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Reports on Current
European/Middle Eastern Science

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The European Science Notes Information Bulletin (<i>ESNIB</i>) 91-04 is a compilation of reports on recent developments in European science of specific interest to the U.S. research and development community, and is issued in support of the mission of the Office of Naval Research European Office (ONREUR). Issue Number 91-04 in addition to European area news, notes, and abstracts, contains reports in the fields of Aeronautical Science, Chemistry, Computer Science, Electronics, Materials, Molecular Biology, Physics, and Psychology. The value of the <i>ESNIB</i> to Americans is to call attention to current activity in European science and technology and to identify the institutions and people responsible for these efforts. The <i>ESNIB</i> authors are primarily ONREUR staff members; other reports are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the U.S. Army Research, Development and Standardization Group. Scientists from the U.S. who are traveling in Europe may also be invited to submit reports.					
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ESN INFORMATION BULLETIN

91-04

This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large.

Commanding Officer CAPT Victor L. Pesce, USN
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Editor Ms. Connie R. Orendorf

AERONAUTICAL SCIENCE

- A Recent European Presentation of Research in the
Aeronautical Sciences E.F. Brown
Gabriel D. Roy 1**

This meeting's technical program provided both managerial- and practitioner-oriented coverage of a broad area of the aeronautical sciences. Presentations covered the spectrum from conceptual design to certification and structural testing. Also included were air traffic control, aeroelastic response, combustion, wind-tunnel testing, and computational fluid dynamics.

CHEMISTRY

- The International Conference on Science and Technology of
Synthetic Metals John R. Reynolds
Martin Pomerantz 6**

Included in this conference were discussions on conducting and electroactive polymers, organic superconductors, metal chalcogenides, and nonlinear optics.

COMPUTER SCIENCE

- Computer Science at the University of Manchester Robert D. Ryan 10**

The Department of Computer Science at the University of Manchester is the oldest and one of the highest-rated computer science departments in the U.K. In this article, Dr. Ryan gives an overview of the four major areas--computer systems architecture, design methods and tools, computer engineering, and information systems.

ELECTRONICS

- Mind the Gap J.C. Pazik
G. Kelner
Howard Lessoff 20**

"Mind the gap" is a warning often heard on the London Underground. The term "gap" means the space between the subway car doors and the platform. When entering or leaving a subway car, there is danger of stepping into the gap. In the solid-state electronics, there is another gap that is receiving much attention, namely the band gap. In this article, the authors discuss this concept of the gap.

Il Consiglio Nazionale delle Research, Rome and Parma Howard Lessoff 27

The author discusses organization of research in Italy. He provides a summary of activities of the Institute of Special Materials for Electronics and Magnetism and the Institute for the Theory and Electronic Structure which are part of the National Council of Research.

Atomic Layer Epitaxy of Semiconductor Thin Films S.M. Bedair 33

Dr. Bedair discusses current problems facing atomic layer epitaxy and its unique applications in the field of optical and electronic devices. The potential success of atomic layer epitaxy as a new and novel growth technique will depend mainly on its ability to demonstrate device structures with unique properties.

MATERIALS

Filling the Gap with Explosively Formed Projectiles Ronald W. Armstrong 41

This article summarizes work done in armor penetration and shaped charges at RARDE (U.K.), Centre d'Etudes de Gramat (France), and Ernst-Mach-Institut (Federal Republic of Germany).

MOLECULAR BIOLOGY

New Developments in Diagnosis and Control of Infectious Diseases Jeannine A. Majde 45

The theme of this symposium was the effect of developments in molecular biology on control of infectious diseases in developing countries.

PHYSICS

The 19th International Conference on Low-Temperature Physics D.H. Liebenberg 49

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PSYCHOLOGY

Austria Hosts International Applied Military Psychology Symposium Gerald S. Malecki 57

Topics during this series focused on basic and applied research related to manpower planning, personnel selection, training, motivation and morale, and human factors in military operations. A voluntary international enterprise, IAMPS' principal function is to be a scientific forum to promote the exchange of information among the military psychological services of participating nations.

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SPECIAL ANNOUNCEMENT
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AERONAUTICAL SCIENCE

A Recent European Presentation of Research in the Aeronautical Sciences

by E. F. Brown and Gabriel D. Roy. E. F. Brown is a Professor of Mechanical Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Dr. Roy is the Scientific Officer for Propulsion and Energetics, Office of Naval Research, Arlington, Virginia.

Introduction

The 17th Congress of the International Council of the Aeronautical Sciences (ICAS) was held on September 9-14, 1990, in Stockholm, Sweden, and provided a forum for the presentation of research in the aeronautical sciences. The meeting attracted about 500 attendees from as far away as Australia; however, most of the papers presented were from northern Europe. Countries with the largest attendance were Sweden, the U.S., and the Federal Republic of Germany (FRG). There were 250 presentations organized in 10 parallel sessions during the 4 days of the meeting.

Sweden was a particularly appropriate site for the meeting because it of its technologically advanced aeronautical industry. Some Swedish aeronautical organizations are SAAB-Scania, Volvo Flygmotor, the Research Institute of Sweden (FFA), and the Royal Institute of Technology (KTH). The technical sessions got underway with the Daniel and Florence Gugenheim lecture, presented by Professor Marten Landahl. Professor Landahl has made many important contributions to the aeronautical applications of both solid and fluid mechanics. His topic was computational fluid dynamics (CFD) and turbulence. The talk pointed out the importance of a combined experimental and computational approach, and identified the important and intriguing goal of turbulence control.

The technical program provided both managerial- and practitioner-oriented coverage of a broad area of the aeronautical sciences. Presentations covered the spectrum from conceptual design to certification and structural testing. Also included were such topics as air traffic control, aeroelastic response, combustion, wind-tunnel testing, and CFD. Because of our interests, we chose to follow the combustion, wind-tunnel testing, and CFD sessions.

Combustion

Numerical modeling techniques for gas turbine combustors were presented by J. A. Visser and E. H. Mathews, University of Pretoria, Republic of South Africa, and by J. X. Zhao, Nanjing Aeronautical Institute, Peoples Republic of China, and his colleagues from the University of Leeds, U.K. However, these papers did not represent any real breakthroughs in combustion modeling.

Visser and Mathews used a complete modeling approach. The inlet conditions are calculated rather than prescribed as is usual in the flame tube approach. The area surrounding the flame tube was also included in the computation. The deficiencies in the Arrhenius-type reaction rate models (which do not account for the effect of turbulence on the reaction rate) and the eddy break-up models (which do not account for the effect of flame speed or temperature) can be overcome. It is unclear how the effect of small-scale processes, which dominate the combustion process, can be calculated. They concluded that advanced computer hardware is required to improve the modeling capability.

Zhao modeled reacting recirculating flows in a gas turbine combustor with swirl, including the effects of turbulence, combustion, and radiation. Good agreement with experimental results was shown; however, measured inlet velocity profiles are required to accurately predict the combustion parameters.

H. C. Low and his associates at Rolls-Royce, U.K., addressed the soot formation and deposition rates in gas turbine combustors. He also described carbon deposition in the various regions of the engine components. The experimental investigation indicated an extreme sensitivity of deposition levels to vaporizer stoichiometry. They observed only very modest accretion at design air/fuel ratios, while virtually total obscuration resulted because of carbon buildup at fuel-rich conditions, as expected. In the current numerical

investigation, the soot model equations were decoupled from the basic flow field equations.

In supersonic/hypersonic propulsion, A. Gany and Y. M. Timnat, Israel Institute of Technology, Haifa, advocated using beryllium- and beryllium hydride-containing propellants for the upper stage/orbital phase of hypersonic vehicles. This is because of significant increases in specific impulse can be obtained by using these fuel additives, despite the toxicity of the combustion products. (A 20-percent increase in specific impulse can be obtained by adding beryllium hydride to HTPB/AP propellants.)

S. Molder and R. J. McGregor, Ryerson Polytechnical Institute, Toronto, Canada, presented a methodology for analyzing and optimizing scramjet inlet performance. They concluded that, for the engine studied, the penalty in engine-specific impulse for using a Prandtl-Meyer inlet instead of the ideal isentropic inlet, is about 3 percent throughout the hypersonic Mach number range.

G. D. Roy, presented a comprehensive overview of the U.S. Navy-sponsored research program in ramjet combustion instability. For more than 5 years, this \$6.7-million program has supported 15 academic, industrial, and Navy principal investigators who are studying pressure oscillations associated with combustion instability in compact ramjets. A major breakthrough is combustion control by passively enhancing the vorticity in the combustor with nonaxisymmetric inlets and nozzles. The effects of acoustic forcing and secondary flame holders to reduce pressure fluctuation were also explored. In a follow-up program, the Office of Naval Research is exploring active control of combustor flow fields.

Laminar Flow Experiments

An important goal of turbulence research is reducing drag over aerodynamic surfaces, particularly wings. This can be accomplished by maintaining laminar flow over as much of the wing (both suction and pressure surfaces) as possible. The wind tunnel is a useful tool for demonstrating accomplishing this objective. A. Elsenaar, National Aerospace Laboratory (NLR), Utrecht, the Netherlands, pointed out that wind-tunnel results can be misleading, however, unless care is taken in the collection of wind-tunnel data and its extrapolation to flight conditions. Drawing on the results of experiments at NLR's high-speed tunnel, he pointed out that the reason is that significant differences can result in the location of the transition region (from laminar to turbulent flow) caused by the effects of wind-tunnel noise level and the effects of wind-tunnel model contamination caused by the impact of airborne dirt. In addition, the techniques used for measuring the transition location can, themselves, influence transition. This is particularly true of hot film

methods, as pointed out in a subsequent paper by J. Szodruch, Deutsche Airbus GmbH, FRG. Both Elsenaar and Szodruch pointed to the difficulties of extrapolating the results of wind-tunnel testing when the flow on both the upper and lower surfaces of the airfoil is laminar. Even at higher Reynolds numbers, where either a portion of the upper or lower surface of the wing is transitional, extrapolation is risky and flight testing may represent the only way that such data can be confidently obtained.

Wind-Tunnel Test Facilities

As the flight Mach number reaches transonic speeds, wind-tunnel wall effects begin to contaminate wind-tunnel measurements. Test sections with slotted or perforated walls can be used to minimize the interference effects. However, such test section modifications often represent significant noise sources and are thus to be avoided if laminar flow testing is desired.

A highlight of the new test facilities session was the review of adaptive wall technology. Adaptive wall wind tunnels originated before World War II. Developing adaptive wall wind tunnels began in the early 1970s. S. Wolf, MCAT, Moffett Field, California, pointed out that for two-dimensional (2-D) airfoil testing, adaptive wall wind-tunnel testing has now reached a relatively mature level. Interference-free data can be taken in only a few seconds with flow quality far superior to that of the earlier slotted wall designs. This paper contains a complete description of all known adaptive wall wind-tunnel facilities (including many in Europe) and is an important reference for anyone interested in this technology and its future directions.

Although it uses a slotted test section instead of the adaptive wall technology just described, the new FFA ejector-driven, high Reynolds number wind tunnel is interesting in terms of collecting high-quality, transonic wind-tunnel data. Europe has needed a high Reynolds number wind tunnel for many years. The results of 2 years of certification tests were presented by L. Torngren (FFA) who was in charge of the design and construction of the facility. The Reynolds number is approximately twice that obtainable in NLR's high-speed tunnel at comparable broad-band test-section pressure fluctuation levels. Both wind tunnels have slotted test sections. Starting times were thought to be reasonable, varying from 3-5 seconds depending on the test section Mach number. Flow angularity and the level of test section pressure and Mach number fluctuations were judged to be acceptable. Certification is continuing with full span models directed toward verifying the unusual slot shape used in the facility.

Computational Fluid Dynamics for Complex Shapes

A good example of the level of maturity that CFD has reached was provided by several papers in which the flowfield surrounding a complete airplane configuration was calculated.

The first of these papers was a finite-volume Euler solution presented by P. Berglind, FFA. As with many of the papers presented here, Berglind used Jameson's cell-centered, finite-volume, explicit, Runge-Kutta integration scheme. Calculations were described that used eight blocks to define the flowfield over a SAAB JAS 39 Gripen aircraft. The economy in using blocks was attributed to using an interactive visual grid generation system developed by General Dynamics. The generation of the grid begins with parametrically describing the surface with bicubic splines, smoothing grid slope discontinuities on the surface, and then using transfinite interpolation for the generation of the volume grid. Smoothing is again invoked to remove discontinuities at block interfaces. The most interesting part of the presentation was a comparison of the surface pressure distributions with and without the mass flow through the air intakes taken into account. What was unexpected was the extent of the influence of the intake flow on the Mach number distribution over almost the entire aircraft. Nevertheless, the effect of the inlet flow was barely recognizable in the values of the predicted lift and drag coefficients. Reasonable agreement with measured lift and drag coefficients was reported, with the differences amounting to from one-half to two counts of lift and from one to two counts of drag.

A. Goodsell, NASA Ames Research Center, Moffatt Field, California, reported on inviscid calculations in a single block implementation of Jameson's finite volume code. Of particular interest here was the prediction of vortices resulting from flow separation on the highly swept delta wing of a generic fighter configuration. The algorithm was found to accurately predict the measured pressure distributions, lift curves, drag polars, and moment curves until vortex breakdown. For additional comments on the adequacy of Euler models in the computation of vortex-dominated flows and European contributions to such problems, see ESN 41-1:20-24 (1987).

T. Raj, Lockheed Aeronautical System Company, Burbank, California, reported on an exhaustive study of the application of CFD codes to aerodynamic configurations. Several transonic wing designs were computed with the intention of evaluating the sensitivity of the solutions to grid density, numerical dissipation, and turbulence models. Both multizone Euler and multizone Navier-Stokes methods were examined. By comparing the 161x321 grid and 321x321 grid solutions over an NLR

7301 airfoil, grid independence was demonstrated. Significant differences were seen among the different types of adaptive dissipation used. This sensitivity carried over into the viscous calculations where thin-layer, Reynolds-averaged, Navier-Stokes equations were used. Of all the turbulence models used, the Johnson-King model seemed to provide by far the best agreement with the measured surface pressures and skin friction coefficients. However, viscous-dominated flows, particularly those that involve shock wave/boundary layer interactions, still provide considerable challenge for the computational fluid dynamicist.

The final application of the Jameson algorithm to a complete (or virtually complete) aircraft configuration was provided by A. Bocci and A. Baxendale, the Aircraft Research Association (ARA) Bedford, U.K. Bocci is the director of CFD programs at the ARA and led off with a general description of their Euler multi-block calculations. The ARA multiblock program is a multiple-domain implementation of Jameson's cell-centered Euler scheme. Baxendale's presentation pressed the multiblock method to its limits by focusing on the complex problem of wing/body/pylon/store interaction. Reasonable agreement with measured single-store and pylon pressure distributions was achieved using from 300 to 1,100 individual blocks. For multiple stores, however, multiblock in its present form is not applicable. For such problems, Bocci reported that ARA is developing a hybrid multiblock version in collaboration with University College, Swansea, U.K., in which a zone of unstructured grid will be patched into regions of high geometrical complexity.

Computational Fluid Dynamics Refinements

Several presentations focused on the development and refinement of algorithms from the standpoints of range of application, speed, and accuracy. Perhaps the most innovative work in this connection was done by Y. C.-J. Sedin, SAAB-Scania, Linköping, Sweden. Sedin's work stemmed from an attempt by SAAB to extend transonic Navier-Stokes codes originally developed by FFA into the supersonic and hypersonic regimes. Specifically, the artificial viscosity handling of the convection terms as well as the time-stepping scheme had to be reconsidered. What eventually evolved was an explicit, time-asymptotic, finite-volume method using a four-stage, explicitly expanded Crank-Nicholson scheme. Local time stepping was used to improve the rate of convergence. The calculation scheme seems to be particularly well thought out and contains the best aspects of various existing Euler and Navier-Stokes codes. Several results were shown for laminar flow computations around geometrically simple shapes, like spheres and cylinders, in supersonic flow. Excellent agreement with

experimental normalized heat flux distributions, shock standoff distances, and drag was found for these geometries.

Two other papers are worth mentioning. The first was a description of the development of a characteristic-based, solid-wall boundary condition for a cell-centered Euler method by J. I. van den Berg, NLR. The results of a numerical validation of the method showed that it successfully eliminated most of the entropy layer associated with pressure extrapolation methods. Thus, it could be expected to improve the accuracy of calculations of separation-induced, vortex-dominated flow, such as occur in high angle-of-attack aerodynamics.

D. Drakakis, National Technical University, Athens, Greece, presented a procedure for accelerating the solution of compressible Euler and Navier-Stokes equations. In this paper, a solution is obtained on a sequence of coarse grids with each succeeding solution interpolated up to the next finer grid. Dramatic improvements in convergence histories are shown for a variety of inviscid and viscous problems. Drakakis reports that the method can be combined with other acceleration techniques such as multigrid for additional computational time savings.

Parallel Computing

A most interesting presentation by S. Turnock, University of Southampton, U.K., was entitled "Parallel Implementation of an Explicit Finite Volume Euler Solver on an Array of Transputers." Transputers are a range of high-performance VLSI technology devices developed by Inmos Ltd, Bristol, U.K. They consist of a local memory, four high-speed, two-way links, and a microprocessor unit all mounted on a single silicon chip. Turnock used a T-800 transputer that has a peak performance of 2 Mflops and a data transfer rate up to 20 Mbits/sec on each link. Internal fast access memory (4K) is provided and up to 4 GBytes of memory can be connected to each transputer.

Transputer-based computers are shared-memory, multiple instruction multiple data stream (MIMD) parallel machines. In Turnock's case, a personal computer was connected to the transputer on which the host processor was mounted to provide keyboard input, screen display, and disk access. A communications harness carries out the necessary intertransputer communications. Turnock developed an efficient communications harness which allowed the full potential of the transputer to be reached by minimizing the communications overhead and provided for easy upward migration of the computations to larger transputer arrays. This is important since code can then be developed on inexpensive machines with a small number of transputers and subsequently moved to larger machines for

production calculations. In Turnock's work, machines with 1, 4, 9, 16, and 121 transputers were used.

The CFD algorithm that Turnock used was Ni's explicit finite volume Euler method. Turnock's first task was to rewrite the code from Fortran 77 to occam 2, a high-level language, which exploits the concurrency of the transputer. Turnock reported that his conversion of Ni's scheme to occam 2 was a straightforward exercise.

Ni's method, which employs a cell-vertex finite volume scheme to solve the compressible Euler equations, is ideal for parallel implementation. This is because its explicit nature produces the geometric parallelism that allows the problem to be subdivided into processes requiring minimal communications overhead.

Turnock generates the grids appropriate for the number of transputers being used and the level of fineness required by the multiple grid scheme. Then he calculates the state vector updates for all of the exterior cells, followed by the interior cell updates. Information is exchanged between transputers automatically where the subregion boundaries demand it. After this message communication, the boundary node state vectors are updated using the appropriate assigned boundary conditions. Finally, the interior state vectors are updated.

Turnock used his parallel implementation of Ni's algorithm to solve two test geometries representative of both external and internal 2-D flow. The two test geometries were a 10-percent circular bump in a duct with upstream Mach numbers of 0.5 and 0.675 and a NACA 0012 airfoil at a 3-° angle of attack and a freestream Mach number of 0.5. Convergence was accelerated using Ni's multiple grid scheme.

Code efficiency is the ratio of the calculation time to the sum of the calculation and communication times. Turnock's code efficiency is shown in Figure 1. As expected, the smaller the number of cells allocated to an individual transputer, the lower the code efficiency as the transputer spends most of its time communicating to

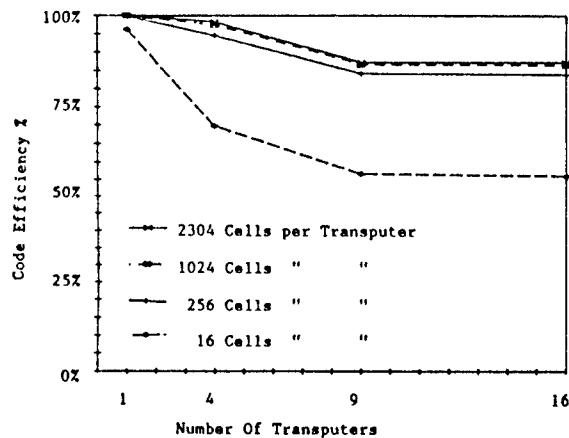


Figure 1. Code efficiency

other transputers. As the number of transputers increases for a fixed number of cells, the code efficiency drops as the transputers must communicate more and more nearest-neighbor information. However, once the number of transputers reaches nine, Turnock found that there was no further decrease in code efficiency. This is an important feature of the code since this allows predictions for the speedup of the calculation on larger transputer arrays to be made since the code efficiency is independent of the number of transputers. Since the computational time is thus inversely proportional to the transputer array size, this also suggests that full advantage has been taken of the geometrical parallelization of Ni's algorithm.

Considerable attention in the CFD community is being focused on parallel computing and a substantial effort in this direction has been mounted in Europe (\$6.2 million in U.K. alone) (see ESNIB 88-03:33-35). As Turnock demonstrated in this meeting, the UK-developed transputer offers an interesting alternative to the Intel and Connection Machine architectures that are better known in the U.S.

Conclusions

There is a renewed interest in ramjet/scramjet propulsion, particularly in the U.S. The effectiveness of passive control of vortical structures, using nonaxisymmetric inlets and nozzles, has been established

and has been transferred to combustor and ramjet designs.

In the gas turbine arena, effort is presently focused on combustor efficiency improvement through efficient inlet design, coupled computation of inlet and combustor flow and chemical kinetics.

From the point of view of the aeronautical community, CFD has reached a comfortable middle age and has become more of an engineering tool and less of a topic of scientific research. Most of the papers pertained to CFD applications. When CFD development was considered, it was in the relatively narrow context of algorithm refinement rather than revolutionary algorithmic discoveries.

Efforts are being undertaken to extend codes to increasingly more complex configurations. In this context, unstructured grids are beginning to receive a considerable amount of attention. Means are being sought to increase the accuracy and effectiveness of these methods. This effort includes parallel computing and the careful comparison of the results of calculations with experimental data. The improved wind-tunnel technology and the new wind-tunnel facilities discussed in this meeting will contribute to these goals.

The proceedings of this meeting can be obtained as the 1990 ICAS Proceedings from the American Institute of Aeronautics and Astronautics, 370 L'Enfant Promenade, Washington, D.C. 20024.

CHEMISTRY

The International Conference on Science and Technology of Synthetic Metals

by John R. Reynolds and Martin Pomerantz, Center for Advanced Polymer Research, Department of Chemistry, The University of Texas at Arlington.

Introduction

The International Conference on Science and Technology of Synthetic Metals was held September 2-7, 1990, in Tübingen, Federal Republic of Germany (FRG). Approximately 925 conference attendees presented over 1,000 papers in various areas, including conducting and electroactive polymers, organic superconductors, metal chalcogenides, and nonlinear optics. In addition, several general tutorials in these areas were presented. Approximately half of the papers described research advances in the chemistry, physics, and materials science of conducting polymers which will be the focus of this report. Papers from the conference will be published in a special series of synthetic metals and will be available by mid 1991. Electrically conducted polymer research has been directed toward several major classes of conjugated polymers. We will detail some of the advances in the families of polymers based on polyacetylene, polyarylenes, polyanilines, poly(arylene vinylenes), and miscellaneous systems.

Polyacetylene

Continued investigations of a variety of forms of polyacetylene $[(CH)_x]$, synthesized via various routes, show that extremely high electrical conductivities of $> 10^4 \text{ S cm}^{-1}$ can be reproducibly attained after redox doping. In some cases, the reported electrical conductivities are on the order of 10^5 S cm^{-1} . Three main routes have been used for these preparations. Highly fibrillar $(CH)_x$ is produced using $Ti(OBu)_4/AlEt_3$ Ziegler-Natta initiator systems, while the soluble precursor route [Durham- $(CH)_x$], U.K. can yield dense amorphous to highly crystalline and oriented material with a very low poly-dispersity. Considering the Ziegler-Natta systems, initiator aging before polymerization has been found to play an important role in ultimate properties. Room-temperature aged systems

are denoted as Shirakawa, Japan, polyacetylene $[Sk-(CH)_x]$, while high temperature (ca. 120C) aged systems are Naarmann/Theophilou, FRG, polyacetylene $[NT-(CH)_x]$. Very little was reported concerning the structural differences between these two polymers. In general, the NT- $(CH)_x$ seems to exhibit higher conductivities than the Sk- $(CH)_x$ after doping. For the best electrical properties, $(CH)_x$ films are stretch oriented immediately after synthesis with draw ratios (l/l_0) of 10 reported by Tsukamoto et al., Japan, and 3 by Shirakawa et al., Japan. The effect of order and morphology on electrical properties was brought out on many polymer systems throughout the meeting. A high degree of order and orientation gives, in addition to the expected improvement in mechanical properties, high ultimate conductivities, optical anisotropy, and improved stability. The $(CH)_x$ /poly-ethylene gels prepared by Heeger et al., U.S., have continuous structures and thus overcome percolation threshold problems. These materials can be doped to high conductivity at 0.02 volume percent $(CH)_x$. An additional morphological effect was reported by Shirakawa et al., and Bernier et al., France, where thin films exhibited significantly higher electrical conductivities than thick films. All of the doped polyacetylenes are air unstable. Though improved stability has been reported, all samples degrade in air and must be handled under scrupulously deoxygenated nitrogen or argon. This practical drawback notwithstanding, $(CH)_x$ has served, and will continue to serve, as an excellent model for conducting polymers. Limits in electrical and optical properties can be examined and serve as a guide to further conducting polymer research.

Poly(Arylene Vinylenes)

Soluble precursor methods of preparing poly(arylene vinylenes) has led to a broad family of polymers containing phenylene, thienylene, and furylene aromatic

linkages. In addition, substitution on the aromatic ring with alkyl and alkoxy substituents has induced processability and improved optoelectronic (lower bandgap, E_g) properties. Work reported by Elsenbaumer et al., U.S., has shown that the sulfonium polyelectrolyte precursors can be stabilized in solution by addition of ca. 0.5 wt percent amine. Though a variety of amines have been examined, the initially utilized pyridine and trimethylamine have given the best results to date. The stabilization is believed to be induced by the partial replacement of the sulfonium ion used in polymerization with a pyridinium ion, as shown in Figure 1, for poly(2,5-dimethoxy-p-phenylene vinylene) (PDMPV).

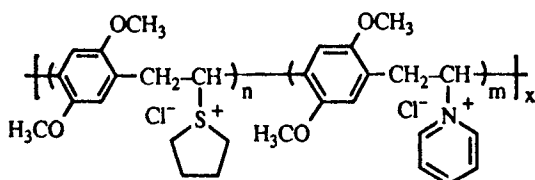


Figure 1.

Aqueous solutions, are stable for greater than 14 months. After thermal elimination, PDMPV produces the structure shown in Figure 2.

The properties of this polymer 2 were reported by researchers from Allied-Signal, U.S., and Cambridge University, U.K. The electron donating alkoxy groups lowered the bandgap to 2.1 eV, approximately 300 mV below the parent poly(phenylene vinylene) (PPV). The bandgap can be highly aligned and x-ray studies on stretch-oriented films show a very high degree of order. Conductivities $> 500 \text{ S cm}^{-1}$ were reported.

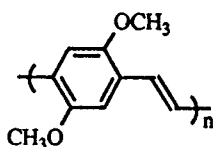


Figure 2.

The sulfonium precursor polymer of poly(thienylene vinylene) (PTV) has also been stabilized with pyridine. This produced PTV having a conductivity in excess of 300 S cm^{-1} after doping. Several soluble PPV derivatives have been prepared by Hörhold, FRG, which contain substituted phenyl groups on the vinylene moieties (see Figure 3) but SbCl₅ doping gave conductivities of only about $10^{-4} \text{ S cm}^{-1}$.

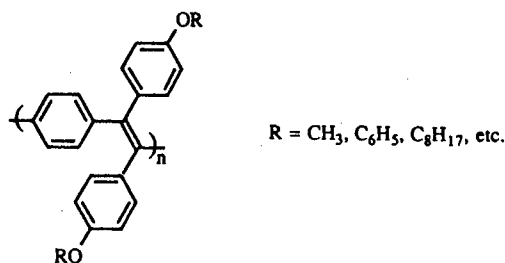


Figure 3.

Studies on model oligomeric systems showed that the system can support many cationic sites and the polymers can be doped up to 200 percent.

Polyanilines

A full family of conducting polymers based on the polyaniline (PANI) backbone have been prepared and studied by several research groups. Again, the ability to process the materials into ordered and oriented structures, in this case from acid or N-methylpyrrolidone solutions, have greatly improved electronic properties. For example, Monkman et al., U.K., have prepared samples of the emeraldine base form of PANI that can be readily stretched 300-450 percent of their original length. Postdoping of the films with acid have led to materials having conductivities up to 350 S cm^{-1} and anisotropic conductivities with $\sigma_{\parallel}/\sigma_{\perp} = 25$.

The diverse chemistry available in the PANI system was demonstrated in presentations by MacDiarmid and Epstein, U.S. Since the electrical properties of PANI can be controlled by both oxidation level and pH, the preparation of pure pernigraniline (see Figure 4) serves as one extreme.

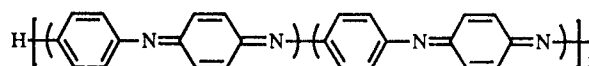


Figure 4.

Pernigraniline is the initial product formed in the typical PANI synthesis utilizing $(\text{NH}_4)_2\text{S}_2\text{O}_8/\text{HCl}$ which is spontaneously converted to the emeraldine oxidation state as the reaction proceeds. This was also found to be true for the substituted polymers prepared from 2-ethoxyaniline and N-methylaniline. A variety of experimental probes have been used to examine the electronic properties of several PANI derivatives. For example, photoexcitation spectroscopy has allowed the importance of changes in the main chain conformation on stabilization of photoexcited holes to be analyzed.

Self-doping concepts have been extended to the PANI family by direct sulfonation methods which yields a polymer containing one sulfonate for every other ring. While unsubstituted PANI retains its conductivity in highly acidic media only, the sulfonated analog remains conducting ($\sigma \sim 0.03 \text{ S cm}^{-1}$) up to a pH of 6.

Polyarylenes

This family of polymers is composed of those containing the 1,4-phenylene, 2,5-thienylene, and 2,5-pyrrolylene repeat units along the main chain. Of these, the poly(3-alkylthiophenes) have gained the most attention since they can be readily chemically synthesized in fairly large bulk yields and are easily melted and solution processed.

Studies reported have varied from the preparation and study of new systems to the more practical aspects of well-known systems. Kaeriyama, Japan, reported on alternating copolymers of the type (see Figure 5) that were prepared by oxidative polymerization of the corresponding bithienyl using $\text{Cu}(\text{ClO}_4)_2$.

The best conductivity can be achieved using this copper salt rather than FeCl_3 or electrochemical polymerization. Havinga, Holland, reported on the preparation and properties of a series of oligomeric "polythiophenes" with up to 11 rings, which contained solubilizing alkyl groups on only selected rings. The system with 11 rings showed conductivities of up to 20 S cm^{-1} when doped with I_2 . Wegner, FRG, who studied a series of 3,4-fused ring polypyrroles and polythiophenes, concluded that conductivity involved electron tunneling and depends on the interchain distances. Also, there was better tunneling when the fused ring contained a polar group. Oligomers, as models for polyperinaphthylene, (see Figure 6) were prepared and studied.

For $n = 0$ to 3 the bandgap was seen to decrease by over 1 eV from 2.67 to 1.5 eV. This is consistent with calculations, which suggest that the bandgap of the polymer should be 0.1 eV. Solid-state (CP-MAS) The ^{13}C -NMR spectroscopy of polyisothianaphthene, Hoogmartens, Gelan et al., Belgium, has been shown to be more consistent with a quinoid structure (see Figure 7), rather than the "aromatic" structure (see Figure 8).

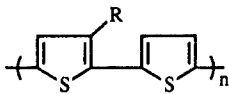


Figure 5.



Figure 6.

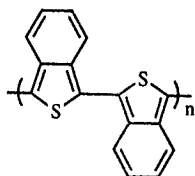


Figure 7.

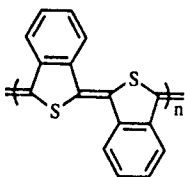


Figure 8.

Earlier, this had been predicted with theoretical calculations by Marynick et al. An interesting annulated polythiophene containing oxygen atom substituents at the 3 and 4 positions (see Figure 9) has been prepared and shown to have extremely stable conductivity.

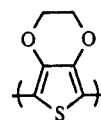


Figure 9.

Indeed, the surface resistance of a doped film did not change after one year in air, and also was quite stable in a 100 percent relative humidity atmosphere. These polymers are also relatively transparent.

Pomerantz et al., U.S., reported on a detailed study of GPC molecular weights of poly(3-alkylthiophenes) using both polystyrene standards and absolute values obtained with a multiangle laser light scattering (MALLS) detector. The MALLS detector showed that the polymers prepared by FeCl_3 polymerization in the presence of oxygen were of very high molecular weights (M_w up to 400,000) and of polydispersities less than three. Further, the MALLS molecular weights were up to five times larger than those obtained using polystyrene standards indicating that polystyrene is a poor standard for these studies.

There were several studies reported on the environmental stability of polythiophenes and polypyrroles. Neste Oy, Finland, has been examining poly(3-alkylthiophenes) for several years and has reported, among other things, that thermal dedoping of the poly(3-alkylthiophenes) involves, to some extent, reaction with and degradation of the polymer. Thus, for example, FeCl_3 and I_2 doped polymers produce HCl and HI , respectively, during dedoping which indicates polymer reaction. Rubner, U.S., reported that chemically prepared poly(3-alkylthiophenes) showed greater stability of conductivity (at 80°C) than electrochemically prepared material, and the longer alkyl chains seemed to show less stability. At elevated temperatures, FeCl_4^- -doped material was more stable than PF_6^- -doped polymer. Also, after thermal undoping, only 30-50 percent of the material is soluble compared to 100 percent before. Although it also shows decay of conductivity in moist air, polypyrrole is stable under nitrogen and it appears to be more stable than the polythiophenes under comparable conditions, especially in dry air.

Several interesting uses of conducting polymers, which do not involve conductivity upon doping, were discussed at the conference. One such interesting study is for use in offset printing. The process, reported by Kossmehl, FRG, takes advantage of the hydrophilicity (wetting ability) of doped polythiophene and the hydrophobicity of the reduced polymer, along with the ability to electrochemically switch from one state to the other.

Pomerantz and coworkers reported on blends of poly(3-decylthiophene) (PDT) and low-density polyethylene which were melt-spun into fibers. Depending on the method of blending, the material was phase separated, with large domains of the PDT. Also, it showed very low conductivity upon doping, or appeared to be continuous by electron microscopy and showed fairly high conductivity upon FeCl_3 or I_2 doping.

Finally, Reynolds et al., U.S., have prepared a series of soluble bis(2-thienyl)benzene polymers (BTP) appropriately substituted at the 2 and 5 positions of the phenylene ring (see Figure 10).

A benefit of this system is that, when $R = R'$, both the monomer and polymer repeat unit are symmetrical.

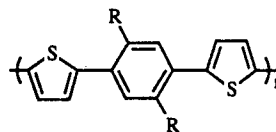


Figure 10.

Thus, the polymer is isoregic; i.e., it does not contain head-head or tail-tail defects. In this instance, when $R = R' = -\text{OC}_{12}\text{H}_{25}$ or $R = R' = -\text{OC}_7\text{H}_{15}$. The polymer is semicrystalline and partially ordered. On the other hand, when $R = -\text{OCH}_3$ and $R' = -\text{OC}_{12}\text{H}_{25}$ or $-\text{OC}_7\text{H}_{15}$, the asymmetric polymers are aregic and totally amorphous.

COMPUTER SCIENCE

Computer Science at the University of Manchester

by Robert D. Ryan, a mathematician currently serving as a Liaison Scientist for Mathematics and Computer Science in Europe and the Middle East for the Office of Naval Research European Office. Mr. Ryan is on leave from the Office of Naval Research Arlington, Virginia, where he is Director of the Special Programs Office.

Introduction

At the invitation of Professor Howard Barringer, I visited the Department of Computer Science (Department) at the University of Manchester recently. I spent a day with Professor Barringer and others talking about research in the department. Although our discussions focused on formal methods and logic, the following report covers all aspects of the Department. To provide a balanced picture, I have used, in addition to my notes, written material developed by the Department.

Background

The Department at the University of Manchester is the largest, the oldest (established in October 1964), and one of the nine top-rated, computer science departments in the U.K. The prospectus for 1991/1992 indicates there are 520 undergraduates (430 full-time equivalents), 57 academic staff, and nearly 100 postgraduate students. The Department employs an additional 50 technical and support staff and 60 contract-funded researchers. Many, but not all, of these researchers would be called post-docs in the U.S.

The Department of Electrical Engineering at the University of Manchester began work on digital computers in 1946. This work grew from the development of a cathode ray tube (CRT) storage device, and led to the design and construction of a series of computing engines. Versions of several of these have been built commercially. These include the Ferranti Mark 1 (1951), an early transistorized machine (predecessor to the Metropolitan Vickers 950) (1956), Ferranti Mercury (1957), Atlas (1963), MU5 (contributed to the design of the ICL 2980) (1973), MU6G and the Manchester Dataflow Machine (1981), ParSiFal Transputer Rack (1987), and the ICL EDS machine prototype (1990). (I will discuss the EDS machine later.) In each case, Department staff produced

the systems software and contributed to the applications that were run on the machines.

Research

Although the Department has a strong background in the development of large systems, their current research represents a diversification of research interests. This is reflected in the wide range of topics described below. For convenience, the Department divides the work into four major areas: (1) computer system architecture, (2) design methods and tools, (3) computer engineering, and (4) information systems.

Computer Systems Architecture. The emphasis is on concurrency, and the Department pursues several lines of parallel architecture research. Two distinct teams in the Department are collaborating on the European Declarative Systems (EDS) Project. The Machine Architecture Group is studying issues of dynamic load balancing, and dynamic data and dynamic process allocation on the EDS machine. The Software Environment Group is investigating issues of a distributed UNIX system as well as the development of generic frameworks for the definition and specification of parallel systems. The EDS is a successor to the Flagship Project at Manchester, and like it, is based on term graph rewriting.

The EDS is a major ESPRIT¹ Project, for which International Computers Limited (ICL) in Manchester is the coordinator. The project involves three other partners (Bull-France; Siemens-Federal Republic of Germany (FRG); the European Computer Research Center-FRG) as well as the University of Manchester, Imperial College, and 11 other associates. The EDS project will result in the design of a large-scale distributed memory parallel processing system including a relational database subsystem, Lisp and Prolog subsystems, and a

¹European Strategic Programme for Research and Development in Information Technologies.

UNIX kernel operating system. The project is targeted at the needs of the industrial partners for large-scale database applications, where EDS can be introduced into customer installations as an accelerator to give an order of magnitude improvement in the current cost/performance ratio. By the completion of the project in 1992, it is planned to have designed and implemented a parallel processing system with

- Distributed store multiprocessor designed for up to 256 processors
- Kernel software matched to the machine architecture and scale and providing basic machine control
- UNIX interface
- Parallel relational database subsystem providing an extended SQL server interface
- Parallel Lisp and Prolog language subsystems.

Prototype machines will be built with the following configurations: Bull-16 node, ICL-64 node, and Siemens-64 node. The ICL intends to use the technology in conjunction with its VME mainframe systems, and the first commercial use as a relational database accelerator is expected to be made in 1993/4. Professors Brian Warboys and Ian Watson are active in the EDS project.

The Department is home for the Center for Novel Computing, whose objective is to establish the scientific basis for solving large-scale computational problems using state-of-the-art computing systems. This is achieved by coordinating work by both applications- and implementation-oriented research groups in Northwestern England, analyzing and evaluating their approaches to large-scale computation and changing the problem-solving environments so they become problem-oriented rather than computer-oriented.

Other work involving parallel computer systems includes the MUSHROOM Project which is concerned with languages and machines for distributed, fine-grain, object-oriented computing. The PARAGRAPH Project aims to develop a new approach to the synthesis of graphical images used to visualize complex phenomena. Visualization is considered an important aspect of high-performance computing for physical problems. An investigation is also being made (using simulation) of the feasibility of constructing dynamic architectures from VLSI devices in a massively parallel neural network system.

Design Methods and Tools. This area includes all of the considerable research on software and hardware development techniques and tools. Professor Cliff Jones led the academic end of the Alvey/SERC IPSE 2.5 Project, under which the VDM-based tool, Mural, was developed. Although IPSE 2.5 ended sometime in 1990, further development (mostly on minor enhancements of functionality) is continuing in the Department with

considerably less money. (Since Mural is an important tool in the formal methods armory, I will discuss it in a separate article.) It suffices here to note that the Mural system has two main subsystems: (1) a specification support tool (for VDM) and (2) a proof assistant. The emphasis from the outset was on the user interface at the expense of functionality. Professor Jones indicated that it would be nice to do Mural-2. However, for now he has gone back to work on problems in concurrency, the area in which he did his Ph.D. work at Oxford in 1979-81.

Research on the application of mathematical techniques to computing problems covers a broad range of activity in the Department. This includes the work on Logical Frameworks by Professor Aczel, which is supported under the ESPRIT Basic Research Action #3245 of the same name, and the work on the use of categorical logic for programming environments by Dr. Rydeheard.

Professor Howard Barringer leads the research efforts on temporal and metatemporal logics, which are being studied for their use in developing real-time and parallel systems. In this connection, the METATEM project is constructing an extensible programming environment as a framework for temporal logic programming.

The use of formal techniques at Manchester is not restricted to software systems. There is a project to develop formal design and verification environments for digital hardware systems, covering aspects from architecture to gate level. There is also a project to extend ELLA (a high-level description system for VLSI) so that verification and transformation techniques can be used to derive correct designs. The ELLA system will be incorporated into a sophisticated interactive graphics environment with verification support tools for use by practicing engineers.

In the area of design tools for hardware construction, computer-aided design (CAD) systems incorporating facilities such as logic simulation, layout of gate arrays and printed circuit boards, and component database management are being developed. For some years, the group involved has investigated the applicability of expert systems and formal methods to VLSI design problems, and the development of tools to allow CAD software to be used within an interactive knowledge board system (IKBS) design system. Now, a major focus of this work is the development of a CAD data model as a step towards integrating applications into a framework environment. Another interest of the CAD group is the interchange of design information using languages such as EDIF and VHDL. A hardware simulation engine is also being implemented.

The Department recently formed the Informatics Process Group to do research in process technology. Basically, the group is concerned with the process-centered view of information systems and the

engineering principles which underlie their production. The group focuses on issues of acceptability and usability of existing technology, on generic model architectures to facilitate the introduction of process modeling concepts into a given environment, and on key issues of handling change and mechanisms for reuse.

Computer Engineering. The Department has a long history of involvement in computer engineering, and there are in-house facilities for the design of integrated circuits. A major project is to develop novel approaches to designing microprocessors to reduce the power required to deliver high computing performance. Professor Furber and his group believe that a near-future requirement will be for microprocessors that deliver high performance with very low power consumption. Concurrently, a new approach to microprocessor design will be required to achieve the necessary reductions in dissipation. They note that portable equipment is expected to increase in market share and performance over the next decade. Portable computer-based products are being announced regularly, but truly portable machines with support for good user interfaces--handwriting and speech recognition--require high performance that cannot tolerate the power demands of present day high-performance processors.

Research is taking place into development environments for applications that use digital signal processing hardware. The idea is to allow the developers access to the sorts of tools that are now readily available for general purpose systems. There is also work in the Department on optical computing and on facilities for multimedia group communications. The latter involves the investigation of communications techniques for the support of shared environments.

Other interests include modeling of semiconductor devices and designing wafer-scale parallel machines for declarative languages.

Information Systems. In addition to the applications of computers mentioned above, there is interest in the wider application of computer systems. The Medical Informatics Group is engaged in various projects involving the use of computer technology, in particular, expert systems in medicine. The largest of these is the PEN & PAD Project which is designing a prototype human/computer interface for general medical practice employing user-centered design techniques. The project aims to throw light on patient care by summarizing information and by making patterns obvious without adding to the physician's load.

There is also work on the management of multimedia data, on the construction of knowledge-based interfaces for systems, and on problems involving large or distributed databases. Neural networks are not neglected. There are theoretical studies as well as work focused on using neural networks for syntactic

processing. Other interests include using connectionist networks and aspects of machine translation.

Tables 1, 2, and 3 (pages 14-19) provide names of professors, lecturers and senior staff and their respective research interests at the University of Manchester Computer Science Department.

Education

As previously indicated, there are 430 full-time equivalent undergraduates in the Department. Of these, 340 are single honors students (fulltime in computer science), and 180 are joint honors students (joint with computer science and either mathematics, physics, or accounting). I do not wish to dwell on undergraduate (or even graduate) education except to note a couple of impressions. In the first instance, I was struck by the balance between theory and practice in the course offering. There is clearly an effort to prepare people for British industry, as well as provide a good background for further education, should the student elect graduate school. I was also impressed with the Department's efforts to recruit undergraduates, including publishing an attractive brochure describing Manchester and the University, as well as the Department, and career opportunities in computer science.

I will describe in more detail the Department's activity in continuing education, for I believe this says something about the Department's attitude towards computer science and its role as a scholarly and practical endeavor.

The acronym, PEVE, is used in the U.K. for post-experience vocational training. The program appeared in a government report on the needs of industry for "reprofiling" (read retraining) of technical staff, particularly in information technology (IT). In February 1988, the Department of Computer Science at Manchester set up a special unit, the PEVE(IT) Unit (Unit), which is housed within the Department. The purpose of the Unit is to establish and maintain contacts with the IT industry, both to further research collaboration and to facilitate technology transfer. The strategy is to establish contacts initially through the provision of specialized training courses, with the long-term aim of establishing mutually beneficial collaboration. So far, the Department has made two collaborative agreements: (1) with the Computer Products Division of ICL and (2) with SUN Microsystems Limited. The Unit has delivered over 1,000 student days on open courses and more than 1,000 days on company-specific courses. The Unit is housed in a specially built suite of rooms; the facility has 10 dedicated SPARC 1+ workstations, and the Unit employs 6 full-time staff.

The Unit is actively seeking more collaborative agreements with other IT companies and generally

broadening its base by cultivating new areas of interest. The areas they hope to develop include:

- Increasing the number and variety of short courses
- Extending the collaborative agreements to include other IT companies
- Participating in the U.K. Modular MSc in Software Engineering. (This is a scheme whereby one can earn a masters degree in software engineering by putting together credits earned at several institutions. The existence of this scheme testifies to the importance placed on software engineering in the U.K.)
- Marketing and exploiting the Department's research results (includes the commercialization of Mural)
- Increasing the number of short courses run off campus for individual companies
- Participating in teaching company schemes
- Developing open and distance learning courses, including an international perspective (involves activities like off-site training, computer-aided courses, and video courses).

An example will illustrate teaching company schemes. Such a scheme is operating and concerns the technology transfer of the use (and associated benefits) of formal methods in software engineering from the Manchester Department to the Mainframe Systems Division of ICL. The scheme specifically involves the engineering group at ICL charged with the support and continuing development of the VME operating system for the ICL Series 39 and 2900 computers.

The idea is that Unit employees (known as teaching company associates and well versed in formal methods) will perform a formal specification and redevelopment of a chosen subsystem. This is done alongside ICL engineers working on a conventional redevelopment of the subsystem. The intention is to demonstrate, over a 3-year period, the advantages of the mathematical methods over the less rigorous, present-day approaches. I note that this is exactly the scheme used by INMOS and the Programming Research Group at Oxford for developing the floating-point unit of the T800 Transputer (See ESNIB 90-06:71-72).

Summary Comments

The Computer Science Department at the University of Manchester is the largest in the U.K., and it was awarded the highest rating by the Universities Funding

Council based on research performance. Manchester graduates work throughout the IT industry in the U.K. and Europe, and many work in the U.S. Many University positions in the U.K. and elsewhere are also filled with Manchester graduates. Research done in the Department, from logic and formal methods to the design and development of new machines, has, and continues to have, a significant influence on computer science world wide. Whether in hardware or theory, the Department has both breadth and depth. These are, of course, the standard criteria for excellence, and they are applied in the U.S., as well as the U.K. and Europe. On these criteria, good departments in the U.S. and the U.K. are comparable. The thing that I find different, the thing that in my mind sets Manchester apart from, say the collection of top departments in the U.S., is the Department's attitude towards industrial involvement.

It is surely true that many individuals in U.S. computer science departments are involved with the U.S. computer industry. It is also true that U.S. departments, taken as a group, have been criticized for being inward looking. More than once I have heard the comment, "They only talk to each other." The chair of one of the top U.S. departments once complained to me about the difficulty he was having in getting members of his department involved with the outside world. What I see at Manchester, and at other U.K. universities, is a different attitude towards outside involvement. At Manchester, it is the policy of the Department to seek outside involvement. The Department's PEVE(IT) Unit is devoted to promoting industrial cooperation. This is not a matter left to individual members.

I believe that the major forces that have molded this position are obvious: early involvement in designing and developing hardware and a funding structure--the Alvey Program, ESPRIT--which encouraged and often required industrial participation. Today the Manchester department has many contracts with the Science and Engineering Research Council (SERC), the Department of Trade and Industry (DTI), ESPRIT, and British industry, amounting to something like \$2.4M for their financial year 1989/90. At the same time, their Unit produced about \$400K. All computer science departments in the U.K. face decreasing support from the government, that is from SERC, DTI, and other government sources. Manchester's response is to look outward and to increase their efforts to promote industrial involvement and to market their products.

Table 1. University of Manchester, Computer Science Department Professors

Name	Research interest
Professor P.H.G. Aczel	Mathematical logic and constructive mathematics; semantics of programming and natural languages; proof development systems.
Professor H. Barringer	Compositional temporal logic specification and verification; automated state-based verification techniques; temporal and modal logic programming; temporal planning; formal methods in hardware specification, design, and verification.
Professor D.S. Brée	Semantics of natural languages; representation of knowledge knowledge-based systems.
Professor S.B. Furber	High-performance microprocessor design for low power consumption; asynchronous logic design techniques.
Professor J.R. Gurd	Application and performance of parallel computer systems; parallel simulation of parallel computer architectures; specification and verification of digital systems; parallel program transformation.
Professor C.B. Jones	Tractable methods for the specification and development of concurrent systems.
Professor F.H. Sumner	Computer design; computer applications in industry; microprocessor applications.
Professor B.C. Warboys	Formal software development methods for parallel machines; operating systems for parallel machines; integrated project support environments; processor modeling languages
Professor I. Watson	Architecture of parallel computers for the support of declarative programming; computation models for parallel computing; distributed memory parallel computer architectures.

Table 2. University of Manchester, Computer Science Department Lecturers

Name	Research interests
Dr. R.H. Banach	Graph rewriting computational models: their semantics and formal properties; dataflow analysis; type inference.
Dr. B. Banieqbal	Formal digital hardware design; CAFS database filter.
Dr. L.E.M. Brackenbury	Logic, architectures, and interconnections for digital optical computers.
Dr. V.J. Bush	Parallel program transformation; formal descriptions of parallel computer models; mapping of problems to parallel architectures.
Dr. A.F. Carpenter	Hardware acceleration for mixed-mode simulation; hardware acceleration for fault simulation; hardware emulation of mixed-signal ASICs.
Dr. M.E. Clarke	Modeling for power semiconductor devices; the use of knowledge-based methods for VLSI floor-planning and layout.
Dr. T.P. Clement	The formal development of software from specifications.
Dr. R.N. Dixon	Industrial inspection applications of computer vision.
Dr. N.P. Filer	Applications of Artificial Intelligence (AI) techniques to Electronic Computer-Aided Design (ECAD).
Dr. J.D. Garside	Research in low-power VLSI techniques.
Dr. R.W. Giordano	Gender biases in expert systems; organizational adoption of expert systems technology assessment measures for office systems; pedagogical measures for hypermedia systems parsing methods for textual form and content.
Ms. C.A. Goble	Multimedia databases; multimedia document architectures, hypermedia models; data models, especially integrity and security; semantic models; medical applications, especially primary care; gender issues in technology: women in computing; Human Computer Interface Systems (UMIS).
Dr. G.D. Gough	The use of temporal logic for the formal specification and verification of reactive systems, with a particular interest in tool support for verification; development of executable temporal logic.
Mr. T.L.J. Howard	Hierarchical computer graphics systems and user interfaces.
Mr. T.J. Hawkins	Application of information technology to medical systems specializing in general practice.

Table 2. (Continued)

Name	Research interests
Mr. P.J. Jinks	Design and implementation of a procedural language suitable for teaching programming via formal specification.
Mr. S. Kay	Medical informatics knowledge representation and the user interface; document architectures; measuring data entry/display capabilities of workstations; standardization issues.
Dr. A.E. Knowles	Computer architecture with a special interest in virtual memory management hardware; this interest was exploited in the design of the MU5 and MU6-G computer systems; more recently, the direction of interest has changed towards parallel simulation of novel parallel computer architectures and the programmable interconnection of transputers in the ParSiFal project; currently on leave of absence working on the architecture of a shared memory multiprocessor supercomputer.
Dr. J.T. Latham	Software specification and verification.
Dr. K.K. Lau	Algorithm synthesis; computer-aided construction of algorithms logic program synthesis; computer-aided construction of logic programs.
Dr. D.R. Lester	Application and performance of parallel computer systems; parallel simulation of parallel computer architectures; specification and verification of digital systems; parallel program transformation.
Dr. B.W. Marsden	Local area networks of microcomputers; standard protocols for resource sharing in local area networks; network operating systems; network simulation.
Dr. W.P.R. Mitchell	Using finite tree automata as control strategies for reduction sequences, developing a first order linear temporal logic for reasoning about racing hazards in digital circuits and investigating the uses of automated deduction for analytical reasoning about hardware design.
Dr. R.B.E. Napper	Have now joined the CAD research group working on language specification languages.
Dr. I.E. Pratt	Problems of inference for intelligent interfaces; spatial reasoning; mental representation.
Mr. A. Rawsthorne	Supercomputer architecture (with the Advanced Computer Research Institute, Lyon, France).

Table 2. (Continued)

Name	Research interests
Dr. D. E. Rydeheard	Foundations of computation: applications of logic, algebra, and category theory; mathematics of program design and the structure of programming environments; design of programming languages and their semantics; functional programming and type theories; term rewriting: algorithms and applications.
Dr. J.L. Shapiro	Theoretical aspects of neural networks; application of connectionist models to psychology; parallel computer architectures for neural network implementation.
Dr. M.J. Shute	The application of asynchronous, self-timed digital logic to a multiprocessor computer whose assembler language is a pure declarative language in itself.
Dr. M.A. Spink	Silicon compilation, multi-level design languages, EDIF generation, technology adaptability.
Dr. D.G. Wastell	Integrated process support environments and support for cooperative human work; psychophysiology of human/computer interaction, stress, and computer-based office work; information systems implementation: longitudinal case studies.
Dr. A.J. West	Construction of a graphic-based software environment; transputer-based machines.
Dr. M.M. Wood	Artificial intelligence and computational linguistics, especially syntax, parsing, and metatheory in categorical grammars; machine translation; computational lexicography and related issues in knowledge representation.

Table 3. University of Manchester, Computer Science Department, Senior Staff

Name	Research interests
Dr. P.C. Capon	Exploitation of transputer-based parallel systems.
Mr. I.D. Cottam	Routing algorithms; formal specification and verification of hardware.
Dr. T.P. Hopkins	Architecture for object-oriented languages; multimedia communications architectures; object-oriented design.
Dr. R.J. Hubbard	High-Performance graphic systems for interactive visualization; application of parallel computer systems to visualization; 3-D imaging models, user interface managements systems.
Miss H.J. Kahn	Development work on the SIDESMAN silicon design system; information modeling for electronic design; digital and mixed-mode simulation, evaluation, and development of the Electronic Design Interchange Format (EDIF); integration of electronic design data with the manufacturing process; application of KBS to electronic design hardware design languages.
Dr. C.C. Kirkham	Dataflow architectures and dataflow software; the SISAL programming language.
Dr. C.H. Lindsey	Compilation of ALGOL 68S; extensible programming language ELSA; specification languages and program transformation.
Dr. A.L. Rector	Application of advanced informatics to medicine, including user centered design and formative evaluation methodologies, user interface management design, and studies of the semantics of medical terminology and language.
Dr. H. Simmons	Mathematical logic and its application in computing.
Dr. I.R. Wilson	Use of artificial intelligence and natural language techniques to create, deliver, and subsequently analyze questionnaires used in social surveys.
Dr. J.V. Woods	Parallel computer architectures for declarative programming environments; performance of parallel computer systems; novel microprocessor architectures.

Table 3. (Continued)

Name	Research interests
Dr. R.N. Zobel	OOPS bases systems for design, simulation, test and evaluation of digital signal processing (DSP) systems; software systems for computer simulation of continuous systems; high-performance DSP hardware, software, algorithms and applications; principles and application systems for production of complex time domain waveforms from time-varying, nonlinear, nonharmonic spectra.

ELECTRONICS

Mind the Gap

by Drs. J.C. Pazik and G. Kelner are research scientists in the Electronics Science and Technology Division at the Naval Research Laboratory, Washington, DC. Coauthored with Howard Lessoff, a physicist serving as Liaison Scientist for solid-state chemistry and physics at the Office of Naval Research European Office. Specializing in crystal-growth and material sciences dealing with electronics and opto-electronics, he was formerly Head of the Electronic Materials Branch, Naval Research Laboratory, Washington, D.C.

Introduction

"Mind the gap" is a warning often heard on the London Underground. The term "gap" refers to the space between the subway car doors and the platform. When entering or leaving a subway car, there is a danger of stepping into the gap. In the solid-state electronics, there is another gap that is receiving much attention, namely the band gap. This is the distance between the valance band and the conduction band. The wider the band gap, the more energy it takes to move an electron from the valance band to the conduction band and the higher the potential operating temperature of a semiconductor. The application of various semiconductors depends on many factors including the band gap. The band gap of infra-red detector materials is 0.2 eV or less, (Si is 1.11 eV, and gallium arsenide [GaAs] is 1.43 eV). Visible light-emitting devices are greater than 2.0 eV. There is now an interest in wider band gap materials such as SiC and diamond. The band gap of beta-SiC is 2.2 eV and diamond is 5.4 eV. Of course, diamonds have been used for centuries before the age of solid-state electronics.

Diamonds' use as gems requires no further discussion beyond the statement developed by the diamond industry--"Diamonds are a girl's best friend." But what about diamonds as an engineer's best friend? There have been major applications of diamonds in industry, especially in cutting and grinding tools. Other areas where diamonds are used include applications where low-friction and wear resistance are important, such as styli in phonograph records. Of course, much of the styli production has been displaced by the introduction of compact disc and tape recorders. As a thermal conductor with high resistance, diamonds are outstanding. They are used as heat sinks and standoff for semiconductors and microwave tubes. Until recently, the use of silicon carbide (SiC) has been basically for cutting and grinding applications. Large amounts of SiC are used

for grinding papers and cloths (for example: sand paper uses SiC as the grinding media). However, with the improvement of thin-film growth technology for SiC, electronic applications are now being realized.

The search for wide-band gap semiconductors has been ongoing since the 1950s. Among the materials studied were gallium phosphide, diamond, and SiC. Blue light-emitting diodes were demonstrated in SiC crystals, grown via vapor sublimation and subsequent ion implantation. Unfortunately, the difficulties in achieving reproducible growth and large-area SiC crystals were major factors in limiting efforts in device fabrication. Very early in the age of solid-state electronics, diamond was known to be a semiconductor. The semiconducting properties of the natural diamond were extensively studied. Of course being natural diamonds, the control of the electronic properties was not possible. This limitation prevented accurate determination of the real potential of diamond as a semiconductor.

Today, with the advent of new methods to grow crystals (especially via vapor growth), efforts were renewed to achieve both diamond and SiC semiconductors. The initial demonstrations of the growth of diamond and SiC by vapor transport can be credited to activities in the U.S.S.R. and Japan. Homogeneous growth of diamond-on-diamond substrates, and silicon carbide-on-silicon carbide substrates has resulted in materials that once again stirred up the dreams of both engineers and the public.

Research into diamonds and SiC has a long history. The European Material Research Society (E-MRS) fall meeting 1990 at Strasbourg reflected the different areas of diamond and SiC science and technology. The symposium, entitled "Properties and Applications of SiC Natural and Synthetic Diamond and Related Materials," was used to assess the status of diamond and SiC technology in Europe. Both SiC and diamond have properties which lend themselves to the fabrication of

high-temperature, high-power, and high-frequency devices. Specifically, wide-band gap semiconductors show promise as light-emitting blue/green sources, low-power transistors, high-temperature semiconductors, ultraviolet detectors, and a variety of other devices.

SiC has a wide band gap ranging from 2.2 to 3.2 eV for different polytypes; it has a high-breakdown field and a high-thermal conductivity. Diamond, also a wide-band gap material (band gap of 5.4 eV), has the potential to operate in electronic devices at high temperature (500°C). Diamond has an excellent thermal conductivity which at room temperature is five times higher than that of copper. In addition, the theoretical electron mobility of diamond is higher than that of Si and hole mobility is higher than that of Si and GaAs. Even though both SiC and diamond show promise, to date only the application of SiC-based materials in semiconductor devices have been realized. The fate of diamond as an electronic device material is still unknown. Currently, SiC-based blue/green light-emitting diodes are commercially available. For diamond, only Schottky devices have been fabricated. To determine the value of a semiconductor in terms of potential device applications, figures of merit based on the physical and electrical parameters of a semiconductor were defined. The Johnson's figure of merit considers the high-frequency and the high-power capability of discrete devices, while the Keyes' figure of merit considers the switching speed of transistors in integrated circuits. This data is given in the Table 1.

Table 1. Figures of Merit

Material	Johnson	Keyes
Silicon	1.0	1.0
GaAs	6.9	0.46
beta SiC	1138.0	5.8
diamond	8000.0	32.0

Using Table 1, the advantages of both SiC and diamond as transistors are very obvious. Unfortunately, the issues are not as simple as the calculations of figures of merit lead one to believe. Other factors must be considered, including:

- Availability of the material in the proper form
- Selective doping to form junctions must be demonstrated
- The properties must be confirmed experimentally.

These issues for diamond are part of a controversy I will address later in this paper.

The E-MRS 1990 fall meeting offered a variety of papers dealing with bulk and thin-film growth of the wide-band gap materials, SiC and diamond. Characterization and device fabrication papers were also presented. Although a significant number of papers

dealing with SiC growth and characterization in the Union of Soviet Socialist Republics (U.S.S.R.) were canceled, it is clear that there is a very large effort on SiC devices in the Soviet Union, especially at the Ioffe Center in Leningrad. Other areas of activity in SiC include the Netherlands, the Federal Republic of Germany (FRG), France, Sweden, Japan, the United Kingdom (U.K.), and of course, the U.S. Diamond efforts for active semiconductor devices are most strongly supported in the U.S. and Japan. Diamond research in the UK, the Netherlands, South Africa, FRG, and U.S.S.R., is concerned mainly with hard optical coatings, heat removal, and grinding or cutting applications. The conference provided the opportunity to evaluate worldwide efforts in wide-band gap materials development, and to more clearly define the roles of SiC and diamond in the electronics industry.

All references refer to presentations at the meeting, these presentations will be published in the conference proceedings.

Silicon Carbide Growth and Characterization

The SiC used for abrasives is most conveniently prepared by the Acheson process. The SiC prepared in this manner is the hexagonal type with the 6H, 4H, and 15R polytypes being most abundant. This uncontrolled sublimation process yields SiC which is highly contaminated and of little use for device fabrication. Nonetheless, fundamental investigations into the homoepitaxial growth of SiC by chemical vapor deposition (CVD) made use of the irregularly shaped 6H Acheson substrates. In 1955, platlets of predominantly 6H SiC were produced by the Lely method. In this process, polycrystalline SiC was sublimed and nucleated on SiC seed crystals. The resulting SiC crystals were randomly sized and hexagonally shaped. Although the 6H polytype was prevalent, 15R and 4H polytypes were also observed. The Lely-grown SiC, while improved over that of the Acheson material, was still plagued with imperfections caused by the uncontrollable nucleation on the seed crystals. In the 1980s, a major advance in the SiC materials effort was realized with the preparation of single crystal 6H boules by a modification of the Lely method. The modified Lely method succeeds by carefully controlling deposition of the SiC onto the seed crystal (controlling growth temperature, temperature gradients, and reactor pressure). With this method, boules of 6H SiC up to 24 mm in useful length with a useable diameter of up to 25 mm have been obtained, and efforts are under way to increase the useful diameter to 50 mm.

Through the years there has been a continual improvement in the preparation and quality of bulk single-crystal SiC culminating in the production of

single-crystal 6H SiC by the modified Lely method. Yet even with the success in the modified Lely method, additional problems must be solved. Reduction and elimination of microcracking and tubular growth in 6H boules must be achieved. The source of contaminants such as vanadium must be identified and eliminated. Other contaminants that increase the compensation and lower the mobility must be conclusively identified and reduced. The availability of bulk p-type material is also limited and methods must be investigated to more readily incorporate p-type dopants during the sublimation process. In addition, very little effort has been expended to produce bulk single crystals of β -SiC, the lone cubic polytype, even though most of the thin-film growth techniques were developed for β -SiC. None of these tasks are fundamentally insurmountable, and the outlook for high-quality SiC (α and β) substrates for homoepitaxial growth is quite good.

Among the highlights in growth has been the continued effort at Siemens AG, Erlangen, FRG, to produce high-quality 6H-SiC wafers. At the time of the meeting, Siemens was routinely producing 20-23-mm diameter boules of n-type 6H-SiC using the modified Lely process. Plans were under way to grow 2-mm diameter boules and further develop p-type boules. Stein, Siemens, FRG, presented an interesting paper on polytype control during the growth of SiC boules. By using (0001)-Si side as the seed crystal, regardless of polytype, 6H material was always obtained. However, using the (0001)-C side of the seed crystal resulted in the formation of the 4H polytype. By Electron Spin Resonance (ESR) measurements, Maler, et al., Fraunhofer Institut für Angewandte Festkörperphysik, Freiburg, FRG, saw vanadium deep-level impurities substituted on Si sites in both 4H and 6H samples. In n-type samples, vanadium can act as a deep-level acceptor, and possibly a deep-level donor. Vanadium is believed to be in the +5 state (d_0) in p-type samples and thus cannot be observed by ESR. Maier remarked that all 6H samples examined contained a vanadium impurity believed to originate in the graphite crucible used in the Lely process. The 6H-SiC samples prepared in the U.S. have not yet been examined for the presence of vanadium.

In addition to the work presented on α -SiC growth, several papers were presented on methods of growth for β -SiC. Noteworthy papers in the area of β -SiC growth and characterization of, includes work by Pazik, et al., Naval Research Laboratory (NRL), Washington, D.C., describing the deposition of β -SiC on silicon-on-sapphire (SOS) and silicon-on-insulator (SOI) substrates. Growth experiments on SOS substrates consistently yielded p-type β -SiC films up to 7 μ m thick. Van der Pauw Hall measurements indicate values for n_a - n_d in the low 10^{18} with room temperature mobilities as high as 50 cm^2/Vs . The specular films were characterized by a

variety of techniques including x-ray, infrared reflectance (IR), and Raman spectroscopy. The growth of β -SiC on SOI was also described since it may have application in the fabrication of β -SiC-based integrated circuits. Spencer, et al., Howard University, Washington, D.C., also reported the growth of β -SiC on SOS substrates. The Howard University films tended to peel from the substrate. This led to an investigation in the waveguiding action in the free-standing films and the determination of an electro-optic coefficient. The Howard group also presented results on β -SiC and TaC as optical coatings (reflectances as high as 90 percent at 90° incidence in the 40-250- μ m range) as well as some preliminary results on β -SiC film growth on Si substrates using a low-pressure vertical reactor, also using a low-pressure reactor. Just et al., CS-GmbH Semiconductor and Solar Technology, München, FRG, presented some very interesting results on the heteroepitaxial growth of β -SiC on Si. The group is dedicated to developing a CVD reactor for β -SiC growth which uses a state-of-the-art, ultra-clean system technology. While results were very sparse, the CS-GmbH group suggested that their films were p-type and that better crystal structure could be obtained for growth on Si(111) versus Si(100). If the material proves to be p-type with low-carrier concentration and high-mobility, then it may indicate intrinsic β -SiC grown on Si in an ultra-clean environment is p-type. Other work presented on β -SiC growth included reactive magnetron sputtering by Wahab, Linköping University, Sweden. Temperatures higher than 1100°C were required to obtain single-phase, highly oriented (100) films. Armas of the Institut de Science et de Génie des Matériaux et des Procédés, Font Romeu, France, described the growth kinetics of β -SiC. Armas used tetramethylsilane as a source material at growth pressures between 15 and 100 torr. At temperatures lower than 1250°C, deposition is controlled by formation of growth units. Between 1250°C and 1370°C, deposition is controlled by diffusion through the boundary layer. For temperatures higher than 1370°C, deposition is controlled by depletion of reactive species on the surface.

Amorphous Silicon Carbide

There were also several contributions on amorphous SiC; many of the papers addressed the effect of carbon composition on a variety of physical and structural properties. Kolodzey et al., Technical University, München, FRG, described their work on the interdiffusion of Si and carbon in a-Si:H/a-Si_{1-x}C_x:H multilayers. Atomic fractions of C ranged from 9-38 percent with the 9 percent alloy exhibiting an interdiffusion coefficient (D) equal to $5 \times 10^{-18} \text{ cm}^2/\text{s}$ at temperatures up to 650°C. The carbon suppresses interdiffusion; whereas, in the analogous germanium

system, interdiffusion is complete at 500°C. In addition, the a-Si:H/a-Si_{1-x}C_x:H layers were remarkably stable with no crystallization observed up to 925°C. The stability of heterostructures against compositional changes is important for coatings and device applications. Oktu et al., K.V. Leuven Laboratorium voor Vaste-Stof en Hoge-Drukfysika, Belgium, demonstrated the widening of the optical gap for a-Si_{1-x}C_x:H with increasing carbon content was accompanied by an increase in optical absorption at lower energies. The effect of carbon composition on short-range order in a-Si_{1-x}C_x:H film was investigated by Pascarelli et al., Laboratori Nazionali di Frascati, Italy. Chemical ordering in the alloy was observed. At values of $x > 0.5$, Si preferentially bonded only to Si. Schilwinski et al., Fraunhofer-Institut für Mikrostrukturtechnik, Berlin, FRG, examined the total stress in a-Si_{1-x}C_x:H layers grown in a plasma-excited, chemical-vapor deposition system. Films were deposited at 270°C on Si substrates with a radio frequency power of 550W at 380 kHz. Reduction of stress was achieved through H⁺ implantation and/or annealing. A low H⁺ dose (10^{15}) actually resulted in an increase in stress while a high H⁺ dose (10^{17}) yields a reduction of stress. Exposure of the Si_{1-x}C_x:H to x-rays also led to a reduction in stress. In all cases, a post-thermal annealing cycle further reduced the stress in the films. Pickering et al., Royal Signals and Radar Establishment, Great Malvern, U.K., investigated the dependence of structure on carbon content in Si_{1-x}C_x:H alloys. Films were grown by low-pressure, chemical-vapor deposition at pressures of 150-250 torr and temperatures between 600-700°C. A variety of techniques including spectroscopic ellipsometry, IR transmission, x-ray diffraction, and x-ray transmission microscopy were used to measure characterize the films. For carbon contents less than 15 percent, phase-separated material containing Si microcrystallites and some Si-C bond ordering existed. The Si grain sizes increased with increasing carbon content until, at 30-50 percent, the material is composed of SiC crystallites, amorphous Si_{1-x}C_x, and amorphous Si. Derst et al., MPI Kernphysik, Heidelberg, FRG, described growth on sapphire substrates using plasma-enhanced CVD (PECVD) and ion beam modification. The PECVD samples were deposited at 250°C, and ion beam-modified films were prepared by carbon implantation (10^{17} cm⁻²) at 1000°C. Films grown, by either method, became highly transparent after annealing at 1200°C.

Silicon Carbide Devices

The recent advances in CVD-grown SiC films have created interest in producing electronic devices. At the Ioffe Physico-Technical Institute, Leningrad, U.S.S.R., Anlkin et al., developed the technique of epitaxial growth

of SiC "pn" structures by sublimation in an open system. This growth proceeds at 1800-1900°C. Layers of n- and p-type conductivity can be grown with controlled-carrier concentration. High-temperature SiC diodes have been demonstrated operating up to 500°C. Field effect transistors (FETs) with p-n gate, as well as ultraviolet photodetectors insensitive to visible light, and Schottky barrier diodes operating at 300°C, were fabricated in SiC layers grown by this newly developed technique. In an invited talk, Dr. Chelnokov et al., Ioffe Physico-Technical Institute, Leningrad, U.S.S.R., presented calculated and experimental data related to SiC-based bipolar transistors and dynistors. The p-n junction operating current density was 1000A/cm², and operating temperature reached 700-1000°C. Switching speed of SiC devices was in the order of 10^{-8} to 10^{-9} sec. Anikin et al., presented results of the study of the lifetime and diffusion length of minority charge carriers in 6H-SiC. The SiC p-n structures were produced by different methods of growth using both container-free liquid-phase epitaxy and sublimation epitaxy. Deep-level transient spectroscopy data indicate the presence of a deep $E_c = 1.27$ eV and shallow $E_c = 0.34$ eV donors.

Kelner et al., NRL, presented a new development in α -SiC, buried-gate Junction FET. Devices were fabricated in epitaxially grown 6H α -SiC on 1-inch diameter 6H α -SiC substrate. The fabricated devices have maximum measured transconductance of 17 mS/mm and drain saturation current at 0 gate bias of 450mA/mm. The results are the highest reported for SiC devices. Devices are operational (at least up to 460°C) and show considerable potential for the future.

Diamond Growth and Characterization

The initial force towards the development of synthetic diamonds was to prepare diamonds as gems. The success of growing rubies and sapphires for jewelry was the incentive for further synthesis studies. There was a surge of investigators attempting to synthesize diamond. At low pressures, diamond is metastable. The efforts proved futile until the 1950s. Using high-pressure molten solvent catalysis, the growth of single crystalline diamonds was demonstrated. The sizes were not large but were commercially significant for cutting and grinding applications. It is estimated that nearly 80 tons of synthetic diamonds are being produced annually, with 80 percent of the production used for cutting or grinding tools. Diamonds by the high-pressure synthesis have replaced, to a large extent, natural diamonds in most industrial applications. Another potential use of the diamond particles is to load-printed circuit boards. Now using a refined high-pressure process, diamonds up to 10 carats have been prepared.

The next major advance in diamond technology was to prepare thin films of diamond. Research efforts, especially in the U.S.S.R. and Japan, were established to attempt to grow diamond films. Initially diamond films were grown, but the growth rates were very slow and the material was polycrystalline. Growth rates have increased to many microns per hour. It has been shown that many of the claims of achieving diamond were not quite accurate. What really was grown was a new structure now called diamond-like. The diamond-like films are not diamond; however, the full determination of structure and properties has not been resolved. For most electronic applications, it is essential that diamond films are single crystal. To date, only single crystal films have been grown on diamond substrates. Recently, J. Narayan, V.P. Godbole, and C.W. White (*Science*, vol 252, 416, 19 April 1991) announced the synthesis of a continuous thin film of diamond on a copper substrate. Then using hot filament CVD, thick diamond films were grown epitaxially on the substrate. This may be a solution to the problem of growing thick single crystals diamond films on non-diamond substrates for electronic applications. There are uses of polycrystalline films. Japan has demonstrated high-frequency speaker diaphragms using polycrystalline diamond films. X-ray windows and instrument windows can be made from diamond films. Diamond films have a great advantage for hard wear-resistant coatings and are used in surgical cutting tools.

A significant number of papers were presented on various aspects of diamond technology. Several papers addressed the potential applications of diamond-based materials. Aspects of these papers have been sprinkled throughout this report. The remaining papers address topics including theory, materials growth, and characterization. Müller-Sebert, Fraunhofer Institut, FRG, discussed the preparation of polycrystalline diamond (PCD) via thermally activated CVD (TACVD) or microwave plasma-assisted CVD. They demonstrated that PCD films could be obtained with IR absorption several orders of magnitude lower than amorphous diamond-like films. Increasing the carbon content led to nanocrystalline grains at the expense of increased IR absorption caused by graphitic inclusions. Prins presented the work of Caveney, De Beers Diamond Research Center, South Africa, on the growth of single-crystal diamond and cubic boron nitride. Most impressive was the growth of a 14.2-carat diamond, 13 mm in diameter, grown over a 2-week period. The growth technique involved the diffusion of a powdered carbon source down a temperature gradient with subsequent deposition on a diamond seed crystal (a similar process is utilized for the growth of small cubic boron nitride crystals). Low-impurity incorporation and controlled doping were shown to be feasible. It was pointed out that

for very large diamonds (e.g., 14 carats), this is a very cost-intensive process, thus 14-carat substrates for homoepitaxial growth are not likely to be readily available in the near future.

Several papers describing the characterization and properties of diamond and diamond-like materials were presented. Matsukazu Kamo, National Institute for Research in Inorganic Materials, Tsukuba, Japan, described the effect of carbon concentration and the addition of water, during the growth process, on film properties. Cathodoluminescence showed that films grown in 1 percent methane, containing water vapor, had few structural defects but were strained. Films grown in 0.5 percent methane containing water vapor, had Raman line widths similar to those of natural single-crystal diamonds, which indicated the materials were diamond rather than diamond-like. Huong, Laboratoire de Spectroscopie Moleculaire et Cristalline, France, discussed micro-Raman studies on diamond and diamond-like coatings. The differences in the Raman spectra of diamond, graphite, and amorphous carbon were discussed in terms of carbon movement out of the plane. Tombrello, California Institute of Technology, Pasadena, California, examined secondary electron emission of amorphous carbon. Formation of small graphite crystals in the amorphous matrix resulted in a continually changing conductivity over a range of four orders of magnitude. Several characterization techniques were utilized by Maguire, Nottingham Polytechnic, U.K., to investigate the properties of synthetic, natural, and LPCVD-grown diamonds. Electron spectroscopy of natural and LPCVD diamond indicate the presence of two sets of conduction bands separated by an energy gap of magnitude similar to that of the first conduction band and valence band at the zone center. Homoepitaxial-LPCVD films were shown to be indistinguishable from the substrate by Rutherford backscattering analysis. In addition, some of the lowest values of the frictional coefficient were measured for heteroepitaxial-LPCVD.

Ion implantation into diamond was discussed by several authors. Zaitsev, Byelorussian State University, U.S.S.R., discussed high-energy implantation (0.5 MeV/nucleon) and its ability to cause new effects in semiconductors. Among the effects described, were the formation of multilayer impurity defect structures, stimulation of impurities and defects along the tracks of high-energy ions, and the formation of high-pressure several (GPa) local regions. Zaitsev also presented theoretical work for investigating point defects in diamonds. Derry, University of the Witwatersrand, Johannesburg, Republic of South Africa, presented work on the doping of diamond by implantation. Lithium was discussed as a potential n-type dopant. Derry's studies showed that lithium had diffusional behavior similar to

that of boron and that when annealed, the lithium moved deeper. Thus, lithium did not appear to be a good n-type dopant. Several n-type dopants (P, Li, Na) were investigated theoretically by the Davis group, North Carolina State University, Raleigh. P was found to prefer the substitutional site while Li and Na are interstitial donors. All are shallow impurities with very low solubilities making them unsuitable for incorporation via indiffusion, thus requiring kinetic trapping during growth or implantation. As discussed by Derry, Li was a fast diffuser but Na showed promise in being stable to moderately high temperatures.

Diamond Devices

The most encouraging work regarding diamond devices was presented by Prins, University Witwatersrand. Prins discussed his work on diamond doping by ion implantation. He also discussed the modification of the diamond surface by using a technique of cooling the diamond to a low enough temperature to freeze point defect during the implantation process. In this way, a suitable defect structure can be created which, combined with annealing cycle, leads to dopant activation and removal of the intrinsic radiation damage. To create the diodes junctions in the natural diamond, the n-type region was prepared by carbon ion implantation at substrate temperatures above ambient (Prinz, J.F., Applied Physics Letter, **41** 950-2 [1982]). The interface between this layer and the surrounding diamond formed a diode which luminesced in the blue spectrum when biased in the forward direction. Maximum intensity was emitted at a wavelength of approximately 435 nm.

Perhaps the liveliest discussion was led by Professor Collins of Kings College, London, which addressed the viability of diamond as an electronic material. In his invited talk, Collins expressed doubts that diamond electronic devices could outperform Si and GaAs. This talk is a compilation of earlier talks and publications of Professor Collins. In each, he has stirred up considerable controversy. Various theoretical calculations, such as the high-electron and hole mobility, high-breakdown field, high-saturated electron drift velocity, high-thermal conductivity, and low permittivity seem to be ideally suited to high-temperature, -frequency transistors. More detailed analysis by Collins revealed several practical problems as well as errors in some of the theoretical treatments. Four problems involved with using diamond as an electronic material were clearly identified.

1. Growth of semiconductor grade diamond, even on diamond substrate, is extremely difficult
2. Semiconducting diamond with a conductivity suitable for device applications occurs only as a p-type which will rule out useful p-n junction devices

3. Conductivity of p-type diamond is relatively low at room temperature
4. Hole mobility decreases very rapidly with increasing temperature.

The maximum conductivity of natural diamond of the type IIB occurs at 630 K, but at this temperature the hole mobility drops to $< 200 \text{ cm}^2/\text{V}\cdot\text{s}$. Ultimately, Collins concluded that it is unlikely that diamond devices outperform Si and GaAs devices. While Collins' remarks appear to be well founded, he may have missed the point by comparing diamond to Si and GaAs. Instead, a comparison between diamond and SiC may have been more important. Clearly, SiC materials technology has matured to the point where high-quality materials can routinely be prepared. Indeed, SiC-based devices have been fabricated and, with the continued improvement in material quality, the outlook is very promising. Diamond materials research, on the other hand, is in its infancy. Until vast improvements are made in thin-film growth technology, it is unlikely that diamond can compete with SiC as an electronic material. Even if the film growth technology matures to the level of SiC, serious questions remain as to whether a suitable "n" dopant can be found. In addition, the rapid dropoff in mobility at high temperature may severely limit the practical use of diamond as a high-temperature electronic device.

Activities in Diamond at Catholic University, Nijmegen, the Netherlands

Dr. Gilings group presented no papers at the '90 E-MRS fall meeting. His group consists of two students, two post-doctoral fellows, and a staff scientist, Dr. van Enckevort, Drucker International, Cuijk, the Netherlands. Using hot filament reactors, they have succeeded in growing 20- μm diamond single-crystal films on diamond substrates. Growth rates as high as 50- $\mu\text{m}/\text{hour}$ were achieved. These films have been removed from the substrate by polishing. The films have defects in the outer perimeter but they are quite smooth and uniform in the center areas. Drucker International is trying to prepare large diamond windows, as well as using the films for coating digital discs and metal tooling. Gilings is looking at the physical properties of the single-crystal diamond and at potential electronic applications. Dr. Gilings is not convinced there is no "n" dopant, but feels that the material is still too full of defects and impurities to make such a case. He is also looking at the possibility of making large diamond substrates by putting small chips together and overgrowing on the chips, which may grow in the boundaries between the chips to form a larger substrate. By using the artificially prepared substrates by additional growth, it is hoped that the defects will not propagate at the growth temperature. From the lower-defect materials, efforts could then be

made to characterize the materials for electronic applications and make active devices. This is a long-term research effort and is ideal for the university environment.

Conclusions

As pointed out in a presentations by Seal (Sigillum, B.V., Amsterdam, the Netherlands) and Jones (DeBeers Industrial Diamond, Sunninghill, U.K.-International Division), there are many roles that diamond materials can fill besides electronics. Diamond grits are used as abrasive. The hardness and the low radius of curvature makes diamond a natural choice as a cutting edge used in fine surgical equipment. Incorporating diamond grits and powders in ceramics and plastics may improve the mechanical strength and thermal conductivity properties of these materials.

Perhaps the most promising application for diamond films is in the preparation of optical coatings and windows, especially for continuous infrared observation in various industrial processes (issues such as

graphitization of the windows at high temperature must yet be addressed). The SiC is currently in use in abrasives, optical coatings (x-ray masks, high-reflectivity coatings) and electronics (blue/green LEDs) industries. The share of the market SiC holds for cutting and grinding applications will be in jeopardy if the price of diamond grit continues to fall. Also, the position of SiC in the electronics industry will depend on whether diamond single-crystal layers can be obtained, and whether they will have the properties predicted by Johnson and Keyes, or those projected by Collins. Clearly, more work must be done and many questions answered before it can be determined whether diamonds are an electrical engineer's best friend. In the end, it is likely that both SiC and diamond will each find and fill very specialized roles. Other wide-gap materials, such as boron nitride and gallium nitride, will also emerge and find niches to fill. The potential of materials such as SiC, diamond, and boron nitride suggests that one must continue to "Mind the Gap."

Il Consiglio Nazionale delle Research, Rome and Parma

by Howard Lessoff

Introduction

I visited two Consiglio Nazionale delle Research (CNR [National Council of Research]) activities in Italy.

1. The Institute of Special Materials for Electronics and Magnetism (MASPEC) in Parma
2. The Institute for the Theory and Electronic Structure (ITES-CNR) research area in Rome.

Both ITES-CNR and MASPEC-CNR operate under the umbrella of the CNR. Within the CNR, each of the operating units have a large degree of independence from the parent organization. The methods of operation of ITES-CNR and MASPEC-CNR are dissimilar. I must emphasize that an Italian research organization is quite different from an American counterpart. The following section is a brief introduction to the organization of CNR.

The Il Consiglio Nazionale delle Ricerche

The CNR is a major source of funding for basic and applied research within Italy. Furthermore, CNR also has many research organizations such as in-house laboratories. The charter of CNR gives it the responsibility for the funding, directing, organizing, documenting, distributing, forming of standards, and the carrying out most of research in Italy. Unlike the U.S., the other departments of the Italian government have very limited authority to carry out research. The departments depend on the CNR for research.

The President of Italy appoints the CNR president. The CNR president reports directly to the president of the Council of Ministers (the Prime Minister). The Ministry of University and Research, Scientific, and Technological controls CNR. The research activities are carried out under the direct control and advice of 15 national advisory committees. The President's Council includes the chairs of the advisory committees and the head of the Bank of Italy.

Inbreeding and the concentration of power are an aspect of the committee system. The advisory committee members are primarily university professors, many of whom have been former CNR employees. Although the universities control most of the positions, 14 percent of the committee slots are held by CNR employees. The chair of each consultive committee has a large amount of power in controlling how funds are used. Thus, members of the committee, and more important, the chair, can control what research will be undertaken. As I will point out later, the director of a major research area may have

very limited control of his institute's activities. Close links with members of the national advisory committees are essential for funding. Since the Italian science and university system has been long in evolving, there is a large bureaucracy with the attendant resistance to change.

Nearly all appointments to higher university and CNR laboratory positions are made from within. There is little chance for someone from the outside to reach a position of responsibility or the rank of professor. Once a tenured position has been filled, there is limited ability for other scientists to advance, no matter how good they are. Thus the committees and the work force has become ingrained as an "Old Boys Club." The work force is institutionalized. Once a person is employed, there are a host of regulations and union rules. An ineffective employee can be removed only with great difficulty. Many young scientists leave the country rather than wait for the next step on the ladder.

Based on recommendations of the committees, the CNR distributes monies to specific research activities similar to grants of the National Science Foundation (NSF) in the U.S. There are also a series of major directed programs. These activities are called *Progetti Finalizzati* (Finalized Projects), using about 25 percent of the CNR budget. The term *finalized* does not mean the projects have a defined period of operation. The projects are initiated to address and solve economics or social problems within Italy. The term *Finalized Projects* means each project has a set of goals. These goals should have a major impact on Italian society or industry. Among *Progetti Finalizzati* are activities in mechanization of agriculture, automation of production, historical preservation, pollution monitoring and control, information sciences, preventive medicine, and communications.

The CNR tries to coordinate activities with Italian industry and other laboratories, especially those within the European Economic Community (EEC). There are more than 150 research institutions that are under the CNR umbrella scattered throughout Italy, primarily in the urban centers. When one looks at the location of the CNR activities, it becomes quite clear that sites are partially selected for political reasons to develop regional science and industry. The CNR Research Centers include *Area della Ricerca* (Research Areas), *Istituti* (Institutes), and *Centri di Studio* (Study Centers).

The study center organizations are set up mainly within universities for 5-year projects. Generally, the funding is shared by CNR and the performing organization.

Historically, it is quite rare that after the initial 5-year period, a grant is stopped. The institutes are permanent organizations that are owned and staffed by CNR. In general, the institutes specialize in a given area of research. The research areas are a group of institutes set up at a common location for sharing facilities and administration. The Area Della Ricerca Di Roma is one of the 15 research areas in Italy. Joint efforts are often formed between the institutes and universities. Indeed within a university, there may be full-time CNR employees, and within a CNR institute there may be university personnel. The organization of CNR is best described as a distributed system. A review of the research organization and research problems in Italy is described in a special article compiled by Robert Walgate (1983).

The Institute of Special Materials for Electronics and Magnetism (Dr. Lucio Zanotti, Director)

Located in Parma, MASPEC was founded in 1970. The MASPEC is quite close to the new campus of the University of Parma and is scheduled for quarters within the university complex. The current facilities are fairly old and are bulging at the seams. The annual budget for MASPEC is nearly 3 million lira; a quarter of the funds are from CNR, with about 75 percent from the EEC, industry, and national research programs. There are 48 permanent CNR employees augmented by many collaborators from the University of Parma, industry, and visiting professors (many from outside of Italy). Student involvement with the activities at MASPEC is encouraged. The charter is directed at preparing and characterizing electronic and magnetic materials.

Scientific Activities. The MASPEC's research activities are divided into six sections; however, the various sections coordinate closely. Indeed, because there is such collaboration, I will not discuss the activities by sections. Interactions are strongly encouraged between MASPEC and other laboratories. Unlike the U.S. and other countries, there does not seem to be the tendency for industry to set up research and development activities near major CNR and university laboratories. Therefore, it is difficult for industry to take advantage of the technical potential of the institutes. In an attempt to solve this problem, MASPEC encourages industries to assign full- or part-time employees to the laboratory.

Compound Semiconductors. The activities in compound semiconductors are the main thrust in the development of III-V materials. Using liquid encapsulated crystal growth (LEC) methods, the group has been growing both GaAs, and more recently InP. There is extensive capability in growth, cutting, polishing,

and characterization. The group is trying to reduce the defect structure in bulk single crystals of GaAs and InP. Part of the work is supported by CNR Applied Research Projects, as well as European Common Research Projects. Among the programs within MASPEC for the growth of bulk growth are:

- CNR-finalized project "III-V compound single crystals for micro- and opto-electronic applications"
- EEC-science project "Nature, origin, and importance of structural defects in GaAs substrates for micro- and opto-electronic applications."

The growth and characterization of LEC GaAs has been a major research activity of MASPEC. There is very strong industrial support cooperation in this activity, especially with EniChem and Temav. Both companies have scientists working at MASPEC on bulk growth and characterization of III-V compounds. EniChem has a division in the U.S.--Enimont America, Ltd., Phoenix, Arizona, which is growing and marketing GaAs wafers. At MASPEC, there are some foreign scientists including Dr. J. Weyher. Dr. Weyher is working on the defects structures and mechanism of the formation of defects in single-crystal GaAs. His work includes photo-activated etching. The MASPEC has developed strong evidence that many of the defects in the GaAs wafers are because of or related to nonstoichiometry during crystal growth. Their experiments would indicate that the GaAs congruent melting point is on the arsenic rich side. The evidence also would imply that even for crystals grown in Ga-rich melts, complex microdefects and/or precipitates are formed. The crystals grown from the Ga-rich melt do have a lower etch pit density than crystals grown from an As rich or stoichiometric melt. In all materials grown, there is a submicron defect matrix. They have also been able to show the difference between grown-in dislocations and dislocations produced via thermal stresses occurring during growth. They suggest the commonly observed W-shaped patterns for etch-pit density may not be related to thermal stress. The W-shape appears to be related to gross changes in the temperature of the melt, and thus chemical composition across the melt-solid interface. Results show clearly that more attention must be placed on the microthermal gradients in the melt and their effect on the microcomposition of the growing crystal. These slight changes could result in changes in electrical properties of submicron devices prepared on GaAs substrates.

Dr. R. Fornari directs the activity in bulk growth of InP. He is using standard, liquid-encapsulated Czochralski (LEC RF)-heated puller operating at 35 atmospheres. Most of the growth has been on $\langle 111 \rangle$ P seeds; the charge material is from industry. They are now attempting to grow on $\langle 100 \rangle$ seeds, but excessive twinning has been a problem. A major use of InP

substrates is for light-emitting devices at 1.3 to 1.88 μm for use in fiber optic communication systems. The life of the light-emitting devices is very sensitive to the defect density in the base material. Work at MASPEC has been aimed at defect reduction. Normally, Si is used as the dopant to reduce the defect density. Fornari has been double doping the melts with Cd and S by adding to the melt CdS. The segregation coefficient of Cd (0.23) is less than S (0.5). Therefore, the melt increases in Cd at a greater rate than that of S. The resulting InP crystals show a reduction in the etch pit density with lower doping levels than required using Si doping. Fornari has also shown that besides the normal etch pits, there are micro defects in the co-doped materials. The defects are apparently of chemical nature and suggests that they are caused by sulfur precipitates.

Additional activities in compound semiconductors include growth using hydride chemical vapor transport (CVD), and molecular beam epitaxy (MBE). The studies are for both basic science and for device development. Among the materials under investigation are InGaAs, InGaP, and HgCdTe (the latter is for the investigation of far-infrared detectors). Selinia S.p.a. is cooperating in this effort. A metal-organic vapor deposition kit is being assembled for the growth of the Ga-based III-Vs. However, there is still some debate as to which alloy system will be investigated.

There is extensive characterization capability at MASPEC and the capability of the University of Parma readily available, especially optical properties. There is very close coordination between MASPEC and the university. For x-ray analysis and structural determination, MASPEC has Lang and Hirst capability, as well as multocrystal diffractometry, and a unique double-crystal x-ray topography (camera made by the Academy of Berlin Model RTK).

Magnetics and Superconductivity. In an earlier report by A. Clark (1989), a review was given of the work on magnetic and superconductivity at MASPEC. Much of the work is continuing; however, the emphasis on magnetics has been shifted to research in the high-temperature superconductors.

The group at MASPEC has had a strong magnetic group working on intermetallics and hexagonal ferrites. The activities seem to be reducing. The major remaining efforts are based on measurements of the rare earth iron borides permanent magnets. The activity is part of the EEC program, BRITE/EURAM¹. The MASPEC is doing anisotropy and coercivity measurements on samples supplied by various participants.

Dr. F. Licci has been growing single crystals of the high-temperature superconductors. She has succeeded

in growing from the flux solid cubes of the YBaCuO superconductors having dimensions more than 4 x 4 x 4 mm. The flux system is based on BaO/CuO. They have developed a method to remove the flux from the grown crystals. A porous alumina plug is made to the shape of the crucible. Upon cooling the melt after growth, the plug is inserted into the molten flux. The flux is absorbed into the plug similar to water into a sponge. The crystals of the superconductor are then left free from the flux in the crucible and on the surface of the plug. The MASPEC group has made extensive phase studies of the flux system with the superconductor. From these studies, a method has been found to reduce the contamination of aluminum oxide. The alumina inclusions occur when using alumina crucibles. They have found that as the content of BaO in the flux increase in respect to CuO, there is a reduction in the alumina pickup from the crucible.

Dr. Bolzoni has been making the critical fields in the high-temperature superconductors using a high-pulsed field apparatus. A special pickup coil is used to measure the change of magnetic field with change of time, while an operational amplifier gives the derivative of the differential susceptibility. The method is contactless and does allow the use of very small samples.

Other Activities at MASPEC. There is a new program dealing with nonlinear optics; it is a cooperative effort with the University of Parma and the MARS Center in Napoli (part of the Italian Space activity). The activity has the support of the European Space Agency as a contract program. One component of the effort is directed towards growth of crystals in microgravity environments. One of the first materials to be investigated is urea. The advantage of initially using urea is the relatively low temperature required for vapor transport ($T < 150^\circ\text{C}$). Urea and its derivatives have promise for applications requiring nonlinear optical properties. Using a vapor-phase growth method, it is planned to grow a series of ten crystals in under-microgravity conditions.

Like the service centers at the Rome Research Area (RRA) (to be described later) MASPEC does some service work for other laboratories, particularly material characterization for Italian laboratories. They have extensive capability in x-ray methods, cathodoluminescence, electron, and x-ray beam analysis, and transmission electron microscopy, including atomic resolution. Standard electrical characterization apparatus is available including Hall effect, C/V and Miller profilers, photoluminescence, deep-level transient spectroscopy (both reverse and optical), and thermostimulated capacitance. The facility is certainly on a par with many major laboratories.

¹Basic Research in Industrial Technologies for Europe/European Research on Advanced Materials

The Area Della Ricerca di Roma

Directed by Dr. Paolo Fiordiponti, the RRA is located in Monterotondo about 29 km north of Rome. The facilities are new and extensive. Many technical meetings are held at the conference center. There is a central library and a main administration building. The 150-acre site is quite isolated from the city and from the University of Rome. Public transportation is fairly limited with a few daily trains from Rome. The remoteness of the location has reduced the potential of strong interactions with both the University of Rome and industry. The RRA consists of service centers and institutes. Each of the institutes is housed in its own building.

Service Centers

Staffed by skilled professionals, service centers are activities having major pieces of scientific apparatus usable for many disciplines. They are related to commercial analytical laboratories that offer services for a fee. The centers may take active parts in research programs but usually function as tools for the institute and other laboratories. On a fee basis, they will perform services for industry, universities, and other CNR centers within Italy and internationally. The service units at RRA include:

- **Laser service center.** Cooperates in various research activities that require lasers such as spectroscopy, kinetics, photochemistry, and surface analysis; provides diagnostic and calibration services on lasers and laser systems. (Major equipment: Q-switched dye laser, eximers lasers, various other laser sources)
- **Fungi bank service.** Gathers, stores, preserves, and distributes edible saprophytic mushroom strains with a specialty of fungi in the Mediterranean area; acts as a central clearing house in this area
- **Surface analysis center.** Supports nearly all the institutes within the research area as well as outside requests. (Major equipment: V.G. ESCA3 MK II, and ESCALAB MK II spectrometers)
- **NMR spectrometry service.** Provides NMR analysis of pharmaceuticals, structural analysis, and chemical reactivity. (Major equipment: Bruker AC 200)
- **Mass spectrometry service.** Acts as a consultant to both internal and external customers. (Major equipment: VG-70-70-F having both magnetic and electrostatic sectors, and HP quadrupole spectrometer)
- **Microanalysis service.** Performs analysis of C, H, N, S, and O. (Major equipment: Perkin-Elmer Model 240B and 372 Spectrometers, as well as Carlo Erba automatic analyzers)

- **Fourier transform mass spectrometer or ion cyclotron resonance spectrometer service center.** (Major equipment: Nicolet FT-MS-100)
- **Central service center.** Develops or modifies tools not readily available on the commercial market; has extensive photographic capability and electronic facilities; has CAD/CAM machine tools and a calibration center.

All the centers perform service work for the institutes. Services of the centers are available on a fee basis to industry, universities, and laboratories throughout Europe. The internal CNR projects generally have priority. To a certain extent, the service centers are the unifying unit at the RRA.

The Institutes

At the RRA are eight institutes (independent of each other), as well as a regional occupational health unit. Each institute is responsible for its own funding as well as manpower ceilings from the appropriate CNR committee. They can have collaborative programs or funding from outside organizations, especially within the EEC. The employees are normally CNR staff with additional support from visiting scientists and university students. For those who consider publications as an indication of productivity, the RRA had 186 publications in journals and 119 publications in proceedings of conferences. Most of the funds for each institute are received from the CNR committee concerning the particular specialty. They act as isolated organizations within the RRA. The projects within the institutes do not necessarily have the approval of the director of the research area. Cooperation occurs when scientists from the various institutes have common interests. The RRA has the following institutes:

- **Institute of Nuclear Chemistry** (Dr. G. Angelini, Director). Applies radiochemistry techniques in studying synthesis and reaction studies in physical/organic chemistry; programs include reactivity studies, radioactive tagging, archaeological dating, and the preparation of radioactive materials for medical and other research activities.
- **Institute of Plant Radio-Biochemistry and Ecophysiology** (Dr. G. Di Marco, Director). Role of the ecosphere as a stress factor in plant culture, growth mechanisms in plant growth, effects of herbicide in crops, use of bacterial cells in plant culture, recovery of plant materials from wastes and effects on soil productivity, and methods of improved plant reproduction.
- **Institute for the Theory and Electronic Structure** (Dr. S. Viticoli, Director). Will be discussed in more detail later.

- **Institute for Chromatography** (Dr. L. Ossicini, Director). Most of the research directed in high-resolution separation methods and their applications to biological, medical, and archaeology; new chromatographic techniques developed for pharmaceuticals and studies in metabolism, and mutation of generic materials by environmental pollution.
- **Atmospheric Pollution Institute** (Dr. I. Allegrini, Director). Wide variety of basic and applied studies; operates a two-pilot station for sensing (Rome and RRA); studies include emission, transport, and deposition of atmospheric pollutants; reactions of pollutants in the ecosystem, especially on monuments and artworks.
- **Institute of Advanced Inorganic Methodologies** (Dr. M. Pagannone, Director). Mainly concerned with the optical and electronic spectroscopy; studies in both gas- and condensed-stage matter; photochemical reactions and photophysical effects, especially for biosystems.
- **Institute of Technologies Applied to Cultural Heritage** (Dr. V. Francaviglia, Director). Concerned with preserving cultural heritage requires a combination of geology, geophysics, and materials; applies the scientific methodology towards developing and applying technology to archeological objects, including identification of factors that influenced and shaped human habitat and the culture's prehistoric settlements.
- **Institute for Phoenician and Punic Civilization** (Dr. E. Acquaro, Director). Researches into origins and development of Phoenician and Punic cultures, and influence and interactions with other Mediterranean civilizations; research includes archeology at sites, preserving and dating antiquities, and linguistic and epigraphic evaluation of discovered relics; publishes *Journal of Phoenicians Studies* and *Collection of Phoenician Studies* (over 30 volumes).

The Institute for the Theory of Electronic Structures

The Charter of Institute for Theory and Electronic Structures (ITES-CNR) is to carry out fundamental research in structures and chemical activity of electronic and magnetic materials. The laboratory has 53 employees (35 professionals and 18 technicians). Indeed, the low ratio of technicians to professional is a problem at the CNR laboratories. Another problem is the lack of students working on advanced degrees. The funding of ITES-CNR is approximately 60 percent from CNR, and the rest from outside contracts including the European Strategic Programme for Research and Development in

Information Technology (ESPRIT) and the Istituto Superiore delle Poste e Telecomunications. The emphasis is on basic research with very limited activity that could be considered to be applied. I note among the staff a concerted attempt to stay with basic research to the detriment of doing applied work. I get the impression that the scientists have the view that having many papers in pure basic research is the way to get a professorship in a university. In 1989, ITES published 35 technical papers. Strong interaction with industry is not considered essential for one's career. A university professorship seems to be the goal of many of the researchers. These positions are very limited, and to achieve a professorship requires scientific credentials and the proper political connections.

There is some excellent basic research in the ITES. Dr. Bellitto is searching for organic analogs to inorganic semiconductor materials. The idea is that organic compounds could allow electronic processing at the molecular level. Dr. Carlo Bellitto is looking at metal-coordinated ligand structures, especially those which are electrically conductive. He has synthesized several organic tetrachlorochromates having chromium as the intercalated metal. The compounds structures related to K_2NiF_4 are ferromagnetic. The Curie temperature is about 49 K. By changing the halogens in the ligand, he has been able to change the Curie temperature. Now, he and his team are looking at ligand that may be superconducting. He has demonstrated changes from insulating to semiconducting materials in charge-transfer salts. The changes occur on increasing the number of dimers attached to $[Pt(S_2C_2O_4)_2]$. Dr. Bellitto has shown that molecular semiconductors do exist and can be doped with donors and acceptors to yield high-electrical conductivity. The conductive mechanism appears to be, by charge hopping, and therefore does not allow high-velocity charge transfer.

Dr. Fiorani and his group have been working on magnetic materials, and more recently on magnetic relaxation effects and critical currents in the high-temperature superconductors of the $BiSrCaCuO$ family. There has been a review of the high-temperature research in Italy (see ESNIB 89-05:50). Dr. Fiorani reported that the $BiSrCaCuO$ superconductors are more susceptible to magnetic fields when compared to the $YBaCuO$ compounds, and therefore would have limited applications. The higher dispersive effects in $BiSrCaCuO$ are related to the defect structure and the electronic anisotropy differences. Dr. Fiorani's activities include magnetic-disordered systems including spin glasses.

An activity in III/V growth has just been initiated with the purchase of a Varian GEM II Molecular Beam epitaxial-growth system. The group is under the direction of Dr. Maria Grazia Proietti. Initial studies are on

strained quantum well structures of InGaAs/GaAs. They have succeeded in growing strained layers that exhibit room temperature photoluminescence (PL). Although they have the MBE unit, they do not have the basic tools needed for electrical characterization. Using PL, the films grown do seem to be very pure. There has been no measurement of carrier concentration, carrier velocity, nor carrier type because of the lack of Hall apparatus on site. I found it difficult to determine the goal of the program beyond structures being grown for optical communications.

Conclusions

The CNR, which has control of a large share of the research dollars in Italy, operates several in-house activities. The activities are funded by committee recommendation. The selection of site for a research center or institution does seem to play a role concerning interactions with other laboratories. The location of the

center appears to control the amount of interactions with other organizations and the universities. Each institute appears to be an independently operated entity. In areas of research, service centers are the unifying factor. The staff at both ITSE-CNR and MASPEC-CNR are very competent scientifically with enthusiasm for their research. The MASPEC has a broad range of technical interactions and is looking at potential applications of its research. In contrast, ITSE-CNR appears to be more basic research oriented. The emphasis on basic and fundamental phenomena has limited industrial cooperation and the corresponding potential for applications.

References

- Clark, A. 1989. Superconductivity research in Italy. *ESNIB* 89-05:50.
- Walgate, R. Can order spring from chaos? May 1983. *Nature*, vol. 303.

Atomic Layer Epitaxy of Semiconductor Thin Films

by Salah M. Bedair, Professor, Department of Electrical Engineering, North Carolina State University, Raleigh, North Carolina.

Introduction

Progress in Atomic Layer Epitaxy (ALE) of III-V compounds has been reviewed by Tischler and Bedair (1989). In this paper, I will concentrate on more recent results obtained at North Carolina State University in the ALE area. The goal of this paper is not to discuss the physical model for the self-limiting mechanism, (Chiu, 1989) (Ohno et al., 1989). I will concentrate on the current problems facing ALE and its unique applications in the field of optical and electronic devices. I will also discuss sidewall growth by ALE, the growth of ternary alloys, ordered structures, nonalloyed ohmic contacts, planar-doped structure, planar-doped field effect transistors, and p-n junction with extremely low reverse saturation current. The potential success of ALE as a new and novel growth technique will depend mainly on its ability to demonstrate device structures with unique properties.

Current Challenges Facing the ALE Technique

The ALE technique has suffered from several shortcomings that I believe has slowed down its potential applications and the interest of many researchers. The first problem is the very low growth rates where in some cases growth rate as slow as $0.02\mu\text{m}/\text{hour}$ was reported (Usui et al., 1986). Some recent improvement in the growth rate was achieved and a growth rate of about $0.1\mu\text{m}/\text{h}$ was reported, (Mochizuki et al., 1988) which I still believe to be discouragingly slow. The main reason for such a low growth rate is the commonly used approach that is based on exposing/purging each of the reactants with a vent/run manifold configuration. The finite gas residence time in the reactor and valve switching times will always lead to the growth of only a few fractions of a micron per hour. The approach adopted in our laboratory (Bedair et al., 1985) relies on rotating the substrate between the different source gas streams that are continuously flowing through a specially designed vertical reactor. The growth rate will depend on the substrate rotation speeds. Growth rates in the range of 0.4 to $0.7\mu\text{m}/\text{h}$ can be achieved with this approach. Such growth rates are comparable with that reported by molecular beam epitaxy (MBE). A schematic of the growth process is shown in Figure 1.

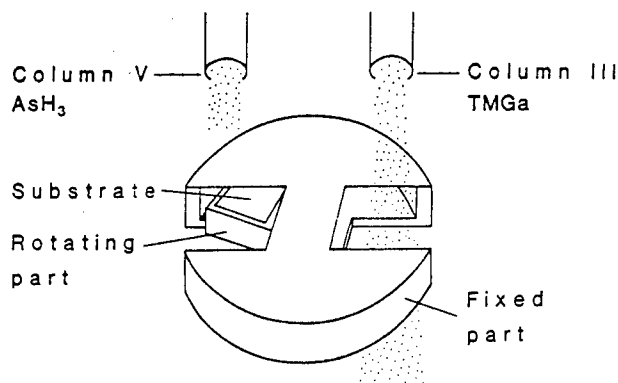


Figure 1. Schematic of the rotating susceptor for ALE.

The second problem facing ALE of III-V compounds is the high carbon background in the ALE-grown films. Recently, (Gong et al., submitted) undoped Gallium Arsenide (GaAs) with background electron concentrations in the high $10^{14}/\text{cm}^3$ to low $10^{15}/\text{cm}^3$ was achieved in our laboratory with liquid nitrogen mobility of about $30,000\text{ cm}^2/\text{V}\cdot\text{sec}$, which is reasonably adequate for several devices. The device quality GaAs films were achieved by optimizing growth conditions such as growth temperature, flux of reactants, and exposure times. Thus, I believe that (at least for GaAs) the ALE technique can provide films with convenient growth rates and good electrical properties.

Another problem facing ALE is the synthesis of ternary alloys such as Aluminum Gallium Arsenide (AlGaAs) and Indium Gallium Arsenide (InGaAs) that will provide a heterostructure with different binary compounds. The problem with ternary alloys is the lack of compatible group III precursors that will adhere to the self-limiting process at the same growth temperature (Jeong et al., 1989). However, we have recently reported the growth of AlGaAs and Indium Gallium Phosphide (InGaP) that are both lattice matched to GaAs substrate. The ALE growth of these two ternary alloys was achieved over fairly narrow conditions, and will be addressed in more detail later in this paper. Conversely, it was found that alloys with two group V elements such as GaAsP had a fairly broad range of growth conditions.

ALE of Ternary Alloys

AlGaAs (Gong et al., to be published), Trimethylgallium (TMGa), Trimethylaluminum (TMA) and Arsine (AsH_3 , 10 percent in H_2), were the source materials. The TMGa and TMA bubblers were kept at -10°C and 17°C , respectively. The ALE growth cycle consisted of the simultaneous exposure of the substrate to the TMGa and TMA fluxes followed by a rotation to the AsH_3 side to complete one cycle. The substrate made one complete rotation in 2.6 sec, allowing an exposure time of about 0.3 sec for each gas stream and yielding a growth rate of about $0.4 \mu\text{m/h}$. The composition of the ALE-grown $\text{Al}_x\text{Ga}_{1-x}\text{As}$ is controlled by the

$\frac{\text{TMA}}{\text{TMA} + \text{TMGa}}$ a molar ratio in the column III stream. We

have also used the same reactor to grow AlGaAs films by the conventional metal organic chemical vapor deposition (MOCVD) approach. In this case, the substrate is stationary and is exposed simultaneously to the TMGa, TMA, and AsH_3 fluxes. The AlGaAs films with thicknesses of about $0.8 \mu\text{m}$ and $3 \mu\text{m}$ for ALE and MOCVD, respectively, were grown.

The growth conditions that allow the deposition of a monolayer of AlGaAs in a self-limiting fashion in the temperature range $550\text{--}700^\circ\text{C}$ were first determined. The as-grown $\text{Al}_x\text{Ga}_{1-x}\text{As}$ films ($0 < x < 0.4$) have mirror-like surfaces. The thickness dependence of the deposited ALE films per growth cycle on the sum of TMGa + TMA moles in the column III stream is shown in Figure 2. Two

values for the gas phase molar ratio, $\frac{\text{TMA}}{\text{TMA} + \text{TMGa}}$, 0.074

and 0.123, were studied. This gas phase composition resulted in solid compositions, x of about 0.22 and 0.33, respectively. As shown in Figure 2, the monolayer growth of $\text{Al}_{0.22}\text{Ga}_{0.78}\text{As}$ and $\text{Al}_{0.33}\text{Ga}_{0.67}\text{As}$ was only observed in a fairly narrow range of column III total flux. The flux range in which the deposition process becomes self limiting is about the same as for the $550\text{--}700^\circ\text{C}$ growth temperature range. For higher total column III flux ($> 0.075 \mu\text{ mole/cycle}$), the growth rate began to resemble that of conventional MOCVD, where the thickness of the deposited films was doubled by doubling the total column III flux.

Results shown in Figure 2 may require a reconsideration of the self-limiting mechanism, which is believed to be controlled by the surface adsorption processes of column III. For example, ALE in GaAs is believed to result from Ga species adsorbed on the surface to form a monolayer coverage, leading to very small decomposition efficiency of any additional TMGa molecules (Tischler, et al., 1990). Thus, these additional TMGa molecules may re-evaporate before they decompose at the surface. For AlGaAs, if the same mechanism is present, a monolayer of mixed Ga and Al

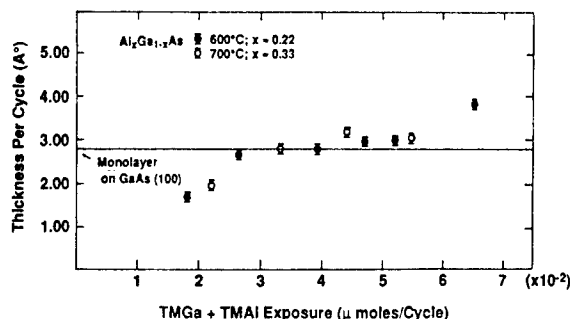


Figure 2. Thickness per ALE cycle of AlGaAs versus (TMGa + TMA) flux.

species will be formed and thus expected to prevent any further dissociation of either TMA or TMGa molecules. Therefore, in the limited range where ALE is observed for AlGaAs, it can be claimed that TMGa or TMAI molecules do not dissociate effectively on both the Ga and Al species forming the monolayer covered surface. This is based on the assumption that no dissociations of TMGa or TMA molecules take place in the gas phase.

Figure 3 shows the dependence of the solid composition x and the 77°K photoluminescence (PL) emission energy on the gas phase composition of $\text{Al}_x\text{Ga}_{1-x}\text{As}$ grown by ALE and MOCVD. The ALE films were grown at substrate temperatures of 550, 600, and 700°C , while the MOCVD films were grown at 800°C . The composition of the MOCVD films, as shown in

Figure 3, depends on the $\frac{\text{TMA}}{\text{TMA} + \text{TMGa}}$ ratio and is

consistent with previously reported results of AlGaAs growth by this technique. Figure 3 shows that Al incorporates during ALE more efficiently than in MOCVD.

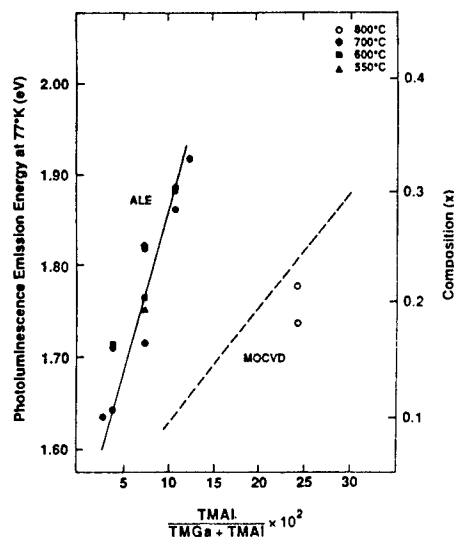


Figure 3. PL emission energy at 77°K of $\text{Al}_x\text{Ga}_{1-x}\text{As}$ and corresponding solid composition x as function of $\frac{\text{TMA}}{\text{TMA} + \text{TMGa}}$ molar ratio in column III stream.

Figures 4 (a,b,c,) show the PL spectral for $\text{Al}_x\text{Ga}_{1-x}\text{As}$ for different values of x grown by ALE and MOCVD. The MOCVD film grown at 700°C showed very weak emission, as shown in Figure 4(a). There were no PL signals observed from MOCVD films grown below 700°C . However, ALE grown films showed fairly strong PL peaks for growth temperatures as low as 600°C and a weaker emission at 550°C , as shown in Figures 4(b) and 4(c), respectively. This is considered to be one of the lowest temperatures where AlGaAs was grown with good optical properties. Also, $0.5\text{ }\mu\text{m}$ ALE films with indirect AlGaAs buffer layers grown at 600 and 700°C have a comparable PL intensity to $4\text{-}\mu\text{m}$ MOCVD films grown at 800°C . The ALE process allows an improvement in the PL properties that can be related to an enhancement in the surface migration of column III adsorbed atoms. It has been shown that Al and Ga species have high surface diffusion coefficient in the absence of AsH_3 or As_2 exposure (Kobayashi et al., 1989). This may result in improving the quality of ALE films, but it would not explain a difference in the incorporation mechanism of oxygen in the two techniques that may be responsible for the PL results. Possibly, TMA is the source of oxygen, and a lower TMA flux in the ALE growth is accompanied by reduced oxygen incorporation in the grown films.

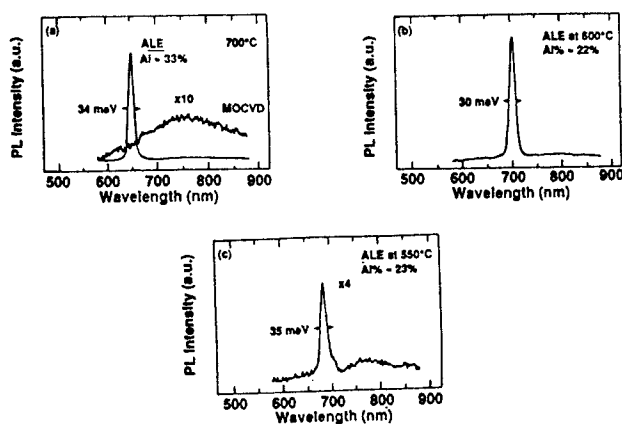


Figure 4. PL at 77°K of AlGaAs grown by MOCVD and ALE at different temperatures; (a) ALE and MOCVD at 700°C , (b) and (c) ALE at 600°C and 550°C respectively. No PL signals were observed from MOCVD films grown below 700°C .

The AlGaAs ALE films are p-type and have carrier concentration in the $10^{18}\text{-}10^{19}/\text{cm}^3$ range for most of the films studied attributed to carbon incorporation in the grown films. This is one of the highest p-type doping levels reported in AlGaAs . However, when the growth conditions were optimized, (Gong et al., submitted) carrier concentrations fell to the mid $10^{17}/\text{cm}^3$ range. Details of this study will be reported elsewhere.

Indium Gallium Phosphide

The InGaP was deposited directly on GaAs substrate (100), 2° off towards [110] (McDermott et al., 1990)(McDermott et al., submitted). The TMGa , Triethylindium (TEI), and phosphine (10 percent in H_2) were used as source materials. During growth, Phosphine Hydrogen (PH_3) flowed continuously on the column V side. While the substrate was under the PH_3 flow, TMGa was turned on and allowed to stabilize, then the substrate was rotated one revolution through the TMGa flux back to the PH_3 to deposit approximately a monolayer of Gallium Phosphide (GaP). The TMGa was then turned off and TEI was turned on and stabilized, while traces of TMGa were purged. The substrate was rotated through the TEI flux back to PH_3 to deposit approximately a monolayer of InP , and thus a Ga-P-In-P structure was deposited. The structure was deposited at substrate temperatures in the range $480\text{-}600^\circ\text{C}$. The grown layers were characterized by x-ray diffraction, photoluminescence, photoreflectance, and transmission electron microscope techniques.

The GaInP -grown films at 500 and 550°C showed high-quality, smooth-surface morphology when examined by Nomarski interference contrast microscopy (McDermott et al., 1990). Samples grown at 600°C showed increasing opacity. This may be because of the rapid surface depletion of P while the substrate is not PH_3 stabilized during the ALE rotation cycle. Double crystal x-ray diffraction rocking curves shown in Figure 5 have the (311) peaks of the GaAs substrate and InGaP epilayer. The relatively broad peaks for the substrate and the InGaP film are because of the limitations of our experimental x-ray set up. The ternary $\text{Ga}_{1-x}\text{In}_x\text{P}$ alloy grown at 500°C (sample A) has a peak corresponding to $x \approx .43$ with mismatch to the substrate of about 0.3 percent (see Figure 5(a)). The sample grown at 550°C has $x \approx 0.49$ and a mismatch of about < 0.1 percent as shown in Figure 5(b). The TEI and TMGa fluxes for these epitaxial films were chosen arbitrarily.

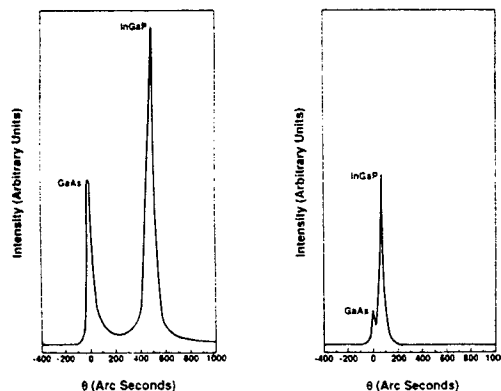


Figure 5. Double-crystal x-ray diffraction rocking curve for InGaP grown on GaAs substrate by ALE (a) grown at 500°C , sample A, (b) grown at 550°C , sample B.

The direct gap E_0 was investigated using room-temperature photoreflectance. The experimental results are shown by the solid line in Figure 6. The dashed line is a least-squares fit to the Aspnes third-derivative functional form for a three-dimensional critical point (Aspnes, 1980). For InGaP sample A, we find an energy gap of 1.797 ± 0.010 eV, as denoted by the arrow at the bottom of the figure, and a broadening parameter of 0.093 eV. Other samples grown using the same ALE growth sequence, the TEI and TMGa fluxes while doubling the PH_3 flux, have E_0 of 1.778 eV. To the best of our knowledge, these band-gap values are the lowest reported for this compound and are close to the theoretical prediction reported by Zunger (Zunger, private communication). The PL at liquid Helium temperatures (4 K) was also performed on sample A. The PL spectrum has a sharp peak at 1.868 eV with full width at half maximum (FWHM) of about 30 meV.

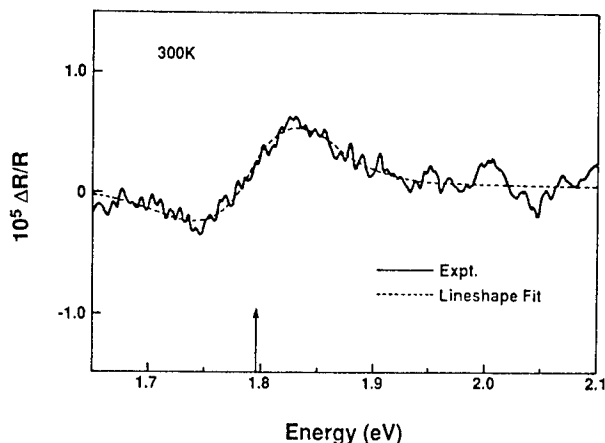


Figure 6. Photoreflectance spectrum at 300K (solid line) of InGaP sample A grown on a GaAs substrate. The dashed line is a least-squares fit to a third-derivative functional form for a three-dimensional critical point. The obtained value of the energy gap is indicated by the arrow at the bottom of the figure.

Cross-sectional transmission electron microscope (TEM) was also performed on these samples. Electron diffraction pattern for the $[110]$ zone axis has extra superlattice spots which are distinct and well defined, indicating the Copper Platinum (CuPt) type of ordering. Ideally, with the ALE deposition regime for this alloy, we would expect the column III sublattice to be ordered in the $[001]$ growth direction. Although we found no evidence of a (001) superlattice from our diffraction studies, preferential ordering took place in (111) alternating planes. Detailed TEM studies are under way of these ALE-grown films and the effect of growth conditions on the degree of ordering.

Sidewall Growth by ALE

Previously, deposition on GaAs grooves has been attempted both by conventional MOCVD and MBE. They both show problems caused by inherent growth mechanisms which are difficult to overcome. With MOCVD, gas hydrodynamics (mass transfer) causes film thickness variation inside grooves, leading to nonuniform growth and even no growth on specific surfaces (Hersee et al., 1986). Growth discontinuities have also been observed near the transition between superlattice structures grown on differently oriented adjacent planes. With MBE, no growth occurs under the mesa overhang because of shadowing effects. Moreover, growth rates on differently oriented crystal planes vary because of the difference in the source beam impingement angles combined with sticking coefficient dependence on crystallographic orientation.

Two types of grooves were patterned on GaAs (100) substrates, 2° off toward $\langle 110 \rangle$, by conventional photolithography and wet chemical etching techniques. Stripe openings, 8-20- μm wide and 300- μm apart were aligned on the photoresist either along the $[011]$ or $[0\bar{1}1]$ directions. For the $[011]$ -oriented stripes, a $1\text{H}_3\text{PO}_4/1\text{H}_2\text{O}_2/3\text{H}_2\text{O}$ etching solution was used, resulting in nearly V-shaped grooves. In case of $[0\bar{1}1]$ -oriented stripes, a $1\text{NH}_4\text{OH}/1\text{H}_2\text{O}_2/5\text{H}_2\text{O}$ etching solution was used, resulting in an inverted-trapezoid-shaped groove surrounded by overhanging reverse mesa structures. The etching was done at 16°C , and the grooves were 4-5- μm deep. The crystallographic orientation of the sidewalls was identified by precise angle measurements on the scanning electron microscope (SEM) image of $\{110\}$ cleavage planes.

The GaAs/ $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ strained multilayered structures were grown on the patterned GaAs substrates by both ALE and conventional MOCVD in the same reactor. For ALE growth, the substrate temperature was either 480 or 520°C and each GaAs layer consisted of 360 growth cycles, while that for InGaAs was 40 cycles. For MOCVD growth the substrate temperature was 630°C . The $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ layers served as markers to show the development of the growth front on variously oriented surfaces. Four or five periods of the multilayer structure were grown, giving a total thickness of the order of $1\mu\text{m}$, depending on the growth scheme.

Figure 7 shows a schematic of a five-period structure grown on $[011]$ -oriented grooves, obtained from a cross-sectional SEM photograph. The GaAs layers appear as dark lines with the InGaAs layers sandwiched in between. It is clear from Figure 7 that the thickness of the deposited film at the bottom of this groove, a (100) plane, is uniform over the whole surface and equal to that deposited on the $(^*100)$ surface on top of the mesa. Such

results have not been achieved either by MBE or MOCVD because of shadowing and gas hydrodynamic effects, respectively. Previously reported MOCVD growth at the bottom of a similar mesa structure shows nonuniformity with thinner films at the corner and thicker films at the middle region (Kamon et al., 1986).

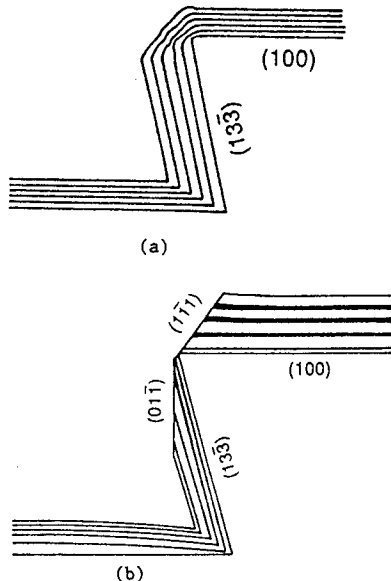


Figure 7 (a) and (b). GaAs/InGaAs multilayer structure grown on a (100) GaAs substrate with [011]-oriented grooves, (a) ALE, (b) MOCVD.

Growth on the (133) sidewalls is uniform over the entire surface with no apparent defects near the transition between the (133) and the (100) planes at the base of the groove. As was previously reported, (Usui et al., 1986) growth per cycle varies for differently oriented surfaces. For the sample shown in Figure 7(a), the growth rate on the (100) surface is 1.3 monolayer ($1.2 \times 2.83 \text{ \AA}$) per cycle while that on the (133) surfaces is approximately $2.16 \text{ \AA}$ per cycle. Samples grown under other growth conditions show different growth rates on the sidewalls. The ALE growth on planes having mixed Ga and As atoms, such as (133), is not fully understood, and in some cases the growth rate does not follow the predicted value (Usui et al., 1987). Thus, we believe that more basic studies are needed.

Figure 7(b) shows a schematic made from an SEM photograph of a four-period multilayer structure grown on an identical groove using conventional MOCVD at 630°C . The growth on the (100) surface at the base of the groove is not uniform because of inherent mass transfer limitations, consistent with previous reports (Usui et al., 1986) (Kamon et al., 1986). Also, the deposited film on the (100) original surface is thicker than that on the groove bottom. Growth on the sidewalls does not conform with the originally etched (133) planes, and thickness variations are observed, as well as formation of

(011) facets. Near the edge between the surface (100) plane and the etched (133) planes, growth is not continuous and (111)B facets are formed. This is probably because of the slow growth rate on (111)B surfaces often seen in MOCVD growth. The above results of conventional MOCVD growth are in striking contrast to ALE.

Planar-Doped Structures for Nonalloyed Contacts (Hashemi et al., 1990)

The ALE offers an attractive approach for the synthesis of δ -doped structures that can avoid some of the above-mentioned problems. The ALE is a low-temperature growth process ($400\text{--}500^\circ\text{C}$) which reduces dopant diffusion and prevents growth interruption by allowing only one temperature for the growth of an entire structure. With ALE, dopant atoms can be selectively introduced during either the Ga or the As exposure part of the ALE growth cycle, thus allowing the dopant to take the As or the Ga sites, respectively. This can enhance dopant incorporation and reduce the compensation ratio. The ALE also allows an accurate control of epilayer thickness between the dopant plane and the gate over a large area wafer, resulting in uniform values of pinch-off voltage and transconductance.

A growth rate of about $0.5 \text{ }\mu\text{m/h}$ was used with the substrate in the temperature range of $450\text{--}500^\circ\text{C}$. The undoped ALE-grown GaAs is n-type with background carrier concentration in the low $10^{15}/\text{cm}^3$ range. This material is slightly compensated because of residual carbon contamination incorporated during the ALE process.

The δ -doped structure was grown by ALE on both Cr-doped and Si-doped GaAs substrates. The H_2Se was introduced during the AsH_3 exposure part of the growth cycle with minimum AsH_3 flux (mass flow controller was set to its minimum value). This would allow the Selenium (Se) atoms to be efficiently incorporated in As sites. Exposure time to the H_2Se flux was on the order of 30 seconds and achieved carrier concentration that peaked in the $10^{18}/\text{cm}^3$ range as indicated from capacitance-voltage (C-V) measurements. Higher sheet carrier concentrations peaking in the $10^{19}/\text{cm}^3$ range were achieved by going through one or two ALE cycles with minimum AsH_3 and maximum H_2Se during the column V exposure. Figure 8 shows the C-V profile of a δ -doped structure grown on a Si-doped substrate. The structure is made of $1000 \text{ \AA}$ of undoped GaAs, then a planar-doped layer, followed by $500 \text{ \AA}$ of undoped GaAs all grown by ALE at the same temperature [500°C]. The observed C-V profile is sharp, peaking at about $10^{19}/\text{cm}^3$ with FWHM of about $50 \text{ \AA}$. The FWHM is comparable to the best reported planar doping achieved by MBE (Chiu et al., 1988). Previous efforts (Usui et al., 1987) to

achieve planar doping by ALE using chloride sources had peak concentrations in the $10^{18}/\text{cm}^3$ range and FWHM of 80 Å.

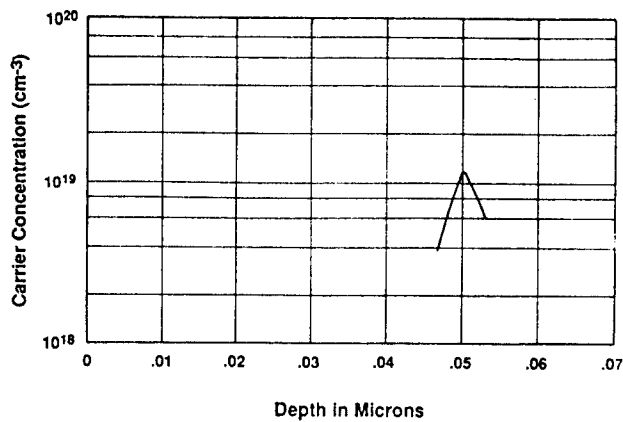


Figure 8. C-V profile of a delta-doped structure

This high carrier concentration achieved by planar doping can be used for nonalloyed ohmic contacts. In this work, a set of ten Se planar-doped sheets, each separated by 50 Å of GaAs, was grown using ALE. Hall measurement for this structure gave carrier concentrations of $2 \times 10^{19}/\text{cm}^3$ for the 500 Å epitaxial film grown on Cr-doped substrate. This value is considered one of the highest carrier concentrations reported for GaAs using metalorganic sources. The peak carrier concentration for these planar-doped sheets is higher than the above-measured bulk value obtained from Hall measurement. The growth of this ALE structure was followed by metalization using Au-Ge-Ni. The nonalloyed contact has contact resistivity in the low $10^{-6} \Omega \text{ cm}^2$, with a lowest measured value of $0.7 \times 10^{-6} \Omega \text{ cm}^2$. The contact resistivity was measured using the transmission line method. We have not observed any improvement in the value of this contact resistivity upon annealing. These results show the potential application of ALE for nonalloyed contacts.

Planar-Doped Field Effect Transistor (Hashemi et al., 1990)

Figure 9 shows a schematic of the δ -doped FET grown by ALE at 500°C. The schematic consists of a GaAs undoped buffer layer followed by five periods of GaInP/GaAs superlattice, a 500 Å undoped GaAs, a Se planar-doped layer peaking to about $10^{18}/\text{cm}^3$, then another 500 Å of undoped GaAs. The sample was then removed from the ALE reactor. Regions under the source and drain were chemically etched, followed by regrowth of n^+ contacting layers. The n^+ contacting layers are made of five planar-doped sheets separated by

50 Å of GaAs. Thus, they allow direct contact to the planar-doped sheet in the channel of FET. This approach was found to reduce the source and drain parasitic resistances and improve device performance. The dc characteristics of the δ -doped FET are shown in Figure 10. The FET has an extrinsic transconductance of 120 mS/mm and current density of 300 mA/mm for gate length and width of 1.2 and 300 μm , respectively. The gate source breakdown voltage was 8V. Finite output conductance and pinch-off difficulty are believed to be a result of the relatively high carrier concentration of the ALE-grown GaAs buffer ($1 \times 10^{16}/\text{cm}^3$), the Se memory effects, and the very small conduction-band discontinuity between the ALE-grown GaInP and GaAs.

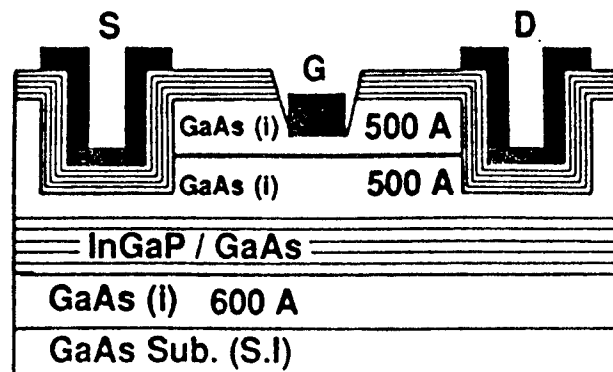


Figure 9. Cross-section of delta-doped FET by ALE.

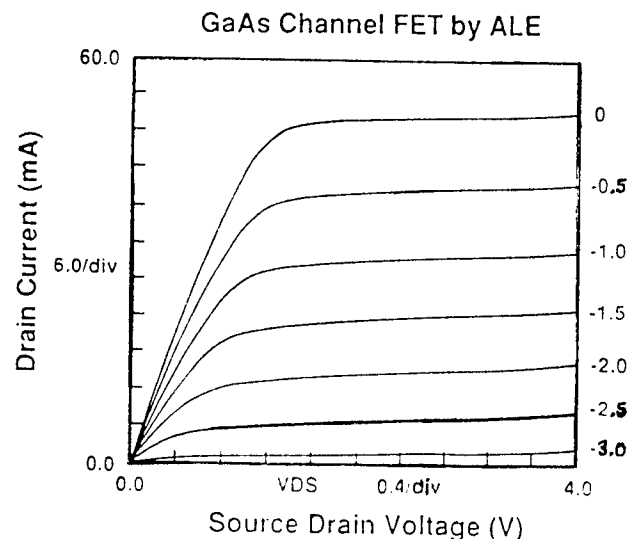


Figure 10. Drain current characteristics of delta-doped FET.

Extremely Low Leakage GaAs PiN Junctions (Bedair et al., accepted).

The properties of a PiN structure in GaAs grown by the ALE technique were studied. The electrical properties of these structures, particularly the reverse bias leakage caused by thermal generation in the depletion region, reflect the quality of ALE-grown material. Additionally, PiNiP capacitors with long-charge storage times are desirable for use in GaAs-based dynamic RAM cells. The layer-by-layer ALE deposition process that proceeds in a two-dimensional fashion can improve bulk material quality to enhance capacitor storage times.

The H_2Se and dimethylzinc introduced with the arsine flux are used as n- and p-type dopants. The growth temperature was 500°C for the N+ and P+ layers (see Figure 11) to achieve a carrier concentration of about $10^{19}/\text{cm}^3$. The other active layers, including the undoped layers, were grown at 600°C . The C-V carrier profiling indicates uniformly doped P- regions of $9 \times 10^{16}/\text{cm}^3$ in the diode structures. Following the growth, Au was thermally evaporated and patterned by liftoff to form nonalloyed contacts to the P+ cap layer.

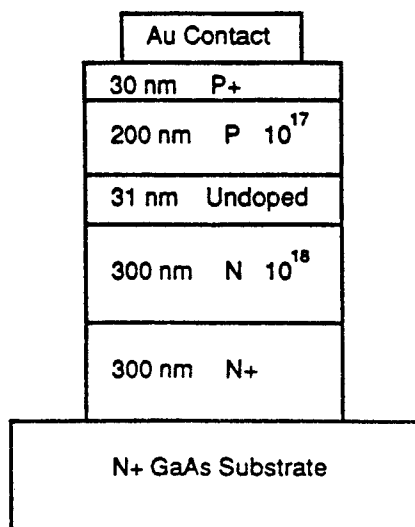


Figure 11. Cross-sections of the PIN diode

The PiN diode reverse leakage currents were too small for measurement with a picoammeter at room temperature, so initial characterization was conducted at temperatures above 110°C . The forward bias characteristics are roughly exponential with average n factors of 1.5 to 2 over the voltage range of 0.1 to 0.6 V. The reverse bias current increases approximately as the square root of the voltage, suggesting that thermal

generation in the depletion region is the primary source of leakage. The reverse bias generation current density is approximated to first order by (Duncan et al., 1987)

$$J_R = J_{R\text{Bulk}} + J_{R\text{Perimeter}} = qW_G G_B + qW_G (P/A) G_p \quad (1)$$

where G_B is the bulk generation rate ($\text{cm}^{-3}\text{sec}^{-1}$), G_p is the effective perimeter generation rate ($\text{cm}^{-2}\text{sec}^{-1}$), and P/A is the diode perimeter-to-area ratio (cm^{-1}). The generation width W_G is approximately the reverse bias depletion width minus the zero bias depletion width.

The surface generation current scales with perimeter, so the measured current density given by (1) increased with shrinking square device dimensions. The experimental dependence of generation current density on perimeter to area ratio at 1 V reverse bias is shown in Figure 12. Using (1), the surface generation rate, G_p , can be extracted from the slope of Figure 12, while the bulk generation rate G_B can be deduced from the y-intercept. When fitting experimental data such as in Figure 12, small variations in the data can cause large perturbations in the intercept, making it difficult to estimate the bulk generation component. However, it is clear from Figure 12 that bulk generation is small compared to the perimeter generation for the size devices tested. The fact that the bulk generation could not be determined accurately indicates the high quality of the ALE-grown junctions.

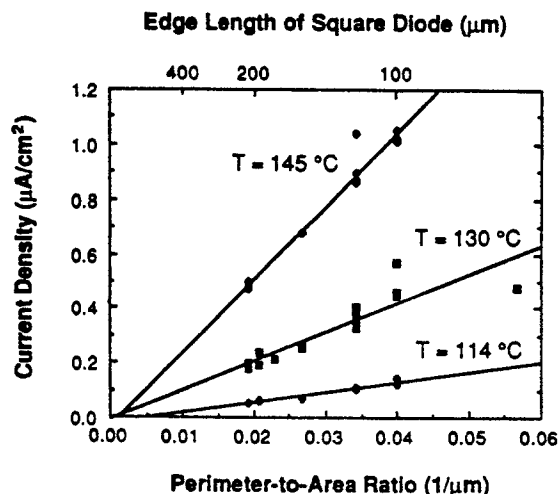


Figure 12. Dependence of current density on device perimeter-to-area ratio at 1V reverse bias. The zero extrapolated y intercept indicates that generation in the bulk ALE-grown material is insignificant.

Conclusion

The ALE growth of III-V compounds has suffered from several shortcomings such as a limited range of growth temperatures, high carbon background, and difficulties in the synthesis of ternary alloys. We have demonstrated that these problems can be minimized by

special reactor and susceptor designs that allow the substrate to rotate between streams of the precursor gases. Such an approach was used to grow ternary alloys such as AlGaAs, InGaP, and InGaAs and deposit superlattice structures on the sidewalls of trenches. ALE was also used for the deposition of highly doped structures for nonalloyed contacts, planar-doped FET, and p-n junctions with extremely low leakage current. We believe that ALE is now capable of offering a growth technique that is comparable with other techniques, while maintaining control of the deposition process on the monolayer level.

Acknowledgement

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References

- Aspenes, D.E. 1980. In *Handbook on semiconductors*, vol. 2, ed. M. Balkanski, 109. New York, North-Holland.
- Bedair, S.M., M.A. Tischler, T. Katsuyama, and N.A. El-Masry. 1985. *Atomic layer epitaxy of III-V binary compounds*, 47: 51-53.
- Bedair, S.M., B.T. McDermott, K.G. Reid, P.G. Neudeck, J.A. Cooper, and M.R. Melloch. 1990. Extremely low-leakage GaAs PiN junction and memory capacitors grown by ALE, *Electronic Device Letters*, 11: 261-263.
- Chiu, T.H. 1989. Direct observation of GaAs atomic layer epitaxy by reflection-energy electron diffraction, *Applied Physics Letters*, 55: 1244-1246.
- Chiu, T.H., J.E. Cunningham, B. Tell, and E.F. Schubert. 1988. Diffusion studies of the Si S-doped GaAs by capacitance-voltage measurement, *Journal of Applied Physics*, 64: 1578-1580.
- Duncan, T.E., J.A. Cooper, M.R. Melloch. 1987. A thermal generation-limited buried well structure for room temperature GaAs dynamic RAMs, *IEEE Electronic Device Letters*, 8: 243-245.
- Gong, J.R., Colter, F., Jung, D., Hussien, S., Parker, C., Dip, A., Duncan, W., and Bedair, S.M., *Journal of Crystal Growth*, submitted.
- Gong, J.R., Jung, D., El-Masry, N., and Bedair, S.M., Atomic layer epitaxy of AlGaAs, *Applied Physics Letters* (to be published).
- Hashemi, M., J. Ramdani, B.T. McDermott, K. Reid, and S.M. Bedair. 1990. Atomic layer epitaxy of planar-doped structures for nonalloyed contacts and field effect transistor, *Applied Physics Letters*, 56: 964-966.
- Hersee, S.D., E. Barbier, and R. Blondeau. 1986. A study of the orientation dependence of GaAlAs growth by MOVPE, *Journal of Crystal Growth*, 77: 310-320.
- Jeong, W., Menu, E., and Dapkus, P.D. 1988. Steric hindrance effects in atomic layer epitaxy of InAs, *Applied Physics Letters*, 55: 244-246.
- Kamon, K., M. Shimazu, K. Kimura, M. Mihara, and M. Ishii. 1986. Selective growth of AlGaAs embedded in etched grooves on GaAs by low-pressure OMVPE, *Journal of Crystal Growth*, 77:297-302.
- Kobayashi, N., T. Makimoto, Y. Yamauchi, and Y. Hovikoshi. 1989. Flow-rate modulation epitaxy of GaAs and AlGaAs, *Journal of Applied Physics*, 66:640-651.
- McDermott, B.T., K. Reid, N. El-Masry, S.M. Bedair, W.M. Duncan, W. Yin, and F.H. Pollak. 1990. Atomic layer epitaxy of GaInP ordered alloy, *Applied Physics Letters*, 56:1172-1174.
- McDermott, B.T., K. Reid, N. El-Masry, and S.M. Bedair, J., *Crystal Growth* (submitted).
- Mochizuki, K., M. Ozeki, K. Kodoma, and N. Ohtsuka. 1988. Carbon incorporation in GaAs layer grown by atomic layer epitaxy, *Journal of Crystal Growth*, 93:557-561.
- Ohno, H., H. Ishii, K. Matsuzaki, and H. Hasegawa. 1989. Self-limiting deposition of Ga on GaAs surface by thermal decomposition of diethylgallium chloride observed by x-ray photoelectron spectroscopy, *Applied Physics Letters*, 54:1124-1126.
- Tischler, M.A. and S.M. Bedair. 1990. Atomic layer epitaxy, ed. T. Suntola and M. Simpson, Chapter 4, Blackie and Son.
- Usul, A. and H. Sunakawa 1986. GaAs atomic layer epitaxy by hydride VPE, *Japanese Journal of Applied Physics*, 25:L212-L214.
- Usul, A. and H. Watanabe. 1987. Atomic layer epitaxy: a new tool for novel modulated semiconductor structures, *Third International Conference on Modulated Semiconductor Structures*, Montpellier, France.
- Zunger, A. Private communications.

MATERIALS

Filling the Gap with Explosively Formed Projectiles

by Ronald W. Armstrong, Liaison Scientist for Energetic Materials and Propellants for the Office of Naval Research European Office. Dr. Armstrong is on leave from the University of Maryland, College Park, Maryland.

Introduction

Research on armor penetration and shaped charges continues in Europe and the U.S. to be an important topic for defense-related objectives because these subjects are not yet fully understood. Di Capua (1989a) gave a recent report on activities at the French-German Research Institute Saint Louis (ISL). Here, a report is given mostly on the British Royal Armament Research and Development Establishment (RARDE), Fort Halstead, United Kingdom (U.K.). The research effort to be described is one component of an European independent program group. Also involved are French researchers at the Centre d'Etudes de Gramat, 46500 Gramat, France, and German colleagues at the Ernst-Mach-Institut, W-7858 Weil am Rhein, Federal Republic of Germany (FRG).

This research description begins with the fact that most materials are known to be stronger when they are forced to deform plastically at faster deformation rates. Explosively formed projectiles (EFPs) are one step removed from the most extreme example (DiCapua 1989c). The EFPs are generated at velocities of the order of several km/sec. This speed is between the speed of a shaped-charge projectile traveling about 10 times faster and the speed of dynamic impact tests done with cylinders, plates, or dropweights, about one-tenth as fast. The fastest conventional laboratory-type tension or compression tester is run at about one hundredth of the velocity for the impact testers and can easily be further reduced to about one millionth of that velocity.

Considering variations in the states of deformation and the sizes and shapes of specimens, the imposed rates of straining over these testing conditions can vary from about a ten thousandth/sec to ten million/sec. A goal is to connect the strength properties of structural materials over this full range of deformation rates. Most reference strength data are obtained at relatively slow rates, but the high strain rate end of such deformation testing (from one thousand/sec onwards to include the generation of shock

waves) is especially interesting recently. This is because of the accumulation of evidence that special internal structural changes occur in this regime (for example, centered on the general observation that materials appear to be even stronger than expected and, also, to be surprisingly tough).

Until now, remarkable progress has been made in this subject area using the continuum theory of plasticity. For it, the "laws" of mechanics are formulated and applied with a minimum amount of information being built into the theory concerning the internal microstructure comprising any material in hand. Now, however, greater emphasis seems to be placed on the contribution that such microstructural information can make to more fully understanding the dynamic deformation and fracturing properties of individual materials (Armstrong et al. 1991).

In the present case, a major goal of current research in Europe, the U.S., and elsewhere, is to obtain reliable constitutive equations for the strain rate, temperature, strain hardening, polycrystal grain size, and other microstructural dependencies of material strength properties. These elements will be employed in computer code predictions of mechanical behaviors too difficult or costly to be directly measured. The indication is that the equations must be based on dislocation micromechanics modeling of deformation and fracturing processes because the microstructurally bound crystal dislocation defect is responsible for these events.

Microstructural Features

Armco iron, produced by the American Rolling Mill Company (or other iron alloys designed to be equivalent) continues to be a reference material for studies from the U.S. to the U.S.S.R. for understanding the deformation and fracturing properties of a reasonably low carbon-iron material. Armco iron contains approximately 0.008 weight percent carbon. At RARDE, Barry Goldthorpe and colleagues have produced well-characterized

material for testing and have done post-test metallurgical analyses of the deformed microstructures. Armco iron EFPs were formed from a liner and charge assembly leading to a velocity of about 2100 m/s going into a soft recovery retrieval system. The starting Armco iron material had been heat treated to produce an average grain size of $30\text{ }\mu\text{m}$ and a Vickers hardness of 80 kgs-force/sq mm. The relatively low hardness was achieved by precipitation of the carbon. Composition B or Octol were the explosives. A 0.4-Mbar primary shock and somewhat lesser reflected wave produced an increase in temperature of about 180°C during the explosive loading. Further larger temperature rises were associated with the follow-on plastic deformation processes to be described.

A longitudinally sectioned and chemically etched specimen, with its leading (top) edge inverted from the original oppositely curved shell, is shown in Figure 1. Three important microstructural regions were differentiated according to the combined appearance of individual crystal "grains" just visible as dots at the relatively low magnification of the figure.

1. A surprisingly lightly deformed original surface region of essentially unchanged grain shapes except for their containing numerous deformation twins that were produced during passage of the initial shock waves
2. A substantially deformed internal EFP region defined by exaggerated grain shapes so heavily deformed that twin boundaries cannot be recognized with the optical microscope
3. A central core of recrystallized, fine-grained polycrystalline material; also showed regions of grain growth.

Deformation Twinning and Shock Hardening. The inverted external surface region of the EFP showed little change in shape of the original grains even though they were heavily crossed with deformation twin lamellae that were attributed to passage of the shocks. The hardness of the material had increased, however, to a substantial value of about 200 kg force/sq mm. Two effects were proposed to be responsible for the shock hardening.

1. Presence of the deformation twins that had formed
2. Remnant hardening from plastic deformation that occurred during the near-reversible coupling of the uniaxial compressive shock followed by its unloading expansion wave; estimated to involve a strain excursion of about 0.2.

Both sources of shock hardening are of interest. In the first case, Zerilli and Armstrong (1988) have proposed that the twins produce an important strengthening increment at the time of shock passage by effectively reducing the grain size of the material. The follow-on



Figure 1. Explosively formed projectile with inverted "bullet-head" and "folded wings."

plastic deformation then occurs in a finer-grained, stronger material. This must be accounted for in computations of the "new" material strength properties. In the second case, the idealized shock condition of a unidirectional strain state precludes the movement of dislocations over any significant distance. Therefore, the strengthening needs to be accounted for at a submicroscopic scale, say, of nanometers (probably in terms of a network of residual dislocation loops). Bandak and colleagues (1991) have been attempting to model the shock/dislocation generation process with molecular dynamics calculations.

An important observation for the dynamic hardening process relates to the shocked and substantially deformed internal region of the EFP where the hardness was found to be essentially unchanged from that for the shocked but otherwise "undeformed" surface grains. This was interpreted at RARDE to mean that the follow-on plastic flow occurred for the internal region during EFP formation with very little further strain hardening. Alternatively, specimens cut out from the surface region showed pronounced hardness increases after further straining. The flow stress of the shocked material was

simply shifted upwards by a constant stress increment compared to the unshocked material when both materials were tested over a range of strain rates.

Ian Cullis, Phil Church, and colleagues have utilized such observations in RARDE DYNA2D hydrocode calculations used to model the EFP results (Church and Cullis 1989). Here, the shock hardening has been accounted for by adding an athermal stress increment to the constitutive equation used to describe the deformation behavior. A modified form of an equation proposed by Zerilli and Armstrong (1987) was used (see DiCapua 1989b). Less success was indicated for an initial French (Gramat) effort to account for the shock hardening in terms of adding a strain increment to account for the effect.

Recrystallization and Localized Flow. Sufficient temperature rises occurred as part of the follow-on plastic deformation processes involved in generating the EFP to lead to the formation and growth of the new grain structure that was observed in the central core region shown in Figure 1. This process of recrystallization (in the solid state) has been extensively studied in the metallurgical community so that reference times at temperatures could be established for local areas of the EFP from separate experiments using combinations of deformation and heat treatments. From such experiments and by using estimates of heat flow, a temperature of 710 to 730°C was estimated for the boundary across which recrystallization had occurred. Temperatures between 850 and 910°C were estimated to have been reached in the center of the EFP where the recrystallized grains had grown in size. These are temperature estimates that apply over regions of multiple-grain diameters and therefore are lower than the temperatures reached, say, within the volume of a single grain.

Quite intense regions of localized shear, even containing small cracks, are observed in the whitish "fingers" spreading from the central now-inverted (inside) zone of the EFP. Flow within these microscopic shear bands was attributed to unstable adiabatic shear. An extremely fine-grained structure was observed adjacent to the cracks contained within these bands, thus being indicative of exceptionally high temperatures having been reached there. The occurrence of such shear banding is an active area of research (Armstrong et al. 1991) both to understand the role of shear banding in EFP formation and in other deformation processes where target penetrations can be achieved with appreciably reduced expenditures of energy if the deformation can be localized in a small volume of the material.

Related Research

The RARDE effort is connected in the U.K. with university research activities at Cambridge, Leeds, Manchester, and Oxford. The development of improved dynamic testing methods and diagnostics are areas of research. For example, a miniaturized cylinder impact (Taylor) test facility has been designed at Cambridge, giving an advantage of increasing achievable strain rates. Test results have been obtained on the metallurgical-composite W7Ni3Fe alloy. High strain-rate fracture testing of copper and iron materials, improving on Bridgman's analysis for the triaxial stress state in unstable "necking" deformation in a tensile test, is being done at Leeds. Breakup of an elongating shaped-charge is now thought to occur as a result of "necking." Bridgman's pioneering worry about fundamental differences between large strain deformations in torsion and tension are relevant today in respect of difficulties in matching stress/strain results now reliably measured after substantial deformations.

Torsion testing is a primary research interest of J. Petit, P.-L. Hereil, and colleagues at the Centre d'Etudes de Gramat, France. Measurements of shock strengthening and the reduced strain hardening characteristics of the shocked material are being investigated in this case for a Holtzer iron containing 0.004-weight percent of carbon. The deformation structures, including twinning, and the subsequent mechanical properties of EFPs, with complementary thermal analysis of their recrystallization properties, are being studied, along with the shocked structures occurring in plate impact experiments.

W. Arnold (formerly at the Fraunhofer-Institut für Kurzzeiddynamik, Ernst-Mach-Institut, Abteilung für Ballistik, FRG and now at Messerschmitt-Bolkow-Blohm, GmbH, W-8898 Schrobhausen) has been investigating, with W. Sachs (1990), the wave profiles of free surface velocities versus time for shocks in plate impact tests of Armco iron and other steel alloys. This testing method is a latest example of application for the dislocation mechanics-based constitutive equations proposed by Zerilli and Armstrong (1991). Twinning occurs in connection with the elastic precursor relaxation here too. A strain-rate regime of 100,000 to 10,000,000/sec applies for the test but the overall strain is small. Locally, fracture can be induced by cleavage or ductile hole-joining in a spall-type laminar splitting of the plate. The important general observation made again with this test, in line with the results described above and those reported by other researchers in the field, is that the shocking process immediately produces its own built-in strengthening that is progressively enhanced to the point of achieving exceptionally high stress levels for spall fracturing.

References

- Armstrong, R.W., V. Ramachandran, and F.J. Zerilli. 1991. Dislocation mechanics description of dynamic plasticity and fracturing properties, Keynote paper for the *Transactions of the Indian Institute of Metals*, in print.
- Arnold, W. and W. Sachs. 1990. Measuring and simulation of steady shock wave profiles in Armco iron. In *Shock Waves in Condensed Matter 1989*, 337. New York: Elsevier Science Publishers B.V.
- Bandak, F.A., R.W. Armstrong, A.S. Douglas, and D.H. Tsai. 1991. Nanodislocation structures for shock strengthening. In *American Physical Society Conference on Shock Compression of Condensed Matter*, held in Williamsburg, Virginia, 17-20 June 1991.
- Church, P. and I.G. Cullis. 1989. The use of microscopically based constitutive models in explosive metal deformation studies. In *Proceedings of the International Conference on the Mechanical Properties of Materials at High Rates of Strain, Institute of Physics Conference Series No. 102*, Her Majesty's Stationary Office, London, 205.
- Di Capua, M.S. March 1989a. Research on armor penetration, shaped charges and segmented kinetic energy projectiles at the French-German Research Institute-ISL-St Louis, France. *ESNIB* 89-03:40.
- Di Capua, M.S. July 1989b. Fourth Oxford conference on the mechanical properties of materials at high rates of strain. *ESNIB* 89-07:35.
- Di Capua, M.S. September 1989c. The 11th international symposium on ballistics. *ESNIB* 89-08:47.
- Zerilli, F.J. and R.W. Armstrong. 1 March 1987. Dislocation-mechanics-based constitutive relations for material dynamics calculations. *Journal of Applied Physics*, 61(5):1816.
- Zerilli, F.J. and R.W. Armstrong. 1988. Dislocation-mechanics-based constitutive relations for material Dynamics Modelling: slip and deformation twinning in iron. In *Shock Waves in Condensed Matter 1989*, 273. New York: Elsevier Science Publishers B.V.
- Zerilli, F. J. and R.W. Armstrong. 1991. Modelling shock waves with dislocation mechanics based constitutive relations. In *American Physical Society Conference on Shock Compression of Condensed Matter*, held in Williamsburg, Virginia, 17-20 June 1991.

MOLECULAR BIOLOGY

New Developments in Diagnosis and Control of Infectious Diseases

by Dr. Jeannine A. Majde, Director, Systems Biology, the Office of Naval Research, Arlington, Virginia

Introduction

Sponsored by the International Union of Microbiological Society (IUMS), the Symposium on New Developments in Diagnosis and Control of Infectious Diseases was held on August 24-26, 1990, in Berlin, Federal Republic of Germany (FRG). The theme was the effect of developments in molecular biology on control of infectious diseases in developing countries. While the impact of parasitic infections such as malaria is generally recognized, the impact of acute respiratory and gastrointestinal infections with bacteria and viruses has received less attention and resources. Bacteria and viruses kill yearly 30-40 million individuals, mostly children, in developing countries. Of those diseases, approximately one third are of viral origin (polio, rotaviruses, paramyxoviruses such as measles, which alone kills nearly 10 million people annually). The World Health Organization has previously eliminated smallpox virus (in large part because it has no vector other than man) by intensive surveillance and vaccination. Their next target is polio virus, followed by yellow fever. Both of these agents have effective vaccines and the polio vaccine is inexpensive enough to consider administering it on a world-wide basis. Measles and hepatitis B are on the drawing board. The human is not the only target for disease control in developing countries where food animal pathogens also play a major social and economic role.

In the last few years, molecular biology has developed diagnostic tools, such as the polymerase chain reaction, that offer great potential for better defining the causative agents of important diseases, especially gastrointestinal viruses that are resistant to cell culture isolation. By allowing the determination of microbial protein structure, molecular techniques can help define common epitopes that may serve as vaccine antigens for more than one organism subtype. Major changes in vaccine technology are promised by genetic engineering and mass production of microbial protein antigens. However, these

products are still too expensive to distribute on a world-wide scale. While using vaccinia virus recombinants as a vaccine approach still receives a lot of attention, reservations about the pathogenicity of vaccinia (as well as the resistance of individuals previously immunized to it) has reduced enthusiasm for the approach. A better vaccine adjuvant is needed that promotes the immune response to peptide antigens, especially mucosal immunity, in a nontoxic and efficient manner that allows one immunization to serve.

A nontechnological need addressed by Dr. Choto, Zimbabwe, is a way to educate largely illiterate populations. He illustrated some successful programs used in his country regarding transmission of AIDS. The symposia presented a balanced and realistic picture of the development of disease control approaches for developing countries.

The VIIIth International Congress of Virology, was held August 26-31, 1990. The first virology congress took place in 1968 with about 500 participants; the 1990 congress had nearly 5,000 participants! The intervening growth reflects both the value of viruses as tools of molecular biology as well as their growing importance as causes of cancer and epidemic disease, especially AIDS. The congress was comprised of 5 symposia, 92 workshops, and 94 poster sessions presenting 3,000 abstracts. This report will cover only the highlights.

A bridge between the IUMS Symposium and the Virology Congress was the Mudd Award Lecture presented by Nobel Laureate Dr. D. Carleton Gajdusek, U.S. National Institutes of Health (NIH). Dr. Gajdusek discussed the interesting theory that a mutant form of the mammalian protein amyloid is the infectious agent causing the spongiform encephalopathies such as Kuru, Creutzfeld-Jakob, and scrapie. This protein is also found in Alzheimer's disease brain. While he made a strong case for the novel concept of a self-replicating protein agent, the critical demonstration that the pure protein can induce the disease has yet to be done. Also recent findings using the polymerase chain reaction reveal that

ribonucleic acid is present in purified Creutzfeld-Jakob "protein" preparations and indicate that a more conventional type of infectious agent may be involved. The amyloid theory fueled much debate throughout the meeting.

Coding Strategies

Viruses are obligate parasites composed of a few proteins and a relatively simple nucleic acid genome. They have apparently arisen many times in evolution and have developed many strategies for replication and maintenance in their host populations.

A. Levine, Princeton University, New Jersey, summarized the strategies of the DNA viruses (herpesviruses, adenoviruses, papovaviruses, hepadnaviruses, parvoviruses), or those RNA viruses with the ability to produce DNA capable of integrating into the host genome (retroviruses) that establish chronic and often oncogenic infections by becoming an actual part of the host. Integrating DNA viruses must stimulate growth (including neoplastic growth) because they need cell division to replicate. This is often achieved by inactivating negative regulators of cell growth. The DNA poxviruses, which are more like chlamydia than viruses, do not integrate their DNA but maintain themselves in part by being extremely stable in air. Recently, they have been found to use host cytokine receptors to gain entry into cells.

J. Strauss, California Institute of Technology, Pasadena, and R. Lamb, Northwestern University, Evanston, Illinois, discussed strategies of the more complex RNA viruses that do not make DNA proviruses (myxoviruses, paramyxoviruses, arboviruses, coronaviruses, rhabdoviruses, arenaviruses) that have exploited animal reservoirs and vectors (including insects, together with their antigenic mutability to maintain themselves in host populations). Some mammalian RNA viruses may actually be derived from plant viruses with which they share some genes (Sindbis with Tobacco Mosaic is the established case). The RNA picornaviruses (mostly water borne) have adopted the strategy of the poxviruses by becoming physically stable in the environment. Many other RNA viruses exploit mammalian vectors that maintain active but nonpathogenic infections. Renaviruses in rodents are a classical example.

H. Sanger, Max-Planck Munich, FRG, described the viroids, recognized primarily in plants, which are composed of small RNA molecules free of associated protein. They protect their tiny naked circular genomes (240-480 nucleotides) by assuming extensive double-stranded secondary structures resistant to nucleases. The delta agent is a human pathogen that is viroid like, replicates only in the presence of hepatitis B

virus, and appears responsible for development of chronic hepatitis. Viruses are omnipresent among *prokaryotes* and *eukaryotes* and even viruses themselves, and seem to have invented an endless array of complex stratagems to survive in a hostile world.

Membrane Proteins and Immunity

Many viruses use host cell membrane lipid for envelopes. Such viruses often fail to kill their host cells by using budding, rather than lysis, as a means of exiting. The envelopes also assist their owners in entering new host cells by fusion or by displaying appropriately viral proteins that bind to host cell receptors.

A. Helenius, Yale, discussed the role of pH and protein kinase C in cell entry by influenza virus, while R. Compans, University of Alabama, Birmingham, described the relationship of epithelial cell polarity to viral entry and exit by several RNA viruses. The exit site may determine whether a virus stays on the epithelial surface or is disseminated systemically.

J. Skehel, National Institute for Medical Research, London, discussed the structure of the B and T cell epitopes of influenza hemagglutinin involved in induction of immunity, while M. Davis, Stanford University, California, illustrated the relationship of influenza hemagglutinin with the major histocompatibility *loci* of man.

The symposium closed with a discussion by M. Oldstone, Scripps Clinic, San Diego, California, illustrating the importance of cytotoxic T-cell-directed epitopes in viral clearance in the acute and chronic lymphocytic choriomeningitis virus models.

Retroid Viruses--Expression and Regulation

Retroid viruses use the enzyme reverse transcriptase to produce DNA, and include the classical retroviruses (such as murine leukemias or HIV-1), hepadnaviruses (hepatitis B), plant viruses (such as cauliflower mosaic), and the virus-like entities termed retrotransposons. An emerging theme in retroid virology is the role of stable RNA secondary structures (dsRNA) in integration and transcriptional regulation.

H. Varmus, University of California, San Francisco, discussed the requirement for long terminal repeats, which contain extensive secondary structure, in provirus integration; the function of the dsRNA is unknown. However in RNA transcription, the dsRNA loops are thought to affect ribosomal movement and allow frameshifting within the viral genome.

W. Haseltine, Harvard, Boston, Massachusetts discussed the role of dsRNA structures, nuclear factors such as NF- κ B, and viral nonstructural proteins in HIV-1 replication. H. Schaller, Heidelberg University, FRG,

discussed the polymerase gene of hepatitis B virus. This gene codes for the viral reverse transcriptase, an RNase H, and a primer, in which proteins are incorporated into the virion along with the circular viral DNA. The polymerase mRNA contains a 94-base dsRNA pseudoknot, also incorporated into the virion, that is highly conserved.

T. Hohn, Friedrich Miescher Institute, Basel, Switzerland, described the presence of dsRNA in the leader sequences of cauliflower mosaic. A. Kingsman, Oxford University, U.K., described the structure of retrotransposons, retrovirus-like particles that are not infectious because they do not exit the host cell, but which do affect host cell function by integrating. They lack the envelope gene of retroviruses, but are otherwise genetically similar. Because they can be produced economically by yeasts, genetic variants containing HIV-1 genes are being considered as vaccines.

The session closed with an added presentation by L. Montagnier, Institut Pasteur, Paris, France, on the possible role of mycoplasma in HIV-1 pathogenesis. Mycoplasma are ubiquitous bacteria-like organisms lacking a cell wall. They contaminate most cell cultures and populate the respiratory tract and other mucosal surfaces of most individuals. They have also been found in blood cells of AIDS patients. Montagnier feels that they may represent a necessary cofactor for successful replication of lentiviruses such as HIV and SIV in lymphocytes. If they are removed by gamma radiation sterilization, they are not killed but are only inhibited by most antibiotics. T-cell lines previously capable of replicating HIV-1 cease to do so. Restoration of the mycoplasma superinfection with common *M. fermentans* species restores the ability to replicate HIV-1. Killed mycoplasma are also active. They appear to function like cytokines that stimulate HIV-1 replication via NF- κ B activation.

Molecular Basis of Disease

H. zur Hausen, Deutsches Krebsforschungszentrum, Heidelberg, FRG, reviewed the role of papilloma viruses in human cancer of the genital tract. Of the known 25 papilloma virus types, types 16 (cervical squamous cell carcinoma) and 18 (adenocarcinoma) have been associated with cancer. These virally associated genital tract tumors are most frequent in developing countries with 500,000 new cases annually. In developed countries, the viruses are more commonly associated with tumors of the lung, breast, and stomach. Certain genes have been defined as being expressed in neoplastic genital keratinocytes; the DNA is not integrated in clinical material. Herpes virus (HSV, CMV) coinfection may contribute to the disease induction, as does smoking,

chronic bacterial and protozoal infections, and mutagenic food.

R. Gallo, NIH, discussed the human CD4 T-cell as a target cell for the oncornaviruses HTLV-1 and -2 (which immortalize the cell), the lentiviruses HIV-1 and -2 (which eventually kill the cell) and human herpes virus-6, or HHV-6, (which also kills the cell). He also talked about the role of the viral gene products *rex* and *tax* in HTLV infections and the homologous proteins of HIV *rev* and *tat*. *Tax* and *tat* are secreted by infected cells and induce IL-2, IL-2 receptor, TNF, GM-CSF, HLA-DR, *c-fos*, etc., via NF- κ B. *Tat* also acts as a growth factor for Kaposi's sarcoma tumor cells, which secrete an angiogenic factor and induce tumors in nude mice. Many affected tissues in AIDS and tropical spastic paraparesis (HTLV-I) patients are not infected by the virus and may be manifesting a toxic effect. Coinfection with any of the CD4 tropic viruses will enhance the development of AIDS in HIV- infected individuals.

B. Roizman, University of Chicago, Illinois, discussed the biology of herpesviruses and latency. These large, complex viruses express at least 22 essential genes and 29 supplemental genes during three cycles of protein synthesis, which kills the host cell. In latently infected sensory neurons, the viral DNA is not integrated into the genome, as previously assumed, but is maintained as an episome: 10-100 copies per neuron. Deprivation of nerve growth factor results in viral replication.

V. ter Meulen, University of Würzburg, FRG, discussed the significance of measles and related paramyxoviruses in human and animal disease and current knowledge of their molecular biology. Measles kills a human every 20 seconds and is possibly associated with several chronic diseases such as multiple sclerosis. The current vaccine does not provide lifelong immunity. About 50 percent of patients in North America have been previously immunized. Subacute sclerosing panencephalitis is a chronic lethal measles disease of children. The disease has been analyzed by molecular techniques to reveal which viral genes are expressed in ganglial and glial cells, together with information regarding mechanisms of viral mutations. Rinderpest, a lethal bovine disease of great significance in Africa, and distemper, a serious disease of dogs and more recently seals, represent related important viruses.

R. Weinberg, Whitehead Institute, Massachusetts Institute of Technology, discussed the association of viruses with retinoblastoma in children. This tumor affects several thousand children annually, and is genetically associated with the Rb gene that codes for a growth suppression factor. Loss of this factor can result in development of the tumor. Oncogenic DNA viruses, such as adenoviruses and papilloma viruses, produce proteins that bind this factor, which are thought to be involved in tumor development.

Control of Virus Infections

G. Darby, Wellcome Tropical Institute, London, gave an overview of the limited successes to date in antiviral chemotherapy. The most successful family of drugs was initiated with acycloguanosine (Acyclovir), a drug developed as an inhibitor of adenosine deaminase for treatment of leukemia. Acyclovir is also effective against herpes simplex and related viruses by specifically inhibiting viral polymerases. Gangcyclovir is a more toxic derivative useful in treating cytomegalovirus, another herpes virus of great medical importance in immunosuppressed patients. Azidothymidine (AZT) interferes with the essential retroviral enzyme reverse transcriptase, and remains the drug of choice for HIV infections. Resistance requires four mutations and is relatively infrequent, although marrow toxicity can limit use of the drug. An HIV viral protease inhibitor is currently under development, and several other strategies are being explored for treatment of AIDS.

S. Cohen, Hahnemann University, Philadelphia, Pennsylvania, discussed the limited information available on the role of cytokines in viral disease. While it is probable that the same cytokines identified in bacterial diseases are involved in viral diseases, little has been reported to date.

R. Beachy, Washington University, St. Louis, Missouri, discussed an approach to inducing viral resistance in plants by introducing viral capsid protein genes into the plant genome, which appears to interfere with viral replication by an unknown mechanism. Ribozymes that will cleave viral RNA introduced via antisense RNA is a promising strategy in plants because most plant viruses are single-stranded RNA viruses that replicate in the cytoplasm and are susceptible to antisense

approaches. However, getting antisense RNA into plant cells remains a challenge; it is most likely to be feasible as a treatment for viruses transmitted during plant cloning.

J. Almond, University of Reading, U.K., discussed a novel strategy for attenuating and exploiting picornaviruses such as polio. Picornaviruses are small, single-stranded RNA viruses that are relatively simple to manipulate genetically. In polio, it has been demonstrated that secondary structure in the 5' noncoding end of the genome is essential for neurovirulence, and that destabilizing a single loop attenuates neurovirulence. The attenuated polio genome may be an appropriate host for antigens of other important picornaviruses, such as hepatitis A and foot-and-mouth disease. Such recombinants could be used as a multivalent oral vaccine/adjuvant as the virus is an efficient inducer of IgA. Possibly, other viral genes such as HIV antigens could be introduced via this route as well.

B. Moss, NIH, closed the final symposium with a discussion of *vaccinia* virus expression vectors. The pox viruses are large and complex, expressing over 200 genes. Indeed, some microbiologists question whether they are not more like chlamydia than viruses. However, their size characteristics make them capable of carrying considerable genetic baggage in the form of other viral genes. Their relatively independent cytoplasmic replication mechanisms (they carry their own transcription apparatus) allow efficient synthesis of passenger viral antigens. Despite the problems associated with *vaccinia* as an encephalitogen and the fact that its own antigenicity limits its application to one immunization in a *vaccinia*-naïve individual, work continues on this versatile genetic vector.

PHYSICS

The 19th International Conference on Low-Temperature Physics

by D. H. Liebenberg, Scientific Officer for Condensed Matter Physics, Physics Division, Office of Naval Research, Washington, D.C. Dr. R. Soulen, Materials, Science, and Technology Division, Naval Research Laboratory, Washington, D.C.

Introduction

The 19th International Conference on Low-Temperature Physics was held in August 1990, in Brighton, Sussex, United Kingdom (U.K.) The conference was sponsored by the International Union of Pure and Applied Physics and the Institute of Physics, London. The meeting was attended by 1,500 delegates from more than 15 countries. The topics ranged from the traditional ^3He and ^4He superfluids to superconductivity. Included were presentations on the high-temperature superconductors, and quantum systems where a combination material/dimension/temperature requires the consideration of quantum behavior. Thus, represented were localization and metal/superconductor-insulator transitions, the hydrogen isotopes, multilayered materials, nanoscale metal and semiconductors, and nuclear matter at subnanoKelvin temperatures. Techniques were discussed such as nuclear moment cooling and laser cooling. Applications were appropriately represented such as astrophysical and space science detectors and high-frequency, low-noise electronics.

The conference host, Professor D. Brewer, University of Brighton, Sussex, U.K., and his committee organized the meeting into plenary, invited, and contributed oral sessions, and poster sessions that simultaneously provided a broad overview of progress in the field as well as detailed sessions. The posters were especially valuable.

Professor D. Betts, University of Sussex, U.K., edited two volumes that included the contributed papers. These volumes, published as part of the *Physica C* series, were available to delegates. A third volume of plenary, invited, and postdeadline papers will be published. These notes will concentrate in the more than 60 plenary and invited talks although it remains a personal selection since many invited talks were presented at overlapping sessions.

Opening Session

At the opening, Professor J. Vinen, University of Birmingham, Birmingham, U.K., represented the International Union of Pure and Applied Physics (IUPAP) Commission 5, and Professor N. Kurti represented a historical perspective on the conference to correspond with the reprinting of the second (LT-2) conference proceedings. Kurti's present interest includes the art of cooking from a physicist's point of view. His new book on cooking is published by the Institute of Physics, London, U.K.

The Fritz London prize to which Professor J. Bardeen, University of Illinois, Urbana, gave his second Nobel Prize funds, was awarded to three people--Drs. R. Dynes and P. Hohenberg, AT&T Bell Laboratories, Murray Hill, New Jersey, and Professor A. Larkin, Institute of Physics, Moscow, U.S.S.R.

Dr. Dynes noted the efforts in tunneling with many collaborators. These efforts have provided the basis for much of the superconducting electronics, as well as drawing out the physics of the energy gap and phonon spectra. Results for the BaKBi-oxide superconductor discovered at AT&T Bell Laboratories were described since this material has a transition temperature T_c up to 35 K and a long coherence length and is three dimensional (3-D) and Bardeen-Cooper-Schrieffer (BCS) like. These results suggest the use in the intermediate temperature range. Dr. Hohenberg described some problems of current interest, including the nonlinear pattern formation needing the development of the dynamical Ginsburg-Landau equations. Thermal convection in a binary fluid as shown by recent AT&T experiments were used to compare the theoretical development. Two important length scales were identified, the chaotic correlation length l and the linear size of the system L . When $L < l$, there are few degrees of freedom; in this regime, the early work of Ahlers and Libchaber was noted. In the region $L < = 10l$, there are few interactions.

For $L \gg 10l$, there is no fluctuation dissipation theorem, and new statistics may be needed. A purely deterministic equation is sought, however. Professor Larkin described the work on fluctuation theory that has lead to many successful descriptions of superconducting phenomena and has been extended to other problems as well.

Dr. Batlogg, AT&T Bell Laboratories, Murray Hill, New Jersey, gave a useful summary of the importance of new materials in the area of high-temperature superconductors (HTSC). New materials are especially important in this field, both from the standpoint of potential increases of transition temperature T_c and in the probing of physical properties with variations of material composition. The work at AT&T Bell Laboratories has been wide ranging. Also, people from AT&T have in some cases moved to universities where solid-state chemists are more easily hired than developed in the U.S. The discovery and subsequent effort on properties studies of BaKBiO material is just one example.

The theoretical aspects of HTSC were discussed by Dr. V. Emery, Brookhaven National Laboratory, Upton, New York, who noted the number of HTSC theories at least equalled the number of theorists so that a complete review was not possible. Weak and strong coupling theories exist. The photoemission studies that show a Fermi surface indicate a strong coupling that puts charge and spin together. There is evidence for intermediate coupling. The interaction is large compared to the kinetic energy. The magnetic field fits to a Heisenberg (strong) limit rather than a weak limit. This theory is better in the limit $E(\text{kin}) < E(\text{pot})$. Start with an undoped Heisenberg model and add holes. The issue is adding or subtracting spins (added with Kondo or Heisenberg and removed with a t-J model). Better experiments are needed. In the t-J model, add a hole to oxygen and form a singlet site with copper spins, and the spin is removed. The actual energies are considered in comparison with experiments. He concludes that the t-J models do not work. Perhaps a modification to a second neighbor hopping or tt' -J model is needed. The normal state phenomena are starting to be understood. The broad peak in Raman measurements needs more work. In the superconducting state, doping increases and then decreases the transition temperature. There is evidence for spin fluctuations in the gap from BNL neutron measurements and the relation $T_c = (\text{carrier concentration}/m^*)$ holds. A nonretarded interaction is suggested, but this leads to difficulties with phonon and spin fluctuations. Hard limits can be set on the models. Some speculations were offered about the self-binding versus pairing models. The attractive forces tend to collapse the system to a liquid in the case of ^3He , but Coulomb repulsion keeps the hole density reduced in the HTSC. (I did not understand why the $^4\text{He}/^3\text{He}$ mixture

would not be expected to have a higher T_c rather than the substantially lower value most theories predict.)

Superconductivity - Mostly HTSC

An example of the richness of the HTSC studies is found in the first poster session where 30 posters were presented representing 16 countries. The superconductors ranged from YBCO including silver doped and with different oxygen loading, to BiSrCaCuO including the Pb doped, to TiPbCaSrCuO , to the electron HTSC of NdCeCuO , and to the lower temperature Chevrel phase PbMoS . A discussion followed each poster session.

For this discussion session, four interesting areas were identified. The even harmonics in susceptibility measurements indicate a magnetic field dependence on critical currents. Within about 5 K of T_c , the magnitude of the even harmonics peaks and decreases in importance at lower temperatures. The Bean critical state model must be applied carefully since the Josephson network must be considered as well as intergranular vortices. The dependence of critical current on magnetic field, $I_c \sim 1/(H + \text{const})$ fits the harmonic picture and is similar to the Anderson-Kim picture. The granularity in low T_c systems like the Chevrel phases may provide a better model system. For example, the disorder can be either structural or coupling. Finally, the noise measured in thick films may have several sources--percolative or intrinsic fluctuations. In ceramics it was further noted that addition, noise sources are known--magnetic flux noise and hysteretic ceramic behavior. An interesting question emerged as to whether there is a field orientation dependence on the noise in a film. These discussion periods provided a good opportunity to compare various work presented and bring out key ideas.

Macroscopic Quantum Tunneling and Coulomb Blockade

The macroscopic quantum tunneling (MQT) and Coulomb blockade process were discussed in a session chaired by Professor J. Clarke, University of California, Berkeley. Dr. M. Devoret, Quantronics Group (DPHG/SPSRM, C.E.M.), Saclay, France, gave the first invited paper. He presented measurements on the latency time of MQT in a Josephson junction (JJ) shunted by a microwave transmission line terminated by a resistor. The rate out of the zero voltage state is measured to determine the average duration of tunneling events. The distance of the resistor from the $10(\mu\text{m})^2$ junction can be varied in situ along the delay; starting from zero, the MQT rate increased and then saturated. The delay at which saturation sets in is the latency time. The Leggett theory was developed to compare the results in the quantum

regime, which was reached experimentally at 18 mK. The temperature dependence also agrees with theory concerning the influence of retarded dissipation on tunneling.

Professor J. Mooij, Delft University of Technology, Delft, the Netherlands, discussed Coulomb blockade effects. Charge quantization effects were studied in networks of tunnel junctions having small areas $0.01(\mu\text{m})^2$ and capacitances less than 10^{-15} Farads. In the normal state, the Coulomb blockade is observed for a voltage of $e/2C$ as is the modulation of conductance in a series array by a gate voltage applied by a nearby (but electrically isolated) electrode. Also, MQT of charge through multiple junctions is observed. A turnstile device was developed that transmits a single electron per cycle of an rf gate voltage. In two-dimensional (2-D) arrays, a charge unbinding (Kosterlitz-Thouless) transition occurs. In the superconducting state, the Coulomb gap and the unbinding transition are related to the charge $2e$. The resistance varies over 10 orders of magnitude and has a temperature dependence similar to the films of Goldman. He suggests that Likharev's ideas can now be turned into devices using this 60-nm scale writing of Al superconductor. In response to a question, he noted that the 60-nm scale is just coming on stream. He also noted that some time will pass before a scale of 20 nm is reached.

Dr. C. Tesche, IBM, Yorktown Heights, New York, discussed a superconducting measurement circuit for an Einstein-Podolski-Rosen (EPR) experiment with an rf superconducting quantum interference device (SQUID). The experiment is to test the quantum mechanical hidden variable theory as applied to a macroscopic quantum system. Leggett and Garg predict the joint probability densities for the flux linking of an rf SQUID in a coherent state will violate a set of inequalities analogous to Bell's inequalities for a microscopic quantum system. A particle decays with initial spin zero will produce two half-spin particles that pass through polarizers. Quantum mechanics gives a statistical answer while an experiment can give an exact answer of both half spin up or both down. In an rf SQUID, the potential energy can have two wells one left-hand polarized and the other right-hand polarized. The experiment will involve looking for coherent oscillations between these states. However, at the present, the proper polarization analyzers have not been found. This experiment is different from that performed on a single atom system.

Dr. P. Delsing, Chalmers University of Technology, Göteborg, Sweden, reported on single electron tunneling oscillations in one-dimensional (1-D) arrays of ultra-small tunnel junctions. The I-V was measured in a linear array of aluminum junctions with an area of $0.006(\mu\text{m})^2$. Time-correlated electron tunneling was measured by phase locking to external microwaves with frequency between 0.7 and 5 GHz. Peaks in the

differential resistance occur at currents corresponding to $I = ef$ where f is the external frequency. Good agreement with theoretical predictions is found. The linear array can be voltage biased and still work. Results at temperatures of 50 mK were shown and a critical voltage develops in contrast to the nearly linear I-V at 4.2 K. Voltage oscillations in a charge-dominated system were noted rather than current oscillations in a flux-dominated system.

Superfluid Transition and Low-Temperature Detectors

During the second day, plenary sessions examined the superfluid transition in confined geometries and low-temperature detectors in subnuclear physics and astrophysics.

Professor M. Chan, Pennsylvania State University, University Park, discussed results of heat capacity measurements and torsion oscillator measurements with the Cornell group on the onset of superfluidity in ^4He in VycorTM glass and an aerogel. The Vycor glass has been well characterized. By techniques to increase the heat capacity measurement sensitivity, he demonstrated that a small peak in c_p at the same temperature as the torsion oscillator measurements determined the onset of superfluidity. This established that the unsaturated film in Vycor glass belongs to the same universality class as the bulk transition. The results with aerogel are different than with the Vycor. The picture is still unclear. The density of aerogel is much less, so helium constitutes a larger fraction of the total mass. While the transition is sharp, the exponent is not bulk like and the attempts are not yet understandable from the perspective of pore-size distribution.

Professor E. Fiorini, University of Milano, Italy, endorsed the use of superconductors as particle detectors for high-energy physics/astrophysics. He noted the high energies that must be reached to test a unification between electromagnetic and gravitational interactions. He described various thermal detectors like superconducting junctions and grains and low-temperature bolometers. The emphasis is on developing and optimizing the detectors: the ultimate impact on particle detection, cosmogeny, and particle physics is yet to be judged (see ESNIB 90-06:56).

Nuclear Magnetic Resonance and Magnetic Neutron Scattering

The electronic and magnetic properties of HTSC as studied by nuclear magnetic resonance (nmr) techniques was reported by Professor H. Alloul, University of Paris South, France. The nmr technique has developed into a very useful probe in these complex unit cells since lines

for ^{89}Y and ^{63}Cu ... can be used to probe both normal and superconducting phases. The importance of stoichiometry of the oxygen atoms is identified. There is no effect on the Y nmr in the transition to the antiferromagnetic (AF) state; defects do broaden the line. For Cu nmr (nuclear magnetic resonance), the intensity drops when the oxygen content drops. In the metallic phase, the line shift of Y nmr is measured. For the 92-K phase ($x \sim 1$), there is Pauli-like insensitivity. However, in the 60-K phase ($x \sim 0.5$), correlations are signaled by a strong decrease with temperature which is an unusual direction of change. ^{17}O nmr has been used to confirm the susceptibility on the oxygen site is dominated by covalency with copper. The covalency between the $\text{Cu}(3d(x-y))$ and O_{2p} holes results in a spin system that behaves as a single spin fluid for $x = 0.65$. The relaxation times for a Korringa law, $T_1T = \text{const}$. A correlation between the variations of T_1T and the nmr frequency shifts is shown for $x < 1$. Support is provided for a Fermi liquid model with strong AF correlations.

Professor Y. Kitaoka, Osaka University, Osaka, Japan, presented spin correlations in the $(\text{La}_{1-x}\text{Sr}_x)_2\text{CuO}_4$ HTSC. The interrelation of superconductivity and antiferromagnetic states in this material was investigated by this group using nuclear-spin lattice relaxation time T_1 and the spin echo decay time T_2 of ^{63}Cu . The composition of Sr was varied through the range $x = 0.05$ to 0.075, the value for maximum T_c . For decreasing Sr, the low energy part of the AF spin fluctuations increases because of the increase of the magnetic coherence length. The normal state is dominated by correlations.

Dr. J. Rossat-Mignod, Nuclear Study Center, Grenoble, France, presented the second invited paper on the spin dynamics in yttrium barium copper oxide (YBCO) examined with neutron scattering. The inelastic scattering was carried out with single crystals and the spin dynamics in the pure AF state $\text{O}_{6.15}$, $T_N = 410$ K, in the doped state $\text{O}_{6.37}$, $T_N = 180$ K, and in the metallic state $\text{O}_{6.15}$, $T_N = 45$ K. There is a 2-D character of the spin wave spectrum in the AF state as denoted by in-plane and out-of-plane intensity versus energy measurements. At higher temperatures, the peaks merge. For the superconducting system, there are no further spin excitations at less than 2 meV. There is no correlation length dependence on temperature up to 300 K. The line width is related to the hole density, and the AF coupling is between the Cu-O planes. Lorentzian fits are inadequate. Rather, Dr. J. Rossat-Mignod thinks the data are showing the quasi-particle spectrum. There is a pseudo gap at 16 meV which is seen up to 250 K (or well above the T_c). This could be interesting in view of the number of experimentalists who have seen some evidence for diamagnetism well above T_c .

Plenary Session

Dr. I. Fomin, Landau Institute for Theoretical Physics, Moscow, U.S.S.R., presented an interesting talk on spin currents in superfluid ^3He . His theoretical work and experimental work by Borovik-Romanov and others seemed to both open and close this topic. The condensate of Cooper pairs in the superfluid phases of ^3He can carry a spin current. Spin transport in the normal phase involves collisions that conserve spin but not spin current. In the normal phase, such a spin current has a lifetime of 10^{-7} sec. In triplet pairing (magnetic ordering), there is anomalous ferromagnetism in the ^3He -A phase and anomalous antiferromagnetism in the B phase. There is a broken symmetry of rotation in the B phase. So spin-orbit interactions mask the spin current in the A phase. In the B phase with pulsed nmr experiments, the spin current can be measured. These energies are much smaller than the 1-mK gap or the mass flow vortex energies. The theory shows an analogy to the Josephson equations so that in channel flow of spin currents, the phase difference grows with time, a spin current flows, and jumps in the nmr signal indicate the quantization of the flow by spin current vortices. This result has been observed. Other aspects of this spin current were discussed.

In a plenary talk, Dr. J. Flouquet, Center for Low-Temperature Research, Grenoble, France, discussed heavy fermions in normal and superconducting phases. He discussed the three types of transitions involved--antiferromagnetic, metamagnetic, and superconducting. The phase diagram of H versus T shows a high field nearly constant in temperature transition to metamagnetic state exemplified by UPt_3 . The superconducting region is at lower field and limited by T_c . The AF state is a zero field transition at T_N greater than T_c . The double peak in specific heat in UPt_3 was noted to have been predicted by R. Joynt. The $H_{c1}(T)$ has a kink in the curve that may also be observed in ultrasound measurements. A phase diagram for H versus T in fields parallel and perpendicular to the c axis was constructed. Experimentally, it was shown that the two transitions merged under an applied pressure of about 3.5 kbar. Thus, the coupling of the AF and superconducting order parameters seems to occur as Joynt predicted. A controversy was discussed in the interpretation of muon results as to whether there are two transitions or a spin density wave transition as favored by R. Heffner, Los Alamos National Laboratory, New Mexico. Other heavy Fermions do not show the double transition, although a thorium-doped UBe_{13} does have this feature.

Flux Pinning and Creep

In an invited paper, Professor M. Tinkham, Harvard University, Cambridge, Massachusetts, discussed the flux motion studies in the HTSC from the viewpoint of achieving a fundamental understanding and in improving the ability of HTSC to carry high-current densities. The fundamental understanding involves the resistive behavior in the zero current limit. He discussed the comparison of collective interactions of flux lines (whether liquid, solid, crystalline or glassy). Additionally, he elaborated on the importance of intrinsic to extrinsic pinning.

Dr. D. Bishop, AT&T Bell Laboratories, Murray Hill, New Jersey, discussed flux lattices in the HTSC. His discussion was from the viewpoint of a phase diagram that has the Meissner region of excluded flux, a vortex glass region melting at higher fields to a vortex liquid, and finally the transition to normal metallic behavior. He discussed decoration experiments and some excellent photographs of the triangular and disordered arrays of vortices were shown. Defects in local regions destroy long-range positional order, but the long-range orientational order remains. Thus, a hexatic glass phase is suggested as theoretically treated by D. Nelson, Harvard. A correlation is suggested between the width of the vortex liquid phase and the anisotropy of the HTSC. The YBCO has high anisotropy and a very narrow vortex liquid phase while the opposite is true for the bismuth strontium calcium copper (BSCCO) material.

Disordered Systems

When Professor A. Leggett, University of Illinois, Urbana, presents an invited paper there is every expectation that the implications are well worth significant attention. He spoke on amorphous materials at low temperatures: "Why are they so different?" While the single crystal has been considered the paradigm for solid-state physics, he noted that more likely amorphous materials are the norm. A similarity of physical properties was noted between materials of quite different classes such as the quasi-linear specific heat at temperatures below 1 K, a T^2 dependence on thermal conductivity, a plateau in thermal conductivity between 1-10 K, a $\log T$ versus v_s and finite ultrasonic absorption in materials ranging from the dielectric oxides, fluorides, polymers, aerogels, and biological materials, to metallic glasses, semiconducting glasses, to disordered materials including the oxide superconductors. Even pure silicon has some amorphous features. The generality of the dimensionless reduced ultrasonic absorption is noted. The explanation by a two-level system model seems to require an unbelievable degree of chance coincidence. While showing a nonuniversal value in the temperature

region plateau, the thermal conductivity is consistent with universal behavior at temperatures higher than the temperature region plateau. The idea that Leggett explored is that the common feature of amorphous materials is the existence of low-lying, nonphononic excitations which are strongly coupled by the strain field in a scale invariant way. Their detailed microscopic nature does not matter. A Hamiltonian is written and at low temperatures the Heisenberg spin glass with strong interactions but lower density of states is obtained and a crossover is suggested to an Ising spin glass at a critical interaction radius equivalent to a temperature of about 10 K. The theory needs a real space-scaling calculation. Also, the experiments need systematic measurements of the ultrasonic absorption, a determination of the effect of polar impurities, measurements in restricted dimensionality, and ultralow temperature data (< 0.1 mK) where the direct interactions are expected to take over. The next conference will undoubtedly offer some of these results.

Theory - Vortex Lattice Melting and Glasses

In a session on the theory of vortex lattice melting and glasses, Dr. M. Fisher, IBM, Yorktown Heights, New York, discussed the vortex glass theory that has analogy to the spin-glass phases in disordered magnets and is in contrast to the Anderson Kim flux creep model. The Abrikosov lattice gives way to the vortex glass along a transition line that is seen in a $\ln V$ versus $\ln I$ plot of resistance data.

Plenary Session

Professor R. Clark, Clarendon Laboratory, University of Oxford, U.K., gave a plenary talk on the optical spectroscopy of the integer and fractional quantum Hall effect (QHE, FQHE). After a review of the QHE and FQHE, he discussed the preparation of samples that provide the photoluminescence in a GaAs structure with high mobility. To prepare these samples, comparison between the quantum well and heterostructures was noted. A yellow and green spectral broadband peak is observed when laser light is supplied via fiber optics to the dilution refrigerator-cooled sample. The green band is associated with the integer QHE and the yellow represents primarily electron screening. The screening can become active and is important for the FQHE. These peaks map out the edges of the plateau or the localized states. The FQHE disappears between 120 mK and 1.2 K; the luminescence goes away. In high fields, with the laser left on shifts the peaks are observed. Data was shown for the relative variation of the peaks. The extreme quantum limit was reached in the 40-T, 10-ms pulsed coil used to detect the onset of a magnetically induced

electron solid in this limit. The results suggest that a crystallite forms of a few hundred ions.

Dr. C. Beenakker, Philips Research Laboratory, Eindhoven, the Netherlands, gave an overview of ballistic and adiabatic electron transport in 1-D and 2-D. While ballistic electron transport was known in the 1960s, the new microfabrication facilities provide an opportunity to study conductance quantization, coherent electron focusing and collimation, electron billiards, and edge channels in the QHE and FQHE. The quantum point contact, which is of variable width compared to the Fermi wavelength, is central to these experiments. An electric field is used to control the gate width. Also, the conductance is measured as a function of gate voltage to show a stepwise increase $\sim N2e^2/h$. The relation deriving from Landauer, Imry, and Buttiker is used. A two-point contact unit can demonstrate focusing of electrons with ballistic orbits that are caustics. In this case, a reversal of the field is not symmetric and there is only focusing in one field direction. Fine structure is noted to be the effect of spatial coherence of electrons. An extension to multipoint contacts was also discussed.

Low-Temperature Imaging Techniques

Professor A. Tonomura, Advanced Research Laboratory, Hitachi, Saitama, Japan, showed interesting images of magnetic flux quanta emerging from the surface of a type II superconductor. A film showed the motion of the lines as the temperature was changed. The images are formed by exploiting the fact that the phase of the electron wave function is altered by the magnetic vector potential. The magnetic field (in this case, the flux vortex) creates interference effects. From such effects, he can generate electron holograms that are read later by laser light.

HTSC SQUIDS and Superconducting Junctions

An invited paper by Dr. R. Koch, IBM, Yorktown Heights, New York, described the impressive gains made recently in the preparation of HTSC SQUIDS. The Josephson equations must be considered in terms of the anisotropy of the HTSC materials. Five methods of making SQUIDS were noted:

1. Grain boundary selection
2. Damage in a constriction
3. Bicrystal substrate for induced grain boundary
4. Superconducting/normal metal/superconducting (SNS)
5. S/insulating/S (SIS) with either a step edge or edge junction configuration.

Numbers 4 and 5 are likely to be manufacturable. No one has yet made a microbridge or tunnel junction. Operation at 77 K has been possible by many groups around the world and various HTSC materials have been used. The thallium-based grain, boundary-selected SQUID still has the best operating characteristics. A bicrystal YBCO junction has good characteristics up to 86 K. The edge junction develops a barrier in a plasma oxidation process and the geometry is such that the barrier is between sections of a,b crystal planes rather than the more difficult contact along the c axis. Both TRW and Julich groups have made a sharp edge junction with high yield that work to 82 K. Comparison curves of noise figures were shown and discussed. The need for low-noise matched input coils was discussed. Also noted was the need for multilayer devices such as J. Clarke, University of California at Berkeley, has been making. The applications are waiting.

Z. Ivanov, of Chalmers University of Technology, Göteborg, Sweden, and the Institute of Electronics, Sofia, Bulgaria, presented data on the SNS junction where Shapiro steps were observed in an rf field. A second contributed paper by Professor D. Cohen, Technion-Israel Institute of Technology, Haifa, Israel, also discussed an SNS junction with a silver normal metal. In each case, tunneling was required along the c axis.

Results of a reactive sputtering process to produce a YBCO/MgO/Pb SIS junction was reported by Professor I. Iguchi, University of Tsukuba, Tsukuba-Ibaraki, Japan. The gap is not seen at 70 K but only about 30 K. As these contributed papers show, there is still work to be done to bring the HTSC SQUIDS to applications.

A final contributed paper of that session by Dr. W. McGrath, Jet Propulsion Laboratory, Pasadena, California, discussed the low-temperature NbN SIS mixers. The NbN has a large gap, is made with $1(\mu\text{m})^2$ size, has $85 \text{ fF}/(\mu\text{m})^2$ capacitance, and has a noise temperature of 133 K. The noise level was stated to be the best ever. A critical current of $20,000 \text{ A}/\text{cm}^2$ is determined and measurements were carried out at 205 GHz.

Plenary Session

We were brought up to date with the extremely challenging experiments in the nanoKelvin range at the Helsinki laboratory of Professor O. Lounasmaa by Dr. A. Oja, Low Temperature Laboratory, Helsinki, Finland. Nuclear spins in metals have been cooled to the lowest temperatures reported anywhere. Early results indicated a first-order phase transition in the copper system at 60 nK and later three AF states were found as a function of applied field.

As an aside, I discussed with Professor Lounasmaa the uninterrupted and long-term (more than 7 years) support

that he noted was absolutely crucial to the support these difficult experiments. Recent neutron diffraction experiments have shown the various spin structures. The phase diagram was discussed in terms of competing dipolar and exchange forces. In silver, the interactions are exchange dominated, which makes this metal a good model for the half-spin Heisenberg AF in an fcc lattice. A clear AF tendency has been observed in silver by susceptibility measurements down to a new record low temperature of 600 pK. At negative temperatures (a population inversion), the data up to -4 nK indicates ferromagnetic behavior. So in silver for $T > 0$ K, the AF state is found. For $T < 0$ K, the ferromagnetic state is determined. Calculations have given a qualitative fit to the phase diagram.

Dr. D. Awschalom, IBM, Yorktown Heights, New York, gave the second plenary talk on Tuesday. He discussed spin dynamics and dimensionality in diluted magnetic superconductors. New optical spectroscopies have been developed to measure the optically induced magnetization and luminescence in femtosecond time scales with very high spin resolution. The system CdTe is nonmagnetic, but when doped with Mn has a magnetic character. He reported on work only in the paramagnetic phase. A quantum well geometry is used and epitaxial growth occurs with varying Mn doping on a GaAs substrate. For a 21 Å superlattice spacing the luminescence shift is 1.95 eV because of large exchange interaction. The use of dc SQUIDS with integrated superconducting electronics of Nb/Pb provides near quantum limit detection. Changes in luminescence for spacing 84, 50, and 21 Å were shown. For the thicker film, three quantum levels could be populated; at 50 Å, two levels, and these coalesced to one for the 21 Å sample. R. Orbach had calculated the cluster size expected in Mn doped randomly and a strong dependence on dilution (as the cubic power of the spin) is in agreement with the measurements. In 3-D, real-time formation and evolution of magnetic polarons were observed. In the lower dimensions, the magnetic manifestations of spin transfer and carrier localization is seen. The magnetic relaxation lasts a much longer time than the electronic relaxation of the carriers.

Superconducting Layered Structures

The superconducting layered structures session brought forward a mostly unexplored field. Both O. Fisher and M. Tachiki discussed early results with multilayer structures involving superconductors. In the first talk, Dr. O. Fisher, University of Geneva, Switzerland, discussed artificially grown copper oxide superlattices. Work with YBCO/PrBCO, where the PrBCO is not superconducting but metallic, permits a study where the different layers have a good lattice match

but very different physical properties. A test of the epitaxial technique was made using DyBCO which has the same T_c as YBCO. Films of this combination behaved as a single film of the total thickness. The PrBCO films behaved very differently. The normalized resistance curves were shown and compared with a 50-50 alloy of the (Y/Pr)BCO which has a greatly reduced T_c . Measurements were made with films of 12 Å each layer or essentially one unit cell stacking of each component. A proximity effect is hard to detect. The Hall effect is measured but for various films (96/96, 24/24) there is little difference in the number of carriers. The magnetic field response was also measured. Thermally activated flux flow was used to describe the results. For a magnetic field in the plane of the multilayers, the broadening of the transition is much less.

Professor M. Tachiki, Tohoku University, Sendai, Japan, described the YBCO/PrBCO and the YBCO/Nd multilayer system, the latter being a nominal hole and electron superconductor combination. For the upper critical field studies a crossover from 2-D to 3-D is found for the proximity effect. The correlation length, when greater than the multilayer period, allows the wave function to be extended between superconducting layers. When the reverse is true, the wave function is restricted and this accounts for the crossover. The systems NbTi, Nb are of interest since these superconductors have nearly equal T_c but much different vortex states and thus H_{c2} of NbTi is much less than for Nb. For YBCO, the superconductivity between planes is maintained by the proximity effect and he finds good agreement between this picture and the results of R. Dynes. For the BiSCCO system, the angular dependence of the field is shown to have a divergence in $H_{c2} \sim 1/\cos(\theta)$. The magnetization versus field varies with angle and indicates a large torque. A discussion of the angular dependence for a Pb/Ge system was also given. A smaller peak in addition to the one for a parallel field was shown to disappear for greater Pb thicknesses. He also discussed reflectivity measurements for multilayers and noted the polarization dependence related to plane or chain orientation in the YBCO.

Final Plenary Session

In the final plenary session, we were treated to a different view of low temperatures and some new studies of superconductivity with the scanning tunneling microscope.

In the first talk Dr. A. Aspect, Laboratory for Hertzian Spectroscopy, Paris, France, described the laser-cooling experiments that have provided a record low temperature for cesium atoms of 2.5 μ K and even lower. The lower temperature is dependent on the ion. Dr. Aspect also discussed the series of experiments with Na, Ce, and He.

The techniques to get near-zero kinetic energies of the species and have them gravitationally fall into a second trap where new mechanisms could be tested.

Dr. H. Hess, AT&T Bell Laboratories, Murray Hill, New Jersey, discussed the scanning tunneling microscope for the study of vortices and vortex cores in a superconductor. The excitation spectrum was shown for an individual flux quantum of NbSe--a type II low-temperature superconductor. This impressive achievement was rewarded by an unexpected discovery: they found bound states in the excitation spectrum of electrons inside the vortex. Another surprise--the density of states obtained by this technique was not cylindrically symmetric about the center of the vortex, but showed a six-fold symmetry. Much additional knowledge is to be anticipated from this work and already new theoretical activity has been stimulated.

Comments

The conference closed with some summary remarks by the local chairman, Professor Brewer. Brewer reminded people of the Pippard remarks around the time of the 1959 Toronto meeting--low-temperature physics was finished. Now, more than 30 years later, it hardly looks that way. The next meeting location was announced as Eugene, Oregon, to be hosted by Professor R. Donnelly. Having the meeting in the U.S. should give students in this area first-hand exposure to the people and ideas and is indeed welcome. The previous meeting in the U.S. was held in 1981, more than three graduate lifetimes ago. Professors Brewer, Betts, and Vinen (among others) are to be thanked for hosting this conference.

PSYCHOLOGY

Austria Hosts International Applied Military Psychology Symposium

by Gerald S. Malecki, Scientific Officer, Cognitive and Neural Sciences Division, Office of Naval Research, Arlington, Virginia.

Introduction

The 26th International Applied Military Psychology Symposium (IAMPS) was held in Vienna, Austria, on May 7-11, 1990. The Military Psychological Service of the Austrian Ministry of Defence hosted the meeting with Bgdr. Dr. Ernst Frise and Dr. Christian Lohwasser, organizers.

Topics during this series focused on basic and applied research related to manpower planning, personnel selection, training, motivation and morale, and human factors in military operations. A voluntary international enterprise, IAMPS' principal function is to be a scientific forum to promote the exchange of information among the military psychological services of participating nations. The participants were both civilian and uniformed military psychologists employed or sponsored by their respective Ministries of Defense. The list of participating nations has grown over the years; delegates from eight nations participated in the first meeting in 1963. Approximately 50 delegates from 18 countries participated in this meeting. The Office of Naval Research European Office (ONR Europe) has maintained an active role in organizing and coordinating this series of symposia.

Welcome Addresses

Welcome addresses were delivered by General Othmar Tauschitz, Inspector General, Austrian Armed Forces, and CAPT Victor L. Pesce, Commanding Officer, ONR Europe. General Tauschitz said he was happy that his country hosted this meeting and emphasized the importance of international cooperation in science and technology. He underscored the value of the Austrian Military Psychological Service's mission in supporting the manpower and personnel needs of the Austrian Armed Forces. He cautioned against loss of vigilance that might be prompted by the relaxation of

tensions in Europe. He emphasized the importance of military manpower preparedness to meet new threats that may supersede the older ones.

CAPT Pesce referred to the new spirit of openness and economic cooperation in Europe stimulated by programs and goals of the Commission of European Communities. He also said that the nineties would be characterized by exciting challenges and opportunities for scientific and technical advances and cooperation. He observed that the IAMPS forum can perform an important future role in facilitating an understanding of those challenges and opportunities through the continued international exchange of information concerning military manpower and personnel issues. He expressed his appreciation to the Austrian Psychological Service for hosting the symposium.

Military Psychology in Austria

Brigadier Dr. Ernst Frise, head, Austrian Military Psychological Service (Service), reviewed the history, mission, and structure of the Service, which is part of the Federal Ministry of Defense. Areas of responsibility include aptitude testing, leadership and other military training, consultation on organizational management, public opinion research, and psychological care of military personnel.

Historical Review of Military Psychology in Austria

The origins of military psychology can be traced to the first Austrian Republic (1918-1938). The Service's main tasks were aptitude testing in aviation, communications, and motor transport. Officers led by Major Kurt Fechner performed these activities. In 1937, the first psychologist, Dr. Peter Hofstätter, was attached to the Service. Dr. Hofstätter is currently Professor Emeritus and

former head of the Department of Psychology, the University of Hamburg.

In 1938 as part of the annexation of Austria, the German Wehrmacht took over part of the personnel of the Service and employed them for the personnel selection and assignment. In 1942, the psychological service of the German Army and Luftwaffe was disbanded because of tensions between the psychologists and the military.

After the State Treaty of Vienna was signed in 1955, which marked the end of Austria's occupation by France, the U.K., the U.S., and the U.S.S.R., military psychologists were organized into a Psychotechnical Service and integrated into the Federal Ministry of Defense. In 1957, the Psychotechnical Service was given its own command and renamed Heerespsychologischer Dienst (HPD) (Military Psychological Service).

Structure and Functions of the Military Psychological Service Today

The HPD is part of the Inspectorate General in the Federal Ministry of Defense. Psychologists serve at the ministry level in subordinate departments and draft commissions in six federal provinces. The HPD is organized into:

- Military psychology and general aptitude testing
- Psychological methodology and applied research
- Special aptitude and computer-assisted testing
- Aviation psychology
- Organization and administration.

Psychological Testing at the Induction Centers

During the induction process, each person liable to military service undergoes a psychological testing procedure. For this purpose, each induction center (Vienna, St. Pölten, Linz, Graz, Klagenfurt, and Innsbruck) has two psychologists and a team of research associates to assist them.

The purpose of these tests is to contribute towards the assessment of the individual concerning his fitness for service, select the job he is best qualified for, and determine leadership potential with respect to his future work in the militia system. The present testing cycle includes a 2-hour written test and, if required, a personal assessment by the psychologist. Research is underway for the development of a personal computer (PC)-based, computer-assisted test system. Christoff Brugger demonstrated a prototype of that system. I will describe the system later in this report.

Pilot Selection

Procedures for pilot selection are based in large measure on research by Giseler Guttman at the Institute of Psychology, the University of Vienna. The tests are conducted in two stages over a period of 8 to 10 hours. The first stage involves using conventional psychological assessing and screening instruments. The second stage involves biopsychometric assessment techniques involving measuring cortical DC-potential (Guttman & Bauer 1984) and ergopsychometric procedures. Ergopsychometric procedures (Guttman 1984) use tests under neutral conditions and under stress conditions. Both techniques have improved the predictive value of the selection procedures. Giseler Guttman participated in this symposium and described his research related to developing the biopsychometric and ergopsychometric assessment techniques.

Psychological Testing of Officer and Noncommissioned Officer Candidates

About 1,200 future officers (both career and reserve) and roughly as many future noncommissioned officers (NCOs) undergo psychological testing each year. Recently developed, these tests apply recent scientific findings to meet the forces' stringent selection requirements. The underlying approach involves assessments of general intelligence, aptitudes, personality, and leadership qualities. The goal is to select well-balanced and mature persons. Military leaders must be able to cope with unusual stresses. Therefore, ergopsychometric procedures, which provide measures of stress-coping ability, are used extensively in the selection.

Other Areas of Applied Psychological Research

The Austrian Armed Forces are increasingly more willing to consider the findings of psychological research in areas such as ergonomics, leadership, and organizational effectiveness. The tasks of the Service are increasing--a development that it welcomes because for many years it had been regarded principally as a testing service. Other areas of endeavor are:

- Selection for U.N. peace-keeping duty; purpose is to screen applicants for undesirable personality traits, both from social and clinical viewpoints
- Military leadership training for officers and NCOs
- Demographic studies and advisory services concerning psychological problems in organizations
- Ergonomics with respect to designing military equipment and systems

- Motivation and morale research involving studies of the psychology of combat and battle stresses, and methods for building one's self confidence in the military organization in its leaders
- Psychological care for military personnel, including the services of medical doctors and a clinical psychologist.

The Service's ultimate purpose is to aid the Austrian Armed Forces in the country's defense. Some acceptance problems were cited. Acceptance problems can best be solved if the Service's activities are performed openly, and if the work is of high scientific quality.

Personnel Selection and Assignment

I will summarize presentations regarding personnel selection and assignment--aptitude testing and computer-assisted testing.

Aptitude Testing. Heinz-J. Ebenrett, Federal Republic of Germany (FRG), presented a retrospective view of experiences with the Psychological Aptitude and Placement Examination (EVP) over the last 25 years by the German Federal Armed Forces (Bundeswehr). Before 1965, vocational testing and selecting had been applied only to volunteers; conscripts were selected randomly by lottery. The reasons for introducing the EVP for selecting and assigning draftees were:

- High frequency of assignments to units for which they were unqualified
- Marked reduction in the manpower pool
- Mismatches between medical and vocational qualifications resulting from lottery selection.

Vocational testing had been used successfully with army volunteers and use with draftees received strong public support. Earlier Wehrmacht tests and the U.S. Armed Services Vocational Aptitude Test Battery (ASVAB) were models for developing the EVP. The EVP consists of 10 tests grouped into three categories:

1. General intelligence
2. Technical comprehension
3. Perceptual speed and accuracy.

Although the EVP is very efficient and effective in meeting the manpower needs of the Bundeswehr, it does have some technical shortcomings. At the same time, there are new social-political challenges; e.g., reduction in the duration of compulsory service for conscripts. Both of these factors require some modifications in testing practices and test contents. The most important test weakness relates to predictive validity. This is a pressing problem with the number of military jobs increasing (now about 450) and changing. Also, the written tests lack fine differentiation at both high and low levels of performance. Initiatives in computer-assisted testing (CAT) have been undertaken to address some of

these problems. Four CAT centers have been established and 10 more are planned. Vigorous research programs, complemented by international collaboration, are addressing the important technical issues of item selection, reliability, predictive validity, and test integrity.

Computer-Assisted Testing. In a companion paper, H. Aschenbrenner, FRG, discussed other CAT developments directed at improving selecting officers and NCOs. In addition, he described innovative developments in simulation-based aptitude testing, which is a project to explore the use of part task simulators for selection purposes. Work is underway to develop a library of complex dynamic tasks and simulation equipment for assessing aptitudes in selecting aviators.

Christoff Brugger, Austria, demonstrated a prototype CAT system that was designed for use at Austrian military induction centers. The Vienna Technical University developed the system, which administers eight separate tests that range from general intelligence and perceptual-motor abilities to stress tolerance. Each test station is equipped with a PC and a monitor that can display text and high-resolution graphics. The test stations are networked and controlled by a master station that supplies the software and stores the test results. The program uses standard programming languages such as BASIC, Pascal, and C. Graphics, track, and text editors and a compiler are used for test developing and modifying. The compiler builds the test and an interpretation program processes the test and produces what the testee sees. This program records the testee's actions. Pilot testing of the prototype has been completed. The program will be installed at induction centers.

In both North America and Europe, the trend in the military psychological services is towards using computer-assisted and -adaptive testing. There are many reasons. Computer-based testing reduces average test times, provides increased measurement precision (especially at high and low ability levels), and reduces the probability of compromise. Computer-based testing also tests certain traits not possible to assess with written tests. To improve effectiveness, Green and his colleagues recommended (Green et al., 1984) improved assessment models and technical guidelines relative to test features such as measurement error, validity, and item pool characteristics.

Cost Effectiveness

Werner Fritcher, FRG, described a series of cost-effectiveness studies conducted in the German Federal Armed Forces to determine the technical and economic merits of computerized testing and placing. Results have been positive, and the German Secretary of

State approved using CAT apparatus at all selection and induction centers.

Senior Officers Assessment Center

In a different assessment context, Yacov Klein, Israel, described the evaluation processes and instruments used at the Israeli Assessment Center for Senior Officers. The process involves an intensive series of interviews, biographical data review, military situation and leadership tests, and clinical evaluations. The process also measures personality traits and intellectual skills. Many of the procedures and tests are administered on an individual basis. The entire process represents high time investments for senior military and staff personnel. Studies are underway to evaluate the long-term effectiveness of the assessment techniques.

Simulation and Military Training

Improved simulation technology provides an alternative to field exercises and operation of equipment. Also, constraints on military budgets and pressures from environmental groups impact field exercises. Simulation technology can be used as a tool to support a range of military functions from basic research and engineering design to evaluation of standards and system performance. However, the primary use of simulators is for training. John Rolfe, U.K., discussed behavioral and psychological issues in military training and simulation, particularly in training aircraft pilots and command and control crews. He provided an overview of the fundamental attributes and benefits of simulation, namely, that modeling and simulating represent powerful tools for conducting systems analysis, investigating functional relationships, and understanding complex phenomena.

Level of Simulation Fidelity

Rolfe observed that the evolution of simulation has been characterized largely by technological advancements to make simulators more realistic, accurate, and comprehensive representations of a system. From a practical standpoint, striving for comprehensiveness can greatly simplify the simulator design problem. That approach entails achieving physical and functional correspondence. The complex characteristics of human skill formation can be largely ignored. However, there are limitations and cost penalties associated with relying on that approach. The degree of duplication or physical fidelity has limits that are principally a function of the characteristics of the operational environment or external events. Simulating the outside environment and events that drive the

simulation can be difficult and expensive. Small gains in realism often are very incrementally expensive. As an example, simulating visual scenes is still one of the most challenging technical problems. The visual system is often the most expensive component of a flight simulator.

Further Research

The premise that high physical fidelity is important has intuitive appeal. However, there is no theoretical foundation to predict precisely how departures from realism and comprehensiveness might affect simulator effectiveness. Our knowledge regarding the need for physical correspondence is limited and fragmented. The psychological approach dictates that the training simulators are supposed to teach. The purpose of a simulator is to provide the conditions, characteristics, and events present in the operational situation necessary for learning, maintaining, or evaluating the skills that will be performed with actual equipment. Therefore, the characteristics and methods of using training simulators should be based on behavioral and training objectives. There have been several pioneering studies on quantifying the degree of transfer of training from simulator to the operational system (e.g., Williams et al., 1949; Caro 1977; Roscoe 1980; Durose 1982; Rolfe 1987). More precise methods are still needed to define training objectives and measure performance. Improved measurement techniques and performance models would contribute significantly to understanding the relationships between physical correspondence and training effectiveness and to the development of more effective training strategies.

Future Prospects

Demographic and economic factors will sharply increase the need to optimize personnel selection, training, and human factors design of military systems (Western European Union 1988). Simulation will play a central role in achieving those goals. Continued growth in developing and using simulation for training is expected. Simulation allows students to practice their skills and enables instructors to teach and examine performance in ways that are impractical, impossible, or unaffordable when using operational equipment. Colman Goggin, Ireland, discussed the need for new tools and approaches to teach problem-solving and decision-making skills. New skills would overcome some of the limitations caused by rigid procedural and mechanistic approaches. This is an important research issue and highlights that improved strategies are needed for training military leaders and command teams.

Training simulators have been successful. Beyond that application, simulators are used to license and certify

commercial aircraft pilots. Also, new developments in this domain may lead to using simulators to certify people in other professions.

In the mid 1980s, Defense Advanced Research Projects Agency (DARPA) sponsored the simulator networking (SIMNET) project. This project provided the foundation for technology of large-scale computer networking. The SIMNET project encompasses local and long-haul networks that can connect many vehicle simulators as well as command and support facilities. Using simulators (many are PC based) of mid-level physical fidelity has been a hallmark of the design. Researchers developed and successfully demonstrated test sites for air/land operations that used simulators for armored vehicles, tanks, aircraft, and command centers using a shared model of the terrain. In the U.S., researchers also developed and successfully demonstrated prototype simulation networks. In Europe, efforts are underway to explore international cooperation and collaboration in establishing sites and networks for multinational participation in simulation exercises. The SIMNET project represents an important new capability for improving training strategies and curricula for military teams.

Human Performance in Sustained Operations

Robert Angus, Canada, described research on sustained operations conducted for the Canadian defense forces. The aim of the research was to investigate the effects of various stressors on cognitive performance. A primary concern is the combined effects of sleep loss and intensive mental work on command and control personnel. Current approach involves developing a laboratory testing facility to adequately approximate command post activities. Experimental subjects assumed the role of operations officers and handled message traffic and related duties during long, intensive work periods while losing 2-3 days' sleep. Experimental results (Angus et al., 1988) indicate that sleep loss combined with intensive mental work leads to greater decrements in performance than reported in studies not emphasizing cognitive demands. For example, performance degrades 25 to 30 percent, compared to baseline values, during the first night with sleep and a further 25 to 30 percent during the second night. Attempts to ameliorate the degradations have included investigations of the effects of physical fitness, physical exercise, and reduced cognitive load. None of those interventions was successful. Experiments were also conducted to investigate the influence of 2-hour naps placed at different times during the circadian cycle. Future work will be directed to investigating the effects of different work/rest schedules, continued development of

noninvasive physiological measures of performance, and development of individualized intervention strategies.

Mary Winsborough, U.K., described a new research project directed at collecting extant performance data to:

- Organize and codify environmental and operational effects in tabular and graphical format
- Explore mathematical and statistical techniques to derive lawful relationships among parameters.

Guy Banta and David Kobus, U.S., reported on studies of cognitive, behavioral, and physiological responses to sustained hostile operations in the Persian Gulf during 1988. Participants were a sample of officers and enlisted personnel aboard nine Navy vessels. Ship types included guided missile cruisers, minesweepers, a guided-missile frigate, and an amphibious transport. Data were collected from combat information center, engineering, and bridge watchstanders. Results indicated that 25 percent of the participants experienced poor-quality sleep, problems falling asleep, and sleep inertia. Nearly 37 percent of all personnel reported severe fatigue. Mental and muscle fatigue and heat distress were the most frequently reported environmental health symptoms. As might be expected, junior enlisted personnel reported greater tension/anxiety than senior personnel. The relationship between tension/anxiety and fatigue measures and an index of total health symptoms was significant ($R = .59$). Quantitative physiological and cognitive measures were also collected and are currently being analyzed. Comparison of those data with the data on health symptoms should provide important information. There are many excellent monographs and review articles on the effects of individual stressors on performance (e.g., Hockey 1983). The Banta and Kobus study focuses on performance effects resulting from the interaction of multiple stressors. The results of further data analysis, particularly interaction effects, should provide useful information.

Orlindo Pereira, Portugal, reported on his longitudinal studies of leadership styles and long-term combat stress. The questions they focused on were whether leadership style, behavior, or leader/follower transactions may buffer or moderate the effects of stress. He formulated a theoretical framework based on the dynamics of leader/follower transactions similar to the model developed by Hunt & Osborn (1982). The Pereira model broadens previous contingency models by introducing the concept of discretionary leadership. Discretionary leadership refers to leader behaviors that may vary and implies performance flexibility and adaptability. In theory, subordinates are more sensitive and responsive to this form of leadership as contrasted to formal, rigid behaviors required by organizational rules. Two leadership training conditions (discretionary and formal authoritarian) were studied with 240 Marine

Corps trainees and instructors. Results indicated that leadership style had a pronounced effect. Discretionary leadership was instrumental in significantly buffering the effects of combat stressors, conflicts, and uncertainty as well as improving cohesiveness and satisfaction. Future work will focus on the refinement of training strategies, improvements in measures of performance, and studies of the long-term effects of leadership styles.

Closing Remarks

The IAMPS steering committee met during the week and accepted the proposal made by the Swedish delegation to host the 1991 IAMPS meeting. Kristina Pollack, Chief Psychologist of the Swedish Air Force, announced that the venue would likely be the Military Academy in Stockholm. More information will be forthcoming.

In closing, I hope that the wonderful tradition of indepth international scientific exchange continues to characterize the IAMPS symposium. With the relaxation of political tensions in Europe, I look forward to expanded national representation at future meetings. I acknowledge the outstanding organizational skills of Brigadier Dr. Ernst Frise and his staff and sincerely thank the Austrian Military Psychological Service for graciously hosting the 26th meeting in such a superbly professional manner.

References

- Angus R.G., R.J. Heslegrave, and R.A. Pigeau. 1988. Psychological performance during sleep loss and continuous mental work. In *The effects of interjected naps*. Downsview, Ontario, Canada. by Defence and Civil Institute of Environmental Medicine.
- Corsini, R.J., ed. 1984. *Encyclopedia of Psychology*. New York.
- Guttman, G. 1984. "Ergopsychometry", by G. Guttman.
- Durose, C.G. 1982. An evaluation of some experimental data on the cost-effectiveness of flight simulators. London: *The Journal of the Royal Aeronautical Society*.
- Green, B.F., R.D. Bock, L.G. Humphreys, L. Linn, and M.D. Reckase. 1984. Technical guidelines for assessing computerized adaptive tests. *Journal of Educational Measurement*, vol. 21: 347-360.
- Hunt, J.G., and R.N. Osborn. 1982. *Toward a Macro-Oriented Model of Leadership: Beyond Established Views*. Chicago, Ill: Southern Illinois Press.
- Guttman, G., and H. Bauer. 1984. The brain trigger design: a powerful tool to investigate brain behavior relations. New York: *Annals of the New York Academy of Sciences*.
- Hockey, R., ed. (1983). *Stress and Fatigue in Human Performance*. New York: John Wiley & Sons.
- Pereira, O.G., and J.C. Jesuino. 1988. *Coping with stress in military setting: Marines at war and peace*. Environmental Social Psychology, NATO Advanced Study Institute Series, ed. Canter, D. vol. D-45. Kluwer Academic Publishers.
- Rolfe, J.M. 1987. Training simulations: knowing what we want and getting what we need. In *Learning from experience through games and simulations*, Saunders D., ed. by Society for the Advancement of Gaming and Simulation and Training.
- Schmidt, F., and J. Hunter. 1979. Impact of valid selection procedures on work-force productivity. *Journal of Applied Psychology*, 64: 609-626.
- Steele, T.P., D.A. Kobus, G.R. Banta, and C.G. Armstrong. 1989. *Sleep problems, health symptoms, tension, and fatigue during wartime cruising in high heat/humidity environment*. San Diego, CA. Naval Health Research Center, Report No. 89-21.
- Western European Union. 1988. *The effects of demographic changes on defence capability in Western Europe*. Paris: Western European Union.

NEWS, NOTES, AND ABSTRACTS

High-Performance Computing Newsbriefs

by Miroslaw Malek, the Liaison Scientist for Computer Science and Computer Engineering in the Office of Naval Research European Office. Dr. Malek is on leave from the University of Texas at Austin, where he holds the Bettie Margaret Smith Professorship in Engineering in the Department of Electrical and Computer Engineering.

Reaching for One Hundred Gigaflops

Twelve physicists (turned computer scientists and engineers) at the Institute of Nuclear Physics at the University of Rome are developing an SIMD quantum chromo dynamics 100-GFLOPS computer. The APE100 is a follow-up on an APE1, whose peak performance is around one GFLOPS. The new machine has a three-dimensional lattice organization with 8x16x16 (2K) custom-designed processors. Each node is connected to its six members (two in each dimension) with wrap-around connections on the boundaries.

Key elements include a 64-MFLOPS processor (10-stage pipelined, floating-point, multiplier and adder; somewhat similar to Intel's i860), and a smart optimizing compiler that virtually squeezes out every cycle of available performance.

At \$10 million funding, this is one of Europe's most interesting projects. A 6-GFLOPS machine should be available in June 1991, and the APE100 in 1992.

Rubbio Report

Professor Carlo Rubbio and his 17-person team, at the request of the Commission of the European Communities, prepared a recommendation report on a European policy for high-performance computing. The report is in tune with the U.S. Federal High-Performance Computing document and calls for high investment, about \$1.2 billion annually by 1995, to support research on high-performance hardware and software. The goal is to develop a trillion floating point operations per second (TERAFLOPS) computer within the next 7-10 years. The report points out a startling paradox: while about 30 percent of high-performance computers are sold in Europe, very few are made in Europe.

Computer Industry

Is European computer industry going to the dogs? Major European computer manufacturers are fighting for survival. Analysts say that they will either collapse or sell out to American or Japanese competitors. All major computer companies seem to have severe problems: Bull

lost \$1.2 billion, Philips lost \$2.25 billion, Siemens-Nixdorf (heavily-advertised as "Synergy at work") does not seem to work, and Olivetti recently laid off 7,000 workers. The French government is determined to rescue Bull by pledging over \$1 billion.

Special Issue of IEEE Micro

A December 1990 special issue of IEEE Micro is devoted to parallel computing in Europe. Several parallel computer projects supported by European Strategic Programme for Research and Development in Information Technologies (ESPRIT) are described. Featured are POOMA, a 100-processor, object-oriented machine developed at Philips, the Netherlands; logic database machine developed at Bull, France; mixed-logic functional machine from CSELT, Italy; and dataflow and logic computers from Nixdorf, Federal Republic of Germany (FRG). All these projects were in cooperation with major European universities and research organizations.

In addition, there are articles on

- Transputers
- European Declarative System - a high-performance database machine with 128 SPARC processors designed at the European Computer Research Center and prototyped by Siemens; design goal - 12,000 transactions/sec!!!
- Pygmalion - neurocomputing project
- Symbolic Processing and Numeric (SPAN) - integrates symbolic and numeric computing on parallel systems.

Renaming of H1

Marketing guys strike again! Marketing at INMOS decided to change the name of the H1 transputer (see ESNIB 91-01: 38-41) to T9000.

Additional feature on the T9000 are cleverly interleaved on-chip memory banks. Although lack of built-in support for virtual memory is a serious drawback (to be fixed in the next model), the chip boasts a 200-MIPS, 25-MFLOPS peak performance and will be incorporated in several parallel platforms to be delivered by Meiko, Parsytech, Parsys, and Telmat.

INMOS will support C, C++, Fortran/77, and occam, as well as operating systems for both distributed computing (in cooperation with Chorus Systems in France) and real-time embedded processing.

European Consortium for Informatics and Mathematics

European Consortium for Informatics and Mathematics (ERCIM), promotes cooperation among government-sponsored computer research organizations in FRG, France, the Netherlands, and the U.K. The ERCIM was founded in April 1988 by Centrum voor Wiskunde en Informatica (CWI), Gesellschaft für Mathematik und Datenverarbeitung mbH (GMD), and Institut National de Recherche en Informatique et en Automatique (INRIA). In November 1989, ERCIM added Rutherford Appleton Laboratory (RAL). Additional members of ERCIM may soon include Italian Consiglio delle Ricerche (CNR) and Portuguese Instituto de Engenharia de Sistemas e Computadores (INESC).

The ERCIM awards fellowships to young European scientists who are interested in research at laboratories of the member organizations, supports cooperation and exchange among researchers, and organizes workshops. The last three workshops took place in Amsterdam and covered computer algebra, mathematical aspects of image processing, and high-speed networking. The ERCIM also offers advanced courses; e.g., a course in large-scale scientific parallel computing.

European Computing Research Center

The European Computing Research Center (ECRC) in Munich is looking for new members. The ECRC was originally set up by Europe's industrial giants Siemens, Bull, and International Computers Ltd. (ICL). After Fujitsu bought ICL, an emerging open-door policy calls for inviting two or three strong Japanese and American companies. I think this is a unique opportunity for companies like Digital and Hewlett Packard.

Advanced Computer Research Institute

Advanced Computer Research Institute (A.C.R.I.) was recently established in Lyon, France, to develop Europe's fastest parallel computer. Jacques Stern is heading ACRI and building an international staff of 150 scientists. The support for this project comes from both private and government sources, including ESPRIT.

Symbiosis of Small Business and University

A unique arrangement has been established between Brunel University (Brunel) located in West London, 15-minutes from Heathrow Airport, and small business for accelerated technology transfer. Several companies are set up and operate on the Brunel campus under the following arrangement: Brunel holds just over 50 percent shares of a company; professors, researchers, venture

capitalists, and others own the rest. Brunel provides space and some administrative support and others contribute their work or funds. Somewhat similar arrangements exist at some U.S. universities, but there are also some vital differences. Remuneration (such as salaries and benefits) come from grants and contracts that amount to over £1 million annually. Sponsors include the British Government, European Community (EC), and in the case of the Associative String Processor (ASP) project, there is additional support from the Naval Ocean Systems Center in San Diego, California. An example of an on-campus enterprise is Aspex, a company that works on the ASP and employs about 12 full-time engineers and programmers. Some professors and other university researchers are employed part-time by the company.

The department's philosophy is best expressed by a quote from Aristotle: "What we have to learn to do we learn by doing," which appears ahead of a foreword to the departmental Research Review written by chairman, Professor Gerry Musgrave. Professor Musgrave spent a few years in the U.S. as one of the top managers of GenRad Corporation, a computer-aided design (CAD) software maker. He is well known in the CAD community for his development of HILO logic simulator. The department's information technology/digital systems group specializes in parallel architectures, computer-aided engineering tools, image processing and neural networks. The parallel computing technology group covers the entire spectrum of fine-grain parallel computer design from specification to implementation and performance evaluation.

Associative String Processor

Professor Lea's group at Brunel is known for its 15-year-old research on the ASP. The main objective is to design and implement SIMD and MSIMD massively parallel computers using a wafer scale integration technology. The group developed several versions of VLSI and ULSI processors, some with over 1 million transistors. One on a wafer with over 10 million transistors is undergoing final testing. This commitment and persistence in pursuing WSI technology may finally pay off.

ASP References

- Lea, R.M. October 1988. The ASP: a cost-effective parallel microcomputer. *IEEE Micro*, 10-29.
- Lea, R. M. August 1989. ASP modules: cost-effective building blocks for real-time DSP systems. *Journal of VLSI Signal Processing*, 1, no.1, 67-76.
- Krikelis, A. 1991. Computer Vision Applications with Associative String Processor, Technical Report, Brunel University (to appear in *Journal of Parallel and Distributed Computing*).

Starlight - High Performance, Low Cost, Small Package

by Miroslaw Malek

Introduction

Starlight is the latest in a series of Distributed Array Processors (DAP) from the Active Memory Technology (AMT), an Anglo-American startup which is a formidable competitor to Connection Machines.

From ICL to AMT

First reports on square arrays of 1-bit processors were published between 1972 and 1976, mainly at International Computers Ltd (ICL) (then the largest British computer company), currently owned by Fujitsu. In 1976, the first array with 1024 1-bit processing elements (PE) was introduced as a front-end computer to ICL 1900 series. In 1980, a 4096-PE array was installed in ICL 2900 series. Although the machine was a commercial failure and only six were manufactured, it created an explosion of interest in academic circles that resulted in over 1,000 publications. The second generation of DAPs appeared 5 years later in the ICL's minicomputer called PERQ. Again, hand-crafted technology, lack of software, and low reliability resulted in only 13 copies of the machine that were distributed mainly to academic and research laboratories. In 1985 and 1986, ICL decided to spinoff the DAP technology. In October 1986, Active Memory Technology Ltd was formed with a £4.2-million investment (ICL - 25 percent, venture capitalists - 50 percent, and staff and founders - 25 percent). A core team came from ICL. After 2 years of intensive design efforts, the company produced and shipped the first DAPs in 1988.

Today, AMT has a staff of 90 (U.K. - 50 percent, U.S. - 50 percent) and over 80 systems installed in 7 countries. Their strategy is to concentrate on European and American markets. Overall system design and software are developed in the U.K., while VLSI design, system integration, and manufacturing are done in the U.S.

Distributed Array Processors

There are currently four AMT DAP models--510, 610, 510c, and 610c. Their performance is shown in Tables 1 and 2.

Although DAP is a single-instruction, multiple-data computer (SIMD), it can tackle an amazing spectrum of problems with surprising efficiency.

A basic architecture of a DAP computer comprises a $32 \times 32 = 1024$ array of 1-bit PEs for 510 models, and $64 \times 64 = 4096$ array of 1-bit PEs for 610 models. Models 510c and 610c have 8-bit PEs (in addition to 1-bit PEs) to enhance floating-point computation. Each processor

Table 1. Summary of DAP Performance

Basic parameters	510	610	510c	610c
Speed	10MHZ	10MHZ	10MHZ	10MHZ
Processors				
1 bit	1,024	4,096	1,024	4,096
8 bit	-	-	1,024	4,096
Peak Performance				
1 bit MIPS	10,000	40,000	10,000	40,000
8 bit MIPS	400	1,600	5,000	20,000
32 bit MFLOPS	15	60	140	560
I/O MBytes/s	40+40	80+80	40+40	80+80
Processor Use	3%	1.5%	3%	1.5%
Relative Power	1	4	10	40
Price Performance				
\$/MFLOPS	8,000	5,000	1,150	700

Table 2. Performance of Some Typical Operations¹

Model	Times in ms	
	510	610
3 X 3 convolution	14	3.5
Frame to frame differencing and thresholding	1.5	0.4
3X3 median filter	15	3.8
Histogramming (256 Levels)	40	10
Binary image thinning	2	0.5
Image normalisation	3	0.8
2-D FFT	68	17
Image segmentation	5	1.3

¹Image size is 512x512 elements with 8-bit pixels.

element is connected to its four neighbors, and a bus system connector processes by rows and by columns. Each processor is connected to a minimum of its own 32 Kbits of local memory which can be extended to 1Mbits. This gives a memory range of between 4 Mbytes and 512 Mbytes. The processor array is controlled by a master control unit which interprets a program located in its own private memory and broadcasts decoded instructions to the entire processor arrays. Then PEs concurrently execute these instructions processing the data in their local memories. Even with 10-MHZ clock, this architecture in a 4096-PE configuration can execute up to 40 Gbit simple operations/sec; e.g., logic operations. Also, a maximum aggregate data rate between processors and their memories may reach 5.12 Gbytes/sec.

A Sun or VAX workstation serves as DAP's host and is connected to the master control unit. This provides a rich interactive environment and interface to a wide range of peripherals. Although Input/Output (I/O) via the host may be sufficient for some applications, there is a capability for direct I/O to the DAP via fast 40 Mbyte/sec bidirectional data channels, which have a negligible impact on array performance (3 percent degradation for DAP510 and 0.8 percent for DAP610). There is also a VME-bus interface to a host connection unit.

From a programmer's point of view, DAP's software can be grouped into two sets.

1. Host machine software which is a standard set (UNIX, tools, libraries)
2. Array software which is written in standard extended language, such as Fortran-Plus or assembler, and exploits parallel capabilities of DAPS.

Fortran-Plus is similar to a recent standard, Fortran-90, and enables array manipulation of any size. The Array of Processors Assembly Language (APAL) is a macro-assembler which provides a complete control of all array elements. A hybrid of APAL and Fortran-Plus is feasible. Thus, integrating APAL into Fortran-Plus may accelerate execution of some time-consuming operations in a given application. Program State Analysis Mode (PSAM) is an interactive debugger for Fortran-Plus and APAL programmers.

Application support libraries include a wide range of functions to manipulate matrices and vectors and other mathematical routines. The libraries also include graphic, image conversion, image processing, digital signal processing, signal generation, and windowing routines. In addition, there is DAP simulator that is fully hardware compatible. The simulator allows users who do not have access to DAP computers to develop and test DAP programs offline.

Performance

There are several performance measures that may give a good understanding of DAPs capabilities, which are especially good in a naturally parallelizable applications.

Performance of exact and partial matches with estimation of statistical significance is measured in millions of cell updates per record (Mcups). For example, DAP610 with Fortran code can execute 28 Mcups, while with assembler 84 Mcups. A Connection Machine CM2 with 32K PEs and microcoded loops can execute 25 Mcups.

In some specific applications when compared with respect to price/performance to IBM's 3090V, Floating-Point Systems 264 machine, and Cray's XMP, DAPs seem to be extremely competitive (see Table 3).

Over 80 systems were sold. The AMT has delivered the systems to 22 British universities, some at U.S. universities, and 3 at government laboratories (2 in the U.K. and 1 at the Argonne National Laboratory, Illinois). Five major British companies own DAPs, including a news agency that uses DAP for keyword searching. As of August, 1990, 36 systems had been bought by American companies and government, including the U.S. Navy and Army. About 10 systems had been sold in Belgium, France, the Federal Republic Germany, the Republic of Ireland, and Japan.

Applications cover a wide range. Image and signal processing dominate in the defense industry, while research on parallel computing and medical imaging is carried out at the universities. Other applications include molecular physics, neural networks, molecular biology, computer design simulation (also circuit simulation), finite element, fluid dynamics, genetic sequence matching, data compression, radar processing, mine detection, human interface, research, and seismic processing.

Table 3. Price Performance Relative to Cray XMP

	DAP 510	DAP 610	FPS 3090V	264	CRAY XMP
Simple Loops					
Fl.pt. 32	4.8	8.1	0.3	0.6	1
Fl.pt. 64	1.6	3.1	0.3	0.6	1
Integer	31.6	49.7	0.3	0.6	1
Livermore					
All	0.8	0.5	0.9	1.6	1
Parallel	4.4	5.8	0.4	0.5	1
Log parallel	0.8	0.3	0.9	2.3	1
Serial	0.4	0.2	1.0	1.6	1
Kernels					
Convolutions	39.6	55.9	0.4	0.4	1
Zero xings	54.0	67.9	0.3	0.5	1
Histogram	5.2	7.7	1.1	0.2	1
Corner find	14.8	17.5	0.6	0.8	1
ESTEC algorithms					
CFD	2.4	1.7	0.4	0.4	1
LLT	1.6	2.4	0.9	1.1	1
Random	5.6	5.3	0.9	0.9	1
Edges	27.6	45.4	0.5	0.6	1

Starlight Module

The latest in DAP series is a multiprocessor called Starlight. Starlight has 4096 processors, clocked at 20 Mhz, 16-Mbyte data memory, 4-Mbyte instruction memory, and 320 Mbytes/second I/O rate. In addition, it uses multichip technology and is packaged in a small cylinder, 5" in diameter and 2.5" long. Starlight delivers 32-bit, 1.2 GFLOPS which makes it the world's smallest MFLOPS engine. At \$250 per MFLOPS and \$10 per MIPS, it is also cost effective. Delivery is scheduled for late 1991.

Conclusion

The DAP multiprocessors are among the most advanced multiprocessors among special purpose parallel computers. The latest model, 610c and Starlight, seem to be highly competitive in performance with Connection Machines while presenting lower cost and superb packaging technology.

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I would like to thank Dr. Geoff Manning, CEO of Active Memory Technology Ltd., for discussing DAP series and demonstrating DAP machines at work.

Formal Methods in Standards: A Report from the British Computer Society Working Group

by Robert D. Ryan, a mathematician currently serving as a Liaison Scientist for Mathematics and Computer Science in Europe and the Middle East for the Office of Naval Research European Office. Mr. Ryan is on leave from the Office of Naval Research Arlington, Virginia, where he is Director of the Special Programs Office.

This is the title of a book edited by C.L.N. Ruggles and published by Springer-Verlag (xi + 135pp, £25 [about \$50], ISBN 3-540-19577-7). I am writing

about it because I believe it contains useful information--particularly for nonexperts--on both formal methods and standards. This is not a comprehensive treatment of formal methods or of standards, but it is a useful sampler for the nonexpert looking for an introduction to either subject.

This book was written by the Formal Methods in Standards Working Group of the British Computer Society (BCS). The group was set up "to promote the practical application of formal methods in improving the quality of standards used in computer systems and software." A secondary (enabling) objective is to educate BCS members and others about formal methods in standards. This report is the group's first product.

After a brief chapter about the group and the way they work, there is a chapter on standards--what standards are, who the main players are, and how the standards development process works. The discussion of standards quality brings out the similarities between standards and software. Both can fail to serve a useful purpose, be difficult to use, be incompatible with other standards/software, be difficult to maintain, and malfunction. Hence, all the arguments for formal methods in software development transfer to standards development.

The background chapter on formal methods will not make you an expert, but it will fill you in on the main ideas and several of the popular formal specification languages, including VDM, Z, LOTOS, Estelle, and SDL. There is information about graphical formalisms, including a paragraph about David Harel's Higraphs. Finally, there is a discussion of tools, not specific tools such as the B-Tool, but a generic description of what different tools do in the development process.

Four case studies of formal methods in standards make up the core of the book. Rather than being completed stories, these are examples of how formal methods have been and are being used in four areas: (1) programming languages, (2) document structure, (3) graphics, and (4) communicating systems. The first example focuses on how Modula-2 is being defined formally using VDM-SL. The subjects of the second example are the standard generalized markup language (SGML) (ISO 8879) and the office documentation architecture (ODA) (ISO 8613). The third example is on the graphical kernel system (GKS), and the last example deals with open systems interconnection (OSI), an area of particular international interest.

The text is supplemented with a 57-page bibliography, a list of acronyms, and a glossary of formal methods terminology. These sections are packed full of information and form a useful desk reference in formal methods.

ONDEL: A Wavelet Workbench

by Robert D. Ryan

The French company DIGILOG, people at the Laboratoire Mécanique et d'Acoustique (LMA) in Marseille, and at the Centre de Physique Théorique (CPT) at Marseille-Luminy are involved in a cooperative effort to transfer the techniques of wavelet analysis to industry. The work is focused on the development of the wavelet workbench called ONDEL. The Centre National de la Recherche Scientifique (CNRS) provides support through the LMA and CPT, while DIGILOG is investing its own resources. This effort is motivated by the considerable interest shown by the scientific and industrial communities in these new signal-processing techniques. I also sense that CNRS would like to see the French maintain a lead in this area, which they pioneered.

ONDEL is advertised as a high-performance, user friendly environment for computing and displaying wavelet transforms and other transforms that have proved useful for treating nonstationary signals. The people at LMA and CPT provided the original algorithms plus their expertise in signal processing, particularly in the fields of speech and music. DIGILOG has integrated these algorithms into an environment that is easily accessible to industry and to other research scientists. DIGILOG also brings to the project their experience in working with applied signal and image processing from areas of defense, communication, and transportation.

From the outset, ONDEL was planned as both a research tool and a tool for practical signal analysis and synthesis. ONDEL accepts input in two forms: (1) analog signals in the audio frequencies, and (2) numerical data for signals of any frequency. Several functions are available:

- Wavelet transforms with the possibility to vary all parameters, including choices for the analyzing wavelet, the resolution and frequency scale, and the algorithm
- Analysis of the frequency and amplitude modulation
- Visualization of the transformed function, including the synthetic color schemes used by LMA/CPT, zoom, and a scheme for displaying the amplitude and frequency modulation
- Synthesis of the signal, total or partial.

One has a wide choice of analyzing wavelets, including the Morlet wavelet and wavelets presented numerically or mathematically. The operator chooses the sampling rate and the support of the wavelet. ONDEL generates a file of discretized wavelets for the analysis. Two algorithms are available: (1) the standard algorithm supporting any rule (linear, logarithmic, etc.) for the dilation parameter, and (2) the algorithm "à trous." Three other transforms are available on ONDEL: (1) Fourier, (2) Wigner-Ville, and (3) Choi and William.

ONDEL is built around a SUN workstation using a 20-Mflop vector card accelerator. The DIGILOG literature notes that this card is compatible with the neural network environment developed by the firm HNC. I mention this because of my impression that using wavelet transforms in connection with classification by neural networks is being diligently pursued by several French industries, including Thomson-Sintra and DIGILOG.

One can use ONDEL by visiting DIGILOG in Aix-en-Provence, or it is available as a software package. For more information, contact DIGILOG at 21, rue Frédéric Joliot, 13763 Les Milles Cedex, France. The telephone number is +33 42 39 93 19.

Computer-Aided Design and Manufacturing in France

by C. Chrysosostomidis, Professor of Naval Architecture, Director of Sea Grant College Program, Massachusetts Institute of Technology, Cambridge Massachusetts.

While in France, I visited Professor Andre Clement, Director of the Laboratoire de Mecatronique (Laboratory of Measurement, Technology, or Mecatronics) at the Institut Supérieur des Matériaux et de la Construction Mécanique, of the University of Paris, École Centrale des Arts et Manufactures. Professor Clement is well known for his work in computer-aided design (CAD) and computer-aided manufacturing (CAM). He has established unique associations with the French defense industry (in particular, the Dassault group) and thereby contributes to the efficient transfer of academic research to industry. He is also an active member of the Conference Internationale de la Recherche de la Production (CIRP), one of the principal international societies in manufacturing technologies.

At the Laboratory of Mecatronics, Professor Clement and his students have been focusing their activities in CAD, analysis, simulation and animation, manufacturing, and inspection. I am interested in computational geometry and CAD so my visit focused on Professor Clement's group research in the area of shape creation, interrogation, and inspection in a computer environment. Typical examples from Professor Clement's laboratory work include the papers identified below.

The creation of mathematical curves and surfaces for the representation of objects with freeform or sculptured shape is formulated as an optimization problem with constraints motivated by the range of permissible variation of the input lower dimensional data (e.g., measured points), the differential character of the shape, (e.g. tangents, sign of curvature) and integral constraints. An example of this work is the recent doctoral thesis by Leon (1986). In this work, curve and surface generation is investigated in terms of high-degree, Lagrange-type

polynomial bases. The focus of the thesis is in the formulation of the problem of automated elimination of the ensuing oscillations of the resulting shape. Following Lagrange-type interpolation of a subset of input data, the problem is formulated as a linear programming problem where the unknown parameters are the permissible position variations of the data. The position variations are subject to linear equality and inequality constraints arising from the above geometric and design considerations. The objective function is based on an integral proportional to the difference between the shape being created and a polygonal approximation of the data.

Beyond the above work on shape generation, I learned of more recent studies by Professor Clement's group on the problem of prediction of the numerical sensitivity of the results of geometric algorithms to imprecision of the input parameters. In this way, given the domain of variation of all input parameters plus the precision with which each input parameter is known, they can estimate the range of variation of the output parameters. This problem has important application in geometric design and manufacturing. For example, after completion of a manufacturing process and inspection via coordinate measuring machines, a usual problem involves the determination of the minimum distance between point sets (e.g., a point and a surface). The algorithms Professor Clement's group derived provide an estimate of the variation of the actual distance if the input (e.g., measured point) is only known with a given accuracy. Another topic of future investigation is the relationship of this problem with the problem of inaccuracy arising from floating point error during execution of a geometric algorithm provided with exact data.

In CAM, Professor Clement has been working on the problem of tolerance analysis and synthesis for assemblies of machine parts encountered in mechanical engineering applications. In addition, Professor Clement and his students and research associates have conducted significant research on the problem of localization (or resolution of the position) of solids to allow automated inspection of manufactured parts by coordinate measuring machines. Localization is formulated as an unconstrained optimization problem. A study of the effects of choosing different objective functions (e.g., least square distance, absolute distance error norm, minimax, or Chebychef norm) was undertaken and the results were published by Bourdet and Clement in 1988. More recently, Professor Clement has introduced and studied the concept of the resolution tensor for positioning solids that captures the relation between the uncertainty with which the position of any point on a solid can be computed. He has also studied the nature of the measurement tools, their relative alignments, and resolutions. Important applications of this work include calibration of machine tools, and high-precision

metrology of very small mechanical parts encountered in nanotechnology.

The following researchers are also studying the problem of shape creation in the computer:

- Professor Horst Nowacki, Technical University, Berlin, the Federal Republic of Germany (FRG)
- Dr. Malcolm Bloor, University of Leeds, U.K.
- Professor Gerald Farin, Arizona State University, Tempe
- Dr. Nickolas Sapidis, University of Rochester, New York, (recently, General Motors)
- Professor Josef Hoschek, Technical University, Darmstadt, FRG
- Dr. Helmut Pottmann, Technical University of Vienna, Austria (recently, Purdue University, Lafayette, Indiana)
- Professor Panagiotis Kaklis, National Technical University, Athens, Greece.

The following researchers are studying the problem of numerical sensitivity of geometric algorithms:

- Professor Leonidas Guibas, MIT
- Professor Christoph Hoffman, Purdue University
- Dr. Rida Farouki, International Business Machines Corporation (IBM), T.J. Watson Research Center, Yorktown Heights, New York.

The following researchers are studying the problem of localization in the position of solids:

- Professor Friedrich Prinz, Carnegie Mellon University, Pittsburgh, Pennsylvania
- Professor Eric Grimson and Professor Nicholas Patrikalakis, MIT
- Professor Leonidas Bardis, National Technical University, Athens, Greece.

The following articles and reports describe some of the work by Professor Clement's research team within the last few years:

Foussier, A., Sicard, M., Clement, A., Degirmenciyan, I., *A Generator of Constraints Solving Algorithms*, Technical Report, 1991.

Clement, A., *The Resolution of Positioning Solids*, Technical Report, 1991.

Clement, A., *Toward a Computer Aided Functional Tolerancing Model*. International Conference on CAD/CAM and AMRT - Jerusalem, Israel, December 1989.

Clement, A., *The Mating Function in CAD-CAM Systems*, ASME Design Automation Conference - Montreal, September 1989.

Clement, A., *Controlling a Mechanical Part Designed with a Feature Based System*. Computer Integrated Quality

System in CIM. IFIP Conference - Belgrade, Yugoslavia, June 1989.

Clement, A., *A Rule Based System for Parts Assembling in CAD/CAM Program*. Symposium on Integrated and Intelligent Manufacturing, ASME Winter Annual Meeting. Boston, U.S.A., December 1988.

Clement, A., *OPERA: Un Systeme Expert de Remontage d'assemblages Mecaniques Pour l'aide a la Decision*. Congres Intelligence Artificielle - Avignon, 1988.

Clement, A., *A Study of Optimal Criteria Identification Based on the Small Displacement Screw Model* by P. Bourdet. CIRP General Assembly - Tokyo, Japan, 1988. Also CIRP Annals Vol. 37/1/1988, pp. 503-506.

Clement, A., *Participation to Keynote Paper: Tolerancing for Function*. R. Weill, Annals of CIRP Vol. 27/2 Tokyo, Japan, 1988.

Clement, A., *Theoretical Modelization and Experimental Identification of the Geometrical Parameters of Coordinate Machines by Measuring a Multi-Directed Bar*. Annals of CIRP Vol. 35/1 - Jerusalem, Israel, 1986.

J.C. Leon, *Approximation de Courbes et de Surfaces Experimentales par des Polynomes de Degre Eleve avec Elimination Automatique des Oscillations*, Ph.D. thesis, École Centrale des Arts et Manufactures, Laboratoire de Mecatronique de l'I.S.M.C.M., Paris, France, 1986.

Clement, A., *Methodology and Comparative Study of Optimal Identification Process for Geometrically Defined Surface*. ISMQC - Tokyo, Japan, 1984.

Clement, A., *Identification et Generation de Courbes Discretisees Dans un Univers Mecanique Imprecis*. Ph.D. Thesis, University of Nancy I, 1982.

Clement, A., *Commande Adaptative Dimensionnelle des Machines et des Robots*. Annals of CIRP Vol. 30/1 Toronto, Canada, 1981.

Clement, A., *A Program to Aid Measurement on a 3-D Measuring Machine*. Seminar of CIRP - Haifa, Israel, 1978.

Clement, A., *Controlling a Complex Surface with a 3-D Measuring Machine*. Annals of CIRP Vol. 25/1 - Paris, France, 1976.

Probabilists Meet in Warsaw

by Raoul LePage, Department of Statistics, Michigan State University, East Lansing, Michigan.

Introduction

Leading probability researchers assembled in Warsaw May 21-June 11, 1990, at the invitation of the Stefan Banach International Mathematical Center, Polish Academy of Sciences. The discussion focused on two specific areas: (1) the rapidly evolving field of stable random processes used as models for data, and

(2) systems contaminated by noise or measurement errors that depart significantly from the normal bell curve of errors.

One of the common sources of stable errors is a summation of many small random disturbances, which are analogous to repeated samples from a very large population of such errors. Stable errors thus retain their distributional form (a stable curve of errors) and are stable when subjected to linear operations such as filtering. Normal errors are the most studied example of stable errors although it has been known for decades that the non-normal stable errors are better able to model volatile or erratic noise. Stable errors are termed symmetric if, like the normal, their curve of errors is symmetric. Many of the techniques used currently for studying stable errors, whether symmetric or not, have only recently become available.

I developed three of the newer techniques.

1. The LePage series representation technique breaks down every stable process into a series of progressively smaller terms connected with the diminishing influence of underlying random jolts present in the system
2. Gaussian slicing represents every symmetric stable process as a mixture (random selection) of normal processes
3. Seamless resampling enables statistical estimates of the sampling error of linear statistics to be made automatically without explicit reference to the specific form of the symmetric stable noise present in the system.

The LePage series representation technique is typically used to study the effects of various operations on stable noise processes through their action on the larger terms of the series. This technique is useful in understanding the oscillatory behavior and extremes of stable processes. Gaussian slicing is used to bring to bear the methods of normal processes on the problems of symmetric stable processes. Seamless resampling allows the development, just begun, of simple statistical procedures that automatically deal with stable noise (if it is present) and produce the usual results in the case of normal bell noise. Notably, many of the results developed for normal and non-normal stable processes carry over to a far larger class of processes in what is termed the domain of attraction of a stable.

These meetings are a part of an effort to understand the broad theoretical structure of stable processes so we can go on to engineering solutions. This particular conference was important since rapid developments were fragmenting the efforts of researchers.

An example illustrates some of the newer understandings achieved concerning stable processes. If stable noise enters a system through wave amplitudes,

then an attempt will proceed to break the resulting composite wave form down into frequencies using (the usual) methods calibrated for normal noise. The method will yield oscilloscope tracings that quickly lock on as the experiment is continued over time. In the case of normal noise, the oscilloscope tracing would not vary if the experiment we repeated restarted. However, for stable but not normal noise repeating the experiment will give an oscilloscope tracing which somehow resembles the first but is decidedly different.

Stable noise entering the system in other ways than through amplitudes will have different, but still anomalous, effects.

Using methods calibrated for stable noise (methods that allow for extreme values in noise components), one can cut through such anomalies to discover the underlying structure.

A frontal attack on this problem is to use an index of stability statistical measurement to ascertain whether a stable model is appropriate, and then formulate procedures appropriate to analyzing the particular model.

Such methods may soon be out of date. Automatic methods which bypass this step appear to be on the way. Methods being developed now are sensitive to the possibility of stable noise. One can have procedures that adapt themselves to non-normal noise if it is present but otherwise behave conventionally.

Highlights of the Conference

Rapid progress in the study of stable processes has resulted in the relative isolation of key groups working in different parts of the world. I will highlight some of the more easily described contributions.

Dr. V. N. Zolotarev, Moscow, showed work on the simultaneous convergence of sums of powers of different orders. This problem appears to also have a solution in terms of the series representations.

Dr. V. Paulauskas, Vilnius, U.S.S.R., visited M. Ledoux, Strasbourg, for the month preceding the conference. During the final week of his visit, he and Dr. Ledoux developed a solution to the problem of rates of convergence in the central limit theorem for stable laws that is based on the LePage series representation.

Contact between the Polish researchers and the U.S. is very good. Drs. M. Lewandowski, M. Ryznar, and T. Zak, Wroclaw, showed a result that uses the series construction to establish an Anderson-type inequality for the stable measure of spherical regions. They actually obtain the result for normal errors as a byproduct of the general stable case. This result is a basic means by which one can show that random processes can be essentially regarded as identically zero. For example, it is used to truncate a series construction after a fixed number of terms. Also, it might be used to judge how many terms of

the series are sufficient to simulate the process to a given accuracy.

Dr. J. Rosinski, University of Tennessee, Knoxville, showed a new series representation and with it some extensions of Gaussian slicing. The method (thinning) generates non-normal errors from normal errors by selectively throwing out most of the normal errors. Dr. B. Rajput, also Tennessee, described the support of stable measures.

Dr. G. Samorodnitsky, Cornell, Ithaca, New York, used Gaussian slicing to prove a Slepian inequality that is useful in signal detection for stable processes. Drs. Samorodnitsky and M. Taqqu, Boston University, Massachusetts, are writing a research monograph covering many aspects of current research on stable models.

Dr. Mandrekar, Michigan State University, showed a new generalized spectrum which applies in particular to every stationary stable process. The method is very general and, as applied to cases where Gaussian slicing is available, produces the spectrum obtained by that method. Also, it applies to ARMA systems driven by symmetric stable noise and virtually all known cases where a spectrum had earlier been obtained by differing methods. It is now important to study the applications of this spectrum to problems of prediction and estimation.

I presented a new bootstrap-like method for symmetric stable errors called seamless resampling. This method recovers the conditional distribution of the sum of errors given the vector of the absolute values of these same errors. The method performs particular random operations on the data during which information is obtained about the absolute values of the errors present in the data. This method is simple to use and automatically adjusts for stable noise when that is present. Seamless resampling is now under development for regression and time series applications where protection from non-normal noise is needed. The method is called seamless because it adapts to non-normal errors as well as to normal errors. This is important since it provides a trustworthy assessment of the standard error that does not become unreliable as the variability of the errors in increased.

Dr. M. Maejima, Keio, Japan, showed results characterizing self-similarity in particular classes of stable processes. Self-similarity is a property relating changes in the time scale to changes in the scale of the oscillations of the process.

Comments on the Conference

The conference was very well organized. Over 30 internationally known experts attended and presented their research findings. The Banach Center hosts, Drs. S. Kwapien, A. Heron (and their staff), and Dr. S. Cambanis (University of North Carolina), gave

generously of their time to look after the needs of the conferees. At the same time, they presented their own very interesting research results. Also, several computer scientists from Poland, the Federal Republic of Germany (eastern), and the U.S.S.R., came to the conference to learn about a stable processes and means of simulating them for use in modeling. There seems to be consensus that the series construction has made such computer simulations of stable processes generally feasible for the first time. Probably more efficient methods exist; they must be sought.

A new Steinhaus Center is starting in Wroclaw with contacts at several U.S. universities. Research on stable processes will also be high on the agenda for this group headed by Dr. A. Weron.

European Science Foundation Ground-Based Astronomy Meeting

by Tom Owens, National Science Foundation European representative

Introduction

The European Science Foundation (ESF) held a meeting of its *ad hoc* group concerned with ground-based astronomy at the ESF headquarters in Strasbourg, France, on January 8, 1991. Professor E.W.J. Mitchell chaired the meeting. I attended as an observer, having requested the opportunity to raise with this group the possibility of cooperation between the National Science Foundation (NSF) and ESF in an ESF network project. An ESF Network seeks to bring together researchers from countries throughout Europe to discuss and plan how they might better cooperate in (and coordinate on) their research activities. Small joint projects are sometimes also supported. The initiative for forming a network is expected to come from the researchers. The proposed network is on small robotic telescopes. The meeting agenda was

- Data handling, networking, and software implementation: Cambridge Granata backbone network - Sir Alan Cook; Centre de Donnes de Strasbourg - Dr. M. Creze
- Small robotic telescopes - Dr. J. Baruch
- Balance between large and small instruments, international and national operations - Professor J.C. Pecker.

Data Handling, Networking, and Software Implementation

Most of the time was spent discussing data handling, networking, and software implementation. Each of the 15 attendees commented on capturing, storing, accessing, and transporting astronomical data. I will present some of the salient points of the discussion.

There was not complete agreement about the necessity in astronomy to capture and preserve all data. Solar astronomers maintained that so much data was captured that a qualitative assessment had to be made before the decision to store the data. Others indicated that observations made to tailored specifications would not likely be useful to anyone else. Data takers must be mindful that others will be using that data. In principle, all data should be available to everyone. Archived data must be on observations that have been done properly.

An expertise center is to be created in Holland that will purchase software, computer hardware, and archiving materials of all kinds for astronomers throughout Holland. A variety of software packages in use by astronomers in different organizations and different institutions makes data sharing very difficult. Telemail offers an opportunity to share data in real time. Innovations in software or other techniques for reducing and analyzing are needed everywhere, and all research organizations have people committed to making improvements. Sharing these improvements in real time could lead to significant savings, releasing professional astronomers from the effort and allowing them to get back into mainline research activities. When software is developed, it must be decided whether it is to be for in-house use or further distribution. Keeping data useful to others is demanding.

At the Isaac Newton Group (Anglo-Dutch) facilities in the Canary Islands, in principle all data must be archived. One copy of data is given to the observer and one to the observatory, complete with inscriptions and other identification. Data tapes are stored at Cambridge and are available to the public after a year. Query software is also available for on-line searching of cataloging data. Observatory facilities at the Canary Islands sites have put in a proposal to the European Community (EC) to extend the archiving procedures to cover each of them. The European Southern Observatory is planning to establish special superscene required procedures for observations. The proposed procedure will be sensitive to the availability of exceptional observing conditions. An observation requiring special observation conditions would take precedence over scheduled observations.

A world view to a solution to these questions is required. Standards for software and hardware to be used in archiving and accessing data, standards for calibration of data and other standards-oriented issues require the participation of all important sources and users of astronomical data. Funding agencies must consider the fate of the data whose collection they support, and the additional uses for it. The small increments of funding must be provided that enable research grant recipients to set up effective archiving activities. This problem now receives little attention.

Dr. A. Cook, Cambridge University, U.K., described the linkage of 30 university departments and 30 colleges at the university in a network of personal and microcomputers. He observed that research itself is being decentralized through the availability of connections to various facilities via networking. He said that wide accessibility is the key to networks in science, with narrow specialized nets being interlinked. He suggested that ESF might collect and disseminate information on existing networks in Europe. At the same time, ESF might promote discussion between computing organizations in Europe.

Dr. M. Creze described the functioning of the Centre de Donnes de Strasbourg, and its role as an agent for the cataloging, archiving, retrieving, and distributing service for astronomical data, and managing the SIMBAD database. The SIMBAD database is interactive and accessible worldwide via major communication networks. The SIMBAD database is a "cross-identified and object oriented data base providing data and bibliography for more than 700,000 (astronomical) objects."

The discussion was summarized by the chairman.

- Archives are necessary
- Archived data must be available through distributed access
- No universally accepted criteria for preservation is available
- Common and effective pathways and how to use them are needed.

After discussing this analysis, the group agreed that the ESF should call a meeting of representatives of the most important astronomical research institutions (perhaps 10). The group would be asked to make suggestions for achieving compatibility of processes; establishing hierarchies for the selection of data to be archived; developing archiving standards, terms of access to archived data, standards for processing data, and other related issues. It was emphasized that American and Japanese institutions must be included in this meeting. The ESF will probably call the meeting in May, June, or fall, 1991. Ways will be discussed in which the Academia Europea might assist in addressing archiving issues.

Small Robotic Telescopes

D. J. Baruch, University of Bradford, U.K., presented the case for ESF support for a network on small robotic telescopes. Dr. Baruch proposes to set up a network that would assist with promoting and deploying small robotic telescopes in the most evolutionary fashion. He also indicated that the telescopes in question would be used in the simplest of astronomical measurements. Quality assessment of the telescopes and of the activities within the network would be built in, and the review process would allocate priorities.

The robotic telescopes would provide CCD photometry and send the data to the originator after archiving. A half-meter telescope could set up on a mountaintop. Observations could include:

- Chaotic phenomena
- Gravitational lens field mapping - microlensing
- Search for planetary systems/life
- Gamma ray burster error box monitoring
- Visible photometric signature concurrent with observations in other wavelengths
- Satellite observations.

There is considerable interest by industry in many of the technologies required for robotic telescopes. The proposed network would provide opportunities for collaboration with industry and would be good for the popular image of astronomy. Application of interest to industry include:

- Artificial intelligence
- Image processing
- Large image archives
- Security
- Networking and teleoperations
- Autonomous systems and robotics.

An ESF network would help to accelerate developing these small telescopes and contribute to scheduling systems, pattern recognition software, software interfaces for robotic systems and uniform data request, archiving, and return interfaces.

Dr. Baruch indicated that work on small robotic telescopes is underway at the University of Bradford, IAC in Spain, European Southern Observatory (Catania), and at several places in the U.S., including the Mount Hopkins autoscope at the Smithsonian Institution.

The networking discussion ended with the committee recommending that the ESF robotic systems committee be brought together with those interested in the astronomy research applications of small robotic telescopes. The question of initiating a network would be deferred pending the results of that interaction.

Balance Between Large and Small

Instruments/International and National Operations

Professor J.C. Pecker presented his view that the discipline will continue to need small instruments even as it moves toward ever-larger and more-dispersed instrumentation. Small instruments will be needed for universities and for student training. Amateurs can use them to do good astronomy that is otherwise not done. Time allocation methods on big machines do not allow for the more routine types of astronomy; e.g., on bright objects for long periods. Some lower-caliber instruments should be considered despite their second-tier status. Those selected for preservation should be opened to the broadest population of researchers, to foreign as well as

domestic researchers, and for activities that are different than those carried out at the larger facilities.

The discussion that followed included examples of using small instruments in educational programs (both graduate and undergraduate) in Holland. There was general agreement that there will always be a use for smaller equipment.

On international versus national activities the maxim--science first, then the agreements--was put forth. It is important to do domestic work first. National communities must be the final arbiter of what is important to do on national facilities.

Comment

This ESF astronomy committee is an *ad hoc* body that persists beyond the time originally envisaged for its operation. The reasons for this emerged during the discussion of the data archiving question. No other European organization with special astronomy expertise to deal with discipline-wide issues could be found to take on this one. The Academia Europea is seen as possibly not yet fully able to handle this kind of issue on a timely basis. The European Astronomy Association is still deciding on how it is to be managed. Therefore, the attendees decided that it would be necessary to meet once more to discuss priority-setting in European astronomy. The ESF is filling a niche of importance to European astronomers interested in planning.

Dynamical Processes in Condensed Molecular Systems

by Michael Shlesinger, Director, Physics Division, Office of Naval Research, Arlington, Virginia

Introduction

As part of the Emil Warburg Symposium in April 1990, the Dynamical Processes in Condensed Molecular Systems meeting was held at the University of Bayreuth, Federal Republic of Germany (FRG). Bayreuth is perhaps best known as the home of Wagner, the famous composer. The meeting was an interesting mix of chemists and physicists, exhibiting the blurring of distinction between these two disciplines. Most of the participants were from the FRG, Israel, and the U.S., with several from the U.S.S.R.

Summaries of Presentations

I. Sokolov, Lebedev Physical Institute-Moscow, was spending the year in Bayreuth as the guest of Dr. Alex Blumen. This is further evidence of the remarkably swift changes that have occurred in Europe. Sokolov was studying diffusion-controlled reaction on fractal structures such as percolation clusters. Slow algebraic decays for the reaction were found via theory, which agreed with computer experiments. Bimolecular annihilation reactions were studied theoretically and via

simulations by A. Blumen, University of Bayreuth. He studied randomly (Poisson distributed) placed immobile reactants, interacting via exchange interactions $w(r) = w_0 \exp(-r/r_0)$ which give the probability that two particles (of types A and B) situated a distance r from each other will interact. This led to nonclassical results, such as decays behaving as $(\ln w_0 t)^{-d/2}$ if the concentration of A's and B's are equal, and $\exp(-c(\ln w_0 t)^{d/2})$ if the concentrations are unequal. These results follow the more familiar case of diffusion-controlled reactions if the diffusion length $(Dt)^{1/2}$ is replaced by the reaction radius $r_0 \ln(w_0 t)$.

One interesting paper grew out of the Office of Naval Research (ONR)-sponsored work of Aaron Lewis--first at Cornell University, Ithaca, New York, then at Hebrew University, Jerusalem. The question is: Can one obtain a resolution with light below its wavelength? It is well known that in the far field the resolution is equal to the wavelength. However, in the near field, shine a light through a hole, and the wavelength can be equal to the size of the hole. One problem with this approach is that the intensity of the light will decrease exponentially fast with distance. Thus, unless an object is right in the hole, it could not be resolved by near-field radiation. One approach is to turn the light into excitons and then re-radiate at a shifted wavelength from a source which is smaller than the wavelength of the light. R. Kopelman, Michigan University, Ann Arbor, working with Lewis, believes that nanometer optics is possible with visible light using molecular exciton wires. A crude demonstration of exciton creation and re-radiation was given by placing anthracene crystals in a micropipette. The idea was put forth that the interplay of light, molecular excitons, and surface plasmons could allow unique designs of nanometer optical components.

A good deal of the conference was devoted to relaxation phenomena. Spectral shifts, in chemical and biophysical processes, are usually interpreted as reflecting an underlying relaxation process. For example, a low-temperature blue shift in the IR absorption band of myoglobin has been interpreted as a solvent relaxation around the protein structure.

N. Agmon, Hebrew University, suggested an alternate explanation in terms of inhomogeneous kinetics. One assumes deoxy-myoglobin conformations where the iron closer to the porphyrin plane rebinds faster and absorbs more to the red than conformations with the iron further out of the plane. Geminate recombination of the CO and oxygen following a short laser flash would deplete preferentially the red conformations. The spectral peak would shift to the blue, but the shift would be caused by hole burning, rather than relaxation. Direct observation of the hole burning has since been observed.

C. Brauchie, University of Munich, also investigated hole burning. He studied surface adsorbed dye molecules; e.g., quizarin/alumina, using fluorescence

line narrowing and hole-burning spectroscopy to find that spectral holes burnt into absorption bands were appreciably broadened when compared to the same molecules embedded in glassy matrices. Fluorescence line narrowing experiments indicated that low-frequency excitations coupled to vibronic excitations of the adsorbate. Thus, the increased hole widths were associated with frustrated translational or rotational motions of the adsorbate.

R. Gerber, Hebrew University, studied molecular reactions in crystalline systems in the picosecond time scale. He emphasized simplicity. The photodissociation of diatomics; e.g., HI, Cl₂, and F₂, were studied in single crystals or rare gas solids. He found that the original reaction cage had little effect on the exit of photofragments in some systems; e.g., Cl₂ in Xe. However, in other cases; e.g., HI in Xe, the exit of photofragments upon immediate photolysis was strongly delayed for several picoseconds. Gerber interpreted the results as some atoms being able to migrate in specific crystallographic channels in the solid to avoid immediately participating in the reaction.

D. Haarer, University of Bayreuth, used photochemical hole burning to study molecular parameters in glasses. Glasses, of course, lack long-range order so dye molecules (inserted as dopants) can experience several different local environments. The photochemical hole burning provides an energy selection scheme to study these local environments. These techniques were able to yield relaxation and lifetime measurements. B. Kohler, University of California at Riverside, used hole-burning techniques to study the cis-trans photoisomerization of polyene 1,3,5,7-octatetraene substituted in an n-alkane matrix. Measurements were taken on the temperature and vibrational energy dependence of the hole widths, the vibrational energy dependence of the photoisomerization quantum yield, and hole burning in the phonon spectra. The data were used to construct potential energy surfaces that could then be used to predict spectroscopic and photochemical responses.

S. Mukamel, University of Rochester, New York (an ONR contractor), theoretically studied femtosecond nonlinear spectroscopy of solvated and aggregated polyatomic molecules. He used a multimode Brownian oscillator model to account for the high-frequency molecular vibrations, the local intermediate molecular modes, and the collective solvent motions. Mukamel used the pump field to create a doorway state whose spectral overlap was calculated with a window state (which is prepared by probe pulse). Both the doorway and window states are wavepackets in phase space. Conditions were derived for observing quantum beats, spectral diffusion, and dynamic Stokes shifts for solvation dynamics.

P. Reineker, University of Ulm, FRG, numerically investigated electron spin resonances (ESR) and optical lineshapes of particles in a solid with Gaussian and dichotomic energy disorder. With spin hopping in one dimension, he found that as the hopping rate increased, a slow-motional narrowing contribution to the lineshape occurred corresponding to the energy distribution on the sites. When the hopping rate was increased further, cluster effects appear and the lineshape asymptotes to Lorentzian behavior. In the case of optical absorption, he finds that the optical spectra are self-averaging quantities which do not depend sensitively on the configuration of the site energies.

I spoke on a defect-diffusion mechanism for the glass transition. If there is a sufficient dispersion in defect hopping times, and defect movement induces relaxation, the stretched exponential law for relaxation results. In this model, the time scale for the relaxation grows inversely with the number of mobile defects. A lattice gas model for the number of single defects (which are assumed to be the most mobile) yields a Vogel-like law for the time scale $\tau = \exp(\text{const.}/T-T_0)$. As fractal scaling in the time distribution of defect hops plays a dominant role in this model. In an after-dinner talk, I discussed the history of scaling in probability theory.

R. Richert, University of Marburg, FRG, discussed a derivation of a different relaxation time divergence law, given by $\tau = \exp(\text{const.}/T^2)$. He studied electron transport in amorphous semiconductors and used an Arrhenius law $\tau = \exp(<E>/kT)$, but with a temperature dependent activation energy, $<E>$, (governed by a Fermi distribution and behaves as $1/T$) to give the $\exp(1/T^2)$ law. In fitting data, both the Vogel law and the $1/T^2$ law do a good job.

Richert also studied solvation dynamics of triplet excitons in polar solutions. The energies related to the absorption and emission of a probe molecule in polar solution are separated by the Stokes shift of the exciton energy caused by the change in the dipole moment. This causes the solvent to relax to a new minimum energy. The relaxation is strikingly nonexponential. This demonstrates the breakdown of continuum theories for relaxation in solvents.

W. Reiss, University of Bayreuth, investigated the mechanism for charge transport in a quasi-one-dimensional organic conductor (FR)₂PF₆. He performed temperature, field, frequency, and AC conductivity measurements to characterize the transport mechanism. Non-Arrhenius and nonlinear behavior were found, including a structural phase transition which was responsible for a hysteresis effect.

M. Schreiber, University of Dortmund, studied the autolocalization of excitons. The optical properties of many insulators are like alkali halides, or rare gas solids, in that they are strongly influenced by the exciton-phonon

interaction. This can lead to the formation of a localized exciton state at the site of the local lattice distortion. As a result, luminescence spectra will show characteristic lines for these self-trapped excitons. To describe the autoionization, he determined the adiabatic potential energy surface. The analysis yielded a potential barrier between the itinerant exciton and the self-trapped exciton, and a tunneling transition between these states was calculated.

Y. Gefen, Weizmann Institute, Rehovoth, Israel, studied localization, dephasing, and dissipation in mesoscopic systems which are induced by the Landau-Zener mechanism. This mechanism comes into play in a system with a discrete spectrum which exhibits a multitude of avoided crossings. When an external parameter is varied, internal transitions can occur. It is in the neighborhood of each avoided crossing that a Landau-Zener tunneling can occur, and the above phenomena; e.g., localization, can occur.

Several talks focused on systems where the composition of an alloy was adjusted so one material percolated through another. In this manner, the effects of fractal properties (fractal mass and spectral vibrational dimension) on physical properties can be explored. C. von Borczyskowski, Freie Universität, Berlin, studied such a lattice of p-dichlorobenzene and p-dibromobenzene. He found, in a Monte Carlo simulation, that the spectral dimension depended on the range of interaction. For short-ranged interaction, a stretched exponential decay was found with an exponent of $1/3$. A. Nitzan, Tel-Aviv University, studied a dynamic percolation lattice where at any instant a percolation cluster exists, but bonds change (form and break) and the cluster changes in time. An effective medium theory was used to study transport on such a lattice. Diffusion on such a dynamic percolation lattice was shown not to exhibit a critical percolation value because if an exciton is isolated, sooner or later, bonds form and transport back to the infinite cluster occurs. On a static subpercolation cluster, the diffusion constant for such an exciton would be zero. R. Hilfer, University of Mainz, FRG, reported on ONR-funded work he performed as a postdoc at UCLA. He studied Na^+ superionic conductors where these ions were blocked by a percolation collection of barium ions. However, at moderate temperatures, the barium ions could move and induce correlation in the sodium conductivity. This caused a pronounced, unexpected maximum in the real part of the conductivity as a function of frequency. An uncorrelated picture would yield a monotonic conductivity.

Comments

Overall, the main theme of the meeting was that a combined modern experimental, theoretical, and simulation approach was yielding explicit answers to the chemistry and physics of condensed molecular systems. The resulting overall impression was that the distinction between chemical physics and condensed matter physics was disappearing.

Hannover Biotechnology Fair

by Steven Kornguth, University of Wisconsin, Madison

Introduction

The Hannover Biotechnology Fair was held in Hannover, the Federal Republic of Germany (FRG), in September 1990. The theme of the opening of markets to the Eastern Bloc provided an excitement not usually present at such fairs. Among the most interesting exhibits were those from the FRG, including the recently integrated Eastern Bloc. These programs of excellence represent a small portion of the Eastern Bloc scientific community. A member of the GDR Academy, Dr. Ringpfeil, estimated that two thirds of the research centers will close following reunification. The Eastern Bloc nations had equipment exhibits on fermenters or single cell culture systems (20 to 1,500 liter capacity). These included Vegyepszer (Budapest) and ZVU (Czechoslovakia). The equipment was not competitive with Western cell growth chambers in performance characteristics or availability. FZB (an independent research facility that previously was the Central Research Unit of the former German Democratic Republic pharmaceutical industry) had advanced peptide synthesis and microencapsulation capabilities.

More than 90 percent of investment in foreign high-technology areas is through acquisition, in part or whole, of established firms with growth potential. Examples include the Boehringer-Ingelheim purchase of a portion of Promega in the U.S.

To deal with the lack of financial resources in the Eastern Bloc, FRG has encouraged the Länder (state governments in the FRG) to form monetary partnerships with a state in the East. For example, Hessen (an affluent state) and Thuringia have entered into a joint venture. Thuringia is the home state of the Leitz optical works in Jena. The general expectation of the partnerships is that investment in low cost, highly trained areas of the former German Democratic Republic will bring high yield returns.

There was general agreement that the infrastructure of the Eastern Bloc presented problems for Western investment. All communications systems are unreliable. Visa requirements remain an impediment to business transactions. Payment depends on upon the priority of the central government.

In biotechnology, the major needs of the emerging Eastern Bloc nations are in equipment, computers and information networking systems, tissue culture media, and marketing skills and arrangements with Western nations.

Biotechnology in the Federal Republic of Germany

The Veterinary Medical School at Dummerstorf near Rostock (Drs. Goetze and Rhode) has produced cloned calves. This work is related to that of Dr. Neal First at the University of Wisconsin-Madison and the American Breeders Service, Wisconsin. The Rostock group needs tissue culture media and will provide a potential market for cattle stock prepared as clones. This group has collaborative efforts with the veterinary school in Liebeckhof near Prague, Czechoslovakia (Dr. Fulka), and the school in Balice near Krakow, Poland (Dr. Katzka). They are exploring avenues leading to collaborative work.

The Martin Luther University, Halle/Wittenberg, is interacting with the research center at Jülich (Dr. G. Lauckner) to produce biosensors for detecting ethanol, glucose, and lactate. The sensors are in production and are based on nicotin adenine monitoring by redox systems. The sensors can be attached to 1 to 10 liter cell reactors. These have applications in the brewing industry, single cell culture systems, and antibiotic preparation. Sensor development in the FRG, based on optical fiber systems, was demonstrated by the Technical Institute in Hannover. These biosensors are for online sensing of pH and penicillin. Also at Hannover Dr. K-D Anders, C. Schelp, F. Plotz, and Th. Scheper are developing a T2 mycotoxin sensor. The GmbH-Dresden (Dr. Uwe) has an extensive single cell plant culture for ornamental flowers. The purpose is to develop virus resistant strains and to prolong the display period of cut flowers. Finally, a software package used to analyze human and animal chromosomes has been developed at the Institut für Zuchtforschung in Quedlinburg, FRG. The work staff in each of these centers appears of excellent quality. The FRG staff has needs in areas of culture media, disposable supplies, and computers.

I visited the Gesellschaft für Biotechnologische Forschung (GBF, Institute for Biotechnological Research, Braunschweig), a leading research institute of the BMFT. This institute has an infrastructure that is funded by the BMFT and the State of Lower Saxony at a level approximating \$35 million. They are leaders in biomolecular design, biosensors and protein engineering

(Dr. R.D. Schmid, the Center for Advanced Protein Engineering CAPE Facility under Dr. Schomburg), biosynthesis and biocatalysis (Dr. J. Collins), environmental remediation and biotechnology, and biochemical engineering/process technology. The targeted research efforts are funded jointly by the private sector, the state and federal governments at approximately \$30 million. The biosensor work is based on enzyme-loaded, thin-layer sensors prepared in Japan and on enzyme-loaded, thick-layer sensors prepared in Braunschweig. The GBF has features that are similar to the University-Industry Technology Centers funded by the Office of Naval Research and the National Science Foundation. The total staff has 233 scientists and 139 technical assistants. In addition to research and development activities, the GBF has 8-week long educational courses, to train undergraduate and graduate level students from developing countries. The GBF is a model for federal facilities responsive to the needs of the private sector in process technology as distinct from product development, which is an in-house activity.

East Meets West--a Symposium for Exploring New Avenues of Cooperation

Dr. Alfred Hellman, Advisor to the U.S. Department of Commerce, coordinated this symposium. Dr. Robert Yuan, University of Maryland, referred to his reports on Biotechnology in Eastern Europe, Biotechnology in Japan, Biotechnology in Singapore, South Korea, Taiwan, Peoples Republic of China (PRC), that were published by National Technical Information Service. In biotechnology, funds have been provided to the PRC by the World Bank, Monsanto, Goodyear, Pharmacia, Genentech. His major points were:

- U.S. firms need capital (an estimated 90 percent will need funds by 1991), therefore cannot provide funds to the East
- All cooperative ventures must be mutually beneficial
- Markets, government incentives, and a low-cost, highly educated labor force will attract Western investment.

Biotechnology in Hungary

Dr. Sandor Pongor, United Nations Industrial Development Organization (UNIDO), and Director of the Institute for Protein Research in Godollo, spoke on behalf of the International Center for Genetic Engineering and Biotechnology (ICGEB), UNIDO, Trieste. The UNIDO operation in Trieste has a budget of \$56 million. The Italian government provides 75 percent, with Rockefeller Foundation providing the rest. Most of the funds are for research and development (R&D) and for training scientists from developing countries. In his role as Director of the Agricultural Biotechnology Center in Godollo, he reported that half of his budget is for a building program and the remainder

for research and training. The 60 trainees take a 2- to 3-year course in the areas of protein research, plant sciences, molecular genetics, and animal sciences. The new programs begun at Godollo include education, patent issues, environmental strategies, and information networking. He wishes to establish a linkage with European Organization for Nuclear Research (CERN) Internet and Bitnet computer networks. As with the other speakers from the Eastern Bloc, he believes a rapid growth area for their scientific community is in bioremediation.

Mr. Rudan, Director, State Office for Technical Development (SOTD), Budapest, said that current funding in Biotechnology in Hungary was \$1 million. The division is existing research institutes - 40 percent, universities - 20 percent, private corporations - 35 percent, and SOTD - 5 percent. The priorities are in virus-free culture for horticulture, medical and health care (their tissue plasminogen activating factor, a mycotoxin detector in food), and environmental remediation (soil pollution and waste water treatment). The SOTD, Hoechst (FRG), and Szeged are jointly training R&D fellows. He believes their strength is in monoclonal antibody and biological response modifier production.

Biotechnology in Czechoslovakia

Dr. Ettler, Czechoslovakian Academy of Sciences, reported on new patent policies in Czechoslovakia emphasizing microbiological areas and the general state of the nation's economy. In October 1990, all small business were privatized and in January 1991, all large businesses made the same adjustment. Current patent policy is that both naturally occurring and genetically modified organisms can be patented in Czechoslovakia (in U.S., only engineered organisms can be patented). Their science base is in the universities. Their strength is in immobilizing cells and proteins.

Biotechnology in Eastern Federal Republic of Germany

Dr. Ringpfeil, Secretary for Biosciences, East German Academy of Sciences, emphasized that the success of the emerging eastern region of Germany will depend upon joint ventures with existing FRG laboratories and firms. The FRG has encouraged joint interactions between the Länder; an example is the Hessen-Thuringia partnership cited above. The labor component of the research force in the eastern region will decrease by 70 percent in the near future. He identified the following as centers of excellence: Molecular Biology (Berlin), Institute of Biotechnology (Leipzig), Institute of Animal Production (Rostock), and Microbiological Research Center (Jena). Biotechnology provides 1 percent of total production earnings in the eastern region. Prof. Ringpfeil believes their strength is in microbiological gated systems (fermentation), biomass conversions.

Biotechnology Research in Poland

Dr. Wlodzimierz Ostrowski, Presidium Polich Academy Sciences, Krakow, indicated that \$20 million were allocated for research but current economic difficulties have reduced the funding levels. Priorities are in the genetic basis of animal breeding and plant protection from viruses. He believes their strength is in antibiotic production.

Biotechnology Research in Russia

The Russian strength is in cosmologic biotechnology (crystal growth in space), membranes (in controlled cell growth), and organic chemistry. Research is being conducted at the Shemyakin Institute and the Institute of Cardiology, both in Moscow.

Science and Technology in Poland

by Tom Owens

Introduction

This report describes a trip to Poland made primarily to gain an understanding of the current situation about the making of science policy. Except where otherwise indicated, the opinions expressed are those of the persons visited, as I understood them.

National Research Committee

Dr. Stephan Amsterdamski is the principal staff member and acting head of the newly established National Research Committee (NRC), which was established by law passed in February 1991. The law mandates a new procedure for the funding of research by the government in Poland, for which the committee is to be the centerpiece. The NRC replaces the Committee for Progress in Science and Development. The 60-member committee is to be elected by all Ph.D.-level researchers in Poland. Some of those directing the sections will be drawn from the people who did not get enough votes to be a committee member and even may include people who were not candidates.

The NRC will initiate a nation-wide and unified process for the support of research. Scientific merit will be the single most important criterion (regardless of the institutional affiliation of the researcher) for obtaining government support. In addition, the committee will determine whether requested new research programs are well founded or likely to have important applications. In 1991, 2 billion zlotys (\$213 million) will be available for research proposals. This represents 20 percent of the Polish science budget.

The new process for NRC research fund allocation was a compromise, but a new system was needed as soon as possible. Unfortunately, even as it is, the first awards will not be made before fall 1991. This delay will cause funding crises in many institutions while they wait to see if they will be funded. The formation of a consensus on

the new system is still underway, and remnants of the nomenclature system are saying that the new procedures will destroy Poland's scientific heritage. On the other hand, those who have been held down by the old system are frustrated by it. The Polish Academy of Sciences (PAS) says not to bring in experts; just give them the money and they will do good work. The NRC is independent, and its grants system will provide uniform standards. We will see who is elected to the committee. Acceptance of the committee is still in question, and the transition will be a painful process.

Establishing the NRC was a no-confidence vote in the PAS. However, it is only the exchange of one central authority for another. How will the committee cope with all the proposals it is receiving? How will Polish research organizations be able to reply to requests for cooperation when they do not know how much money they will have? The PAS does not have any money, and decisions must be made without knowing whether there will be money.

Polish Academy of Science

Four billion zlotys will be used for salaries for researchers, support for the PAS, and other institutional support costs. One billion zlotys will purchase new equipment. The new law eliminates the grants program of the Ministry of Education and PAS support for research to its research institutes. From now on, university laboratories, PAS laboratories, and government research institutes must pass the same review process. The NRC has received the first batch of proposals (hundreds stacked high on tables in three rooms). They are being screened for appropriateness. That is, does the request for research have scientific merit, and does it contain material on which a judgment of the merit of the proposed research can be made? If the proposal is acceptable, it will be subjected to a technical peer review, and finally to the Pure Research or Applied Research Committee for final action. The 50-member staff does not have many people with a research administration background, and it must have more people with such experience.

The new Director of International Relations for the PAS is Dr. Jacek Kornacki. In recent times, the press has criticized PAS as being a Stalinist structure that should be eliminated. The PAS can surely be criticized, but it did preserve a great deal of independence from the previous government. The membership was not formed on the basis of political considerations as in some other countries (like Czechoslovakia). The President and Vice President are elected, and the criticism has abated somewhat. Nevertheless, the general crisis in Polish science and research is affecting PAS.

A new law formed the new National Science Committee. This committee will be responsible for giving money for research to all kinds of researchers in all kinds

of institutional settings, including PAS institutes. While indirect costs and salaries of researchers were previously part of the Polish government budget process, research costs were funded from the proceeds of a 1.5 percent tax on the sale of products in Poland. The research funds were distributed by the predecessor to the NRC, the State Committee for Progress in Science and Development. Now money will come to those who have scientifically sound projects. In addition, grades have been assigned to research institutes throughout the country, on a scale of 1 to 4.

- 1 = 110 percent of previous year's funds.
- 2 = 95 percent of previous year's funds
- 3 = 50-95 percent of previous year's funds
- 4 = 50 percent of previous year's funds.

Most PAS institutes obtained a top 1 or a 2 rating. In some cases, the grade may be changed upon appeal, but the process is taking its toll.

The PAS struggles to survive. The PAS is looking for money to establish foundations for energy research, polar research, and other new activities. The PAS is trying to privatize and prioritize some of its other activities under the blessing of its presidium. A new bill is pending in the Sejm (Poland's parliament) about PAS's future. The current parliament probably will not act on the bill before elections, so it must be taken up by the new one. The bill maintains that PAS

- Should be a learned society with elected and independent members and officers
- Should be a scientific center with its own laboratories
- Should be state budget line item insofar as the laboratories are concerned.

Until a new law is passed, the PAS will continue more or less as it is now.

In addition to the cooperation with Centre Nationale de la Recherche Scientifique (CNRS), the PAS has an agreement for the exchange of about 40 researchers annually with the École des Sciences Sociales and with the National Institute for Agronomy Research (INRA). Cooperation in the latter case is shared with the Academy of Agriculture and Forestry. A new protocol will be signed for an honorific exchange between the PAS and the Institute de France.

National Ministry of Education

Professor Wimbowski, Minister of National Education, will be the interim NRC President. The new law has been adopted for the support of research through the NRC. Now comes the real challenge of implementation. Possibly during the initial stages of implementation, it will be necessary to continue with the present education research grants program. The grants program can cover costs of research for laboratory and human resources development.

Tadeusz Diem is the Deputy Minister for National Education. Among his responsibilities is the support of university-based research organizations. The universities have 72 percent of the personnel whose research organizations are government supported. The PAS has 11 percent, and scientific institutes and research and development (R&D) centers have 17 percent. Each university rector (president) has a personal policy for pursuing the scientific image of the university. Requests for support are made without reference to the actual status of the university's research reputation.

In the past, a 1.2 percent tax on all products and services sold in Poland was dedicated to the support of science. Currently, the government is diverting 52 percent to other uses. Because prices are rising fast, even the 48 percent represents a considerable amount of money, so researchers in Poland have done very well. However, now science will be moved off the direct tax-based funding to funding via the national budget. There will be 9.7 billion zlotys in the budget for 1991 (up from 8.7 billion zlotys in 1990, but affected by 52 percent inflation).

Ministry of Environmental Protection, Natural Resources, and Forestry

Dr. Rajmund Jan Wisniewski is the Director of the Department of Science and Programming in the Ministry of Environmental Protection, Natural Resources, and Forestry (MEP). He is a former researcher in ornithology of penguins in Antarctica, having received NSF support for that work. He is assisted by Ms. Barbara Bulata.

The MEP has five research institutes. These institutes are funded by the interim organization, and will apply to the new grants program for research support. The institutes are

1. Institute of Water Management
2. Institute of Environmental Protection
3. National Institute of Geology
4. Institute of Forestry
5. Research Center for Geological Techniques.

Future cooperation with the Ministry or with the NRC may be possible. The fields of research preferred by the Ministry for Cooperation would have a relation to Polish environmental policy. There are four priority areas within this policy. They are

1. Air pollution
 - Coal burning related (SO_2 , CO, CO_2)
 - Models of transboundary pollution
 - Transport phenomena (work in progress with the International Institute for Applied Systems Analysis)

2. Terrestrial pollution
 - Agricultural
 - Forests
3. Water pollution
 - Pollution of the Baltic Sea
 - Industry
 - Municipalities
 - Agricultural (pesticides, runoff)
4. Solid waste
 - High energy/materials-consuming industry
 - Isolation of wastes from groundwater
 - Collection and recycling of waste
 - Application of social sciences and economics.

There are thousands of hectares of conifers that have died from various-source SO_2 . This forest should be replaced by deciduous forests, along with the application of calcium to neutralize acid rain. Eutrophication of lakes is a problem in Northern Poland, and the influence of agriculture on the environment is profound. This problem is reversed when agriculture is carried out on land polluted by industry.

Grant System

Perhaps a network could be used to build something new in U.S.-Poland mechanisms for science and technology (S&T) cooperation. The Marie Curie Skłodowska Fund (MCSF) is too small to carry the political expectations. As Polish researchers improve and link more to the outside, they will be seeing a small fund for cooperation with the U.S. and a very large fund for cooperation with Europe. For the past 20 years, Polish researchers have been going to the U.S. for research and training. Now Poland wants to adjust the model for scientific exchange to that of joint scientific projects. Such projects would have equal participation and equal rights from both sides.

Professor Roman Ney is Chair of the Sejm Commission for National Education, and Doc. dr hab. Jerzy Zdrada is a member. Until recently, all scientific research had been included in a central program, including basic and applied research. Many disciplines did not fit well into the system, and there was little freedom for research. Economic policy for Poland is just now being created. The present research system was not responding to the needs of society. Scientists will be asked to do more. A law has just been passed that will change the system.

The new grant system will provide some research-only grants, and some research funding within institutional/instrumentation grants. The division will be about 42 percent basic research and 58 percent applied research. Research awards will be distributed from one place. All scientific disciplines will be represented in the sections that will be in charge of reviewing proposals and making recommendations. Some changes were made in the law to accommodate these changes and to allow for a broader base of those who will elect the NRC. All those with Ph.D-level degrees can vote in the elections. Younger researchers and older researchers will have an equal chance. In the previous system, teams of research received their support through the senior team researcher. Decisions will be made with complete openness. Several years will be required to establish and begin operating the system. Evaluation criteria will include, answering such questions as "How useful is it?" and "What kind of progress is being made?" The grants system reform for the support of research is closely linked to several other reform measures. Another organization (perhaps to be called the Polish Academy of Skills) will be a broad-based learned society in parallel with the PAS.

The new system is an experiment. Polish companies do not have the same attitude as U.S. companies, and the state must take the main responsibility for research support. However, the new law requires that industry rather than government exploit the research. The attitude of industry is a problem because much of industry is still in state hands.

Cooperation with France

Cooperation with France has been mainly in the realm of cultural exchanges, humanities, and nuclear matters. Traditionally, interest in technical cooperation was in the Federal Republic of Germany, Switzerland, and Austria. There has been a post-war surge of interest in the U.S. and the U.K. Polish researchers usually took every advantage offered by the French cooperation, and accepted 50-60 French researchers in return. In all, about 300 Polish researchers go to France annually, and about 100 French researchers go to Poland.

Poland and France also cooperate in biotechnology and unconventional energy sources. Joint research in biotechnology is starting that involves 10 Polish academic and governmental research institutes to build a Polish/French institute for biotechnology in Poznan. The institute will be built and maintained by the Polish and equipped by the French. Researchers from both countries will work there under the direction of a joint management council. This is a new form of cooperation for both countries. Universities from both countries will be involved, and the institute will specialize in bioorganic chemistry and the microbiology of plants.

Excellent cooperation in geothermal energy is being carried out with a research institute in Orleans. Two symposia have been held, and a French team will go to central Poland to help construct a geothermal powerplant. In the future, French industry will likely be involved in this project.

The current scheme for cooperation with France is project based, and there are currently four such projects. The PAS is involved in the carbon chemistry project. The current agreement is developing well, with reductions in many subjects becoming a reality.

The Centre National de la Recherche Scientifique (CNRS) is the PAS's most important partner in France, with a new protocol being signed every 3 years. The CNRS contributes FF400,000 to an account for the support of Polish researchers in France, while the PAS provided an equivalent amount (about \$80,000) for French researchers in Poland.

Finally, there is a Polish Scientific Center in Paris which disseminates information on Polish history, culture, and science. The house, purchased before World War II, was converted to this use at the war's conclusion and contains hotel facilities for meetings and visiting Polish researchers.

Cooperation with the European Community

Poland is applying for European Community (EC) membership. There are many problems related to patents and inventions, and conformance to EC regulations and processes. The committee is responsible for working out the connections to the EC, including the necessary legislation for merging with EC S&T programs. Unlike others in Eastern Europe, Polish science has always been connected to the West. There is already some lively cooperation with the EC, including research on energy rationalization. However, there are difficulties associated with financing Poland's participation. Universities and individual scientists will have a great deal of freedom to participate in international cooperative activities under the new system. Now scientific institutes can set up their own cooperation. The quality of many scientific organizations in Poland will be an attraction for foreigners. Results may be better in research than in applications-oriented industrial cooperation.

Poland is very interested in the EC R&D programs, and it wants to participate in them. Hungary is ahead of Poland in this regard, but the EC TEMPUS program and the European Science Exchange program are being participated in by Polish universities and researchers. A TEMPUS office is being set up in each university. The PAS has applied for membership to the European Science Foundation, and expects to become a member in 1992.

Miscellaneous Comments

On the administrative side, it would be very helpful for the implementation of the new research awards system if the National Science Foundation (NSF) could help to resolve problems. Perhaps a panel of experts could go to Poland to discuss grant administration with Polish researchers and administrators. Also, NSF might present a 1-week training seminar or workshop for Polish counterparts.

If American researchers would like to cooperate in any of these areas, the MEP will talk to the institutes concerned to see how the cooperation could be set up and facilitated. Perhaps the MCSF would be a reasonable way to fund such projects. If this course is chosen, one must keep in mind that it often takes so long to get a project approved and funded by the MCSF fund that it is difficult to keep the potential collaborators together.

Poland Institute of Electron Technology (Optoelectronics Division)

by Tom Owens

Introduction

Mr. Coleman Nee, Science Counsellor, American Embassy, Warsaw, accompanied me on this visit to the Institute of Electron Technology (IET). We met with Prof. dr. hab. Cezary Ambroziak, Head of the Computer-Assisted Design Division, Prof. Bohdan Mrozwicz, Deputy Director for Optoelectronics, and Dr. Maciej Bugajski, Associate Professor, Optoelectronics Division. Except where otherwise indicated, the opinions expressed are those of the persons visited, as I understood them.

Institute of Electron Technology

The IET is located on a large campus just outside the center of Warsaw. Founded in 1952 as a research department of the Polish Academy of Sciences (PAS), IET was separated from the Academy in 1956. After it was transformed into an individual research institute, the IET became the Microelectronics Research Center in 1970. The IET acquired its own manufacturing facilities and had very strong connections to industrial enterprises up to about 1985. As an independent institute today, it receives about 90 percent of its budget as a subvention from the national government. That subvention amounts to about 90 billion zlotys (about \$9.5 million)¹. At the height of its activity, the IET had about 800 employees, and today it has 600. The IET's work has traditionally been about 80 percent in applied research and manufacturing and 20 percent in basic research.

¹Inflation is a factor in Poland and assessing value in monetary terms is difficult. The IET budget in 1989 was 8 billion zlotys; the variance is attributed to inflation.

However, this proportion is changing because the devices that it used to design and manufacture can now be purchased from the West.

Optoelectronics Division. The Optoelectronics Division of IET has about 50 people engaged in research. Three researchers are Ph.Ds and 20 have advanced degrees who hold the title of Professor and who can direct and carry out research. About 15 people are engaged in basic research in various aspects of physics and chemistry, and another 15 or more in applied research. The main lines of research in the division are related to characterization of semiconductor materials, and to developing new materials and structures. There is good equipment for the characterization work, and researchers have a good record of publication. Other things done well at the division include

- Selected areas of technology or electronic materials
- Properties of A3B5 materials used in optoelectronics applications
- Physics of electronic materials
- Solid-state physics and semiconductor physics.

The division is building a liquid phase epitaxy laboratory, and has nearly completed assembly of a sophisticated LPE machine. Some of the features of this device include:

- Gallium arsenide (GaAs) and indium phosphate deposition
- Digital 8.5 - 1.3-mm wavelength emitting device
- Double reactor with one vacuum reactor filled with hydrogen
- Palladium diffusion cell
- Mass flow controller
- Furnaces on tracks equipped with magnetic clutch
- Computer controls for all but the vacuum
- High temperature/humidity control.

Gas vapor epitaxy machines were not available to the IET because of export control restrictions in the West where such machines were manufactured. To obtain sophisticated epitaxy capability, the division decided to build its own liquid phase device. This device may be able to produce superlattice structures. Initially, it will be used in making thick layering necessary for the super bright, light-emitting diodes (LEDs) and in the production of high-pulse laser devices. Also in this laboratory are two more modest devices for GaAs layering for photodetectors and pulse laser production.

In another laboratory headed by Dr. Piotrowska (was trained in France), a Leybold instrument for deposition and sputtering of thin-film materials on semiconductor substrates (cost \$400,000). The instrument can lay down metallic (gold, aluminum, titanium) layers and multilayer depositions; gas analysis during sputtering is possible. This laboratory also has photo-lithography, chemical

plating facilities, and a wet chemistry facility. There is an RTP contact annealing machine.

The division also has equipment to analyze large semiconductor wafers for impurities and defects. Optical measurements provide a photo-luminescence mapping of the wafers. This capability to review the entire wafer allows for more efficient and effective decisions on further processing or rejecting the material.

Education at IET

In Poland, law defines status as a research institute, and only some institutes (IET is one) can grant research degrees. The Ministry of Industry granted IET the right to have an educational program. Typically, there are 5-15 students who are new university graduates in training. In addition, employees may obtain higher degrees while on the job. The IET maintains contact with the Technical University of Warsaw, and IET staff give lectures there. Negotiations are underway to allow IET to hold classes at its premises. The university would locate laboratory facilities at the IET, which has better equipment.

Cooperation

The IET is trying to generate cooperation with the West. The European Community (EC) TEMPUS program funding has become available. Researchers at IET are scheduled to go to France, the Federal Republic of Germany, and Belgium to work on integrated circuit design and on other processes related to IET's mission and research interests. Visits will be for 2-9 months each.

The EC assistance to Poland will go primarily to the universities. The funds available so far are divided about two to one for visits to EC laboratories and for equipment to Polish laboratories. Polish participation in EC research and development programs is much harder to come by because of the requirement to make a contribution to these programs in order to be a partner.

Research programs are hard to develop in Poland because of the years of separation from the rest of the world. Ways must be found to link to ongoing work outside Poland and to avoid reinventing the wheel. Polish research groups must obtain stimulation from outside. People are looking for better pay outside science or education because of low wages and lack of prospects for advancement (both within programs and in life). Involvement in international cooperation can stimulate people and provide incentives for young people, which might keep them in research.

The EC programs are affecting research decisions in Poland by helping to define the niches for cooperative research where Poland might be competitive. Poland is not affected seriously by the availability of EC resources. Participation by Polish industry in EC research programs may be the only way to support the electronics industry in Poland. Investment in industry and applied research is needed. One building at the IET is leased by Curtis

International (American) which is using local skills and facilities with new technology that it has brought to Poland.

The IET cannot host large numbers of foreigners, and it is still behind as far as availability of all the latest technology. However, the institute can still provide some valuable research experiences. One of these is coping with adversity and using ingenuity to provide techniques and processes needed to carry out high quality research. Observing how others manage research and having a special life experience are other considerations of value that might be obtained in a research visit to the institute. For now, however, perhaps the best mechanism for cooperation would be projects between two groups who have agreed on research objectives and the contribution that each should make to the effort. At first, exchanges of people should probably be for short periods.

The Future

Science in general needs to be developed in Poland today. There are more invitations to physics graduates in Poland to work in the U.S. (as post-docs) than there are graduates. Common programs that stimulate research in Poland are necessary.

Small high-tech companies must be set up to allow another career opportunity for researchers. Utility is still an important reward. The Polish optoelectronics industry is in retrenchment, and not now interested in innovations that may come from the IEP. The modern electronics industry that results eventually in Poland may consist of small specialized companies rather than large ones. The IEP needs to produce specialists but they also need someplace to go out to opportunities in industry.

Conclusion

The IET researchers have been struggling to maintain currency in a very fast moving area. Their expectations and the circumstances under which they carry out their research have been radically transformed by the political changes of the last year. The IET is still seeking its way in balancing the new opportunities, limited resources, and remainders of the old system that it faces.

New technology is available and an investment in basic research to attain a broad-based position at the cutting edge of science is now possible. But there are more choices now than there are resources available for the possibilities. The organization of research support in Poland on the basis of scientific merit is just getting underway. There are no established bases for allocation of resources that are both respectable and effective. When one walks the corridors of the IET laboratory buildings, there is no sense of connection between the corridors and the activity inside the laboratories. There are few or no windows in the doors, and one has the impression of a place that was not built to encourage the free flow of ideas. Once the doors are opened, however,

they reveal serious and capable people working at a high technical level. They are used to doing good work without the best circumstances. The IET researchers recognize the benefits which they might reap from international cooperation, and seem prepared to contribute to cooperative efforts. Assessing the potential benefit from

such cooperation will be the task of those who might be the IET's partner. There are plenty of obstacles that would have to be navigated but there are well-trained people and competent facilities for a variety of research here.

ONREUR REPORTS AND MAS BULLETINS

Reports

To request reports, indicate the report number on the self-addressed mailer and return it to ONREUR.

European Space Developments and Programs at the 29th Farnborough International Aerospace Exhibition, by CDR Robert C. Treviño. (91-1-C) This report is based on the 29th Farnborough International Aerospace Exhibition, the largest aerospace event of 1990. This major biennial aerospace event is organized by the Society of British Aerospace Companies and emphasized that the trend is toward more international joint ventures among European space organizations and companies. International space cooperation both in the scientific and commercial areas will continue, but European space autonomy in manned and unmanned programs is the long-term goal.

MAS Bulletins

The following Military Applications Summary (MAS) Bulletins were published between January 1, 1991 and May 31, 1991. The MAS Bulletin is an account of accomplishments in European naval research, development, and evaluation. Request copies by number from ONREUR.

- 01-91 Bofors Presented at the Bofors Effect Symposium 90
- 02-91 Harwell Tests New Legionella Killer System
- 03-91 Underwater Scaffolding
- 04-91 MAS Bulletin 1990 Annual Index
- 05-91 SEA BAT 6012, An Electronically Scanned Fast Update Sonar
- 06-91 Bioluminescence *In Situ* Bathyphotometer

REPORTS ON EUROPEAN SCIENCE AND TECHNOLOGY FROM OTHER COMMANDS

Reports

Information on each of the reports listed below was furnished by the following activity. Address requests to:

EOARD - European Office of Aerospace Research and Development, Box 14, FPO New York 09510

Polymers and Ceramics at the University of Strasbourg, by LTC Chet Dymek, EOARD. (26 pp) [EOARD-LR-90-057]

The University of Strasbourg is a center of excellence in material science and related chemistry. The Institute Charles Sadron (ICS) and the École d'Application des Hauts Polymers (EAHP) have several excellent programs in the synthesis of model polymers and new polymer materials, the molecular and structural characterization of polymer systems, and the relationship between macroscopic properties and structure. Because copolymers were essentially invented here (Skoulios), there is a great deal of expertise in this field and copolymer concepts appear in many of the projects. The Department of the Chemistry of Inorganic Materials studies magnetic and dielectric properties of new materials, correlations between structure and properties of ceramics, synthesis of refractory ceramics, metal-ceramic interfaces, and surface treatments and coatings.

International Symposium on Organosilicon Chemistry, by LTC Chet Dymek, EOARD. (34 pp) [EOARD-LR-90-59]

This triennial meeting was held at the University of Edinburgh. The major areas covered were silicon-based ceramics, polymers, and precursors; synthesis of new organosilicon compounds; and use of organosilicon compounds in organic synthesis. There was more emphasis on materials than at previous meetings, but the majority of the work is still hard-core chemistry. Among the highlights were (1) the results on NLO active polymers coming from a collaboration of U.S. scientists (Barton, Grigoras, and Vardeny), (2) the highly original work of Jutzi (at Bielefeld) on the silicon analog of ferrocene called silicocene, and (3) an order of magnitude improvement in ultra high-resolution Silicon-29 NMR achieved at the Latvian SSR Academy of Sciences.

Universite de Paris VI: Transition Metal Oxide SOL-GEL Materials, by LTC Chet Dymek, EOARD. (16 pp) [EOARD-LR-90-060]

The Laboratory for Condensed Matter Chemistry is outstanding. Researchers there have used novel sol-gel procedures to form a range of fine monodisperse

powders and high-quality thin films of transition metal oxides. These include ceramics for structural purposes, tunable solid-state lasers, superconducting and nonlinear optical materials, and ferroelectric applications. They use both metal-organic and totally inorganic precursors for their sols. Their success is largely based on their expertise in the synthetic chemistry of precursors designed to follow specific mechanisms in sol aggregation. They also have an outstanding combination of spectrometric tools to follow the sol-gel process and determine structures and mechanisms.

Science at the Hungarian Military Technical Institute and Central Institute for Physics, by COL Jay Schuman, EOARD. (12 pp) [EOARD-LR-90-062]

Members of EOARD recently visited several sites associated with aerospace research for the Hungarian armed forces. This report explains research activities at the Military Technical Institute (MTI) and Central Institute for Physics (KFKI). At MTI, we learned how the Hungarian armed forces organizes research and development activities. The MTI scientists provided some insights into the subsystems they have developed for the Hungarian and Soviet armed forces. In particular, they have developed small arms and electronics equipment. At KFKI, we saw their research primarily in electronics and physics. Hungary is rebuilding its infrastructure and gaining a foothold in western markets.

Compact Reinforced Composite - High Performance Danish Concrete, by LTC James G.R. Hansen, EOARD. (17 pp) [EOARD-LR-90-064]

Invented at the Aalborg Portland Cement and Concrete Laboratory, Aalborg, Denmark, compact reinforced composite (CRC) is an advanced composite material with strength and toughness rivaling steel. The CRC incorporates a high loading of steel fibers in a high-strength cementitious matrix containing alumina rich sand. The cement is reinforced with a high concentration of steel reinforcing bars. Meter-long beams and plates have been built and tested under static and impact loading. The CRC is a pacesetter application of advanced composite technology, with order of magnitude improvements in strength over conventional reinforced concrete and without brittleness problems encountered by other high-strength concretes.

The Joint European Submicron Silicon Initiative, by Dr. Vince Donlan, EOARD. (8 pp) [EOARD-LR-90-065]

The Joint European Submicron Silicon Initiative (JESSI) program began in 1988 as an 8-year effort to establish a European 0.3-micron ULSI silicon chip technology. Some 32 participants are currently involved

under the leadership of the Philips, SGS Thomson, and Siemens companies. A common CMOS process will be developed for multimegabit DRAM, SRAM, EPROM, and logic chips with complexities up to 100 million transistors. Key technologies to be developed include lithography (e-beam, ion beam, DUV, and x-ray) and an advanced CAD system for the design of the ULSI chips. Total funding for the JESSI program is expected to approach 4 billion ECUs, half to be provided by the companies and half by the European Community governments. This report provides an overview of the JESSI program and its main subprograms: technology, equipment and materials, application, and basic long-term research.

International Semiconductor Laser Conference, by Dr. Eirug Davies, EOARD. (3 pp) [EOARD-LR-90-067]

This was the twelfth in a series of IEEE biennial conferences. More recent innovations were well represented such as strained-layer quantum wells, segmented contacts, and vertical structures.

Strained-layer InGaAsP lasers have current thresholds that now approach the 100Acm⁻² level already established for GaAlAs. Suppression of sublattice ordering with an accompanying bandgap increase allows visible lasers to be produced further into the red and replicate He/Ne lasers. Optical amplifiers based on laser structures are apparently becoming important devices in their own right, and examples were given of their integration with lasers as well as discrete operation.

Night Vision Testing Device, by CPT Jeff Wigle, EOARD. (5 pp) [EOARD-LR-90-068]

A new device has been developed at the Dublin Institute of Technology in Dublin, Ireland. The device measures darkness adaptation and night visual acuity. The device is an all solid-state, computer-driven instrument proposed to be a potential replacement for the venerable Goldman-Weekers adaptometer. A description is provided of the device and its operation. Also available are hand-drawn sketches.

THE EMBASSIES: TECHNOLOGY ROUNDUP

FRANCE

For further information on France items, contact Dr. Michael Michaud, Science Counselor, American Embassy, Paris, APO New York 09777.

French Research in Robotics and Production Technologies

In a recent symposium, the French Ministry of Research and Technology set forth the results of its activities in robotics and production technologies during 1986-1988. Clearly, the objective of the French government is to see France participate in major European programs and remain present at the international level both in research and in industrial competition, particularly with Japan and the U.S. The Ministry of Research and Technology supported over 80 innovative projects based on cooperative efforts between industry and research centers. The creation of regional centers also contributed to the development of research in this area and to technology transfer. In 1990, the Ministry of Research and Technology's budget for research in this sector was FF 33 million (\$6 million).

ITALY

For further information on Italy items, contact Mr. Reno Harnish, Office of the Science Counselor, American Embassy, Rome, APO New York 09794-9500.

Italian Space Agency

The 1991 edition of the Italian Space Agency (ASI) 5-year budget has been framed very carefully in terms of how it can benefit the nation. The principal benefit that has been that increased funding for ASI results in increased jobs for Italy's high-technology sector and stimulated research and development (R&D) activity throughout the economy. Development of the south is another benefit increasingly in favor throughout the Italian research establishment. Finally, it appears that ASI will make a new effort to spin off the provision of services and development of products that are nearly ready for the marketplace.

The ASI will favor promotional procedures like that implemented by Law 46 as it promotes the direct participation of industry. Law 46 allows partial or total financing of industry R&D projects through the government innovation financing organization (IMI). The ASI proposes to create a consultative working group between Murst, IMI, and ASI. Apparently, ASI will even consider going to the financial market to realize operational systems.

The following scientific areas are mentioned for development in the Mezzogiorno (the economically less advantaged southern Italy):

- Earth observation and remote sensing
- Space technological research and physics of the atmosphere
- Space robotics
- Microgravity
- New materials
- Propulsion
- Space biology and biotechnology
- Space medicine
- Support center and earth tracking stations.

These activities will be concentrated in the following geographic areas:

- Basilicata region/Matera - Earth observation and space robotics
- Apulia region - Advanced materials, cryogenic propulsion, robotics
- Campania region - Microgravity, testing grounds
- Sicily region - Stratospheric balloons
- Sardinia region - Space biotechnology.

Industries mentioned in the ASI plan for cooperation and development of space activities are:

- Aeritalia for scientific satellites and manned infrastructures and in joint venture with Seleni Spazio (under the new name Alenia) for orbital infrastructure, telecommunications, and earth observation
- SES for telecommunications and earth observation with active microwaves

Federal Republic of Germany

Mr. Francis M. Kinnelly is now serving as Counselor for Scientific and Technological Affairs at the U.S. Embassy, Bonn. Most recently the Director, Office of Nuclear Safeguards and Technology, OES, Washington, D.C., Mr. Kinnelly previously served as Science and Technology Counselor in Ottawa and Madrid.

Italy

The staff of ESNIB apologizes to Mr. Reno Harnish for incorrectly attributing recent Embassy Roundup inputs from Rome to his predecessor, Mr. Gerry Whitman. Mr. Harnish has been the steady and prolific source of substantial input to both ESNIB and the ONR Europe ASSETS database since December 1989.

- BPD for propulsion systems
- Telespazio for telecommunications and remote sensing services.

Besides these major industries there are other companies that have qualified for producing mechanical, electronic, and propulsive systems: Laben, Fiar, Microtecnica, Contraves, Galileo, Fiat/Avio, Piaggio, Gavazzi, Elsag, VDS, CISE, SMA, and Proel. For management of space services, Telespazio and Ciset have qualified. Software for space systems and earth stations may be produced by companies like SSI Dataspazio and Tecnospazio. Other companies that are beginning to be involved in space production and may qualify as partners in future space projects are Agusta, Ansaldo, Aermacchi, and Tecnomare.

Financial requirement projections (in billion lire) are 1990-1,028; 1991-1,208; 1992-1,356; 1993-1,354; 1994-1,314. At the rate of \$1.00 to 1,250 lire, the 5-year commitment beginning in 1990 would be roughly \$5 billion. Some of this financing is already being provided by multiannual commitments with the European Space Agency, by contracts to complete and operate previous National Space programs of 1987 (Italsat 1, Tethered, Iris, Lageos 2, Sar-X, SAX, Italsat-2), and by commitments included in the law creating ASI (cost of personnel, operation cost of the agency, and funds to universities and CNR for basic space research).

New initiatives to start in the current plan are:

- Cooperate with NASA/JPL for the Cassini mission
- Start a bilateral program with NASA for the logistic segment of the space station
- Develop the San Marco scout prototype and its nationalization for the launching of small satellites
- Develop two small satellites for earth observation and microgravity research.

Short Technology Items

New Environmental Compatible Reagent. The Italian chemical company ENICHEM has produced a new chemical reagent. The compound is dimethylcarbonate which is obtained from carbon dioxide and methanol; it replaces mainly hazardous components like phosgene and dimethylsulphate. ENICHEM presently produces 10,000 tons of dimethylcarbonate in Ravenna.

Oceanographic Ship. In September 1991, the Neapolitan company SOPROMAR will consign to the Italian government a new oceanographic ship *Urania*. The vessel will be rated as the most advanced ship in the Mediterranean Sea for environmental and marine research. The ship is 62 m long and 11 m wide, can house 36 researchers and technicians, and can be self contained

for 45 days. The *Urania* can conduct research on the sea bottom at a maximum depth of 5,200 m and will be connected with a coast station for handling and processing data collected during the oceanographic campaign.

Southern Italy Technology. South of Naples, the company FOS is becoming one of Italy's major producers of optical fibers. In fact, FOS is now the third ranking producer of optical fibers in Europe. In 1991, the company is expected to produce 400,000 km of optical fibers with 20 percent of the production for export to France, Spain, Turkey, Greece, and Australia. In the Brindisi area, the technological park of Mesagne has concluded an agreement with the Soviet Academy of Sciences for Bilateral Research to produce thin films for semiconductors and innovative ceramic material for the aeronautic and automobile industries.

Research and Development Expenditure for Italian Ministries

The Italian financial law for 1991 establishes expenditure of Italian ministries for research and development (R&D). Of 22 ministries, only 6 are involved in R&D with the following figures in million lire (\$1 = about 1,200 lire):

Public works - 507
 Defense - 225,150
 Industry - 4,000
 Health - 60,902
 Cultural assets - 100
 University & research - 9,267,527
Total - 9,558,226 (about \$8 billion).

Of these, 77,685 million lire were carried over from the preceding year.

The Ministry of University and Scientific Research holds the largest share of expenditure and is expected to contribute to the following programs (figures in billion lire):

- National Research Council - 1,000
- Italian Space Agency (ASI) - 700
- Incentive to industry for applied research projects - 625
- National Institute of Nuclear Physics (INFN) - 360
- CERN (Geneva) - 139
- Antarctic Program - 50
- Diffusion of Culture and Scientific Research - 10
- National Program for Aerospace Research - 9.5.

The Ministry of Industry is in addition contributing 500 billion lire to the National Agency for Nuclear and Renewable Energies (ENEA) and 150 billion lire for incentives to industry for innovation.

Thermionic Converter

The Italian Agency for Nuclear and Renewable Energies (ENEA) and the Dutch University of Eindhoven have devised a new thermionic converter that is capable of increasing the output of traditionally fueled powerplants. Generally oil-fired powerplants have an efficiency that does not exceed 40 percent because oil burns at a temperature of 1,800°C. The heat necessary to move the metal turbines should not be over 400°C to prevent turbine melt down. Consequently, the excess heat is mainly dispersed and lost. With the thermionic converter, the excess heat is directed towards materials like tungsten capable of emitting electrons. The flow of electrons obtained is channelled under the protection of a silicon carbonium shelter toward an electrode of titanium which, at a temperature of 650°C, is able to attract and collect electrons. Subsequently, the flow of electrons formed is employed to create electrical energy. This new type of thermionic converter is especially suited for small powerplants where it can increase plant output by 15 percent.

Soviet Launcher Proton May Launch Italian Satellites

Alenia Spazio (recently formed by the merger of Aeritalia and Selenia Spazio) has been in contact with the Soviet Glavkosmos to evaluate using the Soviet launcher *Proton* for future launching of Italian telecommunications satellites. The aspects of this bilateral cooperation are presently under consideration by a joint Italo-Soviet delegation. *Proton* can launch into a geostationary orbit a payload up to 2 tons; it must be adapted to requirements necessary to Alenia Spazio for its own telecommunications satellites. The launches may be scheduled to occur from the Soviet Cosmodrome of Bajkonur for satellites like Italsat-2 and the series of satellites SARIT for direct TV which are being programmed by Alenia Spazio. The negotiations would also include possible bilateral cooperation in telecommunications, remote sensing, and use of other Soviet produced launchers.

Digital Radiotelephone Via Satellite

The European Space Agency (ESA) has awarded to the Italspazio Consortium (Italian companies Alenia and Laben) a contract to study a digital radiotelephone system via satellite. The system named *Iridium-like* will be based on experiences gained during the low earth orbit communications (LEOCOM) study carried out by Italspazio for ESA. The LEOCOM is based on 30/40 leostar minisatellites to be launched on circular polar orbits at about 780 km in altitude. The LEOCOM will supply low-cost telecommunications services to include personal cellular telephones, data transmission, electronic mail, and FAX.

European Consortium for Satellites

The Italian company Alenia and the French companies Aerospatiale and Alcatel Espace have formed a consortium to supply turn-key satellites; i.e., satellites already in orbit complete with monitoring centers, earth tracking stations, and all associated services. The new consortium employs 5,000 people and has a business turnover of 1,400 billion lire (about \$1,170 million) and is ranked second after the U.S. Hughes Aerospace of General Motors. In addition, the U.S. Space Systems Loral is negotiating a partnership with the Italo/French consortium so that consortium may control 49 percent of Loral capital. With the Loral participation, the consortium would become the first organization in the world for satellites and associated orbital systems.

Italy is Losing the High-Tech Challenge

According to a recent book published by the influential technical and economic daily *Sole/24 Ore*, Italy is quietly losing the high-tech challenge. According to data reported in the book, in 1970 Italy was responsible for the export of 4.6 percent of the world's demand for high technology. However, in 1989 the percentage value of this export decreased to 3.5 percent while in the same year France exported 7 percent, Great Britain 7.2 percent, and the Federal Republic of Germany 13.2 percent. The deficit of high tech was 1,700 billion lire in 1980 which grew to 5,000 billion lire (\$4,180 million) in 1989. Industry is reported to have spent only 0.5 percent of the business turnover for advanced research opposed to 1.22, 1.40, and 2.10 percent spent by French, British, and German industry, respectively. Thus, Italian industry has a position of great weakness in the innovation area. Fortunately, current private organization donations and contributions for research amount to about 1,000 billion lire annually, and this sum could be greatly enhanced if the government decides to pass fiscal exemption incentives for donors.

To bridge the gap between university and industry, the book recommends creating an agency for innovation managed by the Italian National Research Council (CNR) and the Association of Industrialists (CONFINDUSTRIA). The first task should be to train young scientists for research. It is calculated that starting from a postdoctoral level, the annual cost of forming a specialized researcher in Italy may be between 60 and 80 million lire. The sum could easily be afforded by a country with enough liquid assets and a desperate need for scientific innovation.

Italian Space Delegation Discusses Italy's Participation in NASA Projects

An Italian delegation led by Undersecretary of Scientific Research Senator Learco Saporito returned from the U.S. at the end of March after meeting with NASA Administrator Truly and White House National Space Council Executive Secretary M. Albrecht. During these meetings, NASA and the Italian National Space Agency discussed a possible agreement for the realization of the logistic module to operate with the space station *Freedom*. Also discussed was Italian participation in the mission Moon-Mars for the construction of a permanent manned base on the moon. In the latter case, Italy is interested in supplying telecommunications systems, logistic services, and robotic equipment. The Italian delegation also met with representatives of LTV for Small Expendable Launch Vehicle (SELV), and for Scout-A2. This launcher (to be manufactured by LTV and the Italian BPD) is now estimated to cost 20 billion lire. This figure is so high that it would put Scout-A2 out of the market.

Portici Center for Photovoltaic Research

At Portici, near Naples, ENEA is managing a center for photovoltaic research. The facility includes a building of 60,000 cm covering an area of 12,500 sqm with a staff of 150 researchers and technicians. The activities of the center are presently focused in three technology branches: (1) photovoltaic cells based on amorphous silicon and its alloys, (2) photovoltaic cells based on polycrystalline composite semiconductors, and (2) photovoltaic cells based on high-efficiency gallium arsenide. In the first case, the center is producing modules of amorphous silicon with a 5 percent efficiency output with a future output of 10 percent. The ultimate goal is at least 15 percent. Concerning photovoltaic cells based on polycrystalline thin films of indium and copper diselenide and cadmium telluride, a 14 percent efficiency rate has obtained at low cost and at considerable time duration.

Beginning with these results, scientists are studying the possibility of selecting a sedimenting technique especially suited for industrial production. For the third case concerning thin film cells based on composite polycrystalline semiconductors, they are studying various aspects of the sedimenting of transparent and conductor oxides with the method of spray pyrolysis obtaining a conversion efficiency of over 30 percent.

Photovoltaic Powerplant

The Italian National Agency for Electricity (ENEL) has announced the construction of a 3-MW photovoltaic

powerplant in the Naples region. The new powerplant, expected to cost 42 billion lire (about \$35 million), should be ready by 1992 and will satisfy the energy needs of a community of 7,500 inhabitants. The project will be carried out jointly with Pacific Gas and Electric with relative exchange of information, results, and projects for the diffusion of solar plants. The powerplant will employ modules made of polycrystalline silicon manufactured by Italian companies such as Ansaldo, Italsolar, and Hellos, but will also compare features and efficiency with modules acquired from the Photowatt (France), Solarek (U.S.), and Kyocera (Japan).

Daphne Replaces Adone

Professor Nicola Cabibbo, President of the National Institute of Nuclear Physics (INFN), announced that it is replacing the old particle accelerator Adone with Daphne, a new, more advanced accelerator. Daphne will be ready by 1995 and when in full operation, can produce 10 billion events annually and explore relatively unknown areas of particle physics. Daphne is small--composed of two intersecting rings each 3 m in diameter. Daphne has a luminosity 1,000 times higher than its predecessor. It is expected to cost 70 billion lire (about \$58.4 million) which is already allocated in the INFN budget. Daphne will make possible before the end of the century the exploration of fields at 1- μ m level.

Italian Space Agency Produces Environmental Satellites

Professor Guerriero, ASI president, has announced that included in ASI's 5-year plan is the project for a satellite to monitor the environment for an estimated cost of 100 billion lire (about \$83 million). The satellite weighs 600 k and will be launched from the Italian S. Marco range in Kenya with an upgraded Scout launcher being developed by the Italian company BPD and the U.S. company LTV. At the same time, Professor Ernesto Vallerani, President of Alenia Spazio, said that (to satisfy the needs for environmental monitoring expressed by the Italian Ministries of Environment and Agriculture) the company is setting up a program for a more complex and sophisticated satellite called Ecosat. Ecosat will be the Italian effort parallel to similar initiatives in France with the Globosat satellite and in the Federal Republic of Germany with the Atmos satellite. Ecosat will be equipped with very advanced and sensitive radar and optical sensors that will allow it to obtain data on the status of the earth and of the existing degree of pollution. This data will then be integrated with information obtained by the French and German satellites.

SPAIN

For further information on Spain items, contact Mr. Leroy C. Simpkins, Office of Science Attaché, American Embassy, Madrid, APO New York 09285

King Juan Carlos Inaugurates Microelectronics Center

Under the auspices of the Royal Foundation, King Juan Carlos gave strong support to an initiative for technological innovation supported by 45 Spanish firms. The initiative promotes awareness of the impact of technological change and facilitates technology transfer to industry.

The King also journeyed to Barcelona to inaugurate the National Microelectronics Center, jointly operated by the Superior Council for Scientific Research (CSIC) and the autonomous University of Barcelona. Costing \$31 million, the facility boasts Spain's biggest clean-room fabrication area (1,000 sqm) for production of semiconductor chips. Cleanliness indices for different parts of the area range from 10 to 10,000. Main activities include design and test of chips, small-scale fabrication, production of tailor-made chips and sensors, and development of chip-associated technology for use by nonelectronics industries.

National Science and Technology Funds Are Unevenly Distributed

A study commissioned by the National Research and Development (R&D) Plan reveals that national funding for science and technology (S&T) is unevenly distributed across Spain. Of over \$1 billion in national funds tracked by the study, the lion's share went to three autonomous regions, and only five received more than two percent. To a major extent, these percentages reflect the population and level of industrialization of the regions, with a double benefit for Madrid for being the capital. Nevertheless, the plan wishes to reduce the perceived imbalance.

Scientists Discover Patents

Although Spain granted its first patent in 1522, its technical development, traditions, and patent system have stimulated few inventors to protect their innovations. Indeed, until Spain's entry into the European Community (EC), its patent system was rudimentary. Only this year has the National Registry of Industrial Property (Patent Office) begun to rule on originality of patent applications. With a staff of 500 and a \$40-million annual budget, it is now able to search its 14 million Spanish and foreign patents on file to see if an application really covers something new.

Another turning point was the opening in 1986 of the European Patent Office in Munich. National patent applications fell from 10,000 to 4,000 annually, while Spanish applications for coverage by European patents were over 20,000 annually. Pharmaceuticals are still not patentable as products in Spain, but will be by October

1992. In the meantime, patents of pharmaceutical process are being enforced as nearly as possible as if they were product patents, notably by shifting the burden of proof to the accused pirate to show that he is not using essentially the same process as that patented. Specialists estimate that only 30 percent of patentable innovations are actually patented in Spain, partly because companies have preferred to keep their innovations as trade secrets. To counteract this, the National R&D Plan has just signed a contract with a patent and trademark consulting firm. The firm will take scientists into its offices for 2 months to teach them about the patent process, and will offer 2-day seminars for government researchers on protection of research results.

Science and Technology Supplements Are Provided to Small Newspapers

Recognizing that few Spanish papers have S&T writers, the Superior Council for Scientific Research (CSIC) distributes an S&T news supplement to small newspapers. The 16-page monthly insert is well designed by CSIC staff in collaboration with the Ministry of Industry. A recent issue contained the articles on: 5 years of Project Eureka (10 pages), the difficult control of chemical weapons, and being prepared for natural disasters, plus shorter articles, announcements, and reviews. The CSIC also distributes the paper separately. Vice President Albert says the reception of the new paper has shown it to be an excellent method of publicizing science accomplishments.

Spain Selects Astronaut Candidates

Spain announced five candidates (aged 27-33) for astronauts in the European Space Agency (ESA) program. One is a biologist, three are aeronautical engineers, and one is a military pilot. They will compete with five candidates from each of the other 12 ESA countries for 10 initial astronaut slots. The original field of 582 men and 76 women required a year to finally select. Special attention was paid to physical and mental fitness for the space environment. All five speak two languages besides Spanish and have extensive scientific training. Testers sought candidates with a balance between adventurousness and romanticism on one hand and fundamental responsibility on the other.

Environmental News

The figure of \$50 billion is frequently mentioned as the total investment needed to bring Spain up to environmental standards set by the EC. Key air pollution targets are high coal-fired powerplants in La Coruna and Teruel, reported to emit 1.2-1.5 million tons of sulfur dioxide annually between them. Sources of industrial pollution identified by the EC include the industrial area around Huelva, heavy industry at Bilbao, and mineral discharges in Murcia.

Sewage purification is another important goal. Some claim that only one-seventh of the country's wastewater is treated, while others say the figure is 45 percent. Madrid is a positive example, since all its wastewater is treated before it flows into the Manzanares River. Estimates for community sewage treatment are not as high as one might think. Perhaps only one-third of the total EC population lives in areas with sewage treatment facilities.

The EC has awarded Spain \$300 million from its regional development fund to help start the cleanup. Water treatment alone may cost \$5 billion. The EC goals call for waste treatment in all towns with more than 15,000 inhabitants by 2000, and in all with more than 2,000 by 2005. In addition to aid from the EC, pollution-reduction costs will be borne by the national government, local governments, and private industry.

Climate Change Study is Planned

By 1995, the National Institute of Meteorology (NIM) will assemble a center for climate research and modeling. The 15-20 scientists will use a \$16-million supercomputer to predict climate change. In setting up the center, the NIM will work closely with more experienced institutions in France, the Federal Republic of Germany (FRG), and the U.K. Plans for the center and the purchase of the supercomputer are included in the 1992-95 Second National Plan for Scientific and Technological Research and Development. Developers of the new installation are working with results and recommendations of the International Panel on Climate Change (IPCC).

Green Candidates Emerge

In 1991 local elections will be held in Spain, and for the first time since its founding in 1984, the Green Party (Greens) will present candidates in every autonomous region. The Greens first entered local elections in 1986 in Madrid, Valencia, Salamanca, and Leon. In 1990, they presented candidates on the Green list for the European Parliament in 40 provinces and received 160,000 votes. Candidates from the Green ecologists split the Green vote, however, and no one from either group made it to Strasbourg.

This year the Greens claim to present a more unified front, lacking support only of certain Basque country groups, yet still feuding with the Green ecologists over their similar name and party symbol. The Greens will run in each of the 17 autonomous regions and all 50 provincial capitals in a total of 200 contests. Estimates of Green support vary from 7-15 percent of the electorate, but party leaders are focusing on races where they think they could pick up seats in regional legislatures or city councils.

Spanish Activity in Antarctica

Spain hosted and chaired the conference of Antarctic Treaty parties, and all delegation heads were received by the King and Queen. With 300 delegates from

39 countries, the meeting stimulated considerable review of Spanish Antarctic activity.

Spain has been a party to the Antarctic Treaty since 1982 and a consultative party since 1988. Spain operates one research base on Livingston Island near the Peninsula, and a base mainly for seismic research on Deception Island. Neither base operates year round.

Nevertheless, Spain is enlarging its base to improve accommodation of its scientists. During the 1990-91 season, there were 54 scientists there working on 14 projects. Spain's Juan Carlos I base is the only one in the Antarctic headed by a woman, Josefina Castellvi. Projects are not limited to these two locations. Some projects this past season also took researchers to Robert Island off the South Shetlands and the top of Mount Vinson above the Ronne Ice Shelf (for ultraviolet studies). Spain also operates a converted Navy tug, *Las Palmas*, as a research vessel supporting the ground operations. A new ship, *Hesperides*, cost \$90 million and will be finished later this year.

Other recent studies in Antarctica focused on marine algae, magnetism, ozone, natural radioactivity, volcanism, bird life, and cartography. Government sources said there was increased cooperation during this campaign among Spanish, American, French, and Chilean scientists.

Nuclear Safety Budget Up, Outages Down

Despite Spain's static nuclear power program and the shrinkage that followed the 1989 closing of the Vandellós I plant, the Nuclear Safety Council's budget for 1991 is \$51 million, up 25 percent over 1990.

In the first half of 1990, there were six outages at the seven nuclear plants (the lowest level for years). During the last half of 1989, there were 26 cases where plants went off-line. The CSN further pursued the prevention of non-nuclear accidents, admonishing Vandellós II for a lack of fire detectors that contributed to three shutdowns caused by electrical fires in 1987 and 1988.

The Vandellós I plant, permanently closed after the 1989 fire, will be dismantled. Work will start this year and be completed by 1994 at a projected cost of \$1 billion. Experts will use robots and lasers to help cut up concrete and metal components. They will also use experience obtained as dismantling of plants proceeds in Belgium, the FRG, the U.K., and France (with EC participating). Spain has no specific regulations on nuclear plant dismantling.

Spanish Scientists Go to U.S. with Fulbright Support

Of the latest subgroup of 41 Fulbright graduate school candidates submitted from Spain (funded by the Ministry of Education), 35 plan to pursue science or engineering in the U.S. Although not every group is so oriented toward S&T, the 160-200 Fulbright scholars who cross the Atlantic each year include a proportion of scientists well above the average for the worldwide program. Most stay

12 months and study at places like Pennsylvania, Stanford, MIT, USC, Minnesota, and Michigan. The U.S.-Spain Fulbright program is the largest in the world, thanks in part to generous participation by Spanish sources, mainly the Ministry of Education and Science.

Industrial Contract Research Creates Jobs

After first contracting for outside R&D with universities and laboratories, some Spanish firms can hire researchers from those institutions for their in-house staffs. Between 1988-90, firms contracted for R&D projects costing \$70 million. In the same period, they created jobs for at least 660 scientists, mainly in food technology, biotechnology, robotics, and communications. Over 250 patents were awarded in the same areas. Government R&D laboratories typically receive 10 percent of their project funds from industry.

Spain Boasts Nine Technology Parks

Spain has nine technology parks either built or under construction. They are designed to provide innovative technological firms with suitable support infrastructure near a center of research and education. Locally financed, the parks are modeled on the U.S. research park concept implemented in places like Palo Alto and North Carolina. They are in or near Barcelona, Madrid, Valencia, Oviedo, Bilbao, Malaga, San Ciprian de Vinas (Galicia), Valladolid, and Tenerife (Canary Islands). Those at least partly operating include Barcelona, Madrid, Valencia, Oviedo, and Bilbao (the oldest, begun in 1983). No park has operated long enough to be evaluated definitely.

Madrid's park grew up around a new ATT integrated circuit plant near the autonomous university. The park in Valencia is home of nine research centers (bioengineering, metals engineering, ceramics, and food technology) and hope to attract firms in the same fields. Four research centers (telecommunications, new materials, robotics and automation, and biotechnology) form the focus of the park at Bilbao. Two miniparks there are following the lead of the main park.

The park in Barcelona has attracted 11 firms, including Olivetti, Alcatel, Esclat (Spain), and other Dutch, French, and Swiss branches. The main areas are microelectronics and computers, telecommunications, automation, lasers and materials, and biotechnology. That park, whose construction was delayed, reportedly is having trouble filling its 25 sites and paying the rest of its \$20 million cost (half paid by the EC).

Spain Launches Minisatellite Program

Minisatellites weighing up to 300 kg are the goal of a new program designed to provide Spain with autonomy in developing space projects in science, communications, and remote sensing. Budgeted initially for \$15 million, the program aims to build minisatellites for \$25 million apiece (\$10 million each for the satellite and launch and \$5 million for the payload). Launch would be by ESA or NASA. The National Institute for Aerospace Technology (INTA) will undertake the program with Inisel (electronics), Sener (systems engineering), and Construcciones Aeronauticas SA - CASA (integration and testing). Technology would necessarily be compact and lightweight, but might not be all Spanish. First launch would be in 1994, with further launches yearly. Tracking and control will be from Masplomas (Canary Islands) and Cebreros (Avila). The University of Texas is reported to be interested in contracting for one of the minisatellites.

Toxic Oil Syndrome Follow-up Continues

Scientists Kilbourne and Philen, U.S. Center for Disease Control (CDC), continue working with Spain on the long-term effects of the toxic oil syndrome epidemic resulting from widespread ingestion of adulterated cooking oil in 1981. The epidemic left 650 dead and 25,000 affected in ways still under study. The CDC scientists' work in Spain is relevant to understanding what may be similar outbreaks in the U.S. A recent example is the October 1989 recall of the dietary supplement containing L-tryptophan in the U.S. Contaminated batches of this product have been blamed for respiratory, muscular, and skin disorders in 1,500 persons, at least 27 of whom have died. Although some symptoms in the two epidemics are the same, the importance of studying the diseases does not arise from any probability that they are the same. Rather, experience with identifying the toxic agent in the oil and tracking the health of affected persons may help clarify the causes of the L-tryptophan syndrome and improve its treatment.

First National Conference Assesses AIDS

Over 1,000 experts attended the first National AIDS Congress in Madrid in March to discuss AIDS prevention, diagnosis, and treatment. The congress marks growing public and governmental awareness of a disease that has reportedly afflicted 7,500 persons in Spain, 2,700 of whom have died. Estimates of HIV-positive carriers range from 100,000 to 300,000. Spain has 75 scientific groups working on AIDS, which it claims is the largest number of any EC country. Most receive financial support through the EC Framework program.

Porpoise Deaths Continue in Mediterranean

Continuing the trend observed in summer 1990, many porpoise deaths have occurred in the Spanish Mediterranean again in 1991. Multinational researchers are checking pollution, food, parasitism, and other environmental factors as possible causes of the porpoises' susceptibility to the Morbilli virus. Most early cases appeared off Spain, but now corpses are found off Italy, France, and Corsica. Discovery of a corpse on the coast west of the Strait of Gibraltar raises the fear that the contagion has spread to the Atlantic.

CSN Cites Hospital After Radiation Accidents

The Nuclear Safety Council (CSN) may take a Zaragoza clinic to court for noncompliance with nuclear regulations after three deaths of patients treated for cancer with a faulty linear electron accelerator. Twenty-four patients are suffering from a radiation overdose. An unlogged repair of the machine left it operating at full power regardless of the control setting. The problem escaped notice during a routine CSN inspection. The clinic stopped using the machine within 10 days, but delayed notifying CSN for 19 days more. General Electric (U.S.) manufactured the Sagittaire model accelerator.

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