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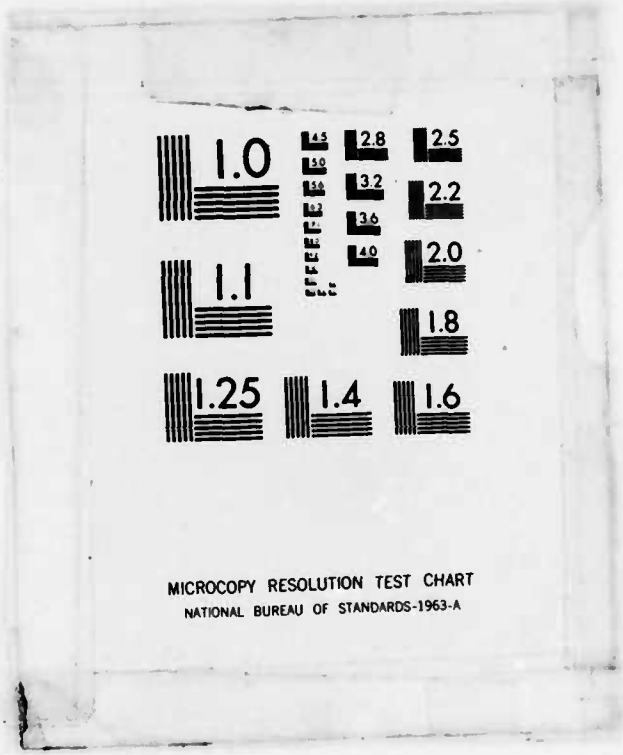
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European Scientific Notes (ESN) is a monthly publication with brief articles on recent developments in European Scientific research. The publication is not intended to be part of the scientific literature. The value of ESN articles to Americans is to call attention to current developments in European science and technology and to the institutions and people responsible for these efforts. ESN authors are primarily ONRL staff members. Occasionally articles are prepared by or in cooperation with staff members of the USAF European Office of

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EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Edited by Vivian T. Stannett
Larry E. Shaffer

Vol 37, No. 3 31 March 1983

THIS REPORT DEALS WITH:

BEHAVIORAL SCIENCES

Experiments in West Germany have shown that putting wind-change data on a single flight-director instrument is probably the best way to indicate wind-shear phenomena to the pilot of an aircraft.

CHEMISTRY

The XII National Colloquium on Specialized Polymers dealt with electrically conducting, piezoelectric, and biocompatible polymers; membranes; and polymers for microlithography and composites.

COMPUTER SCIENCES

An overview of robotics research at Laboratoire d'Automatique et de Micro-Electronique de Montpellier is given. Programs to control manipulators, the cooperation of two manipulator arms in assembly tasks, and the programming system CATIA (a conception-assisted, three dimensional interactive system) are described.

ELECTRONICS

NEXT PAGE

The 16th Biennial Conference on the Physics of Semiconductors reported findings pertinent to higher performance electron devices. Superlattices, III-V materials, and deep level impurities are discussed.

The UK Admiralty Compass Observatory maintains a diversified research effort in navigation techniques. One novel approach seeks to exploit gyroscopic phenomena in virtually the smallest of spinning masses--helium nuclei.

MATERIAL SCIENCES

Metal deformation properties, electron microscopy and semiconductor electrical properties, scanning acoustic microscopy, atom probe-field ion microscopy, improved cement, and materials-related engineering science activities are described as part of the total metallurgy and materials effort at Oxford Univ.

OPERATIONS RESEARCH

Various practical applications of graph theory in communications networks lead to problems whose solutions may require very large computation times. The theory of computational complexity is useful in providing limits for computation times that may be required.

Applied research at the Institute of Mathematical Statistics and Operations Research includes problems related to queueing in telephone systems, storm surge time series, extended Kalman models for control of electrical power grids, the processing of satellite imagery for mineral exploration, production scheduling for small companies, and technology assessment.

PHYSICS

A new technique for the production of plasma annuli researched at the Ecole Polytechnique, Palaiseau, France, is described. The plasma puff technique represents an important advance for the development of intense x-radiation sources.

NEWS & NOTES

Thames barrier, by D.R. Barr; electronics slowdown, physicist's new job, by M.N. Yoder; electron beam welder, by L.E. Shaffer; pipelines, by R.W. Armstrong; bacteria, by N.A. Bond, Jr.

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BEHAVIORAL SCIENCES

A GERMAN WIND-SHEAR DISPLAY

"Wind shear"--various low frequency changes of wind speed and wind direction--has many causes. Wind shear can occur in thunderstorms and other types of weather. For example, precipitation from high clouds may evaporate into hot and dry air at intermediate altitudes, causing a cold downstream of air. Some analysts have maintained that surface structures near airports can, under certain conditions, accentuate wind shear effects. So can turbulent wakes from other aircraft on the same or nearby runways.

In the 1970s, wind shear was implicated as a major factor contributing to several aircraft accidents. In one FAA list of "probable wind shear accidents," there were four that occurred with Boeing 727 aircraft, including two at JFK Airport in New York. Thus, there was a worldwide motivation to explore the air-safety aspects of unexpected changes in wind direction and speed.

To the pilot, wind-shear conditions at high altitudes are not major safety problems. But if an aircraft on final approach is trimmed for constant wind, severe wind shear can produce dangerous flight conditions at low altitudes. An unexpected "downburst" of air will cause rapid loss of altitude, and there can be simultaneous "outbursts" or horizontal wind forces. Airspeed variations of about 20 knots may be experienced, and these could be critical to an aircraft operating just above stall speed during takeoff and landing. Response time constants are also important, as it takes some seconds for thrust to be applied effectively in heavy aircraft. An experienced pilot often can compensate for "topographic wind shear" by watching the difference between the wind sock and the instant wind corrections he is making on final approach, but there are difficulties in teaching that specific discrimination.

In West Germany, a project in wind-shear instrumentation has been under way for the past few years. Three organizations have been involved in the work, sponsored by the German Ministry of Transportation: the Technical Univ. of Braunschweig, the Bodensee Gerätetechnik at Ülserlingen, and the Institute for Flight Guidance (DFVLR) at Braunschewig. F.V. Schick and U. Teegen of the DFVLR have recently reported on the human factors aspects of the project.

Pilot Judgments

The German investigators started with a study of pilot reactions to wind shear. The rationale was that while the physics of wind shear underlies the basic phenomenon, the attitudes and knowledge of the flight crew are important to the design and evaluation of systems to help deal with the problem. Special questionnaires were drafted, refined, and finally sent to 570 members of the German Airline Pilots association ("Vereinigung Cockpit"); all participants were in active flight service at the time of inquiry. The final questionnaire had 63 "agree-disagree" statements, and respondents were asked to respond to these on a six-point scale of agreement-disagreement. Most of the items related to matters such as the detection of wind shear, the significance of radio and other warnings, and ways of dealing with wind-shear conditions. There was also space for subjects to describe informally any experiences with wind-shear phenomena.

The working airline pilots, whether captains or copilots, seemed to agree rather well on the potential hazards of wind-shear effects. For example, more than half said that wind shear on takeoff was more dangerous than an engine failing, and fully 78% rated wind shear during final approach as being more dangerous than an engine failure then. About five-sixths of the sample preferred manual control to automatic control when wind-shear seemed imminent. Nearly all pilots wanted an on-board wind shear display, and some of their responses furnished hints for designing such instrumentation. As one example, the display of changes in wind speed and direction was considered very acceptable. Pilots were a little suspicious of wind signals that were processed through elaborate filtering schemes; this probably relates to the "non-transparency," to the pilots, of some signal processing schemes. A reasonable hypothesis is that the typical pilot wants to have a wind shear display that will permit him to operate his airplane manually and with a relatively transparent and simple mental model of the events.

Manual Reaction to Wind Shear

The Braunschweig concept of wind-shear control uses "energy-rate" and "energy error." Energy rate is expressed by the airspeed acceleration and vertical speed errors that occur instantaneously, say in a glide path approach. "Energy errors" are indicated by net airspeed and by deviations from predicted height. To engineer a system

based on the two sets of quantities, some filtering of signals would have to be done; the result would be a display that would permit the pilot to make effective thrust settings but would not require him to respond unnecessarily to small gusts and weak wind-shear events. A nonlinear filtering algorithm seemed to work rather well in early Braunschweig theoretical studies. The results suggested that if a human pilot's behavior resembled rather closely a proportional controller with a constant time delay, aerodynamically dangerous conditions would be avoided in a very high proportion of wind-shear cases. (Estimating the exact probabilities of "failure" is a fascinating problem itself.)

Display Options

Two cockpit configurations were mocked up and evaluated. In one of these, termed the "Flight Mechanics" concept, energy rate was displayed by a second pointer on the vertical speed indicator (VSI); energy was shown on a modified fast/slow instrument. Presumably the pilot would scan the two indicators (though early research had shown that VSI was less important than the fast/slow detent information).

A second layout was called the "Human Factors" display because it was supposed to reflect better the findings of aviation psychology. By an offset measure that combines both energy and energy rate, this single integrated display shows the aircraft's deviation from a predicted path. The control and thrust-management movements that the pilot must make are supposedly quite evident from the one indicator.

The integrated configuration is shown in Figure 1. The wind-shear condition indicator is on the left side of the instrument. The distance between the two little triangles gives an idea of the range of wind-shear tolerance that exists at this instant. If wind-shear inputs to the airborne sensing instruments are negligible, then these triangles are far apart. If the bar inside the wind-shear indicator is moving downward, then more thrust should be applied. The other flight director, roll angle, and glide slope moving indicators are the same as in conventional flight directors.

Evaluation

A comprehensive simulator study assessed both the pilot acceptance of the two display concepts under realistic conditions, and the actual use of the instruments during different classes of flight challenge. The Braunschweig

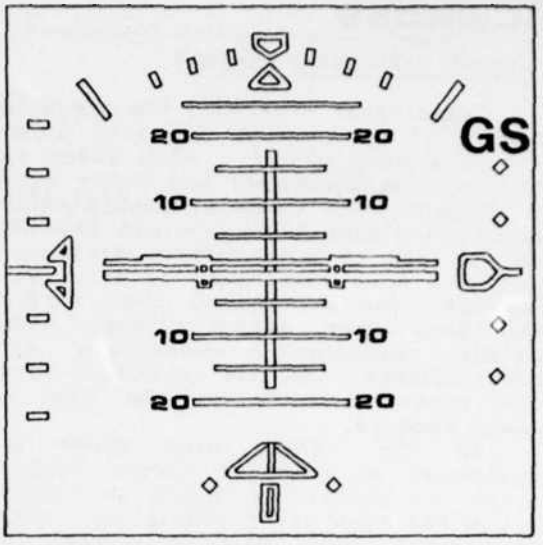

Figure 1. "Human Factors" display.

simulator cockpit setup provided four degrees of freedom (roll, pitch, vertical, and lateral motion); conventional stick forces and realistic engine noises were also programmed. The subjects faced a "reduced" instrument panel, with elements such as fuel gauges and radio control blanked out. All flights were "under the hood," with no outside visual simulation. For throttle settings and the usual control of elevator, aileron, and rudder, equations of motion similar to those in the Airbus 300 provided the aircraft response. Actually, all the information needed was provided by just seven instruments:

- Attitude director, with command crossbar, glide slope, localizer, and fast-slow reading
- VSI
- Airspeed indicator
- Horizontal situation indicator
- Altimeter
- Inertial navigation system panel
- Engine revolutions per minute.

For experimental comparisons, the simulator runs were made according to a two-factorial design, with three levels of display and four levels of wind profile. The three displays were flight mechanics, human factors, and conventional (no wind-shear processing or indications). Four levels of wind-change "challenge" went from gusts only, to thunderstorm with gusts and moderate wind shear, to inversion with moderate wind shear, and finally to thunderstorm with severe gusts and extremely strong horizontal and vertical wind shear.

All 12 pilots in the simulator studies had Airbus 300 experience. This selection policy was followed because the control equations were type-specific to that airplane, and so little or no learning of control characteristics was necessary.

After familiarization, each pilot made from 40 to 45 final approaches, starting at 1,200-ft altitude and 7 km from the end of the runway. Level of weather (wind shear) was counterbalanced in each block of display-condition runs. Glide slope deviations, displayed energy-error and energy, and all control movements were recorded at 10 cps, along with the instantaneous wind conditions. Altogether, the flight record had 23 channels of continuously monitored data. Automatic statistical analysis produced immediate means, variances, and ranges on each variable. Eye movements were recorded with an NAC-IV eye-mark recorder, which furnished a good record of instantaneous eye fixation point, dwell times, and scanning transitions between instruments.

A surprising general result was the extremely high variance in pilot behavior; some pilots apparently had a strong preference for elevator control over thrust control, some favored thrust manipulation, and some were about equal in their distribution of movements between the two control strategies. The result shows individual "control style" differences among *highly* practiced controllers--all flying the same aircraft, and all performing identical simulator tasks. The variance among styles prevented any of the three display versions from being statistically better than the others. The "severe gusts and strong wind shear" weather condition did, of course, produce the worst pilot performance.

Eye movement dwell times, summarized in Table 1, show that the human factors display scanning pattern was similar to the conventional one. But when the flight mechanics display was used for approach, the dwell time on the VSI increased by some eight times (1% to 8%), and over a quarter of the eye-mark fixations were taken up by shifts between the attitude director and the VSI. A reasonable conjecture is that the second pointer imposes a new scanning requirement, which is both visually and cognitively more demanding.

Pilot subjects were generally positive about the simulator's realism, both in aircraft characteristics and in weather representation. In addition, subjects thought that the two new displays were improvements over the intentional layout. The human factors display came out best in pilot opinion ratings, and a few participants commented on the onerous two-indicator scanning task implicit in the flight mechanics display. There was some disagreement about the pre-display processing of the wind signals, with some pilots observing that perhaps deviations should not be shown at all unless wind-shear effects really become extreme.

The Braunschweig work is a good example of aviation psychology in Europe, and aside from the technical excellence of the research and specific data on eye fixations, there are three

Table 1
Mean Percentages of Visual Dwell Time on Seven Instruments

Flight Indicator	Conventional Display	Human Factors Display	Flight Mechanics Display
Flight director	70.8	72.3	66.8
F-S indicator	8.3	10.1	7.1
Glide slope	4.8	4.2	4.0
Airspeed	5.9	4.3	5.0
Course/heading	1.4	0.5	0.6
Vertical speed	1.0	1.0	8.0
Altimeter	0.8	0.8	0.5

general conclusions that ergonomics and design people might ponder. One has already been mentioned: individual differences. You can take a few skilled pilots who spend their working days flying the same airplane, put them in a standard simulator approach task, and note their behavior with a very detailed recording system. But do not expect near-identical behavior; personal control preferences often are dominant.

A second finding is the value of a multi-sided approach when dealing with a well-established technological work environment. As E.C. Poulton's famous critique has shown, and as the present German research has again demonstrated, pilot and other expert judgments may be full of biases and errors, and they are not always to be taken literally. Yet judgment properly supplements the experimental data in the wind-shear studies, and some of the pilot comments about cockpit design proved to be very useful.

As a third general aspect of the research, we can pick up a suggestion or two regarding implementation of a new display or control concept. Pilots may indeed say that they do not want heavily preprocessed signals. But if the signals are presented in ways that the human operator can trust and use easily, then the question of the amount of preprocessing becomes a minor and abstract issue. Pilots may also assert that they always want to be in manual control of crucial stages of the flight, but if provided a reliable and comfortable restructuring of the task that makes human work more reliable and comfortable, which permits better prediction of critical events, and which still has the possibility of manual recovery if all the "aiding" fails, then the operators will accept the new system.

As graphics display capabilities advance, it is fascinating to think of how an "ultimate" wind-shear display might look. The display engineers can already provide, at least in the laboratory, a "tunnel-in-the-sky" which is refreshed as the plane flies down the tunnel; preliminary American tests show that the flight path with the tunnel can be better controlled than with usual flight-path instruments. It seems logical that a dynamic highway, tunnel, or other psuedo-perspective display could incorporate the prevailing variances in wind-current. Nobody knows whether the computerized shading or expansion of tunnel walls, or other displayed features would improve pilot judgment appreciably. It is clear that people do not automatically and easily intrepret variance-type displays, and that both special training and speical aiding probably will be needed.

N.A. Bond, Jr.

CHEMISTRY

FRENCH COLLOQUIUM ON SPECIALIZED POLYMERS

The Groupe Francais d'Etudes et d'Applications des Polymers (GFP) XII National Colloquium on Specialized Polymers was held in Montpellier, France, from 22 through 24 November 1982. The GFP is an independent French society dedicated to every aspect of polymer science and technology: chemistry, physics, and material science and engineering, including molding.

The organization was created in 1970 and now has about 500 members almost equally divided among industry and academia. There is one general annual meeting, such as this colloquium, and four or five specialized meetings. The attendance is largely French and, except for a few invited papers from overseas, is conducted entirely in the French language. There were 140 attendees, of whom only 12 were not from France. Seven invited lectures were presented, two by US participants and five by French. In addition, 26 posters were displayed, one from West Germany and 25 from France. The choice of subjects selected probably reflects French thinking as to the most active areas of research, development, and application in polymers: electrically conducting, piezoelectric, and biocompatible polymers; membranes; and polymers for microlithography and composites.

Electrically Conducting Polymers

Prof. A.G. MacDiarmid (Univ. of Pennsylvania) summarized the extensive work on polyacetylene (PA) at the Univ. of Pennsylvania since 1977. The structure, doping, and electronic properties were discussed in some detail. The as-formed films have a matted fibrillar structure and are polycrystalline; different synthetic methods cause variations in the bulk densities. The room temperature conductivity of the undoped PA films depends on the cis-trans ratio, being $\sim 10^{-9}$ for all cis and $\sim 10^{-5}$ ohm^{-1} cm^{-1} for all trans. The trans isomer is the most

stable, and its formation is favored at higher temperatures. The very pure polymers would probably have lower conductivities. Both p-type (oxidation) and n-type (reduction) doping is readily carried out either by exposure to suitable reagents or by electrochemical methods. Room temperature conductivities up to 1,000 $ohms^{-1}$ cm^{-1} can be achieved. Cis-rich films can be stretched with increasing conductivity in the direction of stretch, with corresponding decreases in the perpendicular direction.

Bonding and conduction in both doped and undoped PA were discussed. The current theory usually invoked to explain bonding and electronic properties in the trans polymer involves the concept of neutral, positive, and negative solitons. Electron spin resonance (ESR) studies show that the former are highly mobile, whereas the positive and negative solitons are relatively localized.

Conductivity-temperature studies show that conduction in PA proceeds by a hopping mechanism in the semiconducting regime. Recent work by S. Kivelson indicates that the dominant hopping mechanism could be the "capture" of an electron from a neutral soliton in one chain by a positive or negative soliton in an adjacent chain. Three main electronic regimes can be defined for PA: the semiconductor low dopant concentration state, where the properties are similar to classical doped semiconductors, a true metallic regime with dopant concentrations above 7%, and finally a transitional region with intermediate properties.

MacDiarmid also discussed the use of PA to construct lightweight, high-power-density, rechargeable organic storage batteries--new concepts in battery technology. PA can be oxidized or reduced electrochemically and reversibly. Either one or both electrodes can be PA; the most-studied types have a strip of foil (e.g., PA film and a strip of lithium, aluminum, or nickel) immersed in a solution of lithium perchlorate in propylene carbonate. However, many other systems have been investigated and show considerable promise.

Dr. L.M. Middleman (Raychem Inc., Menlo Park, CA) described a new and ingenious application of an established class of conducting polymers in electrical and electronic circuitry. One can prepare conductive polymer composites consisting of carbon black, metal flakes or powders, or other highly conductive materials dispersed in a polymer matrix. The conductivity can be increased by increasing the concentration of conducting filler; carbon black has been studied most.

Porous carbon species that give greater conductivity at similar concentrations are available. The agglomeration of the carbon particles forms conducting pathways. As a result of the tunneling mechanism needed for electrons to pass through the polymeric insulating gaps, the resistivity depends very much on voltage and frequency. The gaps become larger as the temperature is raised, causing an increase in the resistivity. The expansion can also lead to disruptions of the conducting carbon agglomerates. Such an anomolous positive temperature coefficient of the resistivity (PTCR) is the key to the use of such polymers for control devices. With semicrystalline polymer matrices such as polyethylene, there is a sharp increase in resistivity at the melting point.

Middleman discussed a number of features of the resistivity and the resistivity-temperature behavior of many composites. Crosslinking improved the performance of amorphous matrices, but different polymers show different patterns of behavior. Problems can arise owing to the slow drifting downward of the resistivity with time because of a restructuring of the carbon black dispersions. Also, repeated cycling can lead to changes caused by oxidation or other processes in the polymer itself. Nonetheless, selected polymer composites have given excellent performance. As with many such applications, it is important to have adequate means of attaching electrodes with low contact resistance.

A number of current control devices were described. The earliest and simplest is a self-regulating heater whose power decreases as the temperature rises and, with the correct formulation, cuts off completely at a predesigned temperature. Such devices can also be designed as reusable fuses. New, specialized conductive composites have been developed and are being applied to novel electrical and electronic uses.

There were five posters related to electrically conducting polymers; four were concerned with PA. M. Galtier (Univ. of Science and Technology of Languedoc [USTL], Montpellier) showed that PA films could be partially oriented after laminating to another polymer. Infrared spectroscopy and polarized light studies showed the degree of orientation, which changed on thermal cis-trans isomerization. It was interesting that the morphology of the films changed during the laminating and

stretching, the fibrous structure essentially disappearing.

M. Pelpaceur and coworkers (USTL) presented new infrared spectroscopic data on iodine-doped PA. The well-known bands at 1370 and 900 cm^{-1}, attributed to solitons, reach their maximum intensities at 2% doping. At higher doping levels, 15 to 20%, the absorption coefficients continue to increase until the PA is saturated with dopant. The results suggest two different contributions to the conductivity of doped PA: solitons in the semiconductor region and another unknown phenomenon in the quasi-metallic region.

M. Maitrot (Univ. of Lyon) reported on the surfacial photoconductivity of PA. Cis and trans isomers were studied as functions of tension, light intensity, and temperature. The principal conductivity was from cis, contrary to previously published results. The importance of residual impurities from the catalyst was demonstrated.

L. Giral (USTL) presented a study of molybdenum pentachloride doped PA using ^{13}C nuclear magnetic resonance (NMR) and ESR. A phenomenon other than isomerism was indicated, and at high degrees of doping, isomerism was not complete. G. Froyer (Centre National d'Etudes des Telecommunications, Lannion) compared the properties of poly paraphenylenes prepared by two methods--one by the oxidation of benzene and one starting from paradibromobenzene. The visible, ultraviolet, and infrared spectra and the conductivity of doped and undoped polymers were measured. The latter method leads to higher molecular weights and better electrical conductivity.

Piezoelectric Polymers

Dr. D. Broussoux (Thomson CSF, Orsay) reviewed the field of piezoelectric polymers. Two mechanisms were defined: the electret and ferroelectric. With the electret mechanism, charge carriers or dipoles are oriented under an electric field and set thermally by cooling into a metastable equilibrium. Examples include polytetrafluoroethylene, polypropylene, and polyvinyl chloride--all rather feeble piezoelectric polymers.

The ferroelectric mechanism is usually found with semicrystalline polymers where the dipolar orientation is associated with a stable equilibrium of minimum energy. The orientation is obtained by the application of a high electric field. Examples include polyvinylidene fluoride (PVF_2), and vinylidene fluoride-trifluoroethylene copolymers.

The crystalline structure and morphology of the two types have been studied by x-ray diffraction, infrared spectroscopy, and small angle light scattering. The results have been correlated with the piezoelectric coefficients and the degree of spontaneous polarization. A theoretical model based on the composite amorphous and crystalline structure was presented. The amorphous structure was judged to control the mechanical properties, whereas the crystalline component governed the spontaneous polarization. Finally, some applications of piezoelectric polymers were described: stethoscopes, pulse measuring devices, hydrophones, loud speaker diaphragms, microphones for telephones, and devices for blood pressure measurements at two points.

There were two posters regarding polyvinylidene fluoride. M. Latour (USTL) discussed copolymers with chlorotrifluoroethylene. Polymers with more than 95% vinylidene fluoride were shown by far infrared spectroscopy to have a structure similar to the pure polymer with a principally α structure. C. Lacabanne (Univ. Paul Sabatier, Toulouse) reported an investigation of the amorphous phase of β piezoelectric PVF_2; transitions and the fine structure were studied using thermally stimulated currents and flow. Two glass transitions were observed with two kinds of amorphous phases--the normal one and one with ordered dipoles.

Microlithography

The use of polymers in microlithography was outlined by Dr. J.C. Dubois (Thomson CSF, Orsay). Two groups were defined: negative resist polymers (where the radiation renders the polymer insoluble in the developing solvent due to crosslinking) and positive (where radiation degrades the polymer, making it soluble). The qualities essential for good "resist" polymers are facility of deposition, good resolution, good mechanical strength, immunity to printing chemicals, and ease of removal after printing. Resolutions of less than a micron are obtainable with ultraviolet (200 to 300 nm), x-rays (4 to 50 angstroms), and electrons. There was a rather detailed discussion of the various polymers currently used or being developed industrially.

Ultraviolet-active resist polymers may be intrinsically photo-crosslinkable, or they may need the addition of a suitable photosensitizer. Examples of both types were given. In addition to the free radical reactions common to both systems, cationic mechanisms have

been developed. Epoxy- and thirane-containing polymers are used together with photosensitizers, which develop Lewis acids under ultraviolet irradiation. The cationic types are, in general, much more sensitive than free radical initiated systems. Negative resin systems tend to have greater sensitivities but lower contrast than the positive species.

Electron resist polymers do not normally need a sensitizer; positive resins are more sensitive and more commonly used than negative resins. Polysiloxanes can be interesting positive resins as they crosslink with electron radiation. On heating they develop by conversion to silica, which is highly resistant to plasma printing. Radiation grafting has also been used to increase sensitivity. Dubois and his colleagues at Thomson CSF have studied both such approaches.

X-ray resist polymers are similar to those used with electrons and follow a similar chemistry. Polymethyl methacrylate is a common example of a positive resist material. Substituting the α hydrogen with chlorine or fluorine increases the radiation sensitivity by three or four times; a nitrile group increases the sensitivity by 10 times. Many other polymers, primarily positive resists, are in use or are being developed. Three posters were displayed by H. Martin et al. (Centre National d'Etudes des Télecommunications [CNET], Meylan). One concerned the measurement of sensitivity to far ultraviolet of various coatings, mainly polymethyl methacrylate. A second compared the advantages and constraints associated with the use of 60-keV x-rays and 500-keV ions for the normal criteria of use. The third poster described results obtained with various methods of plastic encapsulation of integrated circuits. In general, thermosetting resins have been used--especially because of their fluidity before setting up. CNET has begun to use injection molding of thermoplastic for encapsulation to take advantage of the lack of humidity, possibilities for automation, and potential use of waste material. Preliminary results were encouraging. B. Serre et al. (USTL), in cooperation with J.C. Dubois et al., described the study and synthesis of modified methacrylates by the introduction of fluorine and nitrile groups. Substantially more sensitivity to x-rays and electrons was found, as Dubois mentioned in his main lecture.

Biocompatible Polymers

Prof. M. Jozefowicz (Univ. Paris-Nord, Villetaneuse) reviewed work on blood and tissue compatibility of polymers. What is known of the mechanism of blood clotting was summarized from the literature. Heparin and its more highly active species were discussed together with synthetic anticoagulant resins based on polystyrene. Polypara sodium styrene sulfonate was used as the starting material. It was modified directly or prepared as copolymers by reaction through the para-SO_2 group with various amino acids, such as glycine, β-alanine, aspartic acid, glutamic acid, and piperidinic acid. There was a pronounced maximum in the curve of anticoagulant activity versus the number of carbon atoms separating the amino and carboxylic acid groups, three being the best. Epichlorhydrin crosslinked dextrans ("sephadex") were improved in their biocompatibility by substituting with similar compounds. The p-styrene sodium sulfonate monomer could also be grafted to polymers such as polyethylene and subsequently substituted with amino acids, giving good blood compatibility.

There were six posters concerned with biological compatibility and applications of polymers. J.C. Rabadeux (Univ. of Maine, LeMans) described the synthesis of polymer networks of pharmacological interest. Androstene diol was reacted with chlorocarbonyloxy-2 ethyl methacrylate. The product was copolymerized ionically and by free radicals with methyl methacrylate to form gels. The physical properties are under study. The carbonate link is hydrolyzable, releasing the hormone and destroying the network. C. Braud (Université de Haute Normandie, Mont-Saint-Aignan) reviewed the use of the β-malic acid polymer synthesized by Vert and Lenz (1979) for drug release. Biocompatibility was good.

C. Pusineri (Rhone-Poulenc Co., St. Fons), in work carried out with a group at the Institut National de la Santé et de la Recherche Medicale (INSERM), Bron, compared heparinized and nonheparinized catheters prepared from elastomers with cationic sites permitting ionic association with the heparin. The Dudley test indicated that the heparinized catheters were good in dogs for at least 72 hours, compared with 7 to 15 minutes for nonheparinized controls. The rates of liberation of the heparin were also measured.

K. Geckler (Univ. of Tübingen, FRG) described the modification of polyethylene oxide by first adding active chlorine and aldehyde groups and then attaching amino acids. The biocompatibility of the polymers is now being investigated. The synthetic methods were described by Bayer et al.

(1982, 1983). J.P. Payan (Centre de Recherches du Bouchet, Societé Nationale des Ponndres et Explosifs [SNPE], Vert le Petit), working with the Laboratoire de Pharmacie Galénique, Amiens, and the Faculty of Pharmacy, Chatenay-Malabry, reported a study of the kinetics of release of various amines, alcohols, and phenol after reactions with polyvinyl chloroformate. *In vitro* tests were used at various pH values.

C. Lacabanne (Univ. Paul Sabatier, Toulouse) and F. Micheron (Thomson - CSF, Orsay) described the use of piezoelectric polyvinylidene fluoride to induce bone formation. The films were implanted in the femurs of adult rabbits; biocompatibility was good and comparison with nonpiezoelectric films showed that the piezoelectricity induced by movement led to bone formation.

Membranes

Prof. J. Néel (Ecole Nationale Supérieure des Industries Chimiques, Nancy) presented an invited lecture on the techniques and use of synthetic membranes for separations. The present status, known statistics, and technology of hemodialysis, reverse osmosis, ultrafiltration, electrodialysis, and gas separations were reviewed. Pervaporation for the separation of azeotropic mixtures of solvents was also discussed and specific examples provided. It was estimated that there are 161,000 patients using kidney dialysis, and the annual cost of dialyzers is about $500 million worldwide. Reverse osmosis is used to treat 2.5 million m^3 of water each day; only 55,000 m^3 is seawater. The corresponding figure for ultrafiltration was 500,000 m^3 of water for various effluents; about 42,500 m^2 of membranes are used. Electrodialysis was used in Japan and Korea to produce about 1 million tons of salt from seawater. The process was also used to desalt about 100,000 m^3/day of brackish water worldwide; about half of the total was in the US and Mexico. In 1981 about 116 billion m^3 (standard temperature and pressure) of hydrogen was extracted from industrial gases by permeation.

Néel also presented a poster illustrating the use of composite membranes for pervaporation. One polymer with good permeability characteristics but poor mechanical strength has a strong affinity for one constituent and consequently swells. A second polymer is selected to confer adequate mechanical strength. Polymer blends and asymmetric membranes with a thin layer of the active polymer were described, and examples were given for various solvent mixtures. F. Schue (USTL) and M. Josefowitz (Univ. Paris Nord) described the synthesis and characterization of asymmetric synthetic membranes with anticoagulant properties for various medical applications. The double bonds of the base polymer were treated with chlorosulfonylisocyanate, which was added across the double bonds and subsequently transformed to neighboring $NHSO_3Na$ and COONa groups. Compatibility was good. Dr. S. Boileau and colleagues (College de France, Paris) described some novel membranes for electron transport based on polymers from ferrocene and its derivatives. Symmetrical anions such as Ph_4B^- were the best charge carriers.

Composites

Dr. J. Hognat (Laboratoire Central de l'Aerospatiale, Suresnes) gave a general lecture on composite materials. He described their properties and discussed the reasons for the intense interest in their use. The types of fibers and resins used or under development and their advantages and disadvantages were described. Hognat indicated that the lack of an advanced carbon fiber industry is leading to slower developments in France. Finally, Hognat described composites and their various applications in European aircraft--the Airbus, Mirage fighters, and Puma helicopters. Little new material or information was disclosed in his lecture.

J. Jarrin (Institut Francais du Petrole, Malmaison) described in a poster new lightweight composites prepared by including hollow glass spheres in hydrocarbon thermosetting resins; poly 1,2 butadiene plus vinyl toluene was the resin system. Organized foams with densities of 0.35 to 0.70 g/cm^3 resisted hydrostatic pressures of more than 900 daN/cm^2. The materials are being used for floats at considerable depths--mainly on offshore oil installations. W. Lenne (Essilor International Co., Vincennes) discussed the use of composites of organic and mineral glasses for ophthalmic lenses. Specially designed polyurethanes that react with the glass surfaces were used.

There were three posters of general interest. Two by Dr. J.M. Widmaier (Ecole d'Application des Haut Polymeres, Strasbourg) were concerned with interpenetrating networks. One type, defined as a semi-interpenetrating network, was prepared by polymerizing styrene plus divinyl benzene in the presence of polystyrene, polyisoprene, or styrene-diene-styrene block copolymers. Widmaier described the amount of extractable material and swelling behavior.

The second type, prepared by polymerizing methyl methacrylate in the presence of crosslinked polyurethanes, was semi-interpenetrating; with methyl methacrylate plus a multifunctional methacrylate, the networks were fully interpenetrating and easier to obtain in transparent form. The mechanical properties were also superior. Use of the two methods allowed the formation of widely varying types of polymer.

The meeting was extremely interesting and well organized. It is regrettable that language barriers often inhibit scientists from attending such national meetings.

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V.T. Stannett

COMPUTER SCIENCES

ROBOTICS RESEARCH AT LAMM

Research at Laboratoire d'Automatique et de Micro-electronique de Montpellier (LAMM) is in four principal areas:

1. Physics, semiconductors, and hardware applications to very large scale integration (VLSI).
2. Computer aided design, including software development, complex logical circuits, simulation, and testing.
3. Design and implementation of real time control systems. This includes a study of optimization of the number of processors, allocation of memory, and real time languages.
4. Robotics, which this article discusses.

The entire laboratory consists of 90 professionals, including 40 student researchers. In robotics there are seven staff members with PhD degrees and seven students working toward PhDs.

According to Prof. Alain Liégeois--Manager, robotics research--and members of his staff, there are five main projects in robotics:

- The study of geometric, dynamic, and kinematic models of jointed mechanisms.
- Programs to control manipulators.
- Batch programs to simulate the evolution of robots.
- Modelling of robotic control systems.
- The Conception Assistée Tridimensionelle Inter-Active (CATIA) programming system.

Study of Models

A geometric robot model is studied under static conditions. A dynamic model accounts for the forces acting upon the robot, and a kinematic model also takes into account velocity and acceleration.

An algorithm for the automatic generation of the dynamic model of a robot has been developed. Such a model is needed for the design and automatic control of manipulators with high velocities and accelerations. An explicit and compact formulation of the gravity torques and of the inertia matrix coefficients has been obtained by using the rotation matrix properties and the augmented body concept. Such functions and the gradient of the inertia coefficients were completed and stored for points in the work space of the robot. With the stored values, all the dynamic coefficients, including centrifugal and Coriolis terms, could be computed for any configuration. The technique achieves the speed required to compute the torques in real time for a given trajectory and needs less memory than other tabulation methods.

Programs to Control Manipulators

An internal report by Liégeois and Marie-José Aldon entitled "Génération et Programmation Automatiques des Équations de Lagrange des Robots et Manipulateurs" describes their work on the interaction between the robot and its environment. Consider a robot manipulator defined by its structure and its activators. It is necessary to establish automatically the equations permitting either the operator or a computer to ensure that a robot can execute a given task, or to define the modifications of the parameters that permit execution under the best conditions. Such a model must be able to satisfy two types of applications:

1. The computer-assisted conceptions of mechanically articulated systems. The tasks are the inputs of a model defined by its structural parameters; the outputs are the forces and the couplings before being acted upon by the motors. The interactive aspect of programs generating equations is indispensable in order to avoid reprogramming

if the mechanical structure changes or the robot is replaced.

2. The autoadaptive dynamic control. The model is used in real time to determine the controls to apply to the process so that it furnishes the desired response; one sees here the need for a model as compact as possible to reduce the time of computing and the memory size used.

The modelling of mechanically articulated systems has been done nationally and internationally. The differential equations obtained translate the relations between the forces and couplings to the articulations and the positions, speeds, and accelerations of articulated variables.

The methods used can be classified in four principal groups: Lagrange equations, equations of Newton and Euler, principles of the work of d'Alembert, and function of Gibbs. The Lagrange equations were chosen. They are advantageous because they do not lead to a system in which forces of reaction appear; the number of equations obtained is equal to the number of degrees of freedom. In addition, Lagrange equations bring in directly, in algebraic value, the extents of control, forces and couplings to the motors, and other sources of energy dissipation.

The disadvantage of the equations is the requirement for formal calculation of partial derivatives of the kinetic energy. To define the dynamic model of an augmenting mechanism of which all the connections are supposed perfect, the equations of Lagrange are used in the form:

$$\sum_{\lambda=1}^{NN} \left[\frac{d}{dt} \left(\frac{\partial E_{c\lambda}}{\partial \dot{q}_i} \right) - \frac{\partial E_{c\lambda}}{\partial q_i} \right] = Q_i + F_i, \quad (i = 1,2,\ldots N)$$

where NN represents the number of solid bodies S_λ, $(\lambda=1,2,\ldots,NN)$; $E_{c\lambda}$ represents the total kinetic energy of the solid S_λ; q_i designates the ith generalized coordinates of the system $\dot{q}_i = dq_i/dt$; Q_i is the coupling (or force) exercised by the weight on the articulation, i; and F_i represents the generalized force on the articulation i.

The principal problem to resolve is that of calculating the kinetic energy; the solution is different for dynamic models. The matrix method, proposed by J.J. Uicker, was used; the approach is expected to be the subject of a future *FSN* article.

Cooperation of Two Manipulators in Assembly Tasks

The cooperation project shows how complex assemblies can be carried out with two nonspecialized robots when the machines work efficiently together.

Assemblies using two arms are classified as follows:

First category: fixed receptacle; heavy or large part. The receptacle is fixed on the worktable, and the part, because of its weight or dimensions, cannot be handled by a single arm.

Second category: assemblies "in the air." Each manipulator holds one of the parts.

Third category: Case 1--the receptacle is not fixed but set on the worktable and thus has two degrees of freedom in translation and one degree of freedom in rotation. Case 2--one of the arms maintains one of the parts in good position and orientation until the hooking phase of the assembly is completed.

As a result of experiments, it has been determined that using two arms is convenient for many tasks and permits completion of tasks that are difficult or impossible with one arm. However, there are several difficult problems to be solved:

- Avoiding collision between the arms.
- Insuring kinematic compatibility when both arms make a closed loop.
- Avoiding excessive effort on the piece being moved.

Despite the above problems, LAMM is interested in continuing work on coordination of two or more robots on various tasks.

The CATIA System

CATIA is a highly interactive three-dimensional computer aided design/computer aided manufacturing (CAD/CAM) system implemented on IBM computers (3033, 4341) using the IBM-3250 graphic display device. The system is now packaged in four modules:

1. The wire-frame geometry module providing three-dimensional geometry definition, manipulation, and analysis capabilities for points, lines, curves, text strings, and planes. Common services needed by all four modules are also provided. They include data-base management, program management, console

dialogue management, production of hard copy and statistics, and interface to read or write within the CATIA data base.

2. The surface and numerical control module, which is used to define complex three-dimensional surfaces and volumes and to analyze and machine them.

3. The polyhedral solid geometry module, which adds the ability to define simple volumes or solids. Such solids are represented by pseudo-planar polygonal facets. Dynamic hidden line removal is performed on the solids.

4. The kinematics module is used to define a set of solids linked together to form a single degree of freedom mechanism. Thus far, all the motions must be in a plane (two-dimensional kinematics).

The robotics application function, currently being developed at LAAS and Avions Marcel Dassault-Bréguet Aviation, will be another module of the CATIA system.

In the system a robot is represented by a collection of solids connected by revolute joints (one free rotation) or by prismatic joints (one free translation). In most cases, solids are polyhedra and are well adapted to model the articulated bodies of a robot and the other solids of the environment. Solids' and joints' axes are defined by the user. Any articulated mechanism can be described unless it exhibits kinematic loops, in which case only certain configurations can be processed.

The use of pointers within the data base allows geometrical and kinematical descriptions to be independent. A solid description may be interactively changed without altering the joint description and conversely. As a result, several different axis configurations may be given to a single set of solids, possibly making it easier to compare different mechanisms.

There are three levels of hierarchy in the robotics application function. At the highest level the operator chooses between "definition" and "utilization," the former being used to describe the robot's structure and the latter to simulate its behavior.

Using the alphanumeric keyboard or the light pen on the graphic display, the user can specify a joint's type (revolute or prismatic), its axis, and the solids to be linked. Linear and angular joint limits can be introduced and displayed. Coupling of joints can be taken into account in the mechanism definition and in the simulation programs.

The motions of a mechanism may be defined either in the space of the joint variables (direct motions) or in the task reference frame (inverse motions). In the former, the user specifies angular or linear variations for each joint; in the latter, the user can define the motion of any solid of the robot with respect to the environment.

The system allows the designer to evaluate the kinematic performance of a robot and to improve its location with respect to other machines. Future plans include providing facilities for evaluation of the forces and torques, examining the time of operation, simulating force and vision sensors, and developing aids for optimal path planning and collision avoidance.

J.F. Blackburn

ELECTRONICS

INTERNATIONAL CONFERENCE ON HIGHER PERFORMANCE ELECTRONIC DEVICES

The International Conference on the Physics of Semiconductors has held 16 meetings in its 32 years of existence. At the conference in 1954, the general acceptance of semiconductor band structure helped initiate a most extensive collaboration of industry and basic research; the worldwide semiconductor industry can trace its origins to the event. The 1982 conference held in Montpellier, France, was extremely comprehensive; it addressed over 50 categories of semiconductor physics in 5 days.

Twenty-five different organizations provided financial support for the conference, while primary sponsorship was by the International Union of Pure and Applied Physics. During recent years, advances in solid state physics can be attributed largely to the computer, to electron beam lithography, and to improved epitaxial deposition techniques. None of these tools-of-the-trade would exist had it not been for solid state physics, although the tools have production and not physics as their motivating cause for being.

This article describes the conference's highlights, and particularly findings that could lead to new categories of electron devices and a better understanding of III-V semiconductors.

III-V Semiconductors

T. Misugi of Fujitsu Laboratories is an enthusiastic advocate of gallium arsenide (GaAs) technology. He points out that the complexity of GaAs inte-

grated circuit (IC) logic circuits is increasing faster than that of silicon microprocessors. Fujitsu has found that a silicon dioxide capping material deposited on GaAs has a thermal coefficient of expansion sufficiently different from that of GaAs that, upon annealing, a stress is created which getters much chromium to the GaAs surface. Thermally grown native oxides (e.g., Ga_2O_3) cause an excess of As to pile up on the surface. The aluminum nitride cap has no such adverse properties.

A. Zylberstejn of Thompson-CSF reported on a systematic analysis of deleterious effects of deep level traps in GaAs devices. He used a modified deep level transient spectroscopy (DLTS) technique in which a GaAs field effect transistor (FET) was used as its own diagnostic tool. Narrow positive and negative pulses were applied to the FET control gate, and the FET drain resistance was measured as a function of time τ. The applicable formula is $\tau = 1/[C\sigma_c T^2 \exp(-\Delta E/kT)]$, where C is gate capacitance, σ_c is emission cross-section, ΔE is trap activation energy, T is temperature, and k is the Boltzman constant. The technique is unique in that it measures the actual temperature, T, of the electrons if the activation energy is known. The FET drain is fed by a constant current source. The technique is so sensitive that a single trap can be detected and characterized in a background of 10^5 electrons.

Seven different traps with emission time constants from 0.01 nanosecond to 23 minutes have been measured. Zylberstejn has determined that virtually all the excess noise in GaAs microwave FETs can be attributed to traps in the active channel region. The trapping fluctuations induce excess noise with a Lorentzian power spectrum. Other FET characteristics determined by Zylberstejn were that surface leakage is thermally activated and that long-term gate drift magnitude correlates with excess gate reverse leakage current. The findings are particularly relevant to GaAs FET applications where proper and consistent microwave performance is absolutely necessary in the first few seconds of operation after a long dormant period.

R. Wallis, also of Thompson-CSF, developed a technique of using a GaAs FET as its own diagnostic tool. Because a high performance FET has a very large channel width to channel length ratio, Wallis reasoned that the wide source and drain contacts short out virtually all the Hall voltage that may be generated. Mobility was determined in the FET by a measurement of the channel resistance as a function of gate voltage and of a magnetic field (B) applied normal to the device surface. The associated magnetoresistance is then of purely geometric origin and equal to μ^2B^2. The free electron density (n) is a function of the difference between the donor and acceptor densities, while the total ionized impurities (NI) are equal to the sum of the active donors and acceptors. Therefore, the two have been thought to be coupled so that the mobility as a function of n is masked by its larger dependence on NI. Wallis stated that this is not necessarily so and has separated the two characteristics in order to determine the effect of free carrier screening on electron mobility.

Although measurements of FET channel mobility have long been known to decrease near channel pinch-off, the effect had been universally believed to result from compensation. Not so, says Wallis. He reasons that when the FET region under the control gate is almost fully depleted of charge carriers, the electron density falls below the net donor density [i.e., $n<(N_D-N_A)$]. Thus the reduced value of mobility results from reduced free carrier screening. In a second system, Wallis uses a modulation-doped high electron mobility FET (HEMT) composed of GaAlAs/semi-insulating GaAs layers. In such a structure the accumulation layer in the GaAs is characterized by $n<(N_D-N_A)$, and n can be controlled independently of (N_D-N_A) by gate voltage. In the conventional FET, the mobility is nearly constant until near pinch-off, where screening is present. In the HEMT device, the conductance tracks the mobility over a very wide range of gate bias and departs only near pinch-off. The results show that free carrier screening has a pronounced effect on mobility. While the mobility of the HEMT device is higher than that of the conventional device at zero bias, their unscreened values are nearly identical. This illustrates that the enhanced mobility of HEMT devices results not only from the spatial separation of carriers and impurities as has been universally thought, but is also enhanced by the screening provided by the high density of free carriers. The results were obtained from 300°K data; low temperature effects are expected to be even more pronounced.

The GaAs surface is more difficult to control than silicon. W. Mönch and his coworkers (Univ. of Duisburg) may have found a reason. They cleaved many GaAs crystals--including n-type, p-type, and semi-insulating--in an ultrahigh

vacuum. All cleaved surfaces exhibited arsenic excess spots within 48 hours. The spots grew in size at temperatures of 80 to 170°C but shrank when subjected to 280 to 320°C. Upon cooling to 300°K, they grew again to 70 μm. All spots correlated with cleavage imperfections. For spots larger than 70 μm, an outermost ring of pure arsenic surrounds a center ring containing both gallium and arsenic; low-energy electron energy loss spectroscopy revealed marked differences between the center regions and the host crystal.

C. Calandra (Univ. of Modena) has studied the chemisorption processes of GaAs [110] surfaces cleaned in vacuum. He has drawn interesting conclusions regarding the nature of the chemisorbtive bond, the chemisorption sites, and the order of the adsorbate atoms. He finds evidence that adsorbate atoms linked to the substrate by strong covalent bonds are ordered, whereas those forming weaker bonds tend to cluster.

Superlattices

One of the fastest growing areas of solid state semiconductor research is that of superlattices (known also as modulation-doped structures). The concept of the artifact superlattice (it does not appear in nature) was originally proposed by L. Esaki, and it was fitting that he was chairman of the first session devoted to the subject. While the concept of the superlattice has been known for several years, the advent of crystal growing techniques--such as molecular beam epitaxy (MBE) and metal organic chemical vapor deposition (MOCVD)--has provided the methods of layer thickness control most suitable to test the concept. The recent introduction of atomic layer epitaxy (ALE) may provide an even more precise method of depositing the layers necessary to exploit the superlattice concept (see *ESN* 36-10:253 [1982]).

One of the first superlattice experiments was the multiple quantum well (MQW) structure, wherein lattice-constant-matched binary and/or ternary III-V semiconductor materials of differing bandgaps are layered in thicknesses generally between 50 and 1,500 angstroms. A year ago, G. Bostard published variational calculations which predicted that the binding energies of hydrogenic impurities in an infinitely deep well will increase and spread out into a band as the finite thickness of the well (layer) decreases. Using gallium arsenide/gallium aluminum arsenide (GaAs/GaAlAs) MQW structures of varying layer thicknesses, B. Lambert et al. (Univ. of Rennes) excited the structures with excitation densities from 10 mW/cm² to 5 kW/cm² and at temperatures from 4 to 200°K. Three main photoluminescence bands were observed and attributed to hole-to-neutral donor, electron-to-neutral acceptor, and donor-acceptor pair transitions. Band broadening of the spectrum as a function of well thickness decrease was observed in accordance with Bostard's predictions.

M. Inoue et al. (Osaka Univ.) reported that 4.2°K mobilities have now exceeded 1 million cm²/volt-seconds in GaAs/GaAlAs modulation doped FET structures. The two-dimensional (2D) electron gas mobility of 1.2×10^6 achieved by Fujitsu is a record for any semiconductor material. The characteristics of the 2D electron gas in the structures were analyzed as a function of applied electric field strength. Quantum oscillations in magnetoresistance measurements provided direct evidence of polar optical phonon emission and inter-subband transfer of the 2D electrons. With electron densities as high as $1.5 \times 10^{12}/cm^2$, strong magnetophonon resonance was observed even at electric fields less than 1 V/cm. Changes in the electron distribution in the second subband were observed with increased electric field strengths. The impact of the change of distribution on the ballistic nature of the electrons has, unfortunately, not been determined.

G. Fishman and D. Calecki (Univ. of Paris) provided further insight into the modulation doped layers of the type necessary for high electron mobility FET. Their model included three layers: doped GaAlAs, undoped GaAlAs, and undoped GaAs. Fishman and Calecki explored different limit cases and obtained explicitly the discontinuity in the Hall mobility when the Fermi level reaches the bottom of the second subband. They have modelled the Hall mobility as a function of the undoped GaAlAs interface layer of 0- to 150-angstrom thickness, and showed that the overall differential mobility becomes negative as this layer exceeds 300-angstrom thickness. They also found that the ultimate mobility limit is imposed by electron-impurity scattering in the doped GaAlAs layer; other defects distributed over the structure have a negligible influence on mobility.

K. Hess presented data to show that electrons cannot readily move into wells as narrow as 80 angstroms as there is insufficient space for the phonon processes to be involved. The constraint is eliminated at 200 angstroms. He further showed how the negative

resistance effect in quantum wells depends on the impurity gradients at the wells, that no tunnelling or transferred electron (Gunn) processes are involved, and that the oscillations derive from transfers in real space. He explained a mechanism which could make electrons literally jump out of their wells in 5 picoseconds and, depending on their temperature (energy), remain out of the well for times ranging from picoseconds to years.

Superlattices consisting of periodic super-thin layers in which the p-type and n-type layers are interspersed with intrinsic layers (nipi) create structures with Fermi levels periodically above and below the conduction band edge. Space charge induced potential wells are created and offer very desirable new properties, such as tunability of the bandgap luminescence. Papers on the subject were presented by researchers from the Technical Institute of Munich and the Max Planck Institute in Stuttgart. By correlating the concentration of the remaining photoexcited carriers and the effective band gap as measured by the luminescence red shift as a function of time, W. Rehm was able to determine the total decay of the photoexcited carriers. Measurement of luminescence intensity as a function of time provided radiative lifetime. With such measurements he was able to ascertain that the nipi structures exhibited recombination lifetimes hundreds of times longer than in bulk devices.

Deep Level Impurities

A. Sibille and colleagues (French National Center for the Study of Telecommunications) have studied the effect of transition metal impurities in InP. Their reported work concentrated on manganese and copper. Both ion-implantation and diffusion techniques were used to introduce the impurities. In addition to the usual acceptor behavior of Mn in InP, Sibille has found that implanted Mn creates an electron trap close to the conduction band and exhibiting a strong sensitivity to electric field, thus preventing precise measurement. The electron trap is caused by a native defect created by a complex of manganese on an indium site next to a phosphorous vacancy. The trap exhibits very fast diffusion rates and physically extends much deeper than the calculated implant depth. Another (dose-dependent) center was found for most of the transition metals at 0.53 eV below the conduction band edge. It also extends much deeper than implant depths and exhibits fast diffusivity. Copper was found at the usual 1.35-eV level and at 1.2 and 0.98 eV. The latter two levels differ from other published data, but were shown to vary as a function of the background concentration of other impurities and native defects. (See *ESN* 37-2:63 [1983] regarding native defects in InP.) One interesting but unexplained finding was that iron diffuses to the InP surface much more readily than it diffuses into the bulk.

F. Litty and coworkers (French National Institute of Science Applications, Lyon) have used deep level optical spectroscopy (DLOS) to examine transition metal impurities in GaAs. Models are used to extract from the acceptor and donor photoionization cross-sections data such as the optical ionization energies, the Frank-Condon parameter, the spatial extent of the defect electronic wave function, and the relative weights of the transition between the level and the bonds. Until now these models have been heuristic and unable to provide information concerning the nature of the defect. Using systematic excitation spectra, Litty has shown that DLOS measurements can lead unambiguously to the origin of deep level luminescences. One peculiarity has been found; although vanadium has a luminescence spectra in GaAs at 0.7 eV, it does not produce semi-insulating materials as do other deep level defects.

An Austrian, German, and Japanese team--W. Jantsch, K. Wünstel, and O. Kumagai--has developed a technique to differentiate among various traps in GaAs. Deep traps are delocalized in k-space; under pressure they shift in energy at rates comparable to those of the conduction and valence band states (e.g., 1.5 mV/kbar). Shallow states, in contrast, have pressure coefficients 100 times smaller. Without pressure, the activation energies of the M2, EL6, and E3 traps are all located 0.31 eV below the conduction band and have been considered to be of the same origin. The respective pressure coefficients, however, are 9.9, 5.5, and $0.5/1x10^{11}$ eV/Pa, clearly demonstrating their differing characters or origins. The researchers also have found a correlation between energy level and pressure coefficients in GaAs: Fe>V>Ti>Mn.

M.N. Yoder

RESEARCH IN NAVIGATION TECHNIQUES

The UK's Admiralty Compass Observatory (ACO) occupies an ancient manor

house surrounded by a moat, which is still the primary security barrier of the facility. Taken over by the British government during World War I, the site near Slough was considered highly valuable because it is one of the most geologically quiet spots in all of Britain. Sitting on a massive gravel basin, it is free of both magnetic and gravitational anomalies. Thus, it is an ideal location for conducting navigational research.

Although still commonly referred to as ACO, it is now the XTN division of the Admiralty Surface Weapons Establishment (ASWE) because of recent reorganizations within the Ministry of Defense (MoD). Former ACO director E. Hoy now heads XTN, but he spends equal time at ASWE, where he has other duties as well. Day-to-day operations of XTN are handled by the officer-in-charge, Dr. John Preston. Research is carried out in three systems-oriented groups (gyroscope [gyro], radio, and magnetics) and in one support group (physics). Research topics are in five technical areas: inertial navigation, radio navigation aids, integrated navigation, magnetic navigation, and magnetic anomaly detection/nonacoustic detection (M.A.D./NAD). Only highlights of the activities are reported here, with one exception: novel approaches to the creation of a nuclear magnetic resonance (NMR) gyroscope.

Radio Navigation Aids

Among the research and development activities of this group are the UK NAVSTAR global positioning system, Omega (monitoring and propagation), special antennas, acousto-optic processing, and passive astro-navigation. For centuries the navigator relied primarily upon his sextant. Even now the sextant remains the only open-ocean navigational fix source not subject to uncertainties such as power failure, jamming, or electronics malfunction. A primary limitation of the sextant during nighttime, however, has been the availability of both stars and a sharply defined horizon. Generally, the right conditions occur only for a few minutes each morning and evening. Even then, cloud cover can, and frequently does, interfere at the most inopportune times. But this may no longer be a problem since ACO has added a low light acquisition device to the common sextant. With a channel plate multiplier-based device, the horizon can be accurately acquired even in low level starlight. Thus, in addition to the daytime sun lines, the navigator may be able accurately to determine his position anytime during the night when a break in cloud cover occurs.

M.A.D./NAD

Although research in this group is concentrated primarily on signal detection and processing techniques, considerable work has been directed toward magnetic gradiometers. The gradiometers are based on three orthogonally positioned superconducting quantum interference devices (SQUIDs), each having a basic sensitivity of 10^{-14} Tesla (about four orders of magnitude more sensitive than conventional magnetometers). The gradiometer approach is effective because magnetic disturbances affect the local magnetic field gradient much more than an even larger magnetic perturbation does at a greater distance (e.g., an earth's crust anomaly). Research in the field is augmented by contract work at Thorn EMI (magnetic materials department). Josephson tunnelling junctions of niobium/niobium dioxide/lead indium gold are configured into two-hole alternating current (a.c.) SQUIDS operating at 19 MHz obtaining 2xH 10^{-13} Tesla/meter/$\sqrt{Hz}$ sensitivity, although research now appears to be giving increased emphasis to a direct current (d.c.) SQUID approach. Current frequency response of 0.05 to 1.00 Hz is being extended to 0.05 to 100 Hz to permit multifunctional capability. Extensions in the field include investigations into a five-axis gradiometer.

Magnetic Navigation

The research of this group is directed toward sonobuoy compasses, novel compasses, and fiber optic magnetometers. Although fiber optics can be sensitive detectors of magnetic fields, the same fibers are, unfortunately, also sensitive to pressure, acoustics, and temperature. Research needs in the field are primarily the separation of signals of various origins or causes and the synthesis of fibers responsive only to one mode of stimulus.

Integrated Navigation

This group is primarily interested in techniques to integrate or correlate the outputs of various sensors for use in a common display or man-machine interface. Current work includes modelling, optimum filters, displays, and correlation methods, although emphasis is on developing computer aided models to correlate the outputs of bottom bounce sonar, Doppler sonar, and pitometers.

Inertial Navigation

Virtually all types of phenomena and approaches to inertial navigation are investigated by this group: gyro bearings; dry tuned, electrostatically suspended, and ring laser gyros; the superconducting capacitor gyro (otherwise known as the superconducting absolute rotation detecting instrument equipment [SARDINE]); sonar speed logs; low cost inertial systems; and gravity gradiometers. The gradiometers are based on the measurement of the difference between the current signals generated from two superconducting perpetual-current-carrying coils affixed to separate but equal colinearly located masses. The basic objective is to measure changes in the local gravitational field to within 1 m/sec² in 10^8 m/sec² in a temperal period that is short compared with the Schuler period of a gyroscope (e.g., 20 minutes). If this could be measured, it would eliminate the need for local vertical correction tables for inertial navigation systems. The research is in consultation with Prof. Gordon Donaldson, who is doing similar work at the Univ. of Strathclyde in Glasgow.

NMR Gyroscope

Although any device possessing a measurable property that varies as the instrument rotates in space can be used as a basis of a navigational system, few such concepts have proved viable. Not only must the instrument be able to detect and quantify the rotation of the earth, but much lower rates of rotation (generated by movement of the gyro-carrying vehicle with respect to earth) must be measurable with an adequate signal-to-noise ratio. The best-known inertial navigation systems today are based on the mutually orthogonal placement of three single-degree-of-freedom, rate-integrating, floating gyros of the Draper type. Among the major limitations of such a system are cost, size, wear-out, and absence of a strapdown mode of operation. The electrostatically suspended gyro reduces the wear-out problem and may decrease drift, but it still has limitations. Other basic approaches include ring lasers and related fiber optic interferometers, superfluid mass principles, superconducting gyros, and tuning-fork-based devices.

Perhaps the most interesting gyro from a basic physics viewpoint is the one based on NMR. Using purely classical approaches, the magnetic moment (μ) of a particle bearing an electrical charge (e) moving in a circular orbit of discrete radius (r) and exhibiting a tangential velocity (v) can be expressed as

$$\mu = evr/2. \quad (1)$$

If the same particle has a mass (m), then its angular momentum (p) can be expressed as

$$p = mvr. \quad (2)$$

The ratio of the magnetic moment to the angular momentum is known as the gyromagnetic ratio (γ) and is expressed

$$\gamma = e/2m, \quad (3)$$

which is independent of orbital details. When subjected to a magnetic field (B), the orbiting charged particle experiences a torque proportional to the product of μ and B, causing a precession of the axis of rotation about the magnetic field vector at the well-known Larmor frequency (ω_o), where

$$\omega_o = \mu B/p = \gamma B. \quad (4)$$

Figure 1 depicts the above relationship. Quantum theory allows only discrete orbital radii to exist. As early as 1946, quantum changes of spin energy states were observed by measuring the induced magnetic field changes (nuclear induction). Increases in the value of B caused higher spin energy states with minute but detectable losses of power in the driver circuit known as nuclear resonance absorption. Together these changes are called NMR.

After a spin-spin relaxation time (T_1), all nuclei have a resultant magnetic moment (M) aligned with the applied field (B). The application of a stronger magnetic field (B_s) at right angles to B causes the nuclear magnetic moment (M) to align itself with B_s after a spin-lattice relaxation time

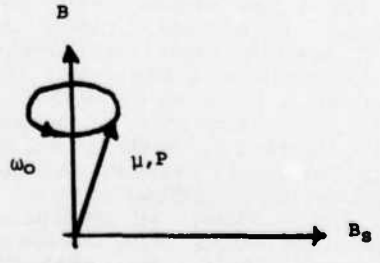

Figure 1. NMR gyro: precession of a nucleus in a magnetic field.

(T_2). In a solid, geometric demagnetization factors generally prevent the application of uniform magnetic fields, thus blurring the sharp NMR lines one would expect otherwise. Gases, of course, do not have the geometric demagnetization factors and have lower spin-spin interaction forces, thus providing much sharper resonance lines and longer values of T_1. If the gaseous nuclei are in a perfectly uniform magnetic field unperturbed by local anomalies and the sensing coils are rigid with respect to the B and B_s magnetic fields, then the NMR signal is the Larmor frequency. If the sensing coils are rotated about the direction of B, however, then the Larmor frequency is shifted by the relative rotation frequency ($\Delta\omega$). Measurement of $\Delta\omega$ then provides a direct indication of rotation rate and, by integration over time, of angular displacement. Attempts to exploit the NMR signal for navigational purposes have, unfortunately, been plagued by local magnetic perturbations. The NMR system not only measures relative rotation rate, but also local magnetic and electromagnetic signals, which induce signal strengths many orders of magnitude greater than those induced by relative rotation.

To overcome the above problems, the ACO team introduced cryogenic superconductivity. Using a modification of the well-known Meissner effect, the team placed the NMR apparatus inside a superconducting cylinder that traps magnetic flux B, which was uniform to within one part in 10 million. The Meissner shield also totally excluded external magnetic perturbations. One major problem remained. At 4.2°K (the cryogenic temperature required for the superconducting Meissner shield) all substances except helium are solid and thus unsuitable. The common $_2He^4$ isotope was also unusable as a result of cancellation of the antiparallel spins of its two protons and two neutrons. Using the isotope $_2He^3$ with but one proton eliminated the problem. Extremely sensitive superconducting SQUIDs are used as the sensing detectors. They have a response time of <10 picoseconds and measure Larmor frequencies in the vicinity of 15 MHz.

NMR-gyro slew rates ($\Delta\omega$) of several megahertz can, in principle, be measured. The NMR-gyro system then has a dynamic range and slew rate capability far above that needed for a strap-down inertial navigation system. Spin-spin relaxation times of nearly 2 minutes are currently being experienced. Thus, two separate NMR apparatus for each of three axes are required so that one NMR system can be B_s-pumped while the other coaxial unit is being read out. Although the three-axis unit has not yet been built, the feasibility has been established on a single unit, single axis system.

M.D. Schroeder, M.N. Yoder

MATERIAL SCIENCES

METALLURGY AND MATERIALS AT OXFORD

The Department of Metallurgy and Science of Materials at Oxford Univ. is conducting impressive research while using every bit of available space in the department. Prof. John W. Christian, FRS, has become acting head of department, while Sir Peter B. Hirsch, FRS, Isaac Wolfson Professor of Metallurgy, also has been appointed Director of the Atomic Energy Authority.

The 1982-83 departmental booklet "Researches in Progress" includes the activities of Michael J. Whelan, FRS, Reader in Physical Examination of Materials, and of 12 lecturers, 5 senior research fellows, 29 research fellows, 8 visitors, and 70 research students. Of the research fellows, 25 already have doctorates. The visitors are from Australia, France, Israel, The Peoples' Republic of China, and South Africa. The UK's Science and Engineering Research Council supports 35 research students; 29 of these have received a Cooperative Award in Science and Engineering (CASE) appointment in direct association with government or industrial places.

"Researches in Progress" lists 31 research sponsors; 126 research projects are divided among 19 topics, including mechanical properties, interfaces, cement, solidification, amorphous materials, corrosion, electron microscopy, x-ray microscopy and microanalysis, electron beam lithography, battery materials, radiation damage, atom probe-field ion microscopy, semiconductors, insulators, superconductors, acoustic microscopy, magnetism, electron theory of solids, and metals-related archaeology. For 1981-82, 165 publications are listed.

Metal Deformation

Christian is continuing his long-standing research in the deformation properties of body-centered-cubic metals and alloys. Recent work has been with Nb-N, Nb-Zr-O, and Li-Mg alloys. He delivered the Edward DeMille Campbell

Memorial Lecture on the topic "Some Surprising Features of the Plastic Deformation of Body-Centered Cubic Metals and Alloys" at the October 1982 combined meeting of the Institute of Metals Division, American Institute of Mining and Metallurgical Engineers, and American Society for Metals Congress, St. Louis, MO. The lecture is being submitted for publication in *Metallurgical Transactions*. Results on pure Nb crystals tested in tension and compression over one or more cycles of applied stress have been analyzed with respect to: (1) the occurrence of anomalous slip on the $(0\bar{1}1)$, almost orthogonal to the direction of applied stress, and (2) the relevance of computer simulations of the atomic displacements for dislocation motion (Chang, Taylor, and Christian, 1983). In either case, most of the answers are still to come from further experiments and the explication of more complex models.

Other mechanical property studies on metals relate to electron microscope observations of ordered alloys such as FeAl and Ni_3Al, anelastic properties of superplastic Pb, Zn, and Al-based alloys, fatigue crack propagation in Al alloys containing dispersed intermetallic phases, creep of two-phase materials, strength of alloyed pearlitic and ultrahigh carbon steels, precipitation reactions in liquid-phase sintered tungsten alloys, phase transformations in depleted-uranium alloys, retained austenite in bainitic and martensitic low-alloy steels, plane-strain ductility of two-phase steels, fast-tempering of low-alloy steels, and dislocation model calculations.

An interesting example is the study by B. Cantor of the mechanical properties of rapidly solidified Al and Fe sheet material manufactured by melt-spinning. Cantor was at the Univ. of Sussex and has spent a research period at the Department of Metallurgy, Banaras Hindu University, Varanasi. He and F. Duflos (1982) have attributed to Hall-Petch strengthening the achievement of a diamond pyramid hardness of 250 kg/mm² for splat-quenched iron exhibiting an ultrafine equiaxed grain size. Cantor and Ramachandrarao (1981) have reported the application of computed dense random packed amorphous model results to evaluating the thermodynamic properties of Au-Ge-Si, Pd-Ni-P, and Pt-Ni-P metallic glasses. Diffusion properties have been dealt with in other studies.

Electron Microscopy and Semiconductor Electrical Properties

Hirsch has a special interest in the activities of electron diffraction and transmission electron microscopy (TEM), scanning electron microscopy (SEM), and x-ray microscopy and microanalysis. (Thirty-seven projects are listed in the departmental booklet on these topics alone.) JEOL and Phillips electron microscopes are installed for high resolution electron microscopy (HREM) results at a resolution of 0.17 to 0.21 nm. A scanning transmission electron microscopy (STEM) unit has been built; it has a resolution better than 1.0 nm and can provide electron diffraction and x-ray analysis of an area 10.0 nm in diameter. An interesting development with modern electron microscopes is that high resolutions are achieved with 300- to 400-kV instruments that fit into a reasonable laboratory space. Alternatively, high voltage electron microscopy (HVEM) on the 1.0-MeV facility allows the direct observation of dynamic in-situ deformation experiments, phase transformations, and surface chemical reactions of specimens, say, approaching 1.0-μm thickness.

E.D. Boyes, B.J. Muggridge, and M.J. Goringe (1982) have developed a system of on-line processing and analysis of HREM images using a software controlled image processor based on a digital video framestore made by Microconsultants Ltd. The system is needed to interpret images obtained for specimens of different thicknesses under controlled known conditions of operating defocus and microscope aberration. A schematic outline of the Oxford system is shown in Figure 1. HREM applications of the system have included silicon lattice images, amorphous silicon, crossed graphite lattices, tungsten trioxide, and, most recently, Naβ-alumina, which is of interest for solid state battery applications.

C.J. Humphreys and colleagues have been involved with the interpretation and computer analysis of HREM images, including computations of image contrast at dislocation cores in direct lattice resolution electron microscopy. The possibility of developing an x-ray laser is being investigated in connection with the observation that discrete, tunable x-rays are emitted by high energy electrons being channeled through a crystal by repeated Bragg reflection. The interface structures of Naβ-alumina and Naβ"-alumina solid state electrolytes are being analyzed with respect to interface breakdown during their use in battery cells. A method of electron beam lithography is being investigated. Drilled hole and grooved line widths 1.0 nm in size have been achieved. The structures of silicide-silicon interfaces are being studied by lattice

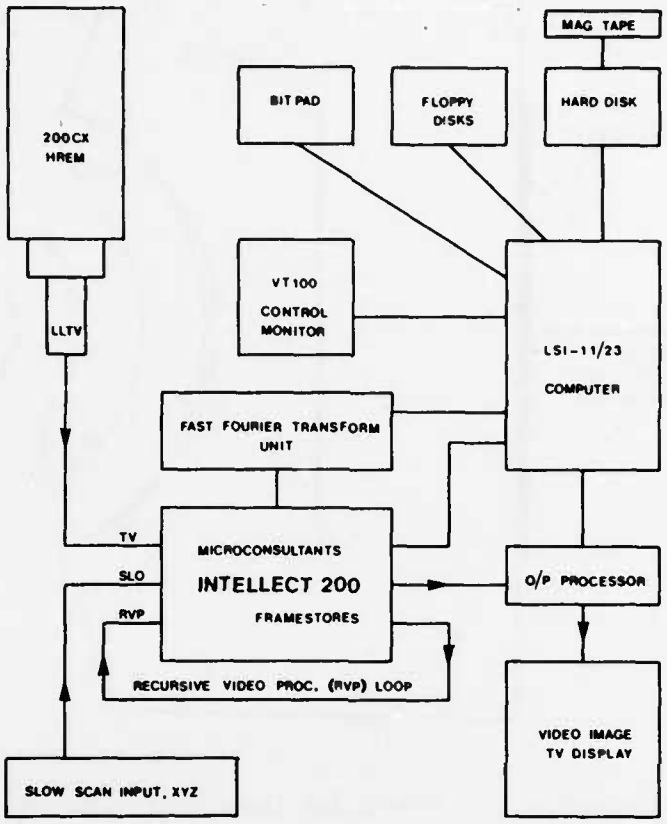

Figure 1. Arrangement for image analysis and interactive control for HREM based on coupling the image processor to the JEOL 200CX THG-2 HREM by an RT Labs LLTV camera with an SIT tube (Boyes, Muggridge, and Goringe, 1982).

imaging experiments and multislice image simulations.

Humphreys and Whelan are studying the effects of inelastic scattering of incident electrons on the character of electron microscope images. Whelan is developing the method of electron energy loss spectroscopy for use on the TEM and STEM instruments. The technique is to be applied to the microanalysis of precipitates and segregation effects in steels for nuclear reactors. The low energy electron scattering from surfaces is also being studied by Whelan to examine the coverage of overlays of various elements on amorphous silicon.

The electrical properties of defects in semiconductors are being pursued by G.R. Booker. He is conference co-chairman, with A.G. Cullis (Royal Signals and Radar Establishment, Malvern) and S.M. Davidson (GEC Hirst Research Center, Wembley), of the Third Oxford Conference on Microscopy of Semiconducting Materials, 21 through 23 March 1983, at St. Catherine's College. (Conference papers will be published by the Institute of Physics.) Hirsch will deliver the paper "Effect of Doping on Mechanical Properties, Recrystallization and Diffusion in Semiconductors." Booker is participating with colleagues in papers involving TEM, SEM, cathodoluminescence, x-ray topography, chemical etching, and Auger spectroscopy methods for characterizing the properties of semiconducting materials and devices. Of particular interest is the use of electron channeling patterns to characterize the perfection of crystal surface layers--especially to observe the contrast from individual dislocations. Other methods are the SEM electron beam induced current and optical photore-

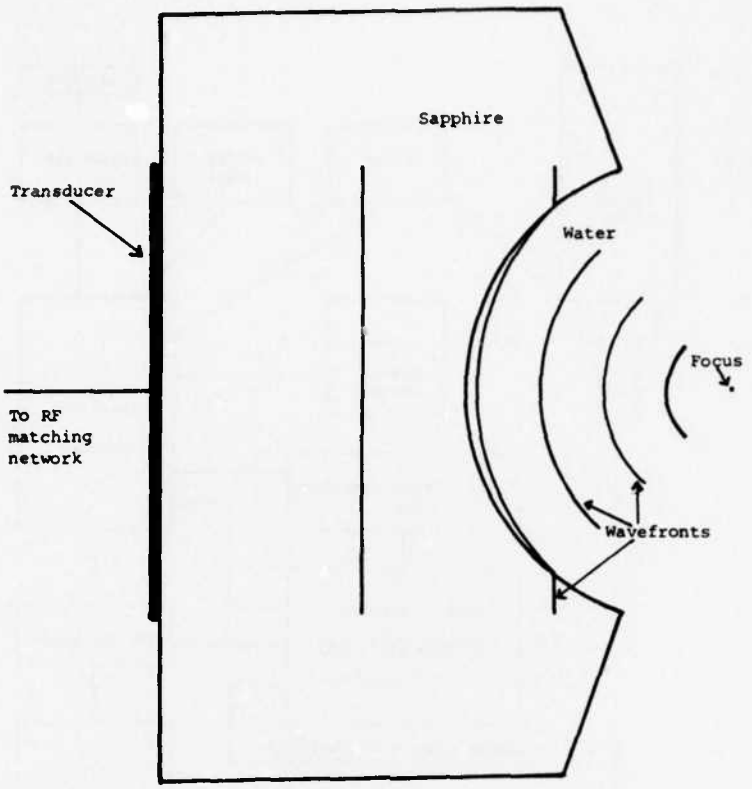

Figure 2. Schematic lens system for the scanning acoustic microscope.

sponse methods, which can be used to observe directly the electrical properties of dislocations.

Two device topics relating to high speed electronic circuitry are silicon-on-sapphire (SOS) layers and silicon devices incorporating buried oxide implanted isolating regions. Devices with SOS are radiation damage resistant and give energy-efficient fast switching. By subsurface implantation of, say, 400-keV oxygen ions concentrated enough to form a buried oxide layer and subsequent epitaxial deposition of silicon on the retained crystalline surface layer, dielectric isolation of integrated circuit elements is achieved and, apparently, faster device operation occurs. Ion-implantation of damage processes in GaAs is being studied; the work includes the effects of laser and electron-beam annealing. Epitaxial-layer structures in GaAs, InP, and other more complicated III-V structures formed by vapor and liquid-phase processes are being studied.

Scanning Acoustic Microscopy

G.A.D. Briggs (1983) has been involved with Hirsch and the Atomic Energy Research Establishment in developing the scanning acoustic microscope and applying it to materials problems. Information is obtained from the spatially dependent reflection or attenuation of ultrasonic waves. Work on the instrumentation of acoustic microscopy is being done by E. Ash and L. Bond at the Department of Electrical and Electronic Engineering, University College, London WC1E 7JE. The sapphire acoustic lens for the Oxford microscope is shown schematically in Figure 2. The second coupling medium is water. A pulsed radio frequency source is used, as shown in Figure 3. Two matched lenses are used for transmission microscopy. Current lens design should allow a resolution of 0.2 mm over a depth range of 0.1 to 1.0 mm with 100 MHz; but, in fact, the results appear better.

Previously, a main application of the microscope was to detect cracks, which can be identified more easily than with an optical microscope. A resolution better than 1.0 μm is claimed. Work at present is to develop new methods for intrinsic microstructural

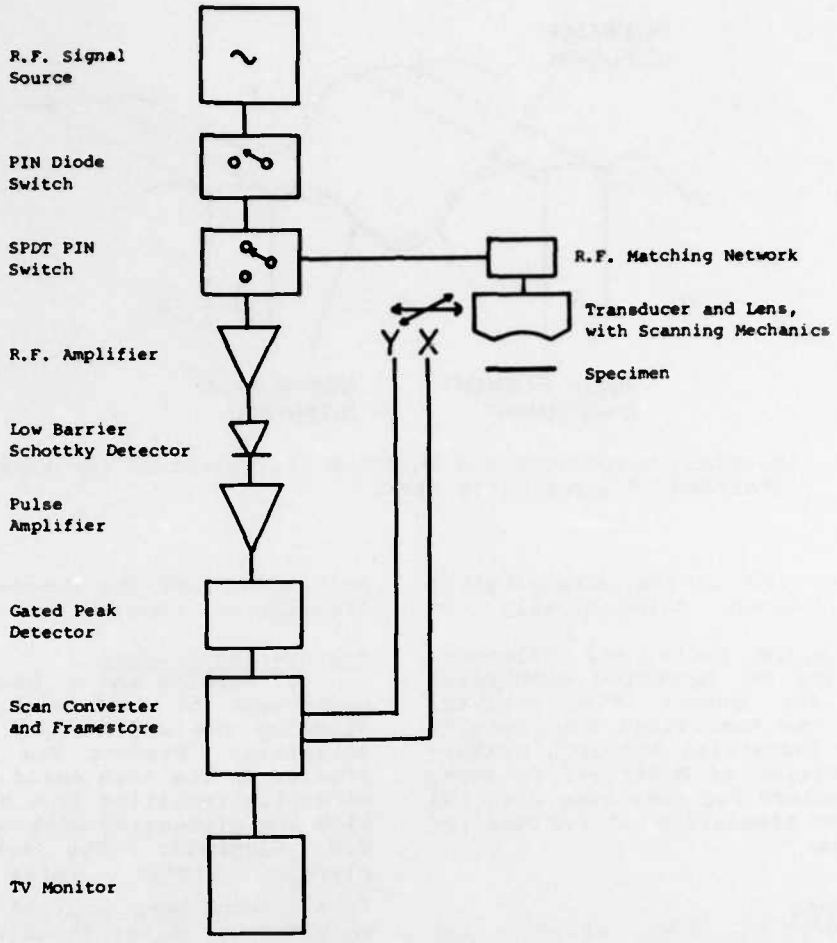

Figure 3. Circuitry for the scanning acoustic microscope.

characterizations by using the elastic anisotropy of materials. Plastic deformation is detected through the damping properties of dislocations. (An interesting consideration is to observe the elastic waves accompanying fast fracture processes.)

Atom Probe-Field Ion Microscopy

G.D.W. Smith is involved with all methods of field ion microscopy (FIM), including microchemical analysis by time-of-flight mass spectrometry, field desorption microscopy for the spatial distribution of selected chemical species, and pulsed laser atom probe microanalysis for application of the FIM to semiconductor, oxide, and catalyst materials. He is working on the chemical partitioning of chromium, manganese, and silicon atoms between the lamellar phases and at the interface of a pearlitic steel transformed below the thermodynamic no-partitioning temperature (*ESN* 37-2:83 [1983]).

Smith spent a 3-month sabbatical leave at MIT in 1980 with A.J. Garratt-Reed and J.B. Vander Sande. They compared microanalytical results obtained on the nickel-base superalloy IN 939 and on tempered martensitic steels with the atom probe-FIM and with x-rays from the field emission-STEM. Garratt-Reed is now at the Department of Natural Philosophy, Univ. of Glasgow G12 8QQ. Smith was at MIT in 1981 and at Glasgow in 1982, where the enrichment of chromium at the pearlitic transformation front of the eutectoid steel was predicted. The result has recently been confirmed. Combined atom probe-FIM and STEM results on partially transformed

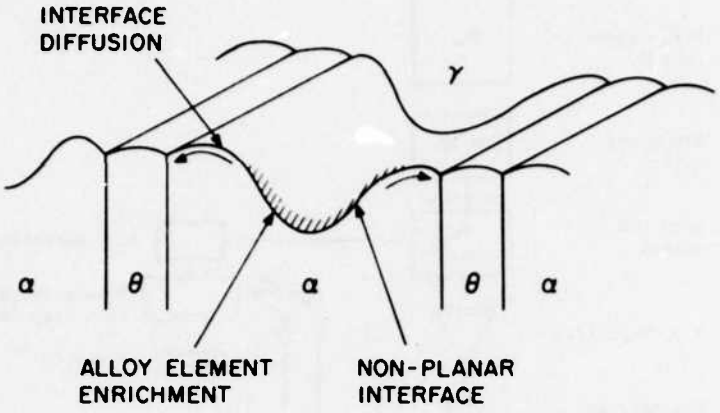

Figure 4. Interface morphology and chromium enrichment of the transformation interface of a pearlitic steel.

material have led to the morphological description shown schematically in Figure 4.

Smith, A.J.W. Moore, and colleagues are developing an automated commercial instrument for modern FIM results. Moore, from the Australian Commonwealth Science and Industrial Research Organization's Division of Materials Science, has been involved for some time with the operation and simulation of FIM desorption patterns.

Improved Cement

D.D. Double, G.W. Groves, and colleagues are concerned with hydration effects on the structure and consequent mechanical properties of cement. Strong, tough cement samples were demonstrated; their mechanical properties were attributed to the ultrafine microstructures on, say, a micron scale. Microstructures are being studied by TEM. The effect of commercial admixtures on hydration in silicate and aluminate cement systems is being observed in ion-beam thinned specimens. The incorporation of intermediate-level radioactive waste into cement is being investigated in association with the Atomic Energy Research Establishment, Harwell. Cementitious calcium silicates and calcium aluminates are being synthesized by high temperature sintering methods. X-ray diffraction, electron microscopy, and microanalysis techniques are being applied. Pulverized fuel ash and silica fume additions are of interest. The various activities are sponsored by British Technology Group, the Cormix Division of Joseph Crosfield and Sons Ltd., and the Cement and Concrete Association, Slough.

Engineering Science

J. Harding and D. Dew-Hughes in the Department of Engineering Science are studying the engineering properties of materials. Harding has continued his studies on the high speed deformation of materials resulting from his association with the pioneering work on the topic by J.D. Campbell. The metal tests at plastic strain rates approaching $10^4 s^{-1}$ have been applied to uranium-2% molybdenum, -0.75% titanium, and -2.25% niobium alloys. The shear strength of metals has been investigated at high strains and strain rates with a torsional Hopkinson-bar apparatus and short tubular specimens. Current interest is in the effect of strain rate on the dynamic flow and fracture of glass-reinforced plastic materials.

Harding is conference secretary for the Third International Conference on Mechanical Properties of Materials at High Rates of Strain, Oxford, 9 through 12 April 1984. The call for papers went out in January 1983 for work in the general areas of material properties, fracture under dynamic loading, surface impact phenomena, and impact of structures. Invited speakers on the topics are, respectively, L.E. Malvern (Univ. of Florida), F. Nilsson (Swedish Nuclear Power Inspectorate), J.E. Field (Univ. of Cambridge), and S.R. Bodner (Israel Institute of Technology).

Dew-Hughes is working on superconducting materials in a joint project with Cantor and D.G. McCartney of the

Department of Metallurgy and Science of Materials and P.A. Hudson of the Clarendon Laboratory. Directional solidification and rapid solidification techniques are of interest for producing new high current superconducting A15 compounds of Nb_3Al structure. Melt spinning is to be used for multilayer tapes. Dew-Hughes visited the Peoples' Republic of China in 1981 to deliver a series of lectures on the superconducting A15 compounds and wrote a report on related activities there (Dew-Hughes, 1982).

A recent project at Oxford is the study of dislocation interactions with cleavage cracks in zinc; it is suggested that the dislocations lower the effective surface energy required for failure. J.C. Bilello, Dew-Hughes, and A. Pucino (1983) report that zinc appears to be the only material giving a large difference between its cleavage surface energy and thermodynamic surface energy.

Other Work

The total activities in metallurgy and materials at Oxford include a number of projects not covered in this article: S.L. Altmann on the theoretical description of electronic properties for solids, D.V. Edmunds on phase transformations in steels relating to their mechanical properties, P.M. Hazzledine on superplasticity and dislocation properties, J.D. Hunt on dendritic solidification, J.P. Jakubovics on magnetic properties of materials and microstructures, and J.W. Martin on creep and fatigue properties of superalloys and other materials.

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R.W. Armstrong

OPERATIONS RESEARCH

COMPUTATIONAL COMPLEXITY RESEARCH

Prof. Francesco Maffioli, head of the communications group of the Electronics Institute at the Milan Polytechnic Univ. (Italy), has been working on methods of finding special tree structures in communications networks. Maffioli worked in electro-physics in the 1970s, but he has become interested in communications networks and various optimization problems associated with them.

The Electronics Institute is somewhat like a Command, Control, and Communications (C^3) department, in that its members are concerned with communications, operations research (optimization), and computer science. Much of the research of Maffioli and a coworker, Dr. P.M. Camerini, involves using general weighting of the components in the networks, which leads to questions of computational complexity.

One of the applications currently under investigation is satellite communications "beam pairing." The problem can be solved with job shop algorithms if any type of splitting of transmissions is allowed. For the case in which transmissions cannot be split, Maffioli is considering a stochastic approach in which message attributes are characterized in terms of statistical distributions. A second problem under investigation involves designing interconnections of small telephone exchanges into a large exchange. The Electronics Institute team has found a randomized algorithm that generates "near solutions"; the algorithm has been shown to be of "random polynomial" complexity, which, according to Maffioli, is a degree of complexity somewhere between polynomial complex and nonpolynomial (NP) complex.

In recent years, the theory of computational complexity has provided

fundamental insights into the inherent difficulty of carrying out the computations required to find solutions for optimization problems according to various algorithms (see, for example, Garey and Johnson, 1979). If the "time" (iterations or steps) required to solve a problem of "size" n (having n variables, for example) is bounded by a polynomial in n, it is said to be "easy," or to be solvable in polynomial time. If no such bounding polynomial is known, the problem is said to be "hard," or to be "NP complex." Combinatorial optimization problems, such as the beam pairing problem mentioned above, are often concerned with tree structured networks; Maffioli has been working on classifying the complexity of finding optimum undirected spanning trees. The work is concerned with finding the boundaries between polynomial bounded and NP-hard problems.

As an example, consider the well-known "traveling salesman" problem: given n "cities" (nodes) on a map (graph), and an n x n matrix D giving the distances between the cities (lengths of arcs between nodes), find a minimum length tour (circuit) which goes through each city exactly once. (The length of a tour is, of course, the sum of lengths of the arcs traversed in the tour.) The problem has been studied extensively over the past 20 years or so, and many algorithms have been proposed for its exact solution. None of the algorithms has worst-case time bounds which are polynomial in n. Complexity theoretic results suggest it is unlikely that there is an exact algorithm for solving the problem in polynomial time. Attention has therefore turned to finding algorithms giving approximate solutions in times bounded by polynomials in n.

Given a heuristic method H for finding approximate solutions to a problem of size n such as the traveling salesman problem with n nodes, the accuracy R_n of H can be defined as the supremum (over all problems of size n) of the lengths of tours found by H to the minimum length possible. One would like to have a polynomial-time heuristic for which $R_n = 1+\varepsilon$ for some small $\varepsilon>0$. Unfortunately, it turns out that the problem of finding a tour within any prespecified accuracy is also NP-hard. Maffioli has investigated the performances of several heuristics which have been proposed during the last 15 years for the traveling salesman problem. The distance function represented by the not necessarily symmetric matrix D is assumed to satisfy the triangle inequality. Maffioli found that, although many of the algorithms are empirically good, they all have worst-case performances R_n, which are bounded below by a polynomial of degree n. This is rather poor, Maffioli says, because triangle inequality implies that no tour can be longer than n times the length of an optimal tour.

Maffioli has recently applied his work to problems related to the reliability of communications networks. He models the network as a graph, where the vertices represent the communication nodes and the edges represent links between the nodes. Both vertices and edges have associated reliabilities P_g, where g is a vertex or edge of the undirected, connected graph. Failures of edges and vertices are all assumed to be independent events, so the reliability between two vertices i and j is the probability that at least one path joining i and j works. Maffioli defines the linkability between i and j to be the maximum reliability of the paths joining i and j. Given sets I and J of vertices, the reliability and linkability between I and J are taken to be the minima of the respective measures over all choices joining $i\in I$ with $j\in J$.

A point of the graph is an ordered pair representing a proportion along an edge between two vertices i and j (so i and j can also be represented as points with proportion values 0 and 1). The above notion of points is used in a probabilistic model for signal propagation between i and j, typical of radio links, for example. If a point χ is θ proportion of the distance from i to j, where the edge between i and j has reliability r, Maffioli takes the reliability ("connection probability") between i and χ to be r^θ. The reliability between any two points of the graph can then be defined in a natural way, and, consequently, the reliability and linkability between sets of points.

Maffioli has investigated two types of optimization problems for the above application. The first is the "most linking center"--find a "center" point of the graph, which must be visited in every connection between two given sets of vertices, and which is optimal with respect to linkability. That is, find a point ξ of the graph such that the linkability from $i\in I$ to ξ, multiplied by the linkability from ξ to $j\in J$, is minimized (over i and j). The second problem, finding a "most linking tree," models the practical case in which one wants to connect two given sets of

vertices with a tree having maximum reliability between the sets. The problem can be considered finding a tree that maximizes the linkability between sets of vertices I and J--that is, maximization over the class of trees whose vertex sets contain $I \cup J$. As a special case, a spanning tree of maximum reliability may be sought.

Maffioli has shown that such problems can be solved efficiently by polynomial bounded algorithms. He and his coworkers have developed a procedure called CENTERTREE, whose running time never grows faster than cubically with the number of vertices. CENTERTREE can be used to solve both the most linking center and the most linking tree problems described above. However, if one associates costs with the edges of the graph, and if the cost of a tree is taken to be the sum of the costs of its edges, then more difficult problems may be posed. For example, among all trees containing the union of given vertex sets I and J, one may seek a tree of maximum linkability with a cost that does not exceed a specified budget. Alternately, one may seek a tree of minimum cost among all trees whose vertex sets contain $I \cup J$ and whose linkability is not less than some specified value. Maffioli has shown that both of these extensions of the most linkable tree problem are equivalent in complexity to NP-hard problems, and thus are most likely not solvable in polynomial time.

According to Maffioli, other extensions of the most linking center and most linking tree problems may be more amenable to solution in polynomial time. For example, when modeling two communications services superimposed on the same network, there would be two reliabilities for each element of the graph, and linkabilities would involve four sets of vertices. Here, the two reliabilities would represent the reliabilities in the two communications systems, or reliability and availability, respectively, in a single system. The subsets I,J and I',J' of the set of vertices may model two distinct (not necessarily disjoint) pairs of communication nodes requiring the two communication services. According to Maffioli, the most linking center problem for this dual system situation is again solvable in polynomial time. The similar extension of the most linking tree problem turns out to be NP-hard; however, the Electronics Institute researchers have developed algorithms for solutions of restricted versions of the problem.

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D.R. Barr

STATISTICS AT THE TECHNICAL UNIV. OF DENMARK

The Technical Univ. of Denmark was founded in 1829 under the direction of Hans Christian Oersted, the discoverer of the connection between electricity and magnetism. It is the only institution in Denmark offering university-level engineering programs. In 1973, the pressure of growth in Copenhagen led to relocation of the university to its present campus in Lyngby, about 12 miles north of Copenhagen. The university offers degrees equivalent to the master of science and PhD in science, engineering, and mathematics. The university's Institute of Mathematical Statistics and Operations Research (IMSOR), headed by Dr. Poul Thyregod, consists of 13 faculty members, 13 "associates" (for example, PhD students, visitors, and research assistants), plus 7 support personnel.

IMSOR faculty and associate members are active in a wide variety of research projects, many of which are joint efforts with other departments of the university. The projects are funded through government sources, such as the Danish research council and the Danish food quality agency, as well as private organizations such as a large gas distribution company. The department is divided (informally) between statistics and operations research, although many projects bridge the gap, as could be expected. The statistics work at IMSOR tends to be applied; Danish work in mathematical statistics is mainly at Copenhagen University. IMSOR grants about 20 master's degrees and one PhD per year. The department has a remarkably good library, which currently receives about 200 journals in statistics and operations research.

Dr. Villy B. Iverson is working on telephone traffic theory and the design of telephone systems. He is particularly interested in waiting time distributions in queueing systems with constant holding times. He has shown that the queueing system (M/D/r·k-FIFO)--i.e., arrivals in accordance with a Poisson process, constant service times and n = r·k servers--has the same waiting time distribution as the queueing system (E_k/D/r-FIFO) with gamma arrivals and

r servers. Iverson thus uses numerical methods for (M/D/n-FIFO) queues to evaluate (E_k/D/r-FIFO) waiting time distributions. He has developed alternatives to the well-known algorithms for calculating waiting time distributions for the system (M/D/1-FIFO). Iverson's algorithms can be used even for large waiting times.

There is a fair amount of work at IMSOR in applications of time series models to a number of problems, including the prediction of storm surge levels and of populations of *E. coli* in various ocean locations. The applications typically have rather large historical data sets, but the data are "difficult"; they exhibit autocorrelations over long periods, and represent records made at unequal time periods using error prone methods. Dr. Henrick Spliid has developed a fast and simple algorithm for estimating the parameters of univariate and multivariate time series and distributed lag models. His method, essentially a method of moments, appears to be especially appropriate for estimation in large multivariate models where it is generally many times faster than maximum likelihood algorithms.

Spliid has shown that the estimators are asymptotically normal, unbiased, and have variances that decrease as the reciprocal of sample size. He bases comparisons of computational speed on the numbers of multiplications used by the algorithms. The choice is justified because in the computations involved in the algorithms being compared (Spliid's algorithm and those using gradients to locate a maximum of the likelihood function), the numbers of other operations, such as additions and loading and storing operations, are proportional to the numbers of multiplications. Based on this measure, Spliid estimated that his algorithm should run about 30 times faster than conditional likelihood algorithms for a three-dimensional problem; actual computations with examples gave an empirical factor of 34. For higher dimensional models the advantage would be even greater. A second time series project at IMSOR is concerned with problems involving very short data sequences. A Bayesian approach is being used in testing lubrication oil. Dr. Lars Pallesen is interested in combining such time series models with experimental designs for situations involving autocorrelated errors.

Further work in the area of stochastic models is being conducted by Dr. Jan Holst. He and a PhD student, Niels Poulsen, have been developing adaptive control models, based on autoregressive moving average models, which can track jumps in the noise distribution (via a 0-1 stochastic mixture). Their estimators have two modes--one to track a stationary process and another (an extended Kalman model) to track jumps in the process. Holst is working on the problem of estimating the error variances in the presence of spikes in the data. The results are being applied to a wide variety of problems, including control of ships, helicopters, house heating, and electrical power loads.

There is great need, for example, for electric utility companies to be able to predict power consumption loads. The load on an electrical system depends on many periodic factors, such as daily and annual consumption profiles, and "spikes," such as changes due to weather. Holst told me that several master's degree students from Iceland at IMSOR are working on such models as part of a student competition to find the best model of the Icelandic power system. Dr. Elbert Hendricks has worked extensively applying the models to the control of a flying model helicopter. Use of the model, which Hendricks calls a "continuous-discrete extended Kalman filter," makes it possible to control the helicopter even with very noisy partial state measurements. The remotely controlled model helicopter has been used to measure radiation and to sample gases emitted from smokestacks.

Dr. Gert Nilsson and a group of his students are using statistical methods in remote sensing applications. One project involves exploration for mineral deposits in Greenland, based on Landsat satellite images of the area obtained from 1978 to 1980. In addition to standard "off-the-shelf" image processing and statistical analysis software, several programs have been developed for producing mosaics and false color composites on the same scales as available topographic and geological maps of the area. Special ratio plots, factor score plots, and canonical variates plots have also been developed for reconaissance mapping of color anomalies.

Several new techniques for classification and discrimination are being tested by the IMSOR group. Augmenting the set of input variables to include ratios of variables and factor scores and using a hierarchical discrimination procedure, Nilsson has substantially improved the classification of potential mineral bearing rocks, which are represented by rust colored regions on the maps he showed me. Nilsson stated that overlays of different types of

information from Landsat imagery on false color composites, produced in the same scales as topographic and geological maps of the same area, have been extremely useful in the classification of areas with potential mineral deposits.

A number of interesting applied operations research problems are being studied by the IMSOR faculty. Prof. Oli Madsen has worked on a variety of location-routing problems, travelling salesman routines, and, currently, production planning for a small glass supply company. The company produces thermopanes in many different sizes specified by its customers; lots of two to three units are typical. For each thermopane, two or more rectangular sheets of glass of the same size must be cut. In addition to size and thickness, customers may specify color, surface treatment, and other glass qualities. Glass is cut from stock sheets using "guillotine cuts," each of which splits one rectangular sheet into two. After each cutting process, the pieces are placed temporarily in a small inventory until all corresponding sheets of the same size, needed for the thermopane, have been cut. The manager of the company wants to decrease both the percentage of glass wasted and the production time necessary with the present method of planning "by hand."

Madsen developed a computer program for finding near optimal solutions to the problem using a nonexact "two-stage guillotine cutting algorithm." However, the procedure could not be used on the company's small computer. According to Madsen, a "near optimal" procedure was developed; it consisted of double one-dimensional knapsack procedures. First, the glass pieces for the thermopanes were composed into sections; then the sections were "formed" into stock sheets using almost the same one-dimensional algorithms. Running the procedure takes about 10 minutes each day. After several months of use, the company estimates that glass waste has been reduced from about 20 percent (under the former planning method) to about 10 percent. The program has also been used to find near-optimal dimensions for the stock glass sheets, and it has been determined that a further reduction of 3% in waste is possible if stock of the best size can be obtained.

Several of the IMSOR researchers are interested in technology assessment. Dr. Victor Vidal is examining technology in the food industries. He has recently completed a study of technology's role in the development of the Danish meat processing industry. According to Vidal, the Danish "butchery trade" made early use of technologies such as mathematical programming, operations research, and computers to solve logistic problems such as plant location, transport, distribution, and inventory. He believes that many features of the development of meat processing are common to other industries in Denmark. According to Vidal, the goal of his work is to develop technology assessment as a methodology that can be used to forecast the social, economic, and environmental effects of introducing specific technologies into given industries.

Lars Anderson and several coworkers have been examining a specific application of technology assessment--the introduction of computer technology into the process industries, particularly fertilizer plants. Anderson's group has developed an approach involving comparison of various technology options for carrying out specific production requirements. The approach has been used to examine the incentives for introducing new technology and the consequences of doing so.

The efforts in technology assessment respond to recommendations made in 1980 by the Danish Ministry of Industry. The agency suggested establishing a Council of Technology Assessment to coordinate technology assessment research in Denmark and ensure that the social impacts of introducing technology are properly assessed. The council would receive funding to support a staff of 100, and would fund and carry out research in technology assessment.

D.R. Barr

PHYSICS

NOVEL PLASMA ANNULI FOR IMPLOSION EXPERIMENTS

Background

During the early 1970s, research at the Naval Research Laboratory (NRL) in Washington, D.C., led to the development of intense x-radiation sources created by the discharge of terrawatt (10^{12} W) electrical pulses through fine (a few times 10^{-3}-cm diameter) metal wires. The intense electrical heating transformed the metal into a keV-temperature plasma (10^{7} degrees Kelvin), which radiated part of the absorbed energy as soft x-ray lines and continuum with

photon energies in the 100-eV to few-keV range.

The high atomic number plasmas were of interest to atomic physicists because of the high ionization states produced (Dozier et al., 1977). The radiation also constituted the most powerful laboratory source of thermal x-rays in existence (Mosher et al., 1973). Because of their intensity, exploded-wire radiation sources have potential applications to material science (*ESN* 36-12: 334 and 345 [1982]) and lithography, and they might be used as pumps (Jones and Ali, 1974) or sources for x-ray lasers (Dahlbacka et al., 1981). In addition, such x-radiation sources became an important part of ongoing Defense Nuclear Agency (DNA) programs assessing the vulnerability of defense systems and components to radiation from nuclear bursts.

During the mid-1970s, researchers at NRL and Physics International Co. (PI), San Leandro, CA, demonstrated that improved coupling to the electrical generator and a higher conversion efficiency of electrical energy to radiation could be achieved by using an array of even finer wires in the form of a cylindrical cage (Stallings et al., 1976). Mutually attractive magnetic forces between the current-carrying filamentary plasmas caused them to be accelerated towards the symmetry axis. The kinetic energy of implosion gained during the 50- to 100-ns electrical pulse was then transformed to plasma internal energy and radiation on the 10-ns timescale of the collision and stagnation of the plasma filaments on the symmetry axis.

Subsequent experiments conducted at the Sandia National Laboratories (SNL) and the Air Force Weapons Laboratory (AFWL) in Albuquerque, NM, indicated that more symmetric, uniform, and tightly convergent implosions could be achieved by distributing the metal mass in a cylindrical shell rather than a cylindrical cage of discrete wires (Baker et al., 1978). SNL experiments and computer modeling indicated that the radiation produced from annular plasma implosions might be useful for driving small deuterium and tritium bearing pellets to thermonuclear ignition. Along with laser and ion beam drivers, that inertial confinement fusion concept is now part of a program by the Department of Energy's Office of Inertial Fusion to demonstrate the feasibility of fusion reactors for electrical power production.

Unfortunately, distributing the required 10^{-4} to 10^{-3} g of matter into a 1- to 2-cm diameter cylinder a few centimeters long means that the shell must be very thin (as low as 100 angstroms). Techniques for making and handling such foils have yet to be developed for most materials of interest. With this problem in mind, researchers at PI and Maxwell Laboratories, Inc. (MLI) have developed annular supersonic nozzles that form a puff-gas annulus of the required mass (Smith et al., 1982). Recently, puff-gas plasmas driven by 3.5-MA discharge currents have been imploded with the 10-terrawatt (TW) BLACKJACK 5 generator at MLI to produce intense argon K-line spectra (Clark et al., 1982).

Gas-puff systems now in use have several drawbacks associated with the need to use materials that are gases at room temperature. The selection of atomic numbers for gases is small, so the ability to choose the spectrum is limited. Even the best nozzle designs suffer from annular divergence and a change in gas density with distance from the nozzle. Because the implosion time depends on the density and annular radius, it is difficult to achieve simultaneous implosion along the plasma length with puff-gas loads. The spread in collapse times results in nonuniform emission along the plasma length and in an increase of the x-ray pulse duration. Special gas-transmitting electrodes opposite the nozzle are needed to limit the back reflection of molecules into the vacuum space. If improperly configured, gas reflected outside the annulus can divert the current, which drives the implosion, thereby shorting out transfer of electrical energy to the load. Electrodes that allow the gas to pass through freely, such as a grid of fine wires, may introduce implosion asymmetries because of localized return currents. Finally, radio frequency excitation or some other form of plasma preionization may be required for optimal coupling of the generator to the annular load and symmetric implosion. Adding a preionizer makes the gas-puff system substantially more complex.

Research at the Ecole Polytechnique

In my January visit to the Laboratoire de Physique des Milieux Ionisés (Labo. PMI) at the Ecole Polytechnique in Palaiseau, France, Dr. Henri Doucet, the laboratory director, described a new approach to the production of annular loads that may solve most or all of the above difficulties. The Ecole Polytechnique is one of the *grandes écoles* from which the French state recruits most of its top staff. The Labo. PMI, employing about 30 researchers, is a group of the

Centre National de la Recherche Scientifique (which controls the cream of most basic science in France) and receives additional funds from the Commissariat a l'Energie Atomique. The facilities of the Labo. PMI include a two-beam, 400-J, phosphate glass laser for laser-matter interactions research, magnetic-multipole plasma confinement systems for the study of waves and turbulence, devices to study negative ion production for tokamak plasma heating by neutral injection (*ESN* 36-12:348 [1982]), a high-impedance intense relativistic-electron beam (IREB) generator for free electron laser studies, and a low-impedance IREB device called GAEL. Doucet is beginning a fundamental study of plasma implosions for x-ray source development using GAEL--a 2-ohm, 500-kV, 50-ns generator with 8-kJ electrical energy storage.

The Plasma-Puff System

Doucet's objective is to generate cylindrically symmetric annuli with low enough mass to be driven by a 250-kA machine and with the right atomic number for x-ray diagnosis. Aluminum is ideal for this purpose because the K lines lie above the absorption band of simple vacuum transmission windows but are low enough in energy to be thermally excited by the electrical energy available. Fabrication of aluminum-foil cylinders with sufficiently low mass was clearly beyond the resources of the Labo. PMI. Instead, the desired annular plasma is generated with the equipment shown in Figure 1.

The foil holder, hub, and slit-defining plate are constructed from stainless steel, and the witness plate is copper. The slit plate is mounted in the door of GAEL's vacuum diode, the foil holder is outside the door, and the witness plate is within the device. The annular plasma is therefore puffed into the interelectrode gap of GAEL. The whole assembly is pumped through the diode vacuum manifold.

The 2-mm-wide, 5-μm-thick aluminum foil annulus is vaporized by discharge of a 7-μf, 25- to 30-nh capacitor system charged to 15 kV. With a low inductance, command-triggered switch (that resembles a rail gap separated by a dielectric flashover board), and a 30- to 35-nh (including the foil support) strip-line feed, the electrical circuit had a ringing period of about 3.5 μs. Foil vaporization occurs about 0.5 μs after switch closure (just before the first quarter-period maximum), when about 160 kA flows through the circuit.

The work has just begun and

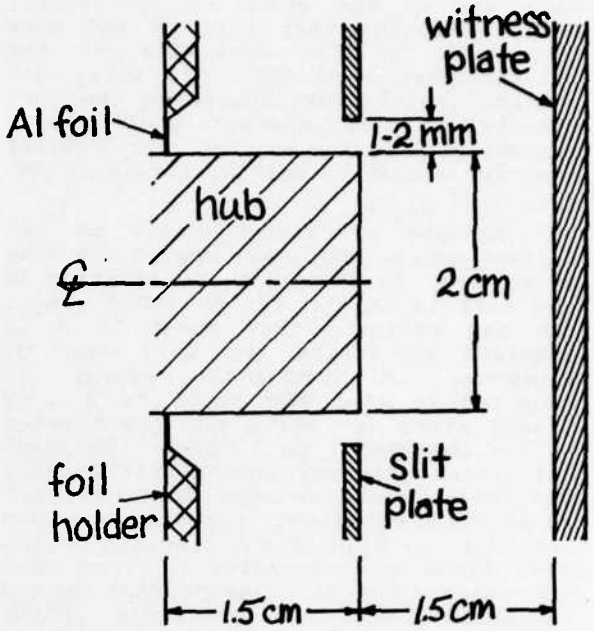

Figure 1. The plasma puff assembly.

measurements on the plasma puff are meager. After a capacitive discharge (GAEL has not yet been fired into this load), the witness plate shows a ring of deposited aluminum well contrasted against the copper. The deposited ring has very sharp inner and outer edges, a thickness and radius about the same as the foil annulus and slit, and appears to have uniform density distribution in azimuth. This seems to indicate collimation over the few centimeter lengths desired for imploding loads. On one shot I observed, the slit plate was not installed. In that case, the witness plate showed a sharp inner edge and a fuzzy outer region with decreasing deposited density on a radial scale of several centimeters.

On some shots, the witness plate was removed, and Faraday cups (small charge-measuring devices) were placed downstream from the slit. The plasma puff velocity determined by the relative timing of two Faraday cups separated by a 1-cm axial distance was in the 1 to 2 cm/μs range. Some early shots with a single Faraday cup 50 cm downstream showed a 7-μs dead time followed by a 2-μs spike with a long (>10 μs) tail at about 10% of the peak level. The fastest ions were therefore moving at a respectable 7 cm/μs, but there is now no information about whether most of the

mass was in the spike or the slower tail. Assuming that half of the mass blows off in the direction of the witness plate and that the fuzzy deposited radial distribution on the shot without a slit characterized plasma spreading from the source, the results indicate annular atomic densities in the 10^{17} cm^{-3} regime.

Because of uncertainties in the voltage across the load, Doucet can only state that the electrical dissipation in the foil is in the 10- to 100-J range. One can estimate that about 50 J is required to ionize the full mass of aluminum. A comparable energy is required to heat the vapor to a 1-eV plasma state for which the sound speed is the observed 1 to 2 cm/μs. The high velocities inferred from single Faraday cup measurements on some shots are not so easily understood. Magnetic acceleration of any significant fraction of the mass leads to velocities of less than 0.1 cm/μs. Doucet suggests that on the anomalous shots, the current flow in the aluminum may have time to filament so that a small fraction of the mass is heated to higher temperature. If that were the case, only about 1% of the matter could be accelerated to the high velocities observed. One would then have expected an apparent azimuthal asymmetry on the witness plates. Doucet hopes to symmetrize the current flow by using lower inductance capacitors, thereby decreasing the time to peak current. The witness plate images themselves are difficult to understand. The slitless image indicates aluminum blowing off into a substantial solid angle, yet the sharp edges of deposited annuli with the slit in place do not indicate dispersion.

Taken at face value, the results of the preliminary experiments are exciting. The technique opens the way for plasma puffs from foils of any metal with the corresponding choice of characteristic spectra. The results indicate unexpectedly good collimation and azimuthal symmetry, so very uniform plasma implosions may be possible. Because the materials are condensable, they should stick to solid, cylindrically symmetric electrodes, thereby eliminating the need for transmission grids and the associated induced implosion asymmetries. Even if some material reflection occurs, the plasma puff is short in duration and can be synchronized with the pulsed power generator pulse so that filling of the vacuum region and subsequent current diversion can be avoided. The Faraday cup signals indicate that there may be enough ionization to make a separate preionizer unnecessary. Best of all, the hardware and associated pulsed power system are simple and inexpensive.

Incorporating a plasma puff capability into the United States' imploded-plasma experimental programs may represent an important advance in radiation source development.

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D. Mosher

NEWS & NOTES

THAMES BARRIER USED

The recently completed flood control barrier on the River Thames was "used in anger" for the first time on 1 February 1983. (See *ESN* 37-1:27-30 [1983].) The worst storm of the season swept the British Isles with hurricane-force winds, causing widespread flooding along the east coast. Six deaths were attributed to the storm. A flood alert was sounded for the Thames estuary, and the barrier was raised at 10:00 p.m. It remained closed until after a 3-ft surge

passed at 4:30 a.m. on February 2. According to newspaper reports of the closing, this first use of the barrier was accomplished without difficulties by a crew of 30 engineers.

D.R. Barr

ELECTRONICS SLOWDOWN IN FRANCE

The French government's plans to cover over half the country with fiber optic cables by 1995 are being revised to protect French industry. Calculations show that it would require an annual output of 120,000 miles of fiber optic cable per year to accomplish the objective. An additional industrial investment of $37 million would be required to increase the present annual French output of 15,000 miles of cable.

Thompson-CSF is the largest of the nationalized French electronics groups and a major contributor to French fiber optic cable production. As they are currently running a 2 billion French franc ($333 million) annual deficit, further capital investment to augment cable production is not prudent. The 1995 deadline is being extended to allow French manufacturers to provide the cable and to discourage foreign supply.

M.N. Yoder

INTERNATIONALLY KNOWN UK PHYSICIST TAKES NEW JOB

Dr. Cyril Hilsum, recipient of many UK and international awards for his pioneering work in and innovative applications of compound semiconductor materials, is changing jobs. During his many years at the Royal Signals and Radar Establishment, he became well known throughout US governmental, industrial, and academic research facilities for his contributions to gallium arsenide and indium phosphide semiconductor materials and devices. His new challenge will be that of chief scientist at the General Electric Company (UK) Hirst Research Center northwest of London. He is expected to continue his appointment as visiting professor at the Univ. of Durham, Department of Applied Physics and Electronics.

M.N. Yoder

ELECTRON BEAM WELDER DEVELOPED

A new high-voltage electron beam welder has been developed by Wentgate Engineers (St. Ives, UK), according to the *Financial Times*, 14 February 1983.

The welder, with full microprocessor control and an electron gun, has a 150-kV maximum accelerating voltage and an initial 6.0-kW maximum beam power.

The *Financial Times* notes that "both the welding parameters set and the actual parameters during welding are displayed on a VDU [visual display unit] and a permanent record of each weld can be obtained by using the optional high-speed analogue recorder."

In addition, the welder has a flexible vacuum control system, provides a very fast response time, and stores up to 10 welding programs.

L.E. Shaffer

MANUFACTURE, FABRICATION, AND OPERATION OF PIPELINES

The Scottish Association for Metals held its biennial conference on "The Manufacture, Fabrication and Operation of Pipelines," 30 September 1982, at the Univ. of Strathclyde, Glasgow. Seven papers were presented by two rapporteurs. Dr. R.E. Dolby, The Welding Institute, presented: "Steel for Transmission Pipelines," by H.C. Cotton; "Material Requirements for British Gas Transmission Pipelines," by C.L. Jones; and "Steelmaking, Casting and Rolling of Pipeline Steels in British Steel Corporation," by R.J. Gray, W.R. Irving, and R. Baker. Prof. G.P. Smedley, Lloyd's Register of Shipping, presented: "The Manufacture of Large Diameter Longitudinal Welded Pipe--the Development of Heavy Wall UOE Pipe," by H. Sunami, M. Nakazawa, and M. Sekizawa (Kawasaki Steel Corporation); "The Manufacture of Spiral Welded Pipe With Special Reference to Integrating Quality Assurance," by P.A. Peters, H.G. Frackmann, W. in der Wiesche, and H. Christmann (Mannesmannröhren-Werke AG); "Circumferential Butt Welding of Pipes for Pipelines," by G.R. Salter and J. Weston; and "Ultrasonic Inspection of Plate and Pipe During Production," by D.H. Davies and A.R. Cornforth.

The conference was attended by 110 persons from the UK, Switzerland, the Netherlands, the Federal Republic of Germany, Denmark, Luxembourg, Norway, France, and Japan. The conference papers were preprinted for the

attendees, and copies are available from Prof. Harry B. Bell, Department of Metallurgy, Colville Building, Univ. of Strathclyde, Glasgow G1 1XN, Scotland. The papers are worthwhile--especially for persons involved with pipe welding.

R.W. Armstrong

BACTERIA IN THE HOME

Microbiologists from Chelsea College, London, recently surveyed over 250 residences in England and took cultures at various places in the houses. Most homes had live enterobacteria and pseudomonads somewhere; contamination levels were higher than expected, often on the order of 100 bacteria per 25 cm^2. The worst sites were moist areas like kitchen sinks, drain boards, dishcloths, and bachroom mats and basins. An implication of the results is that hygienic control of moist places could reduce gut infections; perhaps many cases attributed to "exotic" bugs could be due to local bacteria lurking in the house.

N.A. Bond, Jr.

ONR COSPONSORED CONFERENCES

ONR London can nominate two registration-free participants in the conferences it supports. Readers who are interested in such participation should contact the Chief Scientist, ONR London, as soon as possible.

OHOLO Biological Conference on Mechanisms of Viral Pathogenesis (From Gene to Pathogen), Zichron Ya'acov, Israel, 20-23 March 1983.

First UK Solar Maximum Mission (SMM) Workshop, Oxford, UK, 9-12 April 1983.

International Conference on Insulating Films on Semiconductors, INFOS 83, Eindhoven, The Netherlands, 11-13 April 1983.

Conference on Magnetic Resonance Spectroscopy of Liquid Crystals and Biological Membranes, Leeds, UK, 18-20 April 1983.

European Specialist Workshop on Active Microwave Semiconductor Devices, Maidenhead, UK, 4-6 May 1983.

International Symposium on Phase Relationships and Properties in Multicomponent Polymer Systems, Capri, Italy, 30 May - 3 June 1983.

NATO ASI on Physics of Submicron Semiconductor Devices, Pisa, Italy, 10-23 July 1983.

8th European Symposium on Fluorine Chemistry (ESFC-8), Jerusalem, Israel, 21-26 August 1983.

International Conference on Electronic Properties of Two-Dimensional Systems, Oxford, UK, 5-9 September 1983.

ONRL REPORTS

To request reports, check the boxes on the self-addressed mailer and return it to ONRL.

C-2-82 *Second Conference on Semi-Insulating III-V Materials*, by S.G. Bishop and E.M. Swiggard. The Second Conference on Semi-insulating III-V Materials dealt with four main issues: growth of bulk III-V crystals, assessment of high resistivity materials, behavior of high resistivity materials under heat treatments, and problems of III-V devices related to the semi-insulating conditions.

C-1-83 *Ion Formation From Organic Solids*, by R.J. Colton. The second international workshop on Ion Formation From Organic Solids provided a general review of the field, and dealt specifically with ion formation processes and applications.

C-2-83 *NATO/London Mathematical Society Advanced Study Institute on Systems of Nonlinear Partial Differential Equations*, by R.L. Sternberg. Major topics at the conference included problems in nonlinear elasticity, applications of bifurcation to mechanics, analysis and computational fluid dynamics, nonelliptic problems and phase transitions, and dynamical systems and practical differential equations.

ESN 37-3 (1983)

EUROPEAN VISITORS TO THE US SUPPORTED BY ONR LONDON

Visitor	Affiliation	Organization to be Visited
Mr. A.B. Colquhoun	Department of Applied Physics Univ. of Strathclyde John Anderson Building 107 Rottenrow Glasgow G4 ONG	Workshop on the Use of Gravity Gradiometers Goddard Space Center Greenbelt, MD (28 February - 2 March 1983) NRL (3-4 March 1983) Univ. of Maryland (3-4 March 1983)
Prof. H.C.A. Dale	Ergonomics Research Group Univ. of Hull 26 Newland Park Hull HU5 2DW	Navy Personnel Research & Development Center, San Diego, CA (27-29 June 1983) Aviation Psychology Lab Ohio State Univ. (4-6 July 1983) Wright-Patterson AFB (4-6 July 1983)
Dr. R. Huber	Hochschule der Bundeswehr München Neubiberg, FRG	CNA, Alexandria, VA NPG School, Monterey, CA (June 1983)
Dr. J. Swithenbank	Department of Chemical Engineering Univ. of Sheffield Mappin Street Sheffield S1 3JD	Edwards AFB, CA (7 March 1983) NWC China Lake, CA (8 March 1983) Sandia Labs, CA (9 March 1983)