there were no Korean scientists at the International Congress of Physiological Sciences which convened in Sydney, Australia, in 1983. On the other hand, several hundred Japanese scientists attended the same meeting.

It appears that Korean scientists at the four medical schools visited were well-trained, and in most cases, they had spent some additional training time in American and European laboratories. With the exception of one private school, which was only a few years old, laboratory space allocations were quite generous. On the other hand, research equipment (analytical and experimental) was not always especially abundant, and much of that which was seen was quite old and outdated.

YONSEI UNIVERSITY COLLEGE OF MEDICINE

Yonsei University College of Medicine is the oldest Western style medical school in Korea; it dates back to 1889. The Department of Physiology has eight faculty members who do all the teaching of physiology for the medical and dental students. This is a heavy teaching load and may be a factor detracting from research productivity. Laboratory space in the department appeared to be more than adequate. As noted above however, late model equipment was in short supply.

The research interests of the department members were quite varied and appeared to have been influenced by training in overseas laboratories. Environmental physiology was a prominent part of the research program. Several papers had been published during the last three-four years on various aspects of membrane activity including Ca^{2+} binding, factors affecting membrane potential, and Na^+, K^+-ATPase activity. Considerable research on ion transport and metabolism in erythrocytes also had been accomplished. Twenty-nine reprints were collected which reported work done by department members since 1980, and this number does not represent all publications during that period. Of the 29 papers, only seven had been published in journals outside South Korea, and it is interesting to note that the research for all seven had been done at various universities in the United States in collaboration with American scientists. Nine papers had been published in the *Korean Journal of Physiology* and of these only one was in English. Five papers had been published in the *Yonsei Medical Journal* (a publication of Yonsei University) and all of these were in English. The remainder had been published in the *Yonsei Medical Journal of Science* and were all in Korean. The point is quite clear: only the seven papers published in journals outside Korea could have enjoyed widespread readership, and therefore the worldwide scientific community is scarcely aware of the diversity and quality of research actually conducted in this department.

SEOUL NATIONAL UNIVERSITY COLLEGE OF MEDICINE

The College of Medicine dates back to 1899 but was organized into its present form during the period of control by the United States military government in 1946. The department has ten faculty members who do the teaching for medical and nursing students.

Judging from the reprints provided by faculty, research programs in this department are not as varied as at Yonsei University, as represented by the reprints collected. The work centers primarily around muscle physiology, especially cardiac tissue. Of the nine papers received, only one had been published in English and in a journal outside Korea. Thus it would appear that this department is not as productive as the one at Yonsei University, even though the facilities were adequate. The research areas were roomy and fairly well-equipped. One of the staff had recently returned from West Germany and was instituting a research program utilizing patch-clamp techniques and recording single-cell internal potentials. This program, when fully underway, probably will enhance the research in the department and place it with an area of work which is receiving a great deal of attention worldwide, namely membrane phenomena.

KYUNGPOOK NATIONAL UNIVERSITY SCHOOL OF MEDICINE

The School of Medicine began operation in 1923 as a provincial medical institute and after several reorganizations and name designations was absorbed into Kyungpook National University in 1951. In the Department of Physiology, there are five department members; they teach medical students only since the Division of Nursing has its own faculty.

Again the facilities limitation was observed: the Department of Physiology faculty had more than adequate laboratory space but rather less than adequate equipment. For the most part, however, the research accomplished in this department tends to be of a type which does not require sophisticated equipment. For a small department, research output has been quite productive. During the 1982-83 timeframe, some 18 papers were published. Of these, four papers had been written in collaboration with U.S. researchers and were published in English language journals. All other papers were published in Korean journals including the *Kyungpook University Medical Journal*, the *Keimyung University Medical Journal*, and the *Korean Journal of Physiology*. Out of these 14 papers only those published in the *Korean Journal of Physiology* were in English.

Cardiovascular, fluid and electrolytes, and nutritional studies appeared to be most predominant. The research was not especially innovative although it appeared to be well-done.

KOSIN MEDICAL COLLEGE

This medical school is a new (only four years old) facility in Pusan. It is housed temporarily, in rather crowded facilities which are shared with several other groups, including an element of the music department. Space is at a premium and up-to-date research equipment is practically nonexistent. The Department of Physiology has only one full-time member, the chairman, and one or two assistants. The chairman had been recruited from Yonsei University where he had been very productive, and had published extensively in both Korean and English-language journals. At Kosin, he has established a laboratory for the study of diving physiology but it will be some time before the laboratory is equipped and staffed adequately to produce research of any consequence. The ingenuity and enthusiasm of the chairman will help in solving those problems. At present there are no other research programs in the department.

SUMMARY

This rather cursory survey of research in four physiology departments in medical schools in Korea suggests a few tentative conclusions:

- Research in Korean universities is only minimally supported by the national government. In most cases, outside support was also very scarce. Consequently, laboratories were not well-equipped. Very few new pieces of equipment were evident.

- For the most part, laboratory space was quite adequate, although specialized facilities such as thermal rooms, hoods, etc., were not always available.

- In most departments, technicians and graduate students were not available to assist the investigators.

- Almost without exception, the faculty of all departments had been well-trained and most had spent some time in universities in the United States, Australia, and Europe.

- Because of lack of funds, among other reasons, Korean investigators do not usually publish in English-language journals. Consequently, their work is not generally known to those outside Korea. This is in direct contrast to Japanese scientists who publish very extensively in English-language journals.

- For the most part, Korean physiological research, because of lack of facilities, equipment, and support tends to be rather unsophisticated and will not be on the leading edge of science for some years.

A LOOK AT BIOMEDICAL RESEARCH IN MALAYSIA AND THAILAND

P. F. Iampietro

INTRODUCTION

Research being conducted in Malaysia and Thailand in the biological sciences, or for that matter, in other disciplines, is not well-known in the West. As in Korea, one major reason for this, is that publication in Western English-language journals is not common, even though many papers in the local journals are written in English. Because we do not read many papers from these countries, we presume that there is very little research being conducted. Recently, I had an opportunity to visit several research institutions and universities in Malaysia and Thailand. This allowed me to obtain information which was useful in evaluating biomedical research being conducted at those selected institutions. Attendance at the seventh Malaysian Microbiology Symposium in Penang, Malaysia, allowed a broader look at research being conducted in that domain (see another article in this *Bulletin*).

In both Malaysia (Kuala Lumpur) and Thailand (Bangkok) there is a rather close arrangement between U.S. Army research institutes and segments of the host country's medical research establishments. The Army institutes were established after World War II at the invitation of the host country national government. The idea was to obtain the scientific expertise of the U.S. Army on research problems of mutual interest to the host country and to the U.S. Army. Therefore the research, although including some basic work, is primarily applied and oriented toward prevention, control, and treatment of diseases which pose the most serious health problems--infectious diseases. The U.S. Army is interested in these and other medical problems because there is always the possibility that Army personnel may be exposed to them when military activities are conducted in those areas where the disease exists. No one doubts that the presence of the U.S. Army institutes, with their personnel, equipment, and resources, has had a substantial positive impact on the quality of biomedical research conducted in this part of Asia.

MALAYSIA

U.S. ARMY RESEARCH UNIT

The U.S. Army Research Unit (USAMRU) has been functioning (not always under the current name) as an associate division of the Institute for Medical Research (IMR) in Kuala Lumpur since 1948. The Research Unit is a subordinate laboratory of the Walter Reed Army Institute of Research (WRAIR) in Bethesda, Maryland; IMR is an agency of the Malaysian government. During the early years, the joint organization had collaborated on a wide variety of infectious disease research, but during recent years the areas of research authorized for USAMRU has been somewhat narrowed. This has probably had an effect on the scope of the programs at IMR. The research programs at USAMRU are described in a number of publications put out by USAMRU and by the U.S. Army and will not be discussed here. The quality and quantity of research produced by IMR has been strongly influenced by the almost-40-years association with USAMRU.

Although there is a very close association between IMR and USAMRU, there did not appear to be any interaction between the Department of Physiology at the Universiti Malaya and USAMRU. The department had essentially no research program. Research support through the university was practically nonexistent and grant applications for outside support did not seem to be a serious alternative. Over a period of time this situation has led to an attitude of defeatism toward pursuing scientific investigations. Some faculty members accomplish research programs only during their sabbaticals. Sabbaticals are awarded every five years and are very generous in terms of travel allowances, so a sabbatical in a laboratory in America, Europe, or Australia is not unusual.

THAILAND

ARMED FORCES RESEARCH INSTITUTE OF MEDICAL SERVICES

The Armed Forces Research Institute of Medical Sciences (AFRIMS) began operation in Thailand in 1958 at the invitation of their government under the aegis of the Southeast Asia Treaty Organization (SEATO) pact. In 1977, the laboratory was established as a joint U.S.-Thai venture. This laboratory, like the one in Malaysia, is primarily concerned with work on infectious diseases, specifically malaria, hepatitis, dengue, and Japanese encephalitis. In addition to its own research program, it does collaborative work with the Thai armed forces and the Faculties of Science and Medicine of Mahidol University. It also provides training for Thai students and scientists. AFRIMS' close relationship with the academic community may be one reason that Mahidol University is very active in research. However, the Faculties of Science and Medicine seem to be very strongly research oriented anyway.

UNIVERSITY OF MAHIDOL, FACULTY OF MEDICINE

- Department of Physiology

Unlike many medical school physiology departments in Japan, which consists of four or five members (professor, associate professor, one or two assistant professors, and possibly a lecturer) the Department of Physiology at Mahidol University is composed of eight Ph.D.s, one M.D. and six M.S. faculty members as well as a Ph.D. visiting lecturer. There are several professors and associate professors on the staff. The research program is quite broad and encompasses environmental, gastric, renal, and reproductive physiology, neuroendocrinology and toxiophysiology. Within these general areas, the research programs of individual faculty members are concerned with effects of exposure to altitude on tolerance to hemorrhage, effects of hypercapnia and hypoxia on circulatory response to apnea, calcium metabolism, effects of various treatments and chemicals on sperm motility and fertility in the rat, pepsin secretion, effects of cytocholasins on the digestive process (primarily absorption), uptake and release of neurotransmitters, and diuresis effects after ureteral ligation in the rat. In short, this is a well-rounded medical school department of physiology, with an effective research program.

The Department of Physiology, during the period 1983-84, published 28 research papers. Most of these papers appeared in English-language Western journals. The research programs of the various departments are well-supported by the Thai government. Additionally, the Rockefeller Foundation provided a ten-year aid program (late 1950s-60s) to promote research in the Faculty of Science and to produce M.Sc. and Ph.D. graduates as staff members for Mahidol and other universities in Thailand. Some departments (biochemistry, for example) are also very successful in obtaining research funds from outside Thailand. Among the American sponsors are the U.S.A. National Institutes of Health (NIH), Rockefeller Foundation, and the Ford Foundation. Sweden, Canada, and the World Health Organization have also given support. All departments have graduate programs.

- Department of Pathobiology (Immunopathology Research Laboratory)

The research program in this department centers primarily around infectious diseases (malaria). It is a very active program and combines animal experimentation with clinical studies. The activity in the department seems to be spearheaded by three faculty members who have been with the department for many years and who have maintained an interest in studies of malaria. Immunological aspects of the disease, renal effects accompanying the infection, and effects of various treatments have received the most attention.

FACULTY OF SCIENCE

- Department of Biochemistry

This is one of the largest departments in the Faculty of Science, consisting of 15 Ph.D.s and four M.S.s as the academic staff, and is probably the strongest department of all those visited. There are three well established areas of research: nutrition, parasitology (biochemical), and reproductive biology. These programs have produced a large number of publications over the years. Nutrition research is concerned with the biochemical aspects of vitamin deficiencies, especially A, B, D, and E. As indicated earlier, the Department of Physiology has a strong program in reproductive physiology centered around work on sperm motility. The Department of Biochemistry program is complementary in that sperm, seminal fluid, testes, etc., are studied from the biochemical point of view. The program in parasite biochemistry is strong, partly because of the interest the geographical area, including Malaysia, has in infectious diseases. This program emphasizes the biochemical aspects of the pathophysiology and chemotherapy of tropical diseases, especially malaria.

Two more recent programs have been established: molecular genetics-genetic engineering and biochemical technology. The latter program is dedicated to the application of biochemical information to industrial processes, while the former provides for the utilization of recombinant techniques to problems of special importance to the country. Therefore, both of the new programs, although basic in nature, have the intent of immediate application. The programs seem to be more multidisciplinary in nature and have the strong support of researchers in other departments. They should also, in time, become strong, progressive programs.

SUMMARY

Research activities at the two universities visited are in distinct contrast to each other. While comparisons of all research programs at the two universities cannot be made, it is proper to indicate that at least in the departments of physiology and perhaps other basic science departments, Mahidol University stands out as having a highly productive group of scientists with great enthusiasm for research, and having adequate financial support, both from government and outside sources. The well-trained researchers have instituted new programs instead of just continuing old ones. The influence and support of the Rockefeller Foundation over a number of years most assuredly contributed to the positive situation at Mahidol. Additionally, the presence and collaborative efforts of AFRIMS has had an effect. This relationship is much closer than the relationship between USAMRU and the Universiti Malaya. However, both U.S. Army research units have excellent personnel and facilities and have made significant contributions to research in the area.

MALAYSIAN MICROBIOLOGY SYMPOSIUM: PROGRESS IN MICROBIAL BIOTECHNOLOGY, UNIVERSITI SAINS MALAYSIA, PENANG, MALAYSIA

P. F. Iampietro

The Malaysian Society for Microbiology, at this annual meeting, attempted to provide an international scope to the program. Announcements were sent to selected individuals and institutions outside Malaysia and the resulting two-day program had 11 papers (out of 45) authored or coauthored by non-Malaysians. Microbiology in Malaysia, as in Thailand and Singapore, is rather a strong discipline. One of the driving factors for this strength may be the emphasis placed on solving problems associated with prevention and treatment of infectious diseases.

As the title indicates, this symposium was dedicated to a consideration of progress in the applications of microbiological research. Most of the sessions were devoted to application to problems associated with disease, pollution, foodstuffs, and industry. General microbiology of a much more basic nature was discussed in two sessions; the most interesting of these will be discussed briefly here.

FIRST SESSION

The first session, which consisted of four papers from foreign participants, was devoted to a variety of techniques applied to industrial and environmental problems. For example, the use of marine molluscs as monitors of pollution of coastal waters has been investigated. Indigenous molluscs "bioaccumulate" viruses and other materials dumped into marine waters from waste plants, polluted rivers, etc. There are many parametric and time-series problems associated with the accumulations.

Dr. P. Low and his colleagues at the University of Hawaii have developed, and tested, techniques for recovering and measuring human enteric viruses accumulated by molluscs. The method is an enzyme-linked immunoassay in which the enzyme binds to the virus and a colored macroscopic product is produced which is easily measured. The method is said to be cost-effective. Dr. H. Steiner and his co-workers from West Germany's Institut für Biotechnologie presented a methodology for sugar production from municipal and industrial residues by an enzymatic process. The objective was to provide as economical a process as possible. The authors' analysis indicated that the new materials (wastes) must have a cellulose content of at least 35% in order for the process to be efficient. The enzymes (cellulases) to be used in the process should be produced on the same raw material as will be used as the substrate for the saccharification process. The raw materials were pretreated by exposure to steam, crushed and the slurry incubated at 50°C. Hydrolysis (pH 4.8) was terminated by separating the fibrous material from the sugar solution.

SECOND SESSION

The second session was devoted entirely to environmental problems--specifically various methods for treating wastes. Dr. N. Rao, from the S.J. Polytechnic Campus at Bangalore, India, presented results of studies of microbial treatment of industrial wastes (paper). A unique objective of his method was both anaerobic and aerobic treatment. An added dividend was the production of biogas; the effluents were well within permissible limits for discharge into streams. Dr. M. Hashim and his colleagues at Universiti Malaya tested the efficiency of vertical columns of various soils to remove certain solids from waste water. Garden soil proved to be more efficient than other types of soil. One of the objectionable characteristics of waste sludges is its offensive odor. Many techniques have been employed to alleviate the problem with varying degrees of success. Dr. H. Sidhu and co-workers used actinomycetes to deodorize sludge produced during the production of monosodium glutamate from tapioca starch. Sludge treated with thermophilic actinomycetes during the drying process (50°C) was effectively deodorized. Granular activated carbon in an anaerobic system was used to treat wood-ethanol stillage to remove color and other constituents. Granular activated carbon beds were effective in removing color of the stillage and in recovering energy in the form of methane gas. This last work was reported by Dr. S. Tan, Massey University, New Zealand.

GENERAL MICROBIOLOGY SESSION

The general microbiology session contained a number of papers devoted to the description of methods for collecting, growing, and identifying microorganisms from a wide variety of materials and environments. Since these papers were essentially descriptive they will not be reported here.

A thorough study of the influence of water availability on the occurrence and physiology of coprophilous fungi was made by Dr. A. Kuthubutheen of Universiti Malaya. A supply-and-demand relationship exists between populations of fungi and water availablility. With a limited amount of water some fungi not as demanding of water germinate and grow, while others more reliant on abundant water supplies remain essentially dormant. If they survive the dry conditions these fungi germinate when water or moisture again becomes available. Dr. U. Bongale of Karnatake University, India, proposed that spores of blue-green algae can serve as bioindicators of pollution. When active ingredients of pesticides are present the spores will not germinate; initial suppression followed by gradual recovery of growth might indicate the level of degradation of the pesticide with time. Certain pesticides also permit selective growth of blue-green algae.

Food and industrial microbiology were the subjects of one session. Most of these papers described the use of microorganisms for the extraction or production of materials of commercial value. Drs. M. Karim and J. Madgwich, from the Rubber Research Institute of Malaysia and University of New South Wales, Australia, described the conditions most conducive for the solubilization of copper from low grade ore by an iron-oxidizing bacterium. Maximal recovery of copper was achieved at a pH of 2.0-2.5, which is the optimal pH for the attachment of the bacteria to the ores. When iron precipitates inhibited bacterial attack on the copper, sulfuric acid (pH 1.5) irrigation was used to remove the iron and the pH was then immediately readjusted to the original value.

Several papers were concerned with the production of alcohol--one from a common grass, one from pineapple waste, and another from diluted cane molasses. All systems used saccharomyces as the ethanol producer. The first two papers (Dr. R. Hassan *et al.*, Universiti Malaya and Dr. O. Sana *et al.*, Universiti Pertanian Malaysia) essentially described results of relatively simple and time-tested methods; these gave only modest ethanol production. The third paper (Dr. H. Yoshii, Ajinomoto Company, Japan) described a method which was more innovative. This paper discussed a novel process for alcohol fermentation by immobilizing living saccharomyces cells in artificial resins. The process allowed the cells to be made into thin sheets, which were placed in parallel in the bioreactor. A continuous flow of substrate passed by the sheets. Alcohol yield utilizing this system was several times higher than that of conventional batch system fermentation.

A session on medical and veterinary microbiology consisted of papers concerned with diagnosis and immune modulation of filariasis infection, microbial destruction of mosquito larvae, and production of savine fever vaccine. The session on agricultural microbiology again contained papers dedicated to the application of microbes to enhance processes important in the agricultural industry. Since these papers were especially applied they will not be discussed in detail. Dr. H. Sadu *et al.*, Universiti Sains Malayasia, presented results of studies to determine what microbial spores were most effective against mosquito larvae, at what age larvae were most susceptible, and the mode of action of the spores. Generally, spores of *B. thuringiensis* were more effective against three-day old larvae and attacked the larvae by destroying their midgut. Dr. F. Low *et al.*, Rubber Research Institute of Malaysia, attempted the biodegradation of raw and purified rubber by selected microorganisms. Purified rubber lost 10-15% of its weight after treatment. Other papers reported results of experiments aimed at effective utilization of industrial waste materials for agricultural purposes.

SUMMARY

The contents of this symposium again illustrate that microbiological research in Malaysia and in Thailand tends to be application-oriented toward problems associated with industry, medicine (health), and agriculture. This work is not strong in innovativeness and originality. However, the productivity of all of the institutions represented seemed to be quite high. In fact, microbiology may be one of the strongest research disciplines in Southeast Asia.

HIGH TECHNOLOGY IN AUSTRALIA

Nicholas A. Bond, Jr.

Australia has first-rate universities and scientists, and enjoys world status in such fields as biomedical technology and microsurgery. The conversion of basic research into marketable products, however, always presents problems; these may be especially evident in a country where much of the manufacturing base is controlled from outside, and where risk capital is often limited.

The "relaxin" drug, which is useful in obsteric management, is a good example of Australian science but outside development. Scientists in Melbourne developed the biotechnology; in fact, there are now at least half-a-dozen small biotech firms in that city, with much original work. Patents on the "relaxin" production process were obtained in Australia, and in the major developed countries. To scale up for production, however, enormous capital was required (on the order of $50 million U.S.) and it was simply not available from Australian sources. Also, it was rumored that an American drug firm was "getting close," and near to developing an equivalent product by a different process. So, the rights were sold to an American pharmaceutical house. The principal Australian scientist involved in the work has now moved to America. The case remains controversial in the Australian scientific community, and murmurs of a "sellout" can still be heard at tea time in Melbourne.

Some observers think that Australia is handicapped not only by its relatively small population, but also by political traditions that favor small business development. If small is beautiful, then big is, perhaps, not beautiful. Also, big industries in Australia have often signified outside ownership; one example is robotics in Australian automobile assembly plants. There are some robots in the plants, but they are designed and made in places like Detroit, Cleveland, and Osaka, and then sent to Australia by the plant owners. Thus there has been little inside Australia research in robotics.

There is a growing realization, though, that large-scale efforts are necessary for high technology, and that the backstreet garage, furnished with one or two inspired people and some primitive machines and test gear, is not the route to success. Australia has also had a few high-tech commercial successes, and it seems that if such enterprises are to survive, they must quickly attain a certain size and must put large fractions of their income into research and development.

Perhaps the best Australian success story is the Nucleus Limited group of companies in New South Wales (5 Sirius Road, Lane Cove, N.S.W. 2066). Nucleus now is doing about A$90 million (U.S. $65 million) a year, and is growing at an annual rate of 12 to 15%. Several medical technologies have been explored, with significant achievements in each one. The Teletronics branch produces three or four pacemaker systems, including the Ultima DDD dual chamber device, and the PASAR arrhythmia control version, which delivers pulses to transform tachycardia into sinusoidal rhythm. The company has about 20% of the world market in this fast moving area, and there is a new range of telemetry models about ready for market now. Product "design turnover" is very competitive and rapid, with significant improvements every year or two.

Nucleus has been involved in electrical bone growth stimulation for fifteen years, and claims to have produced the first fully implantable bone-growth stimulation device. An illustrative system is "Osteostim," which is employed in the lumbrosacral spine, and is recommended for cases where fusion is problematic. When implanted, four cathodes emit a constant 20 microamps of current. The alkaline batteries are enclosed in a small titanium case, which can be located in the body under the dorsal fascia.

The "bionic ear," produced by a Nucleus subsidiary, is a multichannel implantable hearing prosthesis. It is designed to aid hearing in the profoundly deaf person. In the 1970s, surgeons at the University of Melbourne began preliminary experiments in a few profoundly deaf patients. It turned out that, if a totally deaf patient has sufficient residual (unused) auditory neurons, then electrical stimulation of these can produce hearing sensations. The procedure is to insert surgically a tapered electrode array (usually, 22 tiny platinum electrodes) onto the cochlea. A receiver unit takes the sound information from the environment, codes it, and delivers constant-current stimulus pulses to the electrode pairs on the cochlea. These may cause partial restoration of hearing. Obviously, there are many technical issues and problems in such a scheme; the surgical techniques are quite advanced (Clark *et al.*, 1984), and the computer processor which weights the outside sound signals may require much adjustment and optimization. Encouraging results have been noted in some dozens of totally deaf patients. American surgeons and engineers are now investigating the equipment and the procedures. There are psychophysical data on hearing improvement, assistance to a patient in lip reading, and so forth (Tong *et al.*, 1979).

Alpha 1, another Nucleus group innovation, is a low-dose x-ray mammography system. Among its features are a rotating anode tube, 1.5 x magnification, dual focal spot capability, motorized compression xerox kit, and an array of facilitating cones and paddles. Related units already on the market are a water offset probe that facilitate the discrimination of deep solid and cystic breast lesions, and a water path whole breast ultrasound configuration.

Nucleus has twice been awarded the Australian Governor General's Award for Outstanding Export Achievement, and is the only company to be so honored. Its significant market shares in competitive American and European markets testify to its business success. For the scientist and technologist, however, perhaps the major questions have to do with the "secret:" What did Nucleus have that other companies or consortiums did not have?

There is probably no simple answer to such a complex question. (One probably should discount testimony from company insiders about the alleged "genius" of particular scientists and promoters.) One lesson from Nucleus seems to emerge, though, and that is to gain an early focus on a high-tech, but manageable domain. Items like pacemakers and implanted bone stimulators are complex indeed; but it does not take a Bell Labs or a $100 million R&D budget to explicate the major problems and processes, and the manufacturing is not extraordinarily difficult. When manufacturing begins, plain old attention to quality pays off in such products, too; the Nucleus pacemakers reportedly have a smaller failure rate than competitive models, and this quality is achieved simply by fanatically rigorous testing (there seem to be no formal "quality circles" or the like, everybody is just quality oriented.) Like high-tech companies everywhere, Nucleus is concerned about the obvious transferability of its technology, and its market share, to countries like Korea and Taiwan.

An encouraging note, then, from the Nucleus story is that the company's clever recognition of a feasible area to pursue, along with the fairly strong Australian tradition of good R&D work in the area, was enough to afford some positive prospects. Then, actually to attain a world standard of products and processes, one or two early "bread-and-butter" marketing successes were needed, to support the enterprise until it could afford to develop its own sources of innovation and to widen its competence. One Nucleus executive remarked that you need a technological awareness in top management, and a market sensitivity in the research staff. That necessity may seem plain enough when stated, but it is critically important in the early phases of company growth (or company dissolution!). Maybe this dual sensitivity is most valuable at middle-management levels. The visitor at companies like Nucleus certainly is impressed with the hard working attitudes of nearly every intermediate-level staff member that is encountered.

Not enough is known about the motivational properties of high-tech projects and companies. There is some anecdotal and hortatory literature by leading people from Silicon Valley on Route 128; but we have previous little data on how work actually is defined and done in such enterprises. Organizational psychology has substantial literature on the power of goal setting as a motivating factor; and accounts of leading high-tech heroes often mention company targets and goals. But the key factors of just how high-tech goals are formulated, perceived, and accepted remains rather unsatisfactory, and there is the haunting possibility that executives who reportedly use goal setting as a tool never have heard of the psychological literature on that subject.

Another matter which has received some common sense notice, but little systematic attention, is self-selection in high-tech enterprises. It could be that the people who gravitate to, and are comfortable in, high-tech projects are a rather special set of folks who respond positively to the pressures, risks, and rewards. If that is so, then one might predict that the successful high-tech enterprise is one wherein self-selection can take place in a valid and economic manner. Again, the conditions favoring self-selection are not clearly established in high-tech domains beyond common sense observations.

Response of high-tech companies to challenge is often unpredictable and disappointing. A firm with an original and ingenious line of products often collapses when faced with a new competitor using a different approach. If true high-tech includes the ability to respond adequately to commercial and technical competition, then the few Australian high-tech firms that now appear successful might be interesting examples to watch. For instance, can enterprises like Nucleus bounce back and reassemble, when comparable but low-priced biomedical products from semideveloped countries hit the markets? And just how will the most promising new areas for development be selected? It is easy to say, "find another niche," but nobody seems to know just how that is done, or how to keep doing it. Certainly the recent flops of the Sinclair firm in England show that a 1982 hero can be the 1985 bust. Perhaps the best lesson from Australia is that one should spend great effort in selecting a technological domain that is subject to development with relatively modest resources.

REFERENCES

"Surgery for an improved multiple-channel cochlear implant," Clark, G. M., Pyman, B. C., Webb, R. L., Bailey, Q. E., and Shepherd, R. K. *Annals of Otology, Rhinology and Laryngology, 93,* 204 (1984a).

"A preliminary report on a multiple-channel cochlear implant operation," Tong, Y. C., Black, R. C., Clark, G. M., Forster, I. C., Millar, J. B., O'Loughlin, B. J., and Patrick, J. F. *Journal of Laryngology and Otology, 93,* 679 (1979).

CRYOGENIC STEELS FOR SUPERCONDUCTING MAGNETS: DEVELOPMENTS IN JAPAN

Harry I. McHenry

INTRODUCTION

Superconductivity is one of the high technologies that Japan has targeted for concerted development. There are national programs to use superconductivity to enhance the efficiency of generating, storing, and transmitting electrical power. Superconducting magnets are being developed for fusion power devices, magnetohydrodynamic (MHD) power generators and high energy physics experiments. Numerous research and development programs are being conducted to develop these applications and to develop improved superconducting materials.

The scope of this report is limited to recent developments in cryogenic steels for structural applications in superconducting magnets. The main source of information was the United States-Japan Joint Planning Workshop on Low Temperature Structural Materials and Standards (Tokyo; 17 to 21 December 1984), which was held to initiate a program of cooperative research in the area of materials and structures technology for superconducting magnets for fusion energy systems. The workshop was cosponsored by the U.S. Department of Energy (DOE) and the Japan Atomic Energy Research Institute (JAERI) and organized by Dr. Susumu Shimamoto of JAERI and Dr. Victor Der of DOE, Office of Fusion Energy. A summary of the workshop topics outside the scope of this report is given in Appendix I. The 30 Japanese participants represented the various organizations involved in Japan's effort to develop superconducting magnets for fusion energy: JAERI, National Research Institute for Metals, universities (Tohoku, Osaka, Tokyo), steel companies (Nippon Steel, Kawasaki Steel, Japan Steel Works, Kobe Steel, and Nippon Kokan), and electrical manufacturers (Hitachi, Toshiba, and Mitsubishi Electric). The six U.S. participants represented organizations in the DOE fusion energy program: Lawrence Berkeley Laboratory, Lawrence Livermore National Laboratory, Massachusetts Institute of Technology, National Bureau of Standards, and Princeton Plasma Physics Laboratory. A list of attendees is given in Appendix II.

REQUIREMENTS ON THE CRYOGENIC STEELS

Cryogenic steels will be used for the main structural members of the superconducting magnets of the Fusion Engineering Reactor (FER), a tokamak device being designed by JAERI to demonstrate the technical feasibility of electrical power generation by fusion energy. Currently in the design stage, the FER will take ten years to build and is not expected to go into operation until about the year 2000. Even then, it will only be an experimental reactor to be followed in the development plan by a prototype reactor and a demonstration reaction. Thus, the market for the steels discussed in this report will not develop fully until well into the twenty-first century, a good example of the long-term outlook of Japanese industry. In the meantime, these steels may be useful for other superconductivity projects.

The superconducting magnets being designed for FER are truly enormous structures. Current designs call for 10-m diameter coils in 12 T field at currents of 20 kA. The stored energy is 30 GJ. A dozen or so of these magnets will be used to confine the hot plasma within a donut-shaped vacuum vessel. A schematic of the conceptual design is shown in Figure 1. The principal design features governing alloy selection are the enormous size and stored energy of the magnets, the extremely high forces exerted by the magnets, and the limited space available for the structure. These features result in the need for steels with sufficient strength to perform the required structural functions within the space available, sufficient fatigue and fracture resistance to operate safely, and sufficient fabricability to be practical. The choice of materials is further restricted by the adverse operating environment of the magnet system: a design temperature of 4 K, magnetic fields up to 12 T, and moderate levels of neutron irradiation.

The Superconducting Magnet Laboratory at JAERI's new Fusion R&D Center in Nakamachi, Ibaraki-ken, is responsible for the FER magnet design. In 1981, a program was initiated to develop a steel that meets the FER design requirements prior to the start of construction, about 1988. The approach was to establish a set of target properties and then work together with the Japanese steel industry to develop a suitable steel. The target properties, first announced in 1982, are:

yield strength	1200 MPa at 4 K
fracture toughness	200 $MPa\sqrt{m}$ at 4 K
fatigue strength	$\sim$ 316 stainless steel
permeability	$\mu<1.02$
corrosion resistance	rust resistance
fabricability	weldability and machinability
plate thickness	up to 200 mm

For initial screening, Charpy V-notch impact tests at 4 K are used in lieu of the fracture toughness tests; the property target is 100 J.

THE JAERI-INDUSTRY DEVELOPMENT PROGRAM

The task of developing an alloy with these properties has been undertaken by three steel companies working in conjunction with JAERI: Japan Steel Works, Kobe Steel, and Nippon Steel. In addition, Nippon Kokan is working independently to develop an alloy with the same property goals. Kawasaki Steel is working with JAERI to develop a sheet material with the same property goals after exposure to the thermal cycle required for the superconductor sheath material. The contracts between JAERI and the participating companies were vaguely described to me as simply the responsibilities of each party in the mutual development program; apparently JAERI does not pay the companies for their developmental efforts.

The yield strength and toughness targets have served as "go-no go" screening requirements. The magnetic permeability requirement has limited the consideration of steels to those that are fully austenitic and nonmagnetic. The corrosion resistance target has led to use of a minimum of 12% Cr. The remaining targets have not yet had an apparent influence on the alloy development efforts.

The development schedule is shown in Figure 2. For initial screening, tensile and Charpy impact tests were conducted at 4 K on 89 candidate alloys in four general alloy classes:

stainless steel (SS)	31 steels
high Mn stainless steel (HMS)	40 steels
high Mn steel (HMS)	14 steels
ferritic steel (FS)	4 steels

A total of 18 stainless steels (9 SS and 9 HMSS) met the yield strength (>1200 MPa) and Charpy impact (>100 J) screening goals. Two high Mn steels met the goals, but were dropped from further consideration because of insufficient Cr to be stainless steels. One ferrite steel met the goals, but was dropped because of the preference for nonmagnetic steels. Of these, some were of similar chemistry, thereby reducing the number of alloys included in the second stage of screening (fracture toughness tests at 4 K) to 11 (4 SS and 7 HMSS); the candidate alloys are shown in Table 1. As shown in Figure 3, the two high Mn stainless steels did not meet the strength and toughness goals; however, the results were judged to be close enough to keep the steels in the program.

The five alloys developed in the JAERI industry program have excellent combinations of strength and toughness at 4 K. Thus, the alloy development phase of the JAERI program has been completed. These alloys also have satisfactory corrosion resistance and the physical properties are assumed to be suitable, i.e., low magnetic permeability and acceptable electrical resistance and thermal expansivity. The remaining tasks for the steel industry participants are, (1) to conduct primary processing studies for scaling up to commercial practice, (2) to verify that the properties can be met in the large plates required for the FER, and (3) to develop the welding materials and procedures for use with these new alloys. The latter task is, perhaps, the most challenging. It has been undertaken primarily by Nippon Steel and Kobe Steel, the two major suppliers of welding consumables in Japan. In addition, JAERI will be conducting fatigue crack growth studies during 1985 to verify that the new steels have fatigue properties at 4 K that are comparable to those of 316 stainless steels.

VISITS TO PARTICIPATING STEEL COMPANIES

Following the workshop, the U.S. delegates had the opportunity to visit the Tokyo area facilities of the four participating steel companies, and in my case, Nippon Kokan. The facilities visited were as follows:

Japan Steel Works	Head Office	Tokyo
Kawasaki Steel Company	Research Laboratories, Chiba Works	Chiba
Kobe Steel	Welding Division	Fujisawa
Nippon Steel Corporation	Research Laboratories II	Sagamihara
Nippon Kokan K.K.	Technical Research Center	Kawasaki

These visits plus additional details regarding each company's research on cryogenic steels are summarized below.

- Japan Steel Works

Japan Steel Works (JSW) is an integrated manufacturer of forgings and castings, steel plates, pressure vessels, equipment, and machinery. It is best known for its Muroran plant in Hokkaido, where it has an electric furnace steelmaking shop that produces heavy steel products: forgings from ingots up to 520 Mg, castings up to 400 Mg, steel plates up to 100 Mg, and pressure vessels up to 1100 Mg. For fusion experiments, JSW manufactured the bucking post, a 27-Mg 304LN forging for the large coil test facility at the Oak Ridge National Laboratory; the 18Mn-5Cr-N austenitic steel coil supports for Japan's JT-60 tokamak; and the ASTM A240-X31 steel center rings for Princeton's TFTR tokamak.

As part of the JAERI program, JSW developed a 12Cr-12Ni-10Mn-5Mo alloy with a yield strength of 1240 MPa and a fracture toughness of 230 MPa√m at 4 K. The alloy development program consisted of fifteen 50 kg ingots with a base chemistry of 12Cr-12Ni-0.025C and 0 to 10% Mo, 1 to 20% Mn, and 0.09 to 0.21% N. Each ingot was forged into 55-mm-thick slabs, rolled into 25-mm-thick plates and solution annealed at 1040°C. Additions of Mo, Mn, and N raised the strength, but Mo levels greater than 5% and Mn levels greater than 10% caused embrittlement owing to precipitation of a second phase. Increasing N over the range 0.1 to 0.2% caused a linear increase of yield strength at 4 K with a slope of 305 MPa/0.1% N. The chemical composition and mechanical properties of the production heat of the optimum chemistry are given in Table 2. Since the hot workability of a stainless steel containing 5% Mo is limited, JSW plans to hot roll plates up to 75 mm and forge thicker plates.

- Kawasaki Steel Company

Kawasaki Steel Company (KSC) is the third largest steel producer in Japan, with an annual capacity of 19.5 Mg. It operates two integrated works, one at Chiba near Tokyo, and the other at Mizushima in Western Japan. The Chiba works started operation in 1951 shortly after KSC was founded. It was the first of the "green field" steel plants built in postwar Japan, and pioneered the idea of building steel plants on land reclaimed from the sea (Tokyo Bay, in Chiba's case).

We visited the manufacturing facilities at Chiba Works for stainless steel plate: the No. 1 steelmaking shop, the No. 1 continuous casting plant, and the plate mill. The No. 1 steelmaking plant has a station for reducing P and S in hot metal, two 76 Mg/heat K-BOP furnaces and an RH degaser, which are used primarily for the production of stainless steel and electrical sheets. The K-BOP is a modified basic oxygen furnace that uses the conventional LD lance for top blowing and the Q-BOP-type concentric tubes for bottom flowing oxygen plus lime (CaO). Bottom blowing agitates the bath and accelerates steelmaking. Kawasaki, which has a 95% continuous casting rate, uses the No. 1 unit (430,000 Mg per year capacity) for stainless and electrical steel slab. The plate mill has 3600 Mg capacity and a width of 3.9 m. The heavy stainless plate needed for fusion magnets would be produced at KSC's Mizushima Works, which as a more powerful rolling mill.

The role of KSC in the JAERI program was limited to the development of a nonmagnetic steel for the sheath of a forced cooled Nb_3Sn superconductor. The strength and toughness requirements are the same, but the sheath material is typically a 1.5-mm-thick sheet. The most demanding requirement is compatibility with an extended thermal treatment, called the wind-and-react process, required to create the Nb_3Sn superconductor from a Nb filament, bronze (Cu-Sn) matrix composite contained within the sheath. The heat treatment is 600 to 800°C for up to 100 h. The problem with conventional stainless steels is a grain boundary precipitation of Cr carbides. Two alloys were developed by KSC: a 316LN stainless steel with 1% V and a 24Mn-7Cr-2Al alloy with 0.5% V. The vanadium causes a preferential precipitation of V carbides that are finely distributed throughout the grain instead of concentrated in the grain boundaries. As shown in Figure 4, this results in increased strength and toughness after heat treatment. Both steels can meet the yield strength (1200 MPa) requirement. The toughness after heat treatment, measured by Charpy impact tests, is somewhat below the plate targets, but may be sufficient for the thin sheets used for conductor sheaths.

- Kobe Steel

Kobe Steel is a diversified corporation engaged in the manufacture of iron and steel (about 50% of sales), nonferrous materials, welding products, and machinery. Kobe is deeply involved in the development of superconducting magnets for fusion energy as a producer of stainless steels, superconductors, welding consumables, and heavy forgings. We visited the Fujisawa Plant of the Welding Division, where filler metals for the cryogenic steels are under development.

Kobe has evaluated 308L and 316L deposited by both the shielded metal (SMA) and gas tungsten arc (GTA) processes for use at 4 K. The alloys had remarkably low C, P (316L only), and S contents. The chemistry of the 316L GTA deposits was of particular interest (weight percent values): C = 0.005, P = 0.007, S = 0.006, and high enough Mn (6.3) and Ni (16.3) contents to give a ferrite-free weld. Although this filler metal does not meet the JAERI strength goals, it would make a good reference wire for studies of metallurgical factors affecting the toughness of 316L welds at 4 K. A modified hot wire gas tungsten arc welding system (called TIL-2T) was demonstrated. The system was particularly impressive and may be evaluated for superconducting magnet construction. The feed wire has a potential that deflects the arc forward and preheats the joint, thereby permitting higher deposition rates. The process is also useful for narrow gap welding and the improvement in efficiency should make it more competitive with the shielded metal arc and gas metal arc processes currently being used.

As part of the JAERI program, Kobe developed and evaluated cryogenic steels in each of the four categories originally considered by JAERI. The experimental materials were 90-kg laboratory ingots that were forged and rolled into 20-mm-thick plates. The one exception was the 9% Ni steel, which was a commercial plate. The chemical compositions and mechanical properties are summarized in Table 3.

All six of these alloys exceeded the 1200 MPa yield strength requirement. The high Mn steels and the 9% Ni steel also exceeded the target of 100 J in Charpy impact tests at 4 K. However, these steels are not sufficiently corrosion resistant, and thus, did not qualify. The 9% Ni steel, which had a remarkable combination of yield strength and toughness, was specially processed to reduce the P level to 0.002% and the S level to 0.001%. The low-P processing, which can be done on a commercial scale [*Scientific Bulletin*, *9*, (2) 127, (1984)] substantially improves low temperature toughness. For superconducting magnet applications, 9% Ni steel has problems over and above the lack of corrosion resistance: hardenability is insufficient for heavy sections, heat-affected zone toughness may be low, and it is ferromagnetic.

The 3.5Mn-24Cr-20Ni-3Mo-0.25N alloy had the second highest (after 9% Ni) Charpy impact toughness at 4 K. However, owing to its high alloy content, it was considered to be too expensive for superconducting magnet applications.

The 22Mn-12Cr-5Ni-0.22N alloy, which had a Charpy value of 77 J at 4 K, was selected for further development. A 14 Mg electric furnace heat was poured into a single ingot and rolled into a 200-mm-thick slab. The slab was then cut into 250-mm-wide minislabs and rolled in a laboratory plate mill to 70-, 100-, and 150-mm-thick plates. The plates were given an accelerated cooling treatment immediately after rolling. The 70-mm-thick plates had yield strengths greater than 1200 MPa, but the toughness ranged from 180 to 200 MPa$\sqrt{}$m. The thicker plates had toughnesses greater than 200 MPa$\sqrt{}$m, but the yield strengths were less than 1200 MPa. As shown in Figure 5, these results correlated with grain size. As grain size decreased, the yield strength increased and the fracture toughness decreased, thus accounting for the thickness effect. Fatigue crack growth rates for the new alloy are similar to those of 316LN, and permeability is less than 1.001 even after 20% strain at room temperature. However, further work is needed to verify that this alloy can meet JAERI's strength and toughness targets.

- Nippon Steel

Nippon Steel Corporation (NSC), the largest steel company in the world, was originally the government-operated Yawata Works founded in 1901. After the war, it was split into private companies, principally the Yawata Iron and Steel Company and the Fuji Iron and Steel Company. In 1970, Yawata and Fuji merged to form NSC. This corporation, with its roots as a governmental enterprise, is involved in many national programs such as JAERI's program to develop cryogenic steels. I did not participate in the visit of the U.S. delegation to NSC. However, I visited NSC in the past and reported my observations in the *Scientific Bulletin, 9,* (2) 144, (1984).

As part of the JAERI program, NSC has developed two alloys that meet the strength and toughness targets: a 25Cr-18Ni-0.35N stainless steel and a 15Cr-25Mn-0.2N high-Mn stainless steel. The high Cr content (25%) of the stainless steel is needed to increase the solubility of N above 0.3%, the level required to meet the yield strength target. The solubility of N in Cr-Ni-Mn stainless steels is shown in Figure 6. The stainless steel has been evaluated at three Ni levels: 18%, 13%, and 14% plus 4% Mn. In each case, the yield strength exceeded 1400 MPa and the fracture toughness was 200 MPa $\sqrt{m} \pm 10\%$. Processing studies indicated that substantial toughness improvements can be obtained by reducing the number of particles in the microstructures, as shown in Figure 7. Production processing can provide greater cleanliness than the laboratory heats evaluated, and thus the toughness goal is considered achievable.

The high Mn stainless steel is a high Cr modification of a 25Mn-5Cr-1Ni alloy previously developed by NSC. The experimental heat evaluated had a yield strength slightly under the 1200 MPa goal, but additional strength can be achieved by increasing the N content above the 0.2% level. As shown in Figure 8, studies of yield strength versus N content indicate that yield strength increases 250 MPa/0.1% N.

The weldability of these cryogenic steels is being studied by NSC. The goal is to develop the welding consumables and procedures that provide the same target properties specified for the base metal. The program includes studies relating to the hot cracking susceptibility of heavy section stainless steel welds and understanding the strength-toughness relationships in weld deposits.

These studies are interrelated in that the weld metals with the highest toughness values are fully austenitic and consequently have the greatest susceptibility to hot cracking. The hot cracking susceptibility resistance occurred as the P and S levels were reduced in the range from 0.01 to 0.005% and as the Si level was reduced from 0.8 to 0.1%.

Nippon Steel is conducting research on the influence of chemical composition (particularly N and C), macrostructure (Δ ferrite content), and the welding process on the toughness of welds. However, the details of these efforts were not discussed at the workshop. In part, this is due to the primary emphasis being given to base metal development, but one receives the impression that filler metal development may be a much more difficult task than base metal development. Screening tests on the weld metals are scheduled to begin in 1985.

- Nippon Kokan K. K.

Nippon Kokan (NKK) is an integrated, heavy industry company engaged in steelmaking, shipbuilding, construction, and engineering. It is the second largest steelmaker in Japan, with works at Fukuyama in Western Japan and at Keihin, near Tokyo. The Keihin Works include Japan's newest integrated steel mill, called Ohgishima, built on an artificial island in Tokyo Bay. I visited the Technical Research Laboratories in Kawasaki to discuss research on cryogenic steels and several other topics including: the development of minimum toughness requirements for welded structures, thermal mechanical processing (TMP) of a Cu-strengthened steel, and fatigue of offshore structures.

Nippon Kokan is not an official participant in the JAERI program; however, they are doing related work and did attend the workshop. Two cryogenic steels are being evaluated as candidates to meet the JAERI requirements: 24Mn-13Cr-5Ni and 18Cr-11Ni-2.6Mo. The 24Mn-13Cr-5Ni alloy is similar to Kobe's alloy in chemistry and properties. The 18Cr-11Ni-2.6Mo alloy is essentially the same as type 316LN, yet preliminary tests on experimental heats indicate that the JAERI strength and toughness requirements are met in 26-mm-thick plates.

Nippon Kokan favors the use of TMP instead of conventional rolling followed by solution treatment. The TMP plates have a finer grain size, and thus, higher yield strength; e.g., the 316LN plate had a 20 μm grain size. One approach is two-stage rolling, where the plate is conventionally rolled to an intermediate thickness, cooled to room temperature, solution treated to eliminate ferrite, finished rolled at a temperature just above the recrystallization temperature, and water quenched after rolling. For the 25Mn-13Cr-6Ni alloy, the yield strength for 26-mm-thick TMP plate is about 15% higher than the yield strength in the solution treated condition. A further 15% increase in yield strength occurs when the finishing temperature is reduced from 1000°C to 850°C (recrystallization temperature is 950°C).

A key feature of the 316LN alloy was the extra low C content of 0.008%. The low C facilitates the use of TMP in place of solution treatment because there is insufficient C for Cr carbide precipitation during TMP. In addition, the P and S levels were particularly low: P = 0.002% and S = 0.001%. NKK has shown that low P improves the toughness of 9% Ni steel at 77 K and claims that the toughness of high Mn steels is also improved. Apparently, low P and S steelmaking practices are also being considered for 316LN.

SUMMARY COMMENTS

The Japanese have made substantial progress in the development of a new class of cryogenic steels for use in superconducting magnet systems. Several candidate alloys meet the strength and toughness targets established by JAERI. Further work is needed to demonstrate that these properties can be obtained in thick plates under production conditioning and to develop welding consumables and procedures that provide comparable properties in the weld.

APPENDIX I

WORKSHOP SUMMARY

The United States-Japan Joint Planning Workshop on Low Temperature Structural Materials and Standards consisted of two and a half days of technical presentations on materials, testing, and design standards for superconducting magnet systems. It was followed by a half-day discussion on potential areas of cooperation and two days of visits to participating companies. The presentations and visits related to cryogenic steels have been discussed in detail. The following is a brief summary of the Japanese presentations related to materials testing and design standards.

The presentations on materials testing in liquid helium covered the methods used in Japan and the United States and introduced several new testing methods. The Japanese presentations discussed a new approach to single specimen J-integral testing based on the key curve approach (H. Takahashi, Tohoku University), an electromagnetic impact testing device and preliminary results (Y. Nakasone and M. Ishikawa, NRIM), and multiple specimen cryostats for tensile and fracture toughness testing.

In the design standards session, papers from both the United States and Japan expressed reservations regarding the applicability of the American Society of Mechanical Engineers (ASME) code to magnet construction. There were the obvious shortcomings stemming from the inapplicability of a pressure vessel code for an electrical device. However, there were also several important concerns with respect to the structural requirements and in the area of materials. Properties of structural alloys at 4 K should be used instead of room temperature properties. Serrations need to be accounted for in establishing stress allowables. Strain limits need to be imposed because of electromechanical deterioration of the superconductor.

In the area of stress analysis, there are difficulties in modeling the conductor pack that create problems in getting agreement of measured strain and finite element (FEM) analyses. Yet, owing to structural complexity, FEM is needed. For close out welds, partial penetration welds (not allowed by ASME) may be required to avoid damaging the conductor. Thus, fracture mechanics analysis may be needed to ensure the safety of these welds. For nonmetallic materials used for insulation, the ASME restrictions given in Section X are too restrictive with respect to design temperature (-55°C is lowest design temperature permitted) and design pressure (10 MPa for cut fiber composites). For these reasons, there was a general consensus that the ASME Pressure Vessel Code is not applicable to superconducting magnets, and work should start on the development of a new code specifically for superconducting magnets. The implication is that cooperation between the United States and Japan in this area will be helpful.

T. Shoji (Tohoku University) introduced a new concern for magnet design--the influence of high magnetic fields on the driving force for fracture, called magnetofracture mechanics. Theory shows that high fields, coupled with eddy currents induced in the material by pulse fields, cause a crack opening force that is potentially significant.

In the final session of the workshop, potential areas of cooperation were explored, which resulted in the outlining of a program of immense scope. The next step will be for each side (DOE and JAERI) to select topics from this outline and propose specific areas of cooperation. In addition, joint working groups may be established to facilitate the cooperation, coordination, and technology transfer needed to develop design standards for superconducting magnets.

APPENDIX II

ATTENDANCE LIST
DOE-JAERI WORKSHOP

LOW TEMPERATURE STRUCTURAL MATERIALS AND STANDARDS

JAPANESE DELEGATES

H. Takahashi H. Shindo T. Shoji	Tohoku University
T. Okada	Osaka University
K. Miya	Tokyo UNiversity
K. Ishikawa K. Nagai Y. Nakasone	NRIM*
S. Shimamoto K. Yoshida H. Nakajima M. Oshikiri M. Hagiwara	JAERI**

JAPANESE OBSERVERS

T. Horiuchi R. Ogawa M. Shimada S. Tone	Kobe Steel Corporation
T. Sakamoto K. Suemune K. Nakagawa T. Ogawa	Nippon Steel Corporation
R. Miura S. Onodera	Japan Steel Works
C. Ouchi S. Yamamoto	Nippon Kokan K. K.
S. Suzuki F. Iida T. Matsumoto	Hitachi, Ltd.
K. Kitamura K. Suzuki	Toshiba Corporation
O. Asai Y. Hattori	Mitsubishi Electric Company

* National Research Institute For Metals
** Japan Atomic Energy Research Institute

U.S. DELEGATES

H. I. McHenry	National Bureau of Standards, Boulder
J. W. Morris	University of California, Berkeley
E. N. C. Dalder	Lawrence Livermore National Laboratory
H. Becker	Massachusetts Institute of Technology
P. J. Heitzenroeder	Princeton Plasma Physics Laboratory
V. K. Der	U.S. Department of Energy

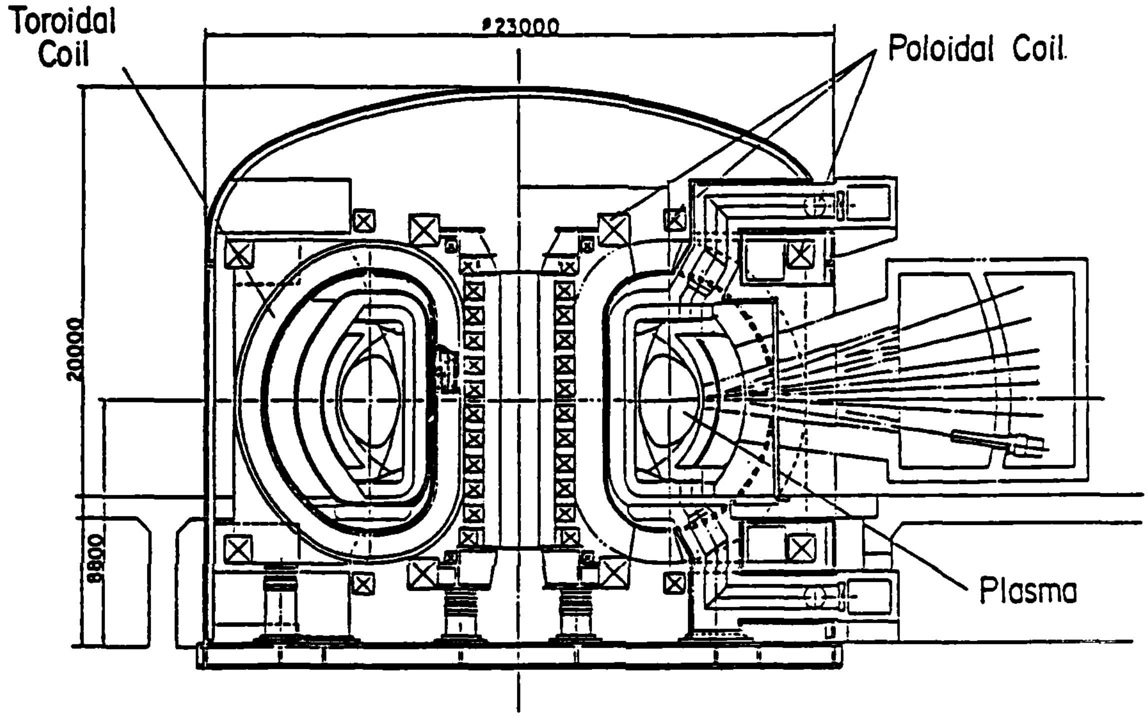


Figure 1. JAERI's proposed Fusion Engineering Reactor. (Presented by JAERI.)

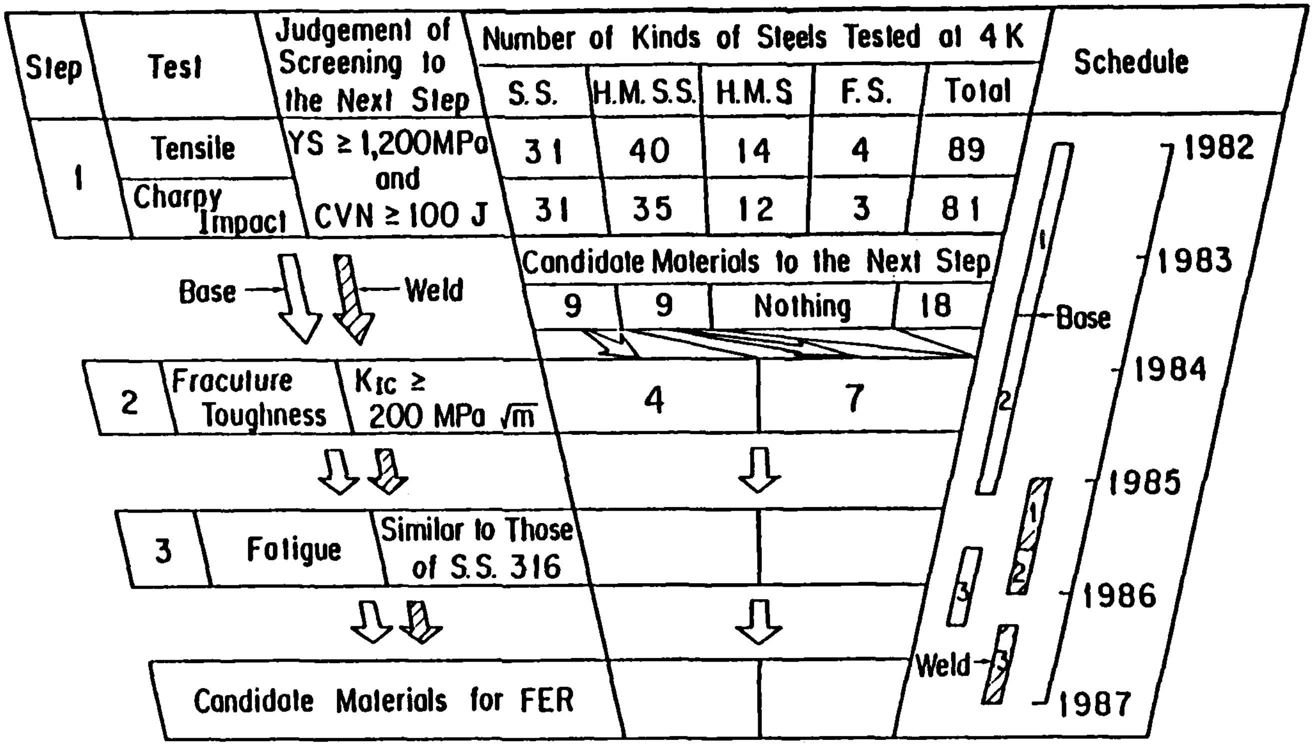


Figure 2. The JAERI program plan for developing cryogenic steels. (Presented by JAERI.)

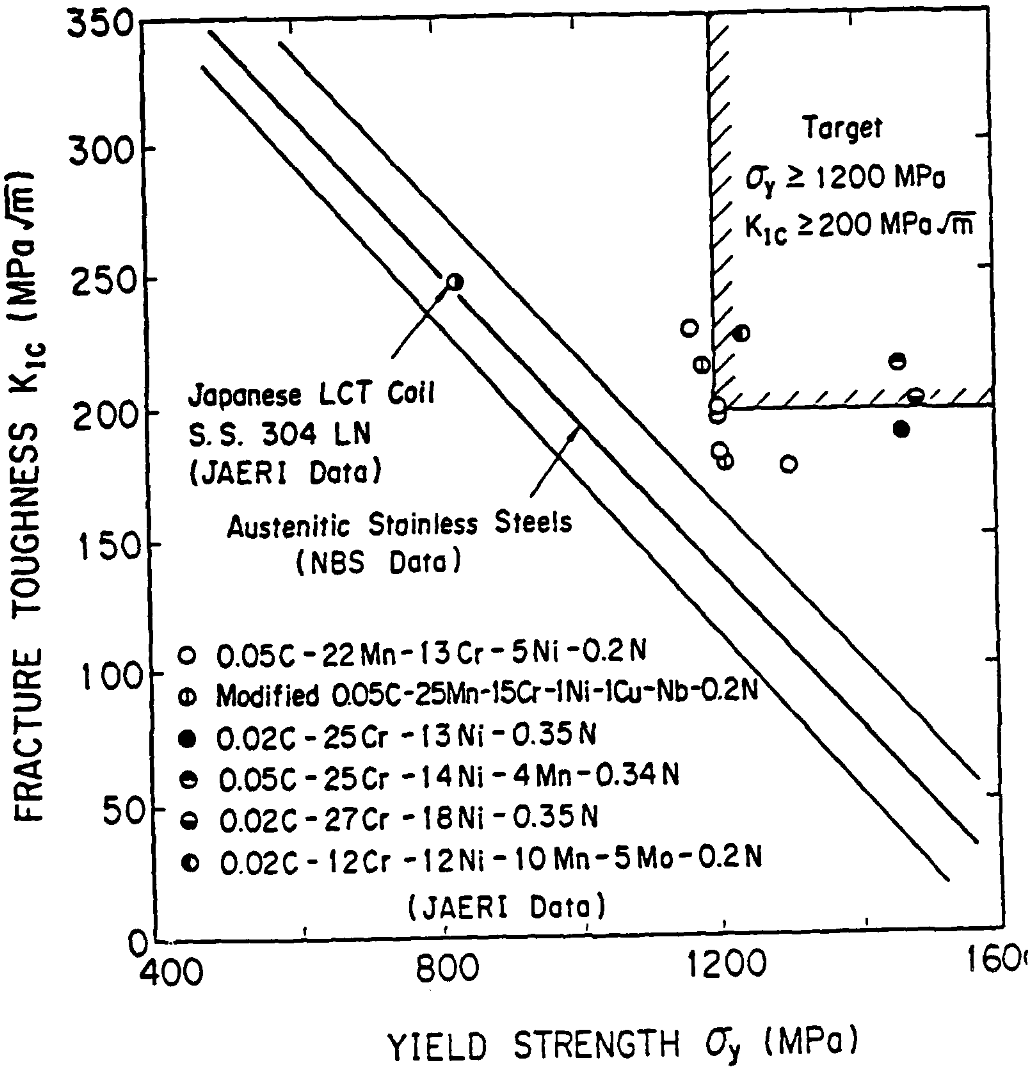


Figure 3. Summary of the strength and toughness data for the new cryogenic steels. All tests were done at 4 K. (Presented by JAERI.)

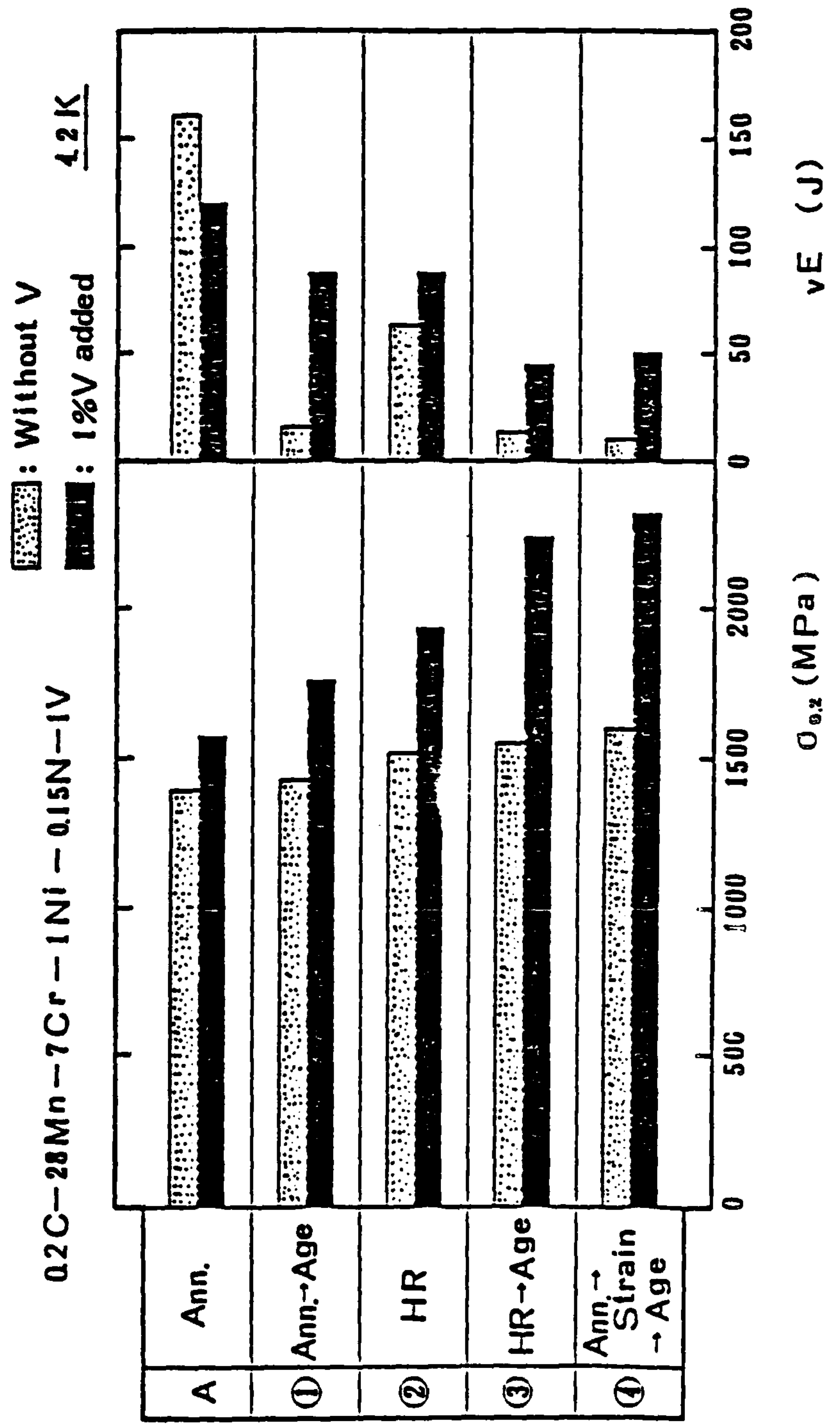


Figure 4. The influence of vanadium on the yield strength and Charpy impact toughness of a 28Mn-7Cr-1Ni alloy. (Presented by Kawasaki Steel.)

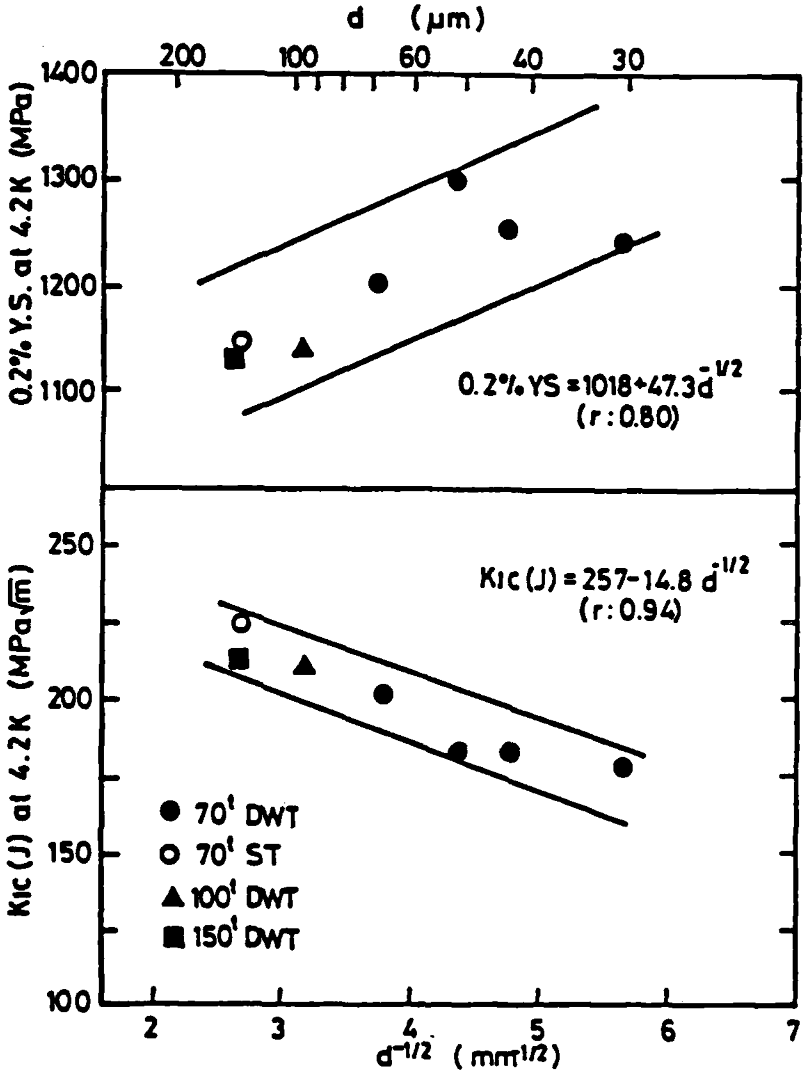


Figure 5. Relationship between mechanical properties at 4.2 K and austenite grain size (d) of 22Mn-13Cr-5Ni steel. (Presented by Kobe Steel.)

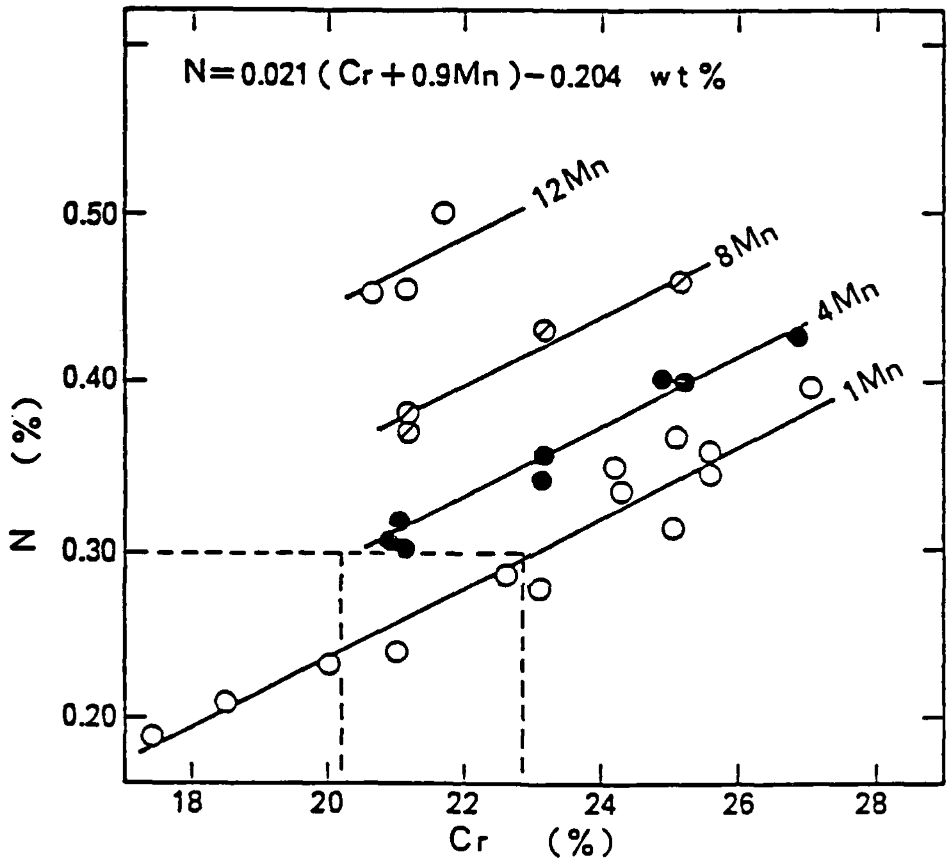


Figure 6. The solubility of N in austenitic stainless steel as a function of Cr and Mn.
(Presented by Nippon Steel.)

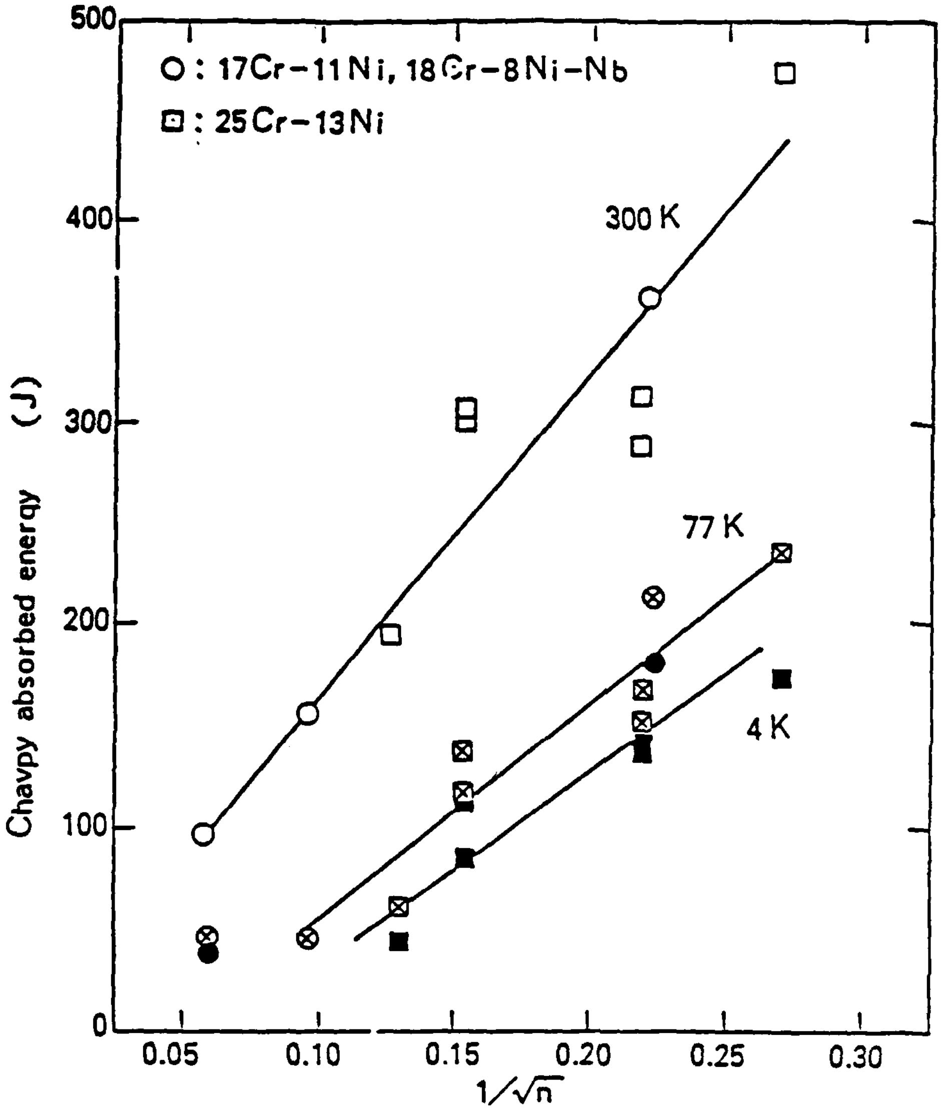


Figure 7. Effect of small particles on Charpy absorbed energy. (Presented by Nippon Steel.)
n = number of particles per 0.1 mm^2 area; counting size ≥ 0.5μ m diameter.

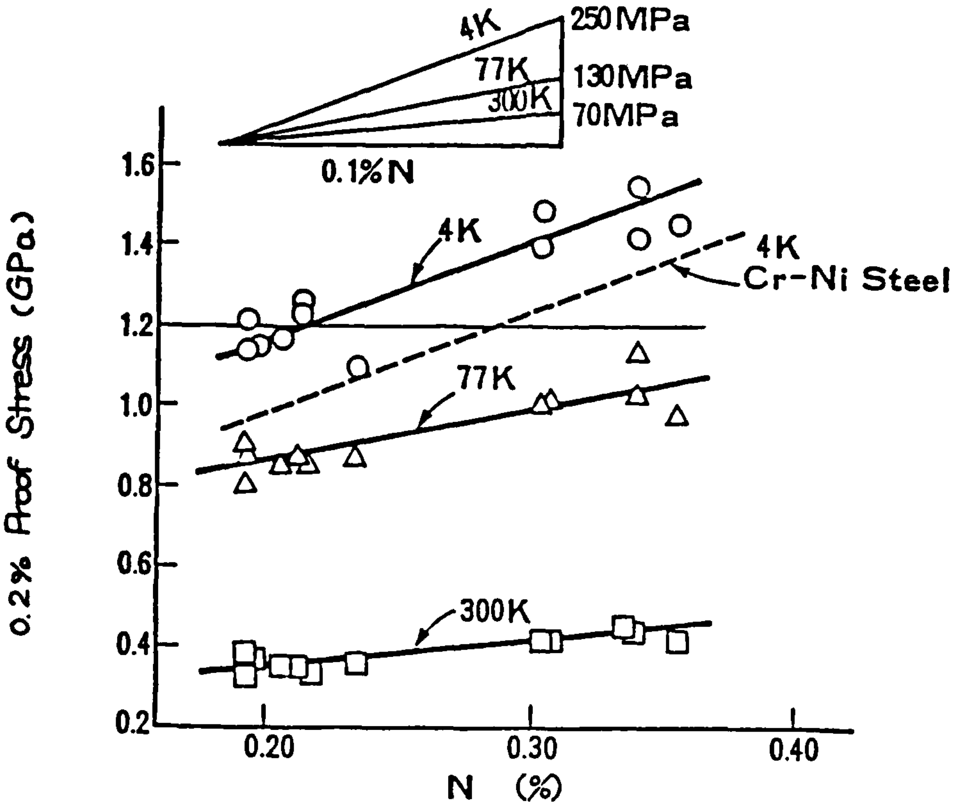


Figure 8. Effect of N on proof stress of Mn-Cr steels. (Presented by Nippon Steel.)

TABLE I

CHEMICAL COMPOSITION (wt.%) OF THE NEW CRYOGENIC STEELS

Alloy	Developer	C	Cr	Ni	Mn	N	Other
SS	NSC	0.02	25	14	4	0.34	
	NSC	0.02	25	13	-	0.35	
	NSC	0.02	27	18	-	0.35	
	JSW	0.02	12	12	10	0.2	5 Mo
	NKK*	0.01	18	11	-	0.2	2.6 Mo
HMSS	Kobe	0.05	13	5	22	0.2	
	NSC	0.05	15	1	25	0.2	[illegible] Nb
	NKK*	0.03	14	5	23	0.2	
S/C Sheath Alloys							
SS	KSC	0.02	17	12	1		1 V, [illegible].5 Mo
HMS	KSC	0.02	7	-	24		0.5 V, 2 Al

*Not part of JAERI program.

TABLE II

CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES OF A 12 Ni-12Cr-5Mo CRYOGENIC STEEL

Chemical Composition of the Alloy, wt.%

C	Si	Mn	P	S	Ni	Cr	Mo	N
0.017	0.53	10.46	0.020	0.006	12.47	12.38	5.16	0.208

Mechanical Properties of the Alloy

	Tensile Properties					Impact Properties			
Temp.	0.2% Y.S., MPa	T.S., MPa	E.L., %	R.A., %	μ*	CVN, J	L.E., mm	μ*	Fracture Toughness $K_{Ic}(J)$, MPa $\sqrt{m}$
RT	338	695	51.1	71.1	1.001	205	2.13	1.001	310
77K	862	1369	57.1	56.5	1.046	118	1.11	1.001	340
4K	1241	1614	41.6	49.5	1.012	91	0.87	1.001	230

Grain size: 2.6 in ASTM No.

*Magnetic permeability (MPa) measured at fracture surface of broken specimen

TABLE III

SUMMARY OF THE CRYOGENIC STEELS DEVELOPED BY KOBE STEEL

Type	Heat Treatment	C	Mn	Ni	Cr	N	Others	Properties at 4K: Yield Strength, MPa	Properties at 4K: Charpy Impact, J
SS	ST	0.02	3.5	20	24	0.25	3 Mo	1275	174
HMSS	AR	0.04	22	5	12	0.22		1429	77
HMS	ST	0.61	18	3	8	0.04	1.5 Cu	1349	122
HMS	ST	0.6	24	5	3	0.13		1384	112
FS	QT	0.005	0.6	9	-	-	0.002 P	1300	180
FS	ST	0.001	-	18	-	-	1.9 Mo, 1.5 Ti	1442	55

U.S.A.-JAPAN SEMINAR ON CORROSION

E. McCafferty

INTRODUCTION

The U.S.A.-Japan Seminar on Corrosion was held in Nikko, Japan, on 11-13 March 1985. The subject of this seminar was "Critical Issues in Reducing the Corrosion of Steels." Coorganizers were Professor Shiro Haruyama of the Tokyo Institute of Technology and Professor Henry Leidheiser, Jr., of Lehigh University, Bethlehem, Pennsylvania. This seminar was sponsored by the Japan Society for the Promotion of Science and the National Science Foundation of the United States and was held under the auspices of the U.S.-Japan Cooperative Science Program.

The theme of steel corrosion was selected for this conference as it is one of the primary considerations in selection of materials in many different industries. Steel has many advantages over other materials in terms of mechanical properties, availability and cost, but it does not have inherently good resistance to corrosion. This seminar was pertinent to both the U.S. and Japan because of the importance of the steel industry to the economy of both countries and because of relevant technical advances made by scientists in the two countries.

This seminar brought together 16 corrosion scientists from Japan and an equal number from the United States. The participants were distributed almost equally between universities and industrial organizations, with the U.S. also having two representatives from government laboratories and one from a contract research institute.

PROGRAM

The meeting was organized into three parts, with emphasis on

- the environmental factor in corrosion,
- the material factor in corrosion, and
- measurement and monitoring of corrosion.

There were both oral presentations and informal discussions. The program is listed below, with the names of conference participants in italics.

- The Environmental Factor in Corrosion

Title	Author
Environmental considerations in the SCC of mild steel in carbonate solutions	J. A. Might and *D. J. Duquette*. Rensselaer Polytechnic Institute
Effect of pH and (Cl^-) on the stochastic process of pitting corrosion of Mo-containing stainless steels	*T. Shibata* and H. Takamiya. Osaka University
Inhibition of aqueous chloride corrosion fatigue by control of crack hydrogen production	*Richard P. Gangloff*, Exxon Corporation

The dependence of the sulfide stress cracking of low alloyed steels on environmental factors and materials	T. Kaneko, A. Ikeda, and *T. Moroishi*. Sumitomo Metal Industries
The corrosion of sheet steel products in coil form	*Robert A. Legault*, Inland Steel Corporation
Effects of oxygen concentration of the corrosion behavior of carbon steel in high temperature water	M. Mabuchi, Y. Horii, H. Konno, *H. Takahashi*, and M. Nagayama. Hokkaido University
Localized corrosion enhanced by liquid junction potential between anolyte and catholyte	*Noboru Masuko*, University of Tokyo
A common mechanism of various types of localized corrosion in carbon steel	*Iwao Matsushima*, Nippon Kokan K. K.
Mass transport and solution chemistry in localized corrosion cells	*T. Tsuru*, K. Hashimoto, and *S. Haruyama*. Tokyo Institute of Technology
Corrosion beneath polymeric coatings on thin metal films as studied using concurrent ac impedance and parallel dc resistance measurements	J. C. McIntyre and *H. Leidheiser, Jr.* Lehigh University
Corrosion phenomena on single crystals of stainless steel	*J. B. Lumsden*, Rockwell International

- Material Factor in Corrosion

Making AISI type 304 stainless steel immune to stress corrosion cracking	*B. E. Wilde*, Ohio State University
The effect of alloying elements on the repassivation potential for crevice corrosion of stainless steels in 3% NaCl solution	*S. Tsujikawa*, S. Okayama, and Y. Uesugi. University of Tokyo
Effect of corona discharge treatment on the electrochemical behavior of zinc-filled organic coatings on steel sheet	D. J. Frydrych, R. G. Hart, and *H. E. Townsend*. Bethlehem Steel Corporation
Corrosion resistance of rapidly quenched alloys	*R. M. Latanision*, A. Saito, R. Sandenbergh, and S. X. Zhang, Massachusetts Institute of Technology

Atmospheric corrosion of metallic coated steels--forty years testing experience — *Herbert H. Lawson*, Armco, Inc.

Preparation of corrosion-resistant amorphous surface alloys on conventional crystalline metals by laser treatment — *K. Hashimoto*, K. Asami, and A. Kawashima. Tokyo University

Surface modification by laser or ion beams — *E. McCafferty*, Naval Research Laboratory

Amorphous alloy coatings by pulsed-current electrolysis — I. Ohno, H. Ohfuruton, and *S. Haruyama*. Tokyo Institute of Technology

A new approach to improving resistance to transgranular stress corrosion cracking — M. J. Kaufman and *E. N. Pugh*. National Bureau of Standards

- Measurement and Monitoring of Corrosion

Chronoellipsometric studies on passive film formation — *M. Yamashita*, Doshisha University

Laser Raman spectroscopy for *in situ* study of thin corrosion films on iron — *T. Ohtsuka* and N. Sato. Hokkaido University

EXAFS as a technique for studying the effect of alloying elements on the nature of the oxide films on steels — *J. Kruger* and G. G. Long. Johns Hopkins University

New techniques and applications in corrosion research — *Howard W. Pickering*, Pennsylvania State University

Quantitative AES composition-depth profiles of oxide films on iron-chromium alloys — *R. P. Frankenthal* and D. J. Siconolfi. AT&T, Bell Laboratories

A microcomputer-based prediction of the probable maximum pit depth on pipelines by means of extreme value statistical analysis — *Y. Ishikawa*, Hitachi, Ltd.

Impedance measurements for corrosion monitoring — *D. D. Macdonald*, SRI International

Electrochemical monitoring of hydrogen in steel exposed in corrosive environment — *K. Yamakawa*, H. Tsubakino, and S. Yoshizawa. University of Osaka

Present status of corrosion monitoring and corrosion control in chemical plants	*K. Yamamoto* and K. Satoh. JGC Corporation
Adhesion failure of cemented side seam cans of tin-free steel after retort treatment	*S. Maeda,* T. Asai, and M. Yamamoto. Nippon Steel Corporation
Chemical studies of the organic coating/ steel interface after exposure to aggressive environments	*Ray A. Dickie,* Ford Motor Company

SUMMARY

Dr. Henry Leidheiser, coorganizer of the seminar, noted that most critical corrosion problems are mass-transfer related. These include the transfer of a corrodent to a crack tip or through an organic coating, as well as the transport of hydrogen through metals. Interfering with operative mass transport processes is thus a useful generic approach to corrosion control.

New developments presented or discussed at the conference were:

- Nippon Steel's work on amorphous silica protective coatings on steel,
- Bethlehem Steel's work on the use of a corona discharge to improve the performance of zinc-filled organic coatings, and
- research by B. E. Wilde (currently at Ohio State University) on 5% additions of silicon to improve the resistance of 304 stainless steel to pitting and crevice corrosion.

There was considerable interest in improving corrosion resistance by surface modification techniques such as laser processing or pulse electroplating. Interest also continues in the use of rapid solidification to produce corrosion resistant amorphous or microcrystalline bulk alloys.

The Japanese are very active in the application of statistics to corrosion research. This includes both the stochastic approach to interpret corrosion phenomena as well as the use of statistics to predict the service life of actual systems or components.

In addition to the interesting papers which were presented, this conference was very productive in promoting informal discussions and exchange of ideas between the U.S. and Japanese participants. The first U.S.A.-Japan Seminar on Corrosion was held in 1975 on "Passivity and its Breakdown on Iron and Iron Base Alloys."

MAGNETICS LABORATORIES IN JAPAN

C. D. Graham, Jr.

INTRODUCTION

The observations reported here stemmed from a visit to Japan which started in late 1984, and continued until mid-1985. A little background information about recent developments in the permanent magnetic industry may be helpful for the nonspecialist. Until about 1965, the two major classes of permanent magnets were alnico (metallic) and ferrite (oxide) materials. The use of rare-earth (RE) compounds as permanent magnets resulted mainly from work done by Karl Strnat, then at Wright-Patterson Air Force Base and now at the University of Dayton. U.S. firms [Raytheon and General Electric (GE)] were the first to make useful magnets of the hexagonal compounds $SmCo_5$ which were better than existing magnets by about a factor of three. However, as is so often the case, commercial exploitation and further technical advances have been largely Japanese. In particular, Japanese firms have mastered the arcane heat treatment of complex multiphase alloys near the composition $Sm_2(CoFeCu)_{17}$+(Zr or Ti), known generically as 2-17 type magnets. These have a significantly higher magnetization and energy product than $SmCo_5$. Widespread use of RE magnets has been hindered by their high cost, a situation exacerbated by the temporary, but sudden and alarming jump in price and drop in availability of cobalt due to the civil war in Zaire in 1978.

The big, recent news (1983) has been the development of a new class of RE magnets, based on the previously unknown compound $Fe_{14}Nd_2B$. This material uses no cobalt, and less and cheaper RE than the previous RE magnets; it also has substantially better magnetic and mechanical properties. Its principal disadvantage is a relatively strong temperature dependence of the magnetic properties due to its low Curie temperature (310°C). Two quite different production processes have been independently developed for this material: a more or less conventional powder metallurgical method by Sumitomo Special Metals Company in Osaka, and a rapid solidification process by General Motors (GM). The GM process includes a mysterious and highly secret step that converts a random (no crystallographic orientation) material into a strongly-aligned anisotropic magnet. The GM work came as something of a surprise to the magnetism community, since GM had no history of work on magnetic materials and little recognition for its research in materials work of any kind.

As far as I know, no patents have been issued, but GM and Sumitomo Metals are widely believed to have filed numerous and extensive patent claims. Overlap of claims seems likely; furthermore, the licensing terms that will be offered to other producers (if and when the patents issue) remains unclear. In this situation, some U.S. manufacturers (Crucible Division of Colt Industries and IG Technologies) are offering FeNdB magnets for sale now, proposing to deal with patent licensing when they must. This approach is feasible because FeNdB magnets can be made with the same production equipment as $SmCo_5$ magnets, so that no capital investment is required by a current producer of RE magnets.

The Japanese magnet makers seem to be proceeding much more cautiously. They are all experimenting with FeNdB and variations thereon, but none would admit to offering products for sale. None of the company laboratories I visited was very forthcoming with details of their processing, or of the level of success they have achieved.

RESEARCH INSTITUTES AT PRIVATE CORPORATIONS

- Hitachi Metals

Hitachi Metals separated from the parent company, Hitachi, Ltd., in 1956. Both companies use the same logo, but they are essentially independent. Hitachi Metals (HM) is a major world producer of special steels, rolls for metal rolling, automobile parts, pipe components, magnetic materials, and magnetic devices. Total company sales in 1983-84 were $1.4 billion. I was principally concerned with magnetic materials, and visited the company's central research and development laboratory in Kumagaya, about an hour's train ride northwest of Tokyo. This is also the site of several manufacturing operations, including magnetic hard ferrites, alnico, and rare-earth magnets; other magnetic manufacturing is done at other locations in Japan and also at Hitachi Magnetics in Edmore, Michigan, formerly the General Electric permanent magnet manufacturing plant. In addition to producing virtually all the commercial hard and soft magnetic materials except sheet steel, HM makes microwave components, linear actuators, recording heads, traveling wave tubes, and magnetic separating equipment of various kinds.

I had a brief tour of the hard ferrite manufacturing plant, which is a very large-scale operation producing 35,000 tons per year. The starting iron oxide comes as a by-product of steelmaking, and the barium and strontium carbonates are imported from China. Ferrite production, involving the handling of very fine oxide powders, is an intrinsically dirty operation, and the plant was not the model of spotless cleanliness one associates with Japanese industry. Every part is tested for dimensional tolerances, cracks, chips, etc., but the production controls are sufficient to guarantee magnetic performance without testing. HM estimates that this plant produces 30 to 35% of the world output of hard ferrite.

An alnico plant is in operation, but production is down from a capacity of 600 tons to about 250 tons per year. Alnico is now used only where good temperature stability is required, as in meters and control equipment. This plant also produces Fe-Cr-Co magnets. The rare-earth magnet plant was not open to inspection.

HM produces a range of subassemblies using its own magnetic materials. There is a large production of copier parts, especially the magnetic roller that applies the toner to the semiconductor drum, plus heater roll assemblies, toner level detectors, and various printer parts. Switching power supplies are also produced in these devices; the magnetic core material represents a substantial fraction of the total cost. There is a large design department for these assemblies, which are produced for both Japanese and foreign manufacturers. The design group has to be carefully subdivided in order to protect the customers' design secrets and production figures. HM is also a supplier of ferrite powder used as the toner (ink) carrier in various brands of copiers, and considerable research is in progress to improve the magnetic and electrostatic properties of these powders.

HM makes and sells heavy equipment of various kinds, and has installed complete ferrite manufacturing plants in Poland, the U.S.S.R., and China. The presses used for compacting the ferrite powder are of HM design and construction.

The laboratory is a modern three-story building, expanded in 1983, which seems very well-equipped. There is a substantial electron microscopy facility, and extensive magnetic measuring equipment. Equipment that typically would be designed and built in-house in a U.S. laboratory is commercially made in Japan; small Japanese firms often undetake to make one or a few special-purpose instruments. I saw a vibrating sample magnetometer made by Riken Denki that used a synchronous motor drive with a large amplitude vibration (about 4 mm), rather than the usual voice-coil drive and 0.2 mm amplitude used by the U.S.

PAR magnetometer and its imitators. The large-amplitude motor-drive system is one we regularly use at the University of Pennsylvania; we find it simple and reliable.

The HM laboratory is now working on a wide range of materials not limited to magnetic materials. These include gadolinium gallium garnet substrates, sapphire single crystals, fine ceramics, sputtering targets, gadolinium molybdate for optical devices, etc. Many of these involve the handling of fine powders. In order to prevent cross contamination, each material research group occupies separate laboratory space. There is, however, one giant room where all the research staff (about 200) have desk space. This is a typical Japanese management device to promote interaction.

With respect to FeNdB magnets, HM is clearly working hard, and has made magnets with 44 MGOe energy product. Our major technical discussion was based on recent high resolution electron microscopy done at HM. They find the nominal $Fe_{14}Nd_2B$ composition, both as-cast and after grinding, pressing, and sintering, contains three phases in addition to the matrix phase. These are a boron-rich phase, a neodymium-rich phase containing mostly Nd, and a Nd-rich phase containing mostly Nd oxide. The total non-14-2-1 phase looked to be about 10 volume %, but I was assured that quantitative measurements show the true value is less than 5%. The grain boundaries of the matrix 14-2-1 phase appears to contain a thin layer of the Nd-rich phase; in addition, these boundries show a well-defined layer about 150 Å wide on each side of the boundary that has different crystal structure, but apparently the same composition as the matrix. Sumitomo Metals claims this layer has bcc structure (the matrix is tetragonal), and furthermore, that this phase is necessary in order to achieve high coercive fields. HM has not confirmed this interpretation, but does not dispute it.

Magnetic measurements (at the University of Pennsylvania, the University of Dayton and elsewhere) on FeNdB magnets from various manufacturers indicate the presence of roughly equal amounts of magnetic material with quite different minor hysteresis loops. The connection between this bulk magnetic behavior and the details of the grain boundary microstructure remain to be resolved.

The manager of the laboratory, now known as the Electronic and Magnetic Materials Laboratory, is Hideki Harada. A physicist by training, he has served previously as manager of the hard ferrite plant and manager of the copier assembly production plant.

HM gives the impression of being an aggressive and determined producer of materials and devices, prepared to move rapidly in any direction that seems likely to be profitable. Clearly, they are looking to diversify from their traditional base of heavy industrial products, and do not regard themselves as limited to metals or to magnetic materials. The strongly international character of the business was emphasized to me. In addition to the current custom of sending Japanese employees abroad, HM wants to hire foreign nationals and bring them to Japan for periods of two to four years.

- Suwa Seikosha

Suwa Seikosha is the parent organization of a family of companies located in central Japan in or near Suwa City. Seikosha's original business was the production of watches: they make the well-known Seiko brand, as well as the lower priced Lorus and higher priced Lassalle and Corvus. Having been selected to provide timing equipment for the 1964 Tokyo Olympics, Seikosha recognized the need for small, fast, inexpensive printers; in due course, this led to the Epson line of dot matrix printers. Epson is the world's largest supplier of printers (the printer sold with the IBM personal computer is an Epson with an IBM label), and the printer business has overtaken the watch business as a source of company revenue. Printer sales volume in 1982 was nearly $400 million, and has surely grown substantially since then.

Epson (incorporated separately from Seikosha) is also a large maker of LCD display units and microcircuits for voice and music production (talking alarm clocks, Hallmark musical greeting cards). Recently, Epson has introduced floppy disk drives, and also makes a small portable computer and a desk-top computer. The desk-top model is an ambitious design, intended to be especially easy to use. However, there have been complaints that it is slow in operation. Also, its incompatibility with the IBM PC has hurt U.S. sales.

Rare-earth permanent magnets made by Suwa Seikosha (SS) are used in Seiko watches, and more recently in small stepper motors used in Epson printers and disk drives. SS is unique in making only resin-bonded 2-17 type magnets. The RE magnet material is produced as a fairly coarse powder, which is then mixed with a binder such as epoxy resin, aligned in a magnet field, and hardened. The advantage is that thin sections can be made that are impossible in sintered material because of its brittleness. Also ring magnets with radial alignment of the easy axis are possible (favorable for motor design). In sintered material, the anisotropic thermal expansion tends to cause cracking during heat treatment in radially aligned magnets. The disadvantage of bonded magnets is that 15 to 30% of the volume is nonmagnetic resin, so the magnetic properties are substantially degraded. SS is now the principal Japanese maker of bonded magnets. However, a recent trend is for plastics or chemical companies to buy rare-earth magnetic material in powder form, mix it with resin, and mold finished parts. SS thus faces increasing competition in its market niche.

The SS bonded magnets are made entirely from 2-17 type material. Since this alloy develops its coercive field by a domain-wall pinning mechanism, its properties are not significantly degraded by surface reactions or surface contamination as is the case for $SmCo_5$. The bonded magnets are used in small motors and positioning devices where the operating temperature is 125°C or higher, and the 2-17 material works well under these conditions. The heat treatment of 2-17 alloys is complicated and tricky; SS was one of the first to master this art.

SS is working with FeNdB type magnets, but making no commitment to production until the patent situation is resolved.

My host at SS was Tatsuya Shimoda, and I spoke also with Kouji Akioka, Ryuichi Ozaki, and Itaru Okonogi, all relatively young members of the Research and Development Department. My impression is that this is all or most of the permanent magnet R&D group.

- Nippon Steel Fundamental Research Laboratory

Nippon Steel (NS) operates three central research facilities in addition to the research groups attached to the major manufacturing sites. Two of the laboratories are in Kawasaki, between Tokyo and Yokohama, and the third is on the southern Japanese island of Kyushu, and was the former Yawata Steel Company laboratory. I visited the fundamental laboratory at Kawasaki which employs about 300; the other two laboratories each employ about 600 people.

Magnetic materials are a relatively small part of Nippon Steel's total production, and at present, oriented silicon steel is the principle magnetic product. However, NS, like its U.S. counterparts, is experiencing slow or negative growth, and increasing competition from low cost producers in Korea, Taiwan, Brazil, etc. NS is responding by looking actively for new business opportunities, not necessarily related to steel or even to materials. There is, for example, a major research program on carbon fibers. The magnetic oxide (ferrite) business and geothermal energy production are also possibilities. NS also sells steel plants to other countries--a possibly self-destructive enterprise, except that if Nippon Steel does not someone else will.

My visit concerned principally amorphous magnetic alloys. NS is working, with government support, toward a goal of 15 cm wide ribbon, made in a continuous run of 200 kg. (At 35 μm thickness, this works out to a 5 km continuous strip.)

At a meeting in West Germany in late 1984, NS reported some properties of amorphous ribbon up to 70 μm thick (the usual limit is about 35 or 40 μm). I examined some of this ribbon (the production method was not disclosed) and found its geometrical properties to be excellent. The surface is so smooth that the equilibrium domain size is very large, and considerable work has been done to refine the domain size by the laser scribing technique used for silicon steel. Laser scribing can reduce the losses by 10 to 20%; it is found that it is better to do the laser treatment before the annealing treatment rather than after. Although microscopic examination of the laser-treated surface shows clear evidence of local melting, no crystallization is detected. The thick ribbon tends to be brittle, but not disastrously so.

The NS results show a surprising scatter in measurements of saturation magnetization, and also considerable changes in saturation (up to 1000 G) as a result of laser scribing and annealing. I think this must be the result of measuring the magnetization in fields too low to achieve true saturation.

Among the measuring equipment I saw in use was a single strip tester for amorphous ribbon built by Toei, using a Yokugawa high sensitivity wattmeter. I also saw some excellent SEM domain photographs, indicating very clearly the effect of laser scribing in refining the domain size of amorphous alloys.

I asked about progress in crystalline magnetic alloys made by rapid solidification, and was told that a relatively small-scale effort was continuing.

My principal host was Takashi Sato, who has published a number of papers on amorphous alloys. A group of about 25 listened to my talk about a model of the amorphous structure developed by T. Egami and V. Vitek at the University of Pennsylvania, and several people asked penetrating questions showing a thorough grasp of the subject. Among those present was Dr. Hirowo Suzuki, a former student at the University of Pennsylvania. The senior host was Dr. Yasushi Nakamura, manager of the second materials research laboratory of the Fundamental Research Laboratory.

- TDK Corporation

TDK is a major manufacturer of recording tape (video and audio), floppy disks for digital recording, recording heads, inductors, and other small components. TDK also makes and sells RE magnets, mainly of the 2-17 type, for use in motors, loudspeakers, headphones, etc. They are licensed by Allied Corporation to make and sell amorphous alloy recording heads, inductors, and filter cores, but not to sell the amorphous alloy as a material.

My visit took place not at the company's laboratory in Ichikawa (Chiba-ken, just outside Tokyo), but at the elegant main office on the top floors of an office building near Tokyo station. I obtained information generally only in answer to direct questions, and fairly often not even then. I learned that TDK's sales of video tapes now exceed those of audio tapes by at least a factor of two; that TDK expects Sumitomo Special Metals to license production of FeNdB magnets at the usual and reasonable rate of about 3% of sales; and that TDK has a subsidiary called Tokyo Magnetic Printing Company, Ltd., specializing in printing magnetic strips on credit cards, tickets, etc.

I did see some excellent polarized light micrographs of the magnetic domain structure in several FeNdB permanent magnet samples of widely varying grain size made by TDK. The sample surface was perpendicular to the alignment axis, and in the demagnetized state the grains show the flowerlike pattern typically seen in uniaxial materials where the domain walls are free to move, such as Co metal and MnBi. This agrees with the observation that thermally demagnetized or pristine FeNdB magnets are easily magnetized. I also was given a preprint of a paper to appear in the *Journal of Applied Physics* giving fairly extensive data on density as a function of composition in high-cobalt zero-magnetostriction amorphous alloys. The authors have achieved higher accuracy than is usual in density measurements on amorphous alloys by using a relatively large sample size, about 3 grams.

I talked mostly with Osamu Kohmoto and Tetsuhiro Yoneyama of the Ichikawa laboratory; both are now working on permanent magnet materials, presumably FeNdB. Also present was Teruhiko Ojima, technical manager of the Development Division, and Dr. Teitaro Hiraga, new president of the Tokyo Magnetic Printing Company. Dr. Yasuo Imaoka, general manager of Corporate Research and Development, made a brief formal appearance.

- Sony Research Center

In addition to its production of a wide range of consumer products, Sony is one of the three largest magnetic tape producers in Japan (the other two are TDK and Maxell). Sony also makes magnetic recording heads and various other magnetic components, using both amorphous alloys and ferrites. Sony does not produce permanent magnet materials, although the compact design of the Sony Walkman portable cassette player is possible only because RE magnets are used in the motor drive and in the earphones.

Sony is increasing its development and marketing efforts in devices for computers and business machines, since the consumer products market (TV, radio, cassette recorders) is approaching saturation in the developed countries, and the price competition is fierce. Sony's Betamax video recording system has lagged behind the competing VHS system; this is seen by Sony developed products--the compact digital audio disk, the Mavica magnetic recording still camera, and the $3\frac{1}{2}$ -inch floppy disk for computers--great care is being taken to avoid the Betamax syndrome. The compact digital audio disk and the $3\frac{1}{2}$ -inch floppy disk are highly successful products. The Mavica camera, first announced in 1981, is now scheduled to appear on the market in 1986. Part of the delay has been in getting agreement among various manufacturers on the technical specifications of the system.

The Sony Research Center in Yokohama is not a large establishment (about 220 staff members). Much of the company's development work is done in two other research centers, or in some cases at manufacturing locations. My visit was on a Saturday afternoon, and there was plenty of activity. I saw work on high frequency (10 GHz) filter materials; perpendicular magnetic recording on $3\frac{1}{2}$-inch disks using a Co-Cr medium and the Sony "WSP" perpendicular recording head (named for its "W" shape); extensive sputtering equipment producing a variety of magnetic, dielectric, and optical films; and a number of large-scale vacuum chambers being used for evaporative coating of magnetic metal layers on long rolls of polymer tape. The most interesting display was a videotape of a digital recording system combining bubble domain technology with magneto-optic technology. A conventional LPE garnet bubble film is used, with etched depressions about 6 μm square used to confine the bubbles, which are about 2 μm in diameter. The conventional permalloy guide channels and rotating field are not used; instead, bubbles are individually created and destroyed by a moving pulsed laser spot. Readout is by the Faraday effect, using the laser at reduced power. Some details are given in the *IEEE Transactions on Magnetics, MAG-19,* 1763-65 (1983).

My principal host was Dr. Yoshimi Makino, assistant director of the Research Center. Two former students at the University of Pennsylvania, Yutaka Takei and Kazunori Ozawa, were also there although neither is employed at the center. Takei works at company headquarters, planning long-range R&D strategy in magnetic devices, and Ozawa manages a development group at the Sony tape plant in Sendai. However, a small section of Ozawa's group occupies space at the Central Laboratory.

- Shin Etsu Corporation

Shin Etsu is primarily a chemical company. An increasing part of its business is the production of materials for the electronics industry. Shin Etsu (SE) consists of a typically complete group of related companies, subsidiaries, and joint ventures. Total sales in 1984 were about $1.4 billion. SE is doing very well in electronics by supplying basic materials: semiconductor silicon single crystal wafers, optical quartz for photoresist masks, garnet substrates for bubble domain devices, and PVC jackets for floppy disks.

SE got into the rare-earth magnet business through being a producer of rare-earth oxides and metals; the plant and laboratory, located in the small city of Takefu on the west coast of Japan, produce only sintered 2-17 type magnets in a range of grades up to 28 MGOe energy product. The magnets are mainly used in linear actuators for magnetic disk drives, and also in stepper motors, earphones, etc. About 500 different sizes and shapes are made, with magnet sales now running about $2 million per month. Sales are mainly in Japan, partly because SE does not have a very strong magnet sales effort abroad and partly because most of the products using 2-17 magnets are made in Japan.

SE is in the middle of a major expansion of its magnet-producing facilities, including not only presses and furnaces but also commitments for supplies of samarium. Not surprisingly, SE is worried about losing 2-17 magnet business to the new FeNdB magnets. At least in the short-term, there will not be sufficient FeNdB production capacity to meet the demand for magnets, but this could change quite rapidly. SE is doing experimental work on FeNdB, but will not consider offering it for sale until the patent situation is clear. They gave an interesting reason for this decision: they have an obligation to their customers not to supply material that may not be available on a long-term basis. I asked whether their customers had a reciprocal obligation to continue using 2-17 magnets when a better product was available: The answer was "no."

I was shown much more at SE than on any of my other visits. I had a complete tour of the laboratory, which is not particularly impressive as a research facility but is an excellent pilot plant. They do have a new Rigaku Denki x-ray diffraction apparatus, with a rotating anode tube, pole figure and high temperature cameras, and complete computer control. For other experiments (i.e., hysteresis loops), they use personal computers as data logging and plotting instruments. (What we print as PI on a non-Greek printer appears as PAI in Takefu.)

Although SE does not make resin-bonded magnets, the company sells mixed polymer (nylon) rare-earth magnet powder for other companies to mold into finished magnets. Accordingly, SE has a research program on bonded magnets. Since the powders are for injection molding, the magnet fraction is low--50 to 65%.

The most interesting project I saw was a prototype press for impact compacting of 2-17 powders. A fairly heavy (2 kg) metal slug is accelerated by air pressure through a distance of about a meter. The slug impacts a short rod which in turn compresses the powder. A pulsed magnetic field is applied at a carefully timed point to align the powder as the pressure is applied. The reason for all this is to apply a higher aligning field than is attainable with the usual dc fields. DC field measurements to more than 100 kOe at Tohoku University showed that 60 to 80 kOe was necessary for maximum alignment in the case where the field is parallel to the compression axis (lower fields are adequate when the field is perpendicular to the compression axis). The practical limit in the pulsed-field apparatus is about 40 kOe, but SE expects about 2% improvement in energy product, and furthermore expects to make parallel-aligned magnets almost equal in quality to perpendicular-aligned magnets.

A somewhat similar, but larger, pulsed-pressure arrangement is being used with a perpendicular aligning field to reach higher than normal compacting pressures, and thus to make large magnet blocks with reasonable green (presintering) strength. The as-pressed magnets are quite fragile, and large pieces are prone to crumble even with gentle handling. In the larger pulsed-pressure apparatus, the flying slug impacts a water column which transmits the force through a U-turn to the magnet powder.

In a corner of the pilot plant was a complete amorphous alloy ribbon casting machine, with a provision for casting in vacuum. It was purchased ready-made when news of GM's work on rapidly-quenched FeNdB alloys reached Japan. Now the Sumitomo process looks more appealing, and the rapid quenching equipment is unused.

I also saw most of the actual magnet production facilities, except for the melting and casting of the starting alloy. SE uses a single component powder; i.e., no lower melting phase is added to speed the sintering. There were at least 20 presses in the production area. The sintering and heat treatment are done in elaborate multichambered vacuum furnaces with extensive control systems. A small grinding shop is engaged in bringing the finished magnets to dimensional tolerances, but most of this work is farmed out. The magnets are normally shipped in the demagnetized state.

The laboratory, pilot plant, and general office were in old buildings without central heating. The new production facilities, and the pulsed-pressure equipment, were in modern buildings.

My principal host was Dr. Yoshio Tawara, manager of the Magnetic Materials Research and Development Center. He spent a year (1976) at the University of Dayton. Accompanying us was Ken Ohashi, research engineer. The technical staff involved in magnetic materials work is about seven.

- Sumitomo Special Metals

Sumitomo Special Metals is the company that (together with GM) started the recent revolution in rare-earth permanent magnets by investing (or discovering) $Fe_{14}Nd_2B$. The company, located in an unprepossessing industrial neighborhood between Osaka and Kyoto, carries the Sumitomo conglomerate name but operates largely independently. I obtained no figures on sales volume.

Although I was shown neither laboratory nor production facilities (the explanation was that the laboratory and pilot production equipment were intermixed), this was a most productive and rewarding technical visit. We had a long and detailed discussion about permanent magnet behavior, models of coercive field, domain observations, interpretation of minor hysteresis loops, and related matters. Sumitomo has made domain observations in $Fe_{14}Nd_2B$ that support my contention that in ac demagnetized magnets there are two kinds of grains: those containing mobile domain walls and those showing single domain behavior. Presumably, the difference lies in the dependence of the surface-pinning or surface-nucleation field on the maximum field applied as demonstrated by the late J. J. Becker of GE on $SmCo_5$ particles.

The Sumitomo group has made measurements of magnetization as a function of field in various crystallographic directions in small single crystals of a number of $RE_2Fe_{14}B$ compounds: RE=Nd, Sm, Er, Tm, and Y. In a number of these compounds they find a quite remarkable result: an anisotropic saturation magnetization, amounting in the largest case (Tm) to about 6%, as shown in Figure 1. The magnetization appears to be saturated in both easy and hard directions, and the magnetization difference between the [001] and the [100] or [010] is independent of field out to 150 kOe. This might be a noncolinear spin arrangement with very high anisotropy, or else a real orientation dependence of the atomic moment. From another viewpoint, this behavior raises questions about the definition of magnetic anisotropy. In low fields (less than 600 kA/m in Figure 1), the [001] direction is magnetically hard; however, in high fields the magnetization in the [001] is higher than in the [100] or [110], and will therefore have lower energy in a fixed field. This gives rise to the unusual behavior shown in Figure 2: there the samples have been left free to rotate in the applied field so that the measurement is automatically in the easy direction. Measurement of torque curves on these samples over a range of fields should be an interesting exercise. I learned later that Professor S. Chikazumi, now of Keio University, is planning such measurements.

The $Fe_{14}Nd_2B$ permanent magnet material (in single crystal form) shows the same anisotropic magnetization to about 2 or 3%. This fact was not included in Sumitomo's paper on anisotropy measurements presented at the Conference on Magnetism and Magnetic Materials in San Diego in November 1984.

My principal host was Dr. Masato Sagawa, staff manager of Research and Development. He is clearly the leader of the FeNdB development program, and has presented the work at international meetings. Dr. Akira Higuchi, general manager of Research and Development, also attended part of my session with the technical staff, numbering about six.

The published papers from this group tend to be conservative both in the sense that they do not necessarily include all the work that has been done, and in the sense that they tend to avoid interpretation except in a limited and rather formal way. My strong impression is that there is a much higher level of scientific understanding in the group than appears in the papers. The extensive work with single crystals of the REFeB family also shows a strong interest in the physics of these materials.

I heard from several other sources, but not from Sumitomo, that there was recently a serious explosion in the Sumitomo plant or laboratory in which one engineer was killed. This occurred at some stage in the processing of a rare-earth powder or powder mixture. The rare earths react very strongly with oxygen, and in fine powder form must be kept out of contact with air.

- Matsushita Electric Company

Matsushita is a giant electrical and electronics company, marketing a wide range of products around the world under the brand names National, Panasonic, Quasar, and Technics. The Central Research Laboratory is in northern Osaka, and features a large statue of Edison outside the main building, surrounded by smaller busts of Faraday, Marconi, and associated other European and Japanese inventors, engineers, and scientists. I had a quick tour of the Matsushita Museum of Technology, which emphasizes historical and recent developments of the company, and has a very impressive array of current and proposed products. My only complaint is that it was not always clear which products actually exist in the marketplace, and which were prototypes, test models, or publicity devices only.

Matsushita is actively promoting new products for industrial rather than consumer sales; they see the market for consumer electrical and many electronic products reaching saturation. One example I saw was a fluid pressure gage using an amorphous alloy diaphragm as part of a magnetic circuit. The change in permeability of the alloy as it deflects under pressure causes a change in inductance and hence a change in ac voltage at constant drive current. The gage can function to 300 kg/cm^2 (280 psi) and its output is reasonably independent of temperature. The output is badly nonlinear, but this is not seen as a problem since the output will be digitized and processed by a microcomputer in virtually all applications. Matsushita expects the gages to be used in automobiles to monitor engine oil pressure, brake line pressure, etc.

Work is proceeding on a fairly large-scale on perpendicular magnetic recording for digital data writing and reading. Recording heads are made in a variety of materials and design usually from multilayer amorphous CoZr or CoTaZa films separated by thin SiO_2 layers. CoCr (20 wt% Cr) is the favored recording medium. It is made by evaporation onto a heated polymer substrate. The evaporated structure is columnar, with column diameter 700 to 2000 Å, depending mainly on the substrate temperature. Auger spectroscopy shows substantial Cr segregation at the boundaries between the columnar grains. The reason for the segregation is unclear, but it seems to be necessary for good magnetic properties.

The attitude of the research group is that they are engaged in a long-range project, and that it is much too soon to decide on the configuration and design of a production model. This approach seems in marked contrast to U.S. firms pushing hard to get a product on the market quickly.

The Matsushita Laboratory is organized by product areas: optoelectronics, recording technology, semiconductor devices, video devices, etc. In an interesting but I suspect misguided experiment, the materials characterization facilities (electron microscopy, Auger spectroscopy, ESCA, etc.) have been set up as an independent company offering service to Matsushita as well as to outside firms. This arrangement has been in effect since March 1983; it seemed to me the laboratory staff was not entirely happy with the system.

My principal guide was Dr. Yoichi Sakamoto, who heads a group developing perpendicular recording media. My host was Dr. Eiichi Hirota, assistant director (for materials and devices) of the laboratory. I had met him at Matsushita in 1962, when he was working on CrO_2 as a possible recording medium.

- Unitika Corporation

Unitika is a major textile company, producing a wide range of fibers and fabrics from high fashion goods to tire cord, commercial fishing net materials, awnings, and some molded polymers. The connection with magnetism comes because Unitika has picked up a process developed at Tohoku University for making amorphous alloy wires (the usual process produces ribbon or tape, not wire). A water bath is held by centrifugal force on the inside diameter of a rotating wheel, and a liquid metal stream of a circular cross section is injected into the water. Amorphous wires can be made up to about 120 μm in diameter, compared to the usual maximum ribbon thickness of about 35 μm (recently increased to 70 μm or more in some compositions). The lower diameter limit is 80 to 90 μm; at smaller diameters the wire tends to become discontinuous.

The quenching rates for wire production and for ribbon production appear to be similar, since about the same range of compositions can be produced by both techniques. The wire does have some fluctuation in diameter on a scale of a few millimeters lengthwise. This can be removed by cold drawing the wire, which also improves the yield strength; it also rather surprisingly increases the ductility. However, ductility is difficult to measure and even to define in materials such as amorphous alloys that show little or no work hardening. The magnetic properties are generally degraded by cold working, although joint work with Bell Laboratories [*J. Appl. Phys.*, *55*, 1796 (1984)] shows that cold work produces very square hysteresis loops which might be useful for some applications.

Unitika expects a substantial market for amorphous alloy wires, and is planning a production capacity described as "more than kilograms per day." The production cost is substantially higher than that of amorphous ribbon of the same composition, and of course if cold drawing is required, the cost will be even higher. My impression is that the major applications are foreseen to be based on the mechanical rather than the magnetic properties of the wire. The wire is stronger than piano wire, although lower in elastic modulus.

At least until further action in the Japanese courts, Unitika is prevented by Allied Corporation's Japanese composition patents from selling amorphous alloys. Unitika has an option on a license for sales in Japan, but not outside Japan.

I spoke with Isamu Ogasawara, research chief of the Unitika R&D Center, and with Takeshi Kondo, assistant manager. A Mr. Sato, whose first name I missed, acted as translator; he is a polymer chemist who spent two years at the University of Massachusetts. My previous correspondence had been with Michiaki Hagiwara, who signed himself research chief of the R&D Center.

RESEARCH FACILITIES AT PRIVATE UNIVERSITIES

- Toho University

Toho is a former girls college, which was converted to coed status after World War II. It is best known for its medical school, and has only recently (1982) added a physics department to its previous departments of chemistry, biology, and pharmacology. I was invited there by an old friend, Tachiro Tsushima, who moved to Toho about two years ago from the Electrotechnical Laboratory in Tsukuba. Toho has a new physics building, with ample laboratory space. Tsushima, like the other members of the physics department, is trying to build up a laboratory research facility. At present, there are only undergraduate students to help with the work but graduate programs are planned. Tsushima is the only faculty member engaged in magnetism, although other members of the department are working on low temperature physics, laser spectroscopy, combustion chemistry, and surface physics. Tsushima has sputtering and CVD equipment and is investigating the optical properties of various kinds of thin films, including both amorphous and crystalline metals and oxides. This is a small-scale effort, and it is likely to be some time before a significant quantity of work emerges.

- Keio University

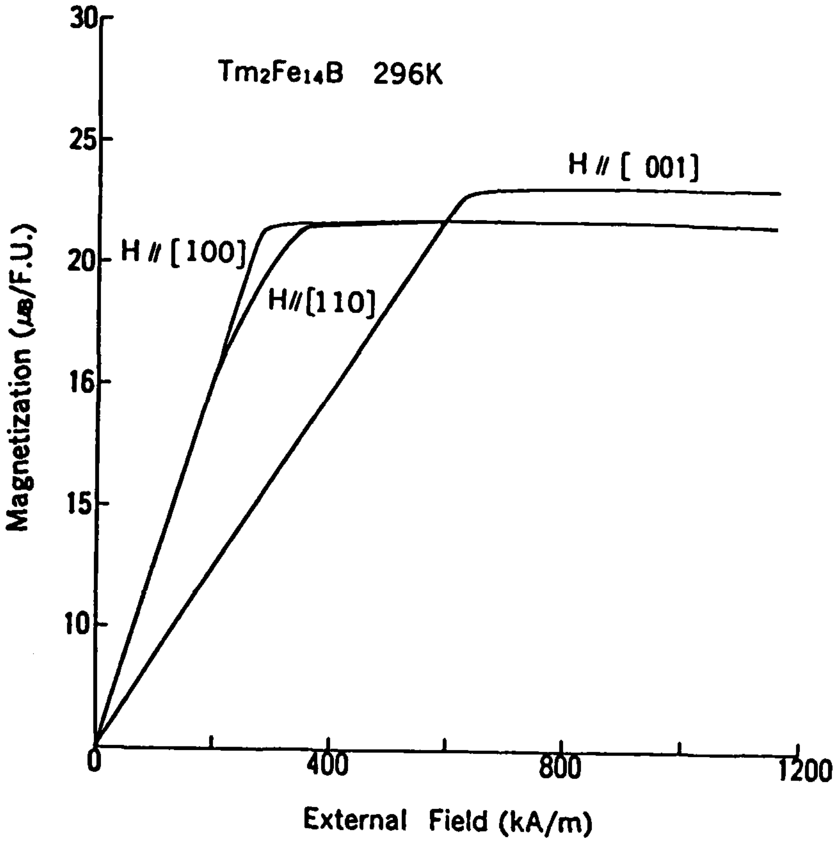
Keio is one of the largest and best of the Japanese private universities, with campuses in Tokyo and Yokohama. The Yokohama campus is devoted to science and technology. I was invited there by Professor Soshin Chikazumi, well-known for his varied work in magnetism and for his book, *The Physics of Magnetism*. Incidentally, Chikazumi has published, in Japanese, a revised and expanded version of this book, in two volumes. John Wiley has agreed to publish an English translation and Chikazumi is at work on the translation.

After about 25 years at the Institute for Solid State Physics of the University of Tokyo, Chikazumi reached retirement age last year, and following Japanese custom moved to a private university where different retirement rules apply. Although at Keio he has a considerably heavier teaching load than at Tokyo where he was essentially a research professor, he is building up a research program of considerable magnitude.

Keio has provided a helium liquifier system for the physics department, and Chikazumi runs a large (90 kOe) superconducting magnet system. He is measuring the properties of $Fe_{14}Nd_2B$ magnets from room temperature down to 4.2 K, and finding evidence for two magnetic phases of very different coercive fields. However, results from measurements indicate that the low coercive phase seems never to develop high coercivity even after being subjected to an 80 kOe field. In this, the magnet in Professor Chikazumi's laboratory is different from those I have tested, and those measured at the University of Dayton. The matter remains unresolved.

The laboratory has also a torque magnetometer which will be used for measuring the single crystals made by Sumitomo Special Metals (see above). There is also a student project on the behavior of ferrofluids when the liquid is frozen. Data collection and plotting is done with personal computers, and some of the programming is very impressive.

The superconducting magnet requires about 50 minutes to reach its maximum field, and so the acquisition of a hysteresis loop is a matter of hours. The magnet laboratory is equipped with bunk beds so the students can stay to tend the equipment as required during the long data collection.



Tm2Fe14B 296K
H // [001]
H // [100]
H//[110]
Magnetization (μB/F.U.)
30
25
20
16
15
10
0
400
800
1200
External Field (kA/m)

Figure 1.

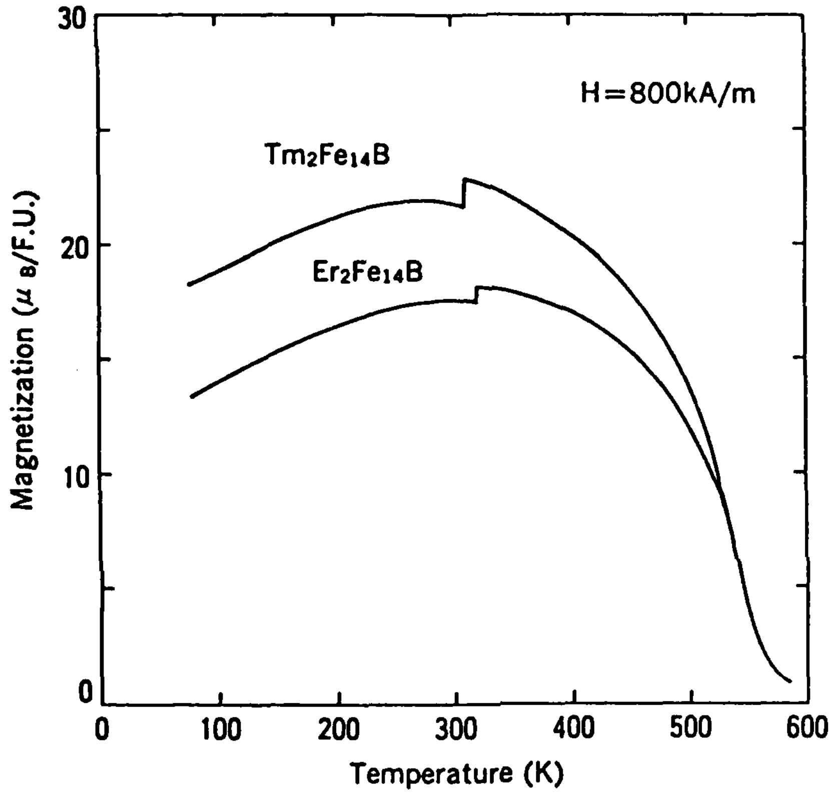

H=800kA/m
Tm2Fe14B
Er2Fe14B
Magnetization (μ B/F.U.)
Temperature (K)
0
10
20
30
0
100
200
300
400
500
600

Figure 2.

THE 49TH GENERAL MEETING OF THE KOREAN PHYSICAL SOCIETY

Sung M. Lee

INTRODUCTION

The 49th General Meeting of the Korean Physical Society was held during 27-28 October 1984, at the Kyung Sang National University campus in Chinju, a city in the southern part of Korea. There is something unusual about these dates, namely that they fall on Saturday and Sunday. I was told that the academic society meetings in Korea are routinely held during the weekend so as not to disrupt the normal instructional activities at the universities.

The Korean Physical Society has adopted the practice of holding spring meetings in Seoul and fall meetings at various different locations in the country. Since Seoul has a large concentration of many universities and laboratories, the fall meeting requires the majority of the participants to travel some distance.

More than 400 participants had registered for the meeting. The Kyung Sang campus is practically a new facility and provided adequate arrangements.

There were more than 250 papers presented, both invited and contributed. As the morning session of the first day was taken up by ceremonial and business activities, except for two keynote addresses by Professor Jin Sup Song, of Kyung Sang University, and Professor Y. Torizuka, of Tohoku University, Japan, some 250 papers had to be scheduled in one full day of working sessions (Saturday and Sunday morning). The result was that there were too many parallel sessions with some only sparsely attended.

The arrangement of the meeting is shown below with the titles of the invited papers.

MEETING STRUCTURE

MORNING SESSION, 27 OCTOBER 1984 (Saturday)

- Measuring Charm and B Decays via Hadronic Production in a Tagged Emulsion Spectrometer
  J. S. Song (Kyung Sang University)

- Next Electron Accelerator at Tohoku University and Electromagnetic Nuclear Physics
  Y. Torizuka (Tohoku University, Japan)

AFTERNOON SESSION (Paper Presentation)

- Division of Elementary Particles (14 contributed papers)

  Report on the 22nd International Conference on High Energy Physics
  J. K. Kim (KAIST) and B. Y. Park (Seoul National University)

  TRISTAN and AMY
  C. S. Kang (Korea University)

- Division of Nuclear Physics (13 contributed papers)

Subbarrier Photofission Using Tagged Photon Beams
J. C. Kim (Seoul National University)

Subbarrier Fusion in Terms of the Direct Reaction Theory
B. T. Kim (Sung Kyun Kwan University)

Improved MIT Bag
C. H. Chun (Choong Ang University)

- Division of Applied Physics (28 contributed papers)

Acousto-optic Conversion Cells Using Liquid Crystals
S. V. Letcher (University of Rhode Island, U.S.A.)

Snow and Cold Environment Research at Michigan Technological University
S. M. Lee (Michigan Technological University, U.S.A.)

- Division of Thermodynamics and Statistical Physics (three contributed papers)

Statistical Mechanics of Nonspherical Molecular Fluids
C. K. Choi (Choong Nam University)

Self-avoiding Walk in Finitely Ramified Fractals
D. C. Kim and B. N. Kang (Seoul National University)

Approximation Methods in Many Body Problems
C. B. Hong (Seoul National University)

- Division of Physics Education (nine contributed papers)

An Examination of Theoretical Bases and Empirical Evidence for the Existence of the Momentum Effect in Learning Scientific Concepts
J. S. Kwon (Institute of Educational Development)

Development and Quality Control of Science Teachers Education
S. J. Park (Seoul National University)

- Division of Plasma Physics (14 contributed papers)

Double Layers
K. Y. Kim (Korea Foreign Language University)

Report on (1), the 10th IAEA Plasma Physics and Fusion Research (London), and (2) ICTP 20th Anniversary Meeting (Trieste): Next 20 Years in Plasma Physics
D. I. Choi (Korea Advanced Institute of Science and Technology) (KAIST)

- Division of Optics and Quantum Electrodynamics (28 contributed papers)

State of Confusion in Nonlinear Optics
S. Y. Shin (Korea Advanced Institute of Science and Technology) (KAIST)

MORNING SESSION, 28 OCTOBER 1984 (Sunday, Paper Presentation)

- Division of Elementary Particles (five contributed papers)

The Month-to-Month Variations of Neutron Monitor Data
J. Y. Yu (Koon San University)

- Division of Solid State Physics (29 contributed papers)

Many Body Effects in Silicon Surface Inversion Layers
K. S. Lee (Pusan University)

Mechanical Properties of Metallic Glass PdSiCu
H. N. Myung (Chun Nam University)

- Division of Applied Physics (25 contributed papers)

The Cases that Solutions Using Typical Approximations in the Dynamical Theory of Electron Diffraction Can Give Significant Errors
H. S. Kim (Pusan Industrial University)

- Division of Optics and Quantum Electrodynamics (21 contributed papers)

DISCUSSION

The character of the papers presented was varied as might be expected from this type of general meeting as compared to a more narrowly-defined, topical conference. Some of the invited talks were technically oriented while others were more in the nature of tutorial or review presentations. The fact that there were many contributed papers is significant testimony to the progress that the Korean physics community is making, particularly among young physicists.

With many parallel sessions going on simultaneously and in a very short span of time, it was difficult to hear the papers one deemed significant. It should be evident from the above summary that particle physics, solid state physics, and quantum electrodynamics are the areas of current interest among Korean physicists. Theoretical particle physics has been a subject of active research in Korea for many years. It can be noted that the interest in nuclear physics is diminishing.

The general tone of the presentation also shows the influence of the many physicists trained abroad. These physicists were returning to Korea with the results of their recent work and eager to present their findings at a meeting such as this. It was also noteworthy that more than a few foreign scientists were participants at the meeting.

As my current research involves characterizing physical properties of snow using a set of acoustic parameters, I was attracted to a series of papers relating to acoustics which was presented by a group from the Korea Advanced Institute of Science and Technology.

C. H. So and H. C. Kim described a new type of acoustic lens which is designed to produce images of acoustic sources with minimum aberrations. Their system consists of concentrated and truncated cones instead of the conventional vane type. Laboratory measurements support the validity of their design concept.

In a paper by S. D. Kwon and H. C. Kim, an analysis of critical angle reflectivity of ultrasonic waves backscattered from crystalline solids (recrystalized polycrystalline aluminum, in this case) was presented. The authors found that the amplitude of backscattered waves (1.25~8.4 MHz) decreased with increasing grain diameter in the diffusive scattering region; the situation was reversed in the other scattering region. This phenomenon was explained based on the scattering mechanism at the liquid-solid interface.

A subject relating to both acoustics and to materials, or material processing, was also taken up by D. G. Hwang and H. C. Kim in their paper on ultrasonic wave propagation in spring steel. They used a pulse-echo method to measure ultrasonic attenuation and velocity in a cylindrical specimen of Si-Mn steel which was ground, quenched, tempered, and shotpeened. Attenuation coefficient, α, was found to be dependent on the frequency f as $\alpha \sim f^{\eta}$ in the frequency range of 2~20 MHz, where η was determined to have values of 1.82~2.32. This observation suggests that the attenuation mechanism is dominated by nonscattering terms ($\eta \sim 2$) such as magnetomechanical and dislocation damping. This view was shown to be valid since the attenuation coefficients were found to be proportional to the stress amplitude of traveling waves, which is in accord with the theoretical prediction of magnetomechanical damping.

These papers, while limited to acoustics, demonstrate a phenomenon that is indicative of developing diversity in the Korean physics community. Korea, as in most other Asian countries and in some European countries, has generally leaned towards highly theoretical endeavors in science. Practical application of science has long been relegated to the status of an incidental amenity from which society can extract. This apparently is no longer the case in Korea, and so much the better for the country's scientific community.

The diversification of research interests are also complemented by the resourcefulness of the researchers in the laboratory. For example, a group of physicists from Yonsei University, Y. H. Back, S. T. Kang, H. K. Kim, C. N. Whang, and C. C. Lee, and D. S. Choe of Kangwon University presented a paper on the effect of ion implantation on the work function change of metals. While the experiment itself was not extraordinary, the significance of the work was related to the equipment used. The low energy ion accelerator, electron gun, and peripheral instruments that measure work function difference were all designed and constructed by the group (I had a chance to see the equipment in the laboratory when I visited with Professor Lee at the Yonsei campus). The character of the design and workmanship on the fabrication was of high quality.

CONCLUSION

Participation in the meeting was a positive learning experience for me. I would wish that future meetings be scheduled for more than one and one-half days, the disruption of the normal university activities notwithstanding. Otherwise, the pace of the meeting will remain hectic.

The proceedings of the meeting containing the abstracts, the majority of which are written in Korean, are printed in the *Bulletin of the Korean Physical Society*, 2, (3), September 1984.

For further information, contact:

Professor Choong Hyun Chung
President, Korean Physical Society
c/o Department of Physics
Yonsei University
Seoul, Korea

VLSI TECHNOLOGY IN JAPAN

Clifford G. Lau

INTRODUCTION

This article is a summary of the technical highlights of the 1985 Symposium on VLSI Technology which was held 14-16 May 1985 at Kobe, Japan. The symposium was sponsored by the Japan Society of Applied Physics and the IEEE Electron Devices Society to promote the exchange of information on VLSI technology between Japan and the United States. A total of 56 contributed papers and two invited papers were presented, with 40 papers submitted from Japan. Although this symposium represented only a small part of the intense VLSI research activities in Japan, none the less it presented the state-of-the-art in VLSI technology in Japan today.

There were nine sessions in the three-day meeting:

Session I	Plenary Session
Session II	IC Process Technology
Session III	Materials for VLSI-1
Session IV	Materials for VLSI-2--SOI Technology
Session V	Bipolar Technology--Interconnects
Session VI	MOS Devices and Modeling
Session VII	Lithography and Etching
Session VIII	Memory
Session IX	Hot Carriers and LDD

Six sessions were also held in the evening to encourage informal discussions and exchange of technical information. The topics of the symposium included virtually all aspects of VLSI technology. Many papers presented results of incremental improvements in VLSI technology, such as trench isolation techniques and E-beam patterning. Two areas of research were particularly interesting and important: (1) three-dimensional integrated circuits, and (2) VLSI reliability. Three-dimensional IC technology is important because of its potential for a tremendous increase in packing density and in signal processing throughput rate. Of course, VLSI reliability is a vital area for VLSI development because the technological development continues to allow reductions to the submicron range.

- Three-dimensional Integrated Circuits

Several Japanese teams reported on the successful fabrication of multilayer three-dimensional integrated circuits. M. Yoshimi and his team of researchers at the VLSI Research Center, Toshiba Corporation, reported on the first successful fabrication of stacked silicon-on-insulator (SOI) CMOS devices by means of seeding lateral epitaxy (SLE). Generally, E-beam annealing has several advantages over laser annealing because of the large area of annealing and because of the controllability of the incident beam. However, fabrication of 3D structures using SLE has difficulty because of the overheating of the thick insulator that protects the underlying devices from melting. A new SLE method for growing large single crystals has been developed, using pseudo line electron beam (PLEB). The PLEB was formed by oscillating a 100 μm diameter spot beam of 12 KeV and 2 mA with a 36 MHz triangular wave. The substrate was kept at 500°C during SLE. A tungsten film of 2000 Å was deposited on Si_3N_4 to promote heat conduction from the SOI to the seed region, and to facilitate the melting of the seed region while suppressing the overheating of the SOI. By using this new SLE process, single crystals as wide as 500 μm has been grown on 1.3 μm-thick silicon dioxide. Two layer circuits were fabricated to study the influence of the SLE process on the bottom layer devices. It was shown that there were only small shifts in the threshold voltage and the effective channel length, and the devices in both layers operated normally. Test circuits with a four-bit full adder on the top layer and memory cells on the bottom layer have been fabricated for 3D image processors.

A team headed by S. Akiyama at the Semiconductor Research Center, Matsushita Electric, reported on the fabrication of multilayer-stacked CMOS by the dual laser beam recrystallization method. Planarized heat sink (PHS) structures were used to stack the laser recrystallized silicon island layers on top of the lower IC layers. Nondoped $MoSi_2$ was used as the interconnection material to make a stable and low resistance contact with CMOS S-RAM on the first layer, a level detector on the second layer, and a sensor on the third layer, which was fabricated and operated successfully.

Another team headed by T. Nishimura at the LSI Research and Development Laboratory, Mitsubishi Electric, reported on the successful fabrication of a 256-bit static RAM with NMOS memory cells on the bottom layer and CMOS peripheral circuits (decoder, sense amplifier, and I/O buffer) on the top layer. An improved selective laser recrystallization technique was used to grow the Si layers. Memory access time was 120 ns at a power supply voltage of 5 V, and was as short as 49 ns at 8 V. The same team also reported on the successful fabrication of a multilayer 1.1 K CMOS-SOI gate array and a 10-bit linear image sensor. The image sensor, with photodiodes on the top SOI layer and signal processing circuits on the bottom bulk-silicon layer, demonstrated the feasibility of a multifunctional device with light detecting ability in three-dimensional structures.

- VLSI Reliability

In the keynote address, Eiji Takeda of Hitachi Central Research Laboratory chose the topic "Hot Carrier and Wear out Phenomena in Submicron VLSI." He correctly stated that among constraints which degrade VLSI's reliability, hot carrier and wear out phenomena in thin oxides ranked with alpha-particle soft error phenomena as the most pressing problems. He presented six hot carrier injection mechanisms: channel hot electrons, drain avalanche hot carriers, secondarily generated hot electrons, substrate hot electrons, Fowler-Nordheim tunneling, and finally, direct tunneling injections. The channel hot electron gate current was modeled as thermionic emission from heated electron gas over the $Si\text{-}SiO_2$ energy barrier. He stated that the degradation of MOS transistors was almost entirely caused by interface state generation rather than threshold voltage shift.

The upper limit of device operating voltage is obviously determined by hot carrier effects. For the next generation of MOS devices with the channel length of 0.5 μm, it will be difficult to make use of the present supply voltage of 5 V because it is necessary to take into account the trade-off between performance and breakdown voltage, and design margins. The suggested standard supply voltage for 0.5 μm devices is 3 V. Furthermore, it will be important to take into account the complicated degradation modes of the six hot carrier injections. Thus, the problem of reliability is increasingly important for VLSI, and high quality gate dielectrics are needed for submicron VLSI technology.

In an evening session, there was heated discussion on the relative merits of oxides versus nitrides as gate dielectrics. The consensus at the end of the evening was that oxides will be satisfactory down to about 100 Å, but that nitrides will be needed for thinner gate dielectrics.

Another major session, with nine papers in this symposium, was in the area of hot carrier effects and lightly doped drains (LDD). A team headed by A. Toriumi at the VLSI Research Center, Toshiba Corporation, discussed the physical mechanisms of carrier injection into gate oxides, and explained the degradation of MOSFETs after stress testing in ultrathin gate oxides (36 to 160 Å). Stress experiments showed that photon-induced hot electrons at the drain were the main causes of device degradations. Another team headed by Y. Tsunashima, also from VLSI Research Center, Toshiba Corporation, reported that self-aligned silicidation techniques can be used to overcome some of the difficulties associated with LDD structures. They proposed a new MOSFET structure called metal-coated lightly-doped drain (MLD). MLD NMOSFETs with channel lengths of 0.8 μm, 1 μm, and 1.2 μm were fabricated, and indicated no differences from conventional NMOS devices in its C-V curve. However, MLD devices showed substantially lower substrate current due to hot electron effects than LDD structures of double diffused drain (DDD) structures. They concluded that MLD devices will be very important in submicron VLSI because of its low contact and interconnect resistance and because of its relative ease in optimum highly reliable design. Still another team headed by M. Kinugawa from the Semiconductor Device Engineering Laboratory, Toshiba Corporation, reported on what they called moderately lightly doped drain (MLDD). These MLDD NMOSFET devices were fabricated and operated at 5 V, and showed a lifetime several orders of magnitude longer than conventional LDD devices. Furthermore, in addition to improved reliability, these MLDD structures had higher current driving capability than conventional LDD devices.

- Summary

This symposium provides ample and convincing evidence of the excellent progress the Japanese have made in VLSI technology. In the three-dimensional integrated circuits area, they seem to have solved the Si recrystallization problem, and are on the threshold of realizing truly integrated 3D IC technology. Excellent progress is also being made to improve the reliability of VLSI technology to reduce the effect of hot carriers.

The technical descriptions presented here are mostly taken from the abstracts of the papers presented at the symposium. It is suggested that those who want more technical detail to consult the *Digest of Technical Papers, 1985 Symposium on VLSI Technology*, IEEE Catalog Number 85CH 2125-3.

INTERNATIONAL SYMPOSIUM ON CIRCUITS AND SYSTEMS, KYOTO, JAPAN

The 1985 International Symposium on Circuits and Systems (ISCAS) was held on 5-7 June 1985 in Kyoto, Japan. This symposium was sponsored by the IEEE Circuits and Systems Society and the IECE (Japan) Technical Group on Circuits and Systems. Total attendance was about 600 persons, with 370 from Japan, 115 from the United States, and the rest from European and Asian countries. Surprisingly, there were a great number of researchers from Canada, West Germany, Great Britain, and the People's Republic of China. There were a total of 450 technical papers in nine parallel sessions per day in the three-day meeting. The topics covered all areas of circuits and systems, including layout for VLSI, CAD, digital filters, large-scale simulation, system analysis, nonlinear circuits, VLSI design and synthesis, VLSI device modeling and simulation, modeling and analysis of discrete event systems, switched capacitor networks, fault diagnosis, graph theory, power electronics, design for testability, image processing, adaptive filters, parallel processing, and power systems.

The single largest topic, for obvious reasons, was in the area of VLSI, which comprised about 30% of the total papers. This included various sessions on VLSI design, synthesis, layout, modeling, simulation, and architectures. In the opening session, a panel discussion was held on the topic, "Circuits and Systems in the VLSI Era." This session was organized by Professor D.O. Pederson of the University of California at Berkeley to discuss the impact of VLSI on the Circuits and Systems Society, its programs, its members, and its future. There was general agreement that the IEEE Circuits and Systems Society should be concerned about the long-term, fundamental aspects of VLSI and not the short-term, immediate technology problems. As VLSI technology matures by the 1990s time frame, architectures and algorithms are viewed as increasingly more important research topics.

Layout is an important area for VLSI because it is directly related to chip area and, therefore, yield and cost. T. Takahiro and H. Baba of the Toshiba Research and Development Center presented a floor plan design system for VLSI layout. The system consisted of five subsystems: data input/output (I/O), input data editor (EDIT), floor plan auto generation (EXEC), interactive improvement (IMPRV), and evaluation (EVAL). In a related paper, M. Sato and T. Ohtsuki of Waseda University, Tokyo, presented an algorithm for VLSI layout on the resizing problem. Other layout systems were also presented, including a multilayer router for standard cells by M. Yamada's team at Toshiba, a global router for polycells by T. Kambe's team at Sharp, and automatic compaction algorithms by M. Ishikawa's team at NEC. Of course there were numerous other papers from the United States on VLSI layout, notably and mostly from the University of California at Berkeley. Many of these layout systems such as BBL and MAGIC are familiar "household" names in the area of VLSI design.

An area of research closely related to VLSI layout was graph theory. Four regular sessions were devoted to various aspects of graph theory and its application to the design of VLSI networks. Another area of research closely related to VLSI was digital filtering. Four regular sessions were devoted to the design of digital filters and digital signal processors, and one session was devoted to the study of limit cycle oscillation in digital filters. Yet another VLSI related area was in the design of switched capacitor networks. Three sessions were devoted to the design, analysis, and application of switched capacitor networks.

One major topic in this symposium that generated a great deal of excitement was in the area of nonlinear circuits and systems, particularly in the study of chaotic phenomena. Chaos in electronic circuits is a condition such that the waveform is neither periodic, nor aperiodic, nor almost periodic, but yet not completely random. For a given initial condition, the trajectory is actually completely determined. Therefore, some people have described chaos as "deterministic noise." Professor T. Matsumoto of the Waseda University, Tokyo, together with Professor L. Chua of the University of California at Berkeley, have been pioneers in the study of chaos. They were the first persons to show the existence of chaos in second order nonautonomous systems. In this symposium, they were further able to show the existence of chaos in third order autonomous systems, and were able to come up with an extremely simple circuit that exhibited chaotic behavior called the double scroll. This research has not only generated excitement among circuit theorists but many other researchers as well. Many first-class mathematicians are now trying hard to prove the existence of chaotic solutions in ordinary differential equations. Also, many first-class physicists are reexamining the very basic assumptions of quantum mechanics. Attempts are now being made to explain, by means of chaos, the phenomena of 1/f noise, which has been an unsolved problem for several decades.

With the large amount of research in VLSI, one would think that classical network and circuit analysis would be taking a back seat. But that is not the case. A paper by T. Nishi (Kyushu University, Fukuoka) and L. Chua on "Topological Criteria for Nonlinear Resistive Circuits Containing Controlled Sources to Have a Unique Solution," was awarded the Best Paper for 1984 for papers in the IEEE Transaction on Circuits and Systems. In a follow-on paper at this symposium, they were able to further show necessary and sufficient conditions for the uniqueness of solution on nonlinear resistive circuits containing strictly monotone-increasing nonlinear resistors, dc sources, and k linear current-controlled current sources or voltage-controlled voltage sources.

In summary, this symposium represented a wide range of topics in circuits and systems. It is not possible to describe in detail the several hundreds of papers; however, those who do want more technical information are encouraged to consult the *Proceedings of the 1986 International Symposium on Circuits and Systems*, IEEE Catalog Number 85CH2114-7.

PULSED POWER RESEARCH IN JAPAN

M. Kristiansen and M. Frank Rose

INTRODUCTION

The area of pulsed power research is of importance to numerous civilian and military applications. The basic idea in pulsed power technology is to store energy at a slow rate in some storage medium (usually capacitors) and then release this energy in a short, intense pulse into some load. This is somewhat analogous to a car battery (slow, low power charging and fast, high power discharging), except for the extreme power levels and time scale. It is common in this field to talk about nanoseconds (1 ns = 10^{-9} s) and terawatt (1 TW = 10^{12} W). The largest such machine under construction is the Particle Beam Fusion Accelerator II (PBFA-II) at Sandia National Laboratories (SNL) with a predicted peak power level of 100 TW (10^{14} W) for some 10's of ns.

The main pulsed power developments in the U.S. have been driven by the Inertial Confinement Fusion Program (DoE), the Nuclear Simulation Program (DNA), and more recently by the Directed Beam Weapons Program (DoD). A very recent boost for pulsed power research has come through the Strategic Defense Initiative (SDI). Because of the obvious military application possibilities of this technology, it is sometimes a rather sensitive topic in Japan and is probably also the cause for the perceived lack of focus of such work in Japan.

We were invited by a group of individuals associated with various university and private interests to hold a series of talks on pulsed power technology. During our three-week visit, we visited numerous cities, universities, and laboratories and, lectured extensively on a wide range of pulsed power topics to a wide range of audiences (laymen, students, practicing engineers, and researchers).

DISCUSSION

The quality and total amount of pulsed power research in Japan was a surprise to us since we had not heard much about it before, except for a few papers at international conferences. We perceive the reason for this to be a lack of focus and coordination of the many small, but high quality, projects we saw. There seems to be no single individual or government agency which has a lead role or coordinating responsibility for this high technology area. Because of its obvious military implications, there also seems to be a reluctance to discuss it except in a clear connection with inertial confinement fusion or laser development.

Some 10-20 years ago, pulsed power technology in the 10's of kV, microsecond regime was heavily driven by high density plasma pinch work for controlled thermonuclear fusion. This line of research has since been deemphasized by most countries, but there are still remnants of this work and technology in Japan (as well as in other countries) for various other applications. The nanosecond, megavolt pulsed power work is of more military interest, but also has important applications in inertial confinement fusion and in various laser developments. Hence, essentially all the work we saw in this parameter range was justified in terms of these two applications.

- Various University and Laboratory Visits

An outstanding example of the microsecond technology was demonstrated at the high magnetic field laboratory at Tokyo University where Dr. Giyuu Kido (now at Tohoku University) showed us their very impressive facilities which were mainly used for studies of magnetic field effects in solids. This was a truly impressive university laboratory with outstanding facilities with several large capacitor banks (up to 5 MJ). The nanosecond, MV technology was pursued for inertial confinement technology at Osaka University (Institute of Laser Engineering) and the Technical University of Nagaoka. We did not have an opportunity to visit the latter place, but we understand that the particle beam facilities at the two places are quite similar in capability. The technology we saw at Osaka University was vintage (pre-1980) and we saw nothing of the modular, parallel plate (rather than coaxial) technology now being developed in the U.S. For instance, the Japanese devices we saw or heard of generally were in the TW or below range, whereas the U.S.A is now completing a 100 TW device (Sandia National Laboratories). Most of the experiments we saw were of university (rather than national laboratory) size, but generally of quite high quality. Among the places we visited and observed interesting experiments were:

- the Electrotechnical Laboratory where they are doing high plasma density research,
- Keio University where we saw, by far, the largest educational activity in pulsed power related work (mainly laser development),
- Tokyo Technical Institute where we were shown the current injection system for explosive generators and various small systems for laser excitation, and
- the National Defense Academy where we were shown several interesting small-scale, graduate student type experiments.

SUMMARY

We understand that there is now a pulsed power group within the Japanese IEEE, but it was not clear to us what its scope and activities were. Because of the previously mentioned lack of coordination of the Japanese pulsed power research, it was difficult for us to unravel and ferret out who was doing what and where. It became clear, however, that the level and quantity of work was higher than we had expected and that it will take relatively little effort for Japan to become one of the "major players" in this important, high technology field.

An interesting and final note is that we saw numerous modest-size beam machines manufactured by the Physics International Company in the U.S., and some fast capacitor banks manufactured by Maxwell Laboratories. Slower capacitor banks generally used capacitors manufactured by Nichicon Capacitor, Ltd., and many of their locally manufactured pulsed power systems were constructed by Nissin Electric Company, Ltd., which seems to be the leading company in this field in Japan.

ACKNOWLEDGMENTS

We also would like to take this opportunity to thank our major hosts in Japan, Dr. I. Ueno, Tokyo University and Dr. T. Fujioka, Keio University, for their most generous hospitality.

INERTIAL CONFINEMENT FUSION RESEARCH IN JAPAN

M. Kristiansen and M. Frank Rose

Inertial confinement fusion (ICF) research attempts to produce miniature hydrogen bomb explosions in a confinement chamber where the released energy can be captured and converted to electrical energy. The basic scheme involves using lasers or charged particle beams focused on a miniature deuterium-tritium "bomb" target. The ablated surface then produces an inward "push" which compresses the target core and causes the nuclear explosion. The three main approaches to this goal pursued in the U.S. are:

- the glass laser program (also using frequency up conversion) at Lawrence Livermore National Laboratory (LLNL) (the Nova Program),
- the CO_2 gas laser program at Los Alamos National Laboratory (LANL) (the Antares Program), and
- the charged particle beam program at Sandia National Laboratories (SNL) (the Particle Beam Fusion Accelerator Program).

In addition, there are significant programs at Rochester University and at KMS Fusion, Inc. In the laser ICF research, the trend is towards shorter wavelength lasers (excimer and frequency multiplied Nd:glass lasers) for better energy coupling. The charged particle beam program has moved from electron beams to light ion beams for basically the same reason. The main near term goal for all these approaches is "scientific break-even." This means that the energy produced by the imploding target will equal that in the incident beams (laser or charged particle beams). The next step is the "engineering break-even" where the efficiency of producing the incident beams is included.

INSTITUTE OF LASER ENGINEERING

The major center for ICF in Japan is the Institute of Laser Engineering at Osaka University under the direction of Professor Chiyoe Yamanaka. The facilities at this institute, which are housed in four buildings, are truly impressive. They cover all the previously mentioned approaches to ICF but the emphasis is clearly on the glass laser program. The project KONGOH (diamond) is aimed at scientific break-even fusion.

Our host and guide during our visit was the vice-director, Professor Masahiro Yokoyama. The staff, judging from a recent progress report, is in excess of 200 people, including students. The institute was established in 1972 for the development and applications of lasers and became the main Japanese research center for laser fusion in 1976. The main laser is the Gekko XII 12-beam, 20 kJ, 1 ns system which has achieved a peak power in excess of 40 TW (47.5 TW in December 1983). This system has two target rooms, one for uniform illumination and one for "bundle" beams. The next generation laser is the KONGOH, 100 kJ system, with which they hope to achieve scientific break-even.

One of the serious obstacles to the success of laser fusion is the preheating and production of hot electrons which heats the target core before the main explosion. To overcome, in part, this effect they have developed the so-called "cannonball" target which are concentric, spherical targets with beam entry openings in the outside shell to trap radiation between the spheres (~ 100 μm o.d.). This target design is also of considerable potential interest to longer wavelength laser fusion schemes, such as CO_2 lasers, which suffer from reduced energy coupling.

Their CO_2 laser fusion effort is relatively modest compared to the Antares modules at LANL. Their laser modules (8 ea @ 800 J in ∿ 1 ns) are reminiscent in style and size to the predecessors of the Antares laser at LANL. Their 1 TW, 60 kJ, Reiden IV, light ion beam fusion experiment is also quite modest compared to recent facilities at SNL. This effort did not seem to have high priority in their work and no recent activity was described. The Japanese built facility employs pre-1980, Hermes (Sandia National Laboratories) type technology. We were also informed that the Technological University of Nagaoka has an active high ion beam fusion program but we were not able to visit this facility. In a later discussion with Dr. K. Yatsui from Nagaoka, we were told that their most recent machine has 200 kJ storage, 7 Ω impedance, and produces a 70 ns, 3 MV beam. Many of their investigations have been concerned with focusing and transport of the ion beams.

OSAKA UNIVERSITY INSTITUTE OF LASER ENGINEERING

In addition to the facilities and programs described above, the Osaka University Institute of Laser Engineering (ILE) also has development programs in free electron and excimer lasers and uses a dense plasma focus for some of their diagnostics development.

Additional work related to inertial confinement fusion is being pursued at several other universities and several of them are cooperating in various ways with the Osaka University ILE.

VARIOUS PROGRAMS AND STUDIES

In a recent theoretical study by three authors, one from Nagoya University (K. Ikuta), the University of Tokyo (I. Ueno), and the Electrotechnical Laboratory (M. Tanimoto), an ablation accelerator scheme for impact fusion where high velocity projectiles impacting with fusion targets cause the fusion reaction is discussed.

Researchers from several Japanese universities reported on results of theoretical studies of ion beam focusing and transport at the Fifth International Conference on High Power Particle Beams in San Francisco in 1983 (Beams '83) and the Collaborative Research Meeting on Particle Beam Applications to Fusion Research at Nagoya University in November 1983. It is our understanding that Beams '85 will be held at a yet-to-be-determined location in Japan. Among the other universities involved in beam research are the Tokyo Institute of Technology, the Tokyo Institute of Agriculture and Technology, the Metropolitan College of Technology in Tokyo, the Kobe University of Mercantile Marine, Osaka City University, Kanazawa University, Waseda University, and Nagoya University. The proceedings of the 1983 Nagoya conference mentioned above gives a good summary of many of these activities.*

In addition to the laser inertial confinement fusion program at Osaka University, there are significant laser development and target interaction programs at several other institutes and universities. At the Institute of Physical and Chemical Research (Riken), there are several laser and beam programs. One of the efforts involve a Raman shifted CO_2 laser (16 μm) for laser isotope separation. The system runs at one pulse per second with a near term goal of 100 and a longer term goal of 1000 pulses per second. They are also working on a wide range of other laser developments for potential use in ICF research, such as high power excimer lasers.

*Nagoya University Institute of Plasma Physics Report, *IPPJ-678*, May 1984.

At Tokyo University, we found some interesting work on the development of a 5 ps, 0.4 TW, two-sided excimer laser and frequency conversion of a Nd: glass laser beam in XeF, XeCl, ArF, and KrF. They were also doing some innovative x-ray laser development using a picosecond glass (1.06 μm) laser as the driver. The facilities for the laser research laboratory at Tokyo University is located in the same building as their high magnetic field laboratory. These two laboratories would be the envy of any U.S. university.

Experimental investigations of laser absorption in a target has been studied at the Electrotechnical Laboratory at wavelengths of 1.06, 0.53, and 0.27 μm. They report very high absorption efficiencies (up to 90%) for the 0.27 μm experiments at an incident power density of 5×10^{14} W/cm^2.

SUMMARY

It is clear that there are many more universities and laboratories in Japan involved in ICF research than we had any chance to visit and that the total program is quite significant. The program at Osaka University is clearly the largest and most visible one, but many of the other programs are quite active and well-equipped.

INTERNATIONAL MEETINGS IN THE FAR EAST

1985-1988

Compiled by Yuko Ushino

The Australian Academy of Science, the Japan Convention Bureau, and the Science Council of Japan are the primary sources for this list. Readers are asked to notify us of any upcoming international meetings and exhibitions in the Far East which have not yet been included in this report.

1985

Date	Title, Attendance*	Site	For information, contact
October 1-3	Regional Conference on Treatment, Disposal, and Management of Human Waste *20-F60-J70	Tokyo, Japan	Japan Society on Water Pollution Research Rm 107, Yotsuya New Mansion, 12 Honshio-cho, Shinjuku-ku, Tokyo 160
October 1-5	International Symposium on Wild Disease of Rice and Leguminous Crops in the Tropics 6-F20-J70	Tsukuba, Japan	Tropical Agricultural Research Center 1-2 Ohwashi, Yatabe-cho, Tsukuba-gun, Ibaraki 305
October 1-5	The 5th International Congress of IAIN (International Association of Institutes of Navigation) 9-F100-J200	Tokyo, Japan	Japan Institute of Navigation 2-1-6 Etchujima, Koto-ku, Tokyo 135
October 6-10	International Society of Cardiology. The 7th International Symposium on Arteriosclerosis	Melbourne, Australia	Dr. P.J. Nestel, Baker Medical Research Institute Commercial Road, Prahran, Victoria 3184
October 14-16	International Committee of Foundry Technical Association. The 52nd International Foundry Congress	Melbourne, Australia	Neil McGaw, Australian Foundry Institute, Materials Division, RMIT P.O. Box 360, Carlton South Victoria 3053
October 14-16	Zinc '85--International Symposium on Extractive Metallurgy of Zinc 20-F70-J100	Tokyo, Japan	Mining and Metallurgical Institute of Japan Nogizaka Building, 9-6-41 Akasaka, Minato-ku, Tokyo 107

*Note: Data format was taken from the Japan International Congress Calendar published by the Japan Convention Bureau.
No. of participating countries
F: No. of overseas participants
J: No. of Japanese participants

1985

Date	Title, Attendance	Site	For information, contact
October 14-17	International Seminar on Laterite 25-F70-J100	Tokyo, Japan	Mining and Metallurgical Institute of Japan Nogizaka Building, 9-6-41 Akasaka, Minato-ku, Tokyo 107
October 19-21	The 4th International Congress of Oriental Medicine 20-F300-J700	Kyoto, Japan	c/o International Congress Service, Inc. New Kyoto Center Building, Higashi-Shiokoji, Shimogyo-ku, Kyoto 600
October 19-22	The 5th International Symposium on Rats with Spontaneous Hypertension and Related Studies 30-F400-J400	Kyoto, Japan	Dr. Y. Yamori, Department of Pathology, Shimane Medical University 89-1 Shioji-cho, Izumo, Shimane 693
October 20-23	China-Japan-USA Joint Seminar on Macromolecule-metal Complexes	Beijing, People's Republic of China	Professor Yoshiyuki Okamoto, Polytechnic Institute of New York, 333 Jay Street, Brooklyn, New York, USA 11201
October 21-24	International Symposium on Microstructure and Mechanical Behavior of Materials	Xian, People's Republic of China	Research Institute of Mechanical Behavior, Xian Jiaotong University Xian, Shaanxi Province
October 23-24	International Symposium on Mechanisms and Treatment in Essential Hypertension 41-F200-J100	Nagoya, Japan	Dr. H. Aoki, Second Department of Internal Medicine, Faculty of Medicine, Nagoya City University 1 Aza Kawasumi, Mizuho-cho, Mizuho-ku, Nagoya 467
October 25-27	International Symposium on Brain and Blood Pressure Control 12-F100-J100	Tokyo, Japan	Nihon Roche Research Center 200 Kajiwara, Kamakura, Kanagawa 247
October 28-November 1	Japan/U.S. Symposium on Polymers	Tokyo, Japan	The Society of Polymer Science 5-12-8 Ginza, Chuo-ku, Tokyo 104
November 4-7	HSLA Steels '85 (High Strength Low Alloy Steels)	Beijing, People's Republic of China	Chinese Society of Metals 46 Dongsizi Dajie, Beijing

1985

Date	Title, Attendance	Site	For information, contact
November 5-8	BIO85 JAPAN: The 1st International Conference on Biotechnology	Osaka, Japan	Osaka Chamber of Commerce and Industry, Osaka Convention Bureau 58-7 Hashizume-cho, Uchihonmachi, Higashi-ku, Osaka 540
November 18-22	The 3rd International Kyoto Conference on New Aspects of Organic Chemistry	Kyoto, Japan	Dr. Zen-ichi Yoshida, Conference Chairman Department of Synthetic Chemistry, Kyoto University Yoshida, Kyoto 606
November 19-28	International Astronomical Union 19th General Assembly	New Delhi, India	Dr. R. M. West, ESO Sky Atlas Laboratory Karl-Schwarzschild Strasse 2, D-8046 Garching bei Munchen, Federal Republic of Germany
November 25-29	The 4th Japan Institute of Metals International Symposium 18-F100-J100	Minakami, Gumma, Japan	Japan Institute of Metals Aoba, Aramaki, Sendai 980
December (tentative)	International Astronomical Union Symposium: Instrumentation and Research Programs for Small Telescopes	Christchurch, New Zealand	J. Hearnshaw, Department of Physics, University of Canterbury Christchurch
December (tentative)	Joint Congress of the Asian and Pacific Federation of Surgeons	Karachi, Pakistan	Dr. F. U. Baquai, Baquai Hospital, III-B Nazimabad, Karachi
December (tentative)	International Union Against Tuberculosis. (The 26th World Conference)	Singapore, Singapore	Dr. A Rouillon 3 Rue Georges Wille, F-75116 Paris, France

1986

Date	Title, Attendance	Site	For information, contact
February 1-9	International Volcanological Congress	Auckland, New Zealand	Professor H.-U. Schmincke, Institut für Mineralogie, Ruhr-Universität Bochum Universitätsstr 150, Postfach 10 21 48, D-463 Bochum, Federal Republic of Germany
February 3-9	The 5th World Congress of the International Rehabilitation Medicine Association	Manila, Republic of Philippines	Dr. Tyrone Reyes, Chairman, IRMA-V, Philippine Congress Organization Center P.O. Box 4486 Metro Manila

1986

Date	Title, Attendance	Site	For information, contact
March (tentative)	The 2nd Asian Pacific Congress on Legal Medicine and Forensic Sciences	Adelaide, Australia	Dr. Andrew Scott, Forensic Science Center Divett Place, Adelaide S.A.5000
March (tentative)	The 6th Conference of the De Bakey International Surgical Society.	Melbourne, Australia	D. G. Macleish 96 Grattan Street, Carlton, Victoria 3053
April 8-11	1986 International Conference on Acoustics, Speech, and Signal Processing 50-F500-J300	Tokyo, Japan	c/o Simul International, Inc. Kowa Building, No. 9, 1-8-10 Akasaka, Minato-ku, Tokyo 107
April 13-17	The 5th International Symposium on Offshore Mechanics and Arctic Engineering	Tokyo, Japan	Jin S. Chung, Department of Engineering, Colorado School of Mines Golden, Colorado, USA 80401
May 8-11	Congress of the International Society of Haematology and the International Society of Blood Transfusions	Sydney, Australia	Dr. I. Cooper, President Haematology Society of Australia Cancer Institute 481 Little Londsdale Street, Melbourne, Victoria 3001
May 28-30	International Congress Biliary Association (IBA) 20-F200-J300	Sendai, Japan	Secretariat: International Congress of Biliary Association c/o International Congress Service, Inc. Kasho Building, 2-7-4 Nihombashi, Chuo-ku, Tokyo 103
June 1-5	International Conference on Science and Technology of Synthetic Metals (ICSM'86)	Kyoto, Japan	Professor Tokio Yamabe, Division of Molecular Engineering, Faculty of Engineering, Kyoto University Yoshida-honmachi, Sakyo-ku, Kyoto 606
July 12-19	International Institute of Welding--Annual Assembly 1986 38-F400-J600	Tokyo, Japan	Japanese Organizing Committee of International Institute of Welding--Annual Assembly 1986 c/o Japan Welding Society 1-11 Kanda-Sakuma-cho, Chiyoda-ku, Tokyo 101
July 15-18	International Conference on Electrical Contacts, Electromechanical Components and their Applications 15-F50-J130	Nagoya, Japan	Study Meeting of Electromechanical Components Association c/o Mano Research Development Technical Center 606 Marine Heights, 5-1 Tashiro-Hondori Chikusa-ku, Nagoya 464

Date	Title, Attendance	Site	For information, contact
July 21-25	The 4th International Congress on Toxicology N.A.-F700-J800	Tokyo, Japan	Secretariat of 4th International Congress on Toxicology c/o International Congress Service, Inc. Kasho Building, 2-14-9 Nihombashi, Chuo-ku, Tokyo 103
August 3-7	The 20th Congress of the International Association of Logopedics and Phoniatrics 36-F300-J500	Tokyo, Japan	Japan Society of Logopedics and Phoniatrics c/o Research Institute of Logopedics and Phoniatrics, Faculty of Medicine, Tokyo University 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
August 17-22	The 7th International Zeolite Conference 20-F200-J300	Tokyo, Japan	Dr. H. Tominaga, Department of Synthetic Chemistry, Faculty of Engineering, Tokyo University 7-3-1 Hongo, Bunkyo-ku, Tokyo 113
August 18-21	The 2nd SPSJ (The Society of Polymer Science, Japan) International Polymer Conference	Tokyo, Japan	The Society of Polymer Science, Japan 5-12-8 Ginza, Chuo-ku, Tokyo 104
August 20-22	1986 International Conference on Solid State Devices and Materials 20-F200-J800	Tokyo, Japan	Organizing Committee of Conference on Solid State Devices and Materials c/o Business Center for Academic Societies, Japan 2-4-16 Yayoi, Bunkyo-ku, Tokyo 113
August 24-29	The 8th IUPAC Conference on Physical Organic Chemistry 18-F350-J600	Tokyo, Japan	Dr. Minoru Hirota, Secretary General The 8th IUPAC Conference on Physical Organic Chemistry c/o Chemical Society of Japan 1-5 Kanda-Surugadai, Chiyoda-ku, Tokyo 101
August 24-30	International Conference on Atomic Physics and Few Body Systems 40-F200-J800	Tokyo and Sendai, Japan	Dr. Tsutomu Watanabe, Institute of Physical and Chemical Research 2-1 Hirosawa, Wako, Saitama 351-01
August 25-30	The 12th International Congress of the International Association of Sedimentologists	Canberra, Australia	Professor K. A. W. Crook, Department of Geology, Australian National University P. O. Box 4, Canberra, A. C. T. 2600
August 26-30	International Conference on Martensitic Transformations (ICOMAT-86)	Nara, Japan	Conference Secretariat, ICOMAT-86, Japan Institute of Metals Aoba, Aramaki, Sendai 980

Date	Title, Attendance	Site	For information, contact
August 31-September 7	The 11th International Congress on Electron Microscopy 56-F1,000-J1,600	Kyoto, Japan	Professor K. Ogawa, Department of Anatomy, Faculty of Medicine, Kyoto University Yoshida Konoe-cho, Sakyo-ku, Kyoto 606
September 1-6	International Association for Bridge and Structural Engineering Symposium—(IABSE) 30-F250-J330	Tokyo, Japan	Secretariat of IABSE c/o International Congress Service, Inc. Kasho Building, 2-14-9 Nihombashi, Chuo-ku, Tokyo 103
September 9-11	The 3rd International Conference on Science and Technology: Zirconia 37-F250-J350	Tokyo, Japan	Ceramics Society of Japan 2-22-17 Hyakunincho, Shinjuku-ku, Tokyo 160
September 21-25	World Congress of Chemical Engineering 35-F300-J1,000	Tokyo, Japan	Society of Chemical Engineers, Japan Kyoritsu Kaikan, 4-6-19 Honhinata, Bunkyo-ku, Tokyo 112
September 22-26	The 9th International Meeting of International Union of Phlebology 27-F200-J300	Kyoto, Japan	Dr. S. Sakakuchi, School of Medicine, Hamamatsu University 3600 Handa-cho, Hamamatsu, Shizuoka 431-31
September 25-October 1	The 7th International Congress of Eye Research 15-F600-J400	Nagoya, Japan	Professor Shuzo Iwata, Department of Biophysical Chemistry, Faculty of Pharmaceutical Science, Meijo University 15 Yagoto-Urayama, Tempaku-cho, Tempaku-ku, Nagoya 488
September 30-October 2	The 6th International Display Research Conference (Japan Display '86) 26-F200-J450	Tokyo, Japan	Secretariat: The 6th International Display Research Conference c/o Japan Convention Services, Inc. Nippon Press Center Building, 2-1-2 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100
October 20-25	The 11th International Conference on Cyclotrons and Their Applications 17-F150-J150	Tokyo, Japan	Dr. Yasuo Hirao, Institute for Nuclear Study, University of Tokyo 3-2-1 Midori-cho, Tanashi, Tokyo 188

1987

Date	Title, Attendance	Site	For information, contact
May 17-22	World Conference on Advanced Materials for Innovations in Energy, Transportation, and Communications	Tokyo, Japan	CHEMRAWN VI Coordinating Office, The Chemical Society of Japan 1-5 Kanga-Surugadai, Chiyoda-ku, Tokyo 101
June 2-5	The 4th Printed Circuit World Congress N.A.-F200-J800	Tokyo, Japan	Japan Printed Circuit Association (JPCA) Tashiro Building, 5-11-10 Toranomon, Minato-ku, Tokyo 105
Undecided	The International Conference on Computers In Chemical Research and Education (the ICCCRE)	Shanghai, People's Republic of China	Dr. Yongzheng Hui, Shanghai Institute of Organic Chemistry, Academia Sinica 345 Lingling Lu, Shanghai 200032
October 20-23	International Conference on Quality Control—1987 Tokyo 40-F350-J350	Tokyo, Japan	Union of Japanese Scientists and Engineers 5-10-11 Sendagaya, Shibuya-ku, Tokyo 151

1988

Date	Title, Attendance	Site	For information, contact
April 26-May 3	The 3rd World Biomaterials Conference 15-F500-J500	Kyoto, Japan	Japan Society for Biomaterials c/o Institute for Medical and Dental Engineering, Tokyo Medical and Dental University 2-3-10 Kanda-Surugadai, Chiyoda-ku, Tokyo 101
June 5-10	The 6th International Conference on Surface and Colloid Science	Hakone, Japan	Division of Colloid and Surface Chemistry, The Chemical Society of Japan 1-5 Kanda-Surugadai, Chiyoda-ku, Tokyo 101
July 1-12	The 16th International Congress of Photogrammetry and Remote Sensing 65-F1,000-J1,000	Kyoto, Japan	Japan Society of Photogrammetry 601 Daiichi Honan Building, 2-8-17 Minami-Ikebukuro, Toshima-ku, Tokyo 171
July 17-23	International Congress of Endocrinology N.A.-F1,500-J2,000	Kyoto, Japan	Japan Endocrine Society c/o Seirenkaikan Kyoto Furitsu Medical University Nishizume Konjinbashi, Kamigyo-ku, Kyoto 602

1988

Date	Title, Attendance	Site	For information, contact
August 1-6	IUPAC International Symposium on Macromolecules	Kyoto, Japan	The Society of Polymer Science, Japan 5-12-8 Ginza, Chuo-ku, Tokyo 104
September 5-9	The 16th World Congress of Rehabilitation International 90-F1,500-J1,000	Tokyo, Japan	Japanese Society for Rehabilitation of the Disabled, Inc. 3-13-15 Higashi-Ikebukuro, Toshima-ku, Tokyo 107

*U.S. GOVERNMENT PRINTING OFFICE: 1985-488-670

➤ NOTICE ⮜

The Office of Naval Research/Air Force Office of Scientific Research, Liaison Office, Far East is located on the second floor of Bldg #1, Akasaka Press Center and bears the following mail identification:

Mailing address:	Office of Naval Research/Air Force Office of Scientific Research Liaison Office, Far East APO San Francisco 96503-0007
Local Address:	ONR Far East/AFOSR Far East Akasaka Press Center 7-23-17, Roppongi Minato-ku, Tokyo 106
Telephone numbers:	Civilian 03-401-8924 Autovon 229-3236 Telex 242-7125 SANTEL TOKYO

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY CARD

FIRST CLASS PERMIT NO 12503 WASHINGTON, D C

POSTAGE AND FEES PAID BY DEPARTMENT OF THE NAVY

OFFICE OF NAVAL RESEARCH
LIAISON OFFICE, FAR EAST
APO SAN FRANCISCO 96503-0007

END

FILMED

1-86

DTIC